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Cone and Seed Studies in Norway spruce (*Picea abies* (L.) Karst.)

Kott- och fröstudier hos gran

by

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1. Introduction

The quality of seed, as well as seed production, are both directly and indirectly of importance for the existence of mankind and also of a considerable number of animal organisms. With regard to agricultural and garden plants the question of seed, from the food production point of view, becomes of vital interest on a global scale. The quality and quantity of seed production in forest trees is an important link in the same chain of interests. For many people the forest, its raw products and the manufacture of its industrial products, means employment, security and a higher standard of living.

Apart from price levels, extent of forest area and management of forestry, the value of the forest land will depend upon, inter alia, our ability to bring into being in different parts of our country—under the prevailing conditions of production and marketing—new forests of the best possible utility or cultivation value, suitable density and composition of species.

The knowledge, gained through seed research and reforestation studies, of the differing qualitative properties of the natural seed within certain extreme climatic regions, for instance in Northern Europe, has helped to increase understanding in Scandinavia of the genetic and physiologic quality of forest-tree seed. Forest genetics and its practical application (provenance research and tree breeding), on the basis of the results achieved from research and experimental plantations, has time after time actualized the physiologic-genetic variation of tree properties, including seed characters, whilst at the same time steps have been taken for the production in seed orchards of certain quantities of forest-tree seed. By locating these seed orchards, built up on selected clones, in areas where the conditions for flowering and seed ripening are favourable, the tree breeder expects, in seed orchards established for, and with clones from regions with poor quality and quantity production of forest seed, both a physiologic and a genetic gain after artificial selection and intercrossing of the clones with reference to seed quality. At the same time a larger seed harvest, in relation to the original trees and their places of growth, is expected in these orchards, due among other things to the better location of the seed orchards from a climatic point of view. The genetic gain may also differ for different tree properties. In the first generation of seed orchards, without having tested the cross combinations of the clones, this gain is the same as for mass selection with an identical selection intensity.

The gain is equal to the product of the degree of heritability in a narrow sense and the selection differential for the characters selected. If selection is applied to more than one character simultaneously, the genetic correlation between them and the number of attributes selected also affect the selection gain.

There are still many questions associated with the quality of the natural seed and with seed production in the seed orchards. The formation of empty seed is influenced by various genetical, physiological and external factors, some of which are known (cf. ANDERSSON, 1947 a and b, LANGNER, 1951 and 1953, JOHNSSON, KIELLANDER and STEFANSSON, 1953, EHRENBERG, GUSTAFSSON, PLYM FORSHELL and SIMAK, 1955, SARVAS, 1955, 1957, 1958, and 1962, JOHNSSON, 1961, KLAEHN and WHEELER, 1961, and GUSTAFSSON, 1962). The components of causes which lead to the formation of empty seed, particularly in Norway spruce, have been investigated in only a small degree. Relatively little information is available for Norway spruce, in contrast to that for Scots pine, on the variation in seed production, in empty seed and in seed germination capacity between individual trees within populations exposed to different environments. Broadly speaking, detailed investigations of the relationships between cone and seed properties and between seed characters are lacking for Norway spruce, as are also investigations of the variation in climatic tolerance during macro- and microsporogenesis.

It would be of great interest to know these variations and relationships, especially for the composition of clones in seed orchards, for seed supply areas at altitudes of about 300 m. and above in northern Scandinavia and comparable climatic regions. The reproductive fitness of the trees in these regions is of particular importance. High seed production and seed germination ability are important attributes for selection, as are always timber production and resistance to diseases, if it is intended that the stands established with orchard seeds shall be able to regenerate naturally by seedlings. Although the natural reproduction of forests has generally diminished and probably will further diminish, it is especially desirable in the high levels of northern Scandinavia, from the economic point of view, to have natural reproduction and increased reproductive fitness of the tree populations. It would therefore seem, in many cases, that studies on variation among trees in reproductive capacity are of importance for selection of plus trees and for seed collection.

From the tree breeder's viewpoint a large range of variation between trees is of great interest, and often of great importance for selection, if there exists a significant correlation (especially in a positive direction) between the phenotypic characters and the genotypic constitution. Although the phenotypic variance includes both the genotypic and the environmental variances as well as the interaction component between genotype and environment, correlation between repeated measurements, e.g. between years, for a phenotypic character on the same individual can also be used as a criterion for selection, and lead to an increased selection gain.

The major purposes of the author's investigation in Norway spruce were the following: 1) to make a study of the association between some cone and seed properties and between some seed characters, 2) to study the range of variation within populations and the variation between populations with respect to seed yield per cone and seed quality, and 3) to study the reproductive fitness of trees and populations in especially extreme climatic regions with regard to the course of meiosis and the formation of male gametophytes. In populations of Norway spruce there exist not only "genic and chromosomal sterility" (cf. DOBZHANSKY, 1933) but also disturbances of meiotic divisions influenced by unfavourable climatic conditions.

Considerable attention is given under point 1 to variations and relationships of cone and seed properties in order to clarify:

a) the treewise and standwise variation of these properties within some provincially distributed spruce populations,

b) these properties' relationships with one another as well as differences in relationships with regard to trees and populations, and

c) what effect various characters may have on seed quality and seed yield per cone, e.g. characters which together with the number of cones per tree are of importance for harvesting of cones, for the selection of seed trees and plus trees in especially high altitudes in northern Scandinavia.

The studies on the reproductive fitness with reference to male meiosis and pollen fertility will be published in a paper at present being prepared, entitled —"Studies of meiosis in Norway spruce (*Picea abies* (L.) Karst.)".

The present work should be regarded as a contribution intended to help to clarify some variations and relationships connected with seed production, seed quality and reproductive fitness of Norway spruce at altitudes above 300 m. especially in northern Sweden. Estimations of covariations between repeated observations on the same trees and of variance components due to different tree characters such as seed production ability and germination capacity give valuable information about the reproduction ability and the reproductive fitness of the trees.

2. Flowering and seed setting in conifers. A short review

Afforestation is intimately bound up with the seed question from both the qualitative and quantitative points of view, and this irrespective of whether it is a matter of natural or artifical regeneration (through sowing or planting). The quality of the seed is in its turn dependent upon the genetic constitution of the seed (cf. e.g. ANDERSSON, 1947 a, b, and 1955, JOHNSSON, KIELLANDER and STEFANSSON, 1953, PLYM FORSHELL, C., 1953, ROHMEDER, 1954, SIMAK and GUSTAFSSON, 1954, EHRENBERG, GUSTAFSSON, PLYM FORSHELL, C., and SIMAK, 1955, HADDERS and ÅHGREN, 1958, and JOHNSSON, 1961) and upon the modifying effect of the milieu upon seed formation and seed maturity. The forced production of seed is of current importance for tree species with a small seed production (e.g. *Picea abies* and *Pinus silvestris*) and especially in regions with a severe climate, where seed production is low and the physiological quality of the seed in most cases poor. In extreme highland country in Central Europe and in highland areas (as a rule more than 300 m. above sea level) in e.g. northern Europe the temperature during the vegetative period is often a striking minimum factor for *seed maturity, seed production* (cf. inter alios, KERNER, 1864, BLOMQVIST, 1883, HOLMERZ and ÖRTENBLAD, 1886, CIESLAR, 1887, ÖRTENBLAD, 1894, MAREK, 1910, SCHOTTE, 1911, RENVALL, 1912, HAGEM, 1917 and 1931, BÜHLER, 1918 and 1922, WIBECK, 1919, 1920 and 1928, HEIKINHEIMO, 1921, OLDERTZ, 1921, EIDE, 1925 a, b, 1927, 1930, 1931 and 1948, KUJALA, 1927, NORDFORS, 1928, OPSAHL, 1931 and 1952, MORK, 1933 and 1948, TIRÉN, 1935, GODSKE, 1948, SKINNEMOEN, 1948, NORDSTRÖM, 1953 a, ROHMEDER, 1954, and EBELING, 1961) and for *growth, conditions of reproduction* and *tree limit* (cf. inter alios DENGLER, 1904, 1910 and 1922, FRIES, 1913 and 1918, WALLÉN, 1917, KOLMODIN, 1923 and 1935, ENQUIST, 1924 and 1933, STÅLFELT, 1924, WIEDEMANN, 1925, EIDE, 1926, 1928, 1930 and 1948, ENEROTH, 1930, HAGEM, 1931, AANSTAD, 1934, LANGLET, 1935 and 1959, ERLANDSSON, 1936, MORK, 1941, ORDING, 1941, NÄSLUND, 1942, ARNBORG, 1943, EKLUND, 1944 and 1954, RUDEN, 1945, ROBAK, 1948, MIKOLA, 1950, MÜLLER-STOLL, 1951, LADEFOGED, 1952, HOLMGREN, 1954 and 1961, HOLMSGAARD, 1955, PETTERSON, 1955, SIRÉN, 1955, EBELING, 1957, 1959, 1961 and 1962, STEFANSSON, 1957, SCHULENBURG, 1958, HAGBERG, 1959, and HAGBERG and ARMAN, 1959). HOLMERZ' and ÖRTENBLAD'S (1886, p. 53) observations concerning the connection between temperature and seed production etc. in extreme highland regions in northern Sweden may be adduced as an illustrative example of the influence of extreme temperatures upon seed setting and seed maturity. They state: "On the other hand, increased cold and shorter vegetative period undoubtedly have an unfavourable effect upon the seed production of trees; and the explanation of the fact that a number of the conifers at the highest altitudes are sterile is probably to seek in the circumstances indicated above. There is in our opinion a seed production and seed quality limit, as well as a vegetation limit. The lowering of the former must keep step with the rise of the land; and if the latter can retain its once encroached boundaries independently of the rise referred to, this is in the majority of cases ascribable to *reproduction by other means than through seed.*" Similar observations with respect to feeble or no flowering in certain trees are mentioned by RENVALL (1912, p. 33).

Also other external factors seem more or less to affect the setting and development of the flower buds, the flowering, seed formation and seed maturity etc., such as the light conditions, rainfall, wind and nutrition, the age of the tree, the density and the height above sea level etc. (Except for the disseminating of the pollen, however, the importance of the wind for the flowering, seed maturity and reproduction (ANDERSSON, 1955) should for northern Europe probably be restricted to extreme and exposed altitudes (cf. e.g. HOLMERZ and ÖRTENBLAD, 1886, NORDFORS, 1928, EIDE, 1930 and HOLMGREN, 1954, 1956 and 1961). Especially at low temperatures the wind strengthens the effect of temperature markedly.) Of the external factors which in the above mentioned biological connections have been made the object of observations and studies, the temperature—probably with every justification—has been generally considered the most important (cf. VESTERLUND, 1896, HAGEM, 1917 and 1931, EIDE, 1930, p. 489, MORK, 1933 and 1948, TIRÉN, 1935, SKINNEMOEN, 1948, and EBELING, 1961).

The effect of climate upon flowering, seed formation and seed maturation is generally divided between:

1) year for bud setting
2) flowering year
3) year for seed maturation.

(For Norway spruce and other tree species of importance for our forestry, with the exception of pine, the flowering year and the year for seed maturation coincide.)

2.1. Year for setting of flower buds

Investigations referring to the year for the setting of buds deal as a rule with questions concerning the effect of the environmental factors upon the setting of the flower buds, their development and the influence they exert on the flowering and cone crop for the following year, and questions of importance for the periodicity of the seed years (cf. inter alios BLOMQVIST, 1883, RENVALL, 1912, LAKARI, 1915 and 1921, SYLVÉN, 1916, HAGEM, 1917, ILVESSALO, 1917, EIDE, 1926 and 1927, OPSAHL, 1931, HEIKINHEIMO, 1932, 1937 and 1948, TIRÉN, 1935, MESSER, 1958, SARVAS, 1957 and 1962, and HAGNER, 1958). TIRÉN (1935) with regard to Norway spruce, and amongst others, HAGEM (1917) with regard to pine, have found that a high summer temperature during the year for the bud setting has a positive effect upon the intensity of the flowering in spruce and pine and upon the cone crop the following year in the case of spruce and the same property in the case of pine recorded during the second year of maturation of the cones. TIRÉN (l.c.) states that where the external morphological flowering threshold exists, in Sweden it is chiefly a high July temperature, or some phenomenon resulting from this, that hastens the buds' developmental phase from vegetative to reproductive. Also an "interior flowering maturity" is a prerequisite for the attaining of this threshold. TIRÉN consequently ascribes to a high July temperature a strong triggering effect upon flowering. The external readiness for flowering is considered by TIRÉN to be connected with, *inter alia*, the occurrence of vegetative buds that may be transformed to floral organs. In a rich flowering year the number of terminal and lateral buds is in the case of Norway spruce—and especially in older spruce trees in the north of Sweden—reduced through the flowering, in contradistinction to what obtains in the case of pine. This reproduction of buds taking place in a rich flowering year has a negative effect upon the flowering in the next 2—3 years, until new buds capable of development have had time to be formed. According to the same researcher, there is reason to assume that a lack of rainfall during a longer stretch of the summer season promotes the next year's spruce flowering. Although TIRÉN (1935) has not given any correlation or regression coefficients to indicate the connection between the cone crop for Norway spruce and the two meteorological factors (temperature and rainfall), either jointly or separately, it does nevertheless emerge from the graphic collations presented by him that the connection between rainfall and humidity and the bud setting year and the cone crop the following year is very weak. Further, the connection between temperature and rainfall is as a rule also very slight (cf. WALLÉN, 1917). As regards pine, ILVESSALO (1917) shows a strong positive connection between summers with little rainfall and a good natural fresh growth three years later. The results of research on the effect of these climatic factors upon flowering and seed production do not, however, show complete agreement. SARVAS (1957, p. 542) shows in the case of Norway spruce that a high summer temperature in combination with drought during the bud setting year can scarcely be considered to exercise any decided effect upon the next year's seed harvest. He does, on the other hand, ascribe a certain triggering effect upon flowering to the combined influence of temperature and drought.

As other external factors of importance for the process of flower formation the literature adduces, as has been partly discussed earlier, the height above sea level, the effect of light (BÜHLER, 1918, p. 467), nutritive factors (PAUL and MARTS, 1931, GEMMER, 1932, CHANDLER, 1938, HAINES, 1946, MURNEEK, 1948, ALLEN, 1953, WENGER, 1953, BERGMAN, 1955, MAKI, 1955 and 1958, OZAWA and MATUZAKI, 1955, NĚMEC, A., 1956, HOEKSTRA and MERGEN, 1957, MATTHEWS and MITCHELL, 1957, HOLST, 1959, DEWITT, 1960, HAUSSER, 1960, MERGEN and VOIGT, 1960, STEINBRENNER, DUFFIELD and CAMPBELL, 1960, KLEINSCHMIT, 1958 and 1961, MATTHEWS, 1961, FAULKNER, 1962, and BARNES and BINGHAM, 1963), site conditions (RENVALL, 1912, p. 114, and SARVAS, 1962, p. 22 and pp. 150—162), variation in 24-hour rhythm between light and darkness (photoperiodism, cf. BÜNNING, 1948 b, MIROW, 1956, and WAREING, 1956), the variation in temperature, e.g. as between night and day or summer and winter (a form of vernalization, cf. BÜNNING, 1948 b, MURNEEK and WHYTE, 1948) and treatment with auxins, kinetin and acids, e.g. gibberelins (cf. SKOOG, 1944 and 1957, SHIDEI, AKAI and ISHIKAWA, 1959, HACHIZUME, 1959 a, b, and KATO, NARAKATSU and REIJI, 1959).

Flowering may to a certain extent be induced with the help of methods of forced fructification such as girdling, strangulation and root pruning etc. (ARNBORG, 1946, LINDQUIST, 1948 a, JENSEN, 1954, BERGMAN, 1955, SYRACH LARSEN, 1956, HITT, 1957, HOEKSTRA and MERGEN, 1957, LONGMAN and WAREING, 1958, WAREING and NASR, 1958, HEITMÜLLER and MELCHIOR, 1960, MELCHIOR, 1960, and MATTHEWS, 1961). The effect of these treatments is as a rule of short duration (one to two years). The treatments reduce the trees' growth and vitality and often cause a high percentage of the trees to die. Girdling and strangulation may in the case of spruce and pine lead indirectly to severe attacks by insects. Root prunings may in their turn occasion root infections in both deciduous trees (GARRETT, 1958) and conifers (LOW and GLADMAN, 1960, FAULKNER and MATTHEWS, 1961). It is therefore very risky to resort to methods of forced fructification, of the kind mentioned, to induce flowering in forest-tree seed orchards or seed stands. The application of girdling and strangulation should be restricted to single individuals—and in this case preferably to a certain branch or certain branches in the crown—to ensure flowering for the carrying out of certain artificial crossings during a particular year.

Trees with large and well developed crowns are generally bigger producers of cones and seeds than smaller trees or trees with much reduced crowns

(FAULKNER, 1962). Sunlight is of great importance for the flowering of forest trees. It is indisputable that trees enjoying much sunlight (e.g. along the edges of stands or in sparsely planted stands) flower more luxuriantly than trees in the shade (cf. RENVALL, 1912, FLORENCE and MCWILLIAM, 1956, and MATTHEWS, 1961).

The genetic and physiological factors (cf. e.g. LANG, 1948), separately and in combination with each other and with external factors, probably play a great role for the forest trees' attainment of their flowering threshold, the intensity of flowering, periodicity of flowering and fertility, although these factors and the connection between them especially with respect to conifers are as yet incompletely investigated. It is therefore of very great importance especially for the work with forest-tree seed orchards (cf. GUSTAFSSON, 1949, JENSEN, 1954, ANDERSSON, 1957, 1958, 1960 and 1962, SYRACH LARSEN, 1956, and STERN, 1960, and others) to investigate as soon as possible the—probably complicated—biochemical reactions and reciprocal processes releasing and regulating the process of flower formation in forest trees.

Genetically conditioned variations have been shown with respect to the earliness of flowering in *Pinus silvestris* (SCHRÖCK, 1949) and with respect to, inter alia, the attainment of flowering threshold and the seed production in *Pinus silvestris* (JOHNSSON, KIELLANDER and STEFANSSON, 1953, ANDERSSON, 1954, ARNBORG and HADDERS, 1957, HADDERS and ÅHGREN, 1958, BLOMQVIST, 1961, and JOHNSSON, 1961) and in *Pinus nigra* (GATHY, 1959, and LENGER and GATHY, 1960). Clone-bound variations in the attainment of flowering threshold, earliness of flowering, pollen fertility and seed production have generally begun to appear in our seed orchards of pine (cf. inter alios JOHNSSON, KIELLANDER and STEFANSSON, 1953, SIMAK and GUSTAFSSON, 1954, ANDERSSON, 1954 and 1960, and JOHNSSON, 1961). SIMAK and GUSTAFSSON (1953 and 1954) and SIMAK (1960) have likewise shown differences in the percentage of empty seeds etc. in pine, of both a genetic and a modificatory character.

Physiologically, a good carbohydrate status is said to have a favourable effect upon the flowering (BÜNNING, 1948 a, MURNEEK, 1948, and BILAN, 1960). Photosynthesis affects the formation of flowering hormones (BÜNNING, 1948 a, p. 200). Good assimilate supply is likewise of great importance for the embryonic development of the seed plants (BÜNNING, 1948 a, p. 209). The embryo or embryos, as is known, get their nourishment from the endosperm, which in e.g. spruce and pine is developed after the fertilization (cf. MORK, 1933, pp. 133 and 136, HÅKANSSON, 1956, p. 10, and SARVAS, 1958, pp. 13—14). If the endosperm is destroyed, the embryo also dies (cf. BRINK and COOPER, 1941, and BÜNNING, 1948 a). A physiologically conditioned variability in male and female flowering frequency between 60-year and 150-year old pines in northern

Finland has been shown by RENVALL (1912, pp. 11 and 25). The older trees flowered more profusely in relation to the younger ones, both male and female. The variability in male flowering as between the age groups was greatest in unfavourable or weak flowering years. In such flowering years the male flowering is less reduced than the female flowering. The older trees produced relatively more male than female flowers also in rich flowering years. The relation between male and female flowers in the younger trees showed the same tendency in good flowering years. In weak flowering years the female flowering was reduced, relatively, to the same extent in both groups.

2.2. Flowering years

If one considers the influence of the weather during the flowering year one finds only few data in the literature concerning the effect of the climate and of climatic variations upon the development of the floral buds (the meiotic divisions of the micro- and megaspore mother cells, pollen mitosis and the continued development of the female gametophytes) and upon the fertilization of forest trees. Indications, observations and studies on modificatory disturbances of the gamete formation in Norway spruce, pine and larch are restricted, as far as I have been able to ascertain, to information by RENVALL (1912), TIRÉN (1935), VOGEL (1936), ANDERSSON (1947 a, b, and 1954), IWAKAWA and CHIBA (1952), BARNER and CHRISTIANSEN (1960) and CHRISTIANSEN (1960). Concerning such influences on the formation of the sex cells and on fertilization in pine, RENVALL (1912, p. 32) writes: "Ehe sich die Befruchtung in dem auf das Blütejahr folgenden Jahre vollzieht, sind besonders an der polaren und alpinen Waldgrenze viele Faktoren wirksam, durch welche die später folgende Samenbildung gefährdet werden kann oder die auch die Samenqualität in ungünstiger Richtung beeinflussen. Sowohl die männliche als die weibliche Blütenentwicklung fängt zeitig im Frühjahr an, wo in den fraglichen Gegenden regelmässig häufige, scharfe und andauernde Witterungswechsel auftreten. Man kann sich leicht vorstellen, dass diese ungünstigen Bedingungen auf die jungen Samenanlagen und Pollenkörner einen bedeutenden Einfluss ausüben. So z.B. könnte die Keimfähigkeit des Pollens aufgehoben werden. Aber auch wenn die Pollenschläuche zur Entwicklung gelangen, ist es nicht ausgeschlossen, dass die Kerne doch nicht mehr befruchtungsfähig sind. Ebenso liegt die Sache bezüglich der weiblichen Anlagen. Vorausgesetzt, dass der erste Frühling den Entwicklungsgang nicht hemmt, folgen doch noch ein Herbst und ein zweites Frühjahr, wo die äusseren Einflusse für die weitere normale Entwicklung der zarten Organe kritisch sein können. Wenn dann auch die Zapfen auswachsen, ist immerhin durchaus nicht gesagt, dass auch die Befruchtung wirklich vollzogen ist."

Similar indications concerning disturbances of the gamete formation have been communicated by TIRÉN (1935, p. 504), as follows in translation from the Swedish text: "As regards Norway spruce, data concerning the date for the formation of the sex cells and their further development are very sparse or altogether lacking. SCHNARF (1933) refers in this connection to MIYAKE, who does not (1903), however, give any definite information of interest in this matter. But a number of other gymnosperm species have been studied more closely, and among these it is common for the most important changes in the buds (inter alia, the reduction division) to take place in the spring. It is thus not improbable that also in spruce we shall find the strongest weather influences in the spring." Especially RENVALL's—and to a not inconsiderable extent also TIRÉN's—above quoted assumptions are remarkable for their time. With the exception of some data regarding the number of chromosomes in different conifers (established by, inter alios, STRASBURGER, 1892, BLACKMAN, 1898, CHAMBERLAIN, 1899, JUEL, 1900, FERGUSON, 1901 and 1904, C. ISHIKAWA, 1902, MIYAKE, 1903, CARDIFF, 1906, LEWIS, 1908, SAXTON, 1909, M. ISHIKAWA, 1910, B. NĚMEC, 1910, MIYAKE and YASUI, 1911, BAILEY, 1920, SMÓLSKA, 1927, or communicated by TISCHLER, 1926/1927 and 1931), there was in 1912 and even in 1935 very sparse information concerning the reduction division of the conifers. No meiotic disturbances in spruce had been demonstrated. Through e.g. HOFMEISTER (1848 and 1851), StrasBURGER (1872, 1878, 1880, 1892, 1897 and 1910), COULTER (1897 and 1898), BLACKMAN (1898), CHAMBERLAIN (1899 and 1935), FERGUSON (1904), LEWIS (1908), BUCHHOLZ (1918, 1920 a and b, 1926 and 1929), DOYLE (1918) and SCHÜRHOFF (1927) and others, however, biological science has been enriched by several new and important observations in the fields of alternating reproductive cycles, anatomy, embryology and cytology. H. J. SAX (1932) was the first to describe chromosome pairing in a coniferous hybrid. She gave a detailed analysis of the chiasma frequency in two larch species, viz., *Larix kaempferi* (Sarg.) and *L. decidua* (Mill.) and in the F_1-hybrid between these species *L. eurolepis* (Henry). At the same time she stated that the appearance and orientation of the chromosomes during meiosis had also been studied in *Pinus*, *Tsuga*, *Taxus*, *Picea*, *Pseudolarix* and *Cedrus*. In the same year DARK (1932) published a work on the reduction division in *Taxus*, *Sequoia*, *Cryptomeria* and *Thuja*. A year later the SAX, husband and wife (cf. SAX and SAX, 1933), published an investigation on chromosome number, chromosome morphology and the chiasma frequency in a number of coniferous genera, including *Pinus* and *Picea*. In the majority of the coniferous species studied the haploid chromosome number was found to be 12. The chiasma frequency for different coniferous genera and coniferous species varied between 1.9 and 2.7 chiasmata per bivalent (e.g. 2.7 for *Picea abies* and between 2.3 and 2.5

for different *Pinus* species). "The meiotic divisions were very regular, and unpaired chromosomes were found only in rare cases. Even the species hybrids show regular divisions and a high percentage of fertile pollen." (Cf. SAX and SAX, 1933, p. 367).

Through, inter alios, TIRÉN (1935) we know that the connection between the flowering time of Norway spruce and the temperature during the spring months is strongly positive. The strongest connection as regards Fennoscandia appears to exist between the temperature in the month of May and the flowering time. There are scattered indications in the literature to the effect that flower buds and even the embryo formation in conifers may be damaged by frost (cf. SCHOTTE, 1911, pp. 179 and 182, BÜHLER, 1918, p. 446, VOGEL, 1936, p. 40, HEIKINHEIMO, 1948, p. 15, SKINNEMOEN, 1948, p. 33, ROBAK, 1948, p. 82, and SARVAS, 1962, p. 125), and that rain, cold, or both in combination, may have a prejudicial effect upon the pollen fertility, pollination and seed setting of conifers (cf. RENVALL, 1912, pp. 32, 90—91, BÜHLER, 1918, p. 467, EIDE, 1925 a, pp. 65—66, 1930, p. 491 and 1932, pp. 276—277, TIRÉN, 1935, p. 419, SKINNEMOEN, 1948, pp. 33—34, ANDERSSON, 1954, p. 3, BARNER and CHRISTIANSEN, 1960, p. 3, CHRISTIANSEN, 1960, p. 77, and SIMAK, 1960, p. 12).

VOGEL (1936) investigated in the years 1933 and 1934 the reduction division, pollen dissemination, fertilization and embryo formation in two provenances of *Pinus silvestris*. In earlier studies carried out at the School of Forestry in Eberswalde, cones of non-local pine provenances at Chorin had proved over a period of several years to contain an abnormal number of empty seeds in relation to seed of the native provenance (Moravian origin). Especially seed with south French provenance (Dent du Longre Haute Loire, 1,140 m. above sea level) had at Chorin (40 m. above sea level) in the winter of 1927/28 an unusually high percentage of empty seeds (85 per cent). The corresponding percentage of empty seed in pine seed of Moravian origin (VOGEL, 1936, p. 35) from the Chorin tract amounted in the same winter to 30. VOGEL's intention in his investigations was chiefly to ascertain the causes of the occurrence of empty seed and of the variation in the amount of empty seed in seed of Moravian and South French origin. The course of the reduction division in the springs of both 1933 and 1934 was regular in both provenances. From communicated temperature data for the months of March and April in the years 1933 and 1934 (VOGEL, 1936, p. 36) it emerges that no night frosts or high day temperatures occurred during the period for the reduction division and pollen mitosis. The weather conditions in other respects seem also to have been favourable during the pollination. It is thus not surprising that no climatically conditioned disturbances of the gamete formation were observable in these years. On the other hand, VOGEL (1936, p. 40) found that "Gerade in den Jahren, die einen hohen Hohlkornprozentsatz bei klimafremder Provenienz zeigten, gingen hiermit parallel anormale Witterungsverhältnisse. Diese Tatsache scheint zu belegen, dass die klimafremden Provenienzen zumindest physiologisch bereits während der Pollenentwicklung in dem der Reife vorhergehenden Jahr beeinflusst werden, wogegen sich der schädigende Faktor erst bei der weiteren Embryoentwicklung degenerierend auswirkt."

The first known case in *Picea abies* with almost suspended chromosome pairing during metaphase$_1$ (so-called asynapsis and asyndesis, cf. BEADLE and McCLINTOCK, 1928, and BEADLE, 1930 and 1933) was demonstrated by the present author in the year 1947 (ANDERSSON, 1947 a and b). The incomplete chromosome pairing resulted in a more or less random chromosome distribution among the daughter cells. This irregular chromosome distribution plus other chromosomal aberrations during anaphase$_1$ and succeeding stages of division during the reduction division gave rise to a very varying pollen size and pollen form and a high degree of pollen sterility. Only 2.6 per cent morphologically good pollen was developed. The climatic conditions were favourable during the reduction division. To judge from the seed setting, the course of the meiosis in the mother cells of the embryo sac appear to have been equally irregular. The percentage of empty seeds after the open pollination with copiously male flowering spruce trees in the vicinity—under climatically very good conditions for seed maturation—amounted to 98.1 per cent. Similar cases of asyndesis have since been observed in some trees of *Pinus silvestris* (ANDERSSON, 1954, pp. 16 and 34, and RUNQUIST, unpubl.) The above-adduced case of asyndesis in *Picea abies* seems in all probability to have been gene-conditioned. In the first place the asyndetic spruce has even under very favourable climatic conditions year after year shown the same defective chromosome pairing, and in the second place grafts of the asyndetic spruce—growing under somewhat different climatic conditions than those prevailing for the original tree—have after attaining flowering age (with the exception of the spring of 1961, when all the flower buds on the grafts were destroyed by frost) shown the same disturbances during meiosis as the original tree. The anomalies during the reduction division have consisted in the irregular distribution of homologous and non-homologous chromosomes to the cell poles, "non-disjunction, misdivision, lagging univalents" and chromatin bridges. Gene-conditioned asyndesis has been shown in, inter alia, *Zea mays* (BEADLE and McCLINTOCK, 1928 and BEADLE, 1930 and 1933), *Nicotiana tabacum* (CLAUSEN, 1931), *Hordeum* (EKSTRAND, 1932), *Datura* (BERGNER, CARTLEGDE and BLAKESLEE, 1934), *Nicotiana sylvestris* (GOODSPEED and AVERY, 1939), *Alopecurus myosuroides* (JOHNSSON, 1941 and 1944), *Secale* (PRAKKEN, 1943), *Rumex* (LÖVE, 1943) and *Triticum vulgare* (LI, PAO and LI, 1945).

Among selected Norway spruce trees with presumed normal meiosis were found three trees with wholly or partly agglomerated chromosomes during the meiosis, so-called stickiness (cf. BEADLE, 1932). The last mentioned disturbances were in this case presumed (ANDERSSON, 1947 a and b), on the basis of certain comparative studies of the course of the meiosis under varying temperatures, to be of a modificatory nature.

Similar meiotic disturbances in *Larix* species have been shown by BARNER and CHRISTIANSEN (1960, p. 1). "The pollen frequently showed irregularities which pointed to disturbances during the reduction division, which might perhaps be the cause of unsuccessful controlled pollinations." Through control germinations of the pollen it was possible to establish the fact that it had no power of germination. The reduction division in the larch may in certain years in Denmark (according to the same authors) begin as early as in February or during the first half of the month of May. In this part of the year longer warm periods on Copenhagen's latitude are rare. Marked temperature changes in the 24-hour cycle are, however, common. BARNER and CHRISTIANSEN were also able to establish the fact that current divisions in *Larix decidua* stopped when the temperature dropped below + 4 to + 2°C., to continue with rising temperature. The temperature changes gave rise to disturbances of the meiotic process. Pollen mother cells with disturbed meiosis produced an irregular pollen with low fertility. In the spring of 1956 CHRISTIANSEN (1960) studied the meiotic process in two trees of *Larix decidua*, and one of these in detail throughout the period during which the divisions were taking place. At the same time a control was performed of the reduction division (in cut off branches of the same tree) at temperatures varying between + 7 and + 15°C. In comparison with the control he observed in the flower buds taken direct from the trees a series of chromosomal disturbances as well as disturbances in the spindle mechanism during meiosis. The low temperature caused a discontinuation of the divisions and, directly or indirectly, the structural chromosome changes arising during the meiotic stages. "Those most frequently observed were: stickiness, pycnosis, chromosome breaks and fragmentation, chromatin bridges at anaphase$_1$ (abbrev.: A_1) and anaphase$_2$ (abbrev.: A_2), abnormal contraction of the chromosomes, irregular cell wall formation, deformities of PMCs and unequal size of nuclei, and abnormal chromosome numbers. The bivalents at the stages diplotene-M_1 were so strongly contracted that it was often difficult to determine the stage" (cf. CHRISTANSEN, 1960, p. 74). The breaking down or inactivation of the nuclear spindle, corresponding to what is known in other organisms (cf. e.g. DARLINGTON, 1937, pp. 408—410, and ÖSTERGREN, 1950, pp. 371—382), has helped to delay or counteract the orientation of the chromosomes during the first and second metaphases and to inhibit the separation of chromosomes and chromatids during the first and second anaphases respectively.

If there is marked partial sterility on both the female and the male side, this should lead to a particularly high percentage of degenerated ovules and probably also a high embryo mortality and therewith weak seed setting. Even if individuals with both male and female sterility are relatively rare, as in maize (cf. EMERSON, BEADLE and FRASER, 1935) and strains of tomato (cf. RICK, 1945 and 1946), then either partial or complete male sterility may of course lead to the occurrence of a high percentage of unfertilized and degenerated ovules owing to incomplete pollination. In cross-fertilized plant species genetically conditioned partial sterility is common in e.g. rye (cf. MÜNTZING, 1939, 1944, 1945, 1946, 1948 a and b, MÜNTZING and PRAKKEN, 1941), and also in many other cross-fertilized populations. In rye this partial gamete sterility occurs on both the male and the female sides, and is often caused by characteristic meiotic disturbances. In addition to climatic factors and partial sterility (haplontic as well as diplontic), seed setting and the seed crop may be strongly affected by the flowering intensity, the relation between the number of male and female flowers and the occurrence of recessive lethal factors in homozygotic form (cf. e.g. LANGLET, 1940, WARREN and HAYES, 1950, and JOHNSSON, 1961, p. 17).

As early as 1910 SYLVÉN was able through his studies on self-fertilization in Norway spruce (*Picea abies*) to prove that this tree-species is partly self-fertile. The result of pollination varied from tree to tree with in general a lower percentage of germination for seed after self-pollination. The vitality of these inbred progeny has since, with respect to percentage of survival and growth, also proved to be considerably lower than that found in comparable progeny from seed after open pollination (LANGLET, 1940).

RENVALL (1912, pp. 29 and 31) found that weak male flowering in *Pinus silvestris* often constituted the chief cause of the poor pollination and seed setting in pines near the northern Artic Circle. "Es ist eine sehr eigentümliche Sache, *dass in einem produktiven weiblichen Blütejahre der Kiefer ein entsprechend reichliches männliches Blühen nicht eintritt und dass andererseits die männliche Blütenbildung durch den Jahreseinfluss stark gesteigert werden kann, ohne auch das weibliche Blühen entsprechend zu begünstigen.*"

2.3. *Year of seed maturation*

Unfortunately, even copious flowering does not necessarily always imply copious seed setting. Already HAGEM (1917, p. 113) observed that "a good flowering year is as a rule (though not always) followed by a rich cone crop in the following year, but a rich cone year is not always a good seed year."

Thus investigations directly connected with the seed maturation year for forest trees do not deal only with course of fertilization, seed setting, maturity and germination rate of the seed and different internal connections between cone and seed properties, seed quality and plant development, but also with factors which have a depressing or stimulating effect upon the size and quality of the seed crop.

Especially as regards pine (*Pinus silvestris*) SARVAS (1958 and 1962) has carried out in Finland detailed investigations of factors reducing seed production and seed quality. In this connection he has made certain causes of non-fertilization and occurrence of empty seeds the main object of his investigations. Light has also been thrown upon the seed setting of Norway spruce (SARVAS, 1957 and 1958). Different causes affect the formation of empty seeds and these causes can vary for different tree species. In contradistinction to spruce, the pine develops no empty seed in case of non-pollination. Only a seed wing shows in the pine that an unfertilized egg cell has degenerated. On the other hand, in the case of pine, only those embryos which collapse for one or another reason give rise to empty seeds (SARVAS, 1962, pp. 111 and 163). According to SARVAS (1958, p. 14), self-pollination is, in pine, the main cause of the appearance of empty seeds. For pine, the percentage of self-pollination amounts to on an average 26 per cent according to the same writer (SARVAS, 1962, p. 185). In the case of Norway spruce, SARVAS (1955 a, p. 34, and 1958, p. 13) states that the greatest amount of empty seed is due to incomplete pollination. But also the percentage of empty seeds arising chiefly from self-pollination is estimated at 20—25 per cent (SARVAS, 1958, p. 13). The average percentage of empty seed due to both incomplete pollination and self-pollination is given as 40—50 per cent. In good agreement with the value for the average empty seed percentage in spruce seed found by SARVAS are HEIKINHEIMO's data. HEIKINHEIMO (1937, pp. 26 and 67) found that the percentage of empty seed in the natural seed of Norway spruce amounted for several years to on an average 45.2 per cent. However, the percentage of empty seed varied very considerably between populations and between years (HEIKINHEIMO, 1937, pp. 27—41) and in certain years—especially in weak flowering years—it might rise to 100 per cent.

Summarizing, several factors seem to affect the formation of empty seed. These causes may as regards spruce be classified in two main groups: 1) factors leading to non-fertilization and 2) factors occasioning the death of the embryo. The factors leading to non-fertilization are pronounced metandry, genetically conditioned sterility (SYLVÉN, 1910, LANGLET, 1940, JOHNSON, L.P.V., 1945, ANDERSSON, 1947 a and b, LANGNER, 1951, EHRENBERG *et al.*, 1955, ORR-EWING, 1957, SARVAS, 1962, and DIECKERT, 1964), sterility due to unfavourable temperature climate during the formation of the sex cells (cf. GUSTAFSSON, 1962, p. 166), adverse wind and weather conditions at the time of pollination, climatic disturbances during the period between pollination and fertilization and the effect of certain damages by insects possibly arising in the nucellus tissue, archegonia or adjacent tissues in the ovules before fertilization. To the other complex of causes, leading to embryo mortality and therewith also formation of empty seed, belong, inter alia, the occurrence of recessive lethal factors in homozygotic form, unfavourable weather conditions after fertilization (SARVAS, 1962, pp. 123 and 125) and a set of damages by insects.

While the percentage of empty seed (in both pine and spruce) and the degree of non-pollination in pine adversely affect chiefly the size of the seed crop, the degree of seed maturity and germinating ability affects the quality of the seed crop.

Further, very close attention, especially in Finland, Norway and Sweden, has been paid to the connection between the questions of seed maturity, cone years and fresh growth on the one hand, and the summer temperature and other climatic factors on the other hand, and also to the reciprocal connection between the questions of seed and fresh growth. The comprehensive literature on forest seed should testify to the interest in and the great importance ascribed to the questions of seed maturity (cf. SCHOTTE, 1905, 1909, 1910, 1911 and 1924, SYLVÉN, 1908 and 1916, WIBECK, 1910, 1919, 1920, 1928 and 1936, HOLMGREN, 1911, RENVALL, 1912, SEEGER, 1913, HAGEM, 1914, 1917 and 1931, LAKARI, 1915, ILVESSALO, 1917, EIDE, 1923, 1925 a, b, 1926, 1927, 1928, 1930, 1931 and 1948, HEIKINHEIMO, 1921, 1932, 1937, 1948 and 1949, KOLMODIN, 1923, KUJALA, 1927, NORDFORS, 1928, SCHMIDT, 1930, MORK, 1931 and 1933, OPSAHL, 1931 and 1952, DENGLER, 1932, 1939 and 1940, HOLMGREN and TÖRNGREN, 1932, SCHNARF, 1933 and 1937, HESSELMAN, 1934 and 1939, TIRÉN, 1935, 1945, 1946 and 1952, MÜNCH, 1936, ACATAY, 1938, RUBNER, 1938, RECKE, 1939, ROHMEDER, 1939 a, b, 1949 and 1954, BALDWIN, 1942, ROESER, 1942, ARNBORG, 1943 and 1958, PLYM FORSHELL, W., 1945, STEFANSSON, 1946, 1950, 1951 and 1962, MESSER, 1948, ROBAK, 1948, NORDSTRÖM, 1950, 1953 a, b and 1955, SARVAS, 1950, 1955 a, 1957, 1958 and 1962, HUSS, 1951 and 1961, CERNÝ and POLNAR, 1951, GUSTAFSSON, 1952, 1956 and 1962, LANGNER, 1953 and 1959, PLYM FORSHELL, C., 1953, SIEGEL, 1953, SIMAK, 1953, a and b, 1955 and 1960, SIMAK and GUSTAFSSON, 1953, 1954 and 1959, BRANTSEG, 1954, MÜLLER-OLSEN and SIMAK, 1954, EHRENBERG, GUSTAFSSON, PLYM FORSHELL, C. and SIMAK, 1955, EHRENBERG, EKLUNDH and SIMAK, 1957, HÅKANSSON, 1956, 1959 and 1960, MÜLLER-OLSEN, SIMAK and GUSTAFSSON, 1956, SIMAK, GUSTAFSSON and GRANSTRÖM, 1956, BERGMAN, 1957, 1959 and 1960, ORR-EWING, 1957, RUDEN, 1957, HAGNER, 1958, HAGNER and SIMAK, 1958, HAGNER and CALLIN, 1959, NILSSON, 1959, and ROHMEDER and SCHÖNBACH, 1959).

In recent years the internal and reciprocal relations between different seed and cone properties in Scots pine—and of these especially the connection between degree of seed maturity and germinating ability—have been investigated by, inter alios, SIMAK and GUSTAFSSON and their co-workers. Certain sections of these seed studies are based upon the roentgen-diagnostic method elaborated by SIMAK and GUSTAFSSON (1953). For certain studies comparisons have been drawn between seed properties in grafts and their trees of origin in different climates (SIMAK and GUSTAFSSON, 1954). These, as well as earlier investigations by e.g. SCHOTTE, HAGEM, HEIKINHEIMO, EIDE, KUJALA, NORDFORS, WIBECK, MORK, OPSAHL, TIRÉN and NORDSTRÖM have shown as clearly as can be desired that, inter alia, the maturity of the seed is strongly positively correlated with a high summer temperature during the year for seed maturation. The more favourable the temperature conditions are during seed maturation, the better the seed quality or the embryo development will be. The better the embryonic state, the higher the germination capacity. This result is further accentuated by the fact that seed which is not quite physiologically up to standard can often be appreciably improved with respect to germinative power and rate of germination through different methods of treatment, e.g. *through relatively early collection* and *suitable storing*, resulting in post-maturity (NORDSTRÖM, 1950 and 1955 and EDLUND, 1959), *through light treatment* (SARVAS, 1950, NORDSTRÖM, 1953 b, HUSS, 1961 and NYMAN, 1963), *through stratification* (STEFANSSON and BERGMAN, 1956, SIMAK and GUSTAFSSON, 1957, HAGNER and SIMAK, 1958, and BERGMAN, 1959), *through equilibration* (SIMAK and GUSTAFSSON, 1959, and BERGMAN, 1959) and *through soaking in water or weak acids* (KARLBERG, 1953) or *potassium nitrate* (BERGMAN, 1959).

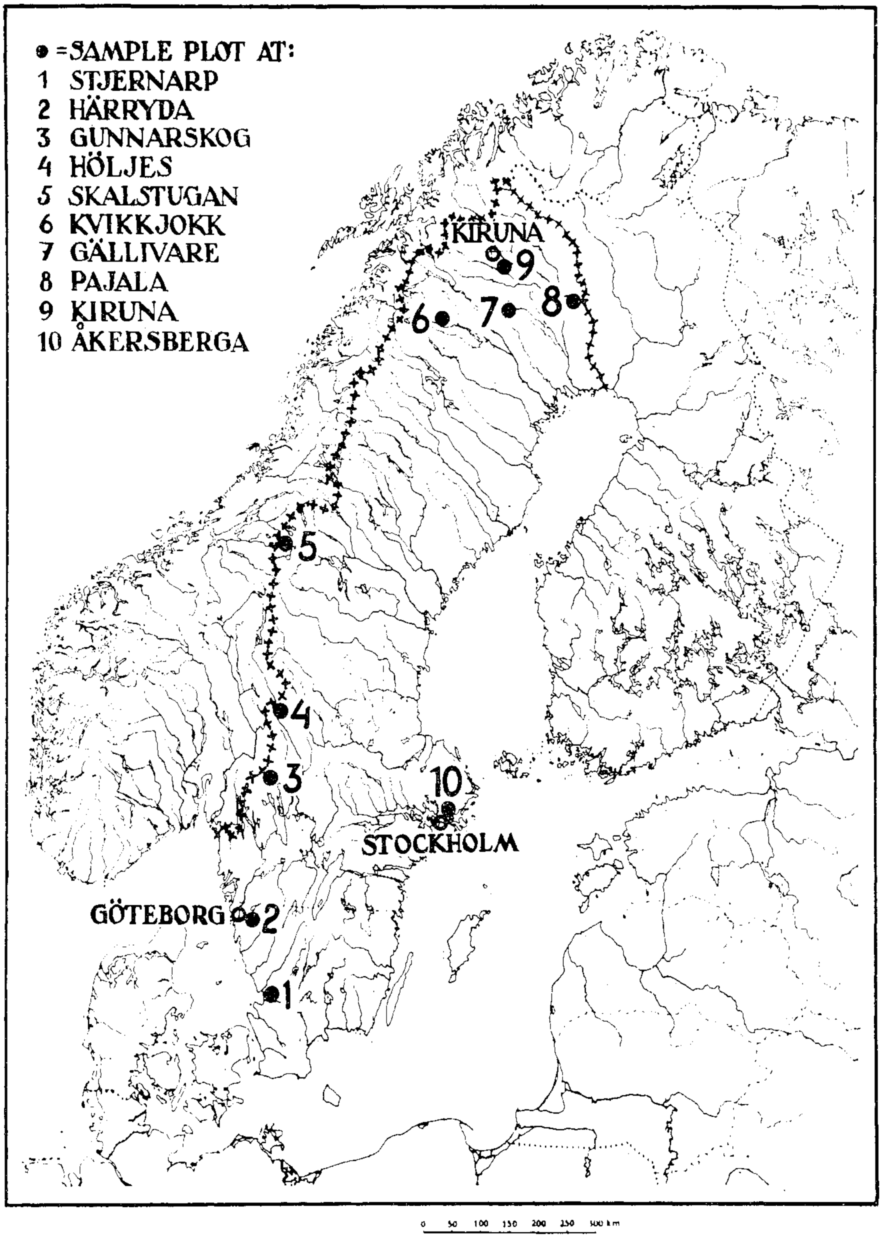


Fig. 1. Geographical distribution of the sample plots.

3. Material and methods

The studies of variation and relationship of cone and seed properties are mainly based on the Norway spruce cone and seed material collected in Sweden in the years 1948 and 1954. The material for 1948 covers 5 sample plots (Stjernarp, Härryda, Gunnarskog, Höljes and Skalstugan) and the 1954 material covers 6 sample plots (Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala). Three of the sample plots are common to both 1948 and 1954, namely Stjernarp, Gunnarskog and Skalstugan. The investigations of seed qualities are for 1948 and 1954 based on the same cone and seed material used for the studies of relationship of cone and seed properties. Some seed studies are also made on the seed material collected in 1960 and 1961 from Gällivare and Kiruna. A certain comparison in the question of cone and seed properties is made with cone and seed collected in 1946 within two of the sample areas (Härryda and Höljes) which are included in the 1948 material. A comparison in respect to seed quality is made with seeds obtained after open-pollination and controlled self-fertilization in 1954 from a trial with inbred lines and offsprings after wind pollination of Norway spruce at Åkersberga (cf. SYLVÉN, 1910 and LANGLET, 1940). Particulars of ages for the stands (with the exception of the trial at Åkersberga) refer to the ages of the trees at breast height in 1955. The localization of the sample plots can be seen in Fig. 1 and from the following short information regarding, among other things, the places where the stands grow.

3.1. The localization of the sample plots

Sample plot 1. *Stjernarp* (56° 38′ lat. N. and 12° 59′ long. E.G.) is situated 10 km. E.S.E. of Halmstad. Altitude is approximately 35 m above sea level. The Norway spruce plantation is of Central European extraction. High crown density. Age of stand 51 years. The ground vegetation consists mainly of various species of herbs. Level ground.

Sample plot 2. *Härryda* (57° 42′ lat. N. and 12° 20′ long. E.G.) is situated approximately 20 km. east of Gothenburg. Altitude—approximately 100 metres above sea level. Natural stand of Norway spruce. Normal crown density. Age of trees 70—100 years. Ground vegetation consists of blueberry shrubs, herbs and a number of mosses. Sloping ground.

Sample plot 3. *Gunnarskog* (59° 51′ lat. N. and 12° 31′ long. E.G.) is situated approximately 20 km. N.N.W. of Arvika. Altitude—approximately 140 m. above sea level. Natural stand of Norway spruce. Age approximately 70 years. High crown density. Ground vegetation consisting of blueberry shrubs, herbs and mosses. Sloping ground.

Sample plot 4. Granberget, *Höljes* (60° 54′ lat. N. and 12° 44′ long. E.G.) is situated approximately 58 km. W.N.W. of Malung. Altitude—approximately 660 m. above sea level. Natural stand of Norway spruce. Age of trees 60 to 100 years. Fairly weak crown density. Most of the trees have broken crowns. Ground vegetation consists mainly of blueberry and cowberry shrubs, herbs and mosses. Sloping ground. The stand is exposed to winds.

Sample plot 5. *Skalstugan* (63° 34′ lat. N. and 12° 17′ long. E.G.) is situated at the spruce forest limit approximately 30 km. N.N.E. of Storlien. Altitude is approximately 585 m. above sea level. Sparse natural stand of Norway spruce interspersed with birch (*Betula tortuosa* and *B. coriacea*). Age of trees from 50 to 200 years. Crown density very sparse. Ground vegetation consists mainly of blueberry and cowberry shrubs, herbs, dwarf birches (*Betula nana*), mosses and lichens. Slightly sloping ground. The stand is extremely exposed to winds.

Sample plot 6. *Kvikkjokk* (66° 58′ lat. N. and 17° 45′ long. E.G.) is situated near the spruce forest limit approximately 100 km. W.N.W. of Jokkmokk in the Norrbotten Lapp-district. Altitude varies from 400 to 550 m. above sea level. Natural stand of Norway spruce interspersed with birch (*Betula tortuosa* and *B. coriacea*). The ages of the trees vary from 50 to 150 years. Crown density is sparse. Ground vegetation consists mainly of blueberry and cowberry shrubs, mosses and lichens with a certain amount of herbs. The stand is fairly strongly exposed to winds.

Sample plot 7. Dundret, *Gällivare* (67° 07′ lat. N. and 20° 38′ long. E.G.) is situated approximately 2 km. S.W. of Gällivare. The altitude varies from 370 to 470 metres above sea level. The ages of the trees vary from approximately 50 to 300 years. Crown density is sparse. Ground vegetation consists of cowberry and blueberry shrubs, mosses and lichens with certain herbs. The stand is strongly exposed to the wind.

Sample plot 8. Kaskuvaara, *Pajala* (67° 09′ lat. N. and 23° 33′ long. E.G.) is situated approximately 10 km. S.E. of Pajala. Altitude —140 m. above sea level. Natural stand of Norway spruce. The ages of the trees vary from 70 to 240 years. Crown density sparse. Ground vegetation consists of cowberry and blueberry shrubs and mosses. Level ground.

Sample plot 9. Aptasvaara, *Kiruna*, (67° 50′ lat. N. and 20° 26′ long. E.G.) is situated 9 km. E.S.E. of Kiruna. The altitude varies from 450 to 500 metres above sea level. Natural stand of Norway spruce. Ages of trees from 50 to

250 years. Crown density fairly sparse. Ground vegetation consists of cowberry and blueberry shrubs, mosses and lichens. Very strongly exposed to winds.

Sample plot 10. *Åkersberga*—spruce trial with offsprings after open pollination and controlled self-pollination (see SYLVÉN, 1910). Situated approximately 25 km. N.E. of Stockholm (59° 30′ lat. N. and 18° 21′ long. E.G.). Altitude approximately 20 metres above sea level. The test was started in 1916 with six year old seedlings (cf. LANGLET, 1940). Planting distance 3 × 3 metres. Ground vegetation consists of herbs and a certain amount of blueberry shrubs. Slightly sloping ground.

3.2. Material for the year 1948

Cone samples, consisting of 25 cones from every tree, were collected from 5 sample plots (sample areas 1—5) and from 50 trees per plot. The cones were taken from within the top third of the tree crowns, on the southern side. Only trees with more than 30—40 cones within this area and on this side of the tree crown were included in the investigation. The cones from every tree, on the other hand, were chosen as randomly as possible in consideration of distribution and size. The cones were stored individually in bags which were bundled together in "trees" for every area. The cones were highly resinous.

All the cone material was first treated with circulating warm air in a drying room for cones, at a temperature of 45° C., for 24 hours. After this the cone scales were removed from each cone by hand, one by one, at the same time as every seed (both large and small) together with all the cone residue, was carefully collected. The seed was dried at a temperature of 45° C. for 24 hours before weighing. The weight of the cone residue was determined after drying at 100° C. for 24 hours. The lengths of the cones were measured before the seed extraction. The seed was divided up by cone and tree into two size classes; 1) seed $>$ 1 mm. and 2) seed $\leq$ 1 mm. (Appendix Tables I—V).

Mean cone values of cone and seed properties, for individual trees and populations, are also listed in the Appendix Tables I—V. Every mean cone-value for individual trees in 1948 is based on 25 cones or cone values and provided with a standard error, calculated according to the formula $s/\sqrt{n}$, where s is the empiric standard deviation among the individual cone values. The standard error for mean plot values in the appendix tables are calculated according to the same formula on the basis of 50 mean tree values within each sample plot. The weights of the seeds are not included in the cone weights.

Spruce flowering as well as the supply of cones was, in general, mediocre in Southern and Central Sweden during 1948. In the area of Höljes in Northern Värmland, and further north, the flowering was considerably weaker and the supply of cones low (cf. Huss, 1949 and Hagner, 1958, p. 47). The ripening and fertility of the seed was satisfactory in the South but somewhat less satisfactory in Central Sweden.

3.3. Material for the year 1954

In the Autumn of 1954 cone samples were collected from 6 sample plots (no. 1, 3, 5—8) and 50 trees per plot. The material during this year was restricted to 15 cones per tree. As in 1948 the cones were selected as indiscriminately as possible in regard to size and disposition, within the top third portion of the tree crowns, on the southern side. On account of the number of trees felled by storms or by thinning that had occurred within the sample plots between 1948 and 1954, or the large variation in the supply of cones, it was only possible in a small degree to include the same trees in the examination of 1954 as in 1948, within the two stands at Stjernarp and Gunnarskog. The cone length was measured before the seed extraction, and the seeds were then extracted by hand cone by cone. The residue of the cones was dried before weighing, at a temperature of 100° C. for 24 hours. The drying of the seed was carried out at a temperature of 45° C. for 24 hours, after which the seed was weighed. The cone weights given in the Appendix Tables VI—XI do not include the seed but give the average figure for the residue of 15 cones for every tree. The cones were free from resin.

The seed was divided into four groups; 1) seed $\leqq 1$ mm., 2) seed $> 1 \leqq 1.5$ mm., 3) seed $> 1.5 \leqq 2.0$ mm. and 4) seed > 2.0 mm. The germination percentage for each seed size class was determined after 30 days in the Jacobsen germinator (cf. Huss, 1951). These germination percentages are presented in the Appendix Tables XXIII—XXVIII.

The year 1954 was unusually prolific for flowers and cones (cf. Huss, 1954, Andersson, 1955, and Hagner, 1955 and 1958). The pollen production within large areas of Sweden was in the nature of a record and the conditions for the distribution of the pollen were very good. Large clouds of pollen were observed and these were even mistaken for the clouds of smoke from forest fires. The lakes were covered near the edges with a centimetre thick layer of spruce pollen (cf. Andersson, 1963). Seed production was high and the supply of cones, as well as the ripening and germination capacity of the seed, was generally very good over the whole country (cf. Huss, 1954, and Hagner, 1955 and 1958).

3.4. Material for the years 1946, 1960 and 1961

Cones were first collected in 1946 from the sample plots in Härryda and Höljes. The size of the sample was 15 cones per tree. The same collecting, extraction, cleaning and drying procedure was used as that employed in 1948 and 1954. This method has already been described. In the year 1960 a similar collection within the sample plots was made in Gällivare and Kiruna. The collection was repeated in Gällivare and Kiruna in 1961. The method for collecting, extraction and cleaning the cones, as well as drying the cone residue, was the same as that described for the material from 1948 and 1954. The number of cones examined in the years 1960 and 1961 was restricted to 10 cones per tree.

The supply of spruce cones in the Autumn of 1946 was sparse and seed ripening was fairly incomplete. The supply of spruce cones was also small in 1960. Seed ripening and seed production was very low. With the exception of certain mountain districts the production of spruce cones in 1961 was almost non-existent throughout the whole of Sweden. In Kiruna and Gällivare, however, spruce flowering as well as the production of cones was greater in 1961 than in 1960. Seed ripening was, however, very bad.

As can be seen from the aforementioned descriptions, the cones were chosen, in regard to cone size and cone disposition, as indiscriminately as possible within the top third of the tree crown's length, on the southern side of the tree. Over-and under-representation of certain cone sizes or cones from certain branches within the crown area has, as far as possible, been avoided. The restricting of the collecting of cones to the top third of the crown length, on the southern side of the trees, has been decided upon because the cones are mainly concentrated to this part of the crown during weak and mediocre flowering years. This has especially been the case in 1946 and 1948. The only cones rejected during collection were those with incompletely closed scales or cones destroyed by fungus attacks, where such have appeared.

Although no strict randomisation mechanism was applied, the selection procedure must be considered as nearly equivalent to a simple random sampling of cones from the southern side of the top portion of the crown. The method of sampling should thus warrant consistent estimates of means, regressions, correlations etc. (still with the restriction to the upper third of the southern part of the crown).

It has already been stated that the same number of cones was taken from every tree in one and the same year of collection. The statistical examination and testing of the observation data has thus been simplified. An alternative to this method would be to sample the trees in proportion to their total number of cones. Such an allocation would result in consistent estimates of "per cone averages" in the pooled population of cones from all trees of the plot. For the purpose of the present investigation the above mentioned averages (with each tree weighted according to its number of cones) have no advantage over the unweighted means representing those trees in the population which have the required number of cones. Since the selection of a sample of fixed size from every tree results in much simpler methods for choosing the sample and for processing and analysing the data, it has been preferred to the more complicated method of proportional allocation.

3.5. Seed quality

Embryo and endosperm development as well as the contents of seeds damaged by insects have been examined diagnostically by X-rays, according to the method worked out by SIMAK and GUSTAFSSON (1953 a and b) at the Department of Forest Genetics of the Royal College of Forestry in Stockholm. The seed material from 1954 has also been germinated in the JACOBSEN germinator (see HUSS, 1951).

As has earlier been documented by SIMAK and GUSTAFSSON (1954), MÜLLER-OLSEN and SIMAK (1954), EHRENBERG, GUSTAFSSON, PLYM FORSHELL and SIMAK (1955) and MÜLLER-OLSEN, SIMAK and GUSTAFSSON (1956), there exists a strong connection between the observed germination of the seed and its embryo and endosperm development (examined by the X-ray method). By comparing this morphological seed development with the percentage of germination found after 30 days in the JACOBSEN germinator, these research workers could determine the specially related germination percentage (see Table 1) for decided quality types of embryo and endosperm (so-called embryo and endosperm classes). If the seed is fresh and sound the estimated anatomical rate of seed germination in a certain morphological class or a simple random sample can be regarded as an expression of the probability of germination for the class or the sample in question. On the basis of the percentage of seed in each embryo and endosperm class, an average germination percentage for every tree can be estimated (see the Appendix Tables XVII B—XXI B and XXIX B—XXXIV B).

In regard to the embryonic development the following five embryo classes were used from MÜLLER-OLSEN, SIMAK and GUSTAFSSON (1956):

0: Neither embryo nor endosperm.

I: Endosperm, but no embryo. Embryo cavity developed.

II: Endosperm, and one or several embryos of which none were longer than half of the embryo cavity.

III: Endosperm, and one not wholly developed embryo, the length of which measures between half and three-quarters of the embryo cavity.

IV: Endosperm with one fully developed embryo, completely or almost completely occupying the embryo cavity.

Also, in regard to the endosperm development, the classification that was worked out and applied by MÜLLER-OLSEN, SIMAK and GUSTAFSSON (1956), has been followed.

The embryo classes I—IV have thus been divided into two endosperm classes, namely:

A: The endosperm almost fills the seed coat to capacity and absorbs the X-radiation well.

B: The endosperm only incompletely fills the seed coat and is often shrunken or otherwise deformed. The X-ray absorption is inferior to that of class A (cf. Figs. 31 and 32).

In addition to this division, the 0 embryo class in the sample area at Kiruna was divided into four endosperm subclasses: 0_a, 0_b, 0_c and 0_d. These endosperm subclasses are shown in Figs. 2, 29 and 30, and are defined as follows:

0_a: Seeds with a thick base section but otherwise without visible content and without any hole or other damage to the seed-coat. The seeds have almost certainly arisen through lack of pollination.

0_b: Seeds containing one or two small flake-like remains—remnants of the collapsed female gametophyte. Seeds probably arisen after both non-pollination and pollination (cf. KLAEHN and WHEELER, 1961).

0_c: Seeds containing a diffuse and often spongy endosperm mass without embryo cavity.

0_d: Seeds containing a clear and compact endosperm mass without embryo cavity.

The subclasses 0_c and 0_d include seeds (with aborted ovules) probably arisen after pollination.

Primary or simple polyembryony due to the development of several fertilized eggs seems to be a general phenomenon in *Picea abies* (cf. BUCHHOLTZ, 1950, WARDLAW, 1955, and HÅKANSSON, 1956). Specially small seeds often contain more than one embryo. Seeds containing two or more embryos are classified into embryo classes with the guidance of the best developed embryo.

Table 1. Picea abies: Germination percentage (after 30 days in the Jacobsen germinator) of the embryo and endosperm classes (from Müller-Olsen, Simak and Gustafsson, 1956).

Embryo class	0	I	II	III	IV
Endosperm class					
A	—	—	36 %	82 %	97 %
B	—	—	15 %	71 %	92 %

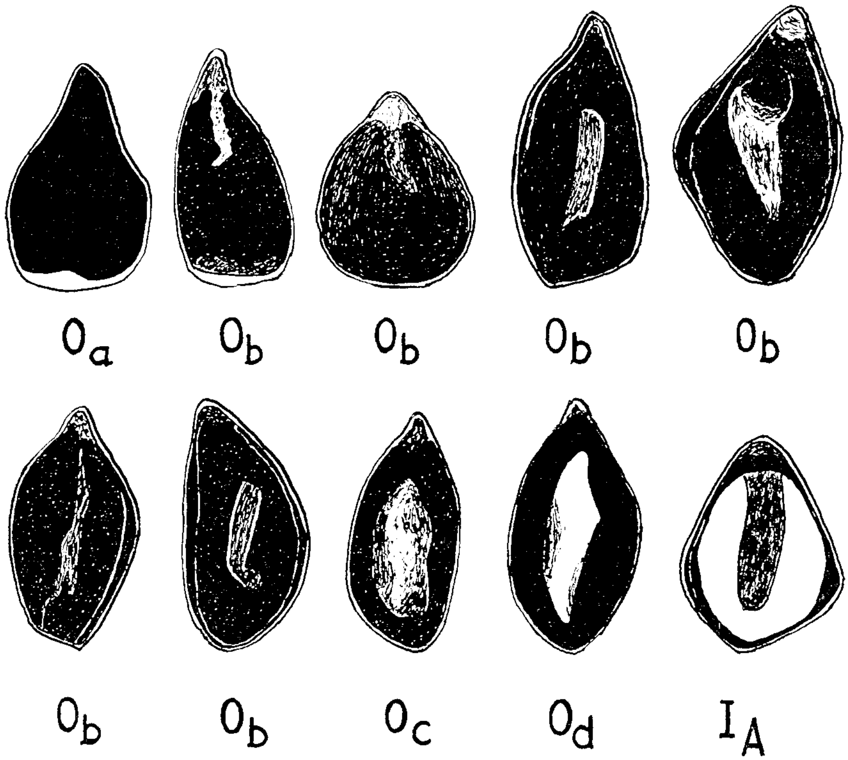


Fig. 2. The embryo classes O and I in Norway spruce. The O embryo class is here divided into four endosperm classes: Oa, Ob, Oc and Od. (The drawings are made with the guidance of the X-ray negatives). —X 12.

For the present investigation the cones have been kept in a temperature of + 6° C. before the seed extraction and all seed samples, after extraction by hand, have been kept in a refrigerator at a temperature of + 4° C. For both the collection years of 1948 and 1954 the cones were collected during November from the sample areas south of Skalstugan. At Skalstugan and from the sample areas north of Skalstugan, the cones were collected from the beginning until the middle of October. The seed material from 1948 was X-rayed in 1954, and the seed material from 1954 was not X-rayed until 1955 and the early part of the year 1956 because of, among other things, the amount of work required for seed extraction and seed cleaning.

The seed germination analyses in the Jacobsen germinator, for all the seed samples collected during the autumn 1954, were carried out during the years 1955—1956 under the following conditions: Number of seeds analysed from each tree varies, with the frequency of seeds > 2 mm., from 300 to 400. The temperature during germination was kept constant at 23 °C. and the seeds were irradiated for 8 hours daily by artificial light from three 40 watt daylight tubes, placed 50 cm. above the germinator. Germination time—30 days. The number of germinated seeds was counted after 10, 20 and 30 days. The seeds were considered as germinated when the roots of the seedlings had reached a length of 5 mm.

For the classification of endosperm and embryo development in the seed material collected in 1948 two random samples of 100 seeds from each tree were used. In the seed material for 1954 the number of seeds from each tree used was about 300 at Stjernarp, Gunnarskog, Kvikkjokk and Gällivare, 200 at Pajala and 100 at Skalstugan.

From the sample plots at Stjernarp, Gunnarskog, Kvikkjokk and Gällivare the same X-rayed seed samples from every tree and every seed size class are used for determining the germination rate in the Jacobsen germinator. For the other sample plots different simple random samples of seed from every tree are used for determining the germination percentage according to both the analysis methods. The seed from the sample plot at Kiruna, in 1960 and 1961, have been extracted and X-ray photographed the same autumn as they were collected. The seed from the progenies at Åkersberga in 1954 have been X-ray photographed early in the year 1955. Seed from Gällivare collected in 1960 and 1961 have been X-ray photographed early in 1961 and 1962 respectively.

The number of seeds damaged by insects (with or without larvae) has been decided with the guidance of the X-ray plates.

3.6. Some statistical procedures

The cone and seed material has been subjected to an analysis of variance with regard to the qualities of cone weight (g.), cone length (mm.), total number of seeds per cone, total weight of seeds per cone (mg.), number of seeds > 1 mm. per cone and the weight (mg.) of seed > 1 mm. per cone. The analyses of variance of the data collected were made by the usual computational methods (Snedecor, 1959). The variance has been divided into the components; between localities, between trees within localities and between cones within trees. The sums of squares of cones *within* trees and between trees within localities have been computed for each separate locality. The results of the analysis are found in Tables 2—8. At the same time, the part in the total variance of the different causes of variation has been estimated (see Table 8).

Correlations and regressions have been computed from the 1948 data in order to elucidate the relationships between cone and seed properties. Owing to the hierarchical arrangement with a primary grouping of the cones into those from the same plot and subdivision into cones from the same tree, various types of correlations and regressions can be computed. The different types of coefficients describe different features of the covariation of the characters studied.

For the zero order correlation (often called "total correlation") between two characters, the following different types of correlations have been computed:

1) Correlations of tree means
   a) for each plot
   b) "average within plot correlation"
   c) for the pooled data from all plots
2) Correlation of cone values
   a) for each tree
   b) "average within tree correlation" for each plot
   c) "average within tree correlation" for the pooled data from all plots
   d) for the pooled data from all trees on a plot
   e) "average within plot correlation"
   f) for the pooled data from all trees on all plots.

The coefficients 1 b), 2 b), 2 c) and 2 e) are based on sums of squares and products "within groups". Another type of "average correlation" also appears in the Tables, viz. an arithmetic average of correlation coefficients. As an example arithmetic averages of correlations of type 1 a) have been computed.

The calculation of correlations in the 1954 data has been mainly confined to correlations for individual trees of the type 2 a) but also correlations of type 1 a) and 1 c) have been computed. Also, some calculations have been made of correlations between the 1948 and 1954 observations of the same tree character.

If we have a linear relationship between three or more variables it is often of interest to make a detailed study of the relations between these variables. The covariation of two variables can be greatly influenced by one or more other factors affecting the two factors under study. To take into consideration the simultaneous relationship between many factors we may have recourse to partial correlations involving several variables and multiple regressions of one variable on several other variables. Expressions of this kind have therefore been computed in several cases. A partial correlation coefficient of the first order measures the relation between two variables, when one other variable (e.g. X_3) is held constant, and a partial correlation coefficient of the second order measures the relation between two variables (e.g. X_1 and X_2) when two other additional variables (e.g. X_3 and X_4), are held constant.

Also other multivariate methods, e.g. principal component analysis can be used in such cases where our interest does not center around the way in which one particular characteristic is dependent on a number of other characteristics. An example is given on page 122.

For studying the regressions of cones and morphological seed characters the following explanations may be given. Three types of regressions have been computed in most cases, in order to compare the five groups (e.g. plots or localities) in the material for 1948 and the six groups in the 1954 material concerning the relationships between the dependent variable y and the independent variables, for instance, u and v.

"Total regression": A regression equation

(1) $y = a + bu + cv$, where y, u and v are mean values for trees, has been determined by the use of the pooled data from all groups for each year separately (denoted by row number 3 in the tables of covariance analysis).

"Parallel regression": Five equations in 1948 and six equations in 1954

(2) $y = a_{Pi} + b_P u + c_P v$ $(i = 1, 2, \ldots, 5$ in 1948 and $i = 1, 2, \ldots, 6$ in 1954)

have been fitted to the data (denoted by row number 2 in the tables). The regression coefficients b_P and c_P have thus the same values in all groups, whereas the constant term has a different value for each particular group.

"Individual regression": A separate regression is determined by means of the data from each particular group. In this way the following regression

(3) $y = a_i + b_i u + c_i v$

is fitted to the data from the ith group (denoted by row number 1 in the tables of the analysis of covariance.

Let the sum of squared deviations from (1) be Q_1. Similarly, let Q_2 denote the sum of squared deviations from the five and six equations respectively (2), and Q_3 the sum of squared deviations from the five and six expressions respectively (3). Comparisons are made between the groups by means of these three sums, in the following manner.

The quantity Q_2—Q_3 is an expression for differences in the slope between the individual regressions (denoted by row number 4 in the tables). By means of a variance ratio test these differences are compared with Q_3. A significant ratio indicates that the data cannot be regarded as randomly drawn from populations with parallel regressions (such as those of Formula 2). Thus—assuming that a linear model is appropriate—at least one of the variables u and v affects y in different ways in the different groups.

However, if this ratio has an insignificant value, and the regression coefficients (b and c) are considered as equal in the different populations, a comparison between $Q_1 - Q_2$ with Q_2 can reveal differences in the levels of the parallel regression (denoted by row number 5 in the tables). The fact that no significance is found does not mean, however, that it is proved that no difference exists. If the corresponding test gives a significant value, the model

(1) cannot be regarded as realistic. In this case one might also formulate the conclusion in the following alternative way. The "adjusted" means of y in the groups (adjusted for linear influence from u and v) are significantly different.

The terminology is chosen in agreement with SNEDECOR (1959). One exception is that the term "parallel regressions" has been introduced here to denote the regressions (2) which have common values for the regression coefficients b and c, but different values for the constant a.

Second and third degree polynomials are also fitted to the data for germination rate in per mille of all seeds not damaged by insects and for empty seed not damaged by insects in 1954 on thousand-grain weight, cone length in tenths of a millimetre, cone weight in centigrams, the total number of seeds per cone and the weight in milligrams of all seeds per cone, using the program developed by WEBER and BROTT (1963) for an electronic computer. Deviations from linearity have been tested for the regressions of the germination rate in per mille of all seeds not damaged by insects and of the empty seed not damaged by insects in 1954 on the other variables.

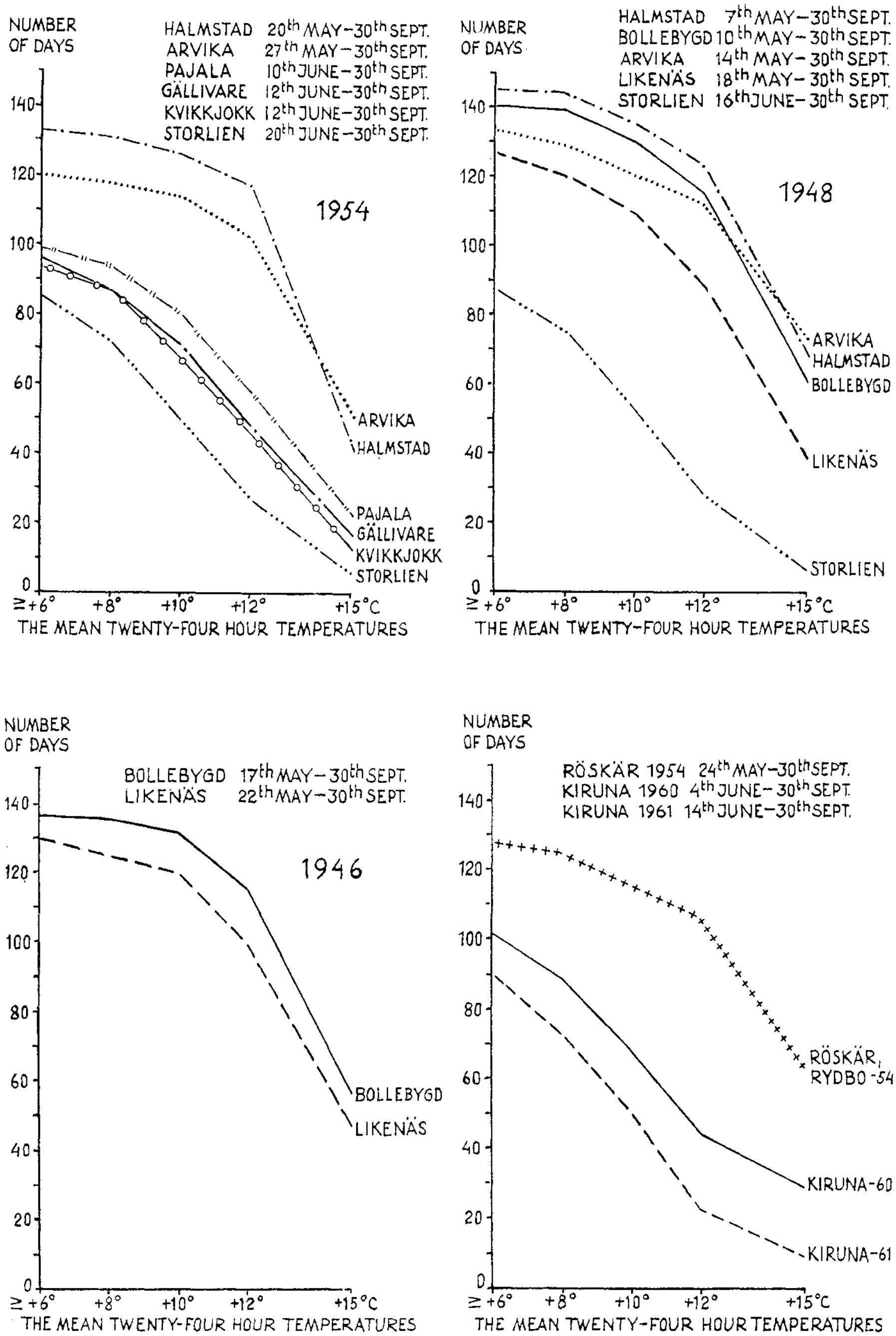
4. Conditions governing air temperatures for the sample plots

Temperature comparisons between the sample plots and between the years 1948 and 1954 have been carried out on the basis of temperature reports from the meteorological stations situated nearest to the various sample plots. The air temperature details are therefore subject to varying grades of inexactitude for the different sample plots, dependent on the difference between the local temperature and that of the observation station. This uncertainty is particularly marked in regard to temperature extremes. The altitude variation and the distance between the sample plots and the meteorological stations can be seen from the Table below.

Sample plots	Meteorological stations	Difference in altitude in m.	Distance in km.
Stjernarp	Halmstad	29	10
Härryda	Bollebygd	25	15
Gunnarskog	Arvika	89	20
Höljes	Likenäs	500	31
Skalstugan	Storlien	10	30
Snjäsak, Kvikkjokk	Kvikkjokk	100	1.5
Dundret, Gällivare	Gällivare	50	2
Aptasvaara, Kiruna	Kiruna	25	9
Kaskuvaara, Pajala	Pajala	46	10
Åkersberga	Röskär, Rydbo	5	11

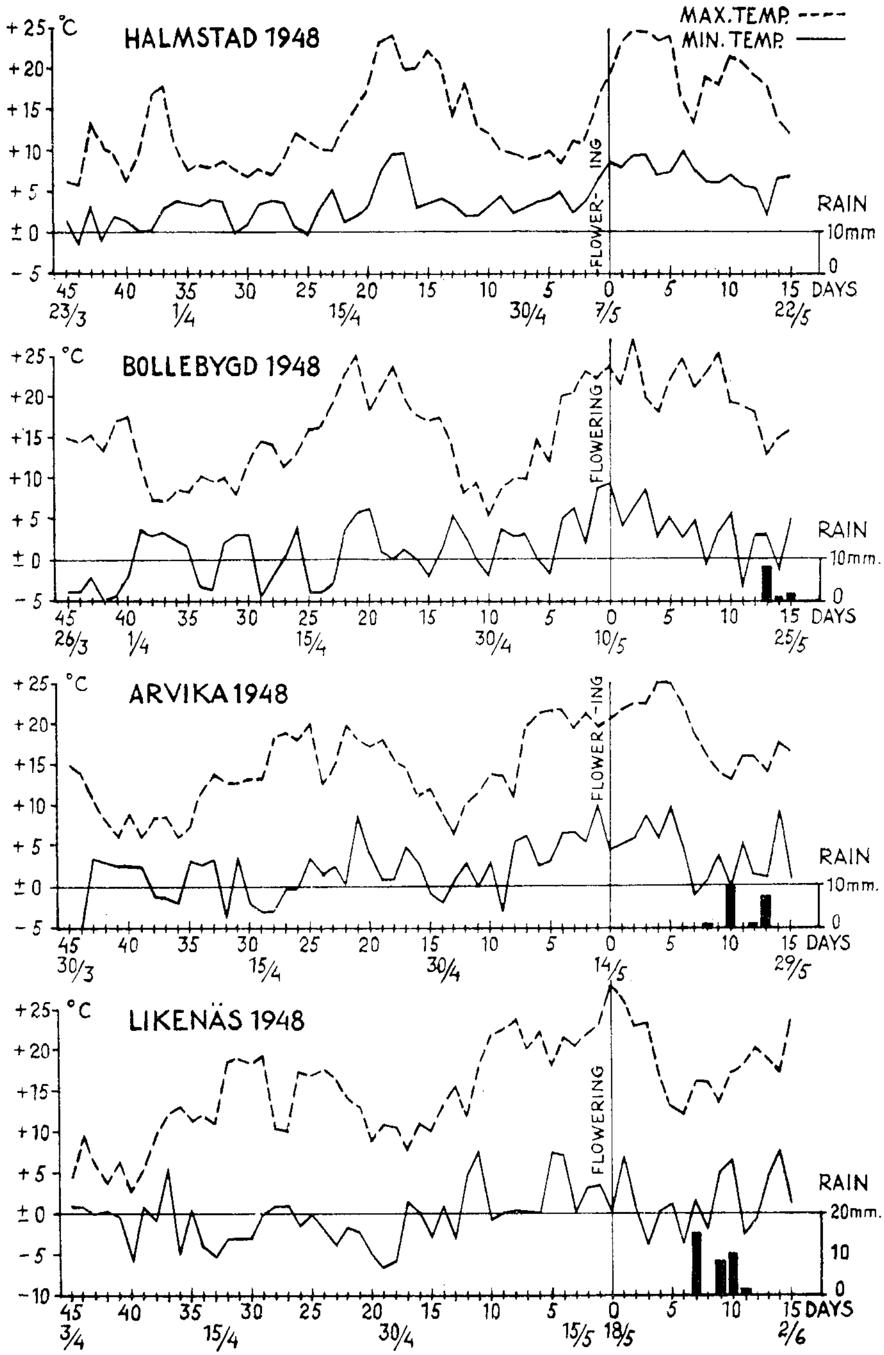
In some cases the differences between the situation of the sample plots and the relevant meteorological stations, as can be seen, are very large. The temperature particulars for the stand at Höljes are particularly uncertain. This stand is situated 31 km. N.N.W. of the meteorological station at Likenäs and lies no less than 500 metres higher than this station. With the exception of Stjernarp, Skalstugan, Pajala and Kiruna the sample plots are all situated higher than their respective meteorological stations.

The influence of air temperature on the ripening of seed can be assumed to depend on the mean 24-hour temperature. In regard to seed ripening, however, one can question if the mean air temperature of the six warmest hours of the day is not a better expression of the temperature factor than the 24-hour average temperature (in the same way as MORK, 1941, and DAHL and MORK, 1959, queried this matter in regard to growth). Since the temperature of the



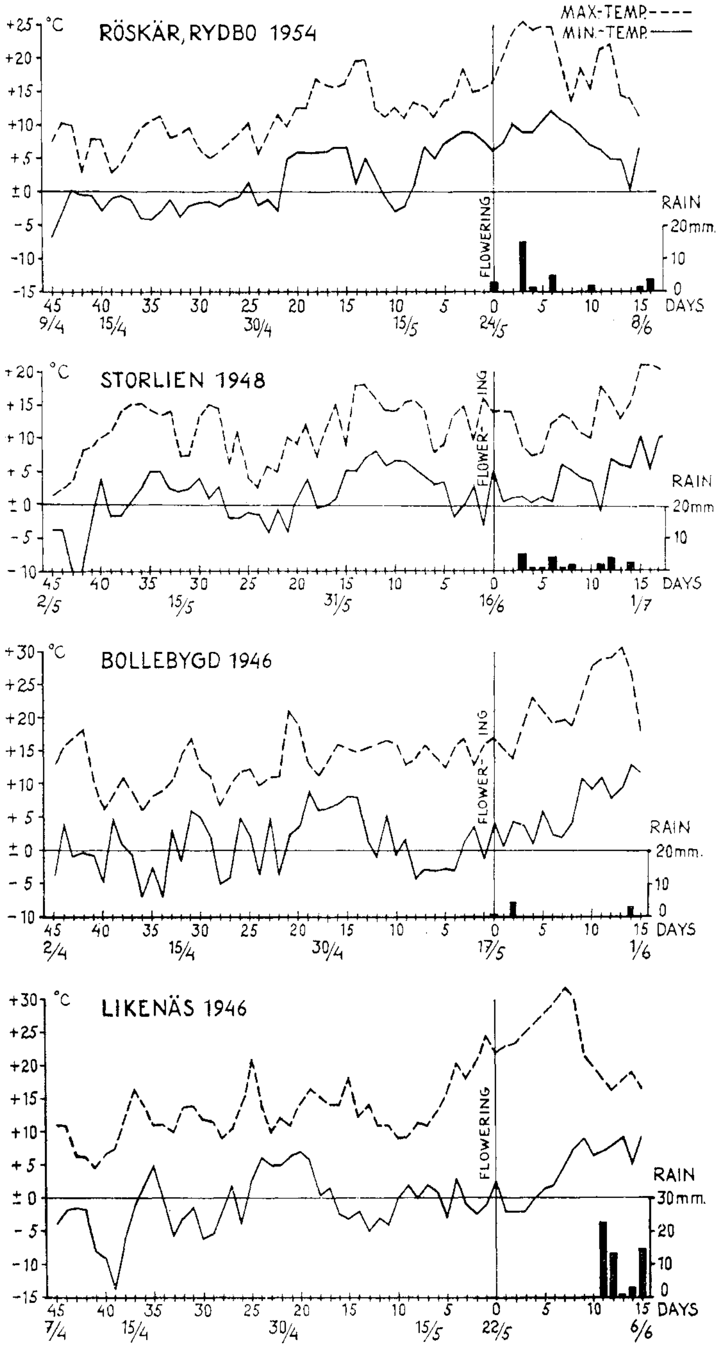
NUMBER OF DAYS WITH MEAN TEMPERATURES ≥ +6°, 8°, 10°, 12° AND 15°C DURING THE PERIOD FROM THE COMMENCEMENT OF SPRUCE FLOWERING UNTIL THE END OF SEPTEMBER.

Fig. 3.



DAILY MAXIMUM AND MINIMUM TEMPERATURES BEFORE AND AFTER FLOWERING.

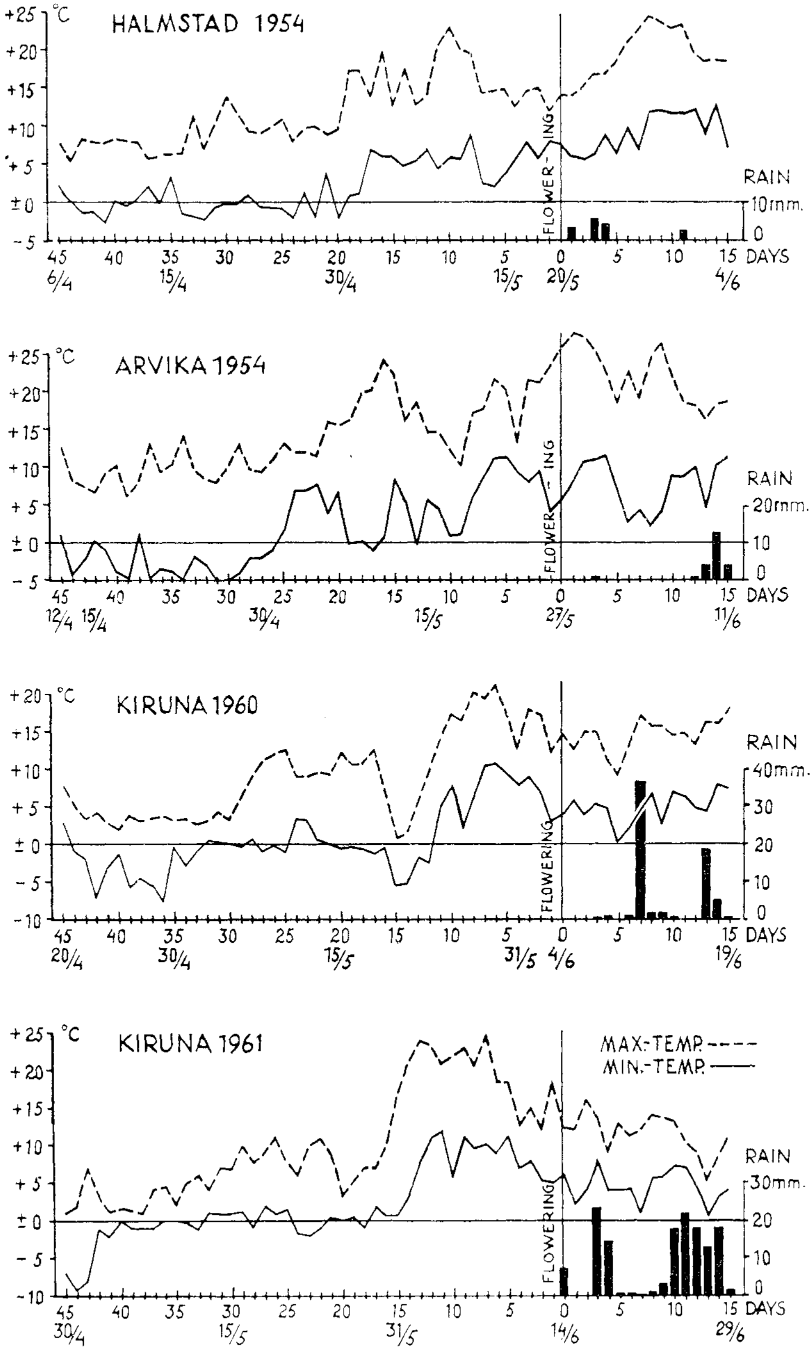
Fig. 4.



DAILY MAXIMUM AND MINIMUM TEMPERATURES BEFORE AND AFTER FLOWERING

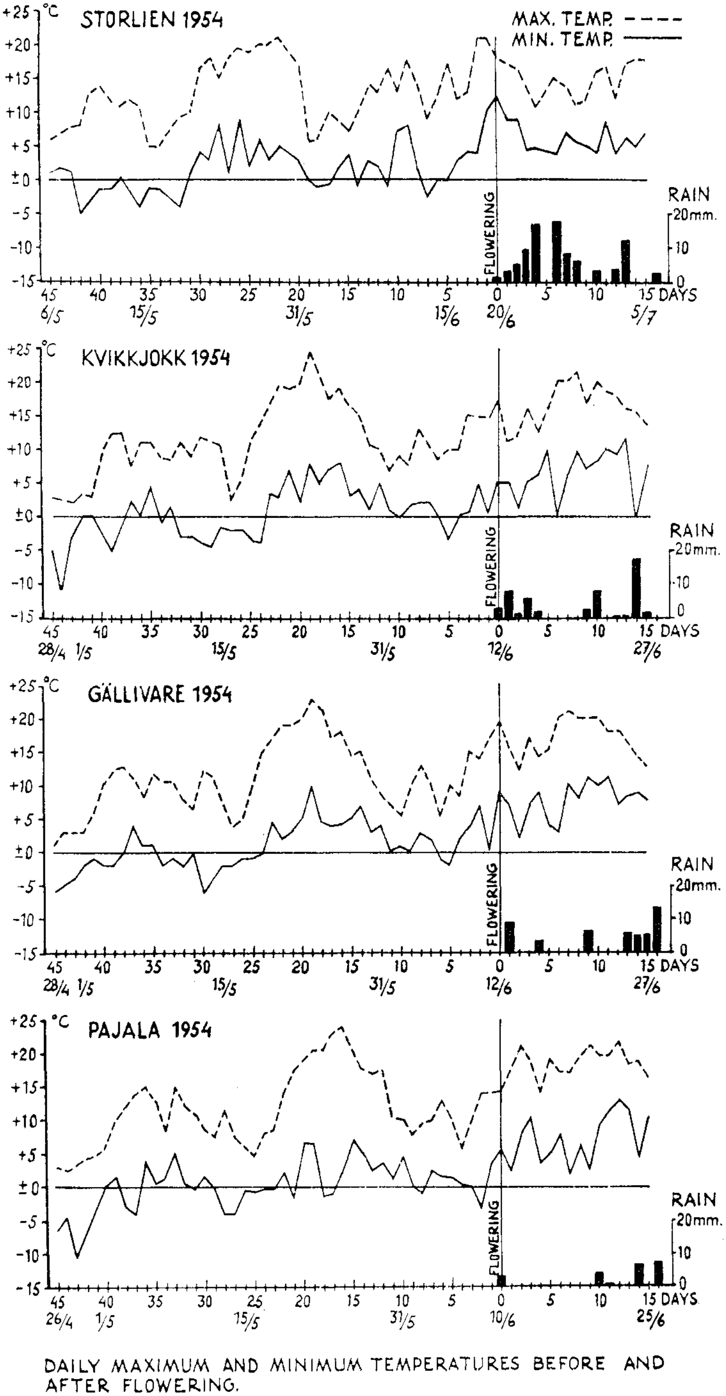
Fig. 5.

air at the meteorological stations is not registered by a thermograph, it is not possible for these stations to calculate the mean temperature for the six warmest hours per day. To illustrate the air temperature conditions at these meteorological stations and the differences in temperature between stations, diagrams have been drawn in Fig. 3 (based on the mean 24-hour temperatures for the various collecting years) which give the number of days with an average temperature of $\geq 6°$, 8°, 10°, 12° and 15° C. during the period from the commencement of spruce flowering until the end of September. In 1948 the mean 24-hour temperatures during the months of June, July and August for Halmstad, Bollebygd, Arvika, Likenäs and Storlien amounted to 16.2, 15.7, 15.7, 14.4 and 10.0° C. respectively. The mean 24-hour temperature for the same stations in 1948, arranged in the same way, during the months of June, July, August and September amounted to 15.6, 14.9, 14.7, 13.1 and 9.2° C. The average 24-hour temperatures during the months of June, July and August in 1954, for Halmstad, Arvika, Storlien, Kvikkjokk, Gällivare and Pajala were 15.4, 14.6, 10.1, 11.7, 12.0 and 12.5° C. respectively. The comparative series of mean air temperatures during the months of June, July, August and September for the same year, for the same stations (in the same order as above) were 14.8, 13.7, 9.1, 10.2, 10.6 and 11.1° C. The average 24-hour temperature in Kiruna for the period June, July and August was 12.2° C. in 1960 and 11.2° C. in 1961. For the period June, July, August and September 1960 it was 10.8° C. and for the same period in 1961it was 10.0° C. The diagrams in Figures 4—7 show the maximum and minimum temperatures, at the different meteorological stations, during the period covering 45 days before spruce flowering until 15 days after the commencement of flowering. At the same time the rainfall in millimetres is given on the diagram for the 15-day period reckoned from the commencement of flowering. The maximum and minimum temperatures have been included in order to show as clearly as possible the characteristic temperature fluctuations during the meiosis and the pollen mitosis, at least for the sample plots that lie relatively near the meteorological stations. The degrees of frost (particularly in combination with high winds) together with sudden and large air temperature changes have shown themselves to disturb the progress of the meiosis and pollen mitosis of the Norway spruce (see the Figs. 33—36). The aberrations include chromosome "stickiness", spontaneous breakage of chromosomes, abnormal anaphases, chromatid breakages and also, especially when the temperature suddenly changes from below zero to about + 20° C. or more, desynapsis, i.e. a number of bivalents fall apart to univalents during early metaphase I. Therefore, the appearance of empty seeds can also be considered to have a certain connection with the influence of the climatic temperatures during the micro- and macrosporogenesis and fertilization (especially with regard to the minimum air



DAILY MAXIMUM AND MINIMUM TEMPERATURES BEFORE AND AFTER FLOWERING.

Fig. 6.



DAILY MAXIMUM AND MINIMUM TEMPERATURES BEFORE AND AFTER FLOWERING.

Fig. 7.

temperature (cf. Fig. 24) and the amplitude between the extreme air temperatures for the 24 hours). The formation of empty seeds on spruce can also be connected with a series of other factors (cf. GUSTAFSSON, 1962), such as purely genetically caused sterility (haplontic as well as diplontic), failure to pollinate (see SARVAS, 1955, 1957 and 1958), self-fertilization and damages caused by insects in a direct or an indirect way to the nucellus cap, pollen tubes, ovules, archegonia, embryos and endosperm tissues.

5. Variation and relationship of some morphological cone and seed characters

The number of cones per tree, the size of cone, the seed weight, the number of seeds per cone and the maturity and germinative capacity of the seed are factors affecting the size and quality of the seed crop. The relation between the three first-mentioned factors and the exchange of seed in Norway spruce, and the regional variation in seed production and seed quality in both pine and spruce have been relatively well known for some time (HAGEM, 1917, WIBECK, 1920, EIDE, 1923, 1927, and 1928—1930, KUJALA, 1927, HEIKINHEIMO, 1932, 1937, and 1948, and WRIGHT, 1945). Since the beginning of this investigation several studies on the seed production and seed quality of conifers, especially pine, have been published (cf. inter alios, JOHNSSON, KIELLANDER and STEFANSSON, 1953, PLYM FORSHELL, C., 1953, SIMAK, 1953 b and 1960, SIMAK and GUSTAFSSON, 1954, EHRENBERG and SIMAK, 1957, SARVAS, 1957 and 1962, HADDERS and ÅHGREN, 1958, HAGNER, 1958, and JOHNSSON, 1961).

Especially PLYM FORSHELL, C. (1953), SIMAK (1953 b, 1955 b and 1960), SIMAK and GUSTAFSSON (1954), EHRENBERG, GUSTAFSSON, PLYM FORSHELL and SIMAK (1955), EHRENBERG and SIMAK (1957), JOHNSSON (1961), and SARVAS (1962) have carried out detailed investigations on the reciprocal variations of the above adduced components and their relation with seed yield and seed quality in the case of Scots pine. Also, the relation between cone weight on the one hand and the number of seeds, the embryo status and percentage of germination on the other hand have been the object of detailed studies (SIMAK, 1955 b, and SIMAK and GUSTAFSSON, 1954). As regards Norway spruce, there are on the whole neither detailed studies of the relation between these factors nor more comprehensive statistical investigations of the variation in the seed production and seed quality of individual trees.

It ought to be pointed out at the outset that every population, represented by a sample plot, as well as every individual tree, occurs only in one geographic locality and every tree in only one specimen within this locality. In the following analysis it is impossible to distinguish exactly between gene-conditioned variation and modifications. It is only in a sample plot with constant environmental conditions that the differences between tree characters are determined mainly by genetical factors. (Such characters are average cone length, correlation between cone length and number of seeds, 1,000--grain weight etc.). In a varying environment (if one disregards possible interactions between the genotypes and the ages of the trees) the variation within trees is dependent on these environments, provided that no spontaneous bud mutations or other somatic mutations have occurred, which seems to be not uncommon in fruit trees (cf. NYBOM, 1961), and given rise to branches and cones of seeds of a different genotype than the other fructiferous branches within one tree or some of the trees. In varying environments the correlations and regressions between some cone values can still be more or less specific for each tree but these relationships are influenced by the effects of environmental factors. The relationships between *tree-means* for two variables are influenced not only by genetic factors, but also by the effect of environmental or site differences between trees, and to a certain degree, by environmental variations of *cone values within trees*. The cone values within a population (without consideration of trees) as well as the correlations and the regressions between cone values are likewise genetically more or less specific for the population. The environmental variations *between trees* and *within trees* however, also in this case, exert their influence on these values and relations.

In a well-planned field test, with replications, it is usually possible, in a general way, to differentiate between genetical and environmental variations, as well as to show different interactions between, for instance, genotypes and environment. However, the possibilities for similar analyses of the data from the present investigation are very limited. The populations have been chosen with the object of examining the generative adaptation of different spruce populations to widely varying climatic conditions, with reference to course of meiosis, pollen fertility, number of seeds with embryo per cone and seed germination rate.

To the environmental variations *between* populations (represented by the sample plots) and *within* populations (in other words the non-genetic variation between trees within the same population and the non-genetic variation between cones within the same population) can be added, in the following material, both climatic and site variations as well as variations caused by the collecting of cone samples. The changes, for instance, in the strength of the correlation between two properties from one year to another in a certain genotype, are referred to interactions between the genotype and environmental factors in the broad sense (e.g. as against non-genetic). The effects of genetic and non-genetic factors on correlations and regressions between different characters (as between cone properties, between cone and seed properties, and between seed characters internally) as well as the genetic and non-genetic fractions of the phenotypic variations, compose a complex problem. A correlation between two characters of a tree may arise, 1) because these characters are genetically correlated, 2) because the tree and its characters had developed in a certain environment, or 3) because the characters, to a certain degree, are the results of the joint effects of genetical and environmental factors. The genotype cannot develop the characters without having access to a proper environment. The characters of the phenotype are thus the result of environmental factors and a series of chain interactions 1) between genes and 2) between the genetic constitution and the external conditions.

5.1. The 1948 material

In the Appendix Tables I—V the mean cone values for individual trees and sample plots at Stjernarp, Härryda, Gunnarskog, Höljes and Skalstugan are presented (cf. Fig. 1). The results of tests of significance for differences between sample plots and between trees within sample plots, as well as the magnitude of the within-tree variance in the material in its totality and in the populations taken separately, for different properties, are shown in the Tables 2—7. The percentages of the total variation constituted by the individual components of variance are given in Table 8. The results of the calculations of average correlation coefficients between cone and seed properties, between cone properties and between seed properties separately, are given in Tables 9, 15, 16 and 17, and of some partial correlations in Tables 21 and 22. Table 9 contains *between-tree* correlations (correlations between tree means) within sample plots or populations. As a complement, the author has included in Tables 9 and 16 the total group correlations between trees for the material in its entirety and a series of coefficients representing the arithmetical means of five average inter-tree correlations within groups or populations for different pairs of variables.

Some series of partial regression coefficients between seed and cone properties are presented in Tables 10 and 14. Some series of regression coefficients between cone weight and cone length, between cone and seed characters and between seed properties for individual trees (see also Table 20) are computed in the Appendix Tables XII—XVI. Correlations have also been computed for each individual tree between characters of the 25 cones. Table 17 shows the frequency distribution of such correlations. Further, correlations have been computed for each locality by treating all the 1,250 cones as one group.

Table 15 presents such correlations between *cone values* within sample plots. Table 16 shows average correlations based on within-tree sums of squares and products of cone values. Similarly correlations between cone values within the total material respectively within-tree correlations for the five localities taken together are shown in Tables 15 and 16. In the material for the year 1948 the variables X_1—X_9 in the tables giving correlation and regression coefficients and in regression equations, correspond to the following cone and seed properties:

X_1 = thousand-grain weight in centigram (when nothing else is pointed out) of all seeds per cone $= \frac{100X_7}{X_4}$

X_2 = cone length in tenths of a millimetre (millimetre in the Appendix Tables XII—XVI and in Table 20)

X_3 = cone weight in centigram (gram in the Appendix Tables XII—XVI and in Table 20)

X_4 = the total number of seeds per cone (in whole numbers)

X_5 = $X_2^3/10^6$ in cm³.

$X_6 = \frac{\text{cone weight in milligram}}{\text{total number of seeds per cone}} = \frac{10X_3}{X_4}$

X_7 = the weight in milligram of all seeds per cone

X_8 = the number of seeds > 1 mm. per cone, and

X_9 = the weight in milligram of seeds > 1 mm. per cone.

The units of length, volume and weight are those used in the punched card processing of the data.

5.1.1. Analysis of variance of properties of cones and seeds

Mean squares and variance ratios for cone weight are shown in Table 2. All variance ratios or F-values (between localities and trees as well as between trees and cones) correspond to probability values far below 0.1 %. The analysis thus shows that a very marked significance exists as regards differences in cone weight between at least some of the populations represented in the investigation and between trees in the whole material. The two high altitude populations at Höljes and Skalstugan differ significantly from the three low altitude populations and from each other with respect to cone weight (both as to mean weights and as to variation between trees within populations and as regards the variation between cones within trees). The differences in cone weight between localities are due chiefly to the great difference between low altitude populations on the one hand and the high altitude populations on the other hand. The difference between the three low altitude populations has the probability value $1\% < P < 5\%$, while the difference in cone weight between the low altitudes and the high altitudes and between the different plots at high altitudes has the probability value $P < 0.1\%$.

Table 2. Analysis of variance of cone weight between and within populations of Norway spruce.

Source of Variation	Sum of Squares		Degrees of Freedom		Mean Square
Between localities	536 098		4		134 025
Between trees within localities	225 778		245		922
viz., at Stjernarp		46 047		49	940
Härryda		92 557		49	1 889
Gunnarskog		61 032		49	1 246
Höljes		20 094		49	410
Skalstugan		6 048		49	123
Between cones within trees	84 605		6 000		14.1
viz., at Stjernarp		23 274		1 200	19.4
Härryda		24 123		1 200	20.1
Gunnarskog		23 218		1 200	19.3
Höljes		10 305		1 200	8.6
Skalstugan		3 685		1 200	3.1
Total	846 481		6 249		

Quotients:

$$\text{Localities} = \frac{134{,}024.62}{921.54} = 145.44^{***} \qquad \text{Trees, Stjernarp} = \frac{939.73}{19.39} = 48.45^{***}$$

$$\text{Trees} = \frac{921.54}{14.10} = 65.35^{***} \qquad \text{» Härryda} = \frac{1{,}888.91}{20.10} = 93.97^{***}$$

$$\text{» Gunnarskog} = \frac{1{,}245.54}{19.35} = 64.38^{***}$$

$$\text{» Höljes} = \frac{410.08}{8.59} = 47.75^{***}$$

$$\text{» Skalstugan} = \frac{123.43}{3.07} = 40.19^{***}$$

*** Statistically significant at the 0.1 % level.

The mean values for cone weight (gram) amount for the different populations to:

Stjernarp	28.1	Höljes	14.8
Härryda	29.8	Skalstugan	8.8
Gunnarskog	32.4	Total mean	22.8

Since the three low altitude populations and the two high altitude populations represent five different provenances, the differences in cone weights as between the localities were probably caused chiefly by the environment, as the differences between the low altitude populations with respect to this property are relatively small. However, the number of populations is small and the cone weight decreases also with northern latitude, so that the conclusion in this case cannot be more than an assumption.

The obvious differences in the averages of the trees are somewhat easier to generalize. There are here a relatively large number of trees within sample plots. At the same time the environmental variations are smaller within than between plots. Since the variations and the differences are undoubtedly both modificatory and genetically conditioned one cannot abstract from either of the causes of variation, but there is some indication that the genotype with regard to many cone and seed properties may have a dominating influence upon this interplay (cf. JOHNSSON, KIELLANDER and STEFANSSON, 1953, pp. 372 and 373, SIMAK and GUSTAFSSON, 1954, pp. 28, 29, 46 and 63, HADDERS and ÅHGREN, 1958, pp. 460, 466 and 467, and JOHNSSON, 1961, pp. 19 and 20). Since the Norway spruce included in the plots, as well as forest trees in general and other cross-fertilizing species are strongly heterozygotic for a large number of genes, and are in consequence very variable in their hereditary constitution, it is, also in this material, legitimate to assume the existence of a not inconsiderable genotypically conditioned variation.

Table 3 shows an analysis of variance of cone length.

Table 3. Analysis of variance of cone length between and within populations of Norway spruce.

Source of Variation	Sum of Squares		Degrees of Freedom		Mean Square
Between localities	3245096		4		811274
Between trees within localities	905811		245		3697
viz., at Stjernarp		249177		49	5085
Härryda		272809		49	5568
Gunnarskog		214867		49	4385
Höljes		98416		49	2008
Skalstugan		70543		49	1440
Between cones within trees	376984		6000		63
viz., at Stjernarp		82664		1200	69
Härryda		88564		1200	74
Gunnarskog		94470		1200	79
Höljes		62164		1200	52
Skalstugan		49122		1200	41
Total	4527891		6249		

If one calculates the variance ratios for the sources of variation *between localities* and *between trees within localities* (as also for the subgroups *between trees within individual localities*) in the same way as the estimates of corresponding ratios in Table 2, one obtains the F-values to which correspond P-values appreciably less than 0.1 %. Thus, the five groups of trees cannot be regarded as pure random samples drawn from identical populations and the cones cannot be regarded as pure random samples drawn from identical trees within the same sample plot, since there are real differences in cone length for the different populations.

Like the cone weight, the cone length for the year 1948 is greatest in Gunnarskog and smallest in Skalstugan. The Central European spruce is considered to have, and probably in general has, longer cones than the native spruce in Scandinavia (cf. SCHRÖTER, 1898, and SYLVÉN, 1912 and 1916). This taxonomic property is, however, *very variable.* Both regional and altitudinal variations are appreciable (cf. MERZERA, 1939, and LINDQUIST, 1948 b). The variation is indeed so great that the difference in cone length between the Central European spruce and the spruce native to Scandinavia may in some cases be effaced, despite the fact that the domestic spruce has been cultivated in a considerably more northern locality than its Central European counterpart (cf. the means for the Norway spruce populations in Gunnarskog and Stjernarp with respect to cone length). There is no significant difference between the cone lengths of the two provenances, but the sample plot at Gunnarskog has, as may be seen, a tendency to greater cone length.

In Tables 4—7 are shown the analyses of variance of seed number and seed weight per cone.

Table 4. Analysis of variance of total number of seeds per cone between and within populations of Norway spruce.

Source of Variation	Sum of Squares		Degrees of Freedom		Mean Square
Between localities	17620034		4		4405009
Between trees within localities	8843694		245		36097
viz., at Stjernarp		1331105		49	27165
Härryda		1895755		49	38689
Gunnarskog		3043803		49	62118
Höljes		1407112		49	28717
Skalstugan		1165919		49	23794
Between cones within trees	6120190		6000		1020
viz., at Stjernarp		927384		1200	773
Härryda		1365360		1200	1138
Gunnarskog		2024688		1200	1687
Höljes		816352		1200	680
Skalstugan		986406		1200	822
Total	32583918		6249		

The analysis shows that there are likewise very definite differences ($P < 0.1\ \%$) in seed number and seed weight between localities and between trees within localities. The Central European spruce in Stjernarp has both the

Table 5. Analysis of variance of the weight of all seeds per cone between and within populations of Norway spruce.

Source of Variation	Sum of Squares		Degrees of Freedom		Mean Square
Between localities	825 692 664		4		206 423 166
Between trees within localities	381 011 081		245		1 555 147
viz., at Stjernarp		112 202 482		49	2 289 847
Härryda		124 157 162		49	2 533 820
Gunnarskog		101 036 436		49	2 061 968
Höljes		32 996 231		49	673 392
Skalstugan		10 618 771		49	216 710
Between cones within trees	208 089 025		6 000		34 682
viz., at Stjernarp		52 126 658		1 200	43 439
Härryda		61 239 889		1 200	51 033
Gunnarskog		60 169 772		1 200	50 141
Höljes		24 746 151		1 200	20 622
Skalstugan		9 806 555		1 200	8 172
Total	1 414 792 770		6 249		

greatest number of seeds and the highest seed weight per cone, at the same time as it has on the average a lower standard deviation for these properties than the populations at Härryda and Gunnarskog. As the number of seeds and the seed weight are markedly reduced with northern latitude and with the height above sea level, it does not seem to be possible to draw any conclusions concerning the differences in the provenance of these characters.

Table 6. Analysis of variance of number of seeds > 1 mm. per cone between and within populations of Norway spruce.

Source of Variation	Sum of Squares		Degrees of Freedom		Mean Square
Between localities	17 592 704		4		4 398 176
Between trees within localities	10 062 034		245		41 070
viz., at Stjernarp		2 042 573		49	41 685
Härryda		2 500 356		49	51 028
Gunnarskog		3 245 798		49	66 241
Höljes		1 433 876		49	29 263
Skalstugan		839 431		49	17 131
Between cones within trees	5 474 345		6 000		912
viz., at Stjernarp		869 930		1 200	725
Härryda		1 255 771		1 200	1 046
Gunnarskog		1 823 595		1 200	1 520
Höljes		750 576		1 200	625
Skalstugan		774 474		1 200	645
Total	33 129 083		6 249		

Table 7. Analysis of variance of the weight of seeds > 1 mm. per cone between and within populations of Norway spruce.

Source of Variation	Sum of Squares		Degrees of Freedom		Mean Square
Between localities	812819827		4		203204957
Between trees within localities	396536001		245		1618514
viz., at Stjernarp		118640232		49	2421229
Härryda		130608943		49	2665489
Gunnarskog		104083223		49	2124147
Höljes		33053206		49	674555
Skalstugan		10150398		49	207150
Between cones within trees	205662074		6000		34277
viz., at Stjernarp		52305679		1200	43588
Härryda		60503981		1200	50420
Gunnarskog		59079360		1200	49233
Höljes		24442587		1200	20369
Skalstugan		9330469		1200	7775
Total	1415017902		6249		

The average seed numbers and seed weights (mg.) per cone in the different localities amount to:

	Total number of seeds	Seeds > 1 mm.	Weight of total number of seeds	Weight of seeds > 1 mm.
Stjernarp	247.2	225.9	1 177.6	1 153.5
Härryda	241.0	221.6	1 149.5	1 126.4
Gunnarskog	182.0	163.8	813.0	790.3
Höljes	148.4	121.2	511.4	484.3
Skalstugan	109.3	92.6	238.9	226.8
Total mean	185.6	165.0	778.0	765.3

The differences between the number of seeds and seed weights for the individual trees within the plots are probably not solely ascribable, any more than are the differences in cone weight and cone length, to the environment-conditioned variation.

The population mean values, calculated on the basis of the cone mean values for trees, for cone length (X_2 in tenths of a mm.), cone weight (X_3 in cg.) and $\frac{\text{cone weight}}{\text{number of seeds/cone}}$ (X_6 in mg.) are:

	X_2	X_3	X_6
Stjernarp	1,132.7	2,806.4	113.6
Härryda	1,147.5	2,976.6	124.7
Höljes	780.2	1,477.7	101.5
Gunnarskog	1,174.0	3,238.2	188.2
Skalstugan	617.6	880.1	83.5

Table 8 shows the estimated percentages of the total variance corresponding to different components of variance.

The percentage of the total variance dependent upon differences between *localities and populations* is naturally very high. The percentage of variance for this source of variation with regard to cone weight, cone length, total number of seeds per cone, the weight of the total number of seeds, the num-

Table 8. Components of variance and percentage of the portions of variance.

Source of Variation	Cone weight (X_3)		Cone length (X_2)		Total No. of seeds per cone (X_4)		Total seed weight per cone (X_7)		No. of seeds >1 mm. per cone (X_8)		Weight of seeds >1 mm. per cone (X_9)	
	Component of variance	%	Component of variance	%	Component of variance	%	Component of variance	%	Component of variance	%	Component of variance	%
Within populations:												
Stjernarp:												
between trees	36.8	65	200.7	74	1055.7	58	89856.3	67	1638.4	69	95105.7	69
within trees	19.4	35	68.9	26	772.8	42	43438.9	33	724.9	31	43588.1	31
Härryda:												
between trees	74.8	79	219.8	75	1502.0	57	99311.5	66	1999.2	66	104602.8	67
within trees	20.1	21	73.8	25	1137.8	43	51033.2	34	1046.5	34	50420.0	33
Gunnarskog:												
between trees	49.0	72	172.3	69	2417.2	59	80473.1	62	2588.8	63	82996.6	63
within trees	19.3	28	78.7	31	1687.2	41	50141.5	38	1519.7	37	49232.8	37
Höljes:												
between trees	16.1	65	78.3	60	1121.5	62	26110.8	56	1145.5	65	26167.5	56
within trees	8.6	35	51.8	40	680.3	38	20621.8	44	625.5	35	20368.8	44
Skalstugan:												
between trees	4.8	79	56.0	52	918.9	53	8341.5	51	659.4	51	7975.0	51
within trees	3.1	21	40.9	38	822.0	47	8172.1	49	645.4	49	7775.4	49
Mean:												
between trees	36.3	72	145.4	70	1403.1	58	60818.6	64	1606.3	64	63369.5	65
within trees	14.1	28	62.8	30	1020.0	42	34681.5	36	912.4	36	34277.0	35
Between and within populations (the entire material):												
between localities	106.4	68	646.1	76	3495.1	59	163894.4	63	3485.7	58	161269.1	62
„ trees	36.3	23	145.4	17	1403.1	24	60818.6	24	1606.3	27	63369.5	25
within trees	14.1	9	62.8	7	1020.0	17	34681.5	13	912.4	15	34277.0	13

her of seeds > 1 mm. in diameter (greatest diameter) and the weight of the seeds > 1 mm., amounts to 68, 76, 59, 63, 58 and 62 per cent respectively of the total variance. To differences *between trees within populations* are ascribable for the same properties, arranged in the same sequence, 23, 17, 24, 24, 27 and 25 per cent respectively of the total variation. To the differences *between cones* of the same tree, for the properties in question, are ascribable 7—17 per cent of the total variance. If, depending on differences *within* populations, the variance is divided among individual populations and these percentages of variance are in turn divided among trees and cones, one obtains (on an average for five populations) an estimate of the compound environment— and genotype-conditioned proportion of the variance *between trees within populations* amounting to 71 per cent for cone properties (cone weight and cone length), 58 per cent for the number of seeds per cone and 64 per cent for the weight of all the seeds per cone. Thus, *of the total variation within populations 29 per cent for the cone properties is attributable to the environment-conditioned variation within trees or between cones within trees.*

5.1.2. The relationship of the average 1,000-grain weight of all seeds per tree with the tree means of cone length, cone weight, number of seeds per cone, cone volume and $\frac{\text{cone weight}}{\text{number of seeds/cone}}$.

(Calculated on the basis of cone mean values for trees by populations and on an average for the populations.)

The correlation, between cone mean values for trees within groups or populations (cf. Table 9), between the variables X_1 (1,000-grain weight of all seeds) and X_2 (cone length) varies within the five populations from 0.350 in Härryda to 0.647 in Skalstugan. For the five groups taken together the average correlation coefficient for X_1 and X_2 amounts to 0.459. The average correlation for this pair of variables is, if the high altitude and low altitude populations respectively are taken together, somewhat more marked within the high altitude populations at Skalstugan and Höljes than within the low altitude populations, or 0.587 against 0.433. If we convert r to z according to FISHER, $z = \frac{1}{2}\left[\log_e (1+r) - \log_e (1-r)\right]$, and divide the z-difference by its approximate standard error we obtain the ratio:

$$\frac{z_1 - z_2}{\sqrt{\frac{1}{3(50-1)-2} + \frac{1}{2(50-1)-2}}} = \frac{0.67 - 0.46}{\sqrt{\frac{1}{145} + \frac{1}{96}}} = \frac{0.21 \times \sqrt{13920}}{\sqrt{241}} =$$

$$= 0.21 \times 7.60 = 1.596°.$$

Entering a table of t for ∞ degrees of freedom, we find that a t value of 1.596 has a probability lying between the 10 and 5 % levels of significance. The average correlation differences between the two groups is, thus, not significant.

If one were to regard the five populations as *one* stand, a total group correlation between the variables X_1 and X_2 amounting to 0.796 would be obtained. This total group correlation is interesting because of its high value. It is influenced by the correlation between population means as well as by the correlation within the populations. From a biological point of view this total group correlation is of secondary interest, as it does not distinguish between the part of the covariation caused by environmental differences between areas and the covariation within areas.

The partial coefficients both for individual regressions (based on the trees within only one sample plot), average regressions and over-all regression of X_1 on X_3 (cone weight), X_4 (number of seeds per cone), X_2 (cone length) and X_6 (cone weight per seed) are given in Table 10 and those for the regressions of X_4 on X_3 and X_5 (cone volume) in Table 14. The partial regression coefficients (e.g. $b_{12.346}$ within the populations and within the whole material) indicate for the sample in question how much X_1 is on an average changed when an independent variable (e.g. X_2) is altered by one unit, and when at the same time the other variables (e.g. X_3, X_4 and X_6) are kept constant. As can be seen from the mean errors in the Tables 10 and 14, many of the regression coefficients are statistically relatively uncertain and far from being significant. On the other hand, these tables give a clear picture of just how complex the relations are between many of the properties or pairs of variates investigated.

It should be observed that X_4 appears as denominator in the expression for X_1. Therefore the regression of X_4 and X_1 (total or partial) must be judged with some caution; a possibility of a "spurious" negative correlation is inherent in the way the values of X_1 and X_4 are computed. Similarly, regressions and correlations involving X_1 and X_7, or those involving simultaneously X_3, X_4 and X_6 may contain elements due to "spurious correlations".

If, as before, we designate the dependent variable (1,000-grain weight of all seeds) with X_1, we get the equations for the individual regression functions with the help of the population mean values for the different properties and the partial regression coefficients in Table 10. They are as follows:

Stjernarp..... $X_1 = -504 - 0.206\,X_3 + 2.069\,X_4 + 0.302\,X_2 + 6.186\,X_6$
Härryda...... $X_1 = 33 - 0.037\,X_3 + 1.584\,X_4 - 0.194\,X_2 + 3.147\,X_6$
Gunnarskog... $X_1 = 370 + 0.114\,X_3 - 1.296\,X_4 + 0.113\,X_2 - 1.024\,X_6$
Höljes........ $X_1 = 176 + 0.090\,X_3 - 0.516\,X_4 + 0.212\,X_2 - 0.559\,X_6$
Skalstugan.... $X_1 = 125 + 0.234\,X_3 - 1.305\,X_4 + 0.167\,X_2 - 0.914\,X_6$

Table 9. Correlations between tree means based on the product sums and sums of squares of tree averages within populations in the year 1948.

Between the variables \ Population	Stjernarp	Härryda	Gunnar-skog	Total material treated as one group. (Total group correlations between trees)
	r	r	r	r
X_1 and X_2	0.558	0.350	0.429	0.796
X_3	0.563	0.600	0.547	0.814
X_4	0.242	0.123	0.160	0.665
X_5	0.524	0.273	0.286	0.625
X_6	0.531	0.590	0.166	0.496
X_2 and X_3	0.835	0.782	0.497	0.912
X_4	0.663	0.425	−0.045	0.693
X_5	0.990	0.980	0.939	0.911
X_6	0.532	0.556	0.484	0.354
X_3 and X_4	0.572	0.443	0.503	0.725
X_5	0.827	0.754	0.249	0.751
X_6	0.801	0.772	0.198	0.655
X_4 and X_5	0.650	0.409	−0.142	0.497
X_6	−0.019	−0.209	−0.689	0.020
X_5 and X_6	0.520	0.525	0.405	0.609

Between the variables \ Population	Höljes	Skal-stugan	Average correlations in the five localities	
	r	r	Arithmetic average	Average based on sums of products and squares within populations
X_1 and X_2	0.549	0.647	0.507	0.459
X_3	0.551	0.649	0.582	0.567
X_4	0.280	0.199	0.201	0.184
X_5	0.539	0.656	0.456	0.299
X_6	0.336	0.436	0.412	0.356
X_2 and X_3	0.835	0.882	0.766	0.692
X_4	0.424	0.499	0.393	0.294
X_5	0.993	0.986	0.978	0.892
X_6	0.546	0.359	0.496	0.492
X_3 and X_4	0.611	0.649	0.556	0.496
X_5	0.816	0.885	0.706	0.464
X_6	0.509	0.280	0.512	0.467
X_4 and X_5	0.409	0.478	0.361	0.119
X_6	−0.344	−0.525	−0.357	−0.437
X_5 and X_6	0.544	0.373	0.474	0.419

Correlation based on:	D.F.	Value of r different from zero at the P % level of significance: $P = 5$ %	$P = 1$ %
1) 50 trees in one locality	48	0.279	0.361
2) 250 trees treated as one group	248	0.124	0.163
3) the product moment correlation coefficients for the five individual populations (arithmetic average)	240	0.126	0.165
4) sums of products and squares for cone-values between trees within the five populations	244	0.125	0.164

X_1 = thousand-grain weight

X_2 = cone length

X_3 = cone weight

X_4 = the total number of seeds per cone

$X_5 = X_2^3/10^6$ in cm³.

$$X_6 = \frac{\text{cone weight in milligram}}{\text{total number of seeds per cone}} = \frac{10\,X_3}{X_4}$$

Table 10. Coefficients in regressions of X_1 on X_3, X_4, X_2 and X_6 in 1948.

(Calculated on the basis of mean cone values for trees)

Population	Type of regression	$b_{13.426}$	$b_{14.326}$	$b_{12.346}$	$b_{16.342}$
Stjernarp .	Individual regression	-0.206 ± 0.154	2.069 ± 1.661	0.302 ± 0.146	6.186 ± 3.647
Härryda ..	,,	-0.037 ± 0.084	1.584 ± 1.207	-0.194 ± 0.119	3.147 ± 1.870
Gunnarskog	,,	0.114 ± 0.034	-1.296 ± 0.645	0.113 ± 0.068	-1.024 ± 0.053
Höljes	,,	0.090 ± 0.094	-0.516 ± 1.038	0.212 ± 0.163	-0.559 ± 1.323
Skalstugan	,,	0.234 ± 0.107	-1.305 ± 0.848	0.167 ± 0.146	-0.914 ± 1.013
The whole material ..	Average regression	0.078 ± 0.016	-0.366 ± 0.271	0.077 ± 0.046	-0.143 ± 0.308
,, ..	Total regression	0.041 ± 0.017	0.468 ± 0.255	0.114 ± 0.049	0.265 ± 0.311

The average regression equation of X_1 on X_3, X_4, X_2 and X_6 becomes:

$$X_1 = 223 + 0.078\, X_3 - 0.366\, X_4 + 0.077\, X_2 - 0.143\, X_6$$

X_1 = thousand-grain weight in cg.
X_2 = cone length in tenths of a mm.
X_3 = cone weigth in cg.
X_4 = the total number of seeds per cone
$X_6 = \frac{10X_3}{X_4}$

As can be seen from the equations, the combined relations between the dependent variable (X_1) and the independent variables (X_3, X_4 and X_6) differ considerably between the individual populations.

Especially the Norway spruce plot in Stjernarp of Central European origin, as well as the spruce plot in Härryda of native origin, show regression coefficients which deviate considerably from those for the other spruce plots of native origin. The partial coefficient of regression of 1,000-grain weight on cone weight is in the first two plots negative when the variables X_2, X_4 and X_6 are held constant. In the three other plots there is a considerable positive association between X_1 and X_3 when X_2, X_4 and X_6 are kept constant. The partial regression of 1,000-grain weight on total number of seeds per cone is positive in the stands at Stjernarp and Härryda and negative in the other three spruce stands when cone length, cone weight and cone weight per seed remain constant. The partial regression of the 1,000-grain weight on the cone weight per seed (X_6), when X_2, X_3 and X_4 are held constant, is positive in the sample plots at Stjernarp and Härryda, while the inverse relation obtains between these variables in the three most northern located sample plots. The sample plot at Härryda is the only plot showing a negative partial regression of 1,000-grain weight on cone length when cone weight, number of seeds per cone and cone weight per seed are constant.

The correlation between X_1 (1,000-grain weight of all seeds) and X_3 ("cone weight" = cone weight minus seed weight) is on the average somewhat more pronounced than between X_1 and X_2 and is of about the same order of magnitude in all groups. The average correlation between 1,000-grain weight and cone weight is for the five groups 0.567. In the case of equal cone weight the partial correlation between 1,000-grain weight and cone length is reduced. The difference between the total correlation coefficient for the whole material $r_{12} = 0.459$, and the corresponding partial correlation coefficient $r_{12.3} = 0.112$, gives a clear indication of this.

The correlation between the 1,000-grain weight (X_1) and the number of seeds per cone (X_4) are within populations weak in all cases (cf. Table 9) and at the same time influenced by other relations (cf. Table 21). The partial correlation within groups between 1,000-grain weight and number of seeds per cone with constant cone weight is - 0.136. The correlation between 1,000-grain weight and cone volume (X_1 and X_2) is weak in two sample plots and moderate in three. In the whole material it amounts on the average to 0.299.

The correlation between the 1,000-grain weight (X_1) and cone weight/number of seeds per cone (X_6) is very variable. The correlation is slight to weak in the two populations from Värmland (Gunnarskog and Höljes) and moderate in the other three.

In Table 11 is shown a testing of the slope and level of the regression lines in the five single populations for the regression of X_1 on X_3.

Table 11. Regression of 1,000-grain weight of all seeds (X_1) on cone weight (X_3).
(Calculated on the basis of mean cone values)

Row number	Variation due to	D.F.	Sum of Squares	Mean Square
			X_1 on X_3	
	Deviations from			
1	individual regressions	240	1041811.37	4340.88
2	parallel regressions	244	1058543.00	4338.29
3	total regression	248	1363349.00	5497.38
	Differences in			
4	slope (2)—(1)	4	16731.63	4182.91
5	level (3)—(2)	4	304806.00	76201.50
6	total differences (3)—(1)	8	321537.63	40192.20

$F_1 = \frac{(4)}{(1)} = 0.96^\circ$ $F_2 = \frac{(5)}{(2)} = 17.56^{***}$ $F_3 = \frac{(6)}{(1)} = 9.26^{***}$

The average regression equation (for the whole material) of X_1 on X_3 is $X_1 = 221 + 0.074\ X_3$.

*** Statistically significant at the 0.1 % level. °Not significant.

The testing of the regression values for the five samples shows that one or several reliable differences exist with respect to one or more of the levels of the parallel regression lines. On the other hand, there are no significant differences between the slopes of the five individual regression lines.

The individual regression equations for the populations in Stjernarp,

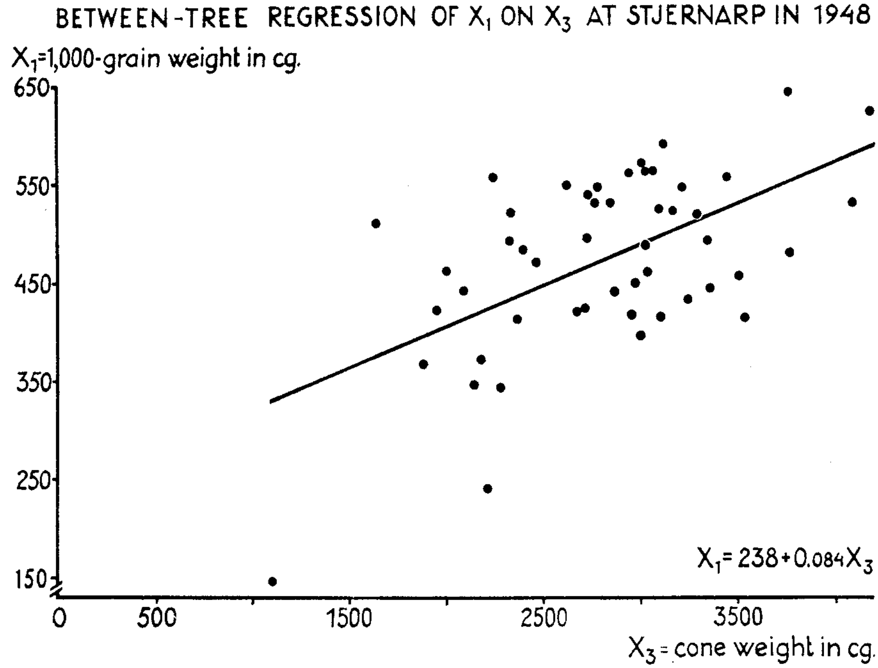

BETWEEN-TREE REGRESSION OF X1 ON X3 AT STJERNARP IN 1948
X1=1,000-grain weight in cg.
650
550
450
350
250
150
0
500
1500
2500
3500
X3 = cone weight in cg.
X1= 238+0.084X3

Fig. 8.

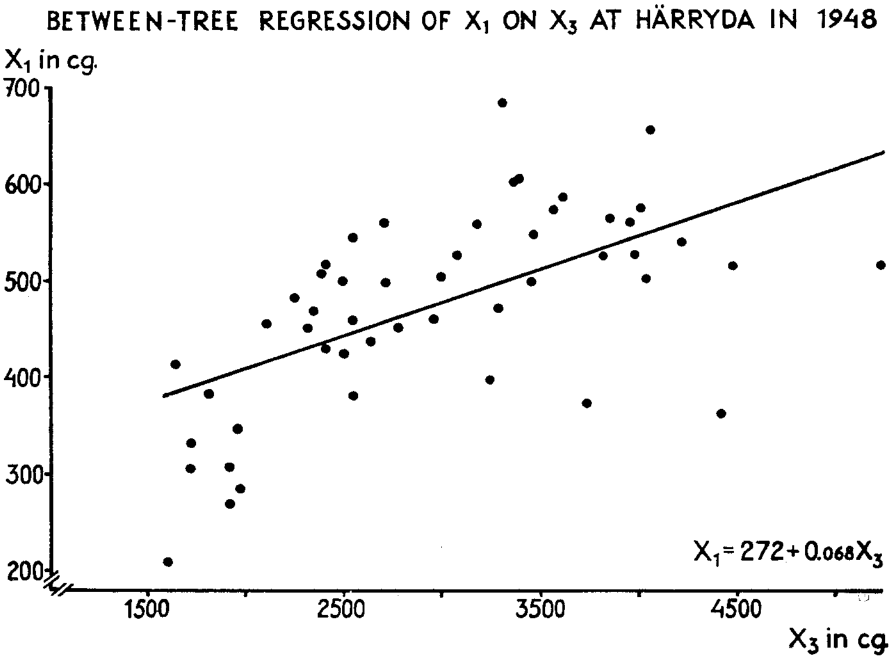

BETWEEN-TREE REGRESSION OF X1 ON X3 AT HÄRRYDA IN 1948
X1 in cg.
700
600
500
400
300
200
1500
2500
3500
4500
X3 in cg.
X1= 272+0.068X3

Fig. 9.


BETWEEN-TREE REGRESSION OF X1 ON X3 AT GUNNARSKOG IN 1948
X1 in cg.
600
500
400
300
200
X1 = 226 + 0.067 X3
2000
3000
4000
X3 in cg.

Fig. 10.

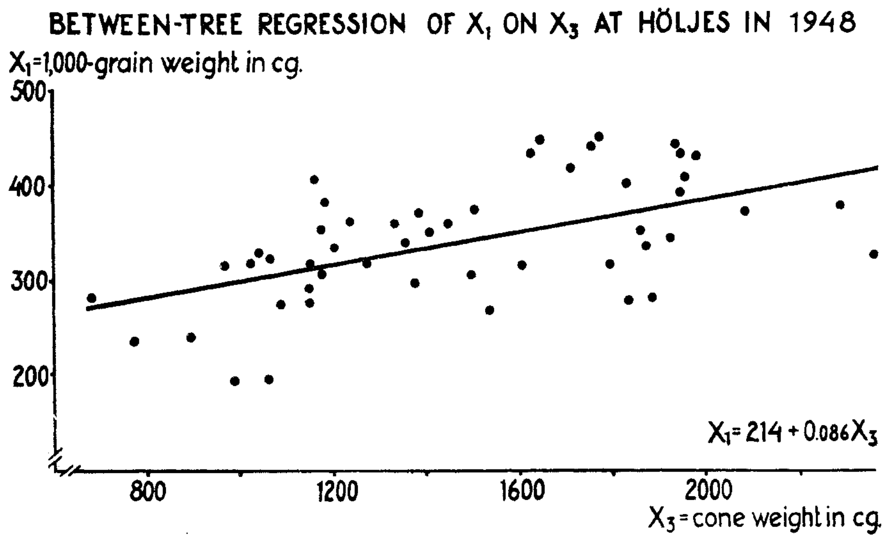

BETWEEN-TREE REGRESSION OF X1 ON X3 AT HÖLJES IN 1948
X1=1,000-grain weight in cg.
500
400
300
200
X1= 214 + 0.086X3
800
1200
1600
2000
X3 = cone weight in cg.

Fig. 11.

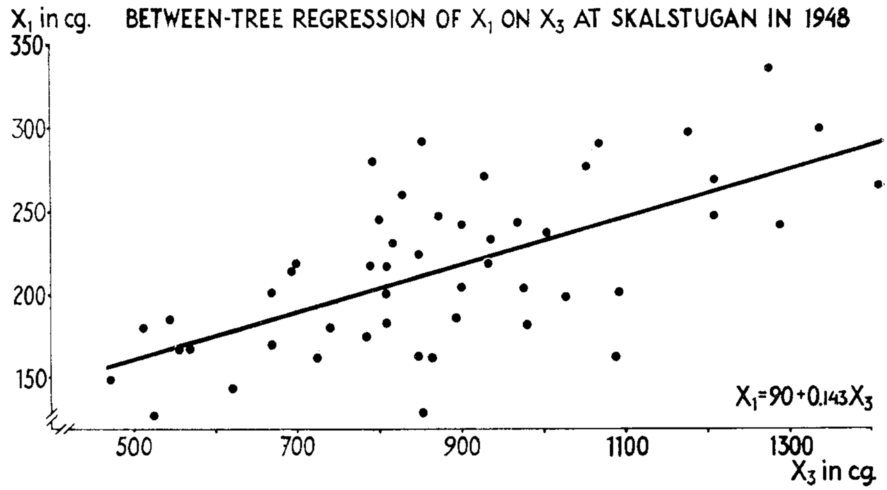


Fig. 12.

Härryda, Gunnarskog, Höljes and Skalstugan respectively, for the two variables (X_1 and X_3) are:

$$X_1 = 238 + 0.084\ X_3$$
$$X_1 = 272 \div 0.068\ X_3$$
$$X_1 = 226 + 0.067\ X_3$$
$$X_1 = 214 + 0.086\ X_3$$
$$X_1 = 90 + 0.143\ X_3$$

Figures 8—12 illustrate the linear regression relationships between the dependent variable X_1 and the independent variable X_3 within different populations.

In Table 12 the same analysis of covariance has been performed where also the regression of X_1 on X_4 and on X_6 has been taken into consideration. The significance test in Table 12 shows that significant differences exist in the levels of the regression of the 1,000-grain weight of all seeds per cone on cone weight, number of seeds per cone and cone weight per seed.

From the equation for the average regression in Table 10 it is apparent that there is a positive regression on the average in the whole material of 1,000-grain weight (X_1) on cone weight (X_3) and of 1,000-grain weight on cone length (X_2) when the other three variables are held constant. A negative regression exists in the total material of 1,000-grain weight on the number of seeds per cone (X_4) when X_2, X_3, and X_6 are held constant, and of 1,000-grain weight on cone weight per seed (X_6). In the case of equal cone weight and cone length there is a tendency for the 1,000-grain weight to be reduced with increased number of seeds per cone (see also Table 21). With equal cone weight and number of seeds per cone but different cone length, the

Table 12. Regression of 1,000-grain weight of all seeds per cone (X_1) on cone weight (X_3), No. seeds/cone (X_4) and $\frac{\text{cone weight}}{\text{No. seeds/cone}}$ (X_6).

Row number	Source of Variation	D.F.	Sum of Squares	Mean Square
			X_1 on X_3, X_4, X_6	
	Deviations from individual regressions:			
	Stjernarp	46	261645.3	5688.0
	Härryda	46	277172.8	6025.5
	Gunnarskog	46	238628.9	5187.6
	Höljes	46	134069.1	2914.5
	Skalstugan	46	57176.0	1243.0
1	Σ individual regressions	230	968692.2	4211.7
2	parallel regressions	242	1038824.0	4292.7
3	total regression	246	1284850.0	5223.0
	Differences in:			
4	slope (2)—(1)	12	70132.0	5844.3
5	level (3)—(2)	4	246026.0	61506.5
6	total differences (3)—(1)	16	316158.0	19759.9

$F_1 = \frac{(4)}{(1)} = 1.39°$ $F_2 = \frac{(5)}{(2)} = 14.33^{***}$ $F_3 = \frac{(6)}{(1)} = 4.69^{***}$

*** Statistically significant at the 0.1 % level. °Not significant

For the average regression for the whole material we have the equation

$$X_1 = 248 + 0.080\ X_3 - 0.221\ X_4 + 0.062\ X_6$$

longer cone contains, on the average, seeds with somewhat higher 1,000-grain weight. If the cone length and the number of seeds per cone are held constant there is a tendency for the 1,000-grain weight to increase in the total material when the cone weight increases.

5.1.3. Between-tree relationship of seed number with cone length, cone weight, cone volume and $\frac{\text{cone weight}}{\text{number of seeds/cone}}$.

(Calculated on the basis of cone mean values for trees by populations and on an average for the populations.)

The correlation between the number of seeds per cone (X_4) and cone length (X_2) is 0.663 for the Central European spruce at Stjernarp and 0.425,–0.045, 0.424 and 0.499 respectively for the native Norway spruce populations at Härryda, Gunnarskog, Höljes and Skalstugan. The average correlation coefficient between the same two variables in the four native spruce populations is 0.213.

The correlation between number of seeds per cone (X_4) and cone weight

Table 13. Regression of total number of seeds/cone (X_4) on cone weight (X_3) and cone volume ($X_5 = X_2^3/10^6$).

Row number	Variation due to	D.F.	Sum of Squares	Mean Square
			X_4 on X_3, $X_2^3/10^6$	
	Deviations from			
1	individual regressions	235	231140.93	983.58
2	parallel regressions	243	261166.00	1074.76
3	total regression	247	496165.00	2008.77
	Differences in			
4	slope (2)—(1)	8	30025.07	3753.13
5	level (3)—(2)	4	234999.00	58749.75
6	total differences (3)—(1)	12	265024.07	22085.34

$F_1 = \frac{(4)}{(1)} = 3.82^{***}$ $F_2 = \frac{(5)}{(2)} = 54.66^{***}$ $F_3 = \frac{(6)}{(1)} = 22.45^{***}$

(X_3) varies between 0.443 in Härryda to 0.649 in Skalstugan, and the average correlation in the whole material is 0.496.

The partial correlation coefficient $r_{34.2}$ between trees within groups is 0.425. Thus if the cone length is kept constant the correlation between X_3 and X_4 decreases. If $r_{35.4}$ and $r_{45.3}$ are calculated for the total material, these numerical relations are found to be 0.470 and - 0.144 respectively. If the number of seeds is kept constant the partial correlation between cone weight and cone volume is thus practically unchanged. With constant cone weight the partial correlation between the number of seeds per cone and the cone volume is slightly negative. With equal cone volume the partial correlation ($r_{34.5}$) between cone weight and number of seeds per cone between trees with in groups is on the average 0.501, which indicates that in the material for the year 1948 the cone volume has no significant influence upon the correlation between cone weight and number of seeds per cone, since r_{34} is 0.496. With equal cone weight and different cone length, the relation ($r_{42.3}$) between the number of seeds per cone and cone length is reduced. The partial correlation coefficient ($r_{42.3}$) is - 0.078, while the average correlation coefficient (r_{42}) within groups, presented in Table 9, is 0.294.

The correlation between the number of seeds per cone (X_4) and cone weight per seed (X_6) is, of course, negative. The more seeds per cone, the less the cone weight per seed will be. The correlation for all plots is on an average - 0.437.

In Table 13 are given the mean squares for three different regression types, referring to the regression of X_4 on X_3 and X_5 (for ascertaining with analysis of covariance whether there is any statistically demonstrable difference with respect to the slope of the individual regression planes and whether there is

Table 14. Coefficients in regressions of X_4 on X_3 and $X_5 = X_2^3/10^6$.

Population	Type of regression	$b_{43.5}$	$b_{45.3}$
Stjernarp	Individual regression	0.006±0.011	0.034±0.012
Härryda	,,	0.014±0.009	0.011±0.012
Gunnarskog	,,	0.041±0.009	−0.011±0.005
Höljes	,,	0.070±0.016	−0.054±0.039
Skalstugan	,,	0.144±0.032	−0.151±0.079
The whole material			
,, ,, ...	Average regression	0.035±0.004	−0.008±0.003
,, ,, ...	Total regression	0.048±0.004	−0.008±0.005

The average regression equation of X_4 on X_3 and X_5 is,

$$X_4 = 113 + 0.035\ X_3 - 0.008\ X_5.$$

The equation for the total regression plane is

$$X_4 = 84 + 0.048\ X_3 - 0.009\ X_5.$$

any established difference in level with respect to the parallel regressions of the five groups).

The variance ratio test in Table 13 shows clearly that the individual regression coefficients of the groups are not all equal, i.e. that at least one of these is statistically different from the regression coefficient for the average regression function for the whole material. The coefficient for the average regression of the number of seeds per cone on cone weight in centigrams with equal cone volume (cf. Table 14) within the five sample plots is on the average + 0.035. When the cone volume remains constant a change in the cone weight of one gram corresponds to a change in the number of seeds per cone by an average of 3.5 seeds.

Finally the individual regression equations of the single population samples are as follows:

Stjernarp	$X_4 =$	$181 + 0.006\ X_3 + 0.034\ X_5$
Härryda	$X_4 =$	$102 + 0.014\ X_3 + 0.011\ X_5$
Gunnarskog	$X_4 =$	$67 + 0.041\ X_3 - 0.011\ X_5$
Höljes	$X_4 =$	$70 + 0.070\ X_3 - 0.054\ X_5$
Skalstugan	$X_4 =$	$18 + 0.144\ X_3 - 0.151\ X_5$

From the average regression equation it follows that the regression of the number of seeds per cone, X_4, on the cone volume, X_5, (in this case the cube of the cone's length in cm., $X_2^3/10^6$) with equal cone weight is on the average slightly negative for the 1948 material. The numerical value of the regression coefficient is of course, in this case as in other cases, also dependent on the unit in which the variate is given.

Since the regression of X_4 on $X_5 = X_2^3/10^6$, like the partial correlation coefficient $r_{42.3}$ at constant cone weight, is negative in the whole material,

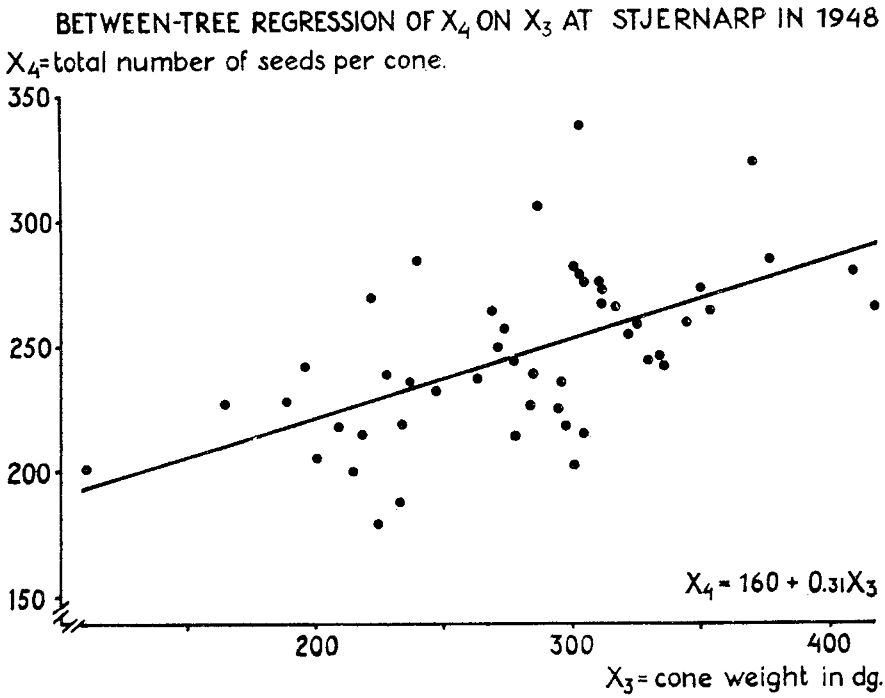

BETWEEN-TREE REGRESSION OF X4 ON X3 AT STJERNARP IN 1948
X4= total number of seeds per cone.
350
300
250
200
150
X4 = 160 + 0.31X3
200
300
400
X3 = cone weight in dg.

Fig. 13.

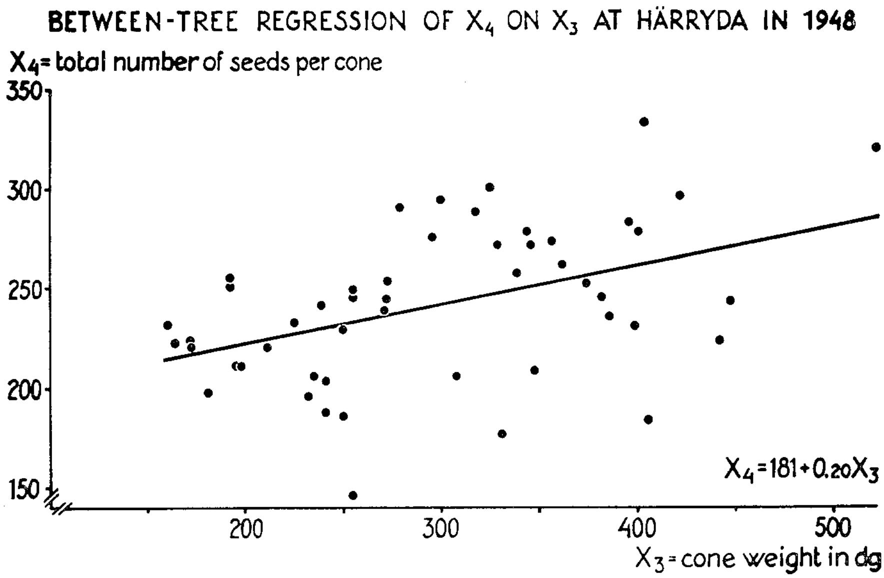

BETWEEN-TREE REGRESSION OF X4 ON X3 AT HÄRRYDA IN 1948
X4= total number of seeds per cone
350
300
250
200
150
X4=181+0.20X3
200
300
400
500
X3 = cone weight in dg

Fig. 14.

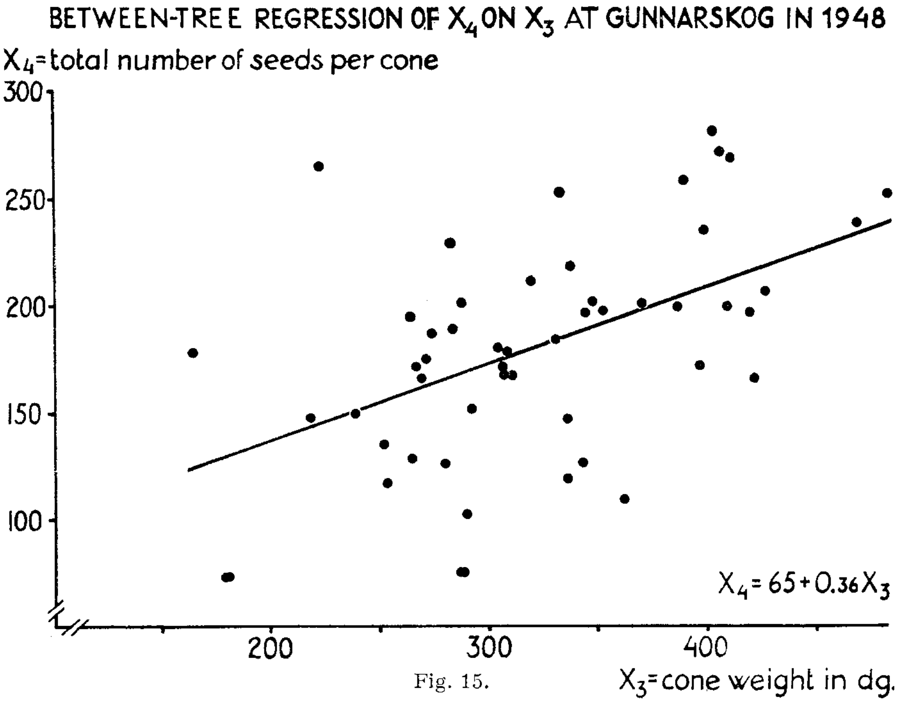


Fig. 15.

this means that with equal cone weight and different cone length the shorter cone contains more seeds per cone. The population in Stjernarp deviates strikingly in this respect from the rest of the material. In the last mentioned population, with equal cone weight and different cone length, the longer cone contains more seeds per cone.

If nothing but the regression of X_4 on X_3 is taken into consideration the following regression coefficients (b_{43}) for the populations at Stjernarp, Härryda, Gunnarskog, Höljes and Skalstugan are obtained: 0.031, 0.020, 0.036, 0.051 and 0.090 respectively (cf. Figures 13—17). The average regression (for the whole material) is

$$X_4 = 115 + 0.031\ X_3.$$

The concordance with corresponding partial regression coefficient ($b_{43.5}$) in Table 14 at a constant cone volume, is—except for the populations in Stjernarp and Skalstugan—surprisingly pronounced. The linear regressions of X_4 on X_3 for individual stands are:

Stjernarp	$X_4 = 160 + 0.031\ X_3$
Härryda	$X_4 = 181 + 0.020\ X_3$
Gunnarskog	$X_4 = 65 + 0.036\ X_3$
Höljes	$X_4 = 73 + 0.051\ X_3$
Skalstugan	$X_4 = 30 + 0.090\ X_3$

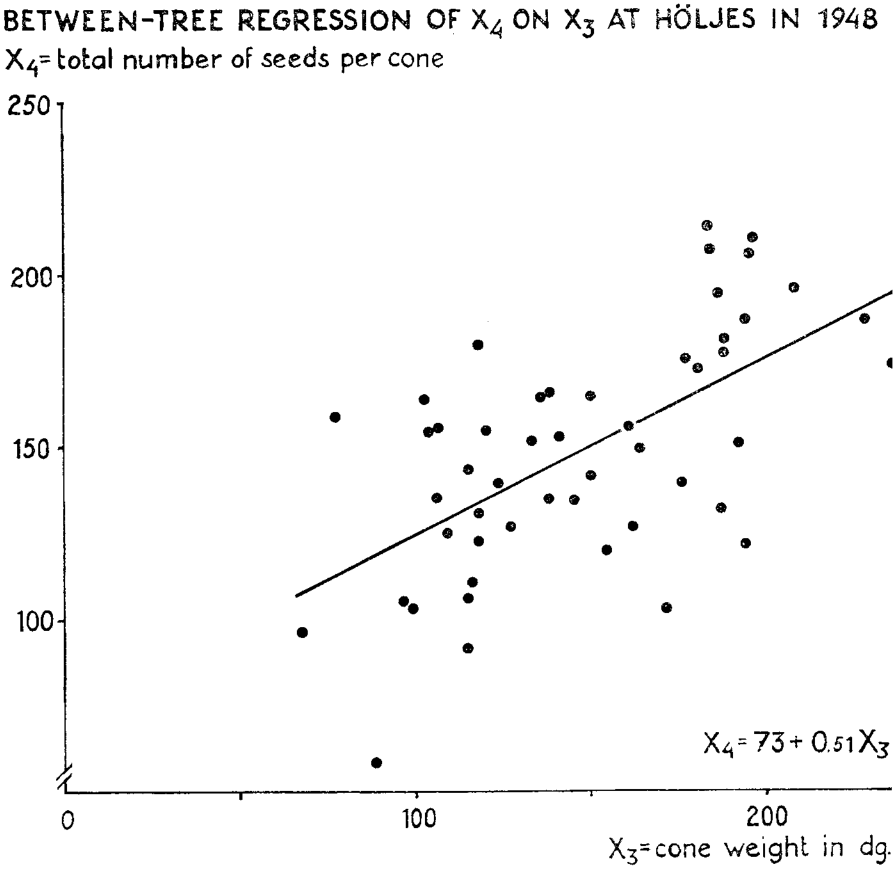

BETWEEN-TREE REGRESSION OF X4 ON X3 AT HÖLJES IN 1948
X4= total number of seeds per cone
250
200
150
100
X4= 73 + 0.51 X3
0
100
200
X3= cone weight in dg.

Fig. 16.

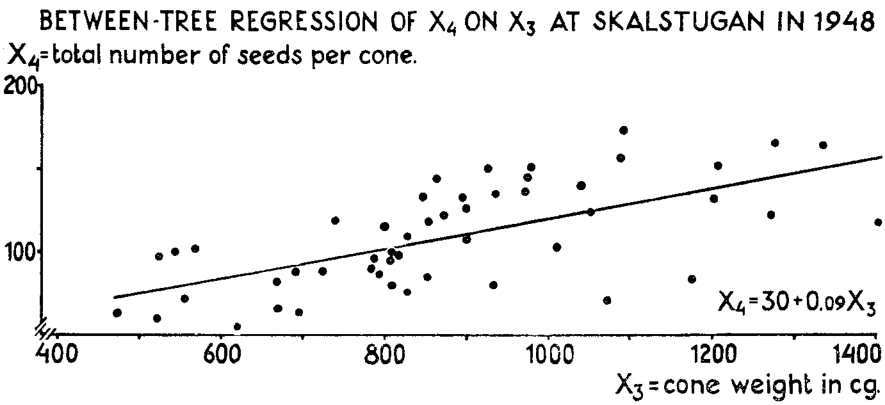

BETWEEN-TREE REGRESSION OF X4 ON X3 AT SKALSTUGAN IN 1948
X4= total number of seeds per cone.
200
100
X4=30+0.09X3
400
600
800
1000
1200
1400
X3 = cone weight in cg.

Fig. 17.

5.1.4. Average correlations and regressions between cones within populations, within trees and between trees within populations of cone and seed properties.

(Calculated on the basis of cone values by populations and within trees within populations.)

If one wishes to clarify the average within-tree correlation in one or several populations or the variation by trees in the correlation and regression coefficients for populations, one is obliged to carry out the correlation and regression analysis on individual cone values within trees. If, on the other hand, one wishes to study the associations of the cone and seed properties in a population (apart from single trees), one must calculate the corresponding correlations and regressions in a sample of cones from a combined cone material.

To elucidate the sizes and internal relationships of these correlation groups we present in this section some average correlations within populations (without respect to trees) in Table 15, and the corresponding total correlations within trees within single populations in the whole material, in Table 16. In addition to these correlations a series of regressions has been calculated to illustrate the relationships within trees within populations for some pairs of variables.

The correlation coefficients in Tables 15 and 16 are in agreement or differ more or less for some pairs of variates. They are not, however, independent of each other, since the coefficients in Table 15 are weighted means of the *inter-tree* and *within-tree* correlation coefficients. The correlation coefficients in Tables 9 and 16, on the other hand, are to be regarded as independent of one another.

It will be seen from Table 15 that the different sets of pairs of variables show different variability and strength. The correlations between the cone length and cone weight (r_{23}) as well as between cone weight and the weight of all seeds per cone (r_{37}) are fairly constant within the sets, whereas the correlation coefficients between, for example, cone length and total number of seeds (r_{24}) and between cone length and the weight of seeds $>$ 1 mm. per cone (r_{29}) differ markedly. The heterogeneity between populations is of the same size for the three sets of coefficients r_{34}, r_{47}, and r_{49}.

If we test the differences of the correlation between populations, we find that there exists a large number of significant differences within most of the sets of coefficients. There are, for example, statistically established differences for all possible differences between the coefficients r_{27}. The differences all reach or exceed the 5 % level of significance. The t-value for the correlation difference between the coefficients r_{27} at Stjernarp and Härryda is e.g.:

$$t = \frac{0.95 - 0.61}{\sqrt{\frac{2}{1247}}} = 8.49^{***}.$$

Table 15. Correlations between cones within localities and in the total material for the year 1948.

Between the variables \ Population	Stjernarp	Härryda	Gunnar-skog	Total material treated as one group Total between cone correlations
	r	r	r	r
X_2 and X_3	0.835	0.797	0.816	0.930
X_4	0.631	0.455	0.173	0.694
X_7	0.738	0.548	0.404	0.788
X_8	0.469	0.290	0.223	0.677
X_9	0.719	0.507	0.406	0.778
X_3 and X_4	0.579	0.475	0.427	0.685
X_7	0.725	0.702	0.619	0.800
X_8	0.496	0.437	0.473	0.688
X_9	0.701	0.684	0.619	0.794
X_4 and X_7	0.711	0.752	0.843	0.892
X_8	0.802	0.889	0.949	0.951
X_9	0.640	0.731	0.825	0.877
X_7 and X_8	0.766	0.782	0.885	0.913
X_9	0.996	0.998	0.997	0.999
X_8 and X_9	0.794	0.780	0.887	0.918

Between the variables \ Population	Höljes	Skal-stugan	Average correlations in the five localities	
	r	r	Arithme-tic average	Average based on sums of products and squares within populations
X_2 and X_3	0.817	0.854	0.824	0.806
X_4	0.454	0.535	0.450	0.421
X_7	0.604	0.687	0.596	0.571
X_8	0.462	0.571	0.403	0.359
X_9	0.599	0.689	0.584	0.553
X_3 and X_4	0.582	0.625	0.538	0.484
X_7	0.719	0.771	0.707	0.687
X_8	0.585	0.650	0.528	0.480
X_9	0.713	0.769	0.697	0.674
X_4 and X_7	0.831	0.853	0.798	0.761
X_8	0.876	0.951	0.893	0.898
X_9	0.805	0.832	0.767	0.727
X_7 and X_8	0.870	0.884	0.837	0.811
X_9	0.996	0.998	0.997	0.997
X_8 and X_9	0.879	0.885	0.845	0.822

Correlation based on:	D.F.	Value of r different from zero at the P % level of significance: $P = 5$ %	$P = 1$ %
1) 1250 cones in one locality	1248	0.055	0.073
2) 6250 cones treated as one group	6248	0.025	0.033
3) sums of products and squares between cone values within trees within the five populations	6244	0.025	0.033

X_2 = cone length
X_3 = cone weight
X_4 = the total number of seeds per cone
X_7 = the weight of all seeds per cone
X_8 = the number of seeds > 1 mm. per cone
X_9 = the weight of seeds > 1 mm. per cone

Table 16. Average correlations between cones within trees for the year 1948.

Between the variables \ Population	Stjernarp	Härryda	Gunnarskog	Höljes	Skalstugan	The five populations
	r	r	r	r	r	r
X_2 and X_3	0.846	0.847	0.837	0.790	0.815	0.820
X_4	0.574	0.524	0.159	0.507	0.433	0.432
X_7	0.727	0.762	0.368	0.634	0.656	0.587
X_8	0.547	0.546	0.177	0.504	0.700	0.451
X_9	0.705	0.674	0.372	0.630	0.637	0.581
X_3 and X_4	0.579	0.588	0.285	0.531	0.596	0.470
X_7	0.772	0.740	0.486	0.718	0.751	0.673
X_8	0.516	0.588	0.295	0.561	0.584	0.474
X_9	0.754	0.737	0.487	0.717	0.713	0.667
X_4 and X_7	0.725	0.834	0.873	0.832	0.883	0.807
X_8	0.889	0.979	0.985	0.923	0.956	0.956
X_9	0.702	0.827	0.864	0.831	0.877	0.796
X_7 and X_8	0.747	0.846	0.887	0.864	0.900	0.828
X_9	0.996	0.999	0.999	0.809	0.997	0.976
X_8 and X_9	0.762	0.847	0.912	0.863	0.909	0.830

Correlation based on:	D.F.	Value of r different from zero at the P % level of significance: $P=5$ %	$P=1$ %
within-tree correlation for individual populations	1199	0.057	0.074
average within-tree correlation in the five populations	5999	0.025	0.033

X_2 = cone length
X_3 = cone weight
X_4 = the total number of seeds per cone
X_7 = the weight of all seeds per cone
X_8 = the number of seeds > 1 mm. per cone
X_9 = the weight of seeds > 1 mm. per cone

We have here applied the z-transformation (v. p. 53) to the r-values. It should be noted that the significance can be due to the possible existence of differences between trees in the same locality with regard to the covariation of the two variates.

On examining the Tables 9, 15 and 16 one finds that the numerical values for the coefficients in Table 15, for each population and variate combination, lie between the corresponding value for inter-tree correlations in Table 9, and for the within-tree correlations in Table 16. The difference in strength of the *inter-tree* and *within-tree* coefficients for comparable pairs of variates, which is very complex, depends partly on the differences in environmental effects, and consequently also on the dissimilarities in interactions between genotypes and external conditions.

In 28 cases out of 75 the total correlation coefficients for single populations, (see Table 15) are larger, seen numerically, than the corresponding coefficients in Table 16. In two cases they are equal and in 45 cases, smaller. The *within-tree correlation coefficients* in this material are therefore on an average larger than the corresponding *coefficients within populations*, when the cones are treated as one group without consideration to trees. In the stand at Härryda, for instance, all within-tree coefficients are larger than the corresponding coefficients in Table 15.

If we further consider the within-tree correlations in Table 16, we find 1) that the correlation between the variables X_2 (cone length) and X_3 (cone weight) amounts on the average for the five populations to 0.820 (as against 0.692 for between trees in Table 9), and 2) that this correlation (like all of the other coefficients in Table 16 and all coefficients in Table 15, and most of the coefficients in Table 9) has a very high significance (see SNEDECOR, 1959, p. 174, MERRINGTON, 1942, p. 311, and the probability values below the Tables 9, 15 and 16).

Since the correlation between cone length and cone weight, r_{23}, is strong within trees, it may be of interest to calculate the proportion of the variability in X_2, which can be referred to a linear covariation with X_3. The proportion of this variation is measured by the value of r^2_{23}, which in this case is 0.6724. About 67 per cent of the variation in X_2 (cone length) may therefore be referred to the covariation with X_3 (cone weight) or conversely.

In the same way, the deviations between the coefficients in Table 9 and the corresponding coefficient in Table 15 are numerous when considered in percentage, and in certain cases of considerable size. The coefficient r_{23} at Gunnarskog is, for instance, *between trees* 0.497 and *inter-cones within* the population 0.816. On calculating the three sets of inter-tree coefficients r_{27}, r_{37} and r_{47}, one obtains (together with the three comparable sets of correlation coefficients in the Tables 9 and 15) six sets of observations, or 30 pairs of coefficients. 15 of these 30 inter-tree coefficients in Table 9 are, in their numerical values, either clearly smaller or somewhat smaller than the equivalent correlation coefficients in Table 15, two are numerically considered the same and 13 are larger than the corresponding coefficients in Table 15. It does not seem to be possible, however, to carry out any tests of these correlation differences which would be entirely free from points of objection.

If we test the differences of the correlation between the coefficients in Tables 9 and 16, we find that (if we abstract from the total group correlations in Table 9) significant differences ($P < 5\ \%$) between the comparable coefficients in the two tables exist between the two coefficients r_{23} at Gunnarskog as well as for the two coefficients r_{23}, and r_{24} in the total material (between trees within populations versus within trees within populations). The t-values for testing the differences are as follows:

$$t_{23}\,(\text{Gunnarskog}) = \frac{0.66}{\sqrt{\dfrac{1}{50-3}+\dfrac{1}{50\times 24-2}}} = \frac{0.66\sqrt{56306}}{\sqrt{1245}} = 0.66 \times 6.725 =$$

$$= 4.44^{***}\ (P < 0.1\ \%),$$

$$t_{23}\,(\text{in total material}) = \frac{0.30}{\sqrt{\dfrac{1}{5\times 49-2}+\dfrac{1}{250\times 24-2}}} = 4.58^{***} \text{ and}$$

$$t_{24} = 2.44^{*}\ (P < 2\ \%).$$

If we furthermore test the significance of the differences between the inter-tree correlation coefficients r_{27}, r_{37} and r_{47} and the corresponding within-tree correlation coefficients in Table 16, we also find significant differences between the coefficients r_{27} at Härryda ($t_{27} = 2.89^{**}$), r_{37} at Gunnarskog ($t_{37} = 2.08^{*}$) and r_{47} at Härryda ($t_{47} = 2.15^{*}$). The three sets of inter-tree correlations used for these comparisons are given below:

	Stjernarp	Härryda	Gunnarskog	Höljes	Skalstugan
r_{27}	0.749	0.518	0.422	0.584	0.718
r_{37}	0.706	0.696	0.686	0.724	0.819
r_{47}	0.710	0.706	0.826	0.842	0.818

These correlation differences at Gunnarskog and Härryda indicate that the magnitude of the *between-tree* and the *within-tree* relationships between identical pairs of cone and seed characters may, in some cases, be significantly different.

In addition to the investigations of the types of correlations and the relative strength (between different cone and seed qualities and between seed qualities themselves) within a tree type, it is of no less interest for practical purposes to clarify and verify whether these relationships for a certain tree genus and species are to be considered as general, or whether the connection can change in a significant way from region to region and from year to year. It is therefore of interest to examine: 1) whether, for example, the two high altitude populations of indigenous Norway spruce at Höljes and Skalstugan deviate significantly in their correlation from the two low altitude populations of Norway spruce at Härryda and Gunnarskog, and in which manner they differ, 2) whether there is any apparent trend in these connections for a number of regions, 3) whether a population and one and the same tree can show different strengths of correlation during different years (or, in other words under various environmental conditions) and 4) whether trees of different genotypes react differently to the same changes of environment. It is of the greatest interest to confirm the differences in interactions between genotypes and environments.

If the z-values for the correlation coefficients in Table 16 are compared with one another between populations, one finds a number of obvious correlation differences. The within-tree correlation between the variates X_2 and X_3 remains constant in the three low altitude populations but decreases to a statistically significant degree in relation to these in the two high altitude populations (taken together). The within-tree correlation difference between the population in Höljes (660 m. above sea level) and that in Stjernarp (or between Höljes—Härryda) is significant and corresponds to a P-value < 0.1 per cent. Almost equally significant is the corresponding difference between Höljes and Gunnarskog (the P-value for this difference is practically equal to 0.1 per cent). There is no statistically established difference in this respect between the sample plot in Gunnarskog and either of the plots in Stjernarp and Härryda. The differences in northern latitude between the tree localities do not in this case seem to have demonstrably affected the correlation between cone length and cone weight. This means, further, that the Norway spruce population of Central European origin in Stjernarp shows on an average the same within-tree correlation between X_2 and X_3 as the spruce populations of native origin at Härryda and Gunnarskog. The within-tree correlation difference for the same pair of coefficients between, on the one hand, the population in Skalstugan (585 m. above sea level) and, on the other hand, the population in Stjernarp or Härryda is significant at the 1 per cent level. On the other hand, the corresponding differences for X_2, X_3 between the spruce plot in Skalstugan and that at Gunnarskog, and between Skalstugan and Höljes, do not quite attain a satisfactory significance. (The differences in z-units are both 0.07 instead of the 0.08 required here at the 5 per cent level.)

If we compare the correlation coefficients for the same pair of variates (X_2 and X_3) in Table 9, we find that the coefficients for the average inter-tree correlation in the plots at Stjernarp and Höljes are exactly the same, viz., 0.835, and that the inter-tree correlation for cone length and cone weight does not seem to diminish with the plots' height above sea level in combination with the more northern location of the stands (with the exception of Gunnarskog), but has rather a slight tendency to increase (cf. Skalstugan—Höljes and Skalstugan—Gunnarskog). The inter-tree correlation difference between the two coefficients, r_{23}, in the stand at Gunnarskog and that at Skalstugan is very highly significant ($P < 0.1$ per cent). The difference between the same coefficients at Höljes and Gunnarskog corresponds to a value of P between 1 and 0.1 per cent.

The correlation within trees between the cone and seed properties is for the year 1948 (in relation to the other four populations) significantly lowest in the population in Gunnarskog. (The P-value is for all comparisons < 0.1 per cent).

If we compare the correlations between X_2 (cone length) and X_4 (number of seeds per cone) within trees, we find (if we disregard the population at Gunnarskog) that the differences between the correlation coefficients of the single populations and the corresponding coefficient for Stjernarp increase in proportion as the tree localities are situated farther north, which in this case implies that the correlations between the variables X_2, X_4 diminish in the north in relation to the connection found in Stjernarp. The differences due to the values for z are the following: between Stjernarp and Härryda $= 0.07°$, between Stjernarp and Höljes $= 0.09*$, and between Stjernarp and Skalstugan $= 0.19**$.

The corresponding inter-tree correlation differences between populations are not significantly different.

The within-tree correlation for the variate pair X_2 and X_7 (total seed weight per cone) is significantly lower at Höljes and Skalstugan than at Stjernarp and Härryda. The difference between the z-values for the correlation coefficients between Stjernarp and Höljes amounts to 0.17***, between Stjernarp and Skalstugan to 0.13** and between Stjernarp and Härryda to 0.08°. If, again, one neglects the population at Gunnarskog, the total correlation within trees between the variables X_2 and X_7 in the present spruce material appears in the first place to decrease with the height above sea level of the tree localities.

The correlation within trees between X_2 (cone length) and X_8 (number of seeds > 1 mm. per cone) at Skalstugan is significantly greater than in the other populations ($P < 0.1$ per cent). There is on the other hand no significance between any of the populations at Höljes, Stjernarp and Härryda with respect to this relation. The within-tree correlation between the variate pair X_2 and X_9 (the weight of the number of seeds > 1 mm. per cone) is, as is the case between X_2, X_7, significantly greater in Stjernarp than in the populations at Höljes and Skalstugan.

For the single populations the within-tree correlation between X_3 and X_4 (with the exception of Gunnarskog) is practically constant. Only the correlation difference between Skalstugan and Höljes amounts to a significance at the 5 per cent level.

The correlation within trees between X_3 (cone weight) and X_7 (total number of seeds per cone) remains (with the exception of the population in Gunnarskog) relatively constant in the populations. This difference in z-units between Stjernarp and Höljes amounts, however, to 0.13**. The within-tree correlation between X_3 and X_8 (number of seeds > 1 mm. per cone) agrees with the corresponding correlation between X_3 and X_4, with the exception of the three comparisons Skalstugan contra Höljes, Stjernarp contra Skalstugan and Stjernarp contra Härryda. The correlation difference between Skalstugan and Höljes is in this case not significant, but the differences between Stjernarp and Skalstugan and between Stjernarp and Härryda, on the other hand, attain a significance at the 5 per cent level.

No essential difference in the strength of the correlation between the populations appears to exist for the pairs of variables X_3 and X_9 (weight of seeds > 1 mm. per cone). With the exception of all comparisons with the population in Gunnarskog, only the correlation difference between Stjernarp ($r = 0.754$) and Skalstugan ($r = 0.713$) is significant.

Characteristic of the correlation within trees between number of seeds and seed weight (X_4, X_7 and X_8, X_9) is, inter alia, 1) that the population in Gunnarskog no longer, in such a striking way as for the covariation of the cone and seed properties, deviates from the four other populations, 2) that the correlation is lowest in the most southern plot (Stjernarp), and 3) that on the average the correlation increases in more northerly situated tree localities. The average correlation within single populations (cf. Table 15) between the variates X_4 (total number of seeds per cone) and X_7 (weight of total number of seeds per cone) increases on the average with northern latitude (from Stjernarp to Skalstugan). The t-values for the within-tree correlation differences between the variate pairs (X_4, X_7) in, on the one hand, Stjernarp, and on the other hand, each of the other four stands, all correspond to P-values < 0.1 per cent. The t-values for corresponding differences between Gunnarskog—Härryda, Gunnarskog—Höljes, Skalstugan—Höljes, and Skalstugan—Härryda amount to 3.67***, 3.92***, 4.89*** and 4.65*** respectively, which means that the correlation differences between Stjernarp and the other sample plots are also for the variate pairs X_8 (number of seeds > 1 mm. per cone) and X_9 (weight of seeds > 1 mm. per cone) very significant. The P-value is in all cases < 0.1 per cent and the correlation, as appears from Table 16, is lowest in Stjernarp. The t-values for the correlation differences between Gunnarskog—Härryda, Gunnarskog—Höljes, Skalstugan—Höljes, and Skalstugan—Härryda amount to 7.10***, 5.63***, 5.14***, and 6.61*** respectively (P is, also in these cases, < 0.1 per cent). The correlation within trees between the variables X_8, X_9 thus seems—in relation to the corresponding connection in the population in Stjernarp—to increase in more northerly situated tree localities.

Since, amongst other factors, the cone weight may affect the seed weight differently in different populations (cf. Table 10) and likewise the covariation of seed weight and number of seeds, as has earlier been shown with respect to the inter-tree correlation, it is highly motivated to compute the partial correlations within trees between number of seeds > 1 mm. per cone (X_8) and weight of seeds > 1 mm. per cone (X_9) at constant cone weight. If we compute these average partial correlations of the first order ($r_{39.3}$) between the variables X_8, X_9, we get for the populations in Stjernarp, Härryda, Gunnarskog, Höljes, Skalstugan and on an average for the five populations, the following coefficient-series: 0.663, 0.757, 0.921, 0.799, 0.865 and 0.783. The t-value for the partial correlation difference in z-units between Skalstugan—Stjernarp is given by

$$t = \frac{(1.31 - 0.08)\sqrt{1197}}{\sqrt{2}} = 12.48^{***}.$$

The corresponding t-values between Härryda—Stjernarp, Gunnarskog—Stjernarp, Höljes—Stjernarp, Gunnarskog—Höljes, Gunnarskog—Skalstugan, Skalstugan—Höljes, and Skalstugan—Härryda amount to 4.65***, 19.57***, 7.09***, 12.48***, 7.09***, 5.38***, and 7.83*** respectively. The P-value is thus in all cases < 0.1 per cent. The correlation differences between the coefficients $r_{89 \cdot 3}$ are still greater and more significant at constant cone weight. The correlation within trees between the number of seeds > 1 mm. per cone and the weight of seeds > 1 mm. per cone at constant cone weight increases likewise in relation to the corresponding partial correlations in Stjernarp and Härryda with northern latitude, but appear also at the same time to have a weak tendency to decrease with the height of the tree locality above sea level.

From Table 17 may be seen the nature and the degree of the correlation for individual trees with respect to some cone and seed properties in the five populations taken separately. Some series of regression coefficients between different pairs of variates are presented by trees and by populations in the Appendix-Tables XII—XVI.

The within-tree correlation between the variables X_7 and X_9 is, as may be seen from Table 17, extremely marked. Moderate to marked is e.g. the correlation between X_3 (cone weight) and X_7 (weight of the total number of seeds per cone) and between X_3 and X_9 (weight of the number of seeds > 1 mm. per cone). The correlations between the variates X_2 and X_4 are, for instance, weak to moderate. A certain percentage (which may be seen from Table 17) of the trees in Gunnarskog and Höljes shows even negative values with regard to four of the six correlations investigated. As regards the sample coefficients of correlation corresponding to r_{23}, r_{34}, r_{24}, r_{37}, and r_{39} in Table 17, it has been found desirable to test for each pair of variates whether it can be assumed that the five sets of 50 correlations can be conceived of as five simple random samples from one and the same population of correlation coefficients. To test this hypothesis the correlation coefficients have first been transformed into z-values, whereupon an analysis of variance has been made of the z's. The degrees of freedom for the populations mean squares are in this case 4 and for the error mean squares (for individual trees within populations) 245. All the five F-values (corresponding to the five combinations of two variates) were found to be highly significant with P far below 0.1 %. Thus, the hypothesis cannot be accepted. The observed mean square of z-values between trees within localities is significantly higher ($P < 0.1$ %) than its expectation under the assumption that the cones from the 50 trees in the same locality are samples from 50 populations having the same correlation between the investigated characters. Thus, the conclusion is reached that there exist differences between trees as regards the strength, and in certain cases also the sign of association between the investigated variables (cf. Table 17).

An analysis of covariance, in accordance with the Table 18, for the 7 pairs of variates in the population samples from Stjernarp, Härryda and Gunnarskog (cf. Table 19) *shows, that* for every investigated pair of variates and each population *the slopes of the individual tree regression lines are significantly*

Table 17. Frequency table showing the distribution of correlations between cones in 1948 computed for 50 individual trees from each population (25 cones from each tree).

Population	Between the variables	No. trees with a correlation coefficient ranking within the following limits of classes														
		−0.49 — −0.40	−0.39 — −0.30	−0.29 — −0.20	−0.19 — −0.10	−0.09 — −0.00	0.00 — 0.09	0.10 — 0.19	0.20 — 0.29	0.30 — 0.39	0.40 — 0.49	0.50 — 0.59	0.60 — 0.69	0.70 — 0.79	0.80 — 0.89	0.90 — 1.00
Stjernarp	X_2 and X_3											1	2	8	26	13
	X_2 and X_4							1	2	5	6	9	13	10	4	
	X_3 and X_4							2	2	3	6	11	7	11	8	
	X_3 and X_7										1	6	9	9	14	11
	X_3 and X_9									1	2	6	7	8	16	10
Härryda	X_2 and X_3											2	3	2	22	21
	X_2 and X_4						2	1	3	2	6	9	16	6	4	1
	X_3 and X_4							1	4	2	3	9	10	10	11	
	X_3 and X_7							1		2	1	4	6	7	24	5
	X_3 and X_9							1		3		5	5	9	22	4
Gunnarskog	X_2 and X_3									1		2	1	8	26	12
	X_2 and X_4	2	2	5	1	5	4	6	9	3	4	3	4	2		
	X_3 and X_4	1		2	1	5	3	5	6	10	5	3	4	3	2	
	X_3 and X_7				1	3	1	5	1	3	11	7	8	5	5	
	X_3 and X_9				1	3	1	4	1	4	12	6	11	2	5	
Höljes	X_2 and X_3												10	8	23	9
	X_2 and X_4			1	1		2	1	4	5	7	6	11	8	4	
	X_3 and X_4			1	1	1	2		2	2	6	11	8	11	4	1
	X_3 and X_7				1			1		1	3	7	5	12	15	5
	X_3 and X_9				1		1	1		2	2	7	5	11	16	4
Skalstugan	X_2 and X_3										1	2	4	10	23	10
	X_2 and X_4			1				2	2	6	7	5	11	11	5	
	X_3 and X_4				1		2	1	4	3	8	6	8	13	3	1
	X_3 and X_7							1	3	2	2	5	8	11	14	4
	X_3 and X_9								3	3	1	5	9	12	12	5
Stjernarp	X_7 and X_9															0.95—1.00: 50
Härryda	X_7 and X_9															0.95—1.00: 50
Gunnarskog	X_7 and X_9															0.95—1.00: 50
Höljes	X_7 and X_9															0.95—1.00: 50
Skalstugan	X_7 and X_9															0.95—1.00: 50

X_2 = cone length
X_3 = cone weight
X_4 = total number of seeds per cone
X_7 = the weight of all seeds per cone
X_9 = the weight of seeds > 1 mm. per cone

Table 18. Regression of number of seeds/cone (X_4) on cone length (X_2) at Stjernarp in 1948.
(Calculated on the basis of individual cone values)

Row number	Variation due to	D.F.	Sum of Squares	Mean Square
			X_4 on X_2	
	Deviations from			
1	individual regressions	1150	582637	506.64
2	parallel regressions	1199	621917	518.70
3	total regression	1248	1375945	1102.52
	Differences in			
4	slope (2)—(1)	49	39280	801.63
5	level (3)—(2)	49	754028	15388.33

$$F_1 = \frac{(4)}{(1)} = 1.58^{*} \qquad F_2 = \frac{(5)}{(2)} = 29.67^{***}$$

different. The values of F obtained fail in three cases only to reach the 0.1 per cent level of significance. In one single case the estimated significance of the differences in slope is rather low (1 % < P < 5 %). These analyses also demonstrate *that there are very significant differences in elevation between the total regression line and the parallel regression lines for each population and any set of paired observations.*

Table 19. Estimated F-values for differences in regression between trees within three population samples for 1948.

(Calculated on the basis of individual cone values)

Regression of	Slopes			Levels		
	Stjernarp	Härryda	Gunnarskog	Stjernarp	Härryda	Gunnarskog
X_3 on X_2	3.43***	3.91***	3.65***	53.31***	127.56***	74.48***
X_4 on X_3	2.89***	2.38***	2.26***	35.65***	44.72***	30.04***
X_4 on X_2	1.58*	2.06**	2.75***	29.67***	41.21***	36.48***
X_7 on X_3	3.44***	4.35***	2.74***	63.74***	58.82***	28.49***
X_8 on X_3	2.09**	2.74***	2.37***	64.22***	65.97***	33.33***
X_8 on X_4	9.02***	13.02***	6.78***	118.63***	346.20***	201.23***
X_9 on X_7	2.93***	6.34***	4.95***	65.51***	317.33***	115.69***

Many of the trees, which grow side by side under apparently the same environment conditions, differ more strikingly from one another as regards correlations and regressions, than such trees that grow under more differing milieu conditions within one and the same sample area. Differences in the genotypical constitution of the trees, therefore, very likely have a different effect upon the seed and cone properties taken separately (cf. also SIMAK and GUSTAFSSON, 1954), as is also the case with correlations and regressions between the cone and seed properties both *between* and *within* trees. On the other hand, the genotype of a tree with a large number of seeds per cone (as in *Picea abies*) should not very much affect, during one and the same seed setting year, the *variation of cone values for both cone and seed properties within a tree.* This *variation* (with the exception of 1) occurrence of somatic mutations, and 2) interactions between genotype and environment, which may change within the crown of a tree) is highly milieu-conditioned. Even inter-cone correlations and regressions *within* trees are more or less influenced by environment. Climatic and pollination conditions as well as fungus and insect damage to cones, and other factors, may also, for various reasons, vary within the crown of a tree.

On the basis of the sums of the products and the sums of squares of the deviations from the means, for single trees, average within-tree regressions are calculated in Table 20 for each population and each investigated pair of variates. The differences between the five populations as regards the slope of the regression lines have been simultaneously tested through an analysis of variance of the 250 regression coefficients within individual trees. The test was intended to show whether the regression coefficients within each combination of variates could be considered to constitute a sample taken at random from one and the same collective. If this had been the case the regression coefficients for the individual populations would not have differed more than would have been brought about by coincidence. The differences between the populations, with regard to the average regression coefficients, however, appeared to be significant. P was in four cases less than 0.1 %, in one case 1 % (for the differences between the five coefficients of regression of X_9 on X_7, for explanations see the text below Table 20), and in one case 5 % (for the differences between the five coefficients of regression of X_8 on X_4).

Table 20 shows the average linear regressions, within population samples between, 1) cone weight (X_3) and cone length (X_2), 2) the total number of seeds per cone (X_4) and cone length (X_2), 3) X_4 and X_3, 4) the weight of all seeds per cone (X_7) and cone weight, 5) the number of seeds $>$ 1 mm. per cone (X_8) and cone weight, 6) X_8 and X_4 and 7) the weight of seeds $>$ 1 mm. per cone (X_9) and X_7. All the regression coefficients are highly significant. The same table shows that the cone weight of Norway spruce changes at Stjernarp with approximately 0.449 grams, and at Skalstugan with approximately 0.223 grams for every millimetre difference in the length of cone. The covariation in cone weight and cone length has, consequently, a tendency to decrease in the two Norway spruce stands which are situated farthest north and at the highest altitudes. The regression of X_3 on X_2 is not absolutely strictly rectilinear but this tendency to "non-linearity" is not significant. The straight

Table 20. Average regressions for different sets of pair of variates and for each locality in the year 1948.

(Calculated on sums of squares and products of cones within trees)

Population	Regression equation	Regression equation
Stjernarp	$X_3 = -22.80 + 0.449\ X_2$	$X_8 = 131.41 + 3.371\ X_3$
Härryda	$X_3 = -20.95 + 0.442\ X_2$	$X_8 = 95.80 + 4.239\ X_3$
Gunnarskog	$X_3 = -16.34 + 0.415\ X_2$	$X_8 = 79.33 + 2.615\ X_3$
Höljes	$X_3 = -10.34 + 0.322\ X_2$	$X_8 = 50.25 + 4.787\ X_3$
Skalstugan	$X_3 = -4.97 + 0.223\ X_2$	$X_8 = 16.10 + 8.625\ X_3$
Stjernarp	$X_4 = 29.30 + 1.922\ X_2$	$X_8 = 13.33 + 0.861\ X_4$
Härryda	$X_4 = -3.53 + 2.131\ X_2$	$X_8 = -4.30 + 0.939\ X_4$
Gunnarskog	$X_4 = 95.83 + 0.734\ X_2$	$X_8 = -6.17 + 0.935\ X_4$
Höljes	$X_4 = 4.79 + 1.836\ X_2$	$X_8 = -9.98 + 0.885\ X_4$
Skalstugan	$X_4 = -47.93 + 2.541\ X_2$	$X_8 = -0.32 + 0.847\ X_4$
Stjernarp	$X_4 = 144.50 + 3.653\ X_3$	$X_9 = -22.64 + 0.998\ X_7$
Härryda	$X_4 = 109.33 + 4.423\ X_3$	$X_9 = -15.96 + 0.993\ X_7$
Gunnarskog	$X_4 = 95.84 + 2.661\ X_3$	$X_9 = -14.87 + 0.990\ X_7$
Höljes	$X_4 = 78.13 + 4.727\ X_3$	$X_9 = 73.16 + 0.804\ X_7$
Skalstugan	$X_4 = 23.26 + 9.743\ X_3$	$X_9 = -5.55 + 0.973\ X_7$
Stjernarp	$X_7 = 161.72 + 36.218\ X_3$	
Härryda	$X_7 = 39.29 + 37.276\ X_3$	
Gunnarskog	$X_7 = 12.02 + 24.737\ X_3$	
Höljes	$X_7 = -9.39 + 35.209\ X_3$	
Skalstugan	$X_7 = -102.11 + 38.763\ X_3$	

N.B. In the table the following variables and units of length and weight have been used:
X_2 = cone length in millimetre
X_3 = cone weight in gram
X_4 = the total number of seeds per cone
X_7 = the weight in milligram of all seeds per cone
X_8 = the number of seeds $>$ 1 mm. per cone
X_9 = the weight in milligram of seeds $>$ 1 mm. per cone

line therefore fits satisfactorily over at least the observed range (cf. Fig. 18). In cases with weak curvilinear regressions, a square root transformation, $y = a + b\sqrt{x}$, a logarithmic transformation, $y = a + b\ logx$, or a second degree polynomial, $y = a + bx + cx^2$, give a better fit especially to higher values of the variates than the linear regression.

If we test the significance of the difference between the average regression coefficients (b_{32}) for localities in Table 20, based on their respective standard errors between trees, we find that the values of t, obtained by such a test, correspond to a significance at the 0.1 % level for the difference between regression coefficients in all comparisons between localities except those within the group Stjernarp, Härryda and Gunnarskog, where no significant differences are found between the coefficients b_{32}.

Positive average regressions exist between number of seeds per cone and cone length. The within-tree regressions are in this case very specific for each population without any indication of a geographic trend.

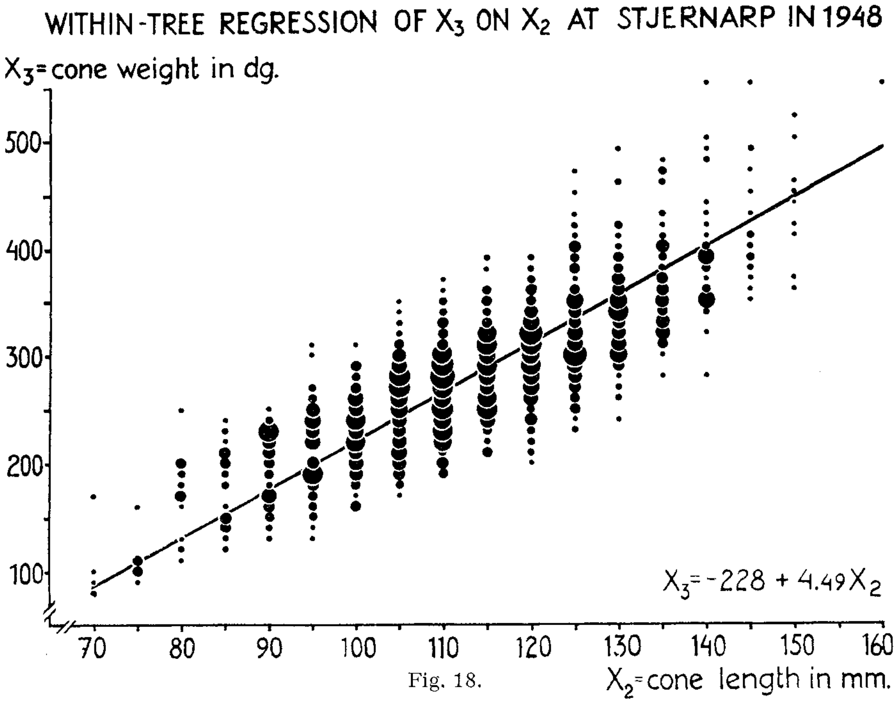


Fig. 18.

The coefficient b_{43} (regression of total number of seeds on cone weight) is much higher for Skalstugan than the other populations. The difference is highly significant. Similarly, the coefficient b_{73} (regression of weight of all seeds on cone weight) is noticeably lower in Gunnarskog than in the other four localities ($P < 0.1$ %). As we have seen, the regressions of X_8 on X_4 and of X_9 on X_7, differ significantly among the five seed sources studied at the 5 %, respectively 1 % level. It is in both cases the two most northerly stands at the highest altitudes (Höljes and Skalstugan) which cause these deviations. There are, however, in these two cases, no statistically significant differences in the regression coefficients between the populations at Stjernarp, Härryda and Gunnarskog.

5.1.5. Some partial inter-tree and within-tree correlations

In order to study the actual relations between two variables, when one or two additional factors are held constant, some partial correlations of the first and second order are calculated in the Tables 21 and 22. The partial correlation coefficients, presented in Table 21 are based on mean cone values for individual trees and the coefficients in Table 22 on cone values within trees.

5.1.5.1. Partial inter-tree correlations

A brief inspection of Table 21 shows that between trees in this material we have: 1) in most cases a strongly reduced partial correlation in comparison with a similar total correlation (which shows that many of the total correlations are to no inconsiderable degree only apparent), 2) a slight, reasonably constant and insignificant partial correlation between the 1,000-grain weight of all seeds per cone (X_1) and the cone length (X_2) in the five populations when the cone weight (X_3) is held constant, 3) a varying, consequent positive and significant partial correlation between the variables X_1 and X_2 when the total number of seeds per cone (X_4) remains constant, 4) a varying, positive and, in two cases out of five, significant correlation between the variables X_1 and X_3 when X_2 is held constant, 5) a moderate reasonably constant positive and significant correlation between X_1 and X_3 when X_4 is held constant, 6) an insignificant correlation between X_1 and X_4 where the cone length is held constant, 7) an insignificant correlation, in four cases out of five, between X_1 and X_4 with the same cone weight (the significant coefficient at Skalstugan, like the other four partial coefficients, also has a negative sign), 8) with the exception of Gunnarskog, positive, moderate in strength and, in four cases out of five, significant correlation between X_2 and X_4 when the 1,000-grain weight is constant, 9) considered on the average weak, falling from the south to the north and, in two cases out of five, significant correlation at the 5 % level between X_2 and X_4 with constant cone weight (of the two significant correlations the one in Gunnarskog is negative), 10) a relatively constant moderate, positive and significant correlation between X_3 and X_4 when the 1,000-grain weight is held constant, 11) a from south to north, from insignificant to moderate, increasing, positive and, in three cases out of five, significant correlation between X_3 and X_4 when cone length is constant, 12) a varying in strength, positive and significant correlation between cone length (X_2) and the weight of all seeds per cone (X_7) when the number of seeds per cone (X_4) remains constant, 13) a moderate strength, fairly constant and significant correlation between X_3 and X_7 when X_4 is held constant, 14) varying between populations, positive, significant and on the average a strong correlation between X_4 and X_7 when the cone length is the same (X_2), and 15) a positive, significant, fairly constant and on the average strong correlation between X_4 and X_7 when X_3 is constant.

The value of X_1 (the average 1,000-grain weight of all seeds per cone) in Table 21 is for individual trees calculated by:

$$X_1 = \frac{X_7 \cdot 100}{X_4}.$$

The numerator X_7 (cf. Table 15, 16 and 22) denotes the average weight of all seeds per cone and the denominator X_4 the average number of all seeds per cone.

It should be observed that the correlations between X_1 and X_4 (total as well as partial) as mentioned earlier must be judged with caution, as a possibility of a negative "spurious correlation" is inherent in the way the values of X_1 and X_4 are computed.

Many of the correlation coefficients of the second order are further reduced in relation to the coefficients of the first order. The coefficients $r_{12.34}$ and $r_{14.23}$ are not significant. A tendency to negative correlation throughout the populations, significant at Skalstugan, exists between 1,000-grain weight and the number of seeds per cone when cone weight and cone length are kept constant. The inter-tree correlations between 1,000-grain weight (X_1) and cone weight (X_3) with the same cone length and number of seeds per cone are positive, as can be seen, but on the other hand they are not significant within two populations out of five. The coefficients $r_{24.13}$, do not reach the 5 % level of significance in three cases out of five. Two of these last named insignificant coefficients have negative signs, in contrast to the equivalent total correlation coefficients, r_{24}, in Table 9. The covariation between cone length and the weight of all seeds per cone, when cone weight and number of seeds per cone are kept constant, is noticeably strong and significant at Gunnarskog, and weak and not significant within the other stands. Regarding the correlation between cone weight and seed weight per cone, when X_2 and X_4 are held constant, the population at Härryda differs from the other stands. The positive coefficients $r_{34.12}$ are significant and moderate in strength at Gunnarskog, Höljes and Skalstugan. A tendency to a trend can be traced in the material with reference to the set of the coefficients $r_{34.12}$ (between cone weight and total number of seeds per cone when 1,000-grain weight and cone length are constant), and the situation of the populations. The numerical value of the correlation for this variate pair with the same 1,000-grain weight and cone length, increases within the more northerly situated populations in relation to the equivalent coefficients in the stands at Stjernarp and Härryda. The difference between the correlation coefficient ($r_{34.12}$) at Stjernarp and at Skalstugan is 0.57 z-units, and the t-value for the difference is given by

$$t = \frac{0.57}{\sqrt{\frac{1}{50-5} + \frac{1}{50-5}}} = \frac{0.57\sqrt{45}}{\sqrt{2}} = 2.70^{**}.$$

Table 21. Partial inter-tree correlations for populations in the year 1948.

$r_{xy \cdot z}$ \ Population	Stjernarp	Härryda	Gunnarskog	Höljes	Skalstugan
$r_{12.3}$	0.193°	−0.239°	0.216°	0.194°	0.208°
$r_{12.4}$	0.547	0.331	0.442	0.495	0.645
$r_{13.2}$	0.213°	0.559	0.426	0.201°	0.218°
$r_{13.4}$	0.533	0.613	0.547	0.500	0.697
$r_{23.1}$	0.759	0.763	0.347	0.763	0.797
$r_{23.4}$	0.741	0.732	0.602	0.803	0.847
$r_{23.7}$	0.652	0.686	0.315	0.736	0.736
$r_{14.2}$	−0.206°	−0.030°	0.199°	0.062°	−0.187°
$r_{14.3}$	−0.118°	−0.199°	−0.159°	−0.086°	−0.384
$r_{24.1}$	0.656	0.411	−0.127°	0.337	0.496
$r_{24.3}$	0.411	0.141°	−0.393	−0.198°	−0.205°
$r_{24.7}$	0.281	0.098°	−0.692	−0.155°	−0.221°
$r_{34.1}$	0.543	0.465	0.503	0.570	0.697
$r_{34.2}$	0.045°	0.196°	0.606	0.516	0.511
$r_{34.7}$	0.142°	−0.095°	−0.155°	0.004°	−0.063°
$r_{27.3}$	0.409	−0.059°	0.128°	−0.054°	−0.016°
$r_{27.4}$	0.533	0.340	0.815	0.465	0.621
$r_{37.4}$	0.519	0.604	0.555	0.491	0.658
$r_{47.2}$	0.430	0.627	0.933	0.808	0.762
$r_{47.3}$	0.527	0.618	0.765	0.732	0.656

Partial inter-tree correlation of the first order

Value of r different from zero at the P % level of significance

D.F.	$P = 5$ %	$P = 1$ %
47	0.282	0.365

$r_{xy \cdot zu}$ \ Population	Stjernarp	Härryda	Gunnarskog	Höljes	Skalstugan
$r_{12.34}$	0.268°	−0.219°	0.169°	0.181°	0.143°
$r_{13.24}$	0.227°	0.577	0.392	0.198°	0.371
$r_{23.14}$	0.634	0.651	0.480	0.738	0.725
$r_{14.23}$	−0.221°	−0.172°	−0.082°	−0.049°	−0.357
$r_{24.13}$	0.445	0.098°	−0.372	−0.185°	−0.138°
$r_{34.12}$	0.093°	0.257°	0.588	0.514	0.576
$r_{27.34}$	0.259°	−0.188°	0.724	0.136°	0.159°
$r_{37.24}$	0.218°	0.554	0.139°	0.223°	0.317
$r_{47.23}$	0.431	0.634	0.894	0.737	0.667

Partial inter-tree correlation of the second order

Value of r different from zero at the P % level of significance

D.F.	$P = 5$ %	$P = 1$ %
46	0.285	0.368

° Note that the value of r does not reach the 5 % level of significance.

This value of t somewhat exceeds the 1 % level of significance. The t-value for the corresponding partial correlation difference between the population at Härryda and the one at Gunnarskog is just below the 5 % level.

If we further test the significance of the inter-tree difference between partial correlations of the second order we find, for example, that the difference between the coefficient $r_{13.24}$ at Härryda and Höljes and between the coefficient $r_{23.14}$ at Gunnarskog and Höljes exceeds the 5 % level of significance. The difference between the coefficient $r_{24.13}$ at Stjernarp and at Gunnarskog, between the coefficient $r_{27.34}$ at Gunnarskog and Härryda and at Gunnarskog and Höljes, and between the two coefficients $r_{47.23}$ at Gunnarskog and Stjernarp, exceeds the 0.1 % level of significance, and the same is true for the difference between for example: the pair of partial coefficients of the first order, $r_{24.3}$, at Stjernarp and Gunnarskog, $r_{23.1}$, at Gunnarskog and Skalstugan, and $r_{24.1}$ at Stjernarp and Gunnarskog. The t-value for the difference between the average inter-tree coefficients, $r_{13.2}$, at Härryda and Höljes is

$$= 0.43 \sqrt{23} = 2.06^{*}.$$

The obtained t-value corresponds to a significance at the 5 % level. *Thus, these five populations show,* with regard to partial correlations for cone and seed properties, *in co-operation with their environments a number of significant different inter-tree associations for comparable pairs of variates.*

5.1.5.2. Partial within-tree correlations

The partial correlations in Table 22, with the exception of five coefficients in the population at Gunnarskog, all show reduced associations in relation to the total correlation coefficients in Table 16. These exceptions are composed of four partial coefficients of the first order: $r_{23.4}$, $r_{27.4}$, $r_{47.2}$, $r_{47.3}$, and of one coefficient $r_{47.23}$, of the second order. The correlations of the first order, $r_{23.4}$, between cone length (X_2) and cone weight (X_3) when the number of seeds per cone (X_4) is equal, are still strong, positive and highly significant. The coefficients, $r_{23.7}$, when the seed weight per cone (X_7) is equal, are more strongly reduced in comparison with the total correlation coefficients, r_{23}, but are still moderate in strength, positive and all highly significant. The correlations between cone length and the number of seeds per cone with the same cone weight ($r_{24.3}$) and between cone length and number of seeds per cone with equal seed weight per cone ($r_{24.7}$) are on the other hand, for the individual populations, greatly reduced in strength. For two of the populations the coefficients $r_{24.3}$ are weak and significantly negative. Within four of five populations there exists a weak, negative and significant within-tree correlation between cone length and the number of seeds per cone when seed weight per cone is constant. The correlation between cone weight and the number of seeds per cone when cone length ($r_{34.2}$) is equal, is also weak but positive and significant throughout for the five populations examined for 1948. When seed weight per cone is equal, the within-tree correlation between cone weight and number of seeds per cone ($r_{34.7}$) is insignificant in the stand at Stjernarp and significantly negative within the four indigenous spruce stands. The correlations between cone length and seed weight per cone when cone weight ($r_{27.3}$) is equal, as can also be seen in Table 22, are weak, significant and positive, with the exception of the sample plot at Gunnarskog. The correlations $r_{27.4}$, $r_{37.2}$ and $r_{37.4}$ with a few exceptions are moderate in strength, positive and highly significant. The correlations between the number of seeds and the weight of seeds per cone when cone length, $r_{47.2}$, is equal, and between the number of seeds and seed weight, when cone weight $r_{47.3}$, is constant, are all positive, moderate in strength at Stjernarp and strong within the rest of the populations.

The partial correlation of the second order *within trees* between cone length and cone weight, with the same number of seeds and seed weight per cone, is moderate in strength, positive and constant within four of the five populations. This within-tree correlation is strongest within the population at Gunnarskog (as opposed to an equivalent inter-tree correlation). The difference between the within-tree correlation coefficient of second order at Gunnarskog and any corresponding coefficient for each and every one of the other four stands exceeds the 0.1 % level of significance. The t-value for this partial correlation difference between Gunnarskog and Höljes is, for instance:

$$= \frac{1.06 - 0.73}{\sqrt{\dfrac{2}{50(25-1)-4}}} = 0.33\sqrt{598} = 8.07^{***}.$$

This means that the positive relation between cone length and cone weight, with the same number of seeds and the same seed weight per cone, is stronger *within trees* at Gunnarskog than *within trees* amongst the four remaining stands examined in 1948. Thus, different localities and populations show in this material different within-tree correlations between cone properties.

The partial correlations within trees of the second order, $r_{24.37}$, between cone length and the number of seeds per cone, with the same cone weight and seed weight per cone, are all significant, strongly reduced in strength in comparison with the total correlations in Table 16, and in three cases out of five, negative. Only the two correlation differences between Stjernarp and Höljes, and between Härryda and Skalstugan, are not significant. The correlations, $r_{34.27}$, between cone weight and the number of seeds per cone, with equal cone length and seed weight per cone, are insignificant in one case and posi-

Table 22. Partial within-tree correlations for populations in the year 1948.

$r_{xy \cdot z}$ \ Population	Stjernarp	Härryda	Gunnarskog	Höljes	Skalstugan
$r_{23.4}$	0.769	0.782	0.837	0.713	0.769
$r_{23.7}$	0.652	0.650	0.810	0.622	0.647
$r_{24.3}$	0.194	0.060	−0.152	0.168	−0.113
$r_{24.7}$	0.099	−0.312	−0.358	−0.048°	−0.413
$r_{34.2}$	0.214	0.318	0.281	0.247	0.465
$r_{34.7}$	0.044°	−0.079	−0.327	−0.172	−0.217
$r_{27.3}$	0.218	0.378	−0.081	0.156	0.115
$r_{27.4}$	0.551	0.692	0.476	0.444	0.647
$r_{37.2}$	0.429	0.275	0.350	0.458	0.495
$r_{37.4}$	0.627	0.559	0.507	0.587	0.596
$r_{47.2}$	0.547	0.788	0.887	0.766	0.880
$r_{47.3}$	0.536	0.733	0.887	0.764	0.821

Partial correlation of the first order

Value of r different from zero at the P % level of significance

D.F.	$P = 5$ %	$P = 1$ %
1198	0.057	0.074

$r_{xy \cdot zu}$ \ Population	Stjernarp	Härryda	Gunnarskog	Höljes	Skalstugan
$r_{23.47}$	0.651	0.660	0.785	0.624	0.627
$r_{24.37}$	0.093	−0.344	−0.168	0.133	−0.366
$r_{34.27}$	−0.027°	0.270	−0.068	−0.182	0.072
$r_{27.34}$	0.138	0.493	0.109	0.045°	0.368
$r_{37.24}$	0.381	0.040°	0.226	0.430	0.202
$r_{47.23}$	0.516	0.769	0.878	0.758	0.845

Partial correlation of the second order

Value of r different from zero at the P % level of significance

D.F.	$P = 5$ %	$P = 1$ %
1197	0.057	0.074

° Note that the value of r does not reach the 5 % level of significance.

tive in two cases out of five. The three correlation differences between Stjernarp and Gunnarskog, Stjernarp and Skalstugan and between Gunnarskog and Skalstugan, are not significant. The correlation, $r_{27.34}$, between cone length and seed weight per cone when the cone weight and the number of seeds per cone are held constant, is positive throughout, significant in four cases out of five, weak in strength at Stjernarp, Gunnarskog and Höljes, and moderate at Härryda and Skalstugan. The correlation difference between this pair of coefficients is not significant for the comparison between Stjernarp and Gunnarskog. The correlation between cone weight and seed weight per cone, $r_{37.24}$, is similarly strongly reduced after the influence of the cone length and the number of seeds per cone is eliminated. It is positive throughout, and significant in four cases out of five. Two of the differences between the coefficient, $r_{37.24}$, are not significant, namely, between the coefficient for the stand in Stjernarp and that in Höljes, and between the coefficient in Gunnarskog and that at Skalstugan. Highly significant differences exist, for example, between the stand at Stjernarp and the stand at Härryda, and between Stjernarp and Skalstugan in regard to the correlation $r_{47.23}$. Thus, a number of significant differences between average correlations of the second order, between comparable pairs of variates for cone and seed properties, are present *within trees* for populations and areas. This is also true for many of the correlation differences of the first order in this material. The partial correlations vary from significant positive to significant negative values.

5.1.5.3. Differences in partial inter-tree and within-tree correlations in 1948

A test of the significance of the differences between comparable partial inter-tree correlations (Table 21) and within-tree correlations (Table 22) shows that a number of significant differences exist between the two correlation groups. For instance, there exists a significant difference, for the correlations of the second order (as well as for the total correlations) within the stand at Gunnarskog, between the inter-tree correlation and the within-tree correlation, in regard to cone length and cone weight, when seed weight and the number of seeds per cone are constant. The t-value for this $r_{23.47}$-difference is given by

$$t = \frac{1.06 - 0.30}{\sqrt{\frac{1}{50(25-1)-4} + \frac{1}{50-5}}} = 0.76 \times 6.585 = 5.00^{***}.$$

The partial correlation *within trees* for these cone properties in Gunnarskog' is therefore stronger than *between trees*. No significant differences between the *inter-tree* and *within-tree* correlations could be shown, however, within the four other stands in regard to the examined cone properties.

Also, other sets of *inter-tree* and *within-tree correlation coefficients* show some significant differences within populations during one and the same year. Thus, there are significant differences between the two coefficients $r_{37.24}$ at Härryda ($t = 3.82^{***}$), $r_{27.34}$ at Härryda ($t = 4.81^{***}$) and, at Gunnarskog ($t = 5.33^{***}$) and between the coefficients $r_{47.23}$ at Skalstugan ($t = 2.90^{**}$). There exist also similar cases of significant differences between certain pairs of coefficients of the first order within some comparable sets of correlations within populations.

The examples of significant differences cited, despite the fact that the number is not large, show that the average mutual variation between cone qualities ($r_{23.47}$), between cone and seed qualities ($r_{27.34}$ and $r_{37.24}$) and between the seed qualities themselves ($r_{47.23}$) can within certain populations amount to significantly different values *within trees* and *between trees.*

5.2. The 1954 material

5.2.1. Cone and seed characteristics 1954 in relation to corresponding characteristics 1948

The investigations are carried out on material from the sample plots at Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala (cf. Fig. 1). Mean values of cone and seed characteristics are presented for each individual tree in the Appendix Tables VI—XI. The averages for individual populations are brought together in Table 23. At the same time, in order to facilitate comparisons between comparable stands in 1948 and 1954's material, a list of corresponding mean cone values for the sample plots examined in 1948 is given in Table 24. An analysis of variance relating to differences between population means, indicates (as in the material for 1948) for all studied properties highly significant differences among geographic areas ($P < 0.1$ %). The comparison between the two years is complicated by the fact that some but not all trees are common to both years. Thus, although 50 trees were observed in each plot in 1948 and in 1954, only two trees at Gunnarskog were observed on both occasions; 41 and 30 trees, respectively, were common to 1948 and 1954 at Stjernarp and Skalstugan. To avoid computational difficulties resulting from this mixed structure of the data, a simplified statistical technique was used. In comparing the 1948 and 1954 means of 50 trees the t-test for two independent samples was applied. This should be a conservative procedure in the sense that the significance of the difference is underestimated. This test was applied to the data from Stjernarp and Skalstugan. As a check, the mean difference between the 1954 and 1948 values for trees observed in both years was tested by the one-sample t-test. A comparison of the population mean cone values of the two years (cf. Tables 23 and 24) shows that the average length of cones for the 50 trees at Stjernarp and Gunnarskog is lower in 1954 than in 1948. If we test the significances of these two differences between years by the two-sample t-test, we find that P is in both cases < 0.1 %. This significance between years can to a certain degree be influenced by the variation in the number of cones per tree (whole tree crown) and by the composition of

Table 23. Mean cone values for populations in the year 1954.

(Unweighted average of mean cone values for trees)

Population / Cone and seed properties	Stjernarp (Latitude 56° 38′ Altitude 35 m.)	Gunnarskog (Latitude 59° 51′ Altitude 140 m.)	Skalstugan (Latitude 63° 34′ Altitude 585 m.)	Kvikkjokk (Latitude 66° 58′ Altitude 400-550 m.)	Gällivare (Latitude 67° 07′ Altitude 370-470 m.)	Pajala (Latitude 67° 09′ Altitude 140 m.)
X_1 = thousand-grain weight in gram of all seeds per cone	3.72 ± 0.14	4.12 ± 0.12	2.84 ± 0.08	2.56 ± 0.09	2.68 ± 0.09	2.59 ± 0.09
X_2 = cone length in cm.	10.23 ± 0.17	9.55 ± 0.14	7.57 ± 0.12	6.93 ± 0.09	6.66 ± 0.10	6.77 ± 0.10
X_3 = cone weight in gram	15.13 ± 0.61	13.83 ± 0.43	8.79 ± 0.29	6.08 ± 0.21	5.45 ± 0.18	6.37 ± 0.22
X_4 = the total number of seeds per cone	276.88 ± 3.61	260.46 ± 4.65	191.64 ± 3.84	165.18 ± 3.31	150.55 ± 3.63	172.01 ± 3.30
X_7 = the weight in gram of the total number of seeds per cone	1.03 ± 0.04	1.07 ± 0.04	0.55 ± 0.02	0.42 ± 0.02	0.40 ± 0.02	0.45 ± 0.02
X_8 = the number of seeds > 1 mm. per cone	226.79 ± 4.99	242.57 ± 4.23	171.02 ± 4.77	135.54 ± 3.79	115.81 ± 4.19	147.72 ± 3.88
X_9 = the weight in gram of seeds > 1 mm. per cone	0.98 ± 0.04	1.06 ± 0.04	0.54 ± 0.02	0.40 ± 0.02	0.37 ± 0.02	0.43 ± 0.02
Number of all seeds per cm. cone length	27.07 ± 0.43	27.27 ± 0.44	25.32 ± 0.42	23.85 ± 0.52	22.61 ± 0.45	25.41 ± 0.53
Number of all seeds per gram cone weight	18.30 ± 0.82	18.83 ± 0.59	21.81 ± 0.62	27.18 ± 0.92	27.62 ± 0.80	26.99 ± 0.10

trees in the plot. In the sample plot at Gunnarskog the average number of cones per tree was about 166 in 1954 compared with roughly 79 cones in 1948, i.e. approximately 110 % higher than 1948. It was, however, impossible in both cases to make an exact calculation of the number of cones per tree, because of the highly variable number of cones that had been pulled down from the trees (mainly by crossbills and squirrels). Simultaneously, the pollen production in 1954 was unprecedently high. In 1954 the Stjernarp stand produced longer cones than the stand at Gunnarskog ($P < 1$ %). In 1948 the proportions were the reverse, although the difference is not found to

Table 24. Mean cone values for populations in the year 1948.

(Unweighted average of mean cone values for trees)

Cone and seed properties \ Population	Stjernarp (Latitude 56° 38′ Altitude 35 m.)	Härryda (Latitude 57° 42′ Altitude 100 m.)	Gunnarskog (Latitude 59° 51′ Altitude 140 m.)	Höljes (Latitude 60° 54′ Altitude 660 m.)	Skalstugan (Latitude 63° 34′ Altitude 585 m.)
X_1 = thousand-grain weight in gram of all seeds per cone	4.74±0.13	4.75±0.14	4.43±0.12	3.41±0.09	2.16±0.07
X_2 = cone length in cm.	11.33±0.20	11.48±0.21	11.74±0.18	7.80±0.13	6.18±0.11
X_3 = cone weight in gram	28.06±0.87	29.77±1.23	32.38±1.00	14.78±0.57	8.80±0.31
X_4 = the total number of seeds per cone	247.15±4.70	241.04±5.56	181.99±7.05	148.37±4.79	109.27±4.36
X_7 = the weight in gram of the total number of seeds per cone	1.18±0.05	1.15±0.05	0.81±0.04	0.51±0.02	0.24±0.01
X_8 = the number of seeds > 1 mm. per cone	225.94±5.77	221.64±6.39	168.09±6.91	121.20±4.84	91.69±3.83
X_9 = the weight in gram of seeds > 1 mm. per cone	1.15±0.04	1.12±0.05	0.79±0.04	0.48±0.02	0.23±0.01
Number of all seeds per cm. cone length	21.81±0.43	21.00±0.48	15.50±0.62	19.02±0.56	17.68±0.71
Number of all seeds per gram cone weight	8.81±0.29	8.10±0.34	5.62±0.24	10.04±0.38	12.42±0.40

be significant. However, the cones from the stand at Skalstugan were longer in 1954 than in 1948 ($P < 0.1$ %). In 1954 the cone length as well as the average seed and other cone characteristics, decreased with the northerly position of the sample areas and with the higher altitude. The length of cones in Gällivare in 1954 was consequently only about 65 % of the cone length at Stjernarp, and approximately 70 % of the cone length at Gunnarskog. The mean cone weights in Stjernarp and Gunnarskog show remarkably greater differences between the two years.

The average 1,000-grain weight of all seeds was higher in 1954 at Gunnarskog than at Stjernarp ($P < 5$ %), in contrast to 1948. The difference in average 1,000-grain weight in 1954 between, on the one hand, Stjernarp and Gunnarskog, and on the other hand, the four most northerly situated stands, is statistically significant. In 1954 the average 1,000-grain weight at Stjernarp is significantly lower than in 1948. The P-value for the difference between the two years is less than 0.1 %. On the other hand, the average 1,000-grain weight at Skalstugan is significantly higher in 1954 than in 1948 ($P < 0.1$ %). If the comparison between the two years is made by the t-test applied to values for those trees which were observed on both occasions, we reach the same level of significance between the two years for cone length and 1,000-grain weight.

The differences in the total number of seeds per cone between, on the one hand the two most southern, and on the other hand the four most northern populations in 1954 are high and statistically significant. The same comparison in 1948 between Stjernarp and Gunnarskog on the one hand, and Höljes and Skalstugan on the other, is similarly highly significant. There are considerable differences between the years. The differences between the years 1948 and 1954 in the total number of seeds per cone are significant at the 0.1 % level within the localities Stjernarp, Gunnarskog and Skalstugan. The total number of seeds per cone is greater in 1954 than in 1948 within the three populations, despite the fact that the cone length, and the weight of the cones, was considerably less at Stjernarp and Gunnarskog in 1954. The increase in the total number of seeds per cone in the year 1954, in comparison with the number of seeds in 1948, in round figures amounted to 12 % at Stjernarp, 43 % at Gunnarskog and 76 % at Skalstugan. The number of seeds > 1 mm. per cone in Stjernarp and Skalstugan, on the other hand, is almost constant in the two years.

The significant difference in the number of seeds per cm. cone weight between stands and geographic areas in 1948 is caused mainly by the low averages at Gunnarskog and Skalstugan. Trees 371 and 377 (see Appendix Table III) provide an additional reason, among other things, for the large deviation in Gunnarskog, but even disregarding these trees, the between-tree heterogeneity within this stand was large and significant. Other trees at Gunnarskog, such as numbers 312, 356 and 364, vary in a most striking way in regard to the length of cone.

The calculations show that the between-sample variation is significantly larger than the between-tree variation in the weight of the total number of seeds per cone in 1948, and is significant in 1954 ($P < 0.1$ %). The difference between geographic seed sources may, of course, be highly influenced by conditions of environment, but much of the between-tree variations within population samples cannot be explained only by environment factors. Different trees produce, as shown earlier, different number of seeds per cone, different seed weights and different percentages of empty seeds per cone (see Appendix Tables XVII—XXI and XXIX—XXXIV). It is therefore interesting to note at this point that Johnsson (1961) found, generally, special and close relationships in *Pinus silvestris* between on the one hand, clones, and on the other hand, seed and cone properties such as the number of seeds per cone, 1,000-grain weight, the percentages of empty seeds, total weight of seeds, the number of cones per tree and the mean cone weight per tree. Similar relationships were also found in Scots pine by EHRENBERG, GUSTAFSSON, PLYM FORSHELL and SIMAK (1955), between original trees and grafts in different regions for certain seed characteristics such as seed shape and some seed details. The difference in average weight of the total number of seeds per cone, between the two years, was significant at the 5 % point for the stand at Stjernarp and at the 0.1 % level at Gunnarskog and Skalstugan. A comparison of the average weight of the total number of seeds per cone made by the *t*-test applied to paired data at Stjernarp (i.e. the data of the 41 trees observed both in 1948 and 1954) gives a difference which is significant at the 0.1 % level. The seed weight per cone was higher at Stjernarp in 1948 than in 1954 but at Gunnarskog and Skalstugan it was higher in 1954 than in 1948. The difference between the average weight of seeds > 1 mm. per cone between the years 1948 and 1954 is significant at the 1 % point at Stjernarp and at the 0.1 % level at Gunnarskog and Skalstugan. Just as the thousand-grain weight has diminished, with the exception of Gunnarskog in 1954, so has the total seed weight per cone, as well as the weight of seeds > 1 mm. per cone shown, on the average, a clear tendency to reduce, in regard to the disposition of the populations towards the north. Similarly, the location of the habitat, in relation to sea level, can be seen to have an influence on the seed weight. The difference with regard to the average weight of seeds > 1 mm. per cone in 1954 between Stjernarp (altitude 35 m.) and Gunnarskog (altitude 140 m.), is not significant. The corresponding differences between Gunnarskog and each of the other populations are significant at the 0.1 % level. Skalstugan (altitude 585 m.) also differs in a highly significant manner from other populations. On the other hand, the difference between the weight of seeds > 1 mm. per cone between the three most northerly districts is negligible in 1954. Only the difference between Gällivare and Pajala becomes significant at the 5 % level.

The total number of seeds per gram cone weight was very variable in 1948. The number was lowest in Gunnarskog and highest in Skalstugan. The average difference between Gunnarskog and Stjernarp, and between Gunnarskog and Skalstugan, is highly significant ($P < 0.1$ %). In 1954 the corresponding numbers were lowest for Stjernarp and Gunnarskog and highest for the three most northerly populations and areas. The difference between, on the one hand, Stjernarp and Gunnarskog, and on the other hand Kvikkjokk, Gällivare and Pajala, is highly significant ($P < 0.1$ %). The corresponding difference between Gunnarskog and Skalstugan is also highly significant. The average number of seeds per unit of cone weight was, in all districts, greatest in 1954. In relation to 1948 the increases in the number of seeds per gram cone weight at Stjernarp, Gunnarskog and Skalstugan were approximately 110, 235 and 76 % respectively.

The number of seeds per cone in Norway spruce is dependent, among other things, on the length of the cone, cone-form (see WITTROCK, 1914 and ARNBORG, 1943) and the number of cone-scales per cone (cf. ARNBORG, 1943). A coarse and cylindrical cone from the same stand, with the same cone length and cone-scale size contains, on an average, more seeds than a narrow or a strongly pointed cone. The cone weight covaries with cone-form and cone-scale thickness (JOHNSSON, 1961) without any regard to the number of cones per tree. Characters such as cone-form and cone-scale, for instance, in a collection of clones at Röskär, Bogesund, planted with primarily northern clones of Norway spruce for studying the sources of meiosis and seed properties, have shown themselves to be specific for clones as noted earlier in regard to cone weight and, in a certain degree, cone size on Scots pine (cf. PLYM FORSHELL, C., 1953, SIMAK and GUSTAFSSON, 1954, EHRENBERG et al., 1955, JOHNSSON, 1961, and EKLUNDH EHRENBERG, 1963).

5.2.2. Some relationships of cone and seed properties

Some series of between-tree linear regressions, mostly between cone and seed properties for the year 1954, are presented in Tables 25 and 26, and sampling errors for the same regressions in Table 28. Table 27 shows multiple regressions of 1,000-grain weight on cone length and cone weight, and of 1,000-grain weight on cone length, cone weight and total number of seeds per cone. Tests of significance of slopes and levels of regressions are given in Tables 29 and 30. Average correlations for some sets of pairs of variates *within trees* for localities, and for the whole material, are found in Table 31. Table 32 shows the frequency distribution of within-tree correlations. Partial correlations within trees are presented in Table 33. Between-tree regressions (linear, quadratic and cubic) of germination rate (found in the JACOBSEN germinator) in per mille of all seeds not damaged by insects on thousand-grain weight in centigram of all seeds per cone, are given by populations and for six populations treated as one group in the Appendix Tables XXII A—XXII E. The percentages of seed germination for the total number of seeds (after 30 days in the JACOBSEN apparatus) are gathered in Appendix Tables XXIII—XXVIII. The distribution of the total number of seeds into embryo and endosperm classes, as well as the percentages of empty seeds, and seeds damaged by insects, of total number of seeds in 1948 and 1954, can be seen in Appendix Tables XVII—XXI and XXIX—XXXIV. Some correlations between years for different cone and seed properties are shown in Table 34 and average within-tree regression equations for populations are grouped together in Table 36. Correlation coefficients for individual trees in the years 1948 and 1954 at Skalstugan and Stjernarp are listed in Tables 35 a and 35 b. Between-tree correlations for populations are presented in Tables 37, 42 and 44. Partial inter-tree correlations for individual populations are given in Tables 38 and 43. Mean values in seed quality for populations in 1948 and 1954 are assembled in Tables 40 and 41. A number of multiple regressions are brought together in Table 46 a and b. Further, linear, quadratic and cubic regressions of X_{13} and of X_{12} on other seed characters and on cone properties are found in Appendix Tables XXII A . . . E and XXXV A . . . E. Values of F for deviations of the second and third degree polynomial from linear regressions are given in Table 47 a and b. Some intra-class correlations for seed characters at Gällivare and Kiruna are presented in Tables 48 a—48 d. Some correlations between tree means for a number of seed characters are shown in Table 49 for the years 1954 and 1960, 1954 and 1961 as well as for 1960 and 1961 at Gällivare and Kiruna. The distribution of seeds into embryo and endosperm classes after open pollination and selfing at Åkersberga is shown in Appendix Table XL A. Finally, seed analyses and germination rates after open and self-pollination are found in Appendix Tables XL B and XLI.

In the material for the year 1954 the variates $X_1, \ldots, X_4, X_7, X_{10}, X_{12}, X_{13}, X_{20}$ and X_{21} in the tables giving regression and correlation coefficients, and in regression equations, are defined as follows:

X_1 = thousand-grain weight in centigram of all seeds per cone $= \frac{100X_7}{X_4}$
(gram in Table 23)

X_2 = cone length in tenths of a millimetre
(millimetre in Table 36)

X_3 = cone weight in centigram
(gram in Table 36)

X_4 = total number of seeds per cone (in whole numbers)

X_7 = weight in milligram of all seeds per cone

X_{10} = germination capacity (in the JACOBSEN germinator) in per mille of total number of seeds per cone
(in per cent in the Appendix Tables XXIII—XXVIII)

X_{11} = germination rate (in the JACOBSEN germinator) in per cent of all seeds not damaged by insects
(the per cent data transformed to corresponding angular value by the formula, angle $= \arcsin \sqrt{\text{per cent}/100}$)

X_{12} = empty seeds (not damaged by insects) in per mille of all seeds not damaged by insects (the per mille data transformed to corresponding angular value by the formula, angle $= \arcsin \sqrt{\text{per mille}/1000}$)

X_{13} = germination rate (in the JACOBSEN germinator) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular value by the formula, angle $= \arcsin \sqrt{\text{per mille}/1000}$)

X_{14} = empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects
(the per cent data transformed to corresponding angular value by the formula, angle $= \arcsin \sqrt{\text{per cent}/100}$)

X_{15} = empty seeds (of embryo type 0) not damaged by insects

X_{16} = seeds (not damaged by insects) with embryo unable to germinate, in per cent of all seeds not damaged by insects
(the per cent data transformed to corresponding angular value by the formula, angle $= \arcsin \sqrt{\text{per cent}/100}$)

X_{17} = calculated germination rate in per cent of all seeds not damaged by insects
(the per cent data transformed to corresponding angular value by the formula, angle $= \arcsin \sqrt{\text{per cent}/100}$)

X_{18} = calculated germination rate in per cent of all seeds (not damaged by insects) with embryo
(the per cent data transformed to corresponding angular value by the formula, angle $= \arcsin \sqrt{\text{per cent}/100}$)

X_{19} = age of the sample tree at breast height

X_{20} = empty seeds (not damaged by insects) of all seeds not damaged by insects (not transformed value)

X_{21} = germination rate (in the JACOBSEN germinator) of all seeds not damaged by insects (not transformed value)

X_{22} = height in metres of the sample tree

The notation is the same as the one relating to the 1948 data. However, some additional characters appear.

5.2.2.1. Between-tree regressions of cone length on cone weight

The regressions of cone length (X_2) on cone weight (X_3) in 1954 are presented in Table 25. All the regression coefficients (for this pair of variates) are very highly significant. The regression of cone length on cone weight are highest at Gällivare ($b_{23} = 0.423$) and lowest at Stjernarp (0.245). The difference between the two regression coefficients is significant at the 1 % level. The coefficient of the regression of X_3 on X_2 is at Stjernarp 3.095 and at Gällivare 1.343. The difference between the regression coefficients is highly significant (P is less than 0.1 %). The two regression lines have therefore different slopes.

The analysis given in Table 29 shows that the differences in slope between the six regressions of X_2 on X_3 for the six localities are only significant at the 5 % level, whereas much more significant differences exist between the levels of the six parallel regressions ($P < 0.1$ %).

In regard to the regression of X_3 on X_2, the author has already commented upon the difference in slopes for Stjernarp and Gällivare. An analysis of covariance comprising all localities gives a highly significant F-value when testing the differences of slopes.

5.2.2.2. Between-tree regressions of 1,000-grain weight of all seeds on cone properties and of 1,000-grain weight on other seed characters

From the regression equations in Table 25 it can be seen, among other things, how the thousand-grain weight is dependent upon cone length, cone weight and certain investigated seed properties. The equations for the multiple regression of thousand-grain weight on cone length and cone weight, and of thousand-grain weight on cone length, cone weight, and the total number of seeds per cone are given in Table 27. The sampling errors of regression coefficients are grouped together in Table 28. As regards the simple regressions of 1,000-grain weight on other investigated seed properties, Table 25 shows that (with the exception of the regressions of 1,000-grain weight on total number of seeds per cone at Stjernarp and Gällivare) positive relationships exist between the 1,000-grain weight and the other investigated variables. It will be noted, however, that the coefficient b_{14}, the slope of the regression of X_1 on X_4, is not found to be significantly different from zero with the exception of the stand at Skalstugan.

Table 30 shows the tests of significance of the differences between populations in regard to simple and multiple regressions. These tests show, among other things, that the differences between population regression levels are significant for all studied comparisons, and that no significant differences between the slopes are found for the regressions of 1,000-grain weight (X_1) on cone length (X_2) and on number of seeds per cone (X_4) as well as of X_1 on X_2, X_3. Deviations of the individual regressions of X_1 on X_3 and of X_1 on X_2, X_3, X_4 from the corresponding parallel regressions are, for instance, significant at the 5 % level and the difference between the regression coefficients, b_{17}, at the 0.1 % point. These varying relations with regard to the slopes can be summed up in the following way:

Table 25. Regressions between trees within populations for different pair of variates in the year 1954.
(Calculated on the basis of mean cone values for trees)

Type of regression	Population	Regression equation	Regression equation
Individual regression	Stjernarp	$X_1 = -91.56 + 0.453\ X_2$	$X_2 = 652.91 + 0.245\ X_3$
,,	Gunnarskog	$X_1 = -23.64 + 0.456\ X_2$	$X_2 = 573.34 + 0.276\ X_3$
,,	Skalstugan	$X_1 = 48.52 + 0.310\ X_2$	$X_2 = 489.26 + 0.305\ X_3$
,,	Kvikkjokk	$X_1 = 15.22 + 0.347\ X_2$	$X_2 = 485.53 + 0.341\ X_3$
,,	Gällivare	$X_1 = 185.33 + 0.125\ X_2$	$X_2 = 435.64 + 0.423\ X_3$
,,	Pajala	$X_1 = -81.31 + 0.502\ X_2$	$X_2 = 477.24 + 0.313\ X_3$
Parallel regression	The whole material	$X_1 = -2.46 + 0.391\ X_2$	$X_2 = 539.16 + 0.276\ X_3$
Total regression	,,	$X_1 = -10.24 + 0.401\ X_2$	$X_2 = 480.11 + 0.340\ X_3$
Individual regression	Stjernarp	$X_1 = 172.11 + 0.132\ X_3$	$X_4 = 190.61 + 0.084\ X_2$
,,	Gunnarskog	$X_1 = 189.99 + 0.161\ X_3$	$X_4 = 101.59 + 0.166\ X_2$
,,	Skalstugan	$X_1 = 104.66 + 0.204\ X_3$	$X_4 = 34.06 + 0.208\ X_2$
,,	Kvikkjokk	$X_1 = 151.47 + 0.172\ X_3$	$X_4 = 103.66 + 0.089\ X_2$
,,	Gällivare	$X_1 = 225.26 + 0.079\ X_3$	$X_4 = 9.54 + 0.212\ X_2$
,,	Pajala	$X_1 = 60.02 + 0.312\ X_3$	$X_4 = 88.72 + 0.123\ X_2$
Parallel regression	The whole material	$X_1 = 160.97 + 0.159\ X_3$	$X_4 = 91.68 + 0.140\ X_2$
Total regression	,,	$X_1 = 167.25 + 0.152\ X_3$	$X_4 = -25.14 + 0.287\ X_2$
Individual regression	Stjernarp	$X_1 = 497.95 - 0.454\ X_4$	$X_4 = 246.88 + 0.020\ X_3$
,,	Gunnarskog	$X_1 = 408.03 + 0.016\ X_4$	$X_4 = 198.00 + 0.045\ X_3$
,,	Skalstugan	$X_1 = 73.53 + 1.096\ X_4$	$X_4 = 117.21 + 0.085\ X_3$
,,	Kvikkjokk	$X_1 = 242.31 + 0.081\ X_4$	$X_4 = 125.41 + 0.065\ X_3$
,,	Gällivare	$X_1 = 294.49 - 0.173\ X_4$	$X_4 = 74.85 + 0.139\ X_3$
,,	Pajala	$X_1 = 160.53 + 0.570\ X_4$	$X_4 = 121.94 + 0.079\ X_3$
Parallel regression	The whole material	$X_1 = 271.30 + 0.183\ X_4$	$X_4 = 162.19 + 0.044\ X_3$
Total regression	,,	$X_1 = 114.59 + 0.956\ X_4$	$X_4 = 108.79 + 0.101\ X_3$
Individual regression	Stjernarp	$X_1 = 30.35 + 0.333\ X_7$	
,,	Gunnarskog	$X_1 = 120.34 + 0.272\ X_7$	
,,	Skalstugan	$X_1 = 110.74 + 0.313\ X_7$	
,,	Kvikkjokk	$X_1 = 74.90 + 0.428\ X_7$	
,,	Gällivare	$X_1 = 86.79 + 0.450\ X_7$	
,,	Pajala	$X_1 = 62.09 + 0.439\ X_7$	
Parallel regression	The whole material	$X_1 = 87.95 + 0.337\ X_7$	
Total regression	,,	$X_1 = 145.52 + 0.249\ X_7$	

X_1 = thousand-grain weight in centigram of all seeds
X_2 = cone length in tenths of a millimetre
X_3 = cone weight in centigram
X_4 = the total number of seeds per cone
X_7 = the weight in milligram of all seeds per cone

1) no significant differences are found between the slopes of the six individual regressions of X_1 on X_2 and of X_1 on X_4 (i.e. these population regression lines are parallel, or not far from parallel, within the groups),
2) no significant differences are found between the slopes of the six individual regressions of X_1 on X_2 and X_3 (these population regression planes are parallel, or not far from parallel) and

Table 26. Regressions between trees within populations for different pairs of variates in the year 1954.
(Calculated on the basis of mean cone values for trees)

Type of regression	Population	Regression equation	Regression equation
Individual regression	Stjernarp	$X_4 = 255.19 + 0.021\ X_7$	$X_{10} = 112.62 + 0.385\ X_2$
,,	Gunnarskog	$X_4 = 185.18 + 0.070\ X_7$	$X_{10} = -19.73 + 0.475\ X_2$
,,	Skalstugan	$X_4 = 116.53 + 0.136\ X_7$	$X_{10} = 188.01 + 0.142\ X_2$
,,	Kvikkjokk	$X_4 = 124.00 + 0.097\ X_7$	$X_{10} = -107.03 + 0.481\ X_2$
,,	Gällivare	$X_4 = 106.19 + 0.110\ X_7$	$X_{10} = 61.48 + 0.143\ X_2$
,,	Pajala	$X_4 = 132.32 + 0.089\ X_7$	$X_{10} = 52.22 + 0.419\ X_2$
Parallel regression	The whole material	$X_4 = 158.51 + 0.068\ X_7$	$X_{10} = 46.49 + 0.350\ X_2$
Total regression	,,	$X_4 = 112.93 + 0.137\ X_7$	$X_{10} = -186.29 + 0.644\ X_2$
Individual regression	Stjernarp	$X_7 = 359.77 + 0.441\ X_3$	$X_{10} = 374.82 + 0.087\ X_3$
,,	Gunnarskog	$X_7 = 240.80 + 0.602\ X_3$	$X_{10} = 186.27 + 0.179\ X_3$
,,	Skalstugan	$X_7 = -8.00 + 0.637\ X_3$	$X_{10} = 200.61 - 0.108\ X_3$
,,	Kvikkjokk	$X_7 = 142.83 + 0.461\ X_3$	$X_{10} = 115.70 - 0.182\ X_3$
,,	Gällivare	$X_7 = 152.68 + 0.460\ X_3$	$X_{10} = 41.72 + 0.211\ X_3$
,,	Pajala	$X_7 = -15.71 + 0.727\ X_3$	$X_{10} = 84.74 + 0.394\ X_3$
Parallel regression	The whole material	$X_7 = 170.11 + 0.522\ X_3$	$X_{10} = 194.09 + 0.142\ X_3$
Total regression	,,	$X_7 = 35.88 + 0.667\ X_3$	$X_{10} = 103.18 + 0.240\ X_3$
Individual regression	Stjernarp	$X_{10} = 36.39 + 1.263\ X_1$	$X_{10} = 900.65 - 1.423\ X_4$
,,	Gunnarskog	$X_{10} = -53.85 + 1.183\ X_1$	$X_{10} = 245.40 + 0.725\ X_4$
,,	Skalstugan	$X_{10} = 13.70 + 0.994\ X_1$	$X_{10} = 41.29 + 1.324\ X_4$
,,	Kvikkjokk	$X_{10} = -146.25 + 1.457\ X_1$	$X_{10} = 291.48 - 0.395\ X_4$
,,	Gällivare	$X_{10} = -60.15 + 0.808\ X_1$	$X_{10} = 43.32 + 0.751\ X_4$
,,	Pajala	$X_{10} = -9.87 + 1.337\ X_1$	$X_{10} = 22.84 + 1.820\ X_4$
Parallel regression	The whole material	$X_{10} = -43.10 + 1.196\ X_1$	$X_{10} = 224.10 + 0.501\ X_4$
Total regression	,,	$X_{10} = -91.53 + 1.353\ X_1$	$X_{10} = -56.25 + 1.882\ X_4$

X_1 = thousand-grain weight in centigram of all seeds per cone
X_2 = cone length in tenths of a millimetre
X_3 = cone weight in centigram
X_4 = the total number of seeds per cone
X_7 = the weight in milligram of all seeds per cone
X_{10} = the germination capacity (Jacobsen's germinator) in per mille of all seeds per cone

3) there are differences between the six populations with regard to the slopes of the regressions of X_1 on X_3, of X_1 on X_7 and of X_1 on X_2, X_3 and X_4. The relationships between 1,000-grain weight (X_1) and other investigated characters appear in detail in the regression equations. The average parallel regression coefficient b_{12} (within the six populations) is 0.391 ± 0.044, b_{13} is 0.159 ± 0.014, b_{14} is 0.183 ± 0.160 and b_{17} is 0.377 ± 0.011. The mean values (within the whole material) are for the independent variables X_2, X_3, X_4 and X_7 in respective units, 795.17, 927.57, 203.00 and 654.30 respectively. Using these values for the averages of the four independent variables and the regression coefficients quoted we find that e.g. a 10 per cent in-

crease in the cone length (X_2) has a stronger influence on the thousand-grain weight (X_1) than a 10 per cent increase in any one of the three variables X_3, X_4 and X_7. The regression of X_1 on X_2 has a slight tendency to curvilinearity (see Fig. 19), but this slight tendency does not appear to change the order of the four variables when ranked according to their effect on X_1. The relationships between the 1,000-grain weight and the weight of all seeds per cone for the populations are very consistent. The connection between 1,000-grain weight of all seeds and the total number of seeds per cone, on the other hand, is very uncertain (with the exception of Skalstugan). As noted earlier, the regression of X_1 on X_7 and of X_1 on X_4 must be judged with caution. The variables X_2 and X_3 are positively correlated. As a consequence, the partial regression coefficients of X_1 on X_2 and X_3 (Table 27) are smaller than the corresponding total regression coefficients (Table 25). In two populations, Skalstugan and Pajala, it can be seen that the cone length has a negative effect on 1,000-grain weight when the cone weight is held constant. On the other hand, the coefficients with a negative sign have large standard errors (0.098 and 0.162 respectively) and cannot be regarded as being significantly different from zero. Except for Stjernarp, the same degree of uncertainty exists with regard to the positive regression coefficients of X_1 on X_2 with a constant cone weight. On the other hand, within the spruce stands of Central European origin at Stjernarp, as in the 1948 material, there exists a clear tendency that the longest cones, with equal cone weight, contain seeds with the highest 1,000-grain weight. Referring to Table 27 we also find that, with the same cone length, the heaviest cone contains seeds with the highest thousand-grain weight. Comparing the coefficients of the multiple regression of X_1 on X_2, X_3 and X_4, we find that with a constant cone length and cone weight there exists, with the exception of Skalstugan, a negative relation between 1,000-grain weight and the number of seeds per cone. The coefficients of regression of 1,000-grain weight on cone weight with constant cone length and number of seeds per cone are positive, but, as can be seen below, these coefficients, as well as $b_{13.24}$ and $b_{14.23}$, often have large standard errors.

Within the whole material (cf. the coefficients of the parallel regression in Table 27) the thousand-grain weight of all seeds increases with an average 9.1 cg. when the length of cone, with the same cone weight and the same number of seeds per cone, increases with 10 millimetres. If the cone weight, with equal cone length and equal number of seeds per cone, increases with 1 gram the 1,000-grain weight increases on the average with 15.9 cg. On the other hand, if the number of seeds per cone is altered by 10 the result is a change in the 1,000-grain weight, with a constant cone length and constant

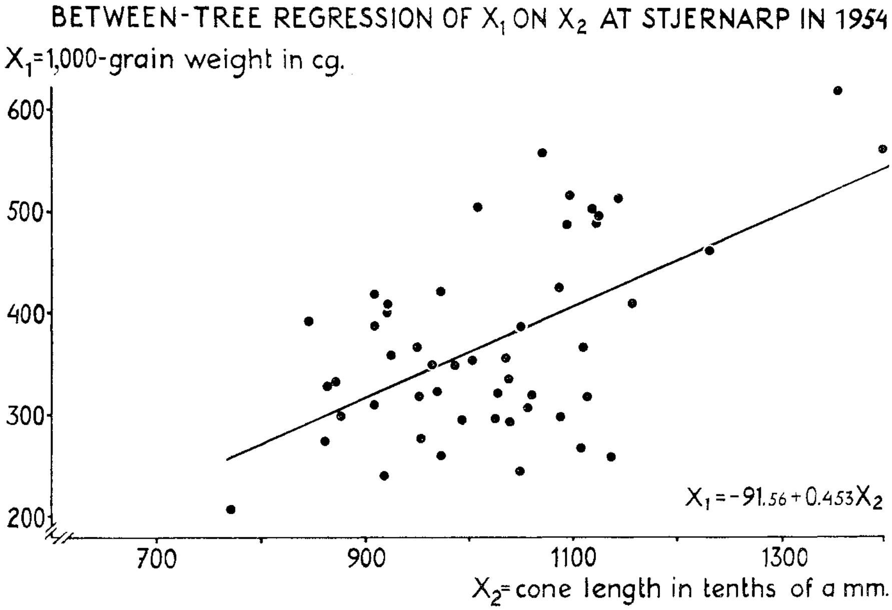


Fig. 19.

cone weight, by an average of about 5.8 cg. With the same cone length and equal cone weight the cones with the lowest number of seeds contain, on the average, seeds with the highest 1,000-grain weight. The individual regression surfaces deviate significantly at the 5 % level from the six parallel regression surfaces. The differences between the parallel regression surfaces are also, in this case, significant at the 0.1 % point.

5.2.2.3. Between-tree regressions of total number of seeds per cone on cone length, cone weight and the weight of all seeds per cone

It appears from Tables 25 and 26 that the regression coefficients of the total number of seeds per cone (X_4) on each of the variables, cone length (X_2), cone weight (X_3) and weight of all seeds per cone (X_7) are positive. The standard errors of these regressions are seen in Table 28. For the regression of X_4 on X_2 there exists no significant difference between the slopes of the regression lines, but there is a significant difference between the levels ($P < 0.1$ %). There are highly significant differences in slopes for the regression of X_4 on X_3 and of X_4 on X_7. The increase in the total number of seeds for the whole material, at one centimetre increase in cone length, amounts to an average of 14 seeds per cone in the six sample plots. From the average parallel regression of X_4 on X_3 for the whole material, we can read

Table 27. Multiple regressions of X_1 on X_2 and X_3, and of X_1 on X_2, X_3 and X_4.
(Calculated on the basis of tree means in 1954)

Type of regression	Population	Regression equation
Individual regression	Stjernarp	$X_1 = 53.57 + 0.182\ X_2 + 0.088\ X_3$
,,	Gunnarskog	$X_1 = 167.20 + 0.040\ X_2 + 0.150\ X_3$
,,	Skalstugan	$X_1 = 175.62 - 0.145\ X_2 + 0.248\ X_3$
,,	Kvikkjokk	$X_1 = 148.03 + 0.007\ X_2 + 0.169\ X_3$
,,	Gällivare	$X_1 = 206.71 + 0.043\ X_2 + 0.061\ X_3$
,,	Pajala	$X_1 = 75.69 - 0.033\ X_2 + 0.322\ X_3$
Parallel regression	The whole material	$X_1 = 143.20 + 0.034\ X_2 + 0.149\ X_3$
Total regression	,,	$X_1 = 160.18 + 0.015\ X_2 + 0.147\ X_3$
Individual regression	Stjernarp	$X_1 = 339.77 + 0.327\ X_2 + 0.083\ X_3 - 1.545\ X_4$
,,	Gunnarskog	$X_1 = 245.01 + 0.180\ X_2 + 0.147\ X_3 - 0.799\ X_4$
,,	Skalstugan	$X_1 = 154.08 - 0.189\ X_2 + 0.230\ X_3 + 0.366\ X_4$
,,	Kvikkjokk	$X_1 = 234.20 - 0.054\ X_2 + 0.219\ X_3 - 0.450\ X_4$
,,	Gällivare	$X_1 = 247.91 + 0.090\ X_2 + 0.156\ X_3 - 0.829\ X_4$
,,	Pajala	$X_1 = 171.07 - 0.045\ X_2 + 0.383\ X_3 - 0.736\ X_4$
Parallel regression	The whole material	$X_1 = 207.16 + 0.091\ X_2 + 0.159\ X_3 - 0.584\ X_4$
Total regression	,,	$X_1 = 168.19 + 0.103\ X_2 + 0.164\ X_3 - 0.465\ X_4$

X_1 = thousand-grain weight in centigram of all seeds per cone
X_2 = cone length in tenths of a millimetre
X_3 = cone weight in centigram
X_4 = the total number of seeds per cone

off that an increase in cone weight, with one gram, gives an average increase in X_4 by 4.4 seeds per cone. If the weight of all seeds per cone (X_7) is altered by 10 cg. the average for the whole material of the total number of seeds per cone (X_4) is altered by 6.8. The regressions of X_4 on X_2, with equal 1,000-grain weight and cone weight, are positive, with the exception of the plot at Kvikkjokk. The coefficients for the regression of X_4 on X_3, with constant 1,000-grain weight and cone length, are all positive. The coefficient $b_{42.13}$ at Stjernarp, Gunnarskog and Skalstugan is significant at the 5 % level and the one at Pajala at the 1 % point. The coefficient $b_{43.12}$ at Kvikkjokk is significant at the 1 % level, and at Gällivare at the 0.1 % point. With equal 1,000-grain weight and cone weight the longest cones, from all sample plots, contain on an average the highest number of seeds per cone. With the same 1,000-grain weight and an equal cone length, the heaviest cones within the whole material contain on the average the highest number of seeds per cone. The differences in slopes between the six individual regression surfaces are significant at the 0.1 % level.

Table 28. The sampling errors of regression coefficients in Tables 25 and 26.

Regression of \ Population	Stjernarp ε_b	Gunnar-skog ε_b	Skalstugan ε_b	Kvikkjokk ε_b	Gällivare ε_b	Pajala ε_b
X_1 on X_2	0.093	0.106	0.086	0.135	0.129	0.133
X_1 on X_3	0.026	0.032	0.027	0.054	0.072	0.048
X_1 on X_4	0.535	0.362	0.251	0.372	0.354	0.434
X_1 on X_7	0.018	0.025	0.020	0.035	0.046	0.029
X_1 on X_{10}	0.057	0.055	0.068	0.038	0.084	0.053
X_2 on X_3	0.020	0.022	0.039	0.033	0.053	0.043
X_4 on X_2	0.028	0.044	0.036	0.054	0.043	0.046
X_4 on X_3	0.008	0.014	0.015	0.021	0.022	0.018
X_7 on X_2	0.228	0.277	0.227	0.267	0.215	0.262
X_7 on X_3	0.063	0.085	0.070	0.101	0.115	0.087
X_{10} on X_1	0.174	0.268	0.204	0.444	0.164	0.222
X_{10} on X_2	0.190	0.266	0.166	0.486	0.181	0.303
X_{10} on X_3	0.054	0.083	0.067	0.200	0.097	0.122
X_{10} on X_4	0.917	0.790	0.476	1.260	0.484	0.860

X_1 = thousand-grain weight in centigram of all seeds
X_2 = cone length in tenths of a millimetre
X_3 = cone weight in centigram
X_4 = the total number of seeds per cone
X_7 = the weight in milligram of all seeds per cone
X_{10} = the germination capacity in per mille of all seeds

5.2.2.4. Between-tree regressions of the weight of all seeds per cone on cone weight

The six regression coefficients for individual regressions, as well as for the average parallel and total regressions, are all highly significant (cf. Table 28). Between the individual regression lines for populations no significant differences appear in slopes but, on the other hand, the differences in elevations are highly significant. The differences in regression relationships, between populations and areas consist therefore, mainly in the variations or changes in the means of the variates from population to population.

5.2.2.5. Between-tree regressions of the seed germination capacity of total number of seeds per cone on thousand-grain weight of all seeds per cone

Large variations in germination capacity (found in JACOBSEN'S germinator) in per mille of total number of seeds per cone, exist between trees within populations, as well as between populations. Two groups of coefficients for the regression of germination rate of the total number of seeds per

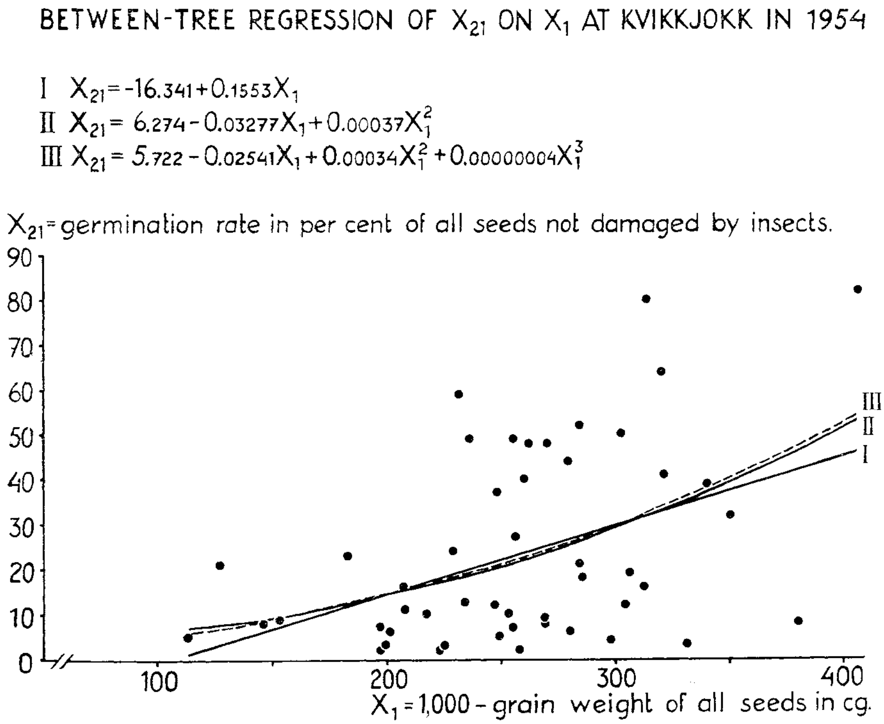


Fig. 20. Graphs of polynomials of first, second and third degree fitted to seed data.

cone on cone properties, and two groups of coefficients for the regression of germination rate of the total number of seeds per cone on other seed characters are presented in Table 26.

In this connection, only the covariation between seed germination rate of total number of seeds per cone, and thousand-grain weight of all seeds per cone is discussed. Regressions and correlations between germination rate of the number of seeds not damaged by insects, on the one hand, and some cone and seed properties on the other hand, are given in the Tables XXII A — XXII E, 41, 42 and 43.

When we consider the regression (linear) of germination rate of all seeds per cone (X_{10}) on thousand-grain weight of all seeds per cone (X_1) we find that the differences in slopes of the individual regressions for populations are highly significant. The coefficients of regression of X_{10} on X_1 for the whole material deviate in a highly significant way from 0. It should be pointed out that within the populations, as well as within the whole material, there exists a positive correlation between the germination capacity of the seed and its 1,000-grain weight. If the 1,000-grain weight per cone is changed

Table 29. Regression of cone length (X_2) on cone weight (X_3) in 1954.
(Calculated on the basis of cone mean values for trees)

Row-number	Source of variation	D.F.	Sum of squares	Mean square
	Deviations from individual regressions:			
	Stjernarp	48	174,266.50	
	Gunnarskog	48	103,756.01	
	Skalstugan	48	148,734.88	
	Kvikkjokk	48	55,926.21	
	Gällivare	48	103,905.27	
	Pajala	48	108,406.57	
1	$\sum$individual regressions	288	694,995.44	2,413.18
2	parallel regressions	293	728,227.01	2,485.42
3	total regression	298	890,406.29	2,987.94
	Differences in:			
4	slope (2)—(1)	5	33,231.57	6,646.31
5	level (3)—(2)	5	162,179.28	32,435.85
6	total differences (3)—(1)	10	195,410.85	19,541.09

$F_1 = \frac{(4)}{(1)} = 2.75^{*}$ $F_2 = \frac{(5)}{(2)} = 13.05^{***}$ $F_3 = \frac{(6)}{(1)} = 8.10^{***}$

by one gram the seed germination capacity of all seeds is changed by an average of 11.96 % within the whole material, for the stand at Stjernarp with a similar average of 12.63 %, for Gunnarskog 11.83 %, Skalstugan 9.94 %, Kvikkjokk 14.57 %, Gällivare 8.08 % and Pajala with 13.37 %. The differences between populations in slopes of the regression lines are not significant. The differences in levels of the parallel regressions are, however, highly significant.

5.2.2.6. Some within-tree correlations in 1954 and in relation to 1948

Six series of seven values of total correlation coefficients are given in Table 31. The first six values in the series represent the average correlation coefficients within trees for single populations, and the seventh value gives the average correlation coefficient within trees for the whole material. The coefficients at Stjernarp, Gunnarskog and Skalstugan in Table 31 are thus comparable with the corresponding coefficients in Table 16 for the year 1948. The trees, and the cones, are selected in the same way as in 1948 and from the same populations. The correlation model is therefore the same as in 1948, but, as noted earlier, not all the trees within the samples are the same for both years. All the coefficients are highly significant.

A characteristic for the correlation data shown in Table 31 is that the coefficients for the same set of variables at Stjernarp, Gunnarskog and Skal-

Table 30. Estimated *F*-values for differences between populations in 1954. (See Tables 25—29)

Regression of	Differences between populations		
	in slopes	in levels	in total differences
X_1 on X_2	1.30°	6.47***	3.90***
X_1 on X_3	2.40*	6.82***	4.69***
X_1 on X_4	2.04°	11.14***	6.69***
X_1 on X_7	6.91***	23.55***	16.42***
X_1 on X_{10}	5.05***	24.23***	15.47***
X_2 on X_3	2.75*	13.05***	8.10***
X_3 on X_2	10.03***	5.14***	7.98***
X_4 on X_2	2.12°	25.67***	14.14***
X_4 on X_3	6.60***	31.01***	20.29***
X_7 on X_2	2.93*	13.86***	8.62***
X_7 on X_3	1.90°	14.68***	8.40***
X_{10} on X_1	0.68°	18.64***	9.61***
X_{10} on X_2	0.32°	9.14***	4.68***
X_{10} on X_3	1.05°	8.14***	4.60***
X_{10} on X_4	1.86°	8.51***	5.25***
X_1 on X_2, X_3	1.42°	6.84***	3.26***
X_1 on X_2, X_3, X_4	2.32*	7.53***	3.75***

X_1 = thousand-grain weight of total number of seeds per cone
X_2 = cone length
X_3 = cone weight
X_4 = total number of seeds per cone
X_7 = the weight of all seeds per cone
X_{10} = the germination capacity of the total number of seeds per cone

* Statistically significant at the 5 % level
** ” ” ” ” 1 % ”
*** ” ” ” ” 0.1 % ”

° Note that the value of *r* does not reach the 5 % level of significance

stugan in 1954, with the exception of the coefficients for the covariation between the variables X_4 and X_7 at Gunnarskog, are numerically larger than in 1948.

Trees and individual populations show a number of significant differences in covariation between the studied pairs of variates but the differences are smaller, on the average, in 1954 than in 1948 even though the geographical variations of the sample plots, in regard to both altitude and latitude, are greater in 1954. All correlation coefficients in Table 31 are highly significant. The correlation between cone length (X_2) and cone weight (X_3), for example, is highest in Gunnarskog followed immediately by Kvikkjokk, and lowest in Pajala. No indication of a trend exists in considering the strength of the correlations and the northern latitude.

Table 31. Average correlations between cones within trees for the year 1954.

Between the variables \ Population	Stjernarp	Gunnar-skog	Skal-stugan	Kvikk-jokk	Gällivare	Pajala	Average within localities
	r	r	r	r	r	r	r
X_2 and X_3	0.898	0.955	0.899	0.921	0.884	0.868	0.892
X_4	0.773	0.801	0.779	0.589	0.592	0.765	0.720
X_7	0.854	0.901	0.805	0.704	0.705	0.769	0.808
X_3 and X_4	0.731	0.803	0.772	0.619	0.629	0.760	0.698
X_7	0.832	0.902	0.842	0.759	0.778	0.890	0.844
X_4 and X_7	0.735	0.794	0.907	0.812	0.830	0.768	0.775

Correlation based on:	D.F.	Value of r different from zero at the P % level of significance $P=5$ %	$P=1$ %
average correlation within trees for individual populations	699	0.074	0.097
average correlation within trees for the total material	4199	0.030	0.040

X_2 = cone length
X_3 = cone weight
X_4 = total number of seeds per cone
X_7 = the weight of all seeds per cone

If a calculation is made of the partial within-tree correlations between the variables X_4 (number of seeds per cone) and X_7 (weight of seeds per cone) when the influence of either X_2 (cone length) or X_3 (cone weight) is eliminated, or when both X_2 and X_3 are eliminated or held constant, the following values for partial correlation coefficients of the first and second order, for the six combined populations in Table 31, are achieved:

$r_{23.4} = 0.784$
$r_{23.7} = 0.665$ $\quad r_{23.47} = 0.659$
$r_{24.4} = 0.301$
$r_{24.7} = 0.252$ $\quad r_{24.37} = 0.224$
$r_{34.2} = 0.178$
$r_{34.7} = 0.130$ $\quad r_{34.27} = -0.052$
$r_{27.3} = 0.228$
$r_{27.4} = 0.570$ $\quad r_{27.34} = 0.097$
$r_{37.2} = 0.463$
$r_{37.4} = 0.670$ $\quad r_{37.24} = 0.437$
$r_{47.2} = 0.473$
$r_{47.3} = 0.484$ $\quad r_{47.23} = 0.447$

Four variables thus give six partial correlation coefficients of the second order.

For the tests of significance of the coefficients the degrees of freedom, for partial correlations of the first order, are in this case 4,198 and for the corresponding coefficients of the second order 4,197. One of the partial correlation coefficients presented, $r_{34.27}$, is significant at the 0.1 % level and all the others exceed this level of significance. The calculated partial correlation coefficients all show a reduced association between the variables, in comparison with the zero order correlations. Between cone weight and total number of all seeds per cone there even exists a slight negative association, when cone length and the weight of all seeds per cone are eliminated. Especially the coefficients $r_{34.27}$ and $r_{27.34}$ give a clear indication that the positive total correlations between the variables X_3 and X_4, and also X_2 and X_7, can be explained as a result of the covariation existing between X_3 and X_2, X_3 and X_7, X_2 and X_4 and between X_4 and X_7.

The multiple correlation coefficient $R_{3.427} = 0.9166$, corresponding to four variables and $6 \times 50 \times (15 - 1) - 3 = 4{,}197$ degrees of freedom within trees, is highly significant. In the present cases the association of X_3 with X_4, X_2 and X_7 collectively accounts for 84 % of the variability in X_3, and the association of X_2 with X_7, X_3 and X_4 accounts for 81.6 % of the variability in X_2, since the value of $R_{2.734}$ is 0.9034. The value of $R_{2.734}$ is therefore highly significant.

We may therefore conclude that X_3 is greatly influenced by the combined effects of X_4, X_2 and X_7 and that X_2 in the same way is greatly influenced by the combined effects of X_7, X_3 and X_4.

To summarize: In the combined cone material for 1954 it appears that within trees there is 1) a significant and positive correlation (although fairly weak) between cone length and the number of seeds per cone, with constant cone weight and constant seed weight per cone (in other words the longer cones, with equal cone weight and equal seed weight per cone, contain on the average more seeds per cone than the shorter cones), 2) a significant and positive correlation (although very weak) between cone length and seed weight per cone, with constant cone weight and constant number of seeds per cone (in other words the longer cones, with equal cone weight and equal number of seeds per cone, show an average tendency to heavier seed than the shorter cones), 3) a significant positive correlation between cone weight and seed weight per cone, with constant cone length and constant number of seeds per cone (in other words the heavier cones, with equal cone length and equal number of seeds per cone, contain on the average heavier seeds than the lighter cones), 4) a very weak negative correlation (although significant) between cone weight and the number of seeds per cone, with constant cone length and constant weight of seeds per cone (in other words the heavier cones, with equal cone length and equal weight of

Table 32. Frequency table showing the distribution of correlations between cones in 1954 computed for 50 individual trees from each population (15 cones from each tree).

Population	Between the variables	No. of trees with a correlation coefficient ranking within the following limits of classes														
		−0.49– −0.40	−0.39– −0.30	−0.29– −0.20	−0.19– −0.10	−0.09– −0.00	0.00–0.09	0.10–0.19	0.20–0.29	0.30–0.39	0.40–0.49	0.50–0.59	0.60–0.69	0.70–0.79	0.80–0.89	0.90–1.00
Stjernarp	X_2 and X_3							1		1			2	3	7	37
	X_2 and X_4									2		3	7	8	23	7
	X_3 and X_4								2		2	3	5	14	16	8
	X_3 and X_7							1				1	4	6	16	22
Gunnar-skog	X_2 and X_3												1		1	48
	X_2 and X_4									2		1	4	6	27	10
	X_3 and X_4									1	2		1	10	23	13
	X_3 and X_7												1	2	7	40
Skal-stugan	X_2 and X_3											1	1	5	10	33
	X_2 and X_4									1	1	4	7	11	18	8
	X_3 and X_4									1		2	8	12	19	8
	X_3 and X_7												3	10	20	17
Kvikkjokk	X_2 and X_3												1	1	8	40
	X_2 and X_4					1	1	2	4	5	2	6	7	10	7	5
	X_3 and X_4				1		1	2	3	1	4	4	8	12	10	4
	X_3 and X_7							1		2	2	4	6	14	12	9
Gällivare	X_2 and X_3												1	6	18	25
	X_2 and X_4					1	1	1	2	1	3	8	13	8	10	1
	X_3 and X_4	1			3			1			4	6	10	11	9	5
	X_3 and X_7				1				1	1	2	2	3	9	13	18
Pajala	X_2 and X_3											1	1	4	19	25
	X_2 and X_4							2	1	1		4	4	13	16	9
	X_3 and X_4					2		1		1	1	2	6	10	19	8
	X_3 and X_7										1			7	10	32

X_2 = cone length
X_3 = cone weight
X_4 = total number of seeds per cone
X_7 = the weight of all seeds per cone

seeds, have on the average a slight tendency to contain a smaller number of seeds than the lighter cones), 5) a significant and positive correlation between number of seeds and the seed weight of all seeds per cone, with a constant cone length and constant cone weight (in other words, cones with a higher total number of seeds, with equal cone weight and equal cone length, have a higher seed weight than cones with a lower number of seeds), and 6) a significant and positive correlation between cone length and cone weight, with a constant number of seeds per cone and a constant seed weight per cone (in other words, the longer cones, with an equal number of seeds per cone and an equal seed weight per cone, have on the average a higher weight per cone than the shorter cones, without any regard being paid to the form of the cones).

Partial correlations within trees for single populations are presented in Table 33. Most of the coefficients are positive, significant and more or less strongly reduced in strength in comparison with the total correlation coefficients in Table 31. Three of the coefficients of the second order are significantly negative, namely $r_{34.27}$ at Skalstugan and Gällivare (i.e. between cone weight and number of seeds per cone with the same cone length and seed weight per cone) and $r_{27.34}$ at Pajala (i.e. between cone length and seed weight per cone with the same cone weight and number of seeds per cone). Two of the coefficients in the $r_{34.27}$-set and three of the $r_{27.34}$-set are negative but not significant. In the population at Pajala, for instance, the within-tree correlation between cone weight and seed weight ($r_{37.24}$), with the same cone length and number of seeds per cone, is significantly larger than the corresponding correlation coefficient in any of the other five stands. The t-value for the difference between the two coefficients at Pajala and Skalstugan is given by

$$t = \frac{0.80 - 0.43}{\sqrt{\dfrac{2}{50(15-1)-4}}} = 0.37\sqrt{348} = 6.90^{***}.$$

This t-value exceeds the 0.1 % level of significance.

5.2.2.7. Correlations between years

Some average total correlations between cone properties and between seed characters based on tree means for a number of trees between the years 1948 and 1954 and between 1946 and 1948 have been computed in Table 34. The correlations between the years have been calculated for the trees in Stjernarp and Skalstugan for the following characters:

X_1 = 1,000-grain weight of all seeds per cone
X_2 = cone length
X_3 = cone weight
X_4 = total number of seeds per cone
X_7 = the weight of all seeds per cone
X_{15} = empty seeds (of embryo type 0) not damaged by insects
X_{20} = empty seeds (of embryo types 0 + I) not damaged by insects.

Table 33. Partial within-tree correlations for populations in the year 1954.

Population / $r_{xy \cdot z}$	Stjernarp	Gunnar-skog	Skalstugan	Kvikkjokk	Gällivare	Pajala
$r_{23.4}$	0.769	0.875	0.747	0.876	0.816	0.685
$r_{23.7}$	0.650	0.758	0.691	0.837	0.753	0.630
$r_{24.3}$	0.388	0.193	0.305	0.062°	0.099	0.326
$r_{24.7}$	0.412	0.324	0.196	0.041°	0.002°	0.426
$r_{34.2}$	0.132	0.215	0.261	0.244	0.280	0.300
$r_{34.7}$	0.318	0.331	0.037°	0.008°	—0.048°	0.262
$r_{27.3}$	0.438	0.309	0.203	0.020°	0.059°	—0.015°
$r_{27.4}$	0.664	0.728	0.373	0.479	0.475	0.440
$r_{37.2}$	0.284	0.323	0.455	0.401	0.467	0.701
$r_{37.4}$	0.637	0.730	0.530	0.558	0.590	0.736
$r_{47.2}$	0.227	0.278	0.752	0.692	0.722	0.436
$r_{47.3}$	0.335	0.271	0.749	0.669	0.697	0.309

Value of r different from zero at the P % level of significance

	D.F.	$P = 5\%$	$P = 1\%$
Partial within-tree correlation of the first order	698	0.074	0.097

Population / $r_{xy \cdot zu}$	Stjernarp	Gunnar-skog	Skalstugan	Kvikkjokk	Gällivare	Pajala
$r_{24.37}$	0.285	0.120	0.236	0.062°	0.058°	0.348
$r_{34.27}$	0.072°	0.137	—0.139	—0.048°	—0.075	—0.009°
$r_{27.34}$	0.354	0.271	—0.041°	—0.025°	—0.014°	—0.130
$r_{37.24}$	0.264	0.280	0.408	0.326	0.398	0.664
$r_{47.23}$	0.199	0.226	0.737	0.669	0.696	0.332

Value of r different from zero at the P % level of significance

	D.F.	$P = 5\%$	$P = 1\%$
Partial within-tree correlation of the second order	697	0.074	0.097

° Note that the value of r does not reach the 5 % level of significance.

As can be seen in the Table 34, correlations between the years 1946 and 1948 have only been computed for the first five characters for the trees in Härryda and Höljes.

The correlations presented in Table 34 show positive and significant coefficients between years for all the examined characters at Stjernarp, with the exception of the coefficient for cone weight, which is not significant.

A negative correlation was indicated between years at Skalstugan for all characters except empty seeds not damaged by insects. None of the coefficients were, however, significant. The relationships between the years 1946 and 1948 were weak and non-significant at Härryda with the exception of the association between the total number of seeds per cone. The total correlations between years for the tree sample at Höljes were positive and moderate to rather strong, but probably because of the small number of observations they were not significant for the 1,000-grain weight and cone length. As can be seen, the correlations at Skalstugan occupy a unique position. These total correlation coefficients indicate the lack of relationships between years for the same genotypes in the characters which have been studied. An examination of Table 34 shows also that the relationships between years for the same cone and seed characters can vary considerably between populations and areas.

The observed tendencies to negative correlations between the years 1948 and 1954 for cone properties and seed weight in the same trees at Skalstugan must be considered as strange and difficult to explain. Large variations in the number of cones per tree and in the mean temperatures of the vegetation periods—as well as in the extreme temperatures for seed properties during certain periods—can contribute towards changing cone and seed properties. The distribution of the colder and warmer days during the period of vegetation is equally of great importance from the biological point of view (cf. among others, LANGLET, 1935). Different genotypes can act differently under the same influences. To judge from the 24-hour mean temperatures for both years for the months of June, July, August and September at Storlien (9.2° C. in 1948 compared with 9.1° C. in 1954), the differences in temperature between the vegetation periods of the two years are wholly insignificant. Fig. 3 gives the same picture of variations in temperature between the vegetation periods during 1948 and 1954 (from the commencement of spruce flowering until September 30th). The temperature at Skalstugan, however, may have been different from that at Storlien, and especially the extreme temperatures (cf. Figs. 5 and 7) can have differed considerably in the two localities.

Four sets of correlation coefficients have been calculated for the years 1948 and 1954, in order to examine whether changes exist in the strength of the correlations for individual trees. The coefficients, presented in Table 35 a and b, are based on 25 cone values per tree for the year 1948, and 15 cone values for 1954. The z-value for the coefficient of the year 1954 is subtracted from the corresponding value in 1948 for each tree, and the differences are considered as a sample from a population of differences. We can first test the hypothesis that in every tree the 25 cones of 1948 and the

Table 34. Correlation between tree means 1948 and tree means 1954 as well as for 1946 and 1948.

(Based on mean values for individual trees)

Population	Between the years	No. of sets of observations = trees	X_1	X_2	X_3	X_4	X_7	X_{15}	X_{20}
Stjernarp	1948 and 1954	41	0.415**	0.482**	0.294°	0.494**	0.466**		
”	1948 and 1954	39						0.509**	0.509**
Skalstugan.	1948 and 1954	30	—0.288°	—0.142°	—0.325°	—0.078°	—0.271°	0.173°	0.219°
Härryda .	1946 and 1948	19	0.171°	0.097°	—0.126°	0.564*	0.250°		
Höljes . . .	1946 and 1948	10	0.516°	0.576°	0.768**	0.661*	0.668*		

X_1 = thousand-grain weight in centigram of all seeds
X_2 = cone length in tenths of a millimetre
X_3 = cone weight in centigram
X_4 = the total number of seeds per cone
X_7 = the weight in milligram of all seeds per cone
X_{15} = empty seeds (of embryo type 0) not damaged by insects
X_{20} = empty seeds (of embryo types 0+I) not damaged by insects
* Significant at the 5 % level
** ” ” ” 1 % ”
° Note that the value of r does not reach the 5 % level of significance

15 cones of 1954 are drawn from populations that are identical as far as the correlation between the two characters studied is concerned. This being the case, each difference should be (approximately) normally distributed with mean 0 and variance

$$\frac{1}{15-3}+\frac{1}{25-3}=0.12879$$

(see CRAMÉR, 1945, p. 400 formula 29.7.4).

Denoting the sum of the squared deviations of differences from their mean by S^2, it is seen that

$$S^2/0.12879$$

has—under the hypothesis mentioned—approximately a chi-square distribution with $n-1$ degrees of freedom, where n is the number of trees observed on both occasions. Applying this method to the coefficients of Table 35 a, the following values of chi-square (with d.f. = 29) were obtained: 53.84**, 66.10***, 68.22*** and 85.60*** respectively for differences between the two years in the coefficients r_{24}, r_{32}, r_{34} and r_{37} respectively, at Skalstugan. The corresponding χ^2-values (with d.f. = 40) for the 41 trees at Stjernarp and for the same sets of differences were: 54.67**, 106.04***, 100.98*** and 88.82*** respectively.

In spite of the approximate character of the test, the very strong signifi-

Table 35 a. Some correlation coefficients for individual trees in the years 1948 and 1954 at Skalstugan.

Tree No.	Year	r_{24}	r_{32}	r_{34}	r_{37}	Tree No.	Year	r_{24}	r_{32}	r_{34}	r_{37}
2	1948	0.636	0.818	0.683	0.766	25	1948	0.734	0.805	0.637	0.826
2	1954	0.608	0.754	0.780	0.713	25	1954	0.710	0.767	0.899	0.894
3	1948	0.726	0.796	0.575	0.714	26	1948	0.622	0.846	0.752	0.853
3	1954	0.954	0.988	0.974	0.957	26	1954	0.565	0.883	0.737	0.758
4	1948	0.196	0.860	0.218	0.852	27	1948	0.730	0.917	0.749	0.774
4	1954	0.874	0.982	0.862	0.959	27	1954	0.931	0.904	0.794	0.863
7	1948	0.637	0.891	0.602	0.820	28	1948	0.804	0.920	0.769	0.858
7	1954	0.927	0.979	0.923	0.958	28	1954	0.717	0.915	0.750	0.826
9	1948	0.840	0.916	0.784	0.926	29	1948	0.813	0.908	0.870	0.904
9	1954	0.805	0.839	0.785	0.852	29	1954	0.847	0.910	0.746	0.676
10	1948	0.456	0.612	0.410	0.264	30	1948	−0.275	0.891	−0.194	0.255
10	1954	0.666	0.927	0.699	0.948	30	1954	0.804	0.876	0.690	0.895
11	1948	0.743	0.916	0.793	0.878	31	1948	0.247	0.851	0.076	0.264
11	1954	0.882	0.985	0.888	0.881	31	1954	0.884	0.921	0.921	0.874
12	1948	0.711	0.819	0.642	0.675	33	1948	0.528	0.622	0.304	0.509
12	1954	0.923	0.971	0.912	0.908	33	1954	0.889	0.971	0.874	0.719
13	1948	0.403	0.697	0.438	0.500	35	1948	0.701	0.862	0.759	0.890
13	1954	0.651	0.940	0.623	0.834	35	1954	0.778	0.926	0.880	0.896
15	1948	0.478	0.812	0.686	0.734	42	1948	0.612	0.890	0.700	0.868
15	1954	0.916	0.959	0.827	0.789	42	1954	0.741	0.981	0.667	0.891
16	1948	0.482	0.906	0.474	0.626	44	1948	0.375	0.821	0.287	0.598
16	1954	0.748	0.963	0.760	0.894	44	1954	0.522	0.961	0.635	0.824
18	1948	0.116	0.406	0.153	0.387	45	1948	0.379	0.606	0.464	0.656
18	1954	0.737	0.792	0.560	0.834	45	1954	0.774	0.799	0.818	0.893
19	1948	0.868	0.943	0.913	0.930	47	1948	0.628	0.837	0.710	0.787
19	1954	0.879	0.893	0.861	0.946	47	1954	0.709	0.665	0.544	0.748
23	1948	0.729	0.813	0.825	0.925	49	1948	0.452	0.578	0.274	0.326
23	1954	0.595	0.912	0.617	0.738	49	1954	0.661	0.905	0.792	0.969
24	1948	0.740	0.919	0.779	0.895	50	1948	0.791	0.860	0.775	0.698
24	1954	0.867	0.906	0.916	0.695	50	1954	0.372	0.814	0.344	0.655

cances obtained indicate clearly that we must reject the hypothesis that the correlation has remained unchanged within each tree. It should perhaps be added that we have made no assumption that the correlation should be the same in different trees. We now test the hypothesis that the changes of the correlations within the trees does not show any tendency towards the positive or the negative side. To test this hypothesis we compute

$$t = \frac{\overline{d}}{\sqrt{\frac{S^2}{n(n-1)}}},$$

Table 35 b. Some correlation coefficients for individual trees in the years 1948 and 1954 at Stjernarp.

Tree No.	Year	r_{24}	r_{32}	r_{34}	r_{37}	Tree No.	Year	r_{24}	r_{32}	r_{34}	r_{37}
3	1948	0.431	0.797	0.531	0.849	73	1948	0.686	0.854	0.640	0.790
3	1954	0.838	0.947	0.856	0.780	73	1954	0.839	0.904	0.774	0.822
9	1948	0.491	0.801	0.457	0.551	75	1948	0.495	0.737	0.510	0.840
9	1954	0.802	0.370	0.438	0.679	75	1954	0.717	0.980	0.745	0.849
11	1948	0.660	0.870	0.454	0.845	76	1948	0.863	0.958	0.828	0.906
11	1954	0.663	0.971	0.613	0.915	76	1954	0.935	0.963	0.910	0.944
40	1948	0.223	0.880	0.364	0.606	77	1948	0.668	0.880	0.728	0.874
40	1954	0.319	0.916	0.244	0.762	77	1954	0.610	0.790	0.491	0.863
51	1948	0.826	0.968	0.856	0.926	78	1948	0.562	0.887	0.739	0.906
51	1954	0.867	0.946	0.756	0.941	78	1954	0.929	0.960	0.852	0.947
55	1948	0.625	0.693	0.716	0.709	79	1948	0.368	0.867	0.314	0.797
55	1954	0.833	0.854	0.755	0.640	79	1954	0.708	0.863	0.710	0.893
56	1948	0.783	0.937	0.869	0.618	80	1948	0.844	0.852	0.847	0.927
56	1954	0.752	0.953	0.635	0.909	80	1954	0.573	0.933	0.755	0.873
57	1948	0.711	0.840	0.755	0.934	81	1948	0.718	0.808	0.746	0.920
57	1954	0.877	0.915	0.877	0.855	81	1954	0.845	0.730	0.519	0.684
59	1948	0.389	0.936	0.480	0.845	83	1948	0.754	0.954	0.769	0.877
59	1954	0.901	0.972	0.925	0.964	83	1954	0.797	0.912	0.752	0.747
60	1948	0.583	0.879	0.440	0.931	84	1948	0.690	0.802	0.505	0.500
60	1954	0.850	0.969	0.849	0.943	84	1954	0.803	0.909	0.731	0.894
61	1948	0.679	0.825	0.530	0.579	85	1948	0.515	0.884	0.667	0.635
61	1954	0.895	0.981	0.844	0.936	85	1954	0.856	0.985	0.836	0.945
63	1948	0.534	0.860	0.693	0.861	86	1948	0.530	0.865	0.544	0.858
63	1954	0.850	0.970	0.847	0.897	86	1954	0.810	0.992	0.827	0.977
64	1948	0.283	0.899	0.429	0.565	87	1948	0.583	0.797	0.478	0.667
64	1954	0.623	0.844	0.721	0.171	87	1954	0.812	0.986	0.821	0.946
65	1948	0.613	0.834	0.596	0.740	88	1948	0.709	0.863	0.677	0.885
65	1954	0.855	0.938	0.884	0.911	88	1954	0.858	0.945	0.838	0.869
66	1948	0.576	0.857	0.147	0.839	89	1948	0.747	0.905	0.692	0.627
66	1954	0.952	0.991	0.964	0.969	89	1954	0.958	0.969	0.942	0.944
67	1948	0.192	0.830	0.142	0.603	90	1948	0.732	0.902	0.804	0.782
67	1954	0.786	0.982	0.821	0.903	90	1954	0.836	0.669	0.284	0.529
68	1948	0.630	0.854	0.610	0.798	92	1948	0.756	0.842	0.719	0.778
68	1954	0.660	0.972	0.637	0.881	92	1954	0.579	0.942	0.541	0.850
69	1948	0.350	0.783	0.269	0.632	93	1948	0.309	0.898	0.353	0.793
69	1954	0.904	0.952	0.933	0.965	93	1954	0.842	0.895	0.926	0.801
70	1948	0.684	0.775	0.735	0.589	94	1948	0.869	0.934	0.891	0.963
70	1954	0.886	0.923	0.749	0.900	94	1954	0.674	0.911	0.703	0.770
71	1948	0.722	0.938	0.841	0.919	95	1948	0.693	0.907	0.746	0.813
71	1954	0.825	0.984	0.813	0.929	95	1954	0.560	0.756	0.799	0.920
72	1948	0.448	0.607	0.210	0.535						
72	1954	0.807	0.957	0.838	0.798						

where $\bar{d}$ represents the arithmetic average of the n differences, and compare it with the significance points of "Student's" t with $n-1$ degrees of freedom. Although there is a tendency for $\bar{d}$ to deviate slightly from zero in the case of two samples of unequal size (cf. the formula referred to above), the very strong deviation of t-values from zero indicate a clear tendency in all four cases that the correlation within trees is stronger in 1954 than in 1948.

The following t-values were obtained in this way:

	r_{24}	r_{32}	r_{34}	r_{37}	
$t =$	– 6.30***	– 4.80***	– 3.69***	– 3.31**	(at Stjernarp)
$t =$	– 4.47***	– 4.30***	– 3.95***	– 3.05**	(at Skalstugan)

** Statistically significant at the 1 % level.
*** » » » » 0.1 % »

The test values have given us information which can be summarized as follows: 1) the correlations between cones within the individual trees have not remained unchanged from 1948 to 1954 and 2) there is a significant tendency that the changes, for all pairs of variates studied, have gone in the direction of stronger correlation in 1954 than in 1948.

Table 35 a and b also shows that different genotypes have reacted very differently to changes of environment within the same sample plot. For example, trees number 28 and 50 at Skalstugan and number 77 and 94 at Stjernarp have larger correlation coefficients throughout in 1948 than they have in 1954. Only one of these 16 correlation differences, however, reaches the 1 % level of significance. In regard to the four studied correlations, other trees in both stands have significantly larger coefficients in 1954 for one or more pairs of variates. Single genotypes of Norway spruce may thus, in respect to the correlation between cone length and total number of seeds per cone, r_{24}, between cone length and cone weight, r_{23}, between cone weight and total number of seeds per cone, r_{34} and between cone weight and weight of all seeds per cone, r_{37}, react differently to different environmental conditions (i.e. between years). They may also in some cases act differently individually under approximately the same external conditions in the same year and within the same sample plot.

5.2.2.8. Some within-tree regressions and correlations for single trees

For five pairs of variates, the total regression of one variate on another variate have been computed for each one of the 300 trees in the six localities.

Table 36. Average regressions for different sets of pair of variates and for each locality in the year 1954.
(Calculated on sums of squares and products of cones within trees)

Population	Regression equation	Regression equation
Stjernarp	$X_2 = 60.62 + 2.755\ X_3$	$X_4 = 177.38 + 6.584\ X_3$
Gunnarskog	$X_2 = 53.06 + 3.069\ X_3$	$X_4 = 123.59 + 9.863\ X_3$
Skalstugan	$X_2 = 43.70 + 3.645\ X_3$	$X_4 = 85.49 + 12.117\ X_3$
Kvikkjokk	$X_2 = 41.70 + 4.534\ X_3$	$X_4 = 83.07 + 13.476\ X_3$
Gällivare	$X_2 = 42.63 + 4.398\ X_3$	$X_4 = 67.30 + 15.358\ X_3$
Pajala	$X_2 = 44.95 + 3.572\ X_3$	$X_4 = 100.01 + 11.302\ X_3$
Stjernarp	$X_3 = -14.74 + 0.292\ X_2$	$X_7 = 132.95 + 59.091\ X_3$
Gunnarskog	$X_3 = -14.53 + 0.297\ X_2$	$X_7 = -35.91 + 80.254\ X_3$
Skalstugan	$X_3 = -8.02 + 0.222\ X_2$	$X_7 = 3.21 + 62.320\ X_3$
Kvikkjokk	$X_3 = -6.87 + 0.187\ X_2$	$X_7 = -7.51 + 70.807\ X_3$
Gällivare	$X_3 = -6.40 + 0.178\ X_2$	$X_7 = -47.10 + 82.404\ X_3$
Pajala	$X_3 = -7.91 + 0.211\ X_2$	$X_7 = -73.58 + 81.880\ X_3$
Stjernarp	$X_4 = 44.78 + 2.270\ X_2$	
Gunnarskog	$X_4 = -32.52 + 3.063\ X_2$	
Skalstugan	$X_4 = -36.20 + 3.013\ X_2$	
Kvikkjokk	$X_4 = -15.38 + 2.604\ X_2$	
Gällivare	$X_4 = -42.34 + 2.903\ X_2$	
Pajala	$X_4 = -15.06 + 2.763\ X_2$	

N.B. In the table the following variables and units of length and weight have been used:

X_2 = cone length in millimetre
X_3 = cone weight in gram
X_4 = the total number of seeds per cone
X_7 = the weight in milligram of all seeds per cone

For each pair an analysis of variance has been performed on the 300 regression coefficients. It was found that there are significant differences between the six populations, as shown by the following F-values, each one with 5 and 294 degrees of freedom for the numerator, and the denominater, respectively.

Regression of	*Variance ratio (F)*
X_3 on X_2	47.07***
X_2 on X_3	33.45***
X_4 on X_3	10.62***
X_4 on X_2	2.99*
X_7 on X_3	8.73***

In Table 36 the average within tree regressions are given for five of the above pairs of variates. (The regressions of Table 36 are based on sums of squares and products of cones within trees.) All the regression coefficients deviate significantly from zero. (The test of significance might equally well be carried out on the corresponding coefficients of correlation in Table 31.) All the regression coefficients are positive. This is in accordance with the finding of Table 31, that there is a positive correlation between each pair of variates considered. That e.g. the coefficient b_{32} is 0.292 in Stjernarp (if only the total regression of X_3 on X_2 is considered) means that for each increase (or decrease) in cone length of one millimetre there is a corresponding increase (or decrease) in cone weight of 0.292 gram.

The constant term $a = -14.74$ in the same equation would indicate that X_3 has a negative value when X_2 is 0. Such a negative value would, of course, have no biological meaning. It can only be interpreted as a warning not to extend the linear relation between the two variates outside the range of the observations.

On comparing Tables 20 and 36 we find that the coefficients for the regression of X_4 on X_2, X_4 on X_3, and X_7 on X_3, calculated on sums of squares and products of cones within trees, at Stjernarp, Gunnarskog and Skalstugan are numerically greater than the coefficients for the corresponding regressions in 1948. We also find that the coefficients for the regression of X_3 on X_2 (at Stjernarp and Gunnarskog) are larger in 1948 than in 1954. A test of the significance shows that these differences (with the exception of the difference between the b_{32}-coefficients at Skalstugan) are highly significant. The differences, on the average, are much greater between years than between populations in one and the same year.

The frequency distribution of individual trees according to inter-cone correlations of a number of variables in 1954 is presented in Table 32. The corresponding distribution in 1948 is found in Table 17. In the same way as for the 1948 data, the present data have been analysed in order to test the possible equality of the six sets of coefficients (from the six different localities). The following F-values were obtained in the analysis of variance of the transformed correlations:

The sets of correlation coefficients	*The values of F (for differences between population means of coefficients within each set)*
r_{23}	13.00***
r_{34}	7.55***
r_{37}	13.42***
r_{24}	9.22***

The degrees of freedom for the population mean squares are 5, and for the error mean squares (for individual trees within populations) 294. Thus, for any one of the pairs of variates the 300 correlation coefficients cannot be

Table 37. Correlation between tree means for individual populations and for the six populations treated as one group in the year 1954.

Between the variables \ Population	Stjernarp	Gunnar-skog	Skal-stugan	Kvikk-jokk	Gällivare	Pajala	The six populations
	r	r	r	r	r	r	r
X_2 and X_3...........	0.870	0.877	0.748	0.828	0.754	0.722	0.944
X_4...........	0.400	0.483	0.636	0.229	0.577	0.358	0.859
X_7...........	0.700	0.696	0.601	0.412	0.421	0.552	0.877
X_3 and X_4...........	0.335	0.416	0.635	0.410	0.679	0.527	0.844
X_7...........	0.709	0.716	0.795	0.551	0.523	0.769	0.898
X_4 and X_7...........	0.222	0.543	0.819	0.510	0.514	0.562	0.851

Correlation based on:	D.F.	Value of r different from zero at the P % level of significance $P = 5$ %	$P = 1$ %
1) 50 trees in one locality	48	0.279	0.361
2) 300 trees treated as one group	298	0.114	0.149

X_2 = cone length
X_3 = cone weight
X_4 = the total number of seeds per cone
X_7 = the weight of all seeds per cone

considered as random samples from six identical populations of coefficients. Also the observed variance of z-values within populations are significantly greater than those expected on the assumption that the cones from the 50 trees in the same population are samples from 50 populations having the same correlation between the investigated properties. The four χ^2-values for the discrepancies between the observed and expected sums of squares exceed the 0.1 % level of significance. Significant differences exist therefore, between trees, in regard to the strength of the correlations between the investigated variables. As seen in Table 32 the correlations can be negative for some trees, and positive for others.

5.2.2.9. Some comparisons of between-tree correlations in 1954 and 1948 and of within-tree and between-tree correlations in 1954 with respect to morphological cone and seed characters

As was found for the inter-tree correlations between morphological cone and seed characters in 1948, the corresponding correlations in 1954 vary in magnitude, and in some cases in sign for different pairs of characteristics and from locality to locality. Both similarities and dissimilarities exist within and between years in regard to correlation coefficients in the three localities which were studied in 1948 and 1954.

A comparison of Table 9 (together with the values of r_{27}, r_{37} and r_{47} on page 71) with Table 37 shows that among the similarities, with respect to the sign and relative size of the correlations in both years, are included: 1) that two of the three localities (Stjernarp and Gunnarskog) show very weak and insignificant associations between 1,000-grain weight of all seeds per cone (X_1) and total number of seeds per cone (X_4), 2) that the populations at Stjernarp and Skalstugan show a positive and strong correlation between cone length (X_2) and cone weight (X_3), 3) that there is no significant difference between Stjernarp and Skalstugan with respect to the value of r_{23}, neither in 1948 nor in 1954, 4) that the correlations between the variables X_2 and X_4 at Stjernarp and Skalstugan in both years are positive and highly significant and about the same relative size, yet these coefficients do not account for much of the variation present, 5) that there is also no difference between the two localities or between the two years with respect to the value of r_{32}, 6) that the correlation between the variables X_3 and X_4 is positive, significant and moderate in strength at each of the three localities and no difference between any pair of the r_{34}-coefficients reaches the 5 % level of significance, 7) that there is no significant difference between the years, nor between the three localities, as to the values of r_{37}, 8) that the correlations between X_4 and X_7 are positive in the three localities, strong at Skalstugan and highly significant at Skalstugan and Gunnarskog in both years, and 9) that the correlation between the variables X_3 and X_4 and between X_3 and X_7 is in both 1954 and 1948 strongest at Skalstugan and between X_2 and X_7 strongest at Stjernarp.

Among the dissimilarities between and within years regarding the studied correlations at Stjernarp, Gunnarskog and Skalstugan are the following: 1) that 1,000-grain weight in 1954, contrary to 1948, is negatively associated with the total number of seeds per cone both at Stjernarp and Gunnarskog, 2) that the correlation between the characteristics just mentioned (X_1 and X_4) at Skalstugan in 1954 is, contrary to 1948, significantly larger than in both Stjernarp and Gunnarskog (the difference is significant at the 1 % level), 3) that the correlation between cone length and cone weight at Gunnarskog in 1954 deviates in a highly significant manner from the corresponding coefficient at Gunnarskog in 1948 (the significance exceeds the 0.1 % level), 4) that the difference between 1954 and 1948 in regard to the value of r_{24} at Gunnarskog is significant at the 1 % level, and that the difference between Stjernarp and Gunnarskog as to the value of r_{24} is significant at the 1 % level in 1948 but not in 1954, 5) that the correlation between the characteristics X_2 and X_7 at Gunnarskog is significantly stronger (at the 5 % level) in 1954 than in 1948, 6) that in 1954, contrary to 1948, significant differences exist between the localities for the association of the total number of seeds per cone with the weight of all seeds per cone (the difference between the r_{47}-coefficient at Skalstugan and Stjernarp in 1954 exceeds the 0.1 % level and the one between Skalstugan and Gunnarskog the 5 % point of significance) and 7) that the correlation difference between X_4 and X_7 is significantly higher (at the 1 % level) in 1954 than in 1948, both in Stjernarp and Gunnarskog.

Summing up the above comparisons and the comparisons between within-tree and between-tree correlations (Tables 31 and 37) we find 1) that significant positive correlations exist within each pair of variates, 2) that (if the values of r_{14} and r_{17} are included in the comparisons) significant differences between localities are found in seven of eight studied pairs of variates, 3) that (with the exception of the associations of the 1,000-grain weight of all seeds per cone with the weight of all seeds per cone) the strongest associations are found, in general, between cone length and cone weight and between these two cone properties on the one hand and the seed characteristics on the other, 4) that significant differences between years are found in four of eight pairs within one or two out of three localities, 5) if the correlation studies are extended to include comparisons between inter-tree and within-tree associations in 1954, we find a very high percentage of significant differences in correlation between within-tree and inter-tree coefficients (see Tables 31 and 37), 6) that most of these differences are highly significant, and 7) that the within-tree coefficients, almost without exception, are larger than the inter-tree coefficients.

5.2.2.10. Some partial inter-tree correlations of cone and seed properties in 1954

Partial correlation coefficients for several associations between the characteristics are calculated and presented in Table 38.

It is apparent from Table 38 that some of the partial correlation coefficients of the first order for the associations studied are similar to their respective simple correlation coefficients in Table 37, whereas the associations between other variables have changed either in size or in direction or both. In some cases the correlation differences between localities, in relation to the differences between total correlation coefficients, have been changed in a significant manner. It would seem that, when seed properties are kept constant, the partial correlations between cone characters do not convey much more information than the corresponding total correlations.

The partial coefficients of the first order for the association of cone length with seed weight are not significant when cone weight is held constant. The association of cone weight with seed weight ($r_{37.2}$) is on the average weak to moderate and significant when cone length is held constant. The association ($r_{37.24}$) of cone weight with seed weight is insignificant in three of six localities when the influence of both cone length and number of seeds is eliminated.

The association of weight of all seeds per cone with total number of all seeds per cone reaches significance in four of six localities when the influence of both cone length and cone weight is eliminated. The partial coefficient of

Table 38. Partial inter-tree correlations in 1954.

$r_{xy \cdot z}$ \ Population	Stjernarp	Gunnar-skog	Skalstugan	Kvikkjokk	Gällivare	Pajala
$r_{23.4}$	0.852	0.849	0.577	0.827	0.604	0.672
$r_{23.7}$	0.742	0.755	0.557	0.790	0.690	0.558
$r_{24.3}$	0.234°	0.270°	0.314	—0.216°	0.135°	—0.038°
$r_{24.7}$	0.351	0.174°	0.314	0.024°	0.463	0.069°
$r_{27.3}$	0.239°	0.203°	0.016°	—0.095°	0.048°	—0.007°
$r_{27.4}$	0.684	0.590	0.181°	0.353	0.178°	0.454
$r_{34.2}$	—0.029°	—0.018°	0.311	0.404	0.455	0.416
$r_{34.7}$	0.258°	0.046°	—0.046°	0.180°	0.561	0.179°
$r_{37.2}$	0.284	0.306	0.651	0.411	0.345	0.642
$r_{37.4}$	0.691	0.642	0.620	0.436	0.276°	0.673
$r_{47.2}$	—0.089°	0.329	0.708	0.469	0.366	0.468
$r_{47.3}$	—0.023°	0.386	0.670	0.373	0.254°	0.289

	D.F.	$P = 5$ %	$P = 1$ %
	Value of r different from zero at the P % level of significance		
Partial correlation of the first order based on 50 trees in one locality	47	0.282	0.365

$r_{xy \cdot zu}$ \ Population	Stjernarp	Gunnar-skog	Skalstugan	Kvikkjokk	Gällivare	Pajala
$r_{23.47}$	0.720	0.759	0.603	0.799	0.586	0.556
$r_{24.37}$	0.246°	0.213°	0.409	—0.196°	0.127°	—0.038°
$r_{27.34}$	0.252°	0.111°	—0.276°	—0.015°	0.015°	0.003°
$r_{34.27}$	—0.004°	—0.132°	—0.280°	0.263°	0.376	0.170°
$r_{37.24}$	0.283°	0.331	0.642	0.274°	0.215°	0.558
$r_{47.23}$	—0.084°	0.351	0.700	0.363	0.250°	0.289

	D.F.	$P = 5$ %	$P = 1$ %
	Value of r different from zero at the P % level of significance		
Partial correlation of the second order based on 50 trees in one locality	46	0.285	0.368

° Note that the value of r does not reach the 5 % level of significance

the second order ($r_{47.23}$) at Skalstugan is significantly larger than any of the other five coefficients for the corresponding association.

A test of the significance of the differences between comparable partial inter-tree correlations (Table 38) and within-tree correlations in 1954 (Table 33) shows that a number of significant correlation differences exist especially between coefficients of the first order. Thus, there are differences significant at the 1 % level between the inter-tree and within-tree correlation coefficients $r_{47.3}$ at Kvikkjokk, $r_{23.4}$, $r_{27.4}$ and $r_{37.4}$ at Gällivare and at the 0.1 % level between the coefficients $r_{34.7}$, $r_{47.2}$ and $r_{47.3}$ at Gällivare. Significant correlation differences at the 5 % level for example, are found between the coefficients $r_{47.2}$ and $r_{47.3}$ at Stjernarp, $r_{34.7}$ at Gunnarskog, $r_{23.4}$ at Skalstugan and $r_{47.2}$ at Kvikkjokk. Only a few significant correlation differences between inter-tree and within-tree coefficients of the second order are found in this material.

5.2.3. Examples of the application of multivariate methods

The presentation of the variation of the observations of cone and seed characters has been made with the help of the concepts and symbols of such now classical statistical fields as analysis of variance, regression and correlation analysis. These are no doubt familiar to the presumptive readers of the paper. This has, however, lead to a rather extensive tabulation of standard deviations, regressions, correlation coefficients etc. It is of a certain interest to try to use some of the more recent methods in multivariate analysis such as discriminant functions, component analysis etc. in order to reduce the presentation to a number of statistics intended to contain, in a concentrated form, as much as possible of the information relevant for the particular problems of estimation and testing considered. For multivariate methods the reader is referred to textbooks, e.g. RAO (1952), ANDERSON (1958), KENDALL (1961). (For genetic applications similar to those shown here see e.g. CLIFFORD & BINET, 1954, pp. 325—336.)

In order to illustrate these methods, two examples, closely related to one another, will be given. For the statistical methods involved, see KENDALL (1961), pp. 167—169. The computations have been carried out on the computer BESK by means of a program (Q9) for finding generalized eigenvalues and eigenvectors.

In the first example the observations from 1954 of the tree means of the variables X_1, X_2, X_3, X_4, X_7 and X_{10} in the six localities are utilized. We try to form new variables of the type

$$W_1 = a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 + a_7X_7 + a_{10}X_{10}$$

which can efficiently discriminate between the six populations. By this we shall mean that the variance ratio "between/within" is large. (More specifically, the variance ratio is the quotient obtained by dividing the mean square between localities by the mean square between trees within localities.) Determining the coefficients in such a way that the variance ratio is maximized, one obtains the maximum ratio $F_1 = 261.63$ for the variable

$$W_1 = 0.31\ X_1 + 4.36\ X_2 + 0.51\ X_3 + 24.76\ X_4 - 0.28\ X_7 + 1.31\ X_{10}.$$

The expression has been normed in such a way that the mean square "within localities" is 10^6. We then try to supplement W_1 by a new variable W_2 orthogonal to W_1 (in the sense that the "within localities" covariance of W_1 and W_2 vanishes) and having the highest possible variance ratio. This condition is satisfied by

$$W_2 = 2.50\,X_1 + 2.22\,X_2 - 3.00\,X_3 - 13.06\,X_4 + 7.32\,X_7 - 6.47\,X_{10}$$

having maximum variance ratio, $F_2 = 20.69$, among variables orthogonal to W_1. Proceeding in the analogous way, four more variables are found, mutually orthogonal and orthogonal to W_1 and W_2 with the variance ratios $F_3 = 5.78$, $F_4 = 3.35$, $F_5 = 0.05$, and $F_6 = 0.00$ respectively. The sum $F_1 + F_2 + \ldots + F_6 = 291.50$ can be considered as a measure of the total difference between the six localities with respect to the variables X_1, X_2, X_3, X_4, X_7, and X_{10}. From the high value of F_1 it is seen that Z_1 accounts for an essential part of this difference. Comparing the coefficients $a_1, a_2, \ldots, a_{10}$ in Z_1 with the variation (standard deviation within localities) of the respective variables, it is seen that the coefficients of X_2 (cone length) and X_4 (total number of seeds per cone) are comparatively large, whereas X_3 (cone weight) and X_{10} (germination capacity of all seeds) have moderate coefficients. The coefficients of X_1 (thousand-grain weight of all seeds) and X_7 (weight per cone of all seeds) are small in comparison with the variation of these variables.

It is found that the total difference between the localities with regard to the four variables X_2, X_3, X_4, and X_7, expressed in the way described above, amounts to 269.11. Of this variation, the greater part, corresponding to a variance ratio of 254.93, is accounted for by the variable

$$Z_1 = 4.37\,X_2 + 0.33\,X_3 + 23.12\,X_4 + 0.72\,X_7$$

which is the linear combination of the four variables having the highest variance ratio. It is seen that Z_1 has an almost as good power to discriminate between the populations as W_1. Supplementing Z_1 by the "best" discriminator orthogonal to Z_1, and having, as has Z_1, the mean square 10^6 within localities we find

$$Z_2 = -2.37\,X_2 - 3.13\,X_3 - 12.98\,X_4 + 7.71\,X_7.$$

However, the corresponding variance ratio is as low as 9.0. Trying to reduce further the number of original variables entering into the linear expression one arrives at the expression

$$U_1 = 5.98\,X_2 + 24.85\,X_4$$

which is the linear expression in two of the original variables with the highest variance ratio (250.7). Thus U_1 contains a considerable part, or 86 %, of the "total difference" 291.5. It is not possible to obtain a very good discrimination by using only one of the original variables. The highest

Table 39. Averages of certain linear combinations of observations.

Locality	Average of				
	W_1	Z_1	U_1	X_2	X_4
Gällivare	7,089	6,867	7,729	666	151
Kvikkjokk	7,677	7,350	8,246	693	165
Pajala	7,933	7,470	8,325	677	172
Skalstugan	8,815	8,427	9,291	757	192
Gunnarskog	11,721	11,428	12,187	955	260
Stjernarp	12,573	12,112	12,999	1,023	277

variance ratio (198.9) is obtained for the variable X_4, the second highest (164.5) for X_2.

It is of a certain interest to compare the mean values of the variables in the six localities. These means are given in Table 39, where the localities are ranged in ascending order of the values of W_1. It is seen that the order is the same also according to Z_1, U_1, and X_4. In the case of X_2, Kvikkjokk and Pajala are interchanged.

It is seen, however, that these two localities show no great discrepancies in regard to the values of W_1, Z_1, and U_1. The other differences between localities are greater. There is an especially large difference between the group consisting of Gunnarskog and Stjernarp and the group comprising the four other localities.

One might label the three closely related variables W_1, Z_1, and U_1 as expressions of the "size" of the cones, whereas the supplementary variables W_2 and Z_2 have a more complicated structure. W_2 might perhaps be considered as related to the "form" of the cones, having coefficients of opposite signs for X_2 and X_3 (cone length and cone weight, respectively), and positive coefficient for X_7 (weight of all seeds per cone) and negative for X_4 (number of all seeds per cone). This variable has, however, a comparatively poor discriminating power.

One might now surmise that the most easily recognizable differences between seeds and cones from widely separated localities refer to the size of the cones, as expressed e.g. by Z_1. This does not preclude the possibility that the differences between trees in the same locality are also primarily related to the size of the cones. However, an analogous comparison of the variation "between trees" in one locality with the variation "between cones within trees" has not given a clear indication of any similar "size variable", accounting for the main differences "between trees". This comparison is made for Kvikkjokk (1954). For this locality, sums and squares and products within and between trees are available for the variables X_2, X_3, X_4, and X_7, i.e. those four variables that are found to contain most information about the differences between populations. The variable

$$V_1 = 25.19\,X_2 - 19.10\,X_3 - 30.37\,X_4 + 12.72\,X_7$$

is the one with maximum variance ratio "between trees" divided by "within trees". The variance ratio corresponding to V_1 is $F_1 = 48.10$. Proceeding to the possible three more orthogonal (within trees) variables, one gets the variance ratios $F_2 = 37.85$, $F_3 = 23.48$, $F_4 = 7.95$. Thus $F_1 + F_2 + F_3 + F_4 = 117.38$. Hence no single linear expression accounts for any greater portion of the variation between trees. The variable with the highest variance ratio, V_1, seems to have some resemblance, although not very distinct, to the supplementary variables W_2 and Z_2 considered above. The linear combination of two variables with the highest variance ratio is

$$36.46\,X_2 - 20.18\,X_3.$$

The corresponding variance ratio is 42.52. Evidently, this expression is more related to the form of the cones than to their size. The original variable with the highest variance ratio (20.02) is X_3.

It is possible to perform other types of multivariate analyses by utilizing the tables of variances, correlations etc. given in the text and the Appendix of the present work.

6. The variation of seed quality

The quality and production of the seed of forest trees, as already mentioned in the introduction, is of great interest for forestry. Access to the necessary quantities of forest tree seed of good genotypic and physiological qualities is the most important requirement for all natural and artificial regeneration. The variations in seed quality and seed crop, like the relationships between cone and seed properties and between seed properties, are influenced by conditions of environment and the genotypical constitution of the trees. A greater knowledge of how these factors affect the formation and the fertility of gametes, seed crop, seed quality and plant development, etc., as well as information on the interaction between genotype and milieu, with respect to different seed and cone characters, is therefore of great interest both for the immediate and for the future provision of forest tree seed. The reproductive fitness of trees for localities with varying climatic conditions, and especially for extremely high altitudes, is of great importance for gamete fertility (ANDERSSON, 1947 and 1954), and for endosperm, embryo and seed development, and seed production (cf. SIMAK and GUSTAFSSON, 1954, and GUSTAFSSON, 1962).

The present part of this work concentrates on the variation of seed quality, including seed germination capacity, the percentage of empty seeds (not damaged by insects), the frequency of seeds (not damaged by insects) with embryo unable to germinate, and the frequency of seeds damaged by insects. The production of seed in 1948, expressed as the number of seeds per cone, has been described and analysed in the same way as the weight of seeds in that year. Mean values for the production and the weight of seeds can be found in the Appendix Tables I—V. Analyses of variance are shown in Tables 4—8. The variation in seed production and seed weight in 1954 is presented in Table 23 and in the Appendix Tables VI—XI. The results of the studies of seed quality for localities are given in Tables 40 and 41, and for individual trees within each sample plot in the Appendix Tables XVII—XXI and XXIII—XXXIV.

6.1. Seed quality in the material of 1948

The present study of seed quality was not designed to determine the variation within trees. Therefore, it is not possible to test whether the variation between trees is larger than the variation within trees. It is interesting, however, to note that the variation between individual trees seems to be very evident within geographical localities. The percentages of empty seeds for individual trees listed in the Appendix Tables XVII—XXI A and B show, namely, a large range of variation within each locality. For example, the percentage of empty seeds not damaged by insects amongst *all seeds not damaged by insects* (see Appendix Tables XVII B—XXI B) varies at Stjernarp (embryo type 0+I) from 34 to 89 with a mean of 62 (the standard errors of means are presented in Table 40). At Härryda this percentage varies from 9 to 83, with a mean of 39 (see Appendix Table XVIII B), at Gunnarskog from 28 to 89, with a mean of 55, at Höljes from 20 to 77, with a mean of 50, and at Skalstugan from 32 to 96, with a mean of 72.

The range of variation in empty seeds between trees within the plots may therefore be considered as large for this material. Both variance analysis and a comparison of means (see Table 40) show that the differences between localities are highly significant. The F-value (38.44) exceeds the 0.1 % level of significance. It can be seen from Table 40 that the percentages of empty seed not damaged by insects amongst all seeds in 1948 are 62, 37, 50, 49 and 70, at Stjernarp, Härryda, Gunnarskog, Höljes and Skalstugan respectively. Thus the percentage of empty seeds is very high in the Central European spruce at Stjernarp. By analysing the corresponding angular values it is seen that this percentage is significantly greater ($P < 0.1$ %) than the corresponding percentages for spruce of native origin at Härryda and Gunnarskog and even from the plot at Höljes, despite the fact that the climatic conditions at Stjernarp were much more favourable for the formation of gametes and for flowering and seed development than at the other three mentioned localities. The environmental influences on meiosis and on seed formation at Skalstugan are especially strong and not at all comparable with corresponding conditions at Stjernarp. The meiotic disturbances, as mentioned earlier, will be discussed in detail in a later work "Studies of Meiosis in Norway spruce (*Picea abies* (L.) Karst.)".

The reason for the high percentage of empty seed is not clear, but may in stands of Norway spruce be due to: 1) the possibly high frequency of recessive lethal genes which should cause a certain percentage of embryo mortality, i. e. the homozygous recessive type dies, 2) a varying degree of spontaneous self-fertilization (cf. LANGNER, 1953) and that the degree of self-sterility varies from tree to tree (cf. SYLVÉN, 1910, LANGLET, 1940, ANDERSSON, 1947 b, and KLAEHN and WHEELER, 1961), and possibly from offspring to offspring (see Appendix Table XLI), probably depending on the occurrence of incompatibility factors, located at one or more loci, acting at different levels through interactions between genes and between embryo and surrounding tissues, or the presence of *recessive* lethal or sub-lethal genes which after

Table 40. Mean values in seed quality for populations in the year 1948.

Calculated on tree values with the guidance of the embryo and endosperm development ($n = 48$)

Population	Stjernarp			Härryda			Gunnarskog			Höljes			Skalstugan		
Seed quality	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error
Germination rate in per cent of total number of seeds	35.92	35.40	36.52±1.08	56.83	57.00	49.03±1.57	39.66	39.20	38.75±1.17	46.66	46.50	42.98±1.19	7.83	7.10	15.50±0.75
Empty seeds (not damaged by insects) in per cent of total number of seeds	61.58	61.60	51.70±1.12	38.04	37.40	37.67±1.73	50.15	50.30	45.16±1.29	49.25	49.20	44.52±1.27	69.38	70.30	56.99±1.30
Seeds damaged by insects in per cent of total number of seeds	0.80	0.26	2.90±0.51	2.79	2.10	8.26±0.68	8.42	7.60	16.05±0.80	1.10	0.53	4.19±0.55	4.15	3.60	10.99±0.62
Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	1.70	1.60	7.25±0.28	2.34	2.20	8.51±0.33	1.77	1.70	7.47±0.23	2.99	2.80	9.56±0.42	18.64	17.60	24.79±1.08
	100 %			100 %			100 %			100 %			100 %		
Germination rate in per cent for all seeds not damaged by insects	36.21	35.80	36.77±1.04	58.62	59.00	50.18±1.66	43.51	43.10	41.03±1.29	47.22	47.10	43.36±1.24	8.16	7.50	15.85±0.76
Germination rate in per cent for all seeds (not damaged by insects) with embryo	95.41	95.60	77.90±0.40	96.10	96.20	78.78±0.31	95.61	95.70	78.06±0.30	93.83	94.30	76.13±0.60	29.15	28.80	32.46±0.79

* transformed by the formula, angle $= \arcsin\sqrt{\text{percentage}/100}$

fertilization, in more difficult cases, can cause the death of homozygotes for the *recessive* lethals or sub-lethals (death may occur under these circumstances at any stage after fertilization), 3) partial gametic sterility owing to the fact that a tree, a population or a provenance is not well adapted generatively to the climatic conditions at a locality, i. e. having an increased sensitivity to temperature disturbances of meiotic divisions and of the mitotic divisions in the gametes (see the Figs. 33—36), 4) damages by insects, 5) the occurrence of partial or complete gametic sterility among trees caused by genetically influenced structural aberrations of chromosomes, 6) delayed pollination, involving cases where the egg cells degenerate, 7) non-pollination, i.e. fertilization has failed because of lack of pollen (cf. SARVAS, 1955, p. 34, and 1958, p. 13) and 8) a combined effect of two or more causes (of those just mentioned 1—7).

Mutations that change the fertility may arise, but dominant lethal genes disappear with their carriers. Dominant lethals result, however, in the death of all gametes which carry such genes.

On seeking for an explanation of the high frequency of empty seed at Stjernarp one finds that numbers 6 and 7 in the list are the most unlikely because flowering intensity was higher at Stjernarp than at Härryda, Gunnarskog and Höljes, and furthermore, the stand density was higher at Stjernarp than at any of the other localities.

The conditions for pollination may also change from year to year and from locality to locality according to the direction of the wind, wind-force, turbulence, air moisture, male flowering intensity, topographical conditions, the frequency of own species' remote-pollen, and the distance to near-pollen sources of own tree species (cf. ANDERSSON, 1955, SARVAS, 1955, and STRAND, 1957). In this connection the time sequence in flowering of the two sexes of flowers is important. If pronounced metandry (protogyny) exists it can mean a protection against self-fertilization. Simultaneously, the risk increases that the female flowers, lacking pollen, or because of delayed pollination can be too old or inconceptible for fertilization. A certain frequency of empty seeds can also be created, under certain conditions, as a result of the metandry. The conditions which must exist in such a case, in addition to metandry, are, 1) that the tree species is able to produce empty seeds without fertilization (which is the case with Norway spruce), and 2) that the amount of own species' remote-pollen in the air is very small or non-existant. A tendency for metandry is indicated in *Picea abies* (cf. SYLVÉN, 1910, p. 222 (406*), 1916, p. 53, and SYRACH LARSEN, 1937, p. 124 and Fig. 27 in this work). It is therefore not impossible that a certain frequency of empty seeds was produced at Stjernarp just because pollination of the earliest opened conceptible female flowers was delayed or incomplete. The probability of this assumption is

Table 41. Mean values in seed quality for populations in the year 1954.

Calculated on tree values with the guidance of the embryo and endosperm development ($n = 50$)

Population	Stjernarp			Gunnarskog			Skalstugan			Kvikkjokk			Gällivare			Pajala		
Seed quality	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error	Average percentage (not transformed)	Angular transformation expressed as percentage	Corresponding angle* with standard error
Germination rate in per cent of total number of seeds	51.30	51.30	45.77 ± 1.43	44.14	43.60	41.34 ± 1.49	16.50	16.00	23.54 ± 0.73	25.15	23.3	28.83 ± 1.54	24.71	23.80	29.21 ± 1.05	28.96	27.70	31.75 ± 1.41
Empty seeds (not damaged by insects) in per cent of total number of seeds	46.21	46.00	42.70 ± 1.48	52.05	52.30	46.33 ± 1.54	44.83	44.60	41.90 ± 1.32	39.88	39.20	38.78 ± 1.55	47.90	47.80	43.72 ± 1.62	57.94	58.40	49.81 ± 1.38
Seeds damaged by insects in per cent of total number of seeds	0.24	0.08	1.61 ± 0.33	1.69	1.20	6.26 ± 1.86	3.03	2.30	8.67 ± 0.74	2.29	1.70	7.59 ± 0.52	11.82	10.40	18.86 ± 1.10	3.15	2.50	9.19 ± 0.65
Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	2.25	2.10	8.31 ± 0.34	2.12	1.90	7.94 ± 0.39	35.64	35.20	36.39 ± 1.00	32.68	31.50	34.15 ± 1.52	15.57	14.80	22.63 ± 0.85	9.95	9.30	17.74 ± 0.75
	100 %			100 %			100 %			100 %			100 %			100 %		
Germination rate in per cent for all seeds not damaged by insects	51.43	51.50	45.84 ± 1.43	44.91	44.50	41.81 ± 1.51	17.05	16.40	23.88 ± 0.74	25.88	24.70	29.77 ± 1.42	28.37	27.30	31.52 ± 1.17	29.97	28.70	32.38 ± 1.45
Germination rate in per cent for all seeds (not damaged by insects) with embryo	95.71	95.90	78.39 ± 0.43	95.31	95.60	77.90 ± 0.51	31.49	31.20	33.97 ± 0.69	44.05	43.70	41.40 ± 1.77	60.68	60.90	51.28 ± 0.93	71.21	72.50	58.40 ± 1.62

* transformed by the formula, $\text{angle} = \arcsin \sqrt{\text{percentage}/100}$

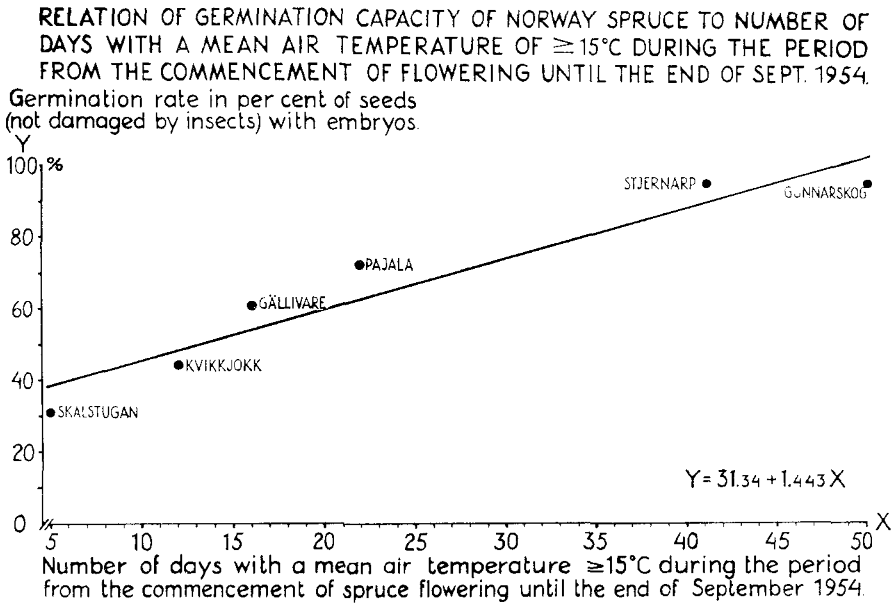


Fig. 22.

Tables XVII B—XXI B, which together with the Appendix Tables XVII A —XXI A and Table 40 summarize the results of the seed germination studies in 1948, that the germination rate in per cent of all seeds varies strikingly from tree to tree within each sample plot. The total range of variation in germination rate (Appendix Tables XVII B—XXI B) expressed in per cent of the total number of seeds, extends at Stjernarp from 10 to 63, with a mean of 36, at Härryda from 16 to 85, with a mean of 57, at Gunnarskog from 10 to 62, with a mean of 40, at Höljes from 22 to 74, with a mean of 47, and at Skalstugan from 1 to 23, with a mean of 8.

In order to facilitate the understanding of the remaining germination percentages given in the Appendix Tables XVII B—XXI B and XXIX B —XXXIV B it can be stated that the germination rate in per cent of all seeds not damaged by insects is given by the formula

$$\frac{100\,G}{100-i}$$

where G is the calculated germination rate in per cent of all seeds (on the assumption that seeds, damaged by insects, with embryo do not germinate), and i the percentage of all seeds damaged by insects. The germination rate in per cent of all seeds (not damaged by insects) with embryo [cf. the sum of the percentages of the embryo and endosperm classes II A—IV B in Appendix Tables XVII A—XXI A and XXIX A—XXXIV A which is $=100-(i+0+I)$] is obtained as

$$\frac{100\ G}{100-(i+0+I)}$$

where 0 means empty seeds (not damaged by insects) containing neither embryo nor endosperm, I denotes empty seeds (not damaged by insects), containing endosperm but no embryo, and $0+I$ represents the total frequency of empty seeds (not damaged by insects) expressed in per cent of all seeds. Seeds (not damaged by insects) with embryo unable to germinate, in per cent of total number of seeds, is expressed as

$$100-(0+I+i+G).$$

Finally, the percentage of seeds (not damaged by insects) with embryo unable to germinate amongst all seeds (not damaged by insects) with embryo is given by the ratio

$$\frac{100\ [100-(0+I+i+G)]}{100-(0+I+i)}.$$

It can be seen from the Appendix Tables that the germination rate *for all seeds not damaged by insects* shows about the same range and pattern of variation within localities. The germination rate in per cent of *all seeds (not damaged by insects) with embryo* falls, at Stjernarp within a range from 88 to 97, with a mean of 95, at Härryda from 88 to 97, with a mean of 96, at Gunnarskog from 90 to 97, with a mean of 96, at Höljes from 74 to 97, with a mean of 94, and at Skalstugan from 16 to 52, with a mean of about 29.

The percentage of seeds (not damaged by insects) with embryo unable to germinate amongst all seeds (undamaged by insects) with embryo, ranges, at Stjernarp from 3 to 12, with the average 4.6, at Härryda from 3 to 12, with a mean of 4, at Gunnarskog from 3 to 10, with a mean of 4, at Höljes from 3 to 26, with a mean of 6, and at Skalstugan within 48 to 84, with a mean of about 71.

The mean percentages of seeds damaged by insects for trees and populations are listed in the Appendix Tables XVII A—XXI A. This percentage falls, at Stjernarp within 0 to 5, with a mean of 0.8, at Härryda within 0 to 7.5, with a mean of 2.8, at Gunnarskog within 0.5 to 23.0, with a mean of 8.4, at Höljes within 0 to 6.5, with a mean of 1.1, and at Skalstugan within 0 to 17, with a mean of 4. The latitudinal range of the sample plots in this study for the year 1948 is rather great, ranging from 56° 38' N at Stjernarp to 63° 34' N at Skalstugan. The range of variation in height above sea level for these plots is also considerable for Scandinavia, ranging from 35 m. at Stjernarp

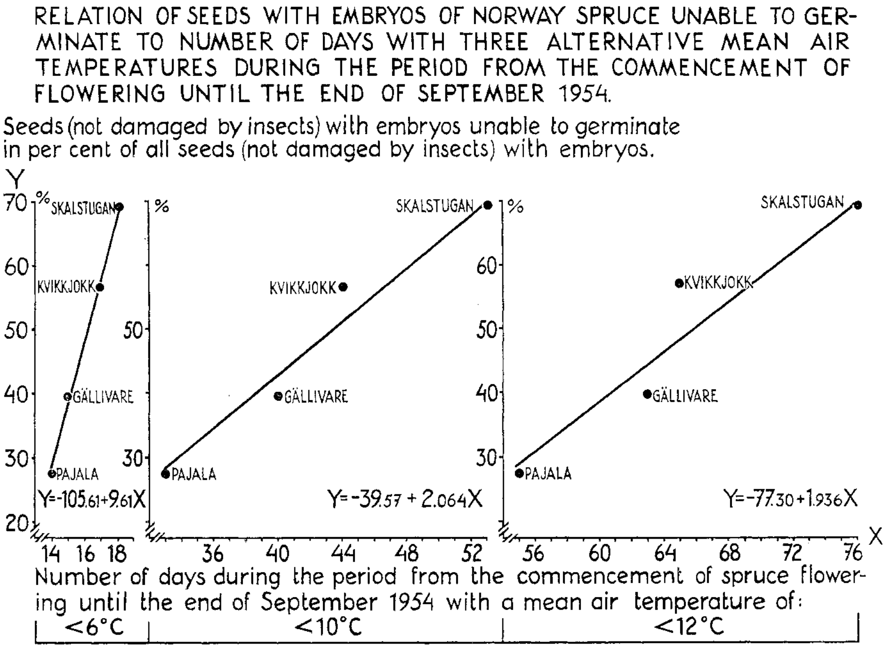


Fig. 23.

to 660 m. at Höljes and 585 m. at Skalstugan. It is therefore not surprising that differences exist between the geographic localities in regard to seed properties. Highly significant differences are also found between localities for all the examined seed quality properties (seed yield per cone included). The obtained F-values all have a significance far beyond the 0.1 % point of significance and accordingly, may be considered to be very highly significant. For instance, the variance ratio, F, (calculated on angular values) between geographic areas is, for seeds damaged by insects in per cent of total number of seeds 68.56 *** with 4 and 235 d. f. for the variances between and within areas respectively, for seeds (not damaged by insects) with embryo unable to germinate in per cent of the total number of seeds 176.58 ***, for seeds (undamaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo 1,558.16***, for germination rate in per cent of total number of seeds 115.10*** and for empty seeds not damaged by insects, here amongst all seeds, 29.57***. All variance ratios have the same number of degrees of freedom.

As it will be impossible to determine, only from this analysis, whether the variation found between populations and areas is primarily due to environmental or genotypic causes, it may be added that the found cytological abnormalities of meiosis and pollen mitosis in Norway spruce (cf. Figs. 33—36) seem to be a result, in a certain degree, of the combined effect of variables of air temperature and time exposure to the temperature, as well as of interactions between these variables and the genotypical constitutions of the trees. The interactions of the various combinations of trees on the one hand and variables of temperature and the time factor on the other hand seem to produce rather complex results in terms of pollen fertility and seed set. The disturbances of meiosis vary with: the number of degrees of frost, the exposure of the flower buds to an unfavourable temperature, the rate of the changes of temperature, the range of the variation in temperature, and with the genotypic constitution and reproductive fitness of the trees. The failure of normal development of conifer seeds (undamaged by insects) containing embryo, seems to be attributed to a low average temperature during the seed maturing period. The effect of temperature during this period has earlier been pointed out by, inter alios, KUJALA (1927), WIBECK (1931), MORK (1933, pp. 124—132), NORDSTRÖM (1950 and 1955), SIMAK and GUSTAFSSON (1954), EHRENBERG, GUSTAFSSON, PLYM FORSHELL and SIMAK (1955), and MÜLLER-OLSEN, SIMAK and GUSTAFSSON (1956). It can also be seen from the regression in Fig. 22 that the seed germination rate in per cent of all seeds (undamaged by insects) with embryo, is strongly influenced by the number of days with a mean air temperature $\geqq$ 15° C. during the seed maturing period. The correlation between these two variables is 0.960** with 4 degrees of freedom. Likewise, the regressions for the four populations in Fig. 23 illustrate a positive significant relationship between the failure of seed maturity and the number of days with a mean air temperature of $<$ 6°, $<$ 10°, and $<$ 12° C. respectively during the seed maturing period. The coefficients of correlation for the associations of seeds with embryo unable to germinate, amongst all seeds, undamaged by insects, with embryo, with the four alternative mean air temperatures of $<$ 6°, $<$ 10°, $<$ 12°, and $\leqq$ 15° C. are 0.998**, 0.979*, 0.952*, and −0.960** respectively. Furthermore, the regressions in Fig. 24 illustrate a positive relationship between the average frequency of empty seeds amongst all seeds, undamaged by insects, in each sample plot and the number of days with a minimum air temperature of −4° and below −4° C. at the nearest weather-station during a period of 45 and 50 days respectively, counting from the commencement of spruce flowering in the studied populations. The coefficients of correlation for the two pairs of variables are 0.452 and 0.693 respectively. These coefficients, however, are uncertain on account of the probable variation in the minimum temperatures between the weather-stations and the respective stands, which in the present case are not found to be significantly different from zero.

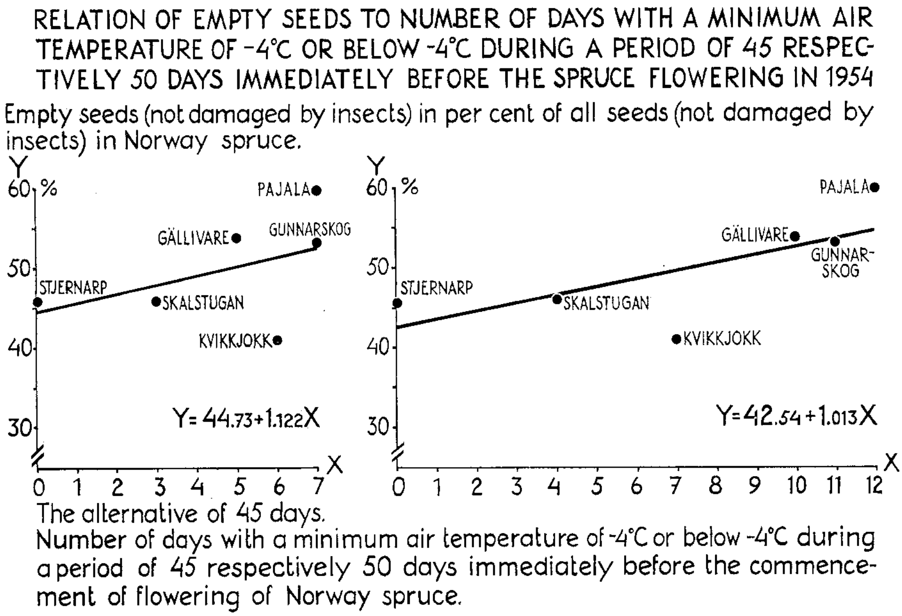


Fig. 24.

Finally, there is a striking increase in the rates of empty seed and of embryo type II at Skalstugan in relation to Höljes and more southernly situated sample plots. The embryo type IV at Skalstugan not only decreases but almost completely disappears.

On considering the variation between trees within sample plots one also finds that different trees appear to be able to produce varying frequencies of embryo types even under equivalent climatic conditions (e. g. see Appendix Table XVII A), which is in agreement with the observations of SIMAK and GUSTAFSSON (1954), and EHRENBERG et al. (1955).

6.2. Seed quality in the material of 1954

The investigation embraces the sample plots at Stjernarp, Gunnarskog' Skalstugan, Kvikkjokk, Gällivare and Pajala (cf. Fig. 1). The plots at Stjernarp, Gunnarskog and Skalstugan, as has already been shown, are included in both the 1948 and 1954 material and Gällivare, and moreover, in the material for 1960 and 1961. The study has been undertaken to determine the range of variation of different seed characters, as in 1948, between trees within the plots, the variation between areas and some inter-tree correlations and regressions between on the one hand, among other things, germination rate (observed in the JACOBSEN germinator) of all seeds, undamaged by in-

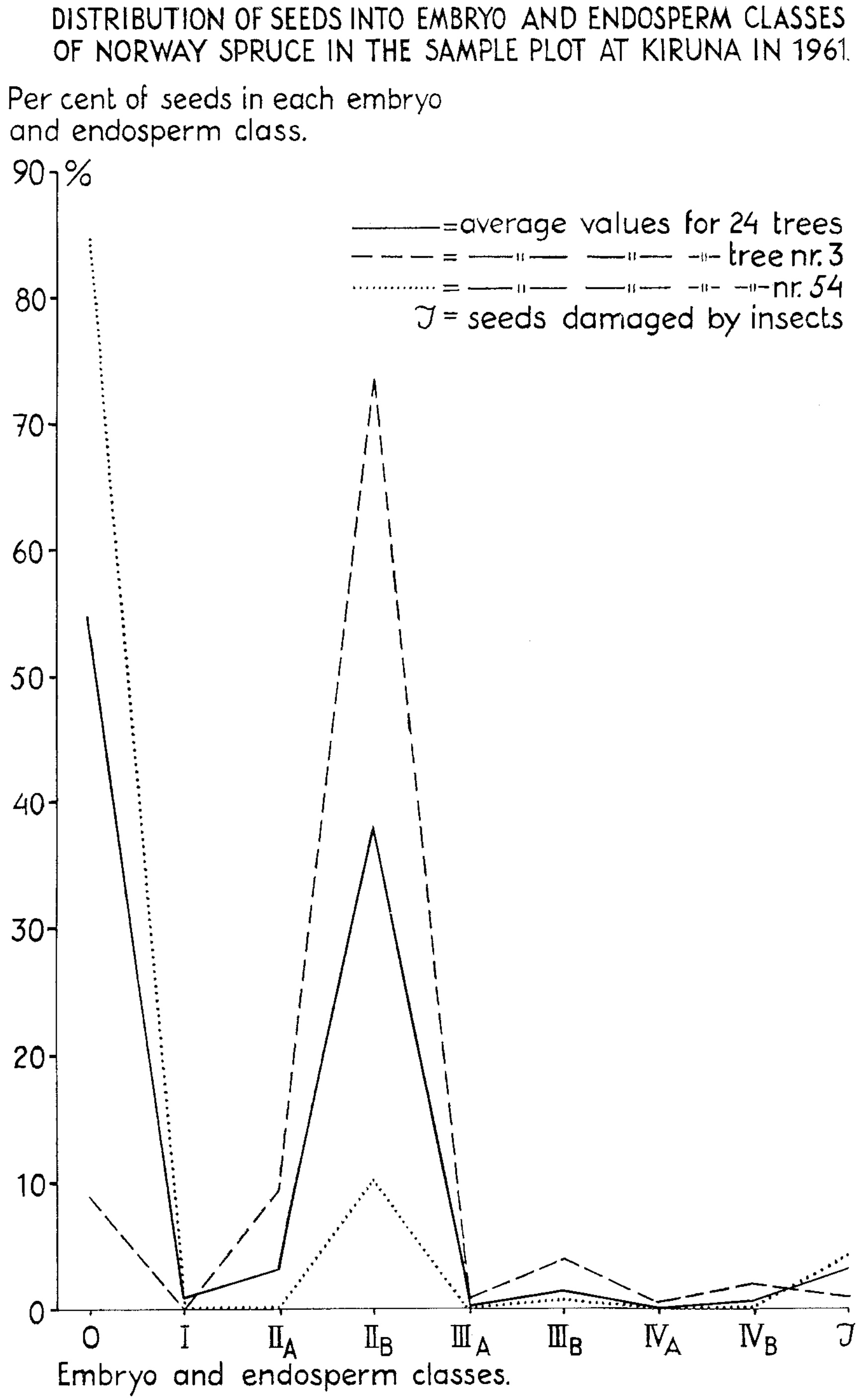

DISTRIBUTION OF SEEDS INTO EMBRYO AND ENDOSPERM CLASSES
OF NORWAY SPRUCE IN THE SAMPLE PLOT AT KIRUNA IN 1961.
Per cent of seeds in each embryo
and endosperm class.
90 %
——— = average values for 24 trees
– – – = ——" —— ——" —— –"– tree nr. 3
··········· = ——" —— ——" —— –"– –"– nr. 54
J = seeds damaged by insects
80
70
60
50
40
30
20
10
0
O I IIA IIB IIIA IIIB IVA IVB J
Embryo and endosperm classes.

Fig. 25.

Table 42. Between-tree correlations for individual populations and for the six populations treated as one group in the year 1954.

Population / Between the variables	Stjernarp	Gunnar-skog	Skal-stugan	Kvikk-jokk	Gällivare	Pajala	The six populations treated as one group
	r	r	r	r	r	r	r
X_{21} and X_1	0.699	0.527	0.597	0.435	0.579	0.675	0.656
X_2	0.285	0.258	0.159	0.152	0.111	0.221	0.534
X_3	0.204	0.315	0.259	0.143	0.275	0.444	0.550
X_4	−0.179	0.137	0.393	−0.031	0.141	0.281	0.514
X_7	0.656	0.539	0.551	0.367	0.554	0.690	0.670
X_{13} and X_1	0.697	0.529	0.610	0.428	0.605	0.675	0.647
X_2	0.284	0.246	0.178	0.170	0.110	0.209	0.524
X_3	0.200	0.316	0.279	0.164	0.283	0.454	0.545
X_4	−0.178	0.129	0.406	−0.021	0.116	0.283	0.509
X_7	0.653	0.536	0.564	0.364	0.573	0.686	0.657

Correlation based on:	D.F.	$P = 5\%$	$P = 1\%$
	Value of r different from zero at the P % level of significance		
1) 50 trees in one locality	48	0.279	0.361
2) 300 trees treated as one group	298	0.114	0.149

X_1 = thousand-grain weight of all seeds per cone
X_2 = cone length
X_3 = cone weight
X_4 = the total number of seeds per cone
X_7 = the weight of all seeds per cone
X_{13} = germination rate (in the JACOBSEN germinator) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular data by the formula, angle = $\arcsin \sqrt{\text{per mille}/1000}$)
X_{21} = germination rate (in the JACOBSEN germinator) of all seeds not damaged by insects (not transformed data)

sects, and on the other hand seed properties as well as cone properties. Among these other seed characters are the total number and weight of all seeds per cone (see among others, Tables 42, 43, 46 and the Appendix Tables XXII A—E). Data on observed seed germination rates in per cent of total number of seeds per cone for individual trees and populations based on test procedures in the JACOBSEN germinator, and the frequency distribution of seed in seed size classes are given in the Appendix Tables XXIII—XXVIII. Calculated percentages of seed damaged by insects, of empty seeds and of a series of seed germination rate (analysed by the X-ray method described by SIMAK and GUSTAFSSON, 1953 and 1954) for trees and populations, are listed in the

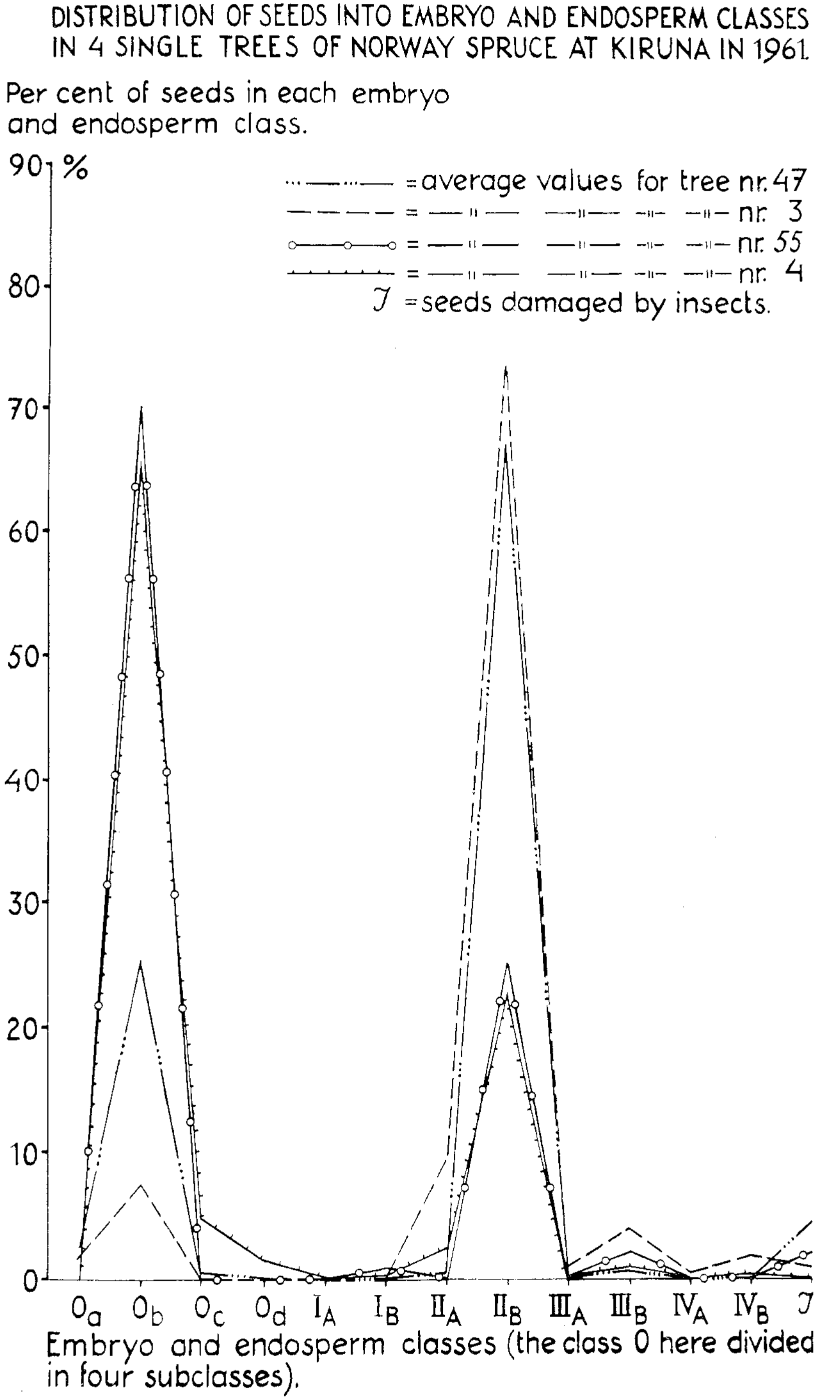

DISTRIBUTION OF SEEDS INTO EMBRYO AND ENDOSPERM CLASSES
IN 4 SINGLE TREES OF NORWAY SPRUCE AT KIRUNA IN 1961.
Per cent of seeds in each embryo
and endosperm class.
90 %
80
70
60
50
40
30
20
10
0
= average values for tree nr. 47
= — " — — " — — " — — " — nr. 3
= — " — — " — — " — — " — nr. 55
= — " — — " — — " — — " — nr. 4
J = seeds damaged by insects.
0a 0b 0c 0d IA IB IIA IIB IIIA IIIB IVA IVB J
Embryo and endosperm classes (the class 0 here divided
in four subclasses).

Fig. 26.

Appendix Tables XXIX—XXXIV A and B. The mean values of seed germination ability for populations are summarized in Table 41.

It can be seen from the Appendix Tables XXIX B—XXXIV B that similarly to 1948 there is a considerable tree to tree variation in seed quality within geographic areas. The germination percentages of total number of seeds (in the Appendix Tables XXIX B—XXXIV B), vary, at Stjernarp from 18.5 to 78, with a mean of 51.3, at Gunnarskog from 5.1 to 76.7, with a mean of 44.1, at Skalstugan from 4 to 31, with a mean of 17, at Kvikkjokk from 6.7 to 62.3, with a mean of 25.2, at Gällivare from 0.2 to 43.2, with a mean of 24.7 and at Pajala from 0.7 to 61.7, with a mean of 29. Also, other rates of seed quality such as the germination percentage of all seeds not damaged by insects shown in the Appendix Tables XXIX B—XXXIV B, the percentage of seeds, not damaged by insects, with embryo unable to germinate in relation to total number of seeds or in relation to all seeds, not damaged by insects, with embryo, and the percentage of empty seeds amongst all undamaged seeds, vary within a wide range. The Appendix Tables XXIX B—XXXIV B summarize the results.

As can be seen from Appendix Tables XXV and XXXI B there is a difference of 13 % between the observed germination rate of all seeds at Skalstugan and the calculated germination rate of all seeds by means of the X-ray diagnostics at the same locality. A similar disagreement between comparable germination percentages, amounting to approximately 9 %, occurs at Gällivare (cf. Appendix Tables XXVII and XXXIII B). The differences between the observed and the calculated germination rates in per cent of all seeds for Stjernarp, Gunnarskog, Kvikkjokk and Pajala amounted to 0.6, 0.8, 2.5 and 4.6 respectively. A comparison of the germination results achieved for each individual tree, according to both methods of analysis, shows that within the sample plot at Skalstugan trees numbers 9, 13, 27, 30, 42, 57 and 67 account for the greatest differences with reference to germination capacity, i.e. trees with very weak embryo and endosperm development. In Gällivare trees numbers 6, 18, 40, 42, 44, 98, 101, 102 and 1002, amongst others, are characterised by a high frequency of seed belonging to the classes II A and II B, which seed classes account for the greatest lack of agreements between observed and calculated germination rates. As a comparison to the observed differences at Skalstugan and Gällivare it is seen, from Table 45, that the difference between the germination rate of two simple random seed samples in the 1948 seed harvest from the sample plot at Höljes, one seed sample germinated in February 1949 in the Jacobsen apparatus, and the other analysed on the basis of X-ray negatives in 1954, amounts to 3.63 %.

An attempt is now made to apply statistical tests in comparing the ob-

Table 43. Partial between-tree correlations for individual populations and for the six populations treated as one group in the year 1954.

Population / $r_{xy \cdot z}$	Stjernarp	Gunnar-skog	Skal-stugan	Kvikk-jokk	Gälli-vare	Pajala	The six popula-tions
$r_{47.(21)}$	0.457	0.563	0.785	0.561	0.529	0.531	0.795
$r_{47.(13)}$	0.454	0.566	0.781	0.556	0.550	0.528	0.796
$r_{4(21).7}$	—0.441	—0.221	—0.122	—0.272	—0.201	—0.179	—0.144
$r_{4(13).7}$	—0.437	—0.229	—0.118	—0.258	—0.254	—0.172	—0.126
$r_{7(21).4}$	0.725	0.559	0.435	0.445	0.567	0.670	0.517
$r_{7(13).4}$	0.721	0.560	0.441	0.436	0.603	0.665	0.495

Partial correlation of the first order based on:

Value of r different from zero at the P % level of significance

	D.F.	$P = 5$ %	$P = 1$ %
1) 50 trees in one locality	47	0.282	0.365
2) 300 trees treated as one group	297	0.114	0.149

Population / $r_{xy \cdot zuv}$	Stjernarp	Gunnar-skog	Skal-stugan	Kvikk-jokk	Gälli-vare	Pajala	The six popula-tions
$r_{47.23(21)}$	0.249	0.394	0.657	0.425	0.319	0.324	0.346
$r_{47.23(13)}$	0.246	0.395	0.657	0.420	0.353	0.324	0.341
$r_{4(21).237}$	—0.404	—0.190	—0.126	—0.250	—0.209	—0.161	—0.084
$r_{4(13).237}$	—0.401	—0.193	—0.123	—0.240	—0.271	—0.161	—0.068
$r_{7(21).234}$	0.744	0.519	0.524	0.419	0.543	0.626	0.477
$r_{7(13).234}$	0.742	0.521	0.520	0.401	0.579	0.614	0.452

Partial correlation of the third order based on:

Value of r different from zero at the P % level of significance

	D.F.	$P = 5$ %	$P = 1$ %
1) 50 trees in one locality	45	0.288	0.372
2) 300 trees treated as one group	295	0.117	0.149

X_2 = cone length
X_3 = cone weight
X_4 = the total number of seeds per cone
X_7 = the weight of all seeds per cone
$X_{(13)}$ = germination rate (in the JACOBSEN germinator) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per mille}/1000}$)
$X_{(21)}$ = germination rate (in the JACOBSEN germinator) of all seeds not damaged by insects (not transformed data)

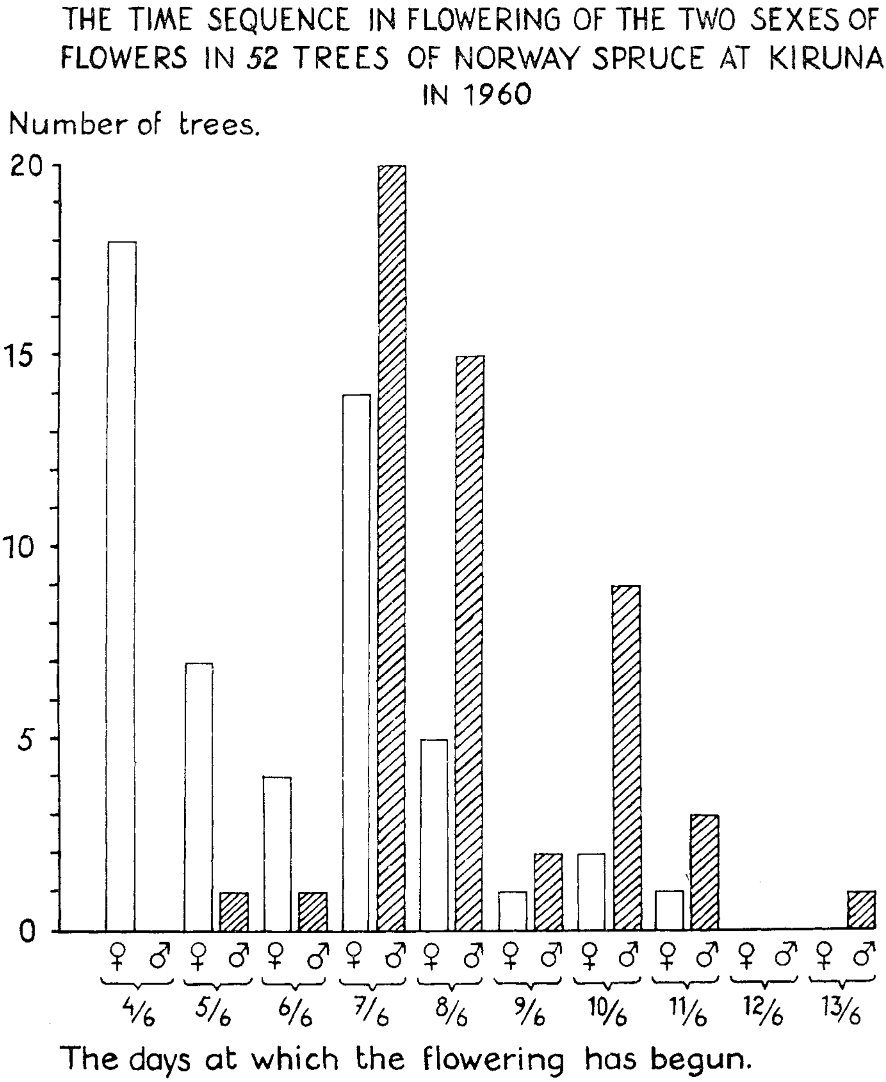
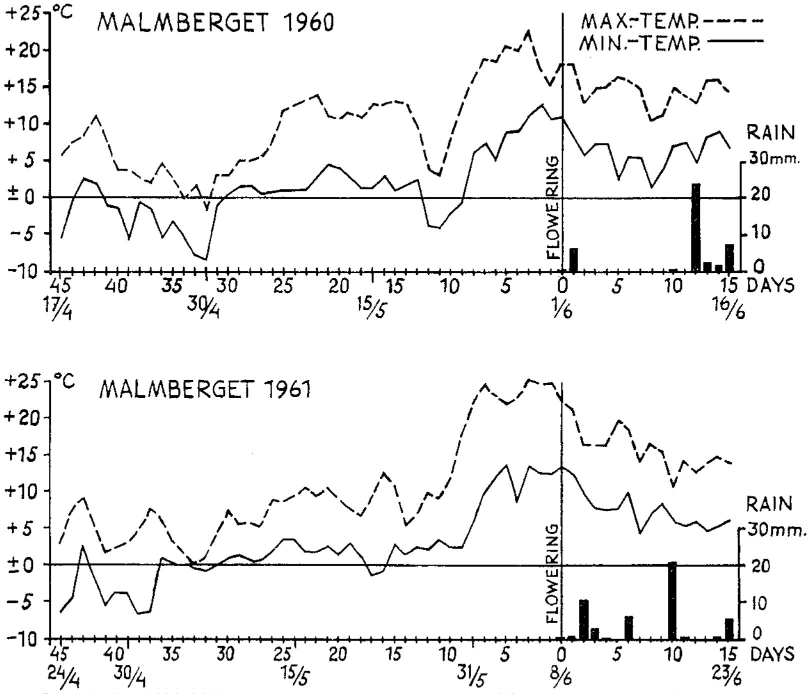
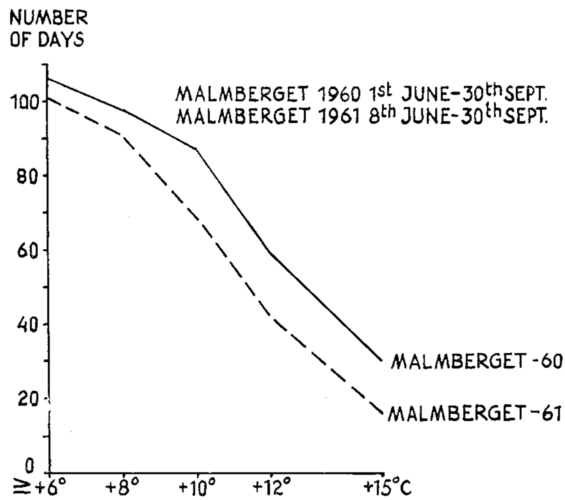


Fig. 27.

served and the calculated germination rates. To avoid the complications of binomially distributed data the angular transformation is applied. It is assumed that the observed and the calculated germination percentages are determined in simple random samples chosen from the same population of seeds. Assuming further that the difference between the two percentages is due solely to sampling errors, the following approximate relations can be proved:



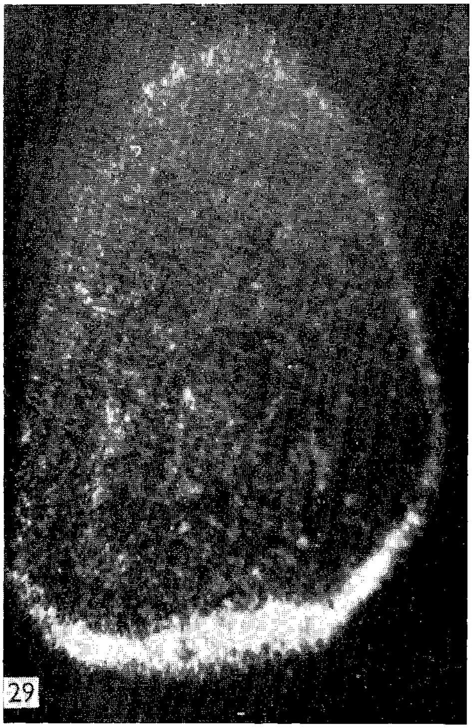
DAILY MAXIMUM AND MINIMUM TEMPERATURES BEFORE AND AFTER FLOWERING.



THE MEAN TWENTY-FOUR HOUR TEMPERATURES.

NUMBER OF DAYS WITH MEAN TEMPERATURES ≥+6°, 8°, 10°, 12° AND 15°C DURING THE PERIOD FROM THE COMMENCEMENT OF SPRUCE FLOWERING UNTIL THE END OF SEPTEMBER.

Fig. 28.



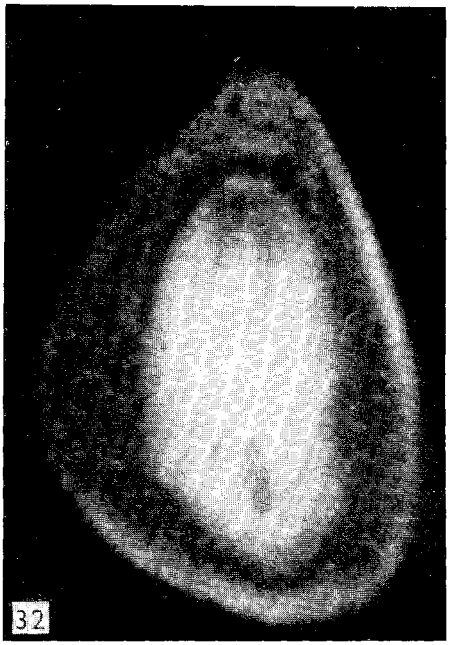
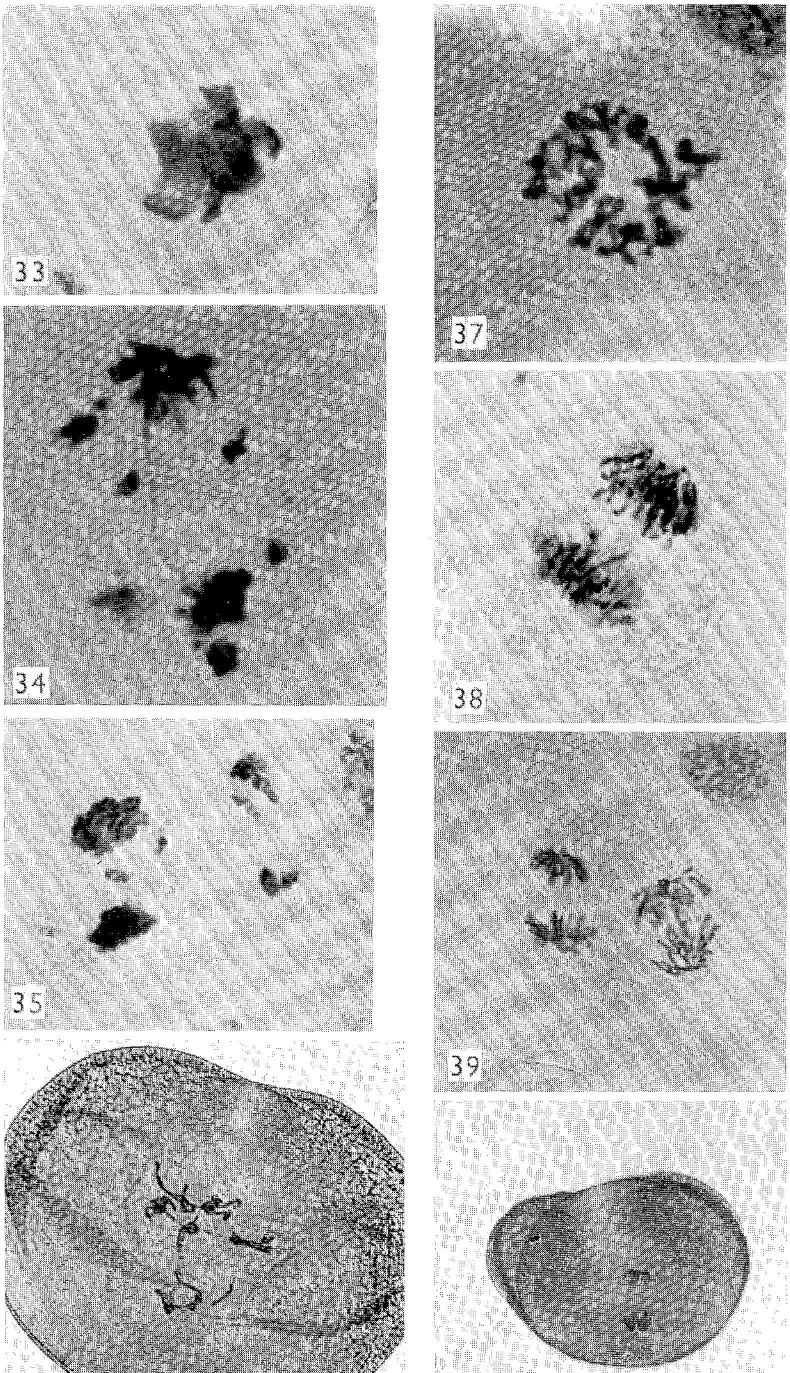


Fig. 29 shows an X-ray negative of a seed of embryo class 0, subclass 0*a*—X 36. Fig. 30 illustrates embryo class 0, subclass 0*b*—X 26. Fig. 31 is a seed of embryo and endosperm class III B—X 28. Fig. 32 seed of embryo and endosperm class IV B—X 28. (See the definitions on the pages 28 and 29, - - - photo N. Wiersma.)



Meiosis in pollen mother cells of Norway spruce. Figs. 33—35 illustrate meiotic abnormalities caused by the effect of minus temperatures (below —4° C.). Figs. 37—39 show the course of normal meiosis. 33, diakinesis to early metaphase I; 34, early telophase I with a chromatin bridge, "fragments" and chromatin clumps; 35, early telophase II; 36, pollen mitosis with "sticky" chromosomes; 37, early metaphase I; 38, anaphase I; 39, anaphase II and 40, normal pollen mitosis.

1) If the two samples are identical, i.e. contain the same seeds, as in Stjernarp, Gunnarskog, Gällivare and Kvikkjokk, the differences between the angles corresponding to the percentages has the expectation 0 and a variance not exceeding

$$\frac{8100}{n\,\pi^2} = \frac{820.7}{n},$$

where n is the number of seeds in the samples;
2) If the two percentages are determined from two independent samples of n_1 and n_2 seeds respectively, as at Skalstugan and Pajala in 1954 and Höljes in 1948, the expected value of the difference is again 0 whereas an upper bound for the variance is

$$820.7\left(\frac{1}{n_1} + \frac{1}{n_2}\right).$$

As is evident from these formulas and all tabular values, the angles are expressed in degrees (Table X in Fisher & Yates, 1963 has been used).

The above expressions for the variance are equally applicable to the case when one or both of these methods are biased in such a way that the two methods give different expected germination rates. Although the above expressions for the variances are upper bounds they are used in the following as the exact variances, thus obtaining conservative tests. The case with seed samples of the same size from each one of N trees is then considered. Let S^2 denote the sum of the N squared differences between angles. In the two cases stated above we obtain:
1. With identical seed samples

$$\frac{nS^2}{820.7}$$

is approximately distributed as χ^2 with N degrees of freedom;
2. With different seed samples

$$\frac{S^2}{820.7\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

is likewise distributed (approximately) as is χ^2 with N degrees of freedom.

If there is a constant bias in angular values, as at Höljes in 1948, we can let S^2 in the above expressions stand for the sum of the squared deviations of the differences from their mean. The degrees of freedom with which to enter the Tables of the χ^2-distribution should then be (N—1).

With the exception of Stjernarp, all cases give values of S^2 exceeding the 0.1 % significance point of χ^2, when the tests are based on simple random samples from each seed size class. The value for Stjernarp is insignificant. The high values of S^2 may be due to several causes. The selection of seeds (in case 2, different samples) may differ from the mechanism of simple random sampling e.g. by a tendency toward cluster sampling. There may be a subjective element in the classification of the seed, possibly resulting in fluctuations in the treatment of cases bordering between two classes. Another possible explanation is that some of the classes can be inhomogeneous with the result that the germination rate for one class may vary from one seed population to another.

The high values obtained for the sums of squares indicate that if a test for a possible systematic difference between the two methods of determining the germination is wanted, the one-sample t-test should be applied to the differences between the angular values. The t-test has been applied to all series mentioned above. Significative t-values were obtained in two cases: at Skalstugan, where the calculated germination rate was significantly lower than the observed rate, and at Gällivare where the calculated rate was significantly higher than the empiric rate.

If one wishes to compare the germination percentages that are weighted averages for four seed size classes, the following approximation formula can be used. Like the other formulas used in this context, it has a tendency to overestimate the standard error. The overestimation of the error variance is due to the fact that it makes no allowance for the Poisson variation connected with the subdivision of the seeds into embryo classes.

Let a population of seeds consist of four size classes with the relative frequencies P_1, P_2, P_3 and P_4 expressed in per cent, where $P_1+P_2+P_3+P_4=$ $=100$. We select n_i seeds at random from the i:th class ($i=1, 2, 3, 4$). The calculated and empiric germination rates for the n_i sample seeds are G_i' and G_i'', respectively. The average germination percentages are

Calculated percentage $G'=(P_1G'_1+P_2G'_2+P_3G'_3+P_4G'_4)/100$
Empiric percentage $G''=(P_1G''_1+P_2G''_2+P_3G''_3+P_4G''_4)/100$
The difference $G''—G'$ has an error variance not exceeding

$$\varepsilon^2 = G'(100-G')\sum_{i=1}^{4}\left(\frac{P_i}{100}\right)^2 \cdot \frac{1}{n_i}\,.$$

Analyses of variance based on tree mean values (angular transformation) for seed germination rates, seeds damaged by insects and empty seeds, all give highly significant differences between areas. All the F-values obtained have a significance beyond the 0.1 % point. The smallest variance ratio (F = 4.38***) is obtained for the percentage of empty seeds amongst all seeds not damaged by insects (degrees of freedom: 5 for the numerator and 294 for the denominator).

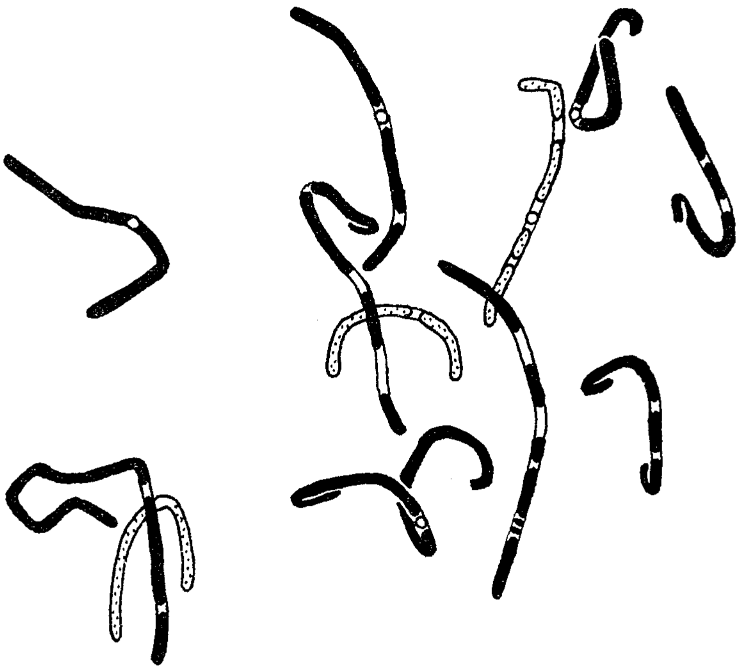


Fig. 41. A haploid chromosome complement in a pollen grain of *Picea abies* ca. ×3200.

Correlations for populations, based on tree mean values, due to the association of germination rate (in the JACOBSEN germinator) of all seeds not damaged by insects (X_{21} = not transformed percentage and X_{13} = corresponding angular transformed percentage) with 1,000-grain weight of all seeds per cone (X_1), cone length (X_2), cone weight (X_3), number of seeds per cone and with the weight of all seeds per cone, are given in Table 42. A moderate to strong positive and highly significant correlation is indicated for the association of seed germination rate of all seeds not damaged by insects, with 1,000-grain weight of all seeds per cone and with the weight of all seeds per cone. The $r_{(21)1}$ and $r_{(21)7}$ values* reflect as the corresponding $r_{(13)1}$ and $r_{(13)7}$ coefficients the consistent association of increasing seed germination rates with increasing seed weights (X_1 and X_7 respectively). About 49 per cent of the between-tree variation in germination percentage of all seeds not damaged by insects at Stjernarp can be referred to the linear covariation with the thousand-grain weight. The $r_{(21)2}$ value of 0.285 at Stjernarp (the only significant $r_{(21)2}$-coeffficient for individual populations) indicates that only about 8 % of the tree to tree variation in germination rate of all seeds

* When the number of a variable consists of two figures, it is placed within parentheses when appearing as an index of a correlation coefficient.

Table 44. Between-tree correlations for individual populations and for the six populations treated as one group in the year 1954.

Between the variables \ Population	Stjernarp	Gunnar-skog	Skal-stugan	Kvikk-jokk	Gällivare	Pajala	The six popula-tions treated as one group
	r	r	r	r	r	r	r
X_{12} and X_1	−0.721	−0.502	−0.531	−0.673	−0.628	−0.670	−0.443
X_2	−0.285	−0.205	−0.123	0.084	0.125	−0.227	−0.112
X_3	−0.218	−0.296	−0.296	0.145	0.063	−0.374	−0.130
X_4	0.140	−0.137	−0.373	0.222	0.022	−0.135	−0.056
X_7	−0.685	−0.509	−0.520	−0.463	−0.566	−0.606	−0.292
X_{20} and X_1	−0.723	−0.499	−0.542	−0.676	−0.600	−0.668	−0.441
X_2	−0.287	−0.213	−0.140	0.082	0.114	−0.216	−0.114
X_3	−0.222	−0.294	−0.314	0.143	0.063	−0.357	−0.131
X_4	0.143	−0.145	−0.384	0.227	−0.014	−0.121	−0.058
X_7	−0.687	−0.511	−0.535	−0.462	−0.552	−0.602	−0.293

Correlation based on:	Value of r different from zero at the P % level of significance D.F.	$P=5$ %	$P=1$ %
1) 50 trees in one locality	48	0.279	0.361
2) 300 trees treated as one group	298	0.114	0.149

X_1 = thousand-grain weight of all seeds per cone
X_2 = cone length
X_3 = cone weight
X_4 = the total number of seeds per cone
X_7 = the weight of all seeds per cone
X_{12} = empty seeds (not damaged by insects) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per mille}/1000}$)
X_{20} = empty seeds (not damaged by insects) of all seeds not damaged by insects (not transformed data)

not damaged by insects can be accounted for by differences in cone length. Inter-tree correlations between seed germination rates and cone weights are significant at two localities (Gunnarskog and Pajala) and nearly significant at Gällivare. The variations in cone weight at Gunnarskog and Pajala account, however, for less than 10 and 20 % respectively of the tree to tree variation in seed germination rate, measured in this way. The association of germination rate of all seeds not damaged by insects with the number of seeds per cone, X_4, is in four cases insignificant and in two cases significant at the 5 % level. In two localities the coefficients, $r_{(21)4}$, are both negative and insignificant.

With constant seed weight, X_7, the correlation coefficients in Table 43 indicate a negative significant association of seed germination rate, X_{21}, with number of seeds per cone, X_4, at Stjernarp and a negative non-significant relation between the same variables at the other localities. The between-tree coefficients, $r_{7(21).4}$, show in all the six localities a strong positive correlation between the variables X_7 and X_{21}, with equal number of seeds per cone. The correlation coefficients of the third order, $r_{4(21).237}$, indicate a negative significant association of seed germination capacity, X_{21}, with the number of all seeds per cone, X_4, at Stjernarp, when cone length, cone weight and the weight of seeds, X_7, are held constant. The corresponding coefficients in the other localities are negative, but non-significant. It appears also from Table 43 that a moderate to strong positive and significant between-tree association of seed germination rate with seed weight, remains in all localities even when cone length and cone weight, besides total number of seeds per cone, are held constant.

In general, it is seen from the Tables 42 and 43 that a moderate to strong positive between-tree correlation exists between the observed germination rate (in the Jacobsen germinator) of all seeds, not damaged by insects, and seed weight (1,000-grain weight of all seeds as well as the weight of all seeds per cone) in the material studied. The correlation between the variables X_{21} and X_7 is stronger than between the other combinations of variates.

Table 44 reflects the lack of a significant positive correlation between the percentage of empty seeds amongst all undamaged seeds, X_{12}, and any one of the variables X_1, X_2, X_3, X_4 and X_7. The degree of negative inter-tree association of the frequency of empty seeds not damaged by insects with seed weight (thousand-grain weight of all seeds, X_1, as well as the weight of all seeds per cone, X_7), as shown in Table 44, is relatively high and in all studied localities highly significantly different from zero. The coefficient $r_{(12)2}$ at Stjernarp indicates a significant negative correlation between the frequency of empty seeds (not damaged by insects) and the cone length. Significant negative between-tree associations of the variables X_{12} with X_3 (cone weight) are found at Gunnarskog, Skalstugan and Pajala. The variables X_{12} and X_4 at Skalstugan show the feature and significance of association.

Table 44 also indicates the presence of 1) a weak positive (though non-significant) inter-tree correlation between the percentage of empty seeds (not damaged by insects) and the number of seeds per cone at Stjernarp and Kvikkjokk and 2) a significant negative correlation between the same variables at Stjernarp. The differences in correlation between Skalstugan, on the one hand, and any of the plots at Stjernarp, Kvikkjokk or Gällivare on the other hand, are all significant. The estimated t-values, between Skalstugan and Stjernarp, Skalstugan and Kvikkjokk and also Stjernarp and Gällivare, are 2.57*, 3.01** and 1.99* respectively. Although these correla-

Table 45. A test of heterogeneity between observed and calculated seed germination rates at Höljes in 1948.

(Simple random samples chosen from the same populations of seed)

Tree No.	Observed germination rate (1948) $\arcsin\sqrt{\frac{\text{percentage}}{100}}$	Calculated germination rate (1954) $\arcsin\sqrt{\frac{\text{percentage}}{100}}$	The difference between samples $= d$	$\frac{d^2}{820.7\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$	n_1	n_2
1	31.69	41.27	− 9.58	11.1827	200	200
2	46.78	52.59	− 5.81	4.1131	200	200
3	52.06	45.57	6.49	5.1322	200	200
4	33.27	31.11	2.16	0.5685	200	200
5	37.94	53.19	−15.25	28.3371	200	200
6	38.94	45.17	− 6.23	4.7292	200	200
7	42.13	52.53	−10.40	13.1790	200	200
8	42.13	54.39	−12.26	18.3146	200	200
9	45.80	54.82	− 9.02	9.9135	200	200
10	46.66	49.60	− 2.94	1.0532	200	200
11	42.65	44.66	− 2.01	0.4923	200	200
12	51.41	45.11	6.30	4.8361	200	200
13	26.42	43.68	−17.26	36.2992	200	200
14	39.11	43.28	− 4.17	2.1188	200	200
15	45.69	56.60	−10.91	14.5032	200	200
16	24.88	31.56	− 6.68	5.4371	200	200
17	18.44	32.27	−13.83	23.3056	200	200
18	41.15	45.75	− 4.60	2.5783	200	200
19	45.69	40.63	5.06	3.1197	200	200
20	42.59	39.52	3.07	1.1484	200	200
21	50.07	39.58	10.49	13.4081	200	200
22	57.99	49.95	8.04	7.8764	200	200
23	46.20	44.89	1.31	0.2091	200	200
25	53.07	29.67	23.40	66.7187	200	200
26	34.27	36.51	− 2.24	0.6114	200	200
28	45.75	58.18	−12.43	18.8260	200	200
29	42.53	41.84	0.69	0.0580	200	200
30	43.97	48.68	− 4.71	2.7031	200	200
31	52.53	43.05	9.48	10.9505	200	200
32	37.52	41.38	− 3.86	1.8155	200	200
33	31.44	33.09	− 1.65	0.3317	200	200
34	40.28	31.50	8.78	9.3930	200	200
35	52.95	31.69	21.26	55.0734	200	200
36	29.93	42.30	−12.37	18.6447	200	200
37	35.43	41.38	− 5.95	4.3137	200	200
38	31.37	58.24	−26.87	87.9733	200	200
39	37.11	35.30	1.81	0.3992	200	200
40	36.81	44.20	− 7.39	6.6543	200	200
41	46.20	29.80	16.40	32.7720	200	200
42	41.61	38.00	3.61	1.5879	200	200
43	36.03	48.85	−12.82	20.0259	200	200
44	43.80	38.76	5.04	3.0951	200	200
45	46.61	47.29	− 0.68	0.0563	200	200
46	50.65	42.25	8.40	8.5975	200	200
47	24.95	33.27	− 8.32	8.4346	200	200
48	32.08	27.76	4.32	2.2740	200	200
49	33.89	44.60	−10.71	13.9764	200	200
50	46.43	59.41	−12.98	20.5289	200	200
Σ	1,956.90	2,064.72	−107.82	607.6705		
$\bar{x}$	40.77	43.02	− 2.246			

Assigning $\Sigma d^2 = S^2$ we obtain:

$$\chi^2 = \frac{S^2}{820.7\left(\frac{1}{200}+\frac{1}{200}\right)}$$

$$= \frac{100 \cdot 4{,}987 \cdot 151}{820.7}$$

$$= 607.67^{***}$$

with $N = 48$ degrees of freedom.

Applying the t test:

$$t = \frac{\bar{d}}{\sqrt{\frac{S_1^2}{(N-1)N}}},$$

where $S_1^2 = S^2 - \frac{(\Sigma d)^2}{N}$ and $\bar{d} = \frac{\Sigma d}{N}$.

$$t = -\frac{2.246}{\sqrt{2.103}}$$

$$= -1.55^{\circ}$$

with $N-1$ degrees of freedom.

tions are not independent of one another, it seems evident that different populations will be able to show different associations between these variables, and that a large number of seeds per mean cone for trees need not necessarily be positively associated with a high percentage of empty seeds in all areas.

6.3. Between-tree regressions of seed germination rate and empty seed frequency on cone and seed properties in the material of 1954

The correlations and regressions reported in the earlier sections are all founded on the assumption of linear relationship between the variables involved. It is obvious, however, that exact linear relationships hardly ever occur in nature. The correlations and regressions given can only be conceived, therefore, as giving a summary and superficial picture of data having a more complex structure. It is therefore of a certain interest to study to what extent description of the data can be improved by the introduction of curved relationships. An investigation of this kind has been made of some total regressions of X_{13} (observed seed germination rate expressed as angle) and X_{12} (frequency of empty seeds among seeds not damaged by insects) on cone and seed properties. These cases were chosen since it was found by ocular inspection that the linearity could be questioned in some of these regressions. As comparison to the linear expressions, polynomials of second and third degree were investigated. The independent variables used in these studies were: thousand-grain weight in cg., X_1, cone length in tenths of mm., X_2, cone weight in mg., X_3, number of seeds per cone, X_4, and seed weight per cone in mg., X_7, (see Appendix Tables XXII A—E, and XXXV A—E).

In this section the multiple regressions of X_{13} and X_{21} (seed germination in per mille) on X_1, X_4, on X_4, X_7, and on X_2, X_3, X_4, X_7, see Table 46 a and b, are also discussed.

Tests of the significance of the departures from linearity are made in accordance with a method described by SNEDECOR (1959) and modified by WEBER and BROTT (1963) for an electronic computer. Values of F for deviations of the second and third degree polynomial from linear regressions are summarized in Table 47 a and b. Here in each single case the values of F represent the quotient between the reduction in sum of squares (caused by either the quadratic or cubic regression in relation to corresponding linear regression) and the mean square remaining after the respective curvilinear regression. It is apparent from these ratios that significant deviations from linear regressions are rather few in the data. However, in some cases significant departures from linearity are found. Thus, the regressions of seed germination, X_{13}, on thousand-grain weight, X_1, depart significantly from linearity at Stjernarp and Skalstugan. This is also the case for the regressions

Table 46 a. Multiple regressions of X_{21} on X_1 and X_4, X_{13} on X_1 and X_4, X_{21} on X_4 and X_7 as well as of X_{13} on X_4 and X_7.

(Based on tree mean values in 1954)

Population	Regression equation	
		$R^2_{(21).14}$ in %
Stjernarp	$X_{21} = 249.2656+1.2103\ X_1-0.6848\ X_4$	49.9***
Gunnarskog	$X_{21} = -290.6409+1.1817\ X_1+0.9487\ X_4$	30.5***
Skalstugan	$X_{21} = -39.9322+0.9604\ X_1+0.3795\ X_4$	36.4***
Kvikkjokk	$X_{21} = -97.3892+1.5579\ X_1-0.4074\ X_4$	19.1**
Gällivare	$X_{21} = -168.7195+0.9213\ X_1+0.6918\ X_4$	36.7***
Pajala	$X_{21} = -190.9545+1.3814\ X_1+1.0549\ X_4$	48.0***
The six populations treated as one group	$X_{21} = -161.3959+1.0988\ X_1+0.7870\ X_4$	46.5***
		$R^2_{(21).47}$ in %
Stjernarp	$X_{21} = 661.2010-2.2771\ X_4+0.4643\ X_7$	54.0***
Gunnarskog	$X_{21} = 248.4730-1.2619\ X_4+0.4857\ X_7$	32.5***
Skalstugan	$X_{21} = 195.9037-0.6451\ X_4+0.4223\ X_7$	31.4***
Kvikkjokk	$X_{21} = 297.2851-2.7104\ X_4+0.9086\ X_7$	19.9**
Gällivare	$X_{21} = 67.1281-0.7494\ X_4+0.5688\ X_7$	33.5***
Pajala	$X_{21} = 163.9045-1.0260\ X_4+0.8049\ X_7$	49.2***
The six populations treated as one group	$X_{21} = 167.3277-0.7170\ X_4+0.4808\ X_7$	46.1***
		$R^2_{(13).14}$ in %
Stjernarp	$X_{13} = 300.3899+0.7185\ X_1-0.4051\ X_4$	49.6***
Gunnarskog	$X_{13} = -36.3946+0.7383\ X_1+0.5614\ X_4$	30.5***
Skalstugan	$X_{13} = 100.1025+0.6358\ X_1+0.2693\ X_4$	38.1***
Kvikkjokk	$X_{13} = 22.8653+1.0934\ X_1-0.2243\ X_4$	18.5**
Gällivare	$X_{13} = -28.2279+0.7515\ X_1+0.4705\ X_4$	39.1***
Pajala	$X_{13} = 7.6394+0.8881\ X_1+0.6864\ X_4$	48.0***
The six populations treated as one group	$X_{13} = 18.0531+0.7157\ X_1+0.5210\ X_4$	45.3***
		$R^2_{(13).47}$ in %
Stjernarp	$X_{13} = 545.0190-1.3499\ X_4+0.2754\ X_7$	53.6***
Gunnarskog	$X_{13} = 300.4227-0.8183\ X_4+0.3031\ X_7$	32.5***
Skalstugan	$X_{13} = 255.7182-0.4026\ X_4+0.2782\ X_7$	32.7***
Kvikkjokk	$X_{13} = 299.8042-1.8329\ X_4+0.6348\ X_7$	19.0**
Gällivare	$X_{13} = 163.4851-0.7311\ X_4+0.4754\ X_7$	37.2***
Pajala	$X_{13} = 235.1175-0.6371\ X_4+0.5135\ X_7$	48.6***
The six populations treated as one group	$X_{13} = 229.3827-0.4230\ X_4+0.3064\ X_7$	44.1***

of seed germination, X_{13}, on seed weight, X_7, at Skalstugan, for the six populations taken together and for the second degree polynomial at Stjernarp. A significant deviation from linearity is likewise noted for the cubic regression of seed germination, X_{13}, on cone length, X_2, at Skalstugan. Finally, both the quadratic and cubic regressions of seed germination rate on cone weight, X_3, deviate significantly from linear regression for the six populations treated as one group. When the departures of the cubic regressions

Table 46 b. Multiple regressions of X_{21} on X_2, X_3, X_4 and X_7 and of X_{13} on X_2, X_3, X_4 and X_7.

(Based on tree mean values in 1954)

Population	Regression equation	
		$R^2_{(21).2347}$ in %
Stjernarp	$X_{21} = 423.0775+0.3335\ X_2-0.2368\ X_3-1.9381\ X_4+0.6214\ X_7$	63.9***
Gunnarskog	$X_{21} = 488.1126-0.4142\ X_2+0.0177\ X_3-1.0901\ X_4+0.5665\ X_7$	34.3***
Skalstugan	$X_{21} = 294.8634-0.0306\ X_2-0.2304\ X_3-0.6835\ X_4+0.6653\ X_7$	40.3***
Kvikkjokk	$X_{21} = 147.1701+0.3014\ X_2-0.1564\ X_3-2.5593\ X_4+0.9357\ X_7$	20.2*
Gällivare	$X_{21} = 193.9959-0.3171\ X_2+0.2225\ X_3-0.9285\ X_4+0.5441\ X_7$	36.5***
Pajala	$X_{21} = 420.4943-0.4708\ X_2-0.0258\ X_3-0.9065\ X_4+0.9345\ X_7$	52.6***
The six populations treated as one group	$X_{21} = 183.2361-0.0674\ X_2-0.0707\ X_3-0.4635\ X_4+0.5600\ X_7$	46.8***
		$R^2_{(13).2347}$ in %
Stjernarp	$X_{13} = 398.2321+0.2079\ X_2-0.1441\ X_3-1.1496\ X_4+0.3695\ X_7$	63.7***
Gunnarskog	$X_{13} = 481.2959-0.3238\ X_2+0.0299\ X_3-0.6896\ X_4+0.3530\ X_7$	34.7***
Skalstugan	$X_{13} = 315.3056-0.0145\ X_2-0.1433\ X_3-0.4325\ X_4+0.4288\ X_7$	40.7***
Kvikkjokk	$X_{13} = 185.4499+0.2168\ X_2-0.0796\ X_3-1.7602\ X_4+0.6361\ X_7$	19.2*
Gällivare	$X_{13} = 265.7905-0.2572\ X_2+0.1984\ X_3-0.9250\ X_4+0.4507\ X_7$	40.9***
Pajala	$X_{13} = 425.4130-0.3604\ X_2+0.0208\ X_3-0.5831\ X_4+0.5831\ X_7$	52.5***
The six populations treated as one group	$X_{13} = 256.0958-0.0810\ X_2-0.0291\ X_3-0.2535\ X_4+0.3527\ X_7$	44.7***

X_1 = thousand-grain weight in centigram of all seeds per cone
X_2 = cone length in tenths of a millimetre
X_3 = cone weight in centigram
X_4 = the total number of seeds per cone
X_7 = the weight in milligram of all seeds per cone
X_{13} = germination rate (in the JACOBSEN germinator) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular value by the formula, angle = $\arcsin\sqrt{\text{per mille}/1000}$)
X_{21} = germination rate (in the JACOBSEN germinator) of all seeds not damaged by insects (not transformed data)

* Statistically significant at the 5 % level
** " " " " 1 % "
*** " " " " 0.1 % "

from the quadratic are tested, only one significant deviation is found in this group of regressions, namely for the regression of seed germination on cone length at Skalstugan, $F = 4.84^*$ for $n_1 = 1$ and $n_2 = 50-4$ degrees of freedom (cf. Fig. 42). The squared correlation coefficient, expressed in per cent, is equally a good indicator of the fit of the regression. As can be seen from Table XXII B the cone length X_2, accounts in the cubic regression for a larger proportion (18.2 %) of the variation in X_{13} than in the quadratic polynomial (9.6 %).

Some significant deviations from linear regressions are likewise found for the curvilinear regressions of empty seed, X_{12}, on 1,000-grain weight and on seed weight and in one case on the number of seeds per cone (see Table

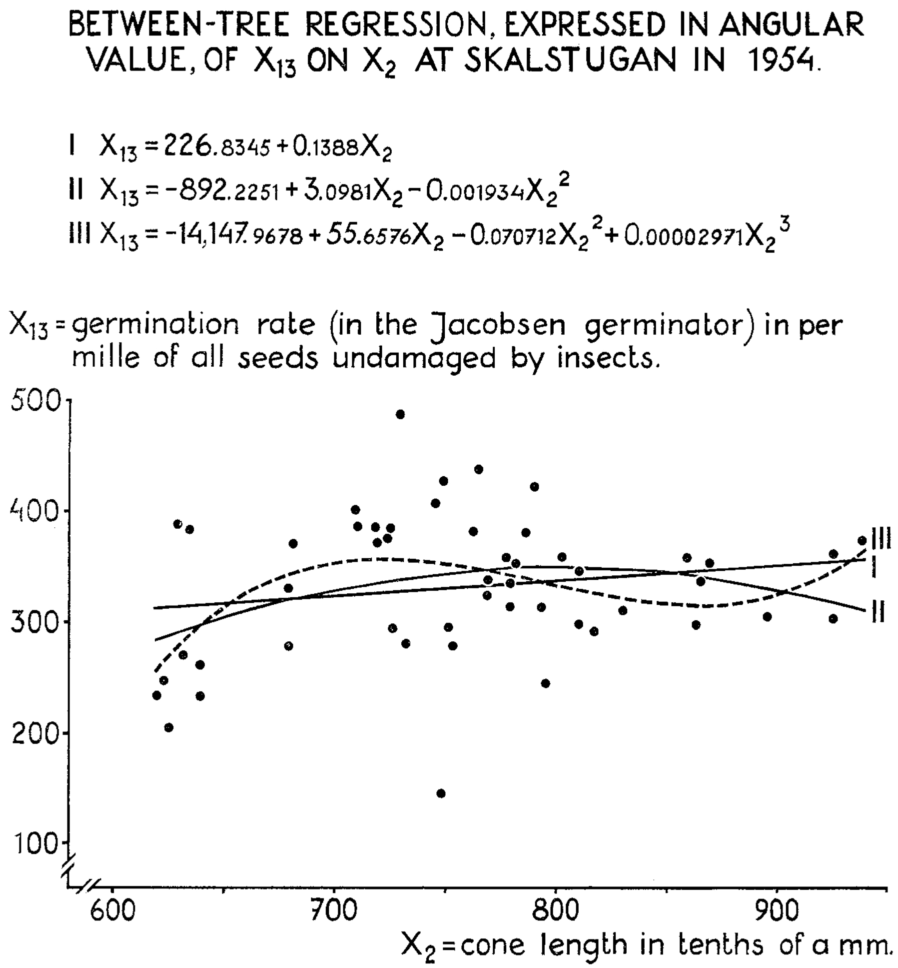


Fig. 42.

47 b). A test of significance of the departure of cubic regressions from the quadratic polynomials shows that the cubic regression deviates significantly from the quadratic in the following tree samples: 1) at Kvikkjokk for the regression of X_{12} on X_7, $F = 4.34^*$ for $n_1 = 1$ and $n_2 = 46$ d.f., 2) at Gällivare for the regression of X_{12} on X_4 (cf. Fig. 43), $F = 8.18^{**}$ and 3) for the six populations treated as one group for the regression of X_{12} on X_1 and of X_{12} on X_7. The F-values are in these cases 8.10^{**} and 18.54^{***} respectively for $n_1 = 1$ and $n_2 = 296$ d.f.

It is interesting from the point of view of selection to see how different cone seed properties, both individually and in combination, influence seed germination, X_{13}, and the frequency of empty seed, X_{12}. The direction and strength of the associations of seed germination, X_{13}, with each of the variables X_1, X_2, X_3, X_4 and X_7 are seen in Table 42 and the Appendix Tables XXII A—E and with some groups of independent variables in Table 46 a and b. The direction and strength of the associations of empty seed, X_{12}, with the same independent variables as above are given in Table 44 and in the Appendix Tables XXXV A—E. Tests of differences of correlation between areas indicate that the differences are, in most cases, insignificant. The difference between the two localities Stjernarp and Skalstugan for the association of seed germination, X_{13}, with the number of seeds per cone is, however, significant at the 1% level. The corresponding differences between the coefficients of correlation for Stjernarp and Pajala and between Skalstugan and Kvikkjokk reach the 5% point of significance. A significant difference at the 5% level is likewise found between Kvikkjokk and Pajala for the association of seed germination rate with seed weight, X_7. The correlations and regressions presented also reveal that the associations of seed germination, X_{13}, with the studied cone and seed properties, except for seed weight (X_1 and X_7) in some localities, are weak and of rather little value as indicators of high seed germination capacity. As seen from the Appendix Table XXII the independent variables, with the exception of X_1 and X_7 at Stjernarp, Skalstugan and Pajala, account for a small fraction of the variation in seed germination rate. R^2 represents a moderate (64%) to a small fraction (19%) of the variation in X_{13}, even in the multiple regressions, including the independent variables X_2, X_3, X_4 and X_7 (see Table 46 b). This means that a large portion of the variation in seed germination is unexplained and that several other independent variables, not considered in these regressions, account for a great part of the variability in seed germination of all seeds not damaged by insects. Among these independent variables, not considered, can be noted certain chromosome disturbances during meiosis, pollen mitosis and the development of embryo sacs caused by unfavourable changes of temperature, the level of temperature during the seed maturing period, failure of fertilization (cf. Figures 22—24), and a set of genetic and physiological factors such as incompatibility reactions and the effects of lethals.

If the same testing method is applied to the differences between areas for associations of empty seed, X_{12}, with each of the variables X_1, X_2, X_3, X_4 and X_7 as for the differences of associations of X_{13} with each of the variables mentioned above, significant differences are found between Stjernarp and Skalstugan, Kvikkjokk and Skalstugan and Skalstugan and Gällivare, for the association of X_{12} with the number of seeds per cone, X_4, and between Kvikkjokk and Skalstugan, Kvikkjokk and Gunnarskog and Kvikkjokk and Pajala for the association of X_{12} with cone weight, X_3. It may, however, be

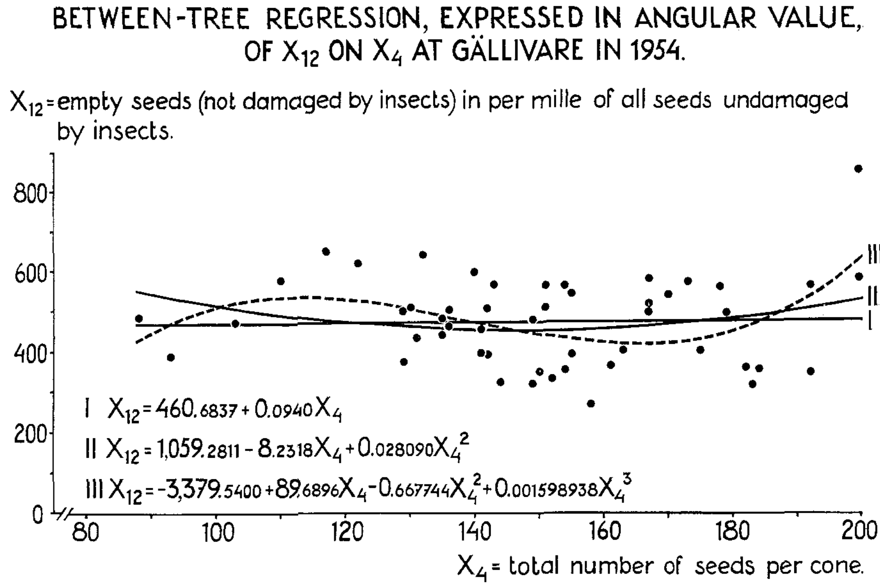


Fig. 43.

noted that these relationships, except for X_{12} with X_1 and X_{12} with X_7, are, in general, very weak. The portion in per cent of the variation in the dependent variable, referring to the correlation between X_{12} and each of the independent variables X_1, X_2, X_3, X_4 and X_7, varies for the cubic regressions as follows:

1. for the correlations between X_{12} and X_1 from 26 % at Gunnarskog to 59 % at Stjernarp,
2. for the correlations between X_{12} and X_2 from 2 % at Gällivare to 12 % at Skalstugan,
3. for the correlations between X_{12} and X_3 from 2 % at Gällivare to 21 % at Pajala,
4. for the correlations between X_{12} and X_4 from 6 % at Kvikkjokk to 19 % at Gällivare and
5. for the associations of X_{12} with X_7 from 28 % at Skalstugan to 53 % at Stjernarp.

Tables XXXV A—E summarizes the results.

6.4. Seed quality in the material for 1960 and 1961 from Gällivare and Kiruna including correlations between years

The mean values of the number of seeds for 10 cones per tree, and the distribution of seeds (in per cent) into embryo and endosperm types and to

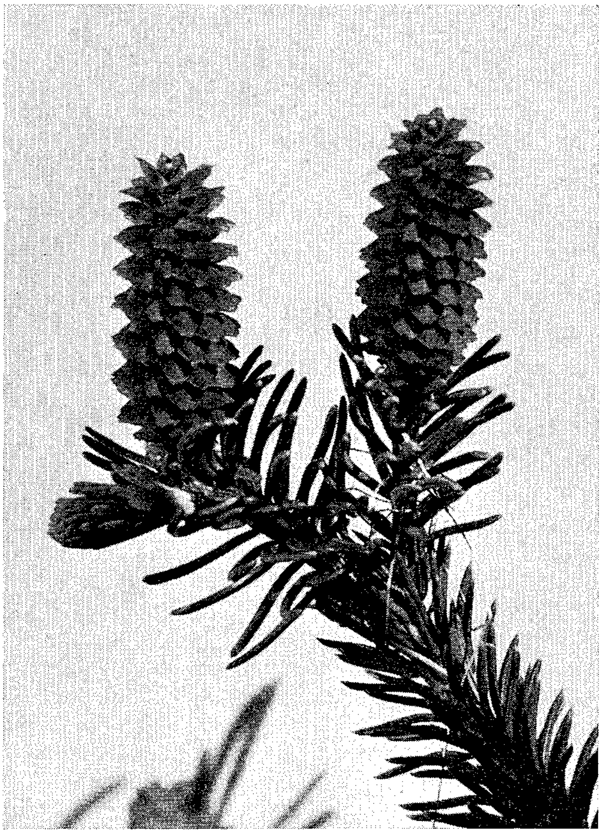


Fig. 44. The stage of pollination of the strobili of Norway spruce. - - - (Photo *H.-R. Jung.*)

the class of seeds (damaged by insects) per tree are listed in Appendix Tables XXXVI A—XXXIX A. Two samples of 100 seeds from each tree were used for the seed analyses. The percentages of empty seeds and the calculated seed germination rates are found in Appendix Tables XXXVI B—XXXIX B. The distribution of seeds from Kiruna in 1961 into embryo and endosperm classes (see the pages 28 and 29) is, moreover, shown graphically in Figs. 25 and 26. Finally, observations of the temperatures before and after spruce flowering at Malmberget and Kiruna are given in Figs. 6 and 28. Malmberget was, namely, the nearest meteorologic station to Gällivare. The climate station at Malmberget is situated approximately 6 km. from the sample plot at Gällivare and at an altitude of 393 m. above sea-level, which can be compared with the minimum height of the sample plot.

In order to determine the relative frequency of so-called "completely empty seed", and of seed containing smaller and larger remains of the collapsed female gametophyte, the empty seeds from Kiruna in 1961 has been classified into four sub-classes (v.p. 29) which are given in Fig. 26. The distribution of seeds in Fig. 26 establishes the fact that only 0 to 3 per cent of the empty seeds from each tree are "completely empty". The percentage of the seed of embryo class 0, containing small visible remnants of the collapsed female gametophyte (sub-class 0_b, cf. Fig. 30), varies for the trees at Kiruna from 7 to 80. According to KLAEHN and WHEELER (1961), 95 % of the unpollinated seed of Norway spruce is "completely empty". The corresponding percentage of empty seed without remnants for four unpollinated spruce cones (isolated in 1964 by N. WIERSMA and B. NILSSON) from Brunsberg, situated about 45 km. south of Gunnarskog, is 14.4. Of the remainder of the seeds 85.1 % were sub-class 0_b and 0.5 % sub-class 0_c.

The sizes of the remnants of the female gametophyte in empty seeds from Kiruna indicate that the ovules or embryos have collapsed at an early stage.

To judge from the remains of ovules in the non-pollinated seed from the four isolated cones at Brunsberg, it would appear to be difficult to distinguish between non-pollinated and pollinated empty seeds arisen as a result of e.g. collapsed ovules and of aborted embryos respectively.

The degree of delayed pollination and non-pollination, as stated earlier, is dependent on the frequency of male flowers, the time sequence in male and female flowering, the weather during pollen dispersion and on the fertility of the gametes. Poor male flowering and the occurrence of unfavourable weather conditions during the flowering period increase the probability of delayed pollination and the lack of pollination (ANDERSSON, 1955, and SARVAS, 1962).

An investigation of the time sequence in flowering of the two sexes of spruce flowers at Kiruna in 1960 (cf. Fig. 27) has shown that fifty per cent of the 52 trees included in this examination had conceptible female flowers three days before the first male flower had opened. About eighty per cent of the trees had conceptible female flowers one day before male flowering began, in about eighteen per cent of the trees the male and female blooming occurred simultaneously and in about two per cent of the trees the male flowers were developed 24 hours earlier than the female flowers.

As can be seen in the tables just mentioned and in Figs. 25 and 26, the degree of ripeness of the seed is particularly low and the percentage of empty seeds is exceptionally high both at Kiruna and at Gällivare in the years 1960 and 1961.

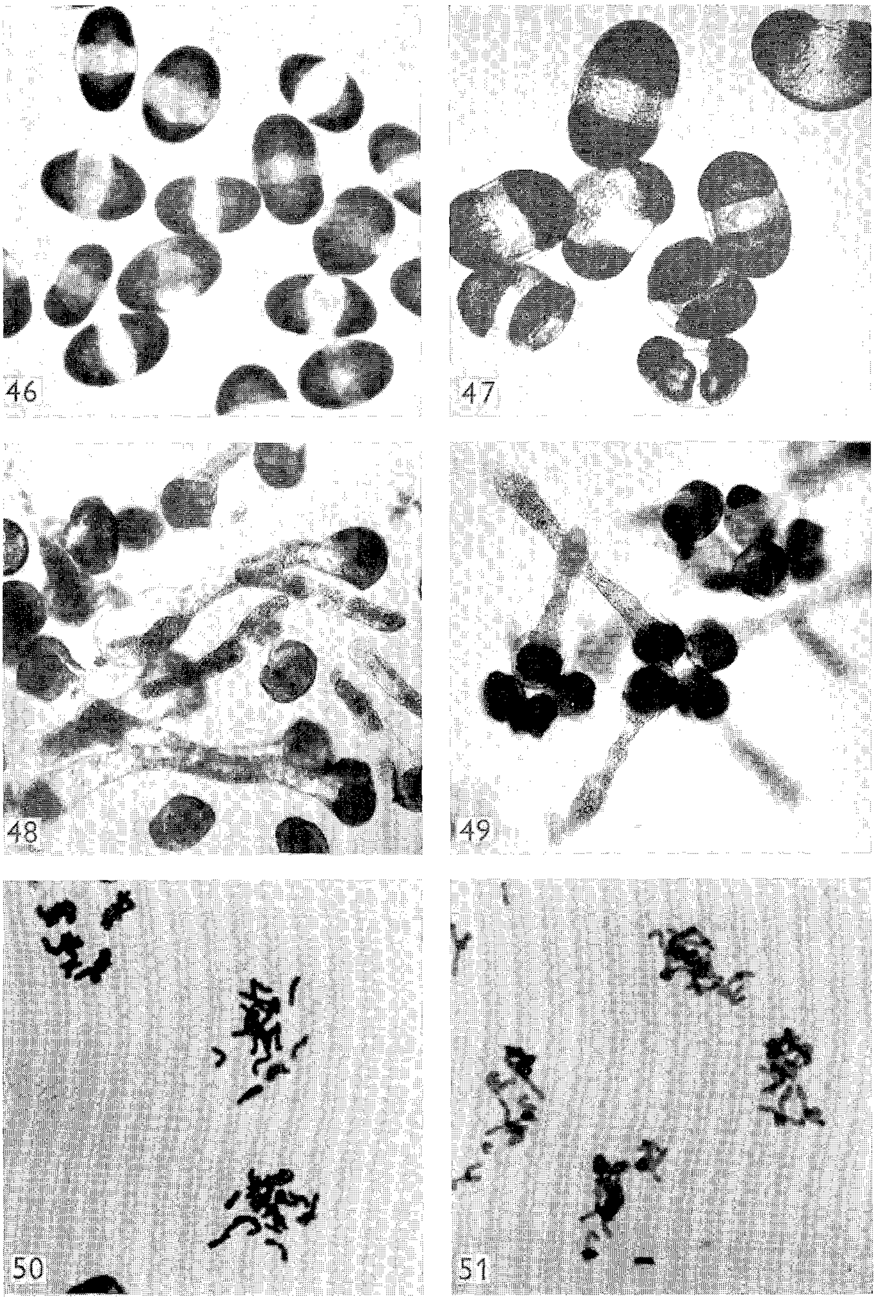
For the 13 trees which produced cones in both 1960 and in 1961 (numbers 1, 3, 4, 6, 22, 25, 29, 34, 35, 39, 50, 54 and 55) in the sample plot at Kiruna, the germination rate, in round figures, of all seeds not damaged by insects, was 8 % in 1960 and 9 % in 1961. The percentage of seeds with embryo unable to germinate, amongst all seeds (not damaged by insects) with embryo, amounted to 62 in 1960 and 81 in 1961. The frequency of empty seeds (embryo

Fig. 45. Seedlings obtained after open-pollination of the spruce 15 (I_1). In the middle a chlorophyll aberrant in homozygous condition which gives rise to needles without chlorophyll. - - - (Photo *N. Wiersma.*)

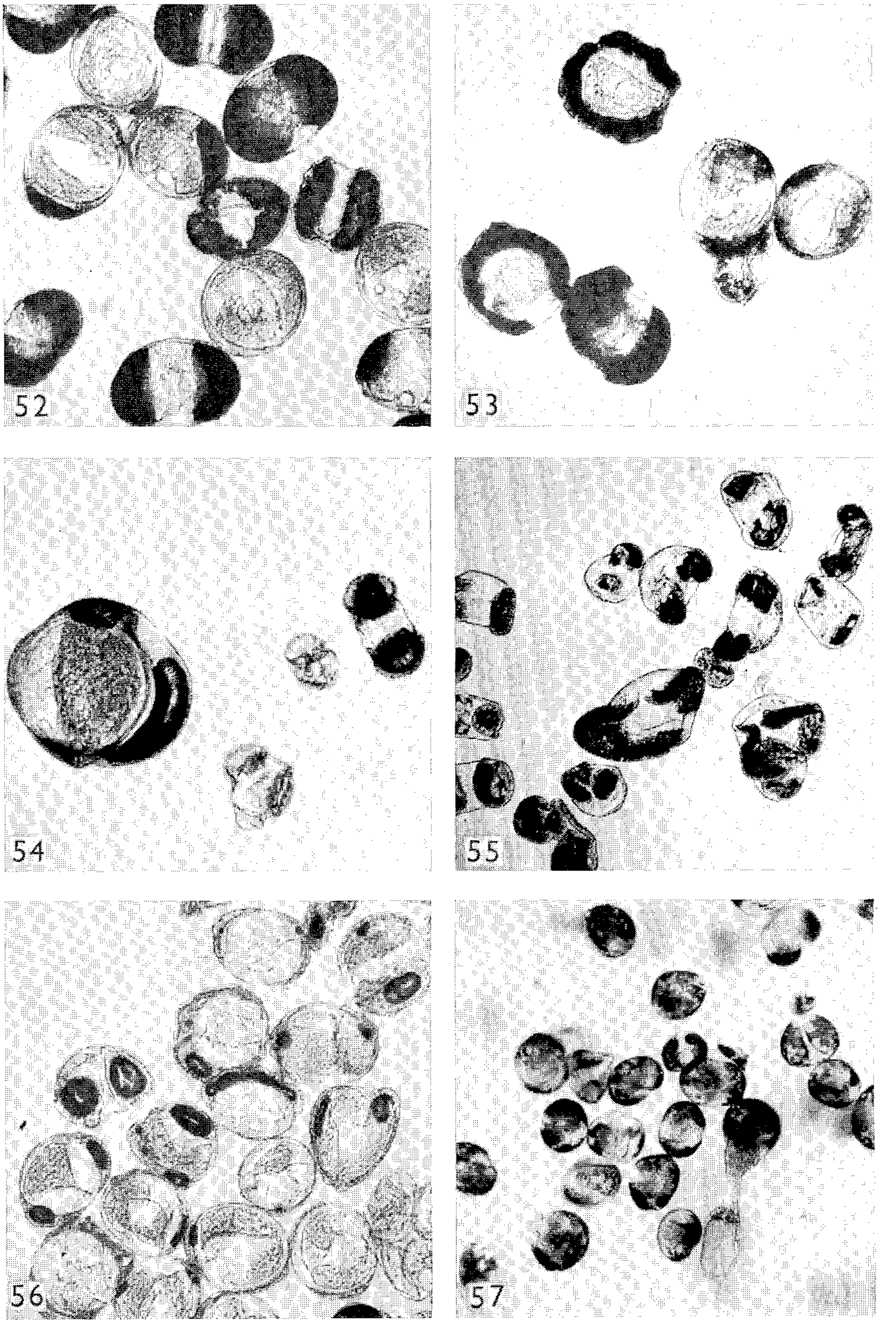
class 0+1) was 80 % in 1960 and decreased to 55 % in 1961. The number of seeds per cone was, on the average, 134 in 1960, and 115 in 1961 and varied in 1960 from 78 for tree No. 35 to 174 for tree No. 29. In 1961 the number of seeds per cone ranged from 42 for tree No. 22 to 183 for tree No. 1.

On referring to corresponding seed characters at Gällivare for the 17 trees included in the material for both 1954 and 1961, it is found that the variation for germination rate in percentage of all seeds, not damaged by insects, ranges from 0.2 for tree No. 99 to 49 for tree No. 103 in 1954 with a mean of 27, and from 1.4 for tree No. 99 to 54 for tree No. 103, with a mean of 28 for the year 1961. The percentage of seeds with embryo unable to germinate amongst all seeds (undamaged by insects) with embryo, at Gällivare, ranges from 29 for tree No. 21 to 71 for tree No. 99, with a mean of 41 in 1954, and 21 for tree No. 7 to 62 for tree No. 31, with a mean of 39 in 1961. The percentage of empty seeds for these trees ranges from 20 for tree No. 98 to 99 for tree No. 99, with a mean of 56 for 1954, and from 15 for tree No. 101 to 97 for tree No. 99, with a mean of 55, for 1961. Only nine trees are available for a comparison of seed characters at Gällivare in the years 1954, 1960 and 1961, namely trees Nos. 5, 18, 19, 21, 31, 75, 99, 102 and 103. The number of seeds per cone varies in 1954 from 117 for tree No. 31 to 200 for the trees Nos. 19 and 99, and has a mean of 165 for the nine trees. In 1960 the number of seeds per cone ranged from 68 for tree No. 31 to 181 for tree No. 5, with a mean of 132, and in 1961 from 125 for tree No. 31 to 212 for tree No. 21, with a mean of 173. The variation in per cent for empty seeds for the nine trees ranges from 28 for tree No. 103 to 99 for tree No. 99, with a mean of 61 for 1954, and from 57 for tree No. 103 to 100 for tree No. 99, with a mean of 77 for 1960, and also from 19 for tree No. 103 to 97 for tree No. 99, with a mean of 53 for the year 1961. The germination rate in per cent of all seeds, not damaged by insects, for the same trees, varies from 0.2 for tree No. 99 to 49 for tree No. 103, with a mean of 24 in 1954, from 0 for tree No. 99 to 35 for tree No. 103, with a mean of 18 in 1960, and from 1 for tree No. 99 to 54 for tree No. 103, with a mean of 30 for 1961. Finally, the percentage of seeds with embryo unable to germinate, of all seeds (not damaged by insects) with embryo, for the nine trees, ranges from 29 for tree No. 21 to 71 for tree No. 99, with a mean of 43 in 1954, from 13 for tree No. 21 to 100 for tree No. 99, with a mean of 35 in 1960, and from 34 for the trees Nos. 5 and 103 to 62 for tree No. 31, with a mean of 40 in 1961.

If the observations on the 9 trees common to the years 1954, 1960 and 1961 at Gällivare and the 13 trees common to 1960 and 1961 at Kiruna, are subjected to an analysis of variance, in which the total variance is divided into portions corresponding to different sources of variation which have been tested in a similar way to that used in Tables 48 a—48 d, significant differences between years at Gällivare are obtained with regard to the total number of



Figs. 46—49 and 52—57 show pollen grains from Norway spruce. Fig. 46. Pollen from a tree with normal meiotic divisions. Fig. 47. Pollen produced by a seedling arising from a asyndetic spruce. Figs. 48 and 49. Germinating pollen grains (after 48 hours in a 2 % sucrose solution at + 30° C.) from two spruces at Kiruna. Figs. 50 and 51 show respectively metaphase I and anaphase II stages of meiosis in Norway spruce, where the chromosome pairing is not complete.



Unequal distribution of univalents to the poles of daughter nuclei may among other things lead to the formation of unbalanced gametes. Figs. 52—57. More or less defective or unbalanced pollen grains from spruces with disturbed meiosis at Kvikkjokk and Gällivare.

Table 47 a. Values of *F* for deviations of quadratic and cubic regressions from corresponding linear regressions.

(Based on tree mean values in 1954)

Population	Regression of	Deviation from linearity for the	
		Quadratic polynomial with $n_1 = 1$ and $n_2 = 47$ d.f.	Cubic polynomial with $n_1 = 2$ and $n_2 = 46$ d.f.
Stjernarp............	X_{13} on X_1	5.92*	3.53*
,, ...	X_2	0.12	0.07
,, ...	X_3	0.23	0.37
,, ...	X_4	0.53	0.95
,, ...	X_7	4.57*	2.98
Gunnarskog.........	X_{13} on X_1	0.01	0.01
,, ...	X_2	0.44	0.38
,, ...	X_3	0.07	0.15
,, ...	X_4	1.58	0.88
,, ...	X_7	0.61	0.34
Skalstugan..........	X_{13} on X_1	12.12**	6.63**
,, ...	X_2	3.35	4.23*
,, ...	X_3	2.61	1.35
,, ...	X_4	0.40	0.51
,, ...	X_7	9.71**	5.50**
Kvikkjokk	X_{13} on X_1	0.44	0.25
,, ...	X_2	0.42	0.49
,, ...	X_3	0.43	0.95
,, ...	X_4	0.00	0.50
,, ...	X_7	0.50	0.40
Gällivare............	X_{13} on X_1	0.85	0.44
,, ...	X_2	1.96	1.54
,, ...	X_3	1.31	0.64
,, ...	X_4	3.81	2.91
,, ...	X_7	2.38	1.16
Pajala..............	X_{13} on X_1	2.16	1.13
,, ...	X_2	0.48	0.24
,, ...	X_3	0.33	1.05
,, ...	X_4	0.01	0.87
,, ...	X_7	0.68	1.22
		$n_1 = 1$ and $n_2 = 297$	$n_1 = 2$ and $n_2 = 296$
The six populations taken together.......	X_{13} on X_1	2.73	1.47
,,	X_2	0.03	0.14
,,	X_3	7.89**	4.58*
,,	X_4	1.53	1.86
,,	X_7	8.37**	5.08**

X_1 = thousand-grain weight in centigram of all seeds per cone
X_2 = cone length in tenths of a millimetre
X_3 = cone weight in centigram
X_4 = the total number of seeds per cone
X_7 = the weight in milligram of all seeds per cone
X_{13} = germination rate (in the JACOBSEN germinator) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per mille}/1000}$)

* Significant at the 5 % level
** ,, ,, ,, 1 % ,,
*** ,, ,, ,, 0.1 % ,,

Table 47 b. Values of F for deviations of quadratic and cubic regressions from corresponding linear regressions.

(Based on tree mean values in 1954)

Population	Regression of	Deviation from linearity for the Quadratic polynomial with $n_1 = 1$ and $n_2 = 47$ d.f.	Deviation from linearity for the Cubic polynomial with $n_1 = 2$ and $n_2 = 46$ d.f.
Stjernarp	X_{12} on X_1	5.57*	3.75*
,, ...	X_2	0.22	0.11
,, ...	X_3	0.28	0.24
,, ...	X_4	0.19	1.22
,, ...	X_7	4.32*	3.18
Gunnarskog	X_{12} on X_1	0.29	0.15
,, ...	X_2	0.14	0.50
,, ...	X_3	0.07	0.04
,, ...	X_4	1.90	1.36
,, ...	X_7	1.70	0.86
Skalstugan	X_{12} on X_1	0.05	0.24
,, ...	X_2	1.05	2.88
,, ...	X_3	0.34	0.23
,, ...	X_4	0.01	0.32
,, ...	X_7	0.36	0.43
Kvikkjokk	X_{12} on X_1	4.85*	2.41
,, ...	X_2	1.07	0.58
,, ...	X_3	0.00	0.08
,, ...	X_4	0.58	0.30
,, ...	X_7	2.36	3.43*
Gällivare	X_{12} on X_1	6.32*	3.11
,, ...	X_2	0.12	0.08
,, ...	X_3	0.80	0.39
,, ...	X_4	2.48	5.52**
,, ...	X_7	1.36	0.67
Pajala	X_{12} on X_1	0.21	0.51
,, ...	X_2	0.30	0.20
,, ...	X_3	3.13	1.99
,, ...	X_4	0.25	1.56
,, ...	X_7	1.06	0.87
		$n_1 = 1$ and $n_2 = 297$	$n_1 = 2$ and $n_2 = 296$
The six populations taken together	X_{12} on X_1	18.03***	3.28*
,,	X_2	1.44	1.39
,,	X_3	0.63	0.37
,,	X_4	0.06	0.06
,,	X_7	2.31	10.49***

X_1 = thousand-grain weight in centigram of all seeds per cone
X_2 = cone length in tenths of a millimetre
X_3 = cone weight in centigram
X_4 = the total number of seeds per cone
X_7 = the weight in milligram of all seeds per cone
X_{12} = empty seeds (not damaged by insects) in per mille of all seeds not damaged by insects (the per mille data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per mille}/1000}$)

* Significant at the 5 % level
** ,, ,, ,, 1 % ,,
*** ,, ,, ,, 0.1 % ,,

Table 48 a. Analysis of variance of number of seeds per cone and estimation of components of variance in the material from Gällivare and Kiruna.

Source of Variation	Gällivare for the years 1954, 1960 and 1961					Kiruna for the years 1960 and 1961				
	Sum of Squares	D.F.	Mean Square	Component of Variance	%	Sum of Squares	D.F.	Mean Square	Component of Variance	%
Between years	8,629.01	2	4,314.51	457.29	35.5	2,378.91	1	2,378.91	121.97	7.0
Between trees	16,750.92	8	2,093.86	631.65	49.1	29,393.57	12	2,449.46	828.09	47.5
Interaction trees × years	3,182.57	16	198.91	103.27	8.0	9,519.52	12	793.29	717.07	41.1
Error				95.64[1]	7.4				76.22[1]	4.4
Total	28,562.50	26		1,287.85	100	41,292.00	25		1,743.35	100

Gällivare — Quotients:

$$\text{Years} = \frac{4{,}314.51}{198.91} = 21.69^{***}$$

$$\text{Trees} = \frac{2{,}093.86}{198.91} = 10.53^{***}$$

[1] obtained from an analysis of variance of cones within trees

Kiruna — Quotients:

$$\text{Years} = \frac{2{,}378.91}{793.29} = 3.00$$

$$\text{Trees} = \frac{2{,}449.46}{793.29} = 3.09^{*}$$

Table 48 b. Analysis of variance of empty seeds (not damaged by insects) in per cent[1] of all seeds (not damaged by insects) and estimation of components of variance in the material from Gällivare and Kiruna.

Source of Variation	Gällivare for the years 1954, 1960 and 1961					Kiruna for the years 1960 and 1961				
	Sum of Squares	D.F.	Mean Square	Component of Variance	%	Sum of Squares	D.F.	Mean Square	Component of Variance	%
Between years	1,093.97	2	546.98	56.38	18.6	1,683.09	1	1,683.09	123.72	47.8
Between trees	5,285.46	8	660.68	207.03	68.3	2,352.22	12	196.02	60.66	23.4
Interaction trees × years + error	633.40	16	39.59	39.59	13.1	896.54	12	74.71	74.71	28.8
Total	7,012.83	26		303.00	100	4,931.85	25		259.09	100

Gällivare — Quotients:

Years = 13.82***

Trees = 16.69***

[1] expressed in angular value

Kiruna — Quotients:

Years = 22.53***

Trees = 2.62

seeds per cone, the percentage of empty seeds (not damaged by insects) amongst all seeds undamaged by insects, and germination capacity of all seeds not damaged by insects. Significant values of F at Kiruna are found, likewise, for differences between years with respect to the percentage of empty seeds not damaged by insects, and seeds (not damaged by insects) with embryo unable to germinate of all seeds (undamaged by insects) with embryo. The variations between the nine trees within years at Gällivare are significant for the four seed characters which were studied. At Kiruna the variations between the 13 trees are significant for two of the four seed characters, namely, for germination rate of all seeds not damaged by insects and for the total number of seeds per cone.

Furthermore, on estimating the components of variance of various seed characters (KEMPTHORNE, 1957, p. 264 et seq. and 1960, p. 103 et seq.), it is found that the percentages, proportional to the tree components, range from 38 to 80 at Gällivare, and from 5 to 75 at Kiruna for the seed characters in question. Moreover, Tables 48 a—48 d show that the percentage of the total variation due to the tree component at Gällivare and Kiruna respectively amounts to: 80 and 75 for the proportion of germinated seeds amongst all seeds not damaged by insects, 49 and 48 for the number of seeds per cone, and 68 and 23 for the proportion of empty seeds (not damaged by insects). Thus, the repeatability (or the constancy of repeated measurements on the same individuals) is high for the germinating ability of all seeds (not damaged by insects) and for empty seeds (not damaged by insects) amongst all seeds undamaged by insects at Gällivare, and for the germination rate of all seeds (not damaged by insects) at Kiruna. A similar estimation of the repeatability on the basis of observations during a number of years can be a good criterion for the advancement of selection.

The percentage of variation due to the tree component for the proportion of seeds (not damaged by insects) with embryo unable to germinate amongst all seeds (undamaged by insects) with embryo, is 38 in the material from Gällivare and only 5 in that from Kiruna. This means that the variation in this character at Kiruna can almost wholly be ascribed to the milieu (i.e. to climatological differences between years). This also applies, to a certain degree, for the variation in the percentage of empty seeds. The differences between years are clearly evident in Appendix Tables XXXVIII B and XXXIX B and in Figs. 3 and 6. The air temperature at Kiruna during the period 4th June—30th September in 1960 was more favourable for seed maturity than the period 14th June—30th September in 1961. The number of days with a mean temperature of $> 12°$ C. during the period from the commencement of flowering until the end of September at this meteorologic station was 44 in 1960 and 23 in 1961. This condition is reflected principally by the fact that the frequency of seeds (not damaged by insects) with embryo unable to germinate amongst all seeds (undamaged by insects) with embryo, is higher in 1961 than in 1960, or also, that the germination rate of seeds (not damaged by insects) with embryo, is greater in 1960 than in 1961. The percentage of empty seeds (not damaged by insects) of all seeds (undamaged by insects) is, however, greater in 1960 than in 1961. The percentage of empty seed (not including empty seeds caused by insects) at Kiruna also seemed to a certain extent to be positively correlated with the unfavourable conditions of temperature before flowering. The meiosis in the pollen mother cells (Figs. 33—35 and 37—39) took place at Kiruna between 15—26th May in 1960 and between 16—27th May in 1961. If these periods are compared with the corresponding periods in the minimum-temperature curves shown in Fig. 6, it is found that there were two nights of frost with temperatures under $-5°$ C., namely, the 20th and 21st of May 1960, i.e. during the period of reduction division. Many aberrations of meiosis could be observed in the pollen mother cells after these frosty nights (Figs. 33—35). The frequency of empty seeds (not damaged by insects) amongst all seeds not damaged by insects, for trees common to both years, was 80 % in 1960 and 55 % in 1961 (see Fig. 61).

A similar situation in respect of modificatory differences between years in germination capacity and the frequency of empty seed can be shown in the material from Gällivare for 1960 and 1961 (cf. Appendix Tables XXXVI B and XXXVII B and Fig. 28). The numbers of days with a mean temperature of $> 12°$ C. at Malmberget, during the periods 1st June—30th September in 1960 and 8th June—30th September in 1961, were 59 and 42 respectively. The corresponding average air temperatures during the same periods were 11.8° C. in 1960 and 11.4° C. in 1961. Under the influence of these local climatic conditions the 17 trees at Gällivare, common to 1960 and 1961, produced seeds during those two years with a germination capacity, expressed in per cent for all seeds (not damaged by insects) with embryo, of 67 and 55 respectively. In the same two years and for the same trees, the frequency of seeds (not damaged by insects) with embryo unable to germinate, in per cent of all seeds (not damaged by insects) was found to be 6 and 19, and that of all seeds (not damaged by insects) with embryo was 32 and 45 respectively. The comparative percentages of empty seed (not damaged by insects) amongst all seeds (not damaged by insects) between the two years for 17 trees at Gällivare were considerable, or 76 and 56. The higher proportion of empty seed in 1960, similarly to Kiruna, can therefore to some extent be associated with the temperature disturbances during meiosis. The reduction division took place at Gällivare in 1960 during the period 12th to 23rd May. The temperature conditions are shown in Fig. 28 on the page 144.

Correlations for some seed characters between the years 1954 and 1960, 1954 and 1961, and 1960 and 1961 at Gällivare, and between 1960 and 1961 at Kiruna have been calculated. These correlations are based on trees common to each pair of years, and the results obtained from this study are shown in Table 49. The correlation coefficients are all positive and highly significant except for the total number of seeds per cone at Kiruna between the years 1960 and 1961, and for seeds (not damaged by insects) with embryo unable to germinate amongst all seeds undamaged by insects at Gällivare between the years 1954 and 1960. The coefficients are significant greater than zero at the 5 % level with the exception of the coefficients for seeds (undamaged by insects) with embryo unable to germinate amongst all seeds not damaged by insects at Kiruna, and for the germinating ability of all seeds (not damaged by insects) with embryo, between the years 1954 and 1961 at Gällivare, as well as between 1960 and 1961 at Gällivare and Kiruna. It is found that these four coefficients do not differ significantly from zero.

Valuable information for mass selection is, thus, given by the correlations between repeated observations on the same trees.

6.5. Seed quality after selfing and open-pollination in the field experiment at Åkersberga in 1954

As mentioned earlier, the trees used for this investigation were some of the progenies of Norway spruce which Prof. NILS SYLVÉN (1910) had raised (after selfing and open-pollination in 1909) and planted in the field experiment at Åkersberga in 1916 (cf. LANGLET, 1940).

Fifteen seedling trees derived from two mother trees, Nos. 1 and 3, were investigated. Five of the trees are inbred offsprings (I_1), two, Nos. 9 and 15, originating from mother tree No. 1, and three, Nos. 21, 22 and 31, from mother tree No. 3. The ten remaining trees are open-pollinated progenies from the mother trees Nos. 1 and 3. The trees Nos. 47, 49, 53, 73 and 78 derive from mother tree No. 1, and trees Nos. 82, 87, 92, 93 and 96 from mother tree No. 3. It can be seen, on reference to Appendix Tables XL A, XL B and XLI, that seed from trees Nos. 9, 15, 21, 31, 47 and 87 was harvested after both selfing and open-pollination. In order to obtain inbred seed, the strobili (cf. Fig. 44) of the six last mentioned offsprings and catkins from the same trees were placed together in bags and artificially pollinated.

The strobili were isolated, about a week before flowering began, by the use of two pergamene paper bags of different sizes, each bag consisting of a double layer of paper. A corner of the outer bag was cut off to reduce any increase in temperature around the strobili in the bags during sunny weather.

Table 48 c. Analysis of variance of germinated seeds in per cent[1] of all seeds (not damaged by insects) and estimation of components of variance in the material from Gällivare and Kiruna.

Source of Variation	Gällivare for the years 1954, 1960 and 1961					Kiruna for the years 1960 and 1961				
	Sum of Squares	D.F.	Mean Square	Component of Variance	%	Sum of Squares	D.F.	Mean Square	Compo-nent of Variance	%
Between years....	312.74	2	156.37	15.26	8.9	5.92	1	5.92	0.00	0.0
Between trees.....	3,461.09	8	432.64	137.86	80.1	596.93	12	49.74	21.39	75.4
Interaction trees × years + error	305.02	16	19.06	19.06	11.0	83.49	12	6.96	6.96	24.6
Total	4,078.85	26		172.18	100	686.34	25		28.35	100

Gällivare — Quotients:
Years = 8.20**
Trees = 22.70***

Kiruna — Quotients:
Years = 0.85
Trees = 7.15***

[1] expressed in angular value

Table 48 d. Analysis of variance of seeds (not damaged by insects) with embryo unable to germinate in per cent[1] of all seeds (not damaged by insects) with embryo and estimation of components of variance in the material from Gällivare and Kiruna.

Source of Variation	Gällivare for the years 1954, 1960 and 1961					Kiruna for the years 1960 and 1961				
	Sum of Squares	D.F.	Mean Square	Component of Variance	%	Sum of Squares	D.F.	Mean Square	Compo-nent of Variance	%
Between years....	50.66	2	25.33	0.00	0.0	876.96	1	876.96	63.94	55.2
Between trees.....	2,727.69	8	340.96	73.58	38.0	696.03	12	58.00	6.12	5.3
Interaction trees × years + error	1,923.60	16	120.22	120.22	62.0	549.09	12	45.76	45.76	39.5
Total	4,701.95	26		193.80	100	2,122.08	25		115.82	100

Gällivare — Quotients:
Years = 0.21
Trees = 2.84*

Kiruna — Quotients:
Years = 19.16***
Trees = 1.27

[1] expressed in angular value

It was intended that the outer, much larger bag should protect the smaller inner bag from being torn apart by adjacent branches during rain or strong winds. Before isolation it was naturally necessary to remove all twigs from the immediate vicinity of the bags. Catkin-bearing branches were detached a day or two before the catkins ripened, and were then kept in water in the laboratory until mature. The actual pollination was accomplished with the help of glass pipettes or medicine droppers or bulles (cf. ANDERSSON, 1947 b, CUMMING and RIGTHER, 1948, and SYRACH LARSEN, 1956). The bags were removed about three weeks after the pollination, by which time the strobili had closed. When the pergamene bags were removed, other bags of fine-meshed metal net (fly-net) were put over all isolated conelets and an equal number of unisolated conelets (chosen at random). This was done to provide protection against squirrels, crossbills and other dangers.

The experimental data from the progenies, with reference to the percentage of germinated seeds, number of seeds per cone, and 1,000-grain weight after selfing, in comparison with the corresponding seed characters after open-pollination, are given in Appendix Tables XL A, XL B and XLI.

The progenies Nos. 9, 15, 21 and 31 showed a markedly lower average seed germination percentage (in the JACOBSEN germinator) after selfing, than after open-pollination. The mean germinating ability of all seeds, not damaged by insects, for these trees, is 0.25 % after selfing and 34.5 % after open-pollination. The corresponding germination percentages for progenies Nos. 47 and 87 are 2.0 and 63.9 respectively. The loss in seed germination capacity is therefore 34.3 % for the first offspring-group, and 61.9 % for the other.

In comparison to the seed development in trees Nos. 47 and 87 after selfing, it can be mentioned that SYLVÉN (1910), after self-pollination of the mother trees Nos. 1 and 3 in 1909, obtained 4.4 and 4.5 per cent respectively germinable seeds of all seeds per cone. As can likewise be seen from the germination data in Appendix Table XLI, the mean germinating ability of all seeds (not damaged by insects) after open-pollination, for trees Nos. 47, 49, 53, 73, 78, 82, 87, 92, 93 and 96, was 56.5 %. The loss in seed germination capacity between open-pollinated seed and inbred seed (I_1) was 54.5 % (if the seed germination data after selfing, for the trees Nos. 47 and 87, are used as an average for I_1-seeds). The mean germination rates for all seeds (not damaged by insects) after open-pollination of progenies from the mother trees Nos. 1 and 3 are 58.1 and 54.9 respectively. A variance ratio test shows that the germinating capacity of the two progeny groups is not significantly different ($F = 0.18$ for $n_1 = 1$ and $n_2 = 8$ d.f.). Estimates of corresponding mean squares and variance ratios for thousand-grain weight and number of seeds per cone after open-pollination show, likewise, that the two offspring-groups do not differ significantly from each other. The values of F are 0.04 and 2.55 respectively.

Table 49. Correlations between tree means for the years 1954 and 1960, 1954 and 1961 as well as for the years 1960 and 1961.

(Based on tree mean values)

Population	Between the years	No. of sets of observations = trees	X_4	X_7	X_{14}	X_{16}	X_{17}	X_{18}
Gällivare	1954 and 1960	11	0.745**	0.949***	0.745**	0.604*	0.735**	0.762**
Gällivare	1954 and 1961	17	0.748***	0.838***	0.857***	0.804***	0.828***	0.082
Gällivare	1960 and 1961	17	0.705**	0.849***	0.696**	0.716**	0.620**	0.274
Kiruna	1960 and 1961	13	0.633*	0.834***	0.652**	0.370	0.756**	0.278

X_4 = the total number of seeds per cone
X_7 = the weight of all seeds per cone
X_{14} = empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects (the per cent data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per cent}/100}$)

X_{16} = seeds (not damaged by insects) with embryo unable to germinate, in per cent of all seeds not damaged by insects (the per cent data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per cent}/100}$)

X_{17} = calculated germination rate in per cent of all seeds not damaged by insects (the per cent data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per cent}/100}$)

X_{18} = calculated germination rate in per cent of all seeds (not damaged by insects) with embryo (the per cent data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per cent}/100}$)

* Significant at the 5 % level
** ,, ,, ,, 1 % ,,
*** ,, ,, ,, 0.1 % ,,

Corresponding tests for germination rate of all seeds not damaged by insects, 1,000-grain weight and number of seeds per cone after open-pollination of I_1-progenies from the two mother trees, give the following values of F, 0.11, 1.04 and 5.34 (for $n_1 = 1$ and $n_2 = 2$ d.f.).

Even though the material is small and does not represent a random sample of a spruce population, nevertheless, the germinating capacity of inbred seeds in relation to that of seeds after open-pollination (outbred seeds) is of interest. It is already apparent that the reduction in germination capacity between open-pollinated seeds and I_1-seeds, and between I_1-seeds and I_2-seeds is remarkably large. The germinating ability of I_1-seeds, in relation to open--pollinated seeds, for trees Nos. 47 and 87, is 1.9 % and 4.4 % respectively. The relative germination capacity of I_2-seeds from trees Nos. 9 and 15 is about 23 % of the germination of I_1-seeds originating from tree No. 47. The corresponding relative percentage for I_2-seeds from trees Nos. 21 and 31 is about 7.4 of the germination capacity of I_1-seeds from tree No. 87. The greatest reduction of seed germination capacity, on the basis of this means of comparison, occurred in the first generation of selfing (I_1). In conjunction with this study of the germinating ability of outbred seeds and inbred seeds (after the most extreme method of inbreeding, viz. *self-fertilization*) it can be justifiable to make two comments. The first concerns outbred seeds. The different offspring-groups in the trial at Åkersberga are planted in straight rows in plots (cf. LANGLET, 1940, p. 5), and therefore, crossings between closely related individuals (sibs and half-sibs) are not precluded. During pollination, however, there was a plentiful supply of near-pollen from trees that were not related. The second comment refers to the surmised unfavourable temperature conditions within the inner isolation bags. Tree No. 26 I_1 had produced cones after open-pollination but not after selfing. The abnormal conditions within the bags could have caused, or contributed to, the non-development of these cones. The same environmental factors may also, more or less, have influenced the degree of seed setting. Independent of this environmental influence on seed development and germination capacity, the progenies of the first generation of selfing show a pronounced inbreeding depression in the question of vigour of growth (see LANGLET, 1940). This strong reduction in vigour has been further accentuated, and indicates that quantitative characters in an outbreeding species such as *Picea abies* are also subjected to effects due to dominance. In the autumn of 1955 the mean heights of the inbred offspring (Nos. 9 and 15) from the mother tree No. 1 (see e.g. Appendix Table XLI) and (Nos. 21, 26 and 31) from tree No. 3 were namely 14.7 m. and 11.1 m. respectively. The corresponding mean heights of the open-pollinated progenies from the same mother trees, Nos. 1 and 3, were 19.5 m. and 17.5 m. respectively.

The effect of inbreeding was also accentuated by an increased frequency of plants carrying deleterious factors. Seeds (arising after open-pollination) from the inbred tree No. 15 produced 358 (84.2 %) normal green seedlings, 6 (1.6 %) light green to yellow-green seedlings with a reduced quantity of chlorophyll, and 16 (4.2 %) white seedlings (see Fig. 45). Of the ten trees which were raised from open-pollinated seeds harvested from the mother trees Nos. 1 and 3 only three, namely Nos. 73, 78 and 87, produced a number of seedlings with chlorophyll defects of the heterozygous state.

7. Discussions and conclusions

The production and quality of spruce seed varies from stand to stand, from one altitude and latitude to another, from tree to tree and from year to year, according to previously presented studies by, among others, SCHMIDT (1930), WIBECK (1931), HEIKINHEIMO (1937 and 1961), ROHMEDER (1954), EHRENBERG, GUSTAFSSON, PLYM FORSHELL and SIMAK (1955), HAGNER (1958) and SCHMIDT-VOGT and co-authors (1964). This truth—already obvious—has been further confirmed by the present work.

Seed characters are to a certain degree conditioned by heredity, but are very strongly modified, as shown earlier, by external factors. In order to facilitate the division of the phenotypic variance of single genotypes into their component parts: environment, genotype and interactions between heredity and environment (LUSH, 1940), experiments on clones in different altitudes or contrasting habitats are very useful. If one whishes to know how superior genotypes in a clone trial of forest trees transmit their desirable characters or performances to their offspring, and how they react to various influences of environment, this must be assessed by progeny testing and by planting out replications of the progeny test in various sites. However, progeny testing takes a long time and if the interval between generations is also long, as in Norway spruce, the determining of certain genetic parameters can be a work covering a considerable period of time. To roughly estimate whether a selection of one or two characters, based on parental merits, can be expected to be successful or not, one must at least within certain areas where the climatic conditions are unfavourable for the development of the trees, begin with certain introductory investigations which can serve as a guide to selection.

For this purpose observations repeated during a number of years on the same trees, for characters such as seed yield per cone and per tree and for seed quality, can result in useful information. The reasons for phenotype variation are often very complex. Characters such as seed yield and seed quality are affected by a sequence of genetic, physiologic and environmental infleunces which mutually can be independent, positively or negatively correlated. It is therefore necessary from the points of view of seed selection and seed production to examine, in each individual case, *partly* those factors that can infleunce the size and quality of the seed harvest, and *partly* their relative portion of the total variation. In consideration of the large number of factors that influence only one phenotypic character, the investigations, similarly, must unfortunately often be strictly limited to include only a smaller number of the most important causes of variation and interaction.

Points taken up for discussion in this work are: 1) variations in seed yield per cone (expressed as number of seeds per cone), in seed weight, in seed germinating ability, and in empty seeds amongst populations and areas and amongst trees within areas, 2) regressions and correlations between tree means of cone and seed characters (such as associations of cone length and cone weight with seed weight and the number of seeds per cone compared with the corresponding population parameters within trees), changes in the behaviour of trees in diverse environments (i.e. in different years) with regard to studied seed and cone properties, the separate effect of some characters on seed germinating ability, and on the percentage of empty seeds, 3) the joint effect of cone and seed characters on seed germinating capacity, 4) component of variance for seed germinating capacity, empty seeds and the number of seeds per cone, 5) the reproductive fitness of trees and populations with regard to seed quality and seed production, and 6) practical applications.

7.1. Variations in seed yield per cone, seed weight, seed germinating ability and empty seeds amongst populations or areas and trees within areas

Seed yield per tree in grams is a character comprising at least three main components: number of seeds and seed weight per cone and number of cones per tree. The third character, number of cones per tree, can be relatively easily observed during cone collecting and the selection of trees, provided that the tree selection is made whilst the trees are cone-bearing. Each of these three main components is in turn influenced by a series of component factors. Seed quality is a complex character composed of genetic, milieu--determinant and physiologically-controlled factors. A high percentage of empty seeds and of seeds with embryo unable to germinate can, of course, very strikingly decrease both seed yield and seed quality (see Appendix Tables XXXI B—XXXIV B, XXXVII B—XXXIX B and Figs. 25 and 26). Seed weight is a useful indicator of the seed yield (when this is not expressed in number of seeds) and, at the same time, a very valuable seed quality factor.

In the present study analyses of variance of seed yield per cone, seed weight, germination capacity and the frequency of empty seeds show that significant differences between sample plots and geographic areas exist for each of the various seed characters in the material for both 1948 and 1954. Significant differences with respect to these characters, inter alia, were also found in most cases between years (see section 5.2.).

In 1948 the total number of seeds per mean cone varies, between the sample plots, from 247 at Stjernarp to 109 at Skalstugan (see Table 24). Accordingly, the number of seeds decreases with the northern latitude and with the height above sea level. The same pattern of variation in respect of altitude and northern latitude is shown in seed weight and the germination capacity as well as, broadly speaking, cone length and cone weight. In 1948 the weight in grams of the total number of seeds per mean cone fell from 1.18 at Stjernarp to 0.24 at Skalstugan, and the thousand-grain weight in grams, of all seeds per cone, for the same localities, fell from 4.74 to 2.16. The calculated germination rate in per cent for all seeds not damaged by insects decreased from 59 at Härryda to 8 at Skalstugan, and for full seeds (not damaged by insects) at the same localities from 95 to 29 (see Table 40). The material for 1954 showed similar variations and the same trend for corresponding seed and cone characters (Table 23). The number of seeds per cone ranged in 1954 from 227 at Stjernarp and 171 at Skalstugan to 116 at Gällivare. In the same year the weight in grams of all seeds per cone was 1.03 at Stjernarp, 0.55 at Skalstugan and 0.40 at Gällivare.

The situation for the calculated seed germinating ability is clarified in Table 41. The percentage for all seeds not damaged by insects fluctuated from 51 at Stjernarp to 17 at Skalstugan, and that for full seeds not damaged by insects from 96 at Stjernarp and Gunnarskog to 32 at Skalstugan. At Kvikkjokk and Gällivare, in the same year, the calculated germination rate for all full seeds (not damaged by insects) was 44 % and 61 % respectively.

When estimating the germination capacity in the Jacobsen germinator for the total number of seeds not damaged by insects, it is found that this germinating ability, at Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in 1954 was: 51, 44, 30, 23, 18 and 35 per cent respectively. The frequency of seeds (not damaged by insects) with embryo unable to germinate, in per cent of all seeds (not damaged by insects) with embryo, like most of the other characters, varies very conspicuously between populations or areas. In 1954 this percentage was 5, 42, 61 and 59 respectively, at Stjernarp, Skalstugan, Kvikkjokk and Gällivare. Therefore, even during such an exceedingly good spruce seed year as 1954 seed ripening was very poor in localities within the extreme latitudes in northern Sweden. Large physiologic gains could therefore be expected in seed yield and seed maturity in clone seed orchards and seedling seed orchards intended for these regions on the basis that these plantations for seed productions are localized to areas with climates which are conducive to flowering and the ripening of the seed. The role of fertilization (Gemmer, 1932, Tamm and Carbonnier, 1961, Matthews, 1963 and 1964 and others), soil treatment and probably also of substances for flower initiation in forest trees should not be forgotten (Matthews, 1963 and 1964).

The range of the phenotypic variation among trees within sample plots, as reported in the previous sections, is very large for all the characters studied. The problem, then, is to test in which degree the phenotypic variation observed between trees is determined by genetic effects. The genetic gain depends, among other things, on the amount of genetic variability (LERNER, 1954, MATHER, 1955), on the complexity of the models of gene action and interaction (LERNER, 1954 and 1958, and MATHER, 1955) and on the number of effective genes controlling characters under selection. The genetic gain may be different for different models of selection (HAZEL and LUSH, 1942, STERN, 1960 and 1961, and STERN and HATTEMER, 1964), for the different degrees of intensity of selection (HAZEL and LUSH, 1942, HAZEL, 1943, and LERNER, 1958) and for various portions of the total genetic variance due to additive variance (LUSH, 1940, and HANSON, 1961). The greater the extent to which additive genetic effects are expressed in phenotypic properties, the more effective the selection for these properties will be.

The percentage of empty seeds (not damaged by insects) among all seeds (undamaged by insects) in this material varies principally between years and between trees within areas (see Appendix Tables XVII B—XXI B, XXIX B —XXXIV B and XXXVI B—XXXIX B). However, highly significant differences exist simultaneously between areas. The mean percentage of empty seeds (undamaged by insects) in relation to all seeds (undamaged by insects) for localities ranged from 39 (at Härryda) to 72 (at Skalstugan) in 1948, with an over-all mean of 55 for the five sample plots. In the material for 1954 the corresponding percentage of empty seeds ranged from 41 (at Kvikkjokk) to 60 (at Pajala), with an over-all mean of 50 for the six sample plots. The over-all mean for the three sample plots (Stjernarp, Gunnarskog and Skalstugan) was 63 in 1948 and 48 in 1954. An analogically estimated percentage of empty seeds in 1960 amounted to 76 for the sample plot at Kiruna, 72 for Gällivare, and 69 for Kvikkjokk (the last value is not given in the tables). In 1961 the corresponding frequency of empty seeds was 57 % at both Kiruna and Gällivare. Thus, in this material there did not appear to be any definite pattern of variation or trend in the relative frequency of empty seeds with respect to elevation and latitude during any one year. In 1948 the sample plot at Stjernarp had a higher percentage of empty seeds (62) than either Härryda and Gunnarskog (55) or Höljes (50). Both the plots at Stjernarp and Skalstugan had 46 % empty seeds in 1954, which was higher than the corresponding percentage for Kvikkjokk. It is already evident that the empty seed percentage is very complex. Apart from empty seed caused by insects, recessive lethals in homozygous condition account for a considerable proportion of all empty seeds, which among other things can be seen from studies of the effects of inbreeding on seed germination. Moreover, even in stands of cultivated spruce, during seed years when it is established that both meiosis and pollen mitosis are undisturbed, when there is an abundance of both male and female flowers and very good conditions for pollen dispersion and inter-crossing of the trees, there exists a frequency of empty seed (undamaged by insects) of about 25—35 per cent. This was the case in the two spruce stands at Älvan and Torslunda in 1954. (*Älvan*, 58° 29′ lat. N. and 15° 17′ long. E.G., situated 15 km. E.S.E. of Motala. The height above sea level at Älvan is 90 m. *Torslunda* at Tierp church, 60° 19′ lat. N. and 17° 28′ long. E.G., situated 45 km. S.S.E. of Gävle. The height above sea level at *Torslunda* is 35 m.). The probability of the occurrence of empty seeds resulting from delayed pollination or failure to pollinate as well as various forms of related mating, must approach the lowest conceivable level in such stands and during such years. During especially poor flowering years and years with less favourable conditions for the dispersal of pollen within a more or less limited geographic area, non-pollination and inbreeding (assuming also that the content of remote-pollen is simultaneously small or non-existent) would seem to contribute to the considerable increase in the percentage of empty seeds in different stands and geographical areas (Bärring, 1956). The percentage of effective pollen for inter-crossing and selfing decreases with the degree of the pollen sterility. Therefore, the possibility of non-pollination can be greater within the stand or the sample plot with increasing pollen sterility. In 1960 at the sample plot at Kiruna the pollen fertility (see Figs. 48, 49 and 57, determined by germination studies in the laboratory) averaged only 55 %. Practically no remote pollen was conveyed to the area by the northerly polar winds. As previously stated, both male and female flowering within this trial area was very sparse. Therefore, the conditions for both non--pollination and self-pollination were specially favourable. The differentiation in time sequence for the flowering of the two sexes of spruce flowers at Kiruna can at least to some extent have neutralized the degree of selfing (i.e. direct self-fertilization). On the other hand, it is less likely that crossings between sibs, half-sibs and other related trees have not occurred, to some extent, between trees in the immediate vicinity. This risk of related crossings is especially great in naturally regenerated stands (see Langner, 1953, 1959, 1960 and 1961, Sarvas, 1955 a, 1957, 1958 and 1962, Andersson, 1963, and others). Crosses between unrelated trees in such stands occur much less frequently than would be expected on the basis of random mating. A study of the percentage of empty seed at Kiruna in 1960 (see Fig. 27) shows that the early (before June 7th) and late flowering trees (after June 9th) have a higher percentage of empty seeds than those trees which flower between the 7th and 9th of June (i.e. the intermediary trees from the point of view of early flowering). This is irrespective of whether the female flowers have opened before or after the male flowers on the same tree. The percentages for the three groups, early, intermediary and late-flowering, are 81.6, 71.9 and 81.5 respectively. The highest frequency of pollen in the air was noted during the period from the 7th to the 9th of June. The percentage of the pollen fertility was however somewhat lower in the middle of the flowering period, or 53.7 compared with 55.0 for the earliest flowering and 62.6 for the latest flowering group of trees.

7.2. Correlation and regression studies

It is of importance, not least from the point of view of selection and seed production, to investigate and determine which component characters (units which together constitute a character) covary with and influence the complex characters which are to be subjected to selection (e.g. characters such as seed yield and seed germination ability for altitudes exceeding 300 m. above sea level, especially in northern Sweden). Similarly, it is of great interest to ascertain how different component characters are mutually correlated, their relative portions of the variation of a character complex, and to what degree the characters are influenced by environment. The selection can be directed either to the complex character or to the component characters. The relative fraction of the environmental influences on each character can determine which selection alternative should be chosen in each individual case. The main principle of the phenotypic selection is to select characters which have large variation whilst at the same time the environmentally-caused effects on the phenotypic expressions and variations are comparatively small.

Estimations of covariations between repeated observations on the same trees and of components of variance due to different tree characters are important means of assistance for estimating the reproduction ability of the trees. These coefficients and fractions of the total variance give valuable information on the degree of the constancy of the phenotypic appearance of a tree under changing conditions (i.e. in different years), or on the more or less purely genotypic portions of the total phenotypic variance.

The influence especially of cone length, cone weight and seed weight, on seed germination capacity and the number of seeds per cone, has been examined in this work. Also, other characters and factors such as the frequency of empty seeds, the minimum temperatures during meiosis (see Fig. 24), the number of days with a certain mean air temperature at the seed source localities during the period from the commencement of spruce flowering until the end of September (Figs. 22 and 23), the ages of the sample trees (Figs. 58—

61), pollen fertility and the height of the trees in certain sample plots are included in the correlation and regression studies.

It can be seen from chapters 5 and 6 and sections 5.1.2.—5.1.5.3. in the material for 1948, and from 5.2.2.—5.2.2.10. and 6.3. in the material for 1954 that cone weight and cone length affect seed weight (Figs. 8—12 and Fig. 19), the total number of seeds per cone (Figs. 13—17) and seed germinative ability (Figs. 20—23) significantly differently in the various geographical areas. Actually, this is perhaps not surprising since the cone properties account for the largest percentage share of the differences existing between areas with regard to the examined variables (see section 5.2.3.). Similarly, there are significant differences in regression and correlation coefficients between individual trees within sample plots, for a number of combinations of variates (see Appendix Tables XII—XVI and Tables 17, 32, 35 a and 35 b). Moreover, a number of significant differences in relationships between variate combinations also exist between years. This is the case between the unusually profuse flowering and abundant cone year of 1954, and the weaker 1948 in regard to flowering and cone production. Variations of the total correlation of tree means for localities are shown for 1948 in Table 9 and for 1954 in Tables 37, 42 and 44. Corresponding correlations of cone values for each plot and area are presented in Table 16 for 1948 and for 1954 in Table 31.

When the total correlation coefficients (between tree means for individual populations) in Tables 9 (page 55), 37 (page 118), 42 (page 139) and 44 (page 150), or the corresponding correlations (between cones within trees for individual populations) in Tables 16 (page 69) and 31 (page 106) are compared, the variations in relationship of the cone and seed characters, which have just been mentioned, within sample plots or localities during the same year or between years, become apparent. The total number of cones per tree generally affects, among other things, the size of the cones. This was larger in 1948 than in 1954 with the exception of the sample plot at Skalstugan. Despite this, the number of seeds per cone and the seed weight per cone were less in 1948 than in 1954. In this connection conclusions of interest can be drawn from the results of the analyses of the correlation coefficients presented in Tables 35 a and 35 b (pages 113 and 114). These analyses show that the correlations between cone and seed characters within individual trees at Stjernarp and Skalstugan in 1954 are significantly stronger, on an average, than the corresponding coefficients in 1948. Single genotypes react very differently to changes of environment. Also, some trees react differently under approximately the same external conditions in the same year and the same plot. The relationships of different order found between cone and seed characters of Norway spruce can also change significantly, with regard to strength and direction, from area to area (see pages 119—122).

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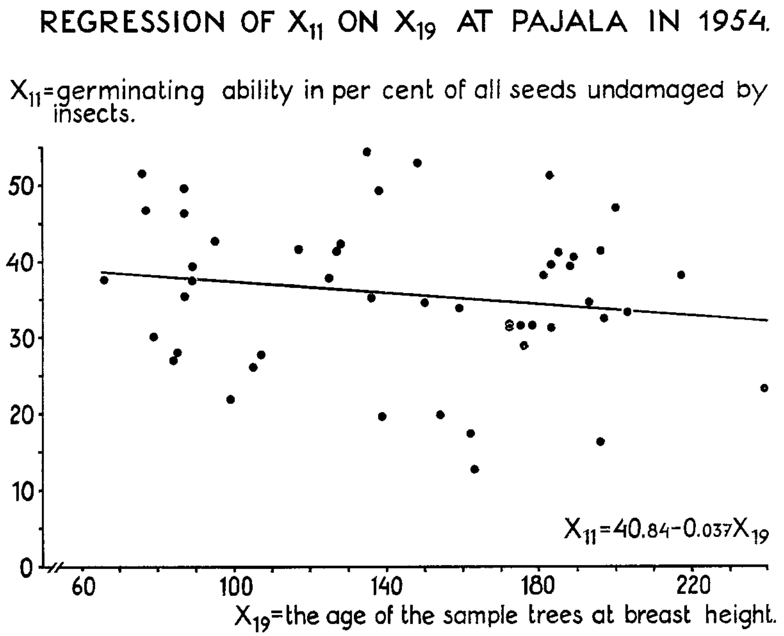

Fig. 58.

The partial inter-tree correlations of the first order between e.g. cone weight and the number of seeds per cone, when cone length was held constant, ranged from 0.045 at Stjernarp to 0.606 at Gunnarskog in 1948 (see Table 21, page 83) and from—0.018 at Gunnarskog and—0.029 at Stjernarp to 0.455 at Gällivare (see Table 38, page 121) in 1954. The corresponding coefficients, within trees within sample plots, ranged from 0.214 at Stjernarp to 0.465 at Skalstugan in 1948 (see Table 22, page 86), and from 0.132 at Stjernarp to 0.300 at Pajala in 1954 (see Table 33, page 110). The between-tree association of cone weight with number of seeds per cone, when the influence of both cone length and seed weight per cone were held constant, was insignificant in all sample plots in 1948 and 1954 except for the plot at Gällivare in 1954. These coefficients ranged from—0.224 at Härryda to 0.177 at Höljes in 1948, and from—0.280 at Skalstugan to 0.376 at Gällivare in 1954. The partial between-tree correlations of the first order between cone length and number of seeds per cone, when cone weight was held constant, show that these coefficients ranged from—0.393 at Gunnarskog to 0.411 at Stjernarp in 1948, and from—0.216 at Kvikkjokk to 0.314 at Skalstugan in 1954. These coefficients at Gunnarskog and Gällivare amounted to 0.270 and 0.135 respectively. The corresponding intra-tree correlations within sample plots ranged from 0.062 at Kvikkjokk to 0.388 at

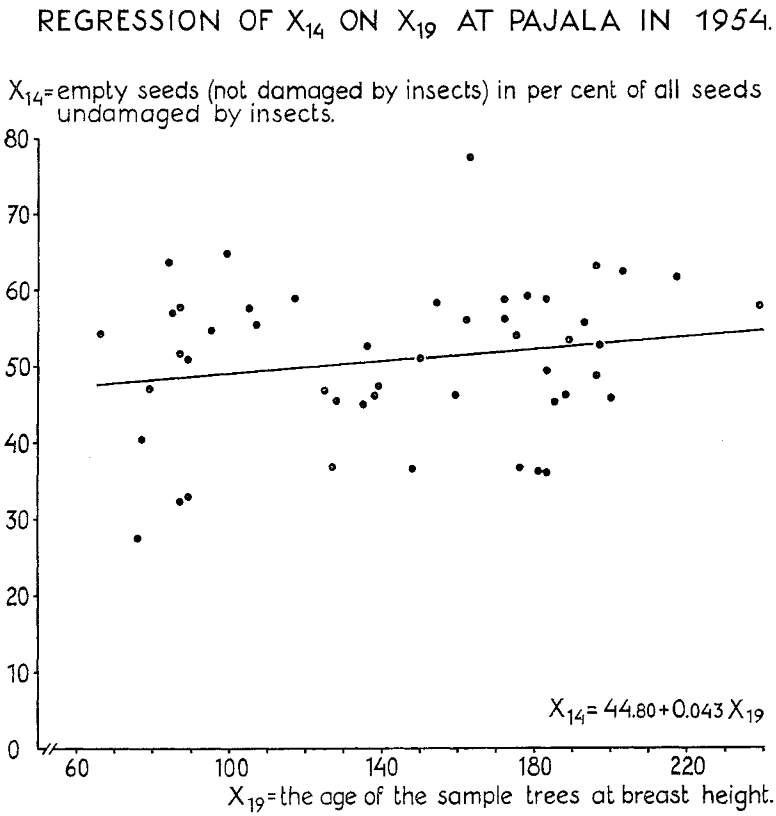

Fig. 59.

Stjernarp in 1948. At Skalstugan, Pajala and Gunnarskog these within-tree coefficients were 0.305, 0.326 and 0.193 respectively.

The between-tree correlations of the first order between the total number of seeds per cone and seed weight per cone, when cone length was equal, ranged from 0.430 at Stjernarp to 0.933 at Gunnarskog in 1948, and from–0.089 at Stjernarp to 0.708 at Skalstugan in 1954. The between-tree correlation of the second order between the total number of seeds and seed weight per cone, when cone length and cone weight were held constant, was significant at the 1 % level in all sample plots in 1948 (see Table 21, page 83). The coefficients ranged between 0.431 at Stjernarp and 0.894 at Gunnarskog. In 1954 this correlation of the second order was significant at the 1 % level at Skalstugan, and at the 5 % level at Gunnarskog, Kvikkjokk and Pajala, and was insignificant at Stjernarp and Gällivare. In the same year the partial inter-tree correlation coefficients ranged from—0.084 at Stjernarp to 0.700 at Skalstugan. Thus, these between-tree coefficients show that cone and seed characters are dependent on each other and at the same time are strongly influenced by environmental factors. The within-tree coefficients are generally somewhat stronger than the between-tree coefficients, but on the other hand, they are controlled by non-genetic factors in an even higher degree than the between-tree associations. Presupposing that no somatic mutations have arisen in the trees, the association of cone weight with cone length within trees, for example, is wholly controlled by environment and interactions.

Total between-tree correlations due to the association of germination capacity (in the JACOBSEN germinator) with the variables X_1, X_2, X_3, X_4 and X_7 in 1954 are given inTable 42, page 139. This table shows, among other things, that 1) about 8 % of the between-tree variation in germination ability of all seeds (not damaged by insects) was accounted for by differences in cone length in 1954 at Stjernarp, 2) the variation in the dry weight of the cones e.g. at Gällivare and Pajala accounted for about 8 % and 20 % respectively of the between-tree variation in seed germination ability (X_{13}), 3) the variation in total number of seeds per cone at Skalstugan and Pajala accounted for about 16 % and 8 % respectively of the tree to tree variation in seed germination capacity (X_{13}), and 4) the variation in the weight of all seeds per cone at Skalstugan, Kvikkjokk, Gällivare and Pajala in the same year accounted for about 32 %, 13 %, 33 % and 47 % respectively of the between-tree variation in seed germination ability.

However, the between-tree relationship between seed germination rate (X_{13}) and the seed weight of all seeds per cone (X_7) also shows a tendency to change (differently for the various sample plots) when other characters such as total number of seeds per cone, cone weight and cone length (see Table 43, page 142) are held constant. Apart from small changes which have arisen in the partial correlations, the found relationships of the first as well as of the third order between germination rate (X_{13}) and the weight of all seeds per cone (X_7) are highly significant in all sample plots. However, as is seen from Table 47 a, the quadratic and cubic polynomials for the regression of X_{13} on X_7 deviate from linearity at Skalstugan and for the six populations taken together (see section 6.3.).

The separate effects of the component characters, which are discussed here, on seed germination capacity are evident from the between-tree regressions for individual populations in Table 26 and Appendix Tables XXII B—E, and on the percentage of empty seed in Appendix Tables XXXV B—E. Total correlations between the frequency of empty seed and the variables included in Appendix Table XXXV are given in Table 44.

As is seen from Table 43, the partial between-tree correlation coefficients of the first and third order between seed germination ability and total number of seeds per cone, when the seed weight of all seeds per cone is equal or when

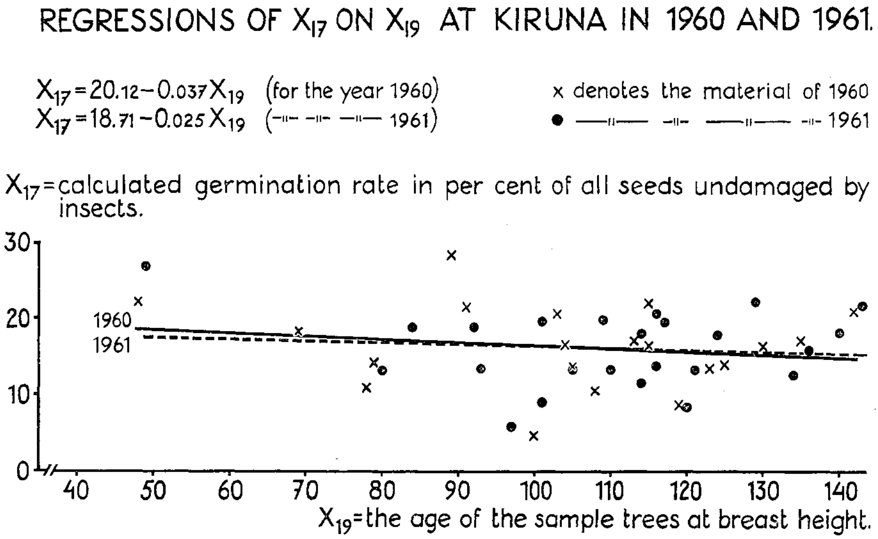

Fig. 61.

cone weight and cone length as well as the seed weight of all seeds per cone are held constant, are negative and do not differ significantly from zero except for the coefficient at Stjernarp. If this tendency to negative correlation is genetically influenced, the obtainment of a selection advance becomes more complicated than when the selection is directed to uncorrelated characters. The work of selection is complicated, namely, only by the fact that it is based on several characters simultaneously (cf. HAZEL and LUSH, 1942, HAZEL, 1943, LERNER, 1958, LE ROY, 1960, RASMUSON, 1964, and STERN and HATTEMER, 1964).

The covariations between: 1) pollen fertility and seed quality, 2) the number of seeds per cone and the pollen fertility, of the same tree, and 3) seed quality and the ages of the sample trees, attract great interest. The relationship between the disturbances of meiosis in pollen mother cells (Figs. 33—35 and 50 and 51) and pollen sterility (Figs. 52—57) in the same tree can always be expected to be strong and positive provided that no disturbances of pollen mitosis (Figs. 36, 40 and 41) have occurred and that no mutations that change the pollen fertility have arisen (see page 129). However, this does not necessarily mean that the association of pollen sterility with seed quality and the number of seeds per cone on the same tree is strong and positive. The Norway spruce is an outbreeding species, even though selfing and weaker forms of related mating may exist to some extent. The pollen fertility of a tree need not necessarily, therefore, have any stronger connection with the seed quality or seed production of the mother tree. A strong correlation between the fertility of the male and female gametes is still more unlikely if the meiosis disturbances do not have a purely genetic cause, but are principally influenced by environmental factors and therefore vary from year to year. The meiotic divisions in the embryosac mother cells (EMC) and in the pollen mother cells (PMC) can even occur at various times on the same tree. Furthermore, the pollen fertility can be reduced by temperature disturbances of the pollen mitosis. Disturbances in meiosis very often result in the formation of aneuploid gametes (Figs. 53—56). Such female gametes, e.g. in rye, can be capable of functioning (MÜNTZING, 1943) and after fertilization, can give rise to aneuploid seeds, which seems also to be the case in Norway spruce (ANDERSSON, 1947 a, page 329, Fig. 34).

In the present material the correlations between, on the one hand, pollen fertility, and on the other the germination capacity in per cent of all seeds (not damaged by insects) with embryo per cone, the percentage of seeds (not damaged by insects) with embryo of all seeds (not damaged by insects) per cone, and the total number of seeds per cone, have been calculated for the sample plots at Kiruna and Gällivare in 1960 and 1961. None of these correlations, however, differ significantly from zero.

In 1960 the correlation between pollen fertility and germination capacity in per cent of all seeds (not damaged by insects) with embryo was — 0.07 at Kiruna and — 0.17 at Gällivare. The correlation between pollen fertility and the percentage of seeds (not damaged by insects) with embryo of all seeds (not damaged by insects) per cone, in 1960 and 1961 respectively, was — 0.27 and — 0.10 at Kiruna, and 0.23 and 0.37 at Gällivare. In 1960 and 1961 the associations of pollen fertility with total number of seeds per cone at Kiruna were — 0.09 and 0.20 respectively, and at Gällivare they were — 0.07 and — 0.16 for the same years. Two sets of correlations and regressions (see Figs. 58—61) have been calculated for the sample plots at Pajala and Gällivare in 1954 and for Kiruna in 1960 and 1961, in order to study the relationship between seed quality and the ages of the sample trees. The association of empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects (X_{14}) with the age of the trees (X_{19}) for the fifty sample trees at Pajala and Gällivare was 0.20 and — 0.01, and at Kiruna in 1960 and 1961 0.25 and 0.09 respectively. The correlation between the germinative capacity (in the JACOBSEN germinator) in per cent of all seeds not damaged by insects (X_{11}) and the variable (X_{19}) at Pajala and Gällivare was — 0.17 and — 0.05 respectively. The corresponding coefficients between the calculated seed germination in per cent of all seeds not damaged by insects (X_{17}) and (X_{19}) at Kiruna in 1960 and 1961 were — 0.16 and — 0.11. None of the coefficients were, thus, significantly different from zero.

Neither was any significant covariation obtained between any one of

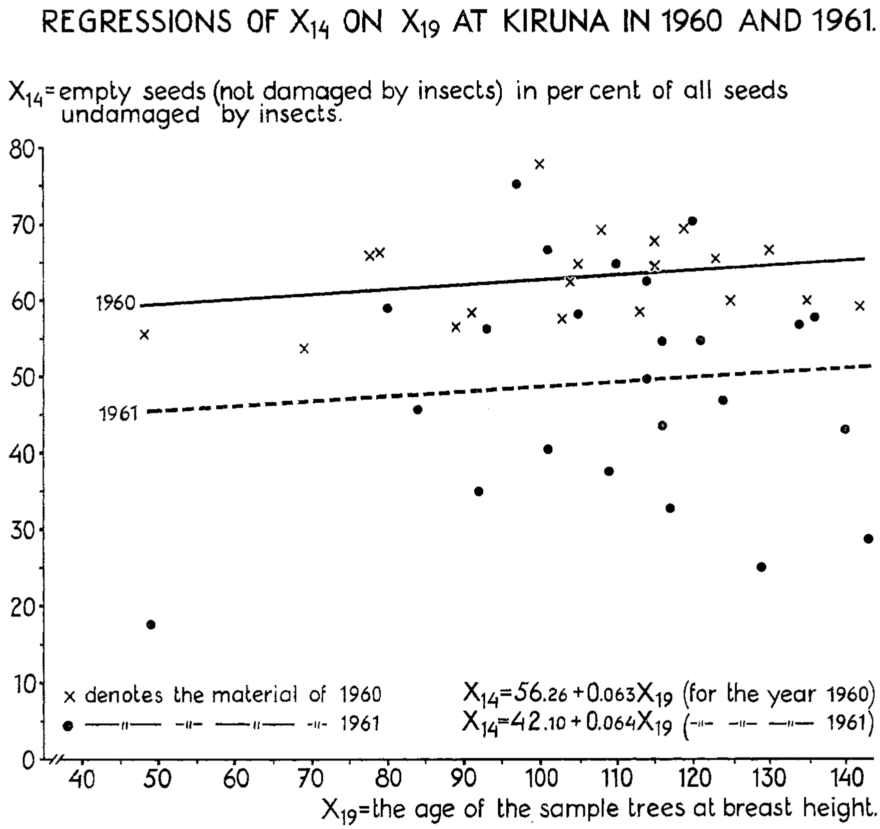

Fig. 61.

the variables X_{11}, X_{14} and X_{17} and the variable for tree height in meters of the sample trees (X_{22}). At Pajala in 1954 the association of X_{11} with X_{22} was -0.04. The correlation between X_{17} and X_{22} at Kiruna in 1960 and 1961 was -0.03 and 0.17 respectively. The associations of X_{14} with X_{22} give about the same correlation picture. This coefficient was -0.23 at Pajala in 1954, and in 1960 and 1961 at Kiruna 0.02 and -0.21 respectively.

7.3. The joint effect of some cone and seed characters on seed germination capacity

We have seen that of the studied morphological cone and seed characters in the 1954 material either the seed weight of all seeds per cone or the thousand-grain weight of all seeds per cone (Appendix Table XXII A) accounts for the largest fraction of the variation in seed germination ability (determined in the JACOBSEN germinator). It is also apparent that various populations show different associations with these variables. Multiple regressions giving the joint effect of some combinations of cone and seed characters on seed germination rate have been calculated in Tables 46 a and 46 b. Considering the multiple regressions of germination rate (X_{13}) on total number of seeds per cone (X_4) and the weight of all seeds per cone (X_7) in Table 46 a, it is seen that the squared multiple correlation coefficient, $R^2_{(13).47}$, in % varies for individual populations between 19.0 and 53.6, which means that the variables X_4 and X_7 at Kvikkjokk and Stjernarp account together for about 19 % and 54 % respectively of the variation in X_{13}. The rest of the variation in X_{13} may be due to random variation or other effects of causes not considered in the regressions. Furthermore, X_{13} and X_4 are negatively associated or dis-associated, and X_{13} is positively associated with X_7. Moreover, a change of 200 milligrams in the weight of all seeds per cone (X_7) at Stjernarp in 1954 would have given a mean change in X_{13} of approximately 5.5 % if X_4 had been held constant. A corresponding change in X_7 with constant number of seeds per cone in the 1954 material for Kvikkjokk would have resulted in an average change of X_{13} (the germination rate of all seeds not damaged by insects) with approximately 12.7 per cent. If the number of seeds per cone is not held constant, but supposing that e.g. at Kvikkjokk in 1954, one had succeeded (through selection or the application of fertilizers) in increasing the seed weight of all seeds per cone with 200 milligrams whilst at the same time the total number of seeds per cone had increased with an average of 69 seeds per cone, there would nevertheless, in this hypothetical case (apart from the larger harvest), be no improvement in the germination capacity. Consequently, the possibility exists that either the seed germination capacity or the seed yield per cone, or even both, can be improved by increasing the seed weight per cone by some means or other. The variation between localities and between trees within localities, in respect of seed weight and the number of seeds per cone, is large (see Appendix Tables I—XI). Individual trees can even have both high seed weight and a large number of seeds per cone simultaneously (see Appendix Tables XXIII—XXVIII).

If the independent variables in the regression equations at present under discussion, in Table 46 a, are increased with cone length (X_2) and cone weight (X_3), one obtains the combination of the independent variables in Table 46 b. These equations show, amongst other things, that about 64 % of the variation in seed germination rate (X_{13}) at Stjernarp can be referred to the joint effect of the covariation with the variables X_2, X_3, X_4 and X_7. The corresponding collective proportion of the variation in X_{13} at Kvikkjokk amounts to only about 19 %. The greater part of the variation in X_{13} is still unexplained. When considering the direction of the influence of each character on seed germination rate, we find for example at Stjernarp that the cone length and seed weight per cone generally increase the percentage of germination rate whilst cone length and the number of seeds per cone tend to decrease the germination capacity. The reverse average interrelationship for e.g. cone weight and seed germination ability is found at Gunnarskog, Gällivare and Pajala. Furthermore, we see that the regression coefficients have changed somewhat with the addition of the two variables, but that in this material only a little new information is gained through the addition of X_2 and X_3, in the regressions in Table 46 b. We should, however, fully understand, that if we should have the opportunity of adding the remaining independent variables to the equations, e.g. the influences of temperature (measured in degrees or in units of growth as is done by MORK, 1941 and 1957) the interrelationship of the independent variables, and possibly even the signs of some coefficients, would alter simultaneously.

7.4. Components of variance for some seed characters

Estimates of variance components in Tables 48 a—d are made on the basis of the following expected values of mean squares:

Between years (or replications) $= \sigma^2_{t \cdot y} + t\sigma^2_y$
Between trees $= \sigma^2_{t \cdot y} + y\sigma^2_t$
Interaction trees × years $= \sigma^2_{t \cdot y}$,
where $\sigma^2_{t \cdot y}$ = variance due to the interaction trees × years + sampling error
σ^2_y = variance due to differences between years
σ^2_t = variance due to differences between trees
t = number of trees studied per sample plot
y = number of years

In addition to the correlations between cone and seed characters on the same trees in different years (except for the tendency found at Skalstugan for the years 1948 and 1954, and that at Härryda for 1946 and 1948) the analyses of variance of seed characters on the same trees in different years, i.e. 1954, 1960 and 1961 (see Tables 48 a and b, page 167 and 48 c and d, page 171) indicate that observations on the same trees are more alike than the corresponding observations on any trees within a sample plot. The genetic interpretation of the estimated variance components indicate that significant genetic differences do exist for characters such as the total number of seeds per cone (see Table 48 a), the germination capacity of all seeds (not damaged by insects) per cone (see Table 48 c), the frequency of empty seeds (not damaged by insects) in per cent of seeds not damaged by insects, at least at Gällivare, for the years 1954, 1960 and 1961 (Table 48 b), and the frequency of seeds (not damaged by insects) with embryo unable to germinate, in per cent of all seeds (not damaged by insects) with embryo, at Gällivare (see Table 48 d). The relative portion of the genetic variability varies for different characters and populations depending upon the environment's very changing part in the phenotypic expression of a character (see Table 48 b—d). Estimates of the trees × years interaction effects and within-tree variations (i.e. the proportion of total variance of the trees × years interaction due to the sampling error) for the total number of seeds per cone at Gällivare and Kiruna (see Table 48 a) indicate that the interaction effect was insignificant at Gällivare and highly significant at Kiruna.

The analyses of variance of seed observations on the same trees at Stjernarp for the years 1948 and 1954 show that the proportions (in per cent) of the total variance due to "trees" or to maximum genotypic causes, for the total number of seeds per cone, the germination rate of all seeds undamaged by insects, and the frequency of empty seeds (not damaged by insects) amongst all seeds not damaged by insects, were 28, 32 and 32, respectively. The three variance ratios due to "trees" were significant at the 1 % level. The corresponding ratios due to replications (i.e. between years) were all significant at the 0.1 % point.

Evidence for genetic improvement is furnished by the found variance components which are upper limits of genotypic variance. These components, expressed in per cent, for Gällivare and Kiruna, amount to 49 and 47 for the total number of seeds per cone (see Table 48 a), and 80 and 75 for seed germination capacity (see Table 48 c). Thus, the intra-class correlations (or repeatabilities) in these four cases are 0.49, 0.47, 0.80 and 0.75. However, there is a risk that these variance components and intra-class correlation coefficients could be over-estimated because of differences in soil conditions and the micro-climate within the sample plots. Such modifications could increase the variance due to "trees". It should also be remembered that we lack information, that it is extremely important to know, about the additive portion of the found maximum genotypic variance. If there is no additive variance there can be no expectation of genetic improvement by selection.

7.5. The reproductive fitness of trees and populations with regard to seed quality and seed production

The estimates of seed germination capacity, the frequency of empty seeds and the total number of seeds per cone have shown that different trees within the same sample plot produce seed with, on an average, different germination capacity, number of seeds per cone, and empty seed percentage. Furthermore, different trees show different climatic tolerance with regard to minimum temperatures below zero and sudden and large changes of temperature during the meiotic divisions in pollen mother cells. Similarly, large variations also exist in the earliness of seed maturity of the trees. This early ripening appears to be dependent on the genotype. A number of already fructiferous grafts at Röskär, taken from trees with early cone and seed maturity at Kvikkjokk, Gällivare and Kiruna show just as early seed maturity in the Stockholm area as the original trees at their habitats. The cones of the Norrland trees are in many cases ripe at the end of September whilst the cones in Central Sweden are still green. The capacity or ability of the genotype to vary in respect of the characters just mentioned would therefore appear to exist.

Accordingly, it is evident from the variation found especially in seed production and seed quality that the indigenous stands of Norway spruce, at least in the extreme climatic regions of Northern Sweden, are not well adapted in regard to the generative phase of the trees. Consequently, there should exist great possibilities of selecting trees which have an advance over others in seed quality and seed production. Such successive improvements of the reproductive fitness of the trees are especially desirable in high level regions with biological conditions for natural regeneration, but where, from the point of view of production economy, it is necessary to avoid the expensive work of plantation.

The aim of this tree selection, in the future, should be to select trees which have an advance in reproduction combined with the high survival of their seedlings which should grow fast and possess desirable wood properties (see Ericson, 1960, a and b, and 1961, Zobel, 1961 and 1964, Mergen, Burley and Yeatman, 1964, and Stonecypher, Cech and Zobel, 1964).

Reproductive fitness as well as overall fitness is compounded of a number of genetic factors which may have different relative importance. Genetic and physiological factors which affect climatic tolerance and resistance to diseases would probably be of more importance for reproductive fitness than factors that influence the seed production. The effect of aberrations in macrosporogenesis is in all probability more derogatory to the reproduction by seeds than the corresponding effect in microsporogenesis. However, different genetical, physiological and ecological factors may have different functional relationship with fitness. Any alteration in the frequencies of genes is, however, a radical step. Several factors or gene complexes enter into the determination of fitness or vital processes connected with fitness, e.g. in the question of the internal balance of the genotype (see Lerner, 1954 and Mather, 1955). Therefore, it can be difficult to change the gene frequency which affects one or more characters, without affecting others of great importance.

7.6. Practical applications

In Sweden, hitherto, when selecting plus trees (ANDERSSON, 1957, p. 193 and 194, 1958, p. 138 and 139, and PLYM FORSHELL, W., 1964, Appendix A, 128 and others) one has principally taken into consideration characters such as growth rate, stem form, branching habit (ANDERSSON, 1960, 1962 and 1963 and PLYM FORSHELL, W., 1964 and others), wood quality (ERICSON, 1960 a and b, 1961, and PLYM FORSHELL, W., 1964), and as far as possible, the resistance and hardiness during the trees' vegetative phase. On the other hand, the generative fitness of the plus trees to the climatic conditions at their habitats has not been *systematically* examined during either the selection of plus trees or the composition of seed orchards. This should not be necessary in regard to seed yield per cone and seed germination capacity, in all the climatic zones in Sweden. The generative adaptation of the trees, however, plays an important roll in those high level areas in Northern Sweden (particularly about 300 m. and above), which have biological conditions for natural regeneration. Therefore, if it is desired that the forest plantations, raised from orchard seed, should have a better ability to generate naturally than that of the existing natural stands, then it is very important from the point of view of reproduction, to take into consideration, among other things, the reproductive fitness of the trees when selecting plus trees for the composition of seed orchards. The genotypic constitution of the seed obviously plays a very important part in the question of reproductive fitness. At the same time, however, it is generally for all seed orchards, that the economic importance of the genetic improvement that can be expected in seed orchards, depends not only on the genetic and physiological quality of the seed, but also on the quantitative seed production i.e. the production of the greatest possible yield of well-filled viable seed.

The present study has shown, amongst other things, that a large variation exists among populations and among trees within populations regarding seed yield per cone and the degree of seed maturity. Seed germination capacity is noticeably poor in the extremely high level regions. Even during the unusually abundant cone year, 1954, when seed maturity was equally exceptionally good, the germinative ability (in the JACOBSEN germinator) of all seeds per cone at Skalstugan, Kvikkjokk and Gällivare amounted to only 29, 22 and 16 per cent, or, estimated on all seeds not damaged by insects, to 30, 23 and 18 per cent respectively.

The main portion of all the seed was composed of empty seeds and seeds with embryo unable to germinate. The relationship between seed production and the germinative ability of spruce is therefore of certain interest (HAGNER, 1958 and SARVAS, 1962). The fertility of a quantity of cleaned spruce seed varies within very wide boundaries according to the degree of cleansing to which the seed has been subjected. Percentages of seed germination should therefore be supplemented with details of the percentage of empty seed in the uncleaned material, since a high proportion of empty seed gives occasion for certain doubts about the genetic quality of the fraction consisting of viable seed. A high precentage of empty seed can indicate: high frequency of meiosis disturbances in the megaspore mother cells or in both megaspore and microspore mother cells; high frequency of sub-lethals in the material; high frequency of inbred seeds in the material, or high frequency of non-pollinated ovules. Combinations of the four alternative reasons would seem to be even more probable. As mentioned earlier, disturbances of meiosis can lead to the development of aneuploid gametes and zygots, and a high frequency of viable aneuploid seeds can result in a considerable deterioration of the vitality of the plants. Similarly, a high frequency of sub-lethals can reduce the viability of the seedlings in comparison with normal plants.

Repeated observations on the same trees within the sample plots at Stjernarp, Kiruna and Gällivare have indicated that genetic and physiological factors influence, among other things, seed yield per cone and seed germination capacity in a significant manner. Therefore, it appears logical to expect satisfactory progress, on the basis of selection, in respect of these seed characters. It seems that large physiological gains in seed maturity could be anticipated in regions between 300 and 500 m. above sea level, by establishing the seed orchards in localities where the climatic conditions are favourable for flowering and seed ripening (compare the percentages of seeds (not damaged by insects) with embryo unable to germinate of all seeds (not damaged by insects) with embryo at Stjernarp and Gunnarskog, in Tables XXIX B and XXX B, with Skalstugan, Kvikkjokk and Gällivare in Tables XXXI B, XXXII B and XXXIII B, respectively). Repeated observations of the seed production ability and seed germination capacity of the trees *usually* belong to the type of investigations which can be carried out in a relatively short time. The adaptability of the original trees (i.e. the parents of the clones) already included in established seed orchards, in regard to seed production and seed germination features, can therefore be determined during the time taken for the testing of the progenies of the clones (JOHNSSON, 1963). Taking into account the following facts: that the seed supply is large in Northern Sweden in regions between 300 and 500 m. above sea level; that the conditions for seed production and seed ripening are poor; and that in this region the area planned for seed orchards of Norway spruce is insufficient, it becomes apparent that it is important for Northern Sweden's forestry and its future supply of forest-tree seed that the spruce seed orchard area should be supplemented. This can be effected either by increasing the area of the *clonal seed orchards* or by establishing special seed stands or *seedling seed orchards* (MATTHEWS, 1964). Regarding, among other things, the initial and maintenance costs of clonal seed orchards of spruce, I personally recommend, in this case, that seedling seed orchards should be established as a complement to the already existing clonal seed orchards. These orchards should be planted, accordingly, with seedlings as in other plantations and should be treated for the present as spruce plantations. The proposed seed stands for the actual climatic zones should be located near the coast of the Gulf of Bothnia, be well isolated from other spruce stands and composed of seedlings from about 60 mother trees. The mother trees should previously have been examined with regard to seed production ability and seed germination capacity, and should moreover, fulfil the qualifications required for plus trees.

The plus trees should be selected within a number of stands or populations within each high level region. In order to make the selection as intensive as possible, about 200 plus trees for each orchard region should be involved in the preliminary test. The preliminary plus tree selection should be based on performance in respect of growth rate, wood quality factors, stem form, branching habit, probable resistance to diseases, hardiness (during the vegetative phase), number of germinable seeds per tree and the repeatability with regard to reproductive fitness. Repeated observations on the same trees should be made in respect of the number of seeds per cone and per tree, the percentages of seed germinative ability and of empty seeds, and early seed maturity, during a succession of seed years.

The tree selection, for the composition of clonal seed orchards and seedling seed orchards, could then be based on the criterion that only trees showing marked superiority to the mean of all plus trees and to standard stands in a region, with regard to repeatability combined with a high seed production and a high seed germinative ability, would be selected as original trees for clonal seed orchards, or as mother trees for seedling seed orchards.

When we select for several characters simultaneously we must use, at least for the present, the method of independent culling (each character has its own level of rejection), since we are still lacking (for each tree species and population) the requisite genetic parameters and information on the relative economic values of the characters under selection.

8. Summary of principal results

1. Studies of variation of cone and seed characters such as cone length, cone weight, total number of seeds per cone (in whole numbers per tree) and seed weight per cone show significant differences between populations and between trees within populations of Norway spruce.
2. Significant differences exist between populations and between trees within populations, for seed germination capacity and the frequency of empty seed in different years as well as in one and the same year.
3. Significant between-tree and within-tree relationships exist within populations for a number of the cone and seed characters studied.
4. Individual populations show a number of significant differences in covariation for comparable pairs of variates in the same year.
5. Cone weight and cone length can affect seed weight and total number of seeds per cone significantly differently in various populations in the same year.
6. Single genotypes of Norway spruce, with respect to covariation between cone properties and between cone and seed properties, can react significantly differently to changes of environment (i.e. between years).
7. Characters such as cone weight, cone length, seed weight and total number of seeds per cone, both separately and in combination, could affect seed germination ability, and, at least separately, the percentage of empty seed, significantly differently in different populations.
8. The associations of seed weight per cone, cone weight and cone length with seed germination ability indicate that seed weight represents a very important component in determining seed germinative capacity in the sample plots under consideration.
9. The association of seed germinative capacity with the total number of seeds per cone can vary significantly from locality to locality.
10. In 1954 the partial between-tree correlations between seed germinative capacity and the number of seeds per cone are negative in all the six sample plots studied, when the weight of all seeds per cone is kept constant.
11. In agreement with previous studies, the seed germination capacity in this material is also negatively associated with the altitude and, simultaneously, with the latitude of the stands.

12. Highly significant differences exist between populations with regard to the percentage of seeds (not damaged by insects) with embryo unable to germinate, of all seeds (not damaged by insects) with embryo.
13. Studies of individual trees during a succession of seed ripening years show that *the portion of the varitation, due to trees*, of seeds (not damaged by instects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo can be relatively moderate as at Gällivare (see Table 48 d, p. 171) or small as at Kiruna (Table 48 d.). Especially in the last mentioned case (Kiruna), there should be a good possibility of increasing the germination capacity in that seed class, by light treatment, stratification and equilibration. In the first case (Gällivare), an increase in germination capacity would probably only be possible if the reason for the seeds' inability to germinate depends on delayed seed maturity. If however, the completely reduced germination ability of the seed has been caused by recessive lethals in homozygous condition, all irradiation or other after-treatment of the seed would probably be without effect.
14. The range of variation between trees within areas and the intra-class correlations between observations on the same trees in different years with regard to seed germination rate and total number of seeds per cone, indicate that it may be possible, under a certain condition, through proper selection in the more or less extreme climatic regions of Northern Sweden, to produce cultivars of Norway spruce which have, among other things, higher seed yield per cone and higher seed germination than the existing indigenous stands in these regions. The condition necessary, for this to be possible, is that the found maximum genotypic variance for these characters includes a component of genetic action due to additive effects.
15. The production of empty seed can either be mainly the result of genetic and physiological factors, as at Gällivare in 1954, 1960 and 1961 (see Table 48 b) or can depend on a larger fraction of environmental causes and a smaller portion of genetic and physiological influences, as at Kiruna in 1960 and 1961. The percentage of empty seed (not damaged by insects) of all seeds (not damaged by insects) can thus, in the same tree, change from seed year to seed year, which indicates that influences other than genetic contribute to the formation of empty seed. To these environmental factors belong, also, non-pollination, temperature disturbances of meiosis in megaspore and microspore mother cells, and changes in the trees' inbreeding frequency from one flowering year to another. The percentage of empty seed is lower during exceptionally good flowering years than during poor flowering

years, but is still high. In 1954 the percentage of empty seed (undamaged by insects) in relation to all seeds (undamaged by insects) ranged from 41 at Kvikkjokk to 60 at Pajala, with an over-all mean of 50 for the six sample plots studied.

16. The high percentage of empty seed after selfing at Åkersberga, together with the high over-all mean of the percentage of empty seed in 1954, shows that the frequency of sub-lethal genes is high in Norway spruce. It is therefore probable that recessive lethals are responsible for the largest portion of the empty seed frequency.
17. No significant relationships are found between: pollen fertility and the height of the sample trees; pollen fertility and seed germination capacity; pollen fertility and the total number of seeds per cone, and seed quality and the ages of the sample trees.

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List of references

AANSTAD, S., 1934: Untersuchungen über das Dickenwachstum der Kiefer in Solör, Norwegen. — Nyt Mag. Naturvidensk., 73: 121—154.

ACATAY, A., 1938: Untersuchungen über Menge und Güte des Samenansatzes in verschiedenen Kronenteilen einheimischer Waldbäume. — Tharandt Forstl. Jahrb., 89: 265—364.

ALLEN, R. M., 1953: Release and fertilisation stimulate longleaf pine cone crop. — Jour. For., 51: 11: 827.

ANDERSON, T. W., 1958: An introduction to multivariate statistical analysis. — New York, London.

ANDERSSON, E., 1947 a: A case of asyndesis in *Picea Abies*. — Hereditas, 33: 301—347.

— 1947 b: Pollen and seed setting studies of an asyndetic spruce and some normal spruces; and a progeny test of spruces. — Sv. Papperstidn., 50: 74—83, 113—117, 146—152 and 177—179.

— 1954: Några data om pollenvariationen och pollenfertiliteten hos gran och tall. (Some data concerning the pollen variation and pollen fertility of spruce and pine.) — Ibid., 57: 242—255 and 654—676.

— 1955: Pollenspridning och avståndsisolering av skogsfröplantager. — Norrl. Skogsv.-förb. Tidskr., 35—100. (With an English summary.)

— 1957: Aus der Arbeit der schwedischen Forstpflanzenzüchtung. — Silvae Genetica, 6: 191—198.

— 1958: Den skogliga fröodlingsverksamheten i Norrland. — Norrl. Skogsv.förb. Tidskr., 135—161.

— 1960: Fröplantager i skogsbrukets tjänst. — K. Skogs- o. Lantbr. Akad. Tidskr., 99: 65—87. (With an English summary.)

— 1962: Die Fichtenzüchtung in Schweden. — Sv. Papperstidn., 65: 44—55.

— 1963: Seed stands and seed orchards in the breeding of conifers. — FAO, Proc. World Cons. For. Gen. Tree Impr., II: 8/1 i—vii, 1—18.

ARNBORG, T., 1943: Granberget. En växtbiologisk undersökning av ett sydlappländskt granskogsområde med särskild hänsyn till skogstyper och föryngring. (Granberget. Eine pflanzenbiologische Untersuchung eines südlappländischen Fichtenwaldgebiets unter besonderer Berücksichtigung von Waldtypen und Verjüngung.) — Norrländskt Handbibliotek, XIV: 1—282.

— 1946: Ett par lyckade resultat av barkringning och strangulering. — Skogen, 33: 84—85.

— 1958: Avelsträd. Om skogsfrö, plusträd och fröplantager. — Medd. nr 93 Sällskapet praktisk skogsträdsförädling. Uppsala, 1—6.

ARNBORG, T. and HADDERS, G., 1957: Studies of some forestry qualities in clones of *Pinus silvestris*. — Acta Horti Gotoburgensis, XXI: 3: 125—157.

BAILEY, J. W., 1920: The cambium and its derivative tissues. III. A reconnaissance of cytological phenomena in the cambium. — Am. Jour. Bot., 7: 417—434.

BALDWIN, H. I., 1942: Forest tree seed. — A new Ser. Plant Sci. Books, VIII: 1—240.

BARNER, H. and CHRISTIANSEN, H., 1960: The formation of pollen, the pollination mechanism, and the determination of the most favourable time for controlled pollinations in Larix. — Silvae Genetica, 9: 1—11.

BARNES, BURTON V. and BINGHAM, R. T., 1963: Flower induction and stimulation in western white pine. — U.S. For. Serv. Res. Paper INT-2.

BÄRRING, U., 1956: Groningsprocenten hos kusttallens frö i förhållande till inlandstallens frö i Halland. — Sv. Skogsv.fören. Tidskr., 54: 423—432.

BEADLE, G. W., 1930: Genetical and cytological studies of mendelian asynapsis in *Zea mays*. — Cornell Univ. Exp. Stat. Ithaca, N. Y., Mem., 1299: 1—23.

— 1932: A gene for sticky chromosomes in *Zea mays*. — Z. Ind. Abstamm.- u. Vererb.-Lehre, 63: 195—217.

— 1933: Further studies of asynaptic maize. — Cytologia, 4: 269—287.

BEADLE, G. W. and McCLINTOCK, B., 1928: A genic disturbance of meiosis in *Zea mays*. — Sci., LXVIII: 433.

BERGMAN, F., 1955: Försök med tvångsfruktificering av tall, gran och björk. — Sv. Skogsv.fören. Tidskr., 53: 275—304.

— 1957: Något om möjligheterna att öka groningsenergin och grobarheten hos ofullständigt moget tallfrö. — Medd. Fören. Växtf. Skogsträd, Sundmo.

— 1959: Försök att öka groningsenergin och grobarheten hos skogsfrö. — Sv. Skogsv.-fören. Tidskr., 57: 21—42.

— 1960: Något om frömognad och fröbeskaffenhet hos tallen i Norrland. — Fören. Skogsträdsförädling information, nr 9.

BERGNER, A. D., CARTLEDGE, J. L. and BLAKESLEE, A. F., 1934: Chromosome behaviour due to a gene, which prevents metaphase pairing in *Datura*. — Cytologia, 6: 19—37.

BILAN, M. V., 1960: Stimulation of cone and seed production in pole-size Loblolly Pine. — For. Sci., 6: 3: 207—220.

BLACKMAN, V. H., 1898: On the cytological features of fertilization and related phenomena in *Pinus silvestris* L. — Phil. Trans. Roy. Soc., Ser. B. 190: 395—426.

BLOMQVIST, A. G., 1883: Finlands trädslag. II Granen. — Finska Forstfören., 3: 2: 5—179.

BLOMQVIST, S., 1961: Den skogliga växtförädlingen vid Kratte Masugn. Mål, medel och vunna erfarenheter. — Norrl. Skogsv.förb. Tidskr., 195—260.

BRANTSEG, A., 1954: Frøproduksjon og tilvekst hos gran. — Tidsskr. Skogbruk, 62: 67—72.

BRINK, R. A. and COOPER, D. C., 1941: Incomplete seed failure as a result of somatoplastic sterility. — Genetics, 26: 487—505.

BUCHHOLZ, J. T., 1918: Suspensor and early embryo of *Pinus*. — Bot. Gaz., 66: 185—228.

— 1920 a: Polyembryony among Abietineae. — Ibid., 69: 153—167.

— 1920 b: Embryo development and polyembryony in relation to the phylogeny of conifers. — Am. Jour. Bot., 7: 125—145.

— 1922: Developmental selection in vascular plants. — Bot. Gaz., 73: 249—286.

— 1926: Origin of cleavage polyembryony in conifers. — Ibid., 81: 55—71.

— 1929: The embryogeny of the conifers. — Proc. Int. Cong. Plant Sci. Ithaca, N.Y., 1: 359—392.

— 1950: Embryology of gymnosperms. — Proc. and Transc. 7th Int. Bot. Cong., Stockholm.

BÜHLER, A., 1918: Der Waldbau nach wissenschaftlicher Forschung und praktischer Erfahrung. Bd I. — Stuttgart.

— 1922: Der Waldbau nach wissenschaftlicher Forschung und praktischer Erfahrung. Bd II. — Stuttgart.

BÜNNING, E., 1948 a: Entwicklungs- und Bewegungsphysiologie der Pflanze. Lehrbuch der Pflanzenphysiologie. Bd 2 and 3. — Berlin.

— 1948 b: Studien über Photoperiodizität in den Tropen. — Vernalization and photoperiodism, A Symposium, 161—164.

CARDIFF, I. D., 1906: A study of synapsis and reduction. — Bull. Torr. Bot. Club, 33: 271—306.

ČERNÝ, R. and POLNAR, M., 1951: Distinguishing between spruce from different altitudes. — Lesnická práse, 30 (4): 319—328. (With summary in For. Abstr. 1953, nr 1952.)

CHAMBERLAIN, C. J., 1899: Oogenesis in Pinus Laricio. — Bot. Gaz., 27: 268—280.

— 1935: Gymnosperms structure and evolution. — Univ. of Chicago.

CHANDLER, R. F. JR., 1938: The influence of nitrogenous fertiliser applications upon deciduous forest trees. — Jour. For., 36: 761—766.

CHRISTIANSEN, H., 1960: On the effect of low temperature on meiosis and pollen fertility in *Larix decidua* Mill. — Silvae Genetica, 9: 72—78.

CIESLAR, A., 1887: Ueber den Einfluss der Grösse der Fichtensamen auf die Entwickelung der Pflanzen nebst einigen Bemerkungen über schwedische Fichten- und Weissföhrensamen. — Cbl. ges. Forstw., 13: 149—153.

— 1898: The origin of gymnosperms and the seed habit. — Ibid., 26: 153—168.

CLAUSEN, R. E., 1931: Inheritance in *Nicotiana tabacum*. XI. The fluted assemblage. — Am. Nat., 65: 316—331.

CLIFFORD, H. T. and BINET, F. E., 1954: A quantitative study of a presumed hybrid swarm between *Eucalyptus elaeophora* and *E. goniocalyx*. — Austr. Jour. Bot., 2: 325—336.

COULTER, J. M., 1897: Notes on the fertilization and embryogenie of conifers. — Bot. Gaz., 23: 40—43.

CRAMÉR, H., 1945: Mathematical methods of statistics. — Stockholm.

CUMMING, W. C. and RIGHTER, F. I., 1948: Methods used to control pollination of Pines in the Sierra Nevada of California. — Un. Stat. Dep. Agr., 792: 2—18.

DAHL, E. and MORK, E., 1959: Om sambandet mellom temperatur, ånding og vekst hos gran (*Picea abies* (L.) Karst.). (On the relationships between temperature, respiration and growth in Norway spruce (*Picea abies* (L.) Karst.).) — Medd. Det Norske Skogf.-vesen, 53: 83—93.

DARK, S. O. S., 1932: Chromosomes of Taxus, Sequoia, Cryptomeria and Thuja. — Ann. Bot., 46: 965—977.

DARLINGTON, C. D., 1937: Recent advances in cytology. — Second edition. Philadelphia.

DENGLER, A., 1904: Die Horizontalverbreitung der Kiefer (*Pinus silvestris* L.). — Neudamm.

— 1910: Neues zur Frage des natürlichen Verbreitungsgebietes der Kiefer. — Forst- u. Jagdwes., 42: 474—495 and 519—539.

— 1912: Die Horizontalverbreitung der Fichte (*Picea excelsa* LK.). — Neudamm.

— 1932: Künstliche Bestäubungsversuche an Kiefern. — Forst- u. Jagdwes., 64: 513—555.

— 1939: Über die Entwicklung künstlicher Kiefernkreuzungen. — Ibid., 71: 457—485.

— 1940: Über die Befruchtungsfähigkeit der weiblichen Kiefernblüte. — Ibid., 72: 48—54.

DEWITT, B., 1960: Fertilization of two improved seed production areas. — For. Res. Rev. British Col. For. Serv., 52—53.

DIECKERT, H., 1964: Einige Untersuchungen zur Selbststerilität und Inzucht bei Fichte und Lärche. — Silvae Genetica, 13: 77—86.

DOBZHANSKY, TH., 1933: On the sterility of the interracial hybrids in *Drosophila pseudoobscura*. — P.N.A.S., 19: 397—403.

DOYLE, J., 1918: Observations on the morphology of *Larix leptolepis*. — Sci. Proc. Roy. Dublin Soc., 15: 310—330.

EBELING, F., 1957: Den nuvarande norrlandslinjen inom svenskt skogsbruk — tillfällig moderiktning eller välgrundad nydaning? (The new Norrland line of policy in Swedish forestry: A passing fashion or a well-founded reorganisation?) — K. Skogs- o. Lantbr. Akad. Tidskr., 4: 264—288.

— 1959: Skogarna och deras vård i övre Norrland från och med 1930-talet. — Sveriges skogar under 100 år. Kungl. Domänstyrelsen, 413—443. Stockholm.

— 1961: Vindens betydelse för skogens avverkning och föryngring särskilt i de norrländska höjdlägena. Ett genmäle. — Norrl. Skogsv.förb. Tidskr., 169—180.

— 1962: Skogen vid ishavet — Tankeställare för traditionalister! — Skogen, 49: 382—387.

EDLUND, E., 1959: Höstplockning av tallkott. — Norrl. Skogsv.förb. Tidskr., 11—21.

EHRENBERG, C. EKLUNDH, 1960: Studies on the longevity of stored pine pollen (*Pinus silvestris* L. and *Pinus contorta* var. *Murrayana* Engelm.). — Medd. Stat. Skogsforskn.-inst., 49: 7: 3—31.

— 1963: Genetic variation in progeny tests of Scots pine (*Pinus silvestris* L.). — Stud. For. Suec., 10: 1—135.

EHRENBERG, C., GUSTAFSSON, Å., PLYM FORSHELL, C. and SIMAK, M., 1955: Seed quality and the principles of forest genetics. — Hereditas, 41: 291—366.

EHRENBERG, C. EKLUNDH and SIMAK, M., 1957: Flowering and pollination in Scots pine (*Pinus silvestris* L.). — Medd. Stat. Skogsforskn.inst., 46: 12: 5—27.

EIDE, E., 1923: Om temperaturmaalinger og frøsætning i nord-Norges furuskoger 1920. (Über Temperaturmessungen und Samenertrag in den Kiefernwäldern des nördlichen Norwegens in 1920.) — Medd. Det Norske Skogf.vesen, 3: 39—87.

— 1925 a: Undersøkelser av norsk furufrø fra modningsaaret 1923. — Ibid., 5: 51—79.

— 1925 b: Om saaforsøk med nord-norsk furufrø. — Ibid., 5: 80—94.

— 1926: Om sommervarmens innflydelse på årringsbredden. — Ibid., 7: 87—102.

— 1927: Undersøkelse av nordenfjelsk granfrø 1925. (Samenuntersuchungen in den Fichtenwäldern des nördlichen Norwegens in 1925.) — Ibid., 8: 15—39.

EIDE, E., 1928—1930: Sommervarmens betydning for granfrøets spireevne. (The influence of summer temperature on the seed germination of Norway spruce.) — Ibid., 10—13: 473—506.

— 1931: Skogstrærnes frøsetning 1931. — Tidsskr. Skogbruk, 39: 274—281.

— 1932: Furuens vekst og foryngelse i Finnmark. (The growth and regeneration of the Pine forests in Finnmark.) — Medd. Det Norske Skogf.vesen, IV: 329—427.

— 1948: Skogen og klimaet. — Bergens Museum, 5—11.

EKLUND, B., 1944: Ett försök att numeriskt fastställa klimatets inflytande på tallens och granens radietillväxt vid de båda finska riksskogstaxeringarna. — Norrl. Skogsv.-förb. Tidskr., 193—226.

— 1954: Årsringsbreddens klimatiskt betingade variation hos tall och gran inom norra Sverige åren 1900—1944. (Variation in the widths of the annual rings in pine and spruce due to climatic conditions in northern Sweden during the years 1900—1944.) — Medd. Stat. Skogsforskn.inst., 44: 8: 5—150.

EKSTRAND, H., 1932: Ein Fall von erblicher Asyndese bei *Hordeum*. — Sv. Bot. Tidskr., 26: 292—302.

EMERSON, R. A., BEADLE, G. W. and FRASER, A. C., 1935: A summary of linkage studies in maize. — Cornell Univ. Exp. Stat. Mem., 180: 1—83.

ENEROTH, O., 1930: Till frågan om sambandet mellan en orts värmeklimat och härdigheten hos dess tallvegetation. — Norrl. Skogsv.förb. Tidskr., 1—49 and 153—172.

ENQUIST, F., 1924: Geologiska föreningens i Stockholm förhandlingar. — Geol. Fören. Förh., 46: 202—213. Stockholm.

— 1933: Trädgränsundersökningar. (Baumgrenzuntersuchungen.) — Sv. Skogsv.fören. Tidskr., 31: 145—214.

ERICSON, B., 1960 a: Latewood percentage, density and volumetric shrinkage in wood of *Picea abies* (L.) Karst. f. virgata Jacq. A comparison with *Picea abies*. — Rapp. Avd. Skogsprod., Skogsforskn.inst., 2. Stockholm.

— 1960 b: Studies of the genetical wood density variation in Scots pine and Norway spruce. — Ibid., 4.

— 1961: Skogsträdsförädling med sikte på ökat massautbyte. Några preliminära forskningsresultat. — Tekn. Vetensk. Forskn., 32: 4. Stockholm.

ERLANDSSON, S., 1936: Dendro-chronological studies. — Data 23 Stockholms Högskolas Geokronol. Inst. Uppsala.

FAULKNER, R., 1962: Seeds stands in Britain and their management. — Quart. Jour. For., LVI: 1: 1—15.

FAULKNER, R. and MATTHEWS, J. D., 1961: The management of seed stands and seed orchards. — Proc. Int. Seed Test. Ass., 26: 3: 366—387.

FERGUSON, M. C., 1901: The development of the egg and fertilization of *Pinus Strobus*. — Ann. Bot., 15: 435—479.

— 1904: Contributions to the knowledge of the life history of Pinus, with special reference to sporogenesis, the development of the gametophytes and fertilization. — Proc. Wash. Acad. Sci., 1—202.

FISHER, R. A. and YATES, F., 1963: Statistical tables for biological, agricultural and medical research. — Sixth edition. London.

FLORENCE, R. G. and MCWILLIAM, J. R., 1956: The influence of spacing on seed production; its application to forest tree improvement. — Z. Forstgenetik, 5: 4: 97—102.

FRIES, TH., 1913: Botanische Untersuchungen im nördlichsten Schweden. Ein Beitrag zur Kenntnis der Alpinen und Subalpinen Vegetation in Torne Lappmark. — Univ. Uppsala, 1—361.

— 1918: Några kritiska synpunkter på skogsgränsproblemet. — Sv. Bot. Tidskr., 12: 3: 273—287.

GARRETT, S. D., 1958: Inoculum potential as a factor limiting lethal action by *Trichoderma viride* Fr. on *Armilaria mellea* (Fr.) Quél. — Trans. Brit. Mycol. Soc., 41: 1958: 2: 157—164.

GATHY, P., 1959: An attempt to determine the fertility of 'Koekelare' Pines. (*Pinus nigra* var. *calabrica* cv 'Koekelare'.) — Trav. Stat. de Rech. Groenendaal, Ser., B 23: 32.

GEMMER, E. W., 1932: Well fed Pines produce more cones. — For. Worker, 8: 5: 15.

GODSKE, C. L., 1948: Klimaet og været i skogen. — Skogen og klimaet. Bergens Museum, 12—18.

GOODSPEED, T. H. and AVERY, P., 1939: Trisomic and other types in *Nicotiana sylvestris*. — Jour. Gen., 38: 381—458.

Gustafsson, Å., 1949: Conifer seed plantations: their structure and genetical principles. — Proc. III World For. Cong. Helsingfors, 117—119.
— 1952: Statens Skogsforskningsinstitut. VII. Genetiska avdelningen. — Medd. Stat. Skogsforskn.inst., 42: 1: 247—270.
— 1956: Skoglig växtförädling: teori och praktik. — Norrl. Skogsv.förb. Tidskr., 455—464.
— 1962: Genetik och växtförädling i skogsbrukets tjänst. — Sv. Skogsv.fören. Tidskr., 60: 111—150.

Hadders, G. and Åhgren, A., 1958: Kott- och fröproduktion samt frökvalitet hos 12-åriga ympträd av tall. — Sv. Skogsv.fören. Tidskr., 56: 455—468. (With an English summary.)

Hagberg, E., 1959: Tillståndet i Sveriges skogar. Föredrag vid Skogsveckans öppnande på Konserthuset den 9 mars 1959. — Sv. Skogsv.fören. Tidskr., 57: 205—214.

Hagberg, E. and Arman, V., 1959: Skogarna och skogstillståndet vid periodens slut. — Sveriges skogar under 100 år. Kungl. Domänstyrelsen, 494—525. Stockholm.

Hagem, O., 1914: Furuens frøsætning under ugunstige livsvillkaar. — Tidsskr. Skogbruk, 22: 162—176, and 284—291.
— 1917: Furuens og granens frøsætning i Norge. — Medd. Vestlandets Forstl. Fors.-stat., 1: 2: 1—188.
— 1931: Forsøk med Vest-Amerikanske treslag. — Ibid., 4: 12: 1—86.

Hagner, S., 1955: Iakttagelser över granens kottproduktion i norrländska höjdlägen kottåret 1954. — Norrl. Skogsv.förb. Tidskr., 181—206.
— 1958: Om kott- och fröproduktionen i svenska barrskogar. (On the production of cones and seed in Swedish coniferous forests.) — Medd. Stat. Skogsforskn.inst., 47: 8: 4—120.

Hagner, S. and Callin, G., 1959: Om insamling av tallkott. — Norrl. Skogsv.förb. Tidskr., 425—483. (With a German summary.)

Hagner, S. and Simak, M., 1958: Stratifieringsförsök med frö av *Pinus Cembra*. (Ein Stratifizierungsversuch mit Samen von *Pinus Cembra*.) — Ibid., 227—275.

Haines, W. B., 1946: Manuring hevea. IV. Conspectus of experimental improvements achieved in mature stands at the end of ten years, with a special note on seed production. — Emp. Jour. Exp. Agr., 14: 56: 182—186.

Håkansson, A., 1956: Seed development of *Picea abies* and *Pinus silvestris*. — Medd. Stat. Skogsforskn.inst., 46: 2: 1—23.
— 1959: Seed development of pine grafts. — Bot. Not., 112, Fasc., 1: 65—72.
— 1960: Seed development in *Larix*. — Ibid., 113, Fasc., 1: 29—40.

Hanson, W. D., 1961: Heritability. — Statistical genetics and plant breeding. Nat. Acad. Sci. — Nat. Res. Council, 1963 Publ., 982: 125—140.

Hashizume, H., 1959 a: The effect of gibberellin on flower formation in *Cryptomeria Japonica*. — Jour. Japan. For. Soc., 41: 10: 375—381.
— 1959 b: The effect of gibberellin upon flower formation and sex transition to female in *Chamaecyparis obtusa* and *C. lawsoniana*. — Ibid., 41: 11: 458—463.

Hausser, K., 1960: Pine fertiliser trials showing unexpected results. — Allg. Forstz., 15: 34: 497—501.

Hazel, L. N., 1943: The genetic basis for constructing selection indexes. — Genetics, 28: 476—490.

Hazel, L. N. and Lush, J. L., 1942: The efficiency of three methods of selection. — Jour. Hered., 33: 393—399.

Heikinheimo, O., 1921: Die Waldgrenzwälder Finnlands und ihre künftige Nutzung. — Comm. Inst. For. Fenn., 4: 1—20.
— 1932: Die Besamungsfähigkeit der Waldbäume. I. — Ibid., 17: 56—61.
— 1937: Die Besamungsfähigkeit der Waldbäume. II. — Ibid., 24: 4: 54—67.
— 1948: On the seeding capacity of forest trees. III. — Ibid., 35: 13—15.
— 1949: Results of experiments on the geographical races of spruce and pine. — Ibid., 37: 2: 37—44.
— 1961: Über die Besamungsfähigkeit der Waldbäume. — Ibid.. 17: 1—61.

Heitmüller, H. H. and Melchior, G. H., 1960: Über die blühfördernde Wirkung des Wurzelschnitts, des Zweigkrümmens und der Strangulation an japanischer Lärche (*Larix leptolepis* (Sieb. et Zucc.) Gord.). — Silvae Genetica, 9: 65—72.

HESSELMAN, H., 1934: Några studier över fröspridningen hos gran och tall och kalhyggets besåning. (Einige Beobachtungen über die Beziehung zwischen der Samenproduktion von Fichte und Kiefer und der Besamung der Kahlhiebe.) — Medd. Stat. Skogsf.-anst., 27: 145—182.

HESSELMAN, H., 1939: Fortsatta studier över tallens och granens fröspridning samt kalhyggets besåning. (Weitere Studien über die Beziehung zwischen der Samenproduktion der Kiefer und Fichte und der Besamung der Kahlhiebe.) — Ibid., 31: 1—64.

HITT, R., 1957: Forest tree improvement in the department of genetics at the university of Wisconsin. — Proc. of third Lake Stat. For. Tree Imp. Con.

HOEKSTRA, P. and MERGEN, F., 1957: Experimental induction of female flowers in young slash Pine. — Jour. For., 55: 11: 827—831.

HOFMEISTER, W., 1848: Ueber die Entwicklung des Pollens. — Bot. Zeit., 6: 425—434, 649—658 and 670—674.

— 1862: On the germination, development, and fructification of the higher cryptogamia, and on the fructification of the coniferae. — Translation, Ray Soc. London. (The original German treatise «Vergleichende Untersuchungen höherer Kryptogamen und der Samenbildung der Coniferen» appeared in 1851.)

HOLMERZ, C. G. and ÖRTENBLAD, TH., 1886: Om Norrbottens skogar. (Sur les forêts de la Norrbothnie.) Bih. t. Domänstr. underdån. ber. rör. skogsväs. år 1885. — Stockholm, 1886, 1—120.

HOLMGREN, A., 1911: Sådd eller plantering i norrlandsskogarna? — Skogsv.fören. Tidskr., 9: 213—235.

— 1954: Trakthuggning och föryngring i norrlandsskogarna. — Norrl. Skogsv.förb. Tidskr., 3—191.

— 1956: Expositionens betydelse för tallkulturens utveckling på stora hyggen å hög nivå i Norrland. — Ibid., 1—110.

— 1961: Vindens betydelse för skogens avverkning och föryngring särskilt i de norrländska höjdlägena. — Ibid., 41—74.

HOLMGREN, A. and TÖRNGREN, E., 1932: Studier i den norrländska föryngringsfrågan. — Ibid., 9—133.

HOLMSGAARD, E., 1955: Årringsanalyser af danske skovtræer. (Tree-ring analyses of Danish forest trees.) — Det Forstl. Forsøgsv., Danmark, XXII: 1: 5—246.

HOLST, M., 1959: Experiments with flower promotion in *Picea glauca* and *Pinus resinosa*. — Proc. Int. Bot. Cong. Montreal, 5: 2: 169.

HUSS, E., 1949: Tall- och granfröets grobarhet 1948. — Skogen, 36: 8—9.

— 1951: Skogsforskningsinstitutets metodik vid fröundersökningar. (Methods used at the Swedish forest research institute in seed experiments.) — Medd. Stat. Skogsforskn.-inst., 40: 6: 3—82.

— 1954: Tall- och granfröets grobarhet 1954. — Skogen, 41: 400—401.

— 1961: Undersökningar över tallfröets ljusbehov. (Investigations of the light requirements of Scots pine seed (*Pinus silvestris*).) — Medd. Stat. Skogsforskn.inst., 50: 6: 1—34.

ILVESSALO, L., 1917: Studien über die Verjüngungsjahre der Kiefernwälder in Süd- und Mittelfinnland. — Acta For. Fenn., 6: 1916, 1917: 1—8.

ISHIKAWA, C., 1902: Über die Chromosomenreduktion bei *Larix leptolepis* Gord. — Beih. Bot. Cbl., 11: 6—7.

ISHIKAWA, M., 1910: Über die Zahl der Chromosomen von *Ginkgo biloba* L. — Bot. Mag. Tokyo, 24: 225—226.

IWAKAWA, M. and CHIBA, S., 1952: Abnormal pollen grains of *Cryptomeria* and *Pinus* occurred in natural conditions. — Rep. Gov. For. Exp. Stat., No 64, Tokyo.

JENSEN, H., 1954: The establishment of forest tree seed orchards at Ramlösa 1941—1954. — Acta Horti Gotoburgensis, 19: 5: 157—192.

JOHNSON, L. P. V., 1945: Reduced vigour, chlorophyll deficiency and other effects of self-fertilization in Pinus. — Can. Jour. Res. C., 24: 145—149.

JOHNSSON, H., 1941: Cytological studies in the genus *Alopecurus*. — Lunds Univ. årsskr. N.F. avd. 2, 37: 3: 1—43.

— 1944: Meiotic aberrations and sterility in *Alopecurus Myosuroides* Huds. — Hereditas, 30: 469—566.

— 1961: Kottskörd och fröutbyte från fröplantager av tall. — Sv. Skogsv.fören. Tidskr., 59: 1—21.

JOHNSSON, H., 1963: Arrangement and design of field experiments in progeny testing. — FAO, Proc. World Cons. For. Gen. Tree Impr., I: 2a/1: i—iii, 1—8.

JOHNSSON, H., KIELLANDER, C. L. and STEFANSSON, E., 1953: Kottutveckling och fröbeskaffenhet hos ympträd av tall. — Sv. Skogsv.fören. Tidskr., 51: 358—389.

JUEL, H. O., 1900: Beiträge zur Kenntnis der Tetradenteilung. — Jahrb. Wiss. Bot., 35: 626—659.

KARLBERG, S., 1953: Om behandling av tall- och granfrö i groningsstimulerande syfte. — Kungl. Skogshögskolans skrifter, 11: 1—42.

KATO, Y., NARAKATSU, F. and REIJI, K., 1959: Stimulation of differentiation of flower buds in conifers by gibberellin. — Jour. Jap. For. Soc., 41: 8: 309—311.

KEMPTHORNE, O., 1957: An introduction to genetic statistics. — New York, London.

— 1960: The design and analysis of experiments. — Second printing. New York, London.

KENDALL, M. G., 1961: A course in multivariate analysis. — Second impression, Griffin, London.

KERNER VON MARILAUN, A., 1864: Studien über die oberen Grenzen der Holzpflanzen in den Österreichischen Alpen. — Österr. Revue, 2 u. 3: 211—224.

KLAEHN, F. U. and WHEELER, W. P., 1961: X-ray study of artificial crosses in *Picea abies* (L.) Karst. and *Picea glauca* (Moench) Voss. — Silvae Genetica, 10: 71—77.

KLEINSCHMIT, R., 1958: Stickstoffdüngungsversuch in einer Samenplantage. — Der Forst- und Holzwirt., 13: 313—315.

— 1961: Stickstoffdüngungsversuch in einer Samenplantage. — Ibid., 16: 403—404.

KOLMODIN, G., 1923: Tillväxtundersökningar i norra Dalarna. — Skogsv.fören. Tidskr., 21: 1—35.

— 1935: Väderlekens inflytande på tallens diametertillväxt. — Ibid., 33: 321—379. (With an English summary.)

KUJALA, V., 1927: Untersuchungen über den Bau und die Keimfähigkeit von Kiefern- und Fichtensamen in Finnland. — Comm. Inst. For. Finl. 12: 1—65.

LADEFOGED, K., 1952: The periodicity of wood formation. — Det Kongl. Danske Videns. Sels. Biol. Skr., 7: 3: 5—98.

LAKARI, O. J., 1915: Studien über die Samenjahre und Altersklassenverhältnisse der Kiefernwälder auf dem Nordfinnischen Heideboden. — Helsingfors.

— 1921: Untersuchungen über die Verjüngungsjahre der Fichtenwälder in Süd- und Mittelfinnland. — Comm. Inst. For. Finl., 4: 1—4.

LANG, A., 1948: Beiträge zur Genetik des Photoperiodismus. — Vernalization and photoperiodism. A Symposium, Lotsya, 1: 175—189.

LANGLET, O., 1935: Till frågan om sambandet mellan temperatur och växtgränser. (Über den Zusammenhang zwischen Temperatur und Verbreitungsgrenzen von Pflanzen.) — Medd. Stat. Skogsf.anst., 28: 3: 299—412.

— 1940: Om utvecklingen av granar ur frö efter självbefruktning och efter fri vindpollinering. (Über die Entwicklung von Teils nach künstlicher Selbstbestäubung, Teils nach freier Windbestäubung entstandenen Fichten.) — Ibid., 32: 1: 1—22.

— 1959: A cline or not a cline — a question of Scots pine. — Silvae Genetica, 8: 13—22.

LANGNER, W., 1951—1952: Kreuzungsversuche mit *Larix europea* D. C. und *Larix leptolepis* Gord. — Z. Forstgenetik, 1951: 1: 2—18 and 1952: 1: 40—56.

— 1953: Eine Mendelspaltung bei Aurea-Formen von *Picea Abies* (L.) Karst. als Mittel zur Klärung der Befruchtungsverhältnisse im Walde. — Ibid., 2: 49—51.

— 1959: Selbstfertilität und Inzucht bei *Picea Omorika* (Pančič) Purkyne. — Silvae Genetica, 8: 84—93.

— 1960: Improvement through individual tree selection and testing seed stand, and clonal orchards. — Proc. World For. Cong., 5th Seattle, 2: 778—782.

— 1961: Einige Versuchsergebnisse zum Inzuchtproblem bei der forstlichen Saatgutgewinnung. — IUFRO, 13. Kongress, Wien, 2: 1: 22—1.

LENGER, A. and GATHY, P., 1960: Biometrical study on the production of cones and seed by 'Koekelare' pine. Criteria for selection. — Biométrie-Praximétrie, 2: 45—60.

LERNER, I. M., 1954: Genetic homeostasis. — New York, London.

— 1958: The genetic basis of selection. — New York, London.

LE ROY, H. L., 1960: Statistische Methoden der Populationsgenetik. — Basel, Stuttgart.

LEWIS, J. M., 1908: The behaviour of chromosomes in *Pinus* and *Thuja*. — Ann. Bot., 22: 529—556.

Li, H. W., Pao, W. K. and Li, C. H., 1945: Desynapsis in the common wheat. — Am. Jour. Bot., 32: 92—101.

Lindquist, B., 1948 a: Genetics in Swedish forestry practice. — Stockholm.

— 1948 b: The main varieties of *Picea Abies* (L.) Karst. in Europe, with a contribution to the theory of a forest vegetation in Scandinavia during the last Pleistocene glaciation. — Acta Horti Bergiani, 14: 7: 249—342.

Longman, K. A. and Wareing, P. F., 1958: Effect of gravity on flowering and shoot growth in Japanese Larch (*Larix leptolepis* Murray). — Nature, 182: 379—381.

Löve, A., 1943: A Y-linked inheritance of asynapsis in *Rumex acetosa*. — Nature, 1943: 358—359.

Low, J. D. and Gladman, R. J., 1960: Fomes annosus in Great Britain. — For. Comm. For. Record, 41: 1—22.

Lush, J. L., 1940: Intra-sire correlations or regressions of offspring on dam as a method of estimating heritability of characteristics. — Proc. Am. Soc. Animal Production, 33: 293—301.

Maki, T. E., 1955: Stimulating seed production by fertilisation and girdling. — Proc. 3rd South. Con. For. Tree Imp. U.S.D.A. South. For. Exp. Stat.

— 1958: Fertilisers in forestry. — South. Lumberman.

Marek, R., 1910: Waldgrenzstudien in den Österreichischen Alpen. — Peterm. Mitt. Ergänzungsh., 168: 1—102.

Mather, K., 1955: Response to selection: Synthesis. — Cold Spring Harbor Symposia Quant. Biol., 20: 158—165.

Matthews, J. D., 1961: The production of seed by forest trees. — IUFRO, 13. Kongress, Wien, 2: 1: 22—9.

— 1963: Factors affecting the production of seed by forest trees. — For. Abstracts, 24: 1: i—xiii.

— 1964: Seed production and seed certification. — Unasylva, 18: 2—3: 104—118.

Matthews, J. D. and Mitchell, A. F., 1957: Forest genetics. — Rep. For. Res. f. the year ended March, 1956. For. Comm., 54—58.

Melchior, G. H., 1960: Ringelungsversuche zur Steigerung der Blühwilligkeit an japanischer Lärche (*Larix leptolepis* (Sieb. u. Zucc.) Gord.) und an europäischer Lärche (*Larix decidua* Mill.). — Silvae Genetica, 9: 105—111.

Mergen, F. and Voigt, G. K., 1960: Effects of fertiliser applications on two generations of slash Pine. — Soil Sci. Soc. Am. Proc., 24: 5: 407—409.

Mergen, F., Burley, J. and Yeatman, Ch. W., 1964: Variation in growth characteristics and wood properties of Norway spruce. — Tappi, 47: 499—504.

Merrington, M., 1942: Table of percentage points of the *t*-distribution. — Biometrika, 32.

Messer, H., 1948: Die Waldsamenernte. — Hannover.

— 1958: Das Fruchten der Waldbäume als Grundlage der Forstsamengewinnung. — Mitt. Hess. Land. forstv., 1: 1—108.

Mezera, A., 1939: Über die Verbreitung der Zapfenformen der Fichte in der Tschechoslowakei. — Lesnická práce, XVIII.

Mikola, P., 1950: On variations in tree growth and their significance to growth studies. — Comm. Inst. For. Fenn., 38: 126—131.

Mirov, N. T., 1956: Photoperiod and flowering of Pines. — For. Sci., 2: 4: 328—332.

Miyake, K., 1903: Contribution to the fertilization and embryogeny of *Abies balsamea*. — Beih. Bot. Cbl., 14: 134—144.

Miyake, K. and Yasui, K., 1911: On the gametophytes and embryo of *Pseudolarix*. — Ann. Bot., 25: 631—647.

Mork, E., 1931: Skogsforyngelsesproblemet i Trondelagen. — Tidsskr. Skogbruk, 13—20.

— 1933: Temperaturen som foryngelsesfaktor i de nordtrønderske granskoger. — Medd. Det Norske Skogf.vesen, 5: 1: 5—153.

— 1941: Om sambandet mellom temperatur og vekst. — Medd. Det Norske Skogf.vesen, 27: 7—76.

— 1948: Om fjellskog og skoggrenser. — Skogen og klimaet. Bergens Museum, 19—30.

— 1957: Om frøkvalitet og frøproduksjon hos furu i Hirkjølen. (Seed quality and seed production for Scots Pine at Hirkjølen.) — Medd. Det Norske Skogf.vesen, 48: 353—379.

Murneek, A. E., 1948: Nutrition and metabolism as related to photoperiodism. — Vernalization and photoperiodism. A Symposium, Lotsya, 1: 83—90.

Murneek, A. E. and Whyte, R. O., 1948: Vernalization and photoperiodism. — Ibid., 1.

Müller-Olsen, C. and Simak, M., 1954: X-ray photography employed in germination analysis of Scots pine (*Pinus silvestris* L.). — Medd. Stat. Skogsforskn.inst., 44: 6: 3—19.

Müller-Olsen, C., Simak, M. and Gustafsson, Å., 1956: Germination analyses by the X-ray method: *Picea Abies* (L.) Karst. — Ibid., 46: 1: 1—12.

Müller-Stoll, H., 1951: Vergleichende Untersuchungen über die Abhängigkeit der Jahrringfolge von Holzart, Standort und Klima. — Bibl. Bot., 30: 122: 1—93.

Münch, E., 1936: Das Lärchensterben. — Forstwiss. Cbl., 58: 469—494, 537—562, 581—590 and 641—671.

Müntzing, A., 1939: Studies on the properties and the ways of production of rye-wheat amphidiploids. — Hereditas, 25: 387—430.

— 1943: Aneuploidy and seed shrivelling in tetraploid rye. — Ibid., 29: 65—75.

— 1944: Cytological studies of extra fragment chromosomes in rye. I. Iso-fragments produced by misdivision. — Ibid., 30: 231—248.

— 1945: Cytological studies of extra fragment chromosomes in rye. II. Transmission and multiplication of standard fragments and iso-fragments. — Ibid., 31: 457—477.

— 1946: Sterility in rye populations. — Ibid., 32: 521—549.

— 1948 a: Cytological studies of fragment chromosomes in rye. IV. The position of various fragment types in somatic plates. — Ibid., 34: 161—180.

— 1948 b: Cytological studies of extra fragment chromosomes in rye. V. A new fragment type arisen by deletion. — Ibid., 34: 435—442.

Müntzing, A. and Prakken, R., 1941: Chromosomal aberrations in rye populations. — Ibid., 27: 273—308.

Näslund, M., 1942: Den gamla norrländska granskogens reaktionsförmåga efter genomhuggning. — Medd. Stat. Skogsf.anst., 33: 1—212. (With a German summary.)

Němec, A., 1956: Improving the seeding of *Fagus sylvatica* by soil improvement. — Práce Výskum Ust. Lesn. C.S.R., 11: 5—25.

Němec, B., 1910: Das Problem der Befruchtungsvorgänge und andere zytologische Fragen. — Berlin.

Nilsson, B., 1959: Om lärkfrö och lärkhybrider för mellansverige. — Sv. Skogsv.fören. Tidskr., 57: 309—324.

Nordfors, G., 1928: Fjällskogens och exponerade skogars föryngringsmöjligheter med särskild hänsyn till det producerade fröets grobarhet under extrema klimatförhållanden. — Norrl. Skogsv.förb. Tidskr., 1—127.

Nordström, L., 1950: Tallfrö för Norrlands höjdlägen. Ett förelöpande meddelande. — Norrl. Skogsv.förb. Tidskr., 354—356.

— 1953 a: Klängning av svårklängd tallkott. — Ibid., 1—19.

— 1953 b: Vår försörjning med tallfrö med särskild hänsyn tagen till Norrlands höjdlägen. — Ibid., 20—84.

— 1955: Vår försörjning med tallfrö med särskild hänsyn tagen till Norrlands höjdlägen. — Ibid., 101—160.

Nybom, N., 1961: The use of induced mutations for the improvement of vegetatively propagated plants. — Mutation and Plant Breeding. NAS—NRC, 891: 252—294.

Nyman, B., 1963: Studies on the germination in seeds of Scots pine (*Pinus silvestris* L.) with special reference to the light factor. — Stud. For. Suec., 2: 1—164.

Oldertz, C., 1921: Om orsaker till eftergroning hos norrlandstallens frö. — Sv. Skogsv.-fören. Tidskr., 19: 157—172.

Opsahl, W., 1931: Furuens foryngelsesforhold i Nord-Norge. — Tidsskr. Skogbruk, 262—273.

— 1952: Om sambandet mellom sommertemperatur og frømodning hos gran. (On relation between summer temperature and seed ripening of Norway spruce.) — Medd. Det Norske Skogf.vesen, XI: 619—662.

Ording, A., 1941: Årringanalyser på gran og furu. — Medd. Det Norske Skogf.vesen, 7: 24—26: 105—354. (With an English summary.)

Orr-Ewing, A. L., 1957: Further inbreeding studies with Douglas Fir. — For. Cron., 33: 4: 318—332.

Örtenblad, Th., 1894: Om skogarne och skogshushållningen i Norrland och Dalarne. II. — Bih. t. Domänstyr. underdån. ber. rör. skogsväs. för år 1893. Stockholm.

Östergren, G., 1950: Cytological standards for the quantitative estimation of spindle disturbances. — Hereditas, 36: 371—382.

OZAWA, J. and MATUZAKI, S., 1955: Promotion of the fruiting of Japanese larch. (1). The effects manures on the formation of flower buds. — Spec. Rep. Gov. For. Exp. Stat., Hokkaido, 4: 58—71.

PAUL, B. H. and MARTS, R. O., 1931: Controlling the proportion of summerwood in longleaf Pine. — Jour. For., 29: 784—796.

PETTERSON, H., 1955: Barrskogens volymproduktion. — Medd. Stat. Skogsforskn.inst., 45: 1A: 1—391.

PLYM FORSHELL, C., 1953: Kottens och fröets utbildning efter själv- och korsbefruktning hos tall (*Pinus silvestris* L.). (The development of cones and seeds in the case of self- and cross-pollination in (*Pinus silvestris* L.).) — Medd. Stat. Skogsforskn.inst., 43: 10: 1—42.

PLYM FORSHELL, W., 1945: Skogsodling. Fröanskaffning och frökvalitet. — Sv. Skogsv.-fören. Förlag, Stockholm, 7—20.

— 1964: Genetics in forest practice in Sweden. — Unasylva, 18: 2—3: 119—129.

PRAKKEN, R., 1943: Studies of asynapsis in rye. — Hereditas, 29: 475—495.

RAO, C. R., 1952: Advanced statistical methods in biometric research. — New York, London.

RASMUSON, M., 1964: Combined selection for two bristle characters in Drosophila. — Hereditas, 51: 231—256.

RECKE, GRAF V. D., 1939: Versuche in der forstlichen Praxis. — Dtsch. Forstzeitung, 8: 843—846.

RENVALL, A., 1912: Die periodischen Erscheinungen der Reproduktion der Kiefer an der polaren Waldgrenze. — Acta Forest. Fenn., 1: 1—154.

RICK, C. M., 1945: A survey of cytogenetic causes of unfruitfulness in the tomato. — Genetics, 30: 347—362.

— 1946: The development of sterile ovules in *Lycopersicum esculentum,* Mill. — Am. Jour. Bot., 33: 250—256.

ROBAK, H., 1948: Lerkekreft og frost. — Skogen og klimaet. Bergens Museum, 79—86.

ROESER, J., 1942: Some aspects of flower and cone production in *Ponderosa Pine.* — Jour. For., 39: 534—536.

ROHMEDER, E., 1939 a: Wachstumsleitungen der aus Samen verschiedener Grössenordnung entstandenen Pflanzen. — Forstwiss. Cbl., 61: 42—59.

— 1939 b: Die Überwindung von Keimhemmungen bei den Samen der Weimutskiefer, Duglasie und Lärche durch Kaltnassvorbehandlung. — Ibid., 61: 393—406.

— 1949: Kiefernsamengewinnung von Einzelstämmen und frühfruchtenden Jungbäumen. — Allg. Forstz.schr., 4: 113—114.

— 1954: Umwelt und Erbenanlagen bei der Fichtensamenausbeute. — Z. Forstgenetik, 3: 113—118.

ROHMEDER, E. and SCHÖNBACH, H., 1959: Genetik und Züchtung der Waldbäume. — Hamburg, Berlin.

RUBNER, K., 1938: Keimung von Samen grün- und rotzapfiger Fichten. — Tharandt Forstl. Jahrb., 89: 247—251.

RUDEN, T., 1945: En vurdering av anvendte arbeidsmetoder innen trekronologi og årringanalyse. — Medd. Det Norske Skogf.vesen, 9: 32: 181—266.

— 1957: Om mulighetene for øket råstoffproduksjon gjennom planteforedling. — Norsk Skogindustri, 11: 298—306.

SARVAS, R., 1950: Investigations into the natural regeneration of selectively cut private forests in northern Finland. — Comm. Inst. For. Fenn., 38: 5—95.

— 1955 a: Investigations into the flowering and seed quality of forest trees. — Ibid., 45: 7: 5—37.

— 1955 b: Ein Beitrag zur Fernverbreitung des Blütenstaubes einiger Waldbäume. — Z. Forstgenetik, 4: 137—141.

— 1957: Studies on the seed setting of Norway spruce. — Medd. Det Norske Skogf.-vesen, 48: 533—556.

— 1958: Tallens fröskörd och dess tillvaratagande. — Skogsbruket, 9—15.

— 1962: Investigations on the flowering and seed crop of *Pinus silvestris.* — Comm. Inst. For. Fenn., 53: 4: 1—198.

SAX, H. J., 1932: Chromosome pairing in *Larix* species. — Jour. Arnold Arb., 13: 368—374.

SAX, K. and SAX, H. J., 1933: Chromosome number and morphology in the conifers. — Jour. Arnold Arb., 14: 356—375.

SAXTON, W. T., 1909: Parthenogenesis in *Pinus pinaster*. — Bot. Gaz., 47: 406—409.

SCHMIDT, W., 1930: Unsere Kenntnis vom Forstsaatgut. — Berlin.

SCHMIDT-VOGT, H., 1964: Forstsamengewinnung und Pflanzenanzucht für das Hochgebirge. — München, Basel, Wien.

SCHNARF, K., 1933: Embryologie der Gymnospermen. — Berlin.

— 1937: Anatomie der Gymnospermen-Samen. — Berlin.

SCHOTTE, G., 1905: Tallkottens och tallfröets beskaffenhet skördeåret 1903—04. — Skogsvårdsf. Tidskr., 3: 165—198.

— 1909: Godt tallfrö i Norrland innevarande år. — Ibid., 7: 53.

— 1910: Skogsträdens frösättning hösten 1909. — Medd. Stat. Skogsf.anst., 7: 5—24. (With a German summary.)

— 1911: Skogsträdens frösättning hösten 1911. — Ibid., 8: 174—196. (With a German summary.)

— 1924: Ytterligare om norrländska tallfröets grobarhet 1923—1924. — Stat. Skogsf.-anst., flygblad 32.

SCHRÖCK, O., 1949: Die Vererbung der Frühblüte der Kiefer. — Der Züchter, 19: 8/9: 247—254.

SCHRÖTER, C., 1898: Ueber die Vielgestaltigkeit der Fichte. — Vierteljahresschr. Naturforsch. Ges. Zürich, Jg. XLIII, 2 u. 3, Zürich.

SCHULENBURG, A. FR. V. DER, 1958: Om lärken och dess odling i Norden. Erfarenheter av finska odlingsförsök. — Sv. Skogsv.fören. Tidskr., 57: 1—12.

SCHÜRHOFF, P. N., 1927: Zytologische Untersuchungen über *Mentha*. — Beitr. Biol. Pflanzen, 15: 129—146.

SEEGER, [ ], 1913: Ein Beitrag zur Samenproduktion der Waldbäume im Grossherzogtum Baden. — Naturw. Zeitschr. Forst- u. Landw., 11: 529—554.

SHIDEI, T., AKAI, T. and ICHIKAWA, S., 1959: Flower bud formation on sugi (*Cryptomeria Japonica*) and *Metasequoia glyptostroboides* by gibberellic acid treatment. — Jour. Japan. For. Soc., 41: 8: 312—315.

SIEGL, H., 1953: Untersuchungen über den Samenertrag der Fichte im Herbst 1951. — Forstwiss. Cbl., 72: 1/2: 369—379.

SIMAK, M., 1953 a: Über die Samenmorphologie der gemeinen Kiefer (*Pinus silvestris* L.). (On the morphology of the Scots pine (*Pinus silvestris* L.).) — Medd. Stat. Skogsforskn.-inst., 43: 2: 3—30.

— 1953 b: Beziehungen zwischen Samengrösse und Samenanzahl in verschiedenen grossen Zapfen eines Baumes (*Pinus silvestris* L.). — Ibid., 43: 8: 1—15. (With an English summary.)

— 1955 a: Bestämning av insektsskador på granfrö medelst röntgenfotografering. (Insect damages on seeds of Norway spruce determined by X-ray photography.) — Norrl. Skogsv.förb. Tidskr., 299—310.

— 1955 b: Samengrösse und Samengewicht als Qualitätsmerkmale einer Samenprobe (*Pinus silvestris* L.). — Medd. Stat. Skogsforskn.inst., 45: 9: 1—19.

— 1960: Influence of cone size on the seed produced (*Pinus silvestris* L.). — Ibid., 49: 4: 1—16.

SIMAK, M. and GUSTAFSSON, Å., 1953: X-ray photography and sensitivity in forest tree species. — Hereditas, 39: 458—468.

SIMAK, M. and GUSTAFSSON, Å., 1954: Fröbeskaffenheten hos moderträd och ympar av tall. (Seed properties in mother trees and grafts of Scots pine.) — Medd. Stat. Skogsforskn.inst., 44: 2: 1—73.

SIMAK, M., GUSTAFSSON, Å. and GRANSTRÖM, G., 1956: Die Röntgendiagnose in der Samenkontrolle. — XI. International Seed Testing Convention, June 1956, Paris.

SIMAK, M. and GUSTAFSSON, Å., 1957: Experimentell förbättring av det norrländska tallfröets grobarhet. — Skogen, 44: 490—493.

SIMAK, M. and GUSTAFSSON, Å., 1959: Röntgenanalys och det norrländska tallfröets kvalitetsförbättring. — Sv. Skogsv.fören. Tidskr., 57: 475—486.

SIRÉN, G., 1955: The development of spruce forest on raw humus sites in northern Finland and its ecology. — Acta For. Fenn., 62: 1—408.

SKINNEMOEN, K., 1948: Frøsetning og klima. — Skogen og klimaet. Bergens Museum, 31—39.

SKOOG, F., 1944: Growth and organ formation in tobacco tissue cultures. — Am. Jour. Bot., 31: 19—24.

SKOOG, F., 1957: Comments on the application on plant tissue cultivation to propagation of forest trees. — Tappi, 40: 4: 257—262.

SMÓLSKA, A., 1927: Die Entwicklung des Archegoniums und der Befruchtungsprozesse bei *Larix europea* DC. — Bull. Acad. Polon. Sci. Lett. B., 993—1038.

SNEDECOR, G. W., 1959: Statistical methods. — Fifth ed., Iowa.

STÅLFELT, M. G., 1924: Tallens och granens kolsyreassimilation och dess ekologiska betingelser. (Untersuchungen zur Ökologie der Kohlensäureassimilation der Nadelbäume.) — Medd. Stat. Skogsf.anst., 21: 183—258.

STEFANSSON, E., 1946: Provklängning av tallkott, sorterad i storleksklasser. — Skogen, 33: 114—115.

— 1950: Bidrag till frågan om tallkottens frövärde innevarande vinter. — Sv. Skogsv.-fören. Tidskr., 48: 51—60.

— 1951: Klängningsförsök med ofullständigt mogen tallkott. — Skogen, 38 (5*): 56—57.

— 1957: Försök med olika barrträd vid Avardo och Muråsen i Frostviken. — Norrl. Skogsv.förb. Tidskr., 129—270.

— 1962: Skogens föryngringsförmåga. — Kungl. Skogs- och Lantbr. Akad. Minnesskr. 1913—1962, 437—462.

STEFANSSON, E. and BERGMAN, F., 1956: Stratifiering av lärkfrö. — Medd. Fören. Växtf. Skogsträd, Sundmo.

STEINBRENNER, E. C., DUFFIELD, J. W. and CAMPBELL, R. K., 1960: Increased cone production of young Douglas fir following nitrogen and phosphorus fertilisation. — Jour. For., 58: 2: 105—110.

STERN, K., 1960: Plusbäume und Samenplantagen. — Frankfurt a. M.

— 1961: Über den Erfolg einer über drei Generationen geführten Auslese auf frühes Blühen bei *Betula verrucosa*. — Silvae Genetica, 10: 48—51.

STERN, K. and HATTEMER, H. H., 1964: Problems involved in some models of selection in forest tree breeding. — Silvae Genetica, 13: 27—32.

STONECYPHER, R., CECH, F. C. and ZOBEL, B., 1964: Inheritance of specific gravity in two- and three-year-old seedlings of Loblolly pine. — Tappi, 47: 405—407.

STRAND, L., 1957: Pollen dispersal. — Silvae Genetica, 6: 129—136.

STRASBURGER, E., 1872: Die Coniferen und die Genetaceen. — Jena, 1872.

— 1878: Über Befruchtung und Zellteilung. — Ibid., 1878.

— 1880: Über Zellbildung und Zellteilung. — Ibid., 1880.

— 1892: Über das Verhalten des Pollens und die Befruchtungsvorgänge bei den Gymnospermen. — Histol. Beitr., 4: 1—46.

— 1897: Angiospermen und Gymnospermen. — Jena, 1897.

— 1910: Über geschlechtsbestimmende Ursachen. — Jahrb. Wiss. Bot., 48: 427—520.

SYLVÉN, N., 1908: Material för studiet af skogsträdens raser. (Material zur Erforschung der Rassen der schwedischen Waldbäume.) — Medd. Stat. Skogsf.anst., 5: 169—193.

— 1910: Om pollineringsförsök med tall och gran. (Über Bestäubungsversuche mit Kiefer und Fichte.) — Ibid., 7: 219—228 (XXIX—XXX).

— 1912: Strödda iakttagelser från en studieresa i Mellaneuropa. — Sv. Skogsv.fören. Tidskr., 10: 43*—57*.

— 1916: De svenska skogsträden. I. Barrträden. — Stockholm.

SYRACH LARSEN, C., 1937: The employment of species types and individuals in forestry. — Roy. Vet. Agr. Coll. Yr.b., Copenhagen, 69—222.

— 1956: Genetics in silviculture. — Edinburgh.

SYRACH LARSEN, C. and WESTERGAARD, M., 1938: Contributions to the cytogenetics of forest trees. — Jour. Genetics, 36: 3: 523—530.

TAMM, C. O. and CARBONNIER, CH., 1961: Växtnäringen som skoglig produktionsfaktor. — K. Skogs.- o. Lantbr. Akad. Tidskr., 100: 95—124. (Stat. Skogsforskn.inst. uppsatser: 82.)

TIRÉN, L., 1935: Om granens kottsättning, dess periodicitet och samband med temperatur och nederbörd. (On the fruit setting of spruce, its periodicity and relation to temperature and precipitation.) — Medd. Stat. Skogsf.anst., 28: 1—524.

— 1945: Skogsodling. Om klängning, frölagring och grobarhetsbestämning. — Sv. Skogsv.-fören. Förlag, Stockholm, 33—44.

— 1946: Om skogsodling i Norrland. — Norrl. Skogsv.förb. Tidskr., 269—307.

— 1952: Om försök med sådd av tall- och granfrö i Norrland. (On experiments in sowing pine and spruce seed in Northern Sweden.) — Medd. Stat. Skogsforskn.inst., 41: 7: 1—110.

TISCHLER, G., 1926/1927: Pflanzliche Chromosomen-Zahlen. — Tab. Biol., IV: 1—83.
— 1931: Pflanzliche Chromosomen-Zahlen. — Ibid., VII: 109—226.
VESTERLUND, O., 1896: Bör någon afverkning ske inom fjällskogen? — Skogshushållning, 24: 156—159.
VOGEL, G., 1936: Die männliche Haploid-Generation von *Pinus silvestris* und ihre Beziehung zur Hohlkornbildung. — Würzburg.
WALLÉN, A., 1917: Om temperaturens och nederbördens inverkan på granens och tallens höjd- och radietillväxt å Stamnäs kronopark 1890—1914. — Skogshögskolan 1917, 413—427.
WARDLAW, C. W., 1955: Embryogenesis in plants. — London, New York.
WAREING, P. F., 1956: Photoperiodism in woody plants. — Ann. Rev. Plant Phys., 7: 190—214.
WAREING, P. F. and NASR, T., 1958: Effects of gravity on growth, apical dominance and flowering in fruit trees. — Nature, 182: 379—381.
WARREN, F. S. and HAYES, H. K., 1950: Correlation studies of yield and other characters in rye polycrosses. — Sci. Agric., 30: 12—29.
WEBER, E. and BROTT, C., 1963: Ein Linearitätstest mit Hilfe elektronischer Datenverarbeitungsanlagen. — Biom. Z., 5: 3: 188—205.
WENGER, K. F., 1953: The effect of fertilisation and injury on the cone and seed production of Loblolly pine trees. — Jour. For., 51: 8: 570—573.
WIBECK, E., 1910: Om sambandet mellan fröets beskaffenhet samt återväxtens mängd och fördelning vid gruppsådd. — Sv. Skogsv.fören. Tidskr., 8: 243*—269*.
— 1919: Om tall- och granfrö från Norrland. — Skogen, 6: 97—107.
— 1920: Det norrländska tallfröets grobarhet. — Medd. Stat. Skogsf.anst., 17: 1—20. (With a German summary.)
— 1928: Det norrländska tallfröets grobarhet och anatomiska beskaffenhet. — Norrl. Skogsv.förb. Tidskr., 4—35.
— 1931: Vad granens innevarande kottår bör kunna lära oss. I. Sambandet mellan sommartemperatur och frömognad. — Skogen, 18: 485—489.
— 1936: Rön över tallens och granens kottsättning och fröbeskaffenhet inom Kopparbergs och Jämtlands läns skyddsskogsområde, jämte redogörelse för vissa inom nämnda områden utförda skogsodlingsförsök. Bil. III till Betänkande med förslag till lagstiftning angående skyddsskogar m. m. — Stat. off. utredn. 1936: 19. Stockholm.
WIEDEMANN, E., 1925: Zuwachsrückgang und Wuchsstockungen der Fichte in den mittleren und unteren Höhenlagen der sächischen Staatsforsten. — Tharandt.
WITTROCK, V. BRECHER, 1914: Meddelanden om granen, särskildt hennes svenska former, i bild och skrift. — Acta Horti Bergiani, 5: 1: 1—91.
WRIGHT, J. W., 1945: Influence of size and portion of cone on seed weight in eastern white pine. — Jour. For., 43: 11: 817—819.
ZOBEL, B., 1961: Inheritance of wood properties in conifers. — Silvae Genetica, 10: 65—70.
— 1964: Breeding for wood properties in forest trees. — Unasylva, 18: 2—3: 89—103.

Sammanfattning

Kott- och fröstudier hos gran

Uppsatsen behandlar: 1) *variationer* inom individuella träd och provytor med avseende på kottstorlek, fröstorlek, frövikt, fröantal, frögrobarhet, tomfröhalt, frekvensen insektskadat frö och frekvensen icke grobara frön med embryo; 2) *samband* inom individuella träd och provytor mellan kott- och fröegenskaper, mellan fröegenskaper sinsemellan, mellan kottlängd och kottvikt, temperaturklimat och frögrobarhet, pollenfertilitet och antalet frön med embryo, pollenfertilitet och fröantal, pollenfertilitet och frökvalitet och mellan frökvalitet och provträdens ålder; 3) kottlängdens, kottviktens, fröantalets och fröviktens relativa andelar av variationen i frögrobarhet och tomfröhalt år 1954; 4) olika kott- och fröegenskapers gemensamma andel av variationen i frögrobarhet, och 5) beräkning av varianskomponenter inom vissa provytor för: miljöeffekter, genotypeffekter och samspelseffekter på basis av upprepade observationer på samma träd under olika fröår med avseende på frögrobarhet, fröantal och tomfröhalt.

Provytornas läge har i mellersta och norra Sverige valts med avsikt att undersöka *dels* trädens generativa anpassning inom extrema höjdlägesområden och *dels* förutsättningarna för att genom urval höja urvalspopulationens reproduktionsförmåga.

1. Undersökningen har visat att stora och signifikanta variationer i kott- och fröegenskaper föreligger mellan de undersökta provytorna eller lokalerna. Likaså existerar mycket stora variationer mellan träd inom provytor. Miljöns andel i variationen mellan ytor och mellan träd är stor, vilket framgår av variationen inom träd och mellan fröår.
2. Sambanden mellan kott- och fröegenskaper och mellan fröegenskaper sinsemellan är *dels* tämligen specifika för populationerna och träden och *dels* relativt komplexa.

Signifikanta populations- och träddifferenser existera i ett flertal fall med hänsyn till regressionslinjernas lutning och nivå. Träd eller genotyper inom en och samma provyta kan reagera olika ifråga om samvariationen av samma kott- och fröegenskaper under ett och samma år. Individuella träd kan också beträffande korrelationer och regressioner för kott- och frökarakteristika reagera helt olika (t. ex. under två fröår) för en miljöförändring.

För att belysa sambandet mellan två variabler, när t. ex. inverkan av en tredje eller fjärde variabel hålles konstant, har bl. a. ett antal partiella korrelationer och multipla regressioner beräknats.

3. Temperaturklimatets inflytande på fröets grobarhet och utmognad är som väntat starkt (se t. ex. fig. 22 och 23). Av de undersökta morfologiska egenskaperna synes frövikten ha det största inflytandet på frögrobarheten. Variationen provytorna emellan är emellertid stor (se tabellbilaga XXII E).

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I t. ex. Kvikkjokk kunde 13% av variationen i frögrobarhet förklaras av variationen i frövikt. I Pajala uppgick denna fröviktens andel av variationen i fröets groningsförmåga till 47%. Motsvarande procenter för kottens torrvikt uppgick i Kvikkjokk och Pajala till respektive 2,7 och 20,6 och för kottlängdens andel av variationen i frögrobarhet till 2,9 och 4,4.

4. Med ledning av de i tabell 46 a beräknade multipla regressionerna och korrelationerna, kan vi för varje variabelkombination och population studera *dels* vilken inflytelse fröantal och frövikt (antingen *gemensamt* eller *var för sig,* när den andra oberoende variabeln hålles konstant) har på fröets groningsförmåga och *dels* hur stor del av variationen i frögrobarhet som kan förklaras av variationen i de två oberoende variablerna. Utökas de oberoende variablernas antal med kottlängd och kottvikt, erhålles variabelkombinationen i tabell 46 b. Vi ser av denna, att de fyra oberoende variablerna: kottlängd, kottvikt, fröantal och frövikt per kott gemensamt svarar i Stjernarp för 64% av variationen i frögrobarhet mot 54% för de två variablerna fröantal och frövikt (se tabell 46 a).
5. För skattning av den genotypiskt maximala andelen av fenotypvariationen ifråga om sådana egenskaper som frögrobarhet, tomfrö, fröantal och procenten icke grobara frön med embryo har en serie upprepade observationer på samma träd under olika froår utförts. Exempel på en dylik skattning och uppdelning av den totala variansen i dess delkomponenter framgår av tabellerna 48 a — d. Metoden synes vara användbar för undersökning av trädens fröproduktion och frökvalitet, d. v. s. trädens reproduktionsförmåga. Liknande undersökningar av plusträd inom höjdlägeszonerna under ett antal fröår kan förväntas att göra trädurvalet effektivare, då det gäller att (ur våra nuvarande höjdslägespopulationer) framställa nya lokalraser med förhöjd fröproduktion, förbättrad frökvalitet och generativ anpassning till rådande miljöförhållanden på växtplatsen.

Undersökningen har visat, att procenten icke insektskadat tomfrö, beräknat på samtliga icke insektskadade frön, växlar för samma träd från fröår till fröår, vilket antyder att andra än genetiskt betingade faktorer inverka på tomfröbildningen. Tomfröprocenten är hos granen lägst under mycket rikliga blomningsår. Till de icke genetiskt betingade orsakerna till tomfröbildning hör utebliven pollination eller befruktning och växlingar i trädens inavelsfrekvens från ett blomningsår till ett annat. Den höga tomfröprocenten efter inavel och under ett så exceptionellt rikligt blomningsår som 1954 tyder emellertid på, att halten av tomfrö hos granen betingas i första hand av recessiva letalfaktorer.

Inga signifikanta samband har kunnat konstaterats mellan pollenfertilitet och frögrobarhet, pollenfertilitet och trädhöjd, pollenfertilitet och fröantal och mellan frökvalitet och provträdens ålder.

Tables I—XLI

APPENDIX

Table I. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., for individual trees in the spruce sample plot at Stjernarp in the year 1948.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. seeds ≦1 mm. per cone	Weight of seeds ≦1 mm. per cone	No. seeds >1 mm. per cone	Weight of seeds >1 mm. per cone
3	22.08±0.83	10.10±0.17	268.80±6.19	0.644±0.029	148.52±4.35	0.117±0.005	120.28± 3.37	0.526±0.025
9	29.52±0.62	11.18±0.13	235.08±5.00	0.980±0.041	7.36±0.23	0.009±0.001	227.72± 5.04	0.970±0.041
11	33.48±1.13	12.20±0.17	242.33±4.25	1.073±0.039	19.52±1.15	0.021±0.001	222.80± 4.16	1.053±0.039
40	11.04±0.39	7.74±0.10	201.40±8.60	0.295±0.028	15.72±1.19	0.008±0.001	185.68± 7.69	0.287±0.028
51	30.32±1.07	12.18±0.20	274.56±5.20	1.264±0.056	8.20±0.50	0.010±0.001	266.36± 5.39	1.254±0.056
52	32.88±1.12	12.68±0.15	243.52±6.87	1.256±0.045	16.28±1.15	0.021±0.001	227.24± 6.48	1.235±0.045
53	28.60±0.92	12.46±0.20	305.08±7.39	1.343±0.050	14.64±0.88	0.014±0.001	290.44± 7.45	1.329±0.050
54	30.20±0.85	11.98±0.20	337.04±5.32	1.652±0.040	14.76±0.83	0.016±0.001	322.28± 5.54	1.636±0.040
55	30.92±0.57	12.64±0.16	273.64±3.94	1.433±0.040	14.04±0.97	0.016±0.001	259.60± 4.06	1.417±0.039
56	29.96±1.00	10.74±0.17	201.76±9.40	0.796±0.034	80.16±9.02	0.122±0.015	121.60± 5.51	0.674±0.037
57	30.16±0.67	12.20±0.16	278.48±4.90	1.568±0.035	13.52±0.85	0.016±0.001	264.96± 4.64	1.553±0.035
58	37.64±0.75	13.78±0.16	284.08±5.54	1.363±0.056	14.68±0.82	0.016±0.001	269.40± 5.33	1.347±0.056
59	37.48±0.82	13.34±0.17	324.08±6.52	2.085±0.050	17.56±1.02	0.022±0.002	306.52± 6.33	2.063±0.050
60	29.96±1.02	12.08±0.17	280.64±6.66	1.594±0.061	15.68±1.68	0.020±0.002	264.96± 6.60	1.574±0.061
61	41.68±1.31	12.98±0.15	264.80±7.15	1.658±0.044	10.92±1.22	0.013±0.002	253.88± 6.47	1.645±0.043
62	32.44±0.88	10.82±0.14	268.12±4.16	1.157±0.051	30.84±8.95	0.039±0.011	237.28±10.45	1.118±0.058
63	18.84±0.59	9.56±0.13	227.64±3.45	0.836±0.029	16.00±1.05	0.018±0.001	215.64± 3.28	0.817±0.029
64	33.32±1.08	11.50±0.17	245.08±5.99	1.205±0.054	13.40±1.31	0.017±0.002	231.68± 6.23	1.188±0.054
65	40.80±1.36	13.74±0.19	279.28±4.89	1.483±0.039	23.20±1.39	0.030±0.002	256.08± 4.96	1.453±0.039
66	22.68±0.45	9.26±0.10	239.32±5.62	0.815±0.028	70.12±2.92	0.072±0.003	169.20± 3.57	0.744±0.026
67	29.72±1.27	10.96±0.21	217.16±6.04	0.978±0.040	10.40±2.47	0.011±0.002	210.76± 5.80	0.968±0.040
68	27.20±0.65	12.22±0.14	255.64±6.28	1.266±0.041	8.32±0.75	0.010±0.001	247.32± 6.02	1.256±0.041
69	27.68±0.70	10.60±0.14	213.76±4.76	1.168±0.031	8.92±0.93	0.011±0.001	204.84± 4.34	1.157±0.031
70	23.16±0.64	8.68±0.14	187.52±5.46	0.923±0.029	8.36±0.80	0.009±0.001	179.16± 5.26	0.914±0.028
71	28.40±0.93	11.14±0.21	238.60±5.47	1.267±0.042	10.96±0.70	0.014±0.001	227.64± 5.40	1.254±0.042
72	24.60±0.79	11.74±0.18	231.72±4.02	1.088±0.031	11.72±2.62	0.013±0.003	220.00± 4.55	1.076±0.032
73	35.28±1.10	13.14±0.23	264.12±9.99	1.093±0.053	108.96±7.94	0.152±0.012	155.16± 8.98	0.941±0.051
74	19.48±0.35	10.60±0.13	241.60±4.30	1.020±0.023	14.72±0.92	0.014±0.001	226.88± 3.82	1.005±0.023
75	23.56±0.45	10.32±0.12	234.96±3.89	0.968±0.027	65.72±2.96	0.079±0.004	169.24± 4.22	0.889±0.027
76	23.88±1.09	11.26±0.22	283.64±5.48	1.371±0.060	18.80±2.17	0.020±0.003	264.84± 6.33	1.352±0.061
77	27.28±0.85	11.56±0.15	226.20±6.47	1.223±0.042	13.52±1.10	0.013±0.001	212.68± 6.16	1.211±0.042
78	34.44±1.04	13.50±0.17	259.44±5.95	1.444±0.042	12.32±1.02	0.014±0.001	247.08± 5.72	1.430±0.040
79	31.12±0.75	11.42±0.15	266.32±3.93	1.570±0.042	19.80±1.16	0.025±0.002	246.52± 3.59	1.546±0.041
80	20.04±0.59	9.88±0.16	205.36±5.17	0.949±0.032	10.88±0.79	0.012±0.001	194.48± 5.06	0.937±0.031
81	20.88±1.03	10.00±0.18	217.36±5.27	0.958±0.041	11.84±0.82	0.012±0.001	205.52± 5.27	0.946±0.041
82	23.32±0.85	10.74±0.18	209.36±4.99	1.090±0.045	9.12±0.82	0.011±0.001	200.24± 4.58	1.079±0.045
83	31.64±1.62	11.66±0.28	264.52±4.49	1.330±0.075	22.08±0.98	0.013±0.001	251.44± 3.89	1.317±0.075
84	35.04±0.98	12.64±0.16	272.96±4.60	1.246±0.036	12.72±1.50	0.014±0.002	260.24± 4.20	1.232±0.035
85	21.40±0.76	9.88±0.15	199.68±6.05	0.690±0.031	7.44±0.85	0.008±0.001	192.24± 5.52	0.682±0.031
86	30.44±0.82	11.18±0.13	224.64±4.94	1.264±0.046	13.88±0.79	0.017±0.001	210.76± 4.79	1.247±0.046
87	26.80±0.57	10.60±0.14	264.48±3.59	1.111±0.029	11.48±0.83	0.012±0.001	253.00± 3.45	1.099±0.029
88	32.08±1.08	11.40±0.15	254.80±4.12	1.393±0.050	12.96±0.72	0.016±0.001	241.84± 3.77	1.377±0.050
89	21.84±0.66	8.94±0.16	215.36±5.36	0.799±0.036	7.56±0.55	0.007±0.001	207.80± 5.32	0.792±0.036
90	30.96±0.70	12.98±0.16	272.44±3.75	1.128±0.037	21.28±1.01	0.024±0.001	251.16± 3.52	1.103±0.037
91	22.36±0.83	8.96±0.17	178.96±4.93	0.997±0.040	11.72±1.27	0.015±0.002	167.24± 1.73	0.982±0.041
92	27.00±0.93	9.96±0.14	249.00±3.55	1.025±0.034	11.72±0.81	0.012±0.001	237.28± 3.45	1.013±0.034
93	16.44±0.37	9.60±0.13	227.12±5.91	1.159±0.033	8.04±1.01	0.008±0.001	219.08± 5.59	1.151±0.033
94	29.40±0.82	12.90±0.19	225.04±4.32	1.263±0.036	7.92±0.65	0.008±0.001	217.12± 4.17	1.256±0.036
95	27.56±0.62	12.06±0.13	243.76±3.67	1.292±0.031	11.88±0.91	0.013±0.001	231.88± 3.76	1.279±0.031
96	26.20±0.72	12.68±0.15	237.32±5.13	1.304±0.032	7.16±0.52	0.007±0.001	230.16± 5.02	1.297±0.032
Mean	28.06±0.87	11.33±0.20	247.15±4.67	1.178±0.043	21.55±3.81	0.024±0.004	225.94± 5.77	1.153±0.044

Table II. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., for individual trees in the spruce sample plot at Härryda in the year 1948.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. seeds ≦1 mm. per cone	Weight of seeds ≦1 mm. per cone	No. seeds >1 mm. per cone	Weight of seeds >1 mm. per cone
51	22.52 ± 1.24	11.76 ± 0.28	233.36 ± 7.25	1.125 ± 0.060	13.88 ± 1.43	0.014 ± 0.005	219.48 ± 7.12	1.110 ± 0.060
52	25.48 ± 0.63	10.78 ± 0.15	249.28 ± 5.97	1.357 ± 0.039	18.96 ± 1.32	0.024 ± 0.002	230.32 ± 6.09	1.333 ± 0.039
53	23.92 ± 0.45	11.20 ± 0.15	241.76 ± 3.56	1.227 ± 0.024	13.04 ± 1.12	0.016 ± 0.002	228.72 ± 4.00	1.211 ± 0.028
54	16.36 ± 0.51	8.58 ± 0.14	226.64 ± 4.83	0.938 ± 0.036	8.24 ± 0.70	0.009 ± 0.001	218.40 ± 4.68	0.929 ± 0.034
55	27.80 ± 0.72	10.44 ± 0.17	291.36 ± 4.49	1.313 ± 0.031	9.48 ± 0.85	0.009 ± 0.001	281.88 ± 4.67	1.303 ± 0.032
56	35.72 ± 1.02	12.02 ± 0.15	263.56 ± 8.05	1.507 ± 0.049	14.04 ± 1.07	0.014 ± 0.001	249.52 ± 7.57	1.493 ± 0.048
57	42.16 ± 0.99	13.72 ± 0.20	297.24 ± 4.73	1.601 ± 0.043	11.64 ± 0.64	0.012 ± 0.001	285.60 ± 4.47	1.589 ± 0.043
58	40.12 ± 1.28	11.84 ± 0.21	269.24 ± 8.28	1.550 ± 0.056	9.04 ± 1.14	0.012 ± 0.002	260.20 ± 7.92	1.538 ± 0.056
59	40.40 ± 0.89	13.24 ± 0.14	333.88 ± 4.08	1.674 ± 0.044	18.08 ± 0.93	0.020 ± 0.002	315.80 ± 3.83	1.654 ± 0.044
60	44.20 ± 1.29	12.64 ± 0.16	232.92 ± 10.19	0.841 ± 0.045	21.92 ± 1.40	0.028 ± 0.002	211.00 ± 10.55	0.813 ± 0.045
61	44.76 ± 0.87	13.92 ± 0.14	233.84 ± 6.03	1.202 ± 0.037	10.68 ± 1.07	0.015 ± 0.001	223.16 ± 5.88	1.187 ± 0.037
62	26.36 ± 0.78	11.66 ± 0.17	243.52 ± 5.06	1.064 ± 0.029	20.48 ± 0.99	0.021 ± 0.001	223.04 ± 4.47	1.042 ± 0.024
63	52.28 ± 1.01	14.42 ± 0.12	321.04 ± 5.09	1.654 ± 0.040	15.64 ± 0.88	0.017 ± 0.001	305.40 ± 4.96	1.637 ± 0.040
64	29.96 ± 1.20	12.00 ± 0.20	294.52 ± 6.43	1.485 ± 0.049	18.68 ± 1.10	0.020 ± 0.001	275.84 ± 6.53	1.465 ± 0.049
65	31.80 ± 1.09	11.88 ± 0.20	288.68 ± 5.61	1.612 ± 0.022	13.44 ± 0.75	0.023 ± 0.001	275.24 ± 5.45	1.589 ± 0.022
66	37.40 ± 0.90	15.86 ± 0.17	252.96 ± 7.56	0.941 ± 0.025	126.00 ± 4.97	0.201 ± 0.007	126.96 ± 4.11	0.740 ± 0.021
67	16.04 ± 0.42	10.84 ± 0.15	231.68 ± 4.32	0.483 ± 0.052	123.84 ± 3.26	0.134 ± 0.004	107.84 ± 2.92	0.349 ± 0.048
68	19.20 ± 0.62	11.18 ± 0.14	254.52 ± 7.35	0.937 ± 0.042	18.32 ± 0.92	0.076 ± 0.0004	236.20 ± 7.32	0.861 ± 0.039
69	25.04 ± 0.72	11.12 ± 0.14	186.08 ± 4.52	0.789 ± 0.022	12.80 ± 0.93	0.017 ± 0.002	173.28 ± 4.22	0.772 ± 0.022
70	25.52 ± 0.70	12.22 ± 0.21	246.84 ± 4.84	0.937 ± 0.020	68.08 ± 2.64	0.076 ± 0.003	178.76 ± 3.62	0.861 ± 0.062
71	38.24 ± 1.26	12.72 ± 0.20	246.20 ± 6.56	1.293 ± 0.044	63.92 ± 3.18	0.070 ± 0.004	182.28 ± 4.41	1.223 ± 0.041
72	19.24 ± 0.63	10.32 ± 0.14	253.08 ± 6.16	0.776 ± 0.043	9.96 ± 1.15	0.006 ± 0.0003	243.12 ± 6.15	0.770 ± 0.037
73	29.60 ± 0.83	12.90 ± 0.14	266.04 ± 3.97	1.223 ± 0.032	10.44 ± 0.85	0.011 ± 0.001	255.60 ± 3.98	1.212 ± 0.032
74	27.20 ± 0.75	11.84 ± 0.12	244.92 ± 7.11	1.218 ± 0.049	10.24 ± 0.79	0.014 ± 0.001	234.68 ± 7.00	1.204 ± 0.049
75	23.52 ± 0.41	11.90 ± 0.10	206.12 ± 4.77	0.965 ± 0.029	10.84 ± 0.72	0.011 ± 0.001	195.28 ± 4.60	0.954 ± 0.029
76	19.60 ± 0.77	10.32 ± 0.17	210.88 ± 7.04	0.729 ± 0.047	9.04 ± 0.68	0.010 ± 0.001	201.84 ± 6.99	0.719 ± 0.047
77	21.08 ± 0.84	9.88 ± 0.16	220.88 ± 6.23	1.005 ± 0.039	12.16 ± 1.16	0.014 ± 0.001	208.72 ± 6.07	0.991 ± 0.039
78	38.60 ± 0.89	13.40 ± 0.19	235.68 ± 4.83	1.327 ± 0.035	9.48 ± 0.77	0.018 ± 0.002	226.20 ± 4.46	1.309 ± 0.035
79	32.88 ± 0.91	10.88 ± 0.07	272.36 ± 4.46	1.284 ± 0.046	9.48 ± 0.91	0.011 ± 0.001	262.88 ± 4.36	1.273 ± 0.046
80	30.76 ± 0.74	10.90 ± 0.13	206.20 ± 4.84	1.125 ± 0.028	12.68 ± 0.96	0.017 ± 0.001	193.52 ± 4.43	1.108 ± 0.028
81	34.68 ± 1.14	12.30 ± 0.21	208.76 ± 7.69	1.142 ± 0.057	4.84 ± 0.64	0.006 ± 0.001	203.92 ± 7.39	1.136 ± 0.057
82	27.12 ± 0.80	10.24 ± 0.22	238.56 ± 6.88	1.336 ± 0.049	12.08 ± 0.66	0.015 ± 0.001	226.48 ± 6.78	1.325 ± 0.049
83	32.48 ± 0.83	11.68 ± 0.12	300.76 ± 6.38	1.193 ± 0.031	15.64 ± 0.91	0.020 ± 0.001	285.12 ± 6.48	1.173 ± 0.031
84	17.16 ± 0.45	9.54 ± 0.13	222.68 ± 8.72	0.738 ± 0.034	13.00 ± 1.32	0.013 ± 0.001	209.68 ± 8.28	0.725 ± 0.034
85	23.20 ± 0.60	8.90 ± 0.10	195.96 ± 4.21	0.883 ± 0.025	14.24 ± 1.27	0.013 ± 0.001	181.72 ± 4.31	0.871 ± 0.025
86	34.56 ± 0.96	11.82 ± 0.20	272.36 ± 7.15	1.359 ± 0.044	11.04 ± 0.74	0.010 ± 0.001	261.32 ± 6.94	1.349 ± 0.043
87	24.08 ± 0.74	9.92 ± 0.14	188.24 ± 9.22	0.809 ± 0.046	17.48 ± 1.27	0.015 ± 0.001	170.76 ± 8.52	0.794 ± 0.047
88	17.24 ± 1.86	8.08 ± 0.15	221.64 ± 4.92	0.677 ± 0.025	7.28 ± 0.60	0.008 ± 0.001	214.36 ± 4.89	0.671 ± 0.025
89	36.24 ± 0.82	11.12 ± 0.13	262.48 ± 6.26	1.536 ± 0.054	12.16 ± 0.90	0.013 ± 0.001	249.92 ± 6.00	1.523 ± 0.054
90	24.08 ± 0.77	11.56 ± 0.23	203.72 ± 5.50	1.051 ± 0.043	7.80 ± 0.66	0.008 ± 0.001	195.92 ± 5.44	1.043 ± 0.043
91	33.88 ± 1.08	11.46 ± 0.23	258.28 ± 6.51	1.560 ± 0.058	15.76 ± 1.05	0.020 ± 0.001	242.52 ± 6.38	1.540 ± 0.058
92	34.36 ± 0.89	12.64 ± 0.13	278.56 ± 6.90	1.680 ± 0.055	12.04 ± 1.04	0.014 ± 0.002	266.52 ± 7.27	1.667 ± 0.055
93	33.08 ± 1.26	11.00 ± 0.24	176.76 ± 10.58	1.207 ± 0.026	7.00 ± 0.90	0.012 ± 0.002	169.76 ± 10.09	1.195 ± 0.026
94	18.12 ± 0.54	9.30 ± 0.13	197.76 ± 6.41	0.757 ± 0.034	12.04 ± 1.03	0.014 ± 0.001	185.72 ± 6.16	0.743 ± 0.034
95	19.72 ± 0.73	9.70 ± 0.19	212.20 ± 8.96	0.602 ± 0.028	15.00 ± 0.94	0.013 ± 0.001	197.20 ± 8.73	0.588 ± 0.028
96	39.92 ± 1.10	12.62 ± 0.20	230.88 ± 4.28	1.215 ± 0.035	21.96 ± 1.01	0.026 ± 0.001	208.92 ± 4.60	1.189 ± 0.035
97	25.52 ± 0.98	10.92 ± 0.18	129.76 ± 12.98	0.594 ± 0.021	4.88 ± 0.35	0.005 ± 0.000	124.88 ± 12.82	0.588 ± 0.021
98	24.96 ± 1.12	10.42 ± 0.20	229.64 ± 5.39	1.145 ± 0.046	5.48 ± 0.42	0.005 ± 0.000	224.16 ± 5.32	1.140 ± 0.046
99	40.56 ± 1.16	12.48 ± 0.17	183.92 ± 8.63	1.202 ± 0.028	23.68 ± 1.20	0.031 ± 0.002	160.24 ± 10.36	1.172 ± 0.028
100	39.60 ± 1.00	11.68 ± 0.15	283.56 ± 7.28	1.589 ± 0.056	11.28 ± 0.86	0.011 ± 0.001	272.28 ± 7.47	1.578 ± 0.056
Mean	29.77 ± 1.24	11.48 ± 0.21	241.03 ± 5.62	1.149 ± 0.045	19.38 ± 3.51	0.024 ± 0.004	221.64 ± 6.39	1.125 ± 0.046

Table III. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., for individual trees in the spruce sample plot at Gunnarskog in the year 1948.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. seeds ≤1 mm. per cone	Weight of seeds ≤1 mm. per cone	No. seeds >1 mm. per cone	Weight of seeds >1 mm. per cone
302	30.68 ± 0.97	10.80 ± 0.18	168.24 ± 9.71	0.585 ± 0.041	18.44 ± 1.46	0.023 ± 0.002	149.80 ± 9.40	0.562 ± 0.041
312	22.20 ± 0.65	9.26 ± 0.15	265.24 ± 8.57	0.888 ± 0.049	28.60 ± 2.78	0.031 ± 0.003	236.64 ± 9.57	0.856 ± 0.050
351	23.76 ± 0.76	11.16 ± 0.21	149.56 ± 6.05	0.680 ± 0.027	8.20 ± 0.90	0.010 ± 0.001	141.36 ± 5.77	0.670 ± 0.027
352	48.20 ± 1.13	14.40 ± 0.58	250.96 ± 6.00	1.373 ± 0.044	13.52 ± 1.15	0.021 ± 0.002	237.44 ± 5.40	1.352 ± 0.044
353	29.24 ± 0.75	11.34 ± 0.16	151.92 ± 5.53	0.769 ± 0.030	18.04 ± 1.26	0.021 ± 0.002	133.88 ± 4.87	0.747 ± 0.030
354	33.04 ± 0.62	11.26 ± 0.13	174.20 ± 6.08	0.790 ± 0.033	17.88 ± 1.16	0.020 ± 0.005	156.32 ± 5.55	0.770 ± 0.033
355	27.44 ± 0.68	11.13 ± 0.15	187.28 ± 6.28	0.628 ± 0.031	80.44 ± 3.53	0.103 ± 0.004	106.84 ± 4.93	0.526 ± 0.034
356	16.40 ± 0.43	8.34 ± 0.11	177.68 ± 5.74	0.346 ± 0.014	99.32 ± 2.71	0.095 ± 0.003	78.36 ± 3.54	0.251 ± 0.013
357	26.68 ± 0.65	10.30 ± 0.17	170.92 ± 8.96	0.582 ± 0.033	14.84 ± 1.62	0.017 ± 0.002	156.08 ± 8.31	0.565 ± 0.032
358	28.32 ± 0.85	10.88 ± 0.23	189.32 ± 9.56	0.828 ± 0.051	11.60 ± 1.10	0.016 ± 0.006	177.72 ± 9.17	0.811 ± 0.051
359	26.40 ± 0.74	10.40 ± 0.16	194.72 ± 6.21	0.825 ± 0.047	19.84 ± 2.19	0.022 ± 0.002	174.88 ± 5.89	0.803 ± 0.043
360	27.12 ± 0.94	10.18 ± 0.15	174.56 ± 8.51	0.813 ± 0.053	15.60 ± 1.31	0.029 ± 0.003	158.96 ± 8.04	0.783 ± 0.052
361	34.44 ± 1.07	11.12 ± 0.17	196.44 ± 9.07	1.092 ± 0.020	7.76 ± 0.72	0.007 ± 0.001	188.68 ± 8.95	1.085 ± 0.020
362	28.20 ± 0.52	11.20 ± 0.16	229.48 ± 7.40	0.761 ± 0.033	12.28 ± 0.69	0.014 ± 0.001	217.20 ± 7.51	0.747 ± 0.033
363	33.56 ± 0.35	12.86 ± 0.25	147.04 ± 9.79	0.698 ± 0.052	12.08 ± 0.79	0.014 ± 0.001	134.96 ± 9.50	0.684 ± 0.051
364	21.80 ± 0.53	8.32 ± 0.16	147.12 ± 5.33	0.597 ± 0.029	9.68 ± 0.85	0.011 ± 0.001	137.44 ± 5.01	0.586 ± 0.029
365	26.88 ± 0.63	11.58 ± 0.14	165.44 ± 6.05	0.963 ± 0.040	7.12 ± 0.53	0.010 ± 0.001	158.32 ± 6.16	0.953 ± 0.040
366	33.24 ± 0.57	12.56 ± 0.10	252.28 ± 8.28	1.409 ± 0.049	17.80 ± 1.29	0.030 ± 0.003	234.48 ± 7.93	1.380 ± 0.049
367	42.68 ± 0.98	12.32 ± 0.17	205.68 ± 10.10	1.083 ± 0.054	13.52 ± 1.07	0.017 ± 0.002	192.16 ± 10.05	1.067 ± 0.054
368	25.28 ± 0.53	10.72 ± 0.15	116.88 ± 7.46	0.480 ± 0.031	11.40 ± 1.26	0.014 ± 0.002	105.48 ± 6.81	0.465 ± 0.031
369	31.92 ± 0.97	11.78 ± 0.22	210.76 ± 7.65	1.288 ± 0.062	10.24 ± 0.98	0.013 ± 0.002	200.52 ± 7.32	1.275 ± 0.061
370	42.12 ± 1.15	12.54 ± 0.20	164.84 ± 7.78	0.746 ± 0.036	8.76 ± 0.70	0.010 ± 0.001	156.08 ± 7.51	0.736 ± 0.036
371	28.68 ± 0.55	12.54 ± 0.16	75.00 ± 10.52	0.254 ± 0.042	14.40 ± 1.56	0.015 ± 0.002	60.60 ± 9.70	0.240 ± 0.041
372	26.48 ± 0.69	11.64 ± 0.15	127.80 ± 8.34	0.562 ± 0.038	14.04 ± 2.02	0.015 ± 0.002	113.76 ± 7.15	0.547 ± 0.038
373	36.20 ± 0.80	13.82 ± 0.23	108.84 ± 9.78	0.481 ± 0.050	26.48 ± 1.74	0.038 ± 0.005	82.36 ± 7.36	0.443 ± 0.046
374	33.68 ± 1.32	11.82 ± 0.20	217.72 ± 10.80	0.806 ± 0.054	12.04 ± 1.05	0.014 ± 0.002	205.68 ± 10.89	0.792 ± 0.055
375	30.76 ± 0.53	11.56 ± 0.13	166.80 ± 5.18	0.752 ± 0.029	17.76 ± 1.12	0.032 ± 0.003	149.04 ± 5.41	0.720 ± 0.034
377	17.88 ± 0.39	9.18 ± 1.13	73.12 ± 6.09	0.190 ± 0.018	12.40 ± 1.04	0.011 ± 0.001	60.72 ± 5.60	0.179 ± 0.018
378	30.60 ± 0.94	12.62 ± 0.21	170.72 ± 9.59	0.670 ± 0.040	11.08 ± 0.81	0.010 ± 0.001	159.64 ± 9.25	0.660 ± 0.040
379	40.88 ± 1.38	12.30 ± 0.26	198.52 ± 11.63	1.059 ± 0.023	6.02 ± 0.64	0.007 ± 0.001	192.32 ± 11.26	1.052 ± 0.022
380	39.56 ± 1.14	12.84 ± 0.17	171.12 ± 10.32	0.867 ± 0.038	5.28 ± 0.78	0.005 ± 0.001	165.84 ± 6.78	0.861 ± 0.038
381	40.24 ± 0.90	12.72 ± 0.16	281.12 ± 9.76	1.184 ± 0.047	27.60 ± 1.62	0.046 ± 0.003	253.52 ± 9.17	1.139 ± 0.051
382	28.68 ± 0.45	11.62 ± 0.09	201.16 ± 6.12	0.796 ± 0.033	11.16 ± 0.99	0.013 ± 0.001	190.00 ± 5.75	0.783 ± 0.032
383	38.64 ± 0.81	13.56 ± 0.20	198.92 ± 6.77	0.620 ± 0.026	90.92 ± 3.11	0.119 ± 0.005	108.00 ± 4.81	0.505 ± 0.020
384	40.48 ± 0.78	12.64 ± 0.15	270.76 ± 4.17	1.196 ± 0.032	9.72 ± 0.70	0.011 ± 0.001	261.04 ± 4.71	1.184 ± 0.033
385	30.48 ± 1.08	12.06 ± 0.24	179.28 ± 7.11	0.841 ± 0.048	12.84 ± 1.01	0.018 ± 0.002	166.44 ± 7.01	0.823 ± 0.048
386	34.68 ± 1.34	11.88 ± 0.28	200.96 ± 9.01	0.961 ± 0.021	14.96 ± 1.01	0.019 ± 0.002	186.00 ± 8.93	0.942 ± 0.020
387	28.00 ± 1.08	11.34 ± 0.25	126.04 ± 8.27	0.493 ± 0.040	12.08 ± 0.98	0.016 ± 0.001	113.96 ± 8.15	0.477 ± 0.040
388	25.16 ± 0.05	10.80 ± 0.14	134.92 ± 7.36	0.564 ± 0.037	10.92 ± 0.80	0.011 ± 0.001	124.00 ± 7.17	0.553 ± 0.036
389	35.20 ± 0.85	11.58 ± 0.16	196.68 ± 14.11	0.792 ± 0.059	14.44 ± 1.10	0.017 ± 0.001	182.24 ± 13.29	0.775 ± 0.058
390	39.76 ± 1.14	11.70 ± 0.19	234.84 ± 7.54	0.921 ± 0.038	14.40 ± 1.21	0.018 ± 0.002	220.44 ± 7.35	0.903 ± 0.037
391	30.88 ± 0.86	12.42 ± 0.18	166.56 ± 11.88	0.716 ± 0.058	16.76 ± 1.54	0.017 ± 0.001	149.80 ± 10.95	0.700 ± 0.057
392	41.92 ± 1.01	14.18 ± 0.18	196.12 ± 10.03	1.060 ± 0.061	11.84 ± 1.32	0.018 ± 0.002	184.28 ± 9.51	1.043 ± 0.060
393	33.64 ± 0.61	12.90 ± 0.14	119.00 ± 5.76	0.647 ± 0.034	5.28 ± 0.50	0.007 ± 0.001	113.72 ± 5.60	0.640 ± 0.034
394	41.00 ± 0.87	13.18 ± 0.15	268.64 ± 5.57	1.217 ± 0.033	15.84 ± 0.89	0.020 ± 0.002	252.80 ± 5.46	1.197 ± 0.033
395	37.04 ± 1.08	12.70 ± 0.21	200.36 ± 7.61	1.020 ± 0.051	15.32 ± 1.20	0.022 ± 0.002	185.04 ± 7.47	0.998 ± 0.051
396	34.28 ± 0.79	12.92 ± 0.16	126.00 ± 7.79	0.635 ± 0.043	8.16 ± 0.89	0.013 ± 0.002	117.84 ± 7.66	0.622 ± 0.034
397	46.80 ± 1.29	12.62 ± 0.20	238.36 ± 6.25	1.427 ± 0.047	14.48 ± 1.25	0.020 ± 0.002	223.88 ± 6.18	1.406 ± 0.047
398	29.00 ± 0.96	11.78 ± 0.20	102.04 ± 10.09	0.517 ± 0.056	9.64 ± 0.76	0.013 ± 0.001	92.40 ± 9.52	0.505 ± 0.055
399	38.92 ± 1.25	11.64 ± 0.20	257.68 ± 7.23	1.175 ± 0.044	16.96 ± 1.09	0.022 ± 0.001	240.72 ± 7.22	1.153 ± 0.045
Mean	32.38 ± 1.00	11.74 ± 0.18	181.99 ± 7.05	0.813 ± 0.040	18.20 ± 2.71	0.023 ± 0.003	163.79 ± 7.28	0.790 ± 0.041

Table IV. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of *all seeds per cone* etc., for individual trees in the spruce sample plot at Höljes in the year 1948.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. seeds ≦1 mm. per cone	Weight of seeds ≦1 mm. per cone	No. seeds >1 mm. per cone	Weight of seeds >1 mm. per cone
1	14.48 ± 0.60	7.48 ± 0.14	133.64 ± 4.64	0.480 ± 0.028	24.08 ± 5.16	0.026 ± 0.002	109.56 ± 4.45	0.454 ± 0.028
2	16.44 ± 0.63	7.58 ± 0.11	149.44 ± 3.89	0.638 ± 0.026	10.32 ± 0.71	0.008 ± 0.001	139.12 ± 3.74	0.624 ± 0.026
3	16.24 ± 2.60	7.56 ± 0.18	125.92 ± 6.10	0.547 ± 0.036	10.04 ± 3.82	0.009 ± 0.001	115.88 ± 5.39	0.538 ± 0.036
4	11.60 ± 0.47	7.26 ± 0.15	110.16 ± 1.62	0.448 ± 0.032	12.56 ± 1.55	0.013 ± 0.0003	97.60 ± 1.41	0.435 ± 0.032
5	15.04 ± 0.61	8.18 ± 0.16	141.44 ± 1.83	0.529 ± 0.037	17.52 ± 1.61	0.016 ± 0.001	123.92 ± 1.83	0.513 ± 0.057
6	14.08 ± 0.58	7.58 ± 0.15	151.60 ± 1.83	0.531 ± 0.030	49.24 ± 2.48	0.061 ± 0.004	102.36 ± 2.44	0.471 ± 0.028
7	19.80 ± 0.74	7.34 ± 0.12	180.12 ± 3.81	0.774 ± 0.033	29.48 ± 4.80	0.034 ± 0.002	150.64 ± 3.41	0.740 ± 0.033
8	11.48 ± 0.30	6.96 ± 0.10	143.48 ± 3.81	0.417 ± 0.047	73.00 ± 2.62	0.053 ± 0.003	70.48 ± 6.18	0.364 ± 0.042
9	12.04 ± 0.38	6.70 ± 0.12	153.96 ± 4.01	0.514 ± 0.059	21.56 ± 0.52	0.016 ± 0.001	132.40 ± 3.60	0.498 ± 0.060
10	13.32 ± 0.51	7.66 ± 0.13	151.36 ± 3.94	0.543 ± 0.023	23.08 ± 1.14	0.022 ± 0.002	128.28 ± 3.96	0.521 ± 0.023
11	8.92 ± 0.40	6.68 ± 0.12	57.76 ± 5.39	0.139 ± 0.047	12.12 ± 3.79	0.008 ± 0.001	45.64 ± 4.82	0.131 ± 0.048
12	10.64 ± 0.49	6.38 ± 0.11	135.24 ± 6.02	0.436 ± 0.028	27.32 ± 4.99	0.026 ± 0.002	107.92 ± 5.35	0.410 ± 0.027
13	10.60 ± 0.36	7.02 ± 0.14	155.00 ± 6.05	0.302 ± 0.051	102.08 ± 4.04	0.095 ± 0.001	52.92 ± 2.47	0.207 ± 0.041
14	13.76 ± 0.58	7.82 ± 0.13	134.04 ± 5.60	0.398 ± 0.021	39.64 ± 4.92	0.038 ± 0.002	94.40 ± 5.56	0.360 ± 0.025
15	13.84 ± 0.50	8.74 ± 0.17	164.80 ± 4.75	0.609 ± 0.030	35.64 ± 5.78	0.035 ± 0.0004	129.16 ± 4.84	0.574 ± 0.030
16	16.08 ± 0.53	7.80 ± 0.09	155.48 ± 3.96	0.490 ± 0.021	18.24 ± 3.10	0.024 ± 0.001	137.24 ± 3.79	0.466 ± 0.021
17	9.88 ± 0.31	6.80 ± 0.11	103.28 ± 4.46	0.200 ± 0.031	42.28 ± 3.64	0.043 ± 0.001	61.00 ± 4.23	0.157 ± 0.035
18	9.68 ± 0.30	7.28 ± 0.11	103.64 ± 4.45	0.326 ± 0.052	19.80 ± 3.27	0.019 ± 0.001	83.84 ± 4.10	0.307 ± 0.051
19	11.84 ± 0.53	6.92 ± 0.15	122.16 ± 4.09	0.468 ± 0.034	13.56 ± 3.61	0.016 ± 0.001	108.60 ± 3.96	0.452 ± 0.034
20	11.52 ± 0.36	7.48 ± 0.12	105.88 ± 4.66	0.335 ± 0.058	34.52 ± 2.31	0.037 ± 0.002	71.36 ± 3.57	0.298 ± 0.055
21	18.32 ± 0.15	8.36 ± 0.14	212.76 ± 4.83	0.854 ± 0.034	26.48 ± 3.76	0.032 ± 0.001	186.28 ± 4.46	0.822 ± 0.033
22	17.72 ± 3.00	8.50 ± 0.20	174.56 ± 5.45	0.785 ± 0.039	21.08 ± 4.53	0.024 ± 0.001	153.48 ± 4.90	0.761 ± 0.038
23	11.76 ± 0.31	7.02 ± 0.11	178.88 ± 2.16	0.548 ± 0.028	25.68 ± 4.92	0.028 ± 0.002	153.20 ± 5.82	0.520 ± 0.027
24	10.24 ± 0.39	6.82 ± 0.14	163.12 ± 4.81	0.521 ± 0.025	21.76 ± 4.47	0.023 ± 0.001	141.36 ± 4.47	0.498 ± 0.025
25	10.40 ± 0.31	6.78 ± 0.12	154.00 ± 4.42	0.506 ± 0.024	16.28 ± 3.13	0.028 ± 0.001	137.72 ± 3.97	0.479 ± 0.024
26	7.72 ± 0.36	6.26 ± 0.13	158.20 ± 0.50	0.372 ± 0.025	20.60 ± 3.46	0.175 ± 0.004	137.60 ± 5.52	0.354 ± 0.025
27	20.84 ± 3.48	8.32 ± 0.18	194.84 ± 2.14	0.722 ± 0.049	35.40 ± 5.12	0.034 ± 0.001	159.44 ± 2.38	0.688 ± 0.049
28	17.12 ± 0.55	9.56 ± 0.13	101.68 ± 6.19	0.425 ± 0.037	15.52 ± 3.99	0.015 ± 0.001	86.16 ± 2.17	0.410 ± 0.038
29	19.36 ± 0.43	9.46 ± 0.11	120.88 ± 4.02	0.534 ± 0.002	14.00 ± 0.16	0.015 ± 0.001	106.88 ± 4.18	0.518 ± 0.026
30	19.44 ± 2.69	8.98 ± 0.20	186.32 ± 4.44	0.809 ± 0.038	22.88 ± 4.97	0.021 ± 0.002	163.44 ± 4.02	0.788 ± 0.038
31	17.56 ± 2.09	8.80 ± 0.15	138.72 ± 4.90	0.612 ± 0.028	23.96 ± 5.04	0.030 ± 0.003	114.76 ± 5.00	0.582 ± 0.028
32	6.80 ± 0.30	6.08 ± 0.12	95.68 ± 5.32	0.270 ± 0.061	15.36 ± 3.46	0.011 ± 0.001	80.32 ± 4.97	0.259 ± 0.060
33	11.48 ± 0.44	7.50 ± 0.13	90.96 ± 5.57	0.251 ± 0.023	21.24 ± 4.40	0.016 ± 0.001	69.72 ± 4.81	0.235 ± 0.022
34	10.88 ± 0.30	6.72 ± 0.10	125.04 ± 5.36	0.342 ± 0.020	10.08 ± 2.81	0.007 ± 0.002	114.96 ± 5.35	0.336 ± 0.020
35	19.24 ± 2.90	8.66 ± 0.14	149.96 ± 2.84	0.516 ± 0.039	19.36 ± 3.03	0.020 ± 0.001	130.60 ± 2.77	0.496 ± 0.039
36	15.36 ± 0.45	7.72 ± 0.13	118.52 ± 3.97	0.318 ± 0.044	17.48 ± 3.47	0.016 ± 0.001	101.04 ± 3.40	0.302 ± 0.042
37	19.48 ± 2.85	9.08 ± 0.20	205.56 ± 2.20	0.803 ± 0.003	28.68 ± 4.94	0.036 ± 0.003	176.88 ± 5.84	0.767 ± 0.040
38	12.72 ± 0.02	7.90 ± 0.10	126.44 ± 2.37	0.401 ± 0.013	35.20 ± 3.83	0.038 ± 0.002	91.24 ± 6.26	0.363 ± 0.032
39	23.60 ± 2.21	9.24 ± 0.21	173.28 ± 3.80	0.565 ± 0.063	43.24 ± 3.31	0.048 ± 0.004	130.04 ± 6.17	0.516 ± 0.059
40	18.84 ± 2.46	7.78 ± 0.14	177.48 ± 5.59	0.497 ± 0.023	60.48 ± 3.18	0.052 ± 0.003	117.00 ± 4.40	0.445 ± 0.022
41	18.60 ± 0.62	8.26 ± 0.16	193.84 ± 4.41	0.680 ± 0.029	27.04 ± 4.97	0.025 ± 0.002	166.80 ± 4.21	0.655 ± 0.029
42	22.84 ± 2.49	9.24 ± 0.28	187.16 ± 5.20	0.708 ± 0.041	28.52 ± 5.81	0.029 ± 0.005	158.64 ± 2.73	0.679 ± 0.043
43	13.56 ± 0.33	7.38 ± 0.10	164.28 ± 3.29	0.555 ± 0.052	14.44 ± 0.54	0.013 ± 0.001	149.84 ± 3.39	0.542 ± 0.052
44	18.72 ± 0.50	8.20 ± 0.10	131.00 ± 4.82	0.440 ± 0.024	20.96 ± 3.71	0.015 ± 0.001	110.04 ± 4.81	0.425 ± 0.024
45	17.96 ± 0.58	8.44 ± 0.12	172.08 ± 4.77	0.544 ± 0.028	17.12 ± 4.90	0.014 ± 0.001	154.96 ± 5.02	0.530 ± 0.036
46	11.76 ± 0.45	8.38 ± 0.13	129.60 ± 5.04	0.458 ± 0.025	15.56 ± 3.83	0.018 ± 0.002	114.04 ± 4.82	0.440 ± 0.025
47	18.36 ± 2.40	8.94 ± 0.12	206.76 ± 5.03	0.572 ± 0.023	32.00 ± 5.71	0.032 ± 0.006	174.76 ± 23.11	0.539 ± 0.045
48	14.96 ± 2.65	7.74 ± 0.16	163.80 ± 8.37	0.499 ± 0.047	47.92 ± 3.43	0.045 ± 0.003	115.88 ± 9.28	0.454 ± 0.048
49	12.36 ± 0.35	7.56 ± 0.10	139.40 ± 3.28	0.504 ± 0.023	20.52 ± 4.60	0.019 ± 0.001	118.88 ± 3.79	0.485 ± 0.023
50	19.56 ± 0.58	9.18 ± 0.15	205.44 ± 6.94	0.839 ± 0.042	23.84 ± 3.95	0.035 ± 0.001	181.60 ± 6.25	0.804 ± 0.041
Mean	14.78 ± 0.57	7.80 ± 0.13	148.37 ± 4.84	0.511 ± 0.023	27.18 ± 2.38	0.030 ± 0.004	121.20 ± 4.70	0.484 ± 0.023

Table V. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., for individual trees in the spruce sample plot at Skalstugan in the year 1948.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. seeds ≦1 mm. per cone	Weight of seeds ≦1 mm. per cone	No. seeds >1 mm. per cone	Weight of seeds >1 mm. per cone
1	8.16 ± 0.29	5.22 ± 0.10	97.96 ± 4.63	0.226 ± 0.017	25.24 ± 2.05	0.019 ± 0.001	72.72 ± 4.85	0.207 ± 0.017
2	8.48 ± 0.30	6.72 ± 0.14	132.52 ± 7.69	0.297 ± 0.021	26.52 ± 2.37	0.025 ± 0.002	106.00 ± 6.07	0.271 ± 0.020
3	10.40 ± 0.37	7.02 ± 0.11	139.60 ± 5.02	0.330 ± 0.018	8.52 ± 0.69	0.006 ± 0.001	131.08 ± 4.86	0.324 ± 0.002
4	10.92 ± 0.46	6.14 ± 0.16	172.68 ± 8.81	0.353 ± 0.029	35.20 ± 4.16	0.024 ± 0.003	138.68 ± 6.43	0.329 ± 0.028
5	12.08 ± 0.45	6.98 ± 0.15	151.96 ± 4.64	0.377 ± 0.018	36.72 ± 2.30	0.023 ± 0.001	115.24 ± 4.18	0.354 ± 0.018
6	8.96 ± 0.29	6.24 ± 0.13	133.28 ± 5.16	0.235 ± 0.014	42.48 ± 4.49	0.036 ± 0.003	90.80 ± 5.80	0.199 ± 0.015
7	9.36 ± 0.51	5.60 ± 0.14	135.04 ± 6.29	0.315 ± 0.023	18.76 ± 1.84	0.015 ± 0.002	116.28 ± 5.49	0.299 ± 0.022
8	8.64 ± 0.35	6.10 ± 0.12	144.04 ± 6.84	0.234 ± 0.016	42.68 ± 2.00	0.027 ± 0.001	101.36 ± 6.51	0.207 ± 0.016
9	5.68 ± 0.38	5.60 ± 0.18	101.68 ± 7.45	0.171 ± 0.017	18.48 ± 1.79	0.015 ± 0.002	41.92 ± 6.33	0.156 ± 0.017
10	7.88 ± 0.32	5.74 ± 0.09	95.60 ± 3.22	0.207 ± 0.011	22.24 ± 1.93	0.014 ± 0.001	73.36 ± 3.21	0.193 ± 0.011
11	9.00 ± 0.47	5.52 ± 0.15	108.20 ± 6.35	0.262 ± 0.025	20.56 ± 1.62	0.014 ± 0.001	87.64 ± 5.54	0.247 ± 0.024
12	13.36 ± 0.44	7.88 ± 0.16	163.56 ± 5.04	0.491 ± 0.021	18.04 ± 1.48	0.013 ± 0.001	145.52 ± 4.42	0.478 ± 0.020
13	7.84 ± 0.29	6.26 ± 0.10	89.64 ± 6.62	0.157 ± 0.015	14.64 ± 1.45	0.014 ± 0.001	75.00 ± 5.43	0.144 ± 0.014
14	5.24 ± 0.31	4.46 ± 0.14	97.36 ± 6.36	0.124 ± 0.011	31.56 ± 2.84	0.017 ± 0.005	65.80 ± 5.43	0.107 ± 0.011
15	9.28 ± 0.28	6.42 ± 0.11	149.96 ± 7.54	0.407 ± 0.028	15.28 ± 1.20	0.012 ± 0.001	134.68 ± 7.20	0.396 ± 0.028
16	8.08 ± 0.47	5.50 ± 0.14	95.36 ± 5.92	0.192 ± 0.016	19.28 ± 1.61	0.015 ± 0.001	76.08 ± 5.05	0.177 ± 0.013
17	10.88 ± 0.38	6.36 ± 0.14	156.72 ± 6.02	0.255 ± 0.013	18.96 ± 1.45	0.010 ± 0.001	137.76 ± 5.28	0.246 ± 0.013
18	6.20 ± 0.20	5.92 ± 0.19	54.08 ± 4.00	0.078 ± 0.008	10.36 ± 1.15	0.006 ± 0.002	43.72 ± 3.39	0.072 ± 0.007
19	6.68 ± 0.43	5.82 ± 0.17	81.64 ± 8.39	0.164 ± 0.024	11.48 ± 1.81	0.006 ± 0.001	70.16 ± 6.84	0.157 ± 0.024
20	10.52 ± 0.37	6.96 ± 0.11	124.48 ± 7.46	0.345 ± 0.028	12.40 ± 1.16	0.010 ± 0.001	112.08 ± 6.87	0.335 ± 0.026
21	9.00 ± 0.18	6.30 ± 0.06	125.56 ± 4.75	0.256 ± 0.012	20.92 ± 1.41	0.014 ± 0.001	104.64 ± 3.91	0.242 ± 0.012
22	9.80 ± 0.36	6.68 ± 0.12	150.56 ± 4.62	0.274 ± 0.012	48.04 ± 3.74	0.032 ± 0.003	102.52 ± 2.78	0.243 ± 0.010
23	5.56 ± 0.26	5.08 ± 0.12	71.56 ± 5.46	0.120 ± 0.013	6.48 ± 0.69	0.004 ± 0.001	65.08 ± 5.12	0.117 ± 0.013
24	9.76 ± 0.47	6.44 ± 0.17	145.92 ± 5.21	0.298 ± 0.019	19.88 ± 1.55	0.013 ± 0.001	126.04 ± 5.29	0.285 ± 0.019
25	8.28 ± 0.27	6.36 ± 0.12	108.80 ± 6.64	0.177 ± 0.013	14.48 ± 1.42	0.009 ± 0.001	94.32 ± 6.24	0.167 ± 0.013
26	14.08 ± 0.52	7.92 ± 0.17	118.16 ± 6.55	0.314 ± 0.025	14.76 ± 1.26	0.011 ± 0.001	103.40 ± 6.02	0.303 ± 0.026
27	12.08 ± 0.50	6.86 ± 0.11	132.44 ± 8.51	0.356 ± 0.030	17.36 ± 1.65	0.016 ± 0.002	115.08 ± 7.25	0.340 ± 0.029
28	5.44 ± 0.28	5.02 ± 0.15	100.00 ± 3.72	0.185 ± 0.014	12.12 ± 1.37	0.007 ± 0.001	87.88 ± 3.59	0.178 ± 0.014
29	12.88 ± 0.50	7.26 ± 0.15	164.84 ± 6.23	0.399 ± 0.025	23.24 ± 1.31	0.021 ± 0.001	141.60 ± 5.85	0.378 ± 0.024
30	10.68 ± 0.35	7.20 ± 0.13	71.40 ± 3.98	0.208 ± 0.013	10.12 ± 0.90	0.010 ± 0.001	61.28 ± 3.37	0.198 ± 0.013
31	12.76 ± 0.27	7.34 ± 0.11	122.44 ± 6.19	0.411 ± 0.025	4.08 ± 0.66	0.003 ± 0.0004	118.36 ± 5.91	0.408 ± 0.025
32	9.68 ± 0.29	6.38 ± 0.10	127.36 ± 4.97	0.309 ± 0.018	22.60 ± 1.28	0.021 ± 0.001	104.76 ± 4.80	0.289 ± 0.056
33	8.00 ± 0.19	6.36 ± 0.10	115.24 ± 3.78	0.282 ± 0.012	9.24 ± 0.89	0.006 ± 0.001	106.00 ± 3.70	0.275 ± 0.012
34	7.40 ± 0.16	5.70 ± 0.09	119.12 ± 5.17	0.215 ± 0.011	13.80 ± 1.44	0.008 ± 0.001	105.32 ± 4.25	0.208 ± 0.011
35	8.56 ± 0.28	6.16 ± 0.13	117.64 ± 5.56	0.152 ± 0.010	20.24 ± 1.79	0.011 ± 0.001	97.40 ± 4.62	0.141 ± 0.009
36	8.72 ± 0.29	6.42 ± 0.13	121.84 ± 6.39	0.301 ± 0.019	8.04 ± 0.88	0.006 ± 0.001	113.80 ± 5.99	0.295 ± 0.018
37	6.92 ± 0.22	5.78 ± 0.12	88.68 ± 3.58	0.190 ± 0.009	5.72 ± 0.64	0.003 ± 0.0004	82.96 ± 5.29	0.187 ± 0.009
38	7.92 ± 0.27	6.20 ± 0.09	87.40 ± 5.60	0.245 ± 0.020	8.08 ± 0.71	0.006 ± 0.002	79.32 ± 5.16	0.239 ± 0.019
39	9.32 ± 0.36	6.16 ± 0.10	79.80 ± 5.37	0.175 ± 0.016	6.52 ± 0.76	0.003 ± 0.0004	73.28 ± 5.09	0.172 ± 0.016
40	10.12 ± 0.51	6.06 ± 0.15	102.72 ± 8.22	0.203 ± 0.023	4.80 ± 0.61	0.003 ± 0.0004	97.92 ± 5.49	0.200 ± 0.023
41	7.24 ± 0.25	5.88 ± 0.10	87.64 ± 4.77	0.142 ± 0.012	12.28 ± 1.03	0.011 ± 0.001	75.36 ± 4.67	0.132 ± 0.012
42	8.52 ± 0.41	6.04 ± 0.16	85.28 ± 4.19	0.249 ± 0.019	16.32 ± 1.29	0.017 ± 0.001	68.96 ± 3.49	0.232 ± 0.018
43	11.76 ± 0.35	7.32 ± 0.11	83.76 ± 4.24	0.250 ± 0.019	8.12 ± 0.60	0.009 ± 0.001	75.64 ± 4.23	0.242 ± 0.019
44	6.96 ± 0.27	5.54 ± 0.11	63.72 ± 2.92	0.138 ± 0.010	5.40 ± 0.54	0.004 ± 0.0004	58.32 ± 2.78	0.134 ± 0.009
45	8.08 ± 0.27	6.24 ± 0.09	80.00 ± 3.49	0.147 ± 0.009	11.04 ± 0.87	0.009 ± 0.001	68.96 ± 3.03	0.138 ± 0.008
46	6.68 ± 0.21	5.58 ± 0.09	65.72 ± 3.12	0.112 ± 0.008	8.40 ± 1.18	0.005 ± 0.0006	57.32 ± 3.00	0.107 ± 0.008
47	8.28 ± 0.36	6.64 ± 0.12	76.44 ± 4.73	0.199 ± 0.020	8.44 ± 0.73	0.008 ± 0.001	68.00 ± 4.63	0.191 ± 0.019
48	5.12 ± 0.31	4.88 ± 0.12	59.84 ± 5.54	0.108 ± 0.015	4.76 ± 1.03	0.003 ± 0.001	55.08 ± 5.28	0.104 ± 0.014
49	4.72 ± 0.20	4.60 ± 0.09	62.88 ± 4.25	0.094 ± 0.009	14.44 ± 1.18	0.010 ± 0.001	48.44 ± 3.65	0.083 ± 0.009
50	8.08 ± 0.30	5.94 ± 0.13	101.28 ± 5.88	0.220 ± 0.017	9.92 ± 1.20	0.006 ± 0.001	91.36 ± 5.37	0.214 ± 0.018
Mean	8.80 ± 0.31	6.18 ± 0.11	109.27 ± 4.37	0.239 ± 0.013	16.78 ± 1.47	0.012 ± 0.001	91.69 ± 3.83	0.227 ± 0.013

Table VI. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., *for individual trees in the spruce sample plot at Stjernarp in the year 1954.*

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. of seeds				Weight of seeds in gram			
					≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.	≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.
1	16.900	10.94	271.93	1.328	12.07	10.13	249.00	0.73	0.015	0.022	1.286	0.004
2	12.727	10.96	230.80	1.194	15.13	6.53	203.60	5.53	0.017	0.014	1.125	0.039
3	17.286	11.07	307.87	0.826	184.20	12.33	110.27	1.07	0.184	0.043	0.592	0.007
4	20.715	11.21	277.80	1.362	51.73	3.00	190.53	32.53	0.058	0.006	1.075	0.222
5	16.192	11.18	263.07	1.326	26.20	6.73	221.80	8.33	0.027	0.021	1.221	0.058
6	15.207	9.72	246.07	1.036	39.73	5.60	180.07	20.67	0.038	0.012	0.870	0.116
7	21.397	11.43	238.60	1.225	22.73	16.40	199.00	0.47	0.022	0.056	1.145	0.002
8	31.578	13.99	302.87	1.703	30.20	2.80	117.13	152.73	0.033	0.007	0.663	1.001
9	17.366	10.08	279.73	1.415	30.06	8.53	235.80	5.33	0.028	0.018	1.340	0.030
11	16.386	10.29	271.87	0.872	34.73	53.67	179.93	3.53	0.019	0.103	0.732	0.019
27	16.980	10.86	309.20	1.316	37.13	69.27	202.73	0.07	0.033	0.250	1.033	0.0004
29	18.089	11.56	273.13	1.119	17.87	54.07	200.73	0.47	0.019	0.156	0.943	0.002
40	13.052	9.09	278.40	1.081	46.80	16.67	213.27	1.67	0.044	0.043	0.988	0.008
51	12.999	10.03	276.07	0.980	21.07	19.20	235.53	0.27	0.019	0.044	0.916	0.002
55	13.580	9.93	272.87	0.806	37.60	91.80	143.47	0.00	0.035	0.264	0.507	0.000
56	13.307	9.73	271.80	0.703	142.20	2.00	121.53	6.07	0.142	0.005	0.527	0.029
57	13.650	10.49	293.40	1.134	36.27	161.20	95.73	0.20	0.040	0.644	0.449	0.001
59	27.590	13.55	277.80	1.721	39.13	4.67	187.73	46.27	0.051	0.011	1.290	0.371
60	12.981	10.37	303.47	1.016	44.33	48.73	210.20	0.20	0.043	0.151	0.821	0.001
61	11.321	9.09	250.67	1.051	35.93	20.07	194.07	0.60	0.031	0.069	0.950	0.003
63	11.561	8.61	259.74	0.715	65.53	85.53	108.00	0.67	0.080	0.215	0.418	0.003
64	19.666	11.13	290.87	0.924	74.13	103.33	113.40	0.00	0.091	0.366	0.467	0.000
65	12.355	10.49	307.80	0.754	84.93	130.20	92.20	0.47	0.071	0.355	0.327	0.002
66	9.853	7.71	251.13	0.524	95.20	46.27	109.47	0.20	0.070	0.113	0.340	0.001
67	15.059	10.39	256.87	0.753	21.13	53.47	182.20	0.07	0.016	0.124	0.613	0.0002
68	12.980	9.66	301.60	1.050	38.80	53.27	209.06	0.47	0.030	0.154	0.865	0.002
69	11.996	9.21	244.13	0.978	13.67	67.20	163.27	0.00	0.010	0.234	0.736	0.000
70	11.964	8.45	260.93	1.025	30.67	74.07	156.13	0.07	0.026	0.268	0.731	0.0004
71	18.098	11.09	290.20	1.065	44.07	19.87	225.60	0.67	0.043	0.062	0.958	0.002
72	7.658	8.65	265.73	0.875	22.20	53.93	189.60	0.00	0.016	0.159	0.700	0.000
73	17.058	11.37	325.33	0.843	159.20	32.93	132.47	0.73	0.150	0.082	0.607	0.004
75	19.839	10.88	297.33	0.882	111.47	12.07	173.27	0.53	0.128	0.025	0.728	0.002
76	12.678	9.69	292.07	0.949	39.73	69.33	183.00	0.00	0.040	0.173	0.736	0.000
77	8.788	8.71	234.87	0.781	30.93	43.33	160.33	0.27	0.021	0.114	0.645	0.001
78	16.842	12.30	310.27	1.436	30.20	34.87	244.87	0.33	0.034	0.143	1.258	0.002
79	12.800	9.21	277.13	1.134	52.40	24.13	200.60	0.00	0.058	0.083	0.994	0.000
80	10.740	9.09	232.13	0.719	58.40	38.00	135.33	0.40	0.047	0.099	0.570	0.002
81	17.958	10.70	259.00	1.448	25.20	3.53	222.53	7.73	0.035	0.019	1.336	0.060
83	15.172	10.56	331.47	1.020	77.67	136.07	117.40	0.33	0.080	0.452	0.487	0.001
84	14.289	10.60	313.60	1.002	40.27	56.13	216.80	0.40	0.035	0.141	0.825	0.002
85	13.025	9.18	256.87	0.618	51.47	48.40	156.73	0.27	0.053	0.099	0.465	0.001
86	14.001	9.25	247.80	0.889	33.27	8.40	131.60	74.53	0.042	0.014	0.436	0.398
87	15.014	9.86	265.93	0.932	47.20	60.67	158.07	0.00	0.083	0.195	0.654	0.000
88	20.727	11.24	307.87	1.530	40.60	9.53	255.53	2.20	0.037	0.028	1.453	0.012
89	14.734	9.54	316.27	0.876	65.40	28.13	221.87	0.87	0.058	0.065	0.750	0.003
90	12.989	9.51	278.80	0.885	47.73	48.60	181.93	0.53	0.044	0.117	0.725	0.003
92	13.383	8.76	282.87	0.853	31.20	176.80	74.87	0.00	0.020	0.555	0.278	0.000
93	11.476	9.51	273.20	1.002	52.27	6.53	212.47	1.93	0.057	0.017	0.921	0.008
94	11.679	10.26	236.93	0.704	68.27	139.93	28.73	0.00	0.055	0.524	0.125	0.000
95	12.944	10.35	277.60	0.994	46.07	38.33	192.93	0.27	0.031	0.109	0.853	0.001
Mean	15.133	10.23	276.88	1.027	50.09	46.33	172.85	7.61	0.049	0.141	0.789	0.048

Table VII. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., for individual trees in the spruce sample plot at Gunnarskog in the year 1954.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. of seeds				Weight of seeds in gram			
					≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.	≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.
178	17.576	9.04	227.47	1.115	8.40	24.33	144.13	50.60	0.006	0.052	0.739	0.318
182	10.163	8.55	240.93	0.908	9.53	77.80	153.40	0.20	0.007	0.222	0.678	0.001
183	9.960	8.66	248.67	0.972	15.20	89.40	144.07	0.00	0.013	0.304	0.655	0.000
189	10.718	8.41	234.20	0.464	50.13	113.73	68.07	2.27	0.039	0.140	0.271	0.013
301	14.398	9.25	283.53	1.006	23.60	65.60	194.33	0.00	0.018	0.158	0.830	0.000
302	14.711	9.74	256.93	0.865	13.87	101.73	141.07	0.27	0.010	0.300	0.553	0.002
303	18.038	10.62	317.13	1.353	56.27	32.40	228.13	0.33	0.053	0.099	1.200	0.001
304	20.465	11.13	294.13	1.433	34.07	13.93	244.07	2.07	0.046	0.038	1.337	0.013
305	13.826	10.74	280.13	1.035	9.00	32.67	227.87	10.60	0.007	0.055	0.912	0.061
306	12.730	10.02	273.60	1.090	8.27	73.07	192.27	0.00	0.007	0.216	0.866	0.000
307	16.674	10.81	206.53	0.929	19.40	64.87	122.07	0.20	0.021	0.262	0.645	0.001
308	18.344	10.95	276.20	1.543	3.93	30.27	240.20	1.80	0.003	0.082	1.447	0.011
309	14.089	9.73	280.73	0.933	25.73	190.80	64.13	0.07	0.020	0.675	0.238	0.002
310	17.467	10.84	320.80	1.027	29.67	159.33	131.67	0.13	0.029	0.302	0.695	0.001
311	12.558	8.65	242.33	1.023	9.93	67.87	164.53	0.00	0.008	0.204	0.811	0.000
312	12.211	8.32	286.60	1.164	16.27	51.47	218.13	0.73	0.012	0.122	1.026	0.004
313	13.107	8.86	242.33	1.081	8.00	46.60	187.13	0.60	0.007	0.114	0.956	0.004
314	9.888	8.62	272.07	0.949	14.40	170.13	87.53	0.00	0.013	0.540	0.396	0.000
315	19.094	11.49	243.80	1.287	5.60	44.87	193.13	0.20	0.007	0.162	1.117	0.001
317	14.523	10.09	344.80	1.233	54.60	130.47	159.73	0.00	0.045	0.442	0.746	0.000
318	16.137	10.76	293.73	1.424	5.47	38.13	249.93	0.20	0.005	0.133	1.285	0.001
319	14.338	9.88	260.60	1.509	19.80	8.60	203.00	29.20	0.020	0.023	1.247	0.220
320	14.224	8.80	263.20	1.198	4.53	57.53	200.53	0.60	0.004	0.204	0.986	0.004
321	9.886	9.00	269.53	0.897	30.40	61.00	178.13	0.00	0.028	0.174	0.695	0.000
322	13.290	10.20	248.80	1.347	11.20	41.60	194.47	1.53	0.008	0.139	1.188	0.011
323	10.957	8.62	250.07	0.923	10.87	90.40	148.80	0.00	0.008	0.279	0.635	0.000
324	16.284	10.04	272.27	1.111	29.00	23.00	219.40	0.87	0.041	0.062	1.003	0.005
325	12.789	9.02	222.60	0.970	8.27	23.93	190.33	0.07	0.006	0.066	0.898	0.0002
326	19.596	11.64	278.73	1.422	5.00	30.00	242.07	1.67	0.005	0.068	1.340	0.010
327	12.654	9.19	206.20	0.997	15.33	40.67	149.80	0.40	0.012	0.156	0.826	0.003
328	16.985	10.65	300.87	1.419	12.60	103.73	184.53	0.00	0.013	0.410	0.996	0.000
329	9.515	8.40	216.47	0.835	8.00	111.87	96.47	0.13	0.007	0.392	0.435	0.001
330	9.287	8.38	238.20	0.494	26.40	165.87	45.93	0.00	0.019	0.352	0.123	0.000
331	17.317	10.74	243.40	1.206	9.07	32.60	201.73	0.00	0.007	0.091	1.108	0.000
332	13.547	9.83	271.07	1.128	7.33	151.60	112.13	0.00	0.006	0.574	0.547	0.000
333	14.133	9.11	211.93	0.787	12.73	70.07	129.13	0.00	0.011	0.164	0.612	0.000
334	8.391	8.09	263.13	0.692	51.27	99.07	112.80	0.00	0.027	0.261	0.404	0.000
335	14.111	10.05	299.53	1.393	39.07	22.27	235.07	3.13	0.052	0.082	1.239	0.019
336	17.094	10.24	309.47	1.349	21.87	72.27	215.07	0.27	0.020	0.224	1.104	0.001
337	14.647	9.33	242.93	0.963	9.87	67.00	166.00	0.07	0.007	0.203	0.753	0.0004
338	11.332	8.67	204.80	0.893	16.13	95.00	93.67	0.00	0.014	0.391	0.489	0.000
339	11.521	8.81	194.13	0.937	9.67	28.60	155.80	0.07	0.005	0.075	0.857	0.0003
340	12.025	9.12	244.00	0.864	12.67	176.87	54.47	0.00	0.011	0.621	0.232	0.000
341	16.863	10.17	303.60	1.397	27.53	38.13	237.60	0.33	0.042	0.150	1.204	0.002
342	8.646	8.24	246.07	0.856	17.73	190.47	37.87	0.00	0.014	0.681	0.161	0.000
343	12.538	9.06	247.73	0.981	16.67	169.93	61.13	0.00	0.015	0.666	0.300	0.000
344	10.139	8.19	237.20	0.859	11.60	92.93	132.67	0.00	0.009	0.271	0.580	0.000
345	15.539	9.91	286.53	1.585	6.20	24.93	128.20	127.20	0.004	0.039	0.672	0.870
346	14.563	9.53	244.07	1.007	14.87	70.87	158.33	0.00	0.011	0.225	0.772	0.000
347	12.791	9.51	279.20	0.851	7.40	56.87	214.93	0.00	0.006	0.108	0.737	0.000
Mean	13.834	9.55	260.46	1.074	17.89	76.74	161.11	4.72	0.016	0.235	0.791	0.032

Table VIII. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., for individual trees in the spruce sample plot at Skalstugan in the year 1954.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. of seeds				Weight of seeds in gram			
					≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.	≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.
2	7.879	7.25	185.67	0.459	5.33	56.07	124.13	0.13	0.004	0.109	0.346	0.001
3	9.984	7.65	238.00	0.690	45.33	78.67	113.67	0.33	0.032	0.225	0.432	0.001
4	12.814	8.63	200.40	0.708	11.33	37.73	143.67	7.67	0.008	0.073	0.588	0.040
7	10.493	8.17	214.73	0.708	19.20	38.13	156.20	1.20	0.012	0.083	0.608	0.005
9	9.713	8.30	205.67	0.525	14.27	58.60	132.80	0.00	0.009	0.133	0.384	0.000
10	8.726	7.45	192.80	0.614	16.87	50.47	125.40	0.07	0.013	0.117	0.484	0.000
11	7.292	7.79	185.47	0.457	19.33	92.40	73.73	0.00	0.011	0.223	0.224	0.000
12	7.229	7.93	172.93	0.390	21.00	68.20	83.67	0.07	0.010	0.144	0.235	0.000
13	10.097	7.10	187.33	0.685	10.73	24.80	149.53	2.27	0.008	0.057	0.610	0.011
15	7.757	7.26	155.87	0.332	67.47	19.07	67.87	1.47	0.039	0.035	0.252	0.007
16	9.223	7.86	171.47	0.550	8.93	30.00	130.47	2.07	0.005	0.057	0.479	0.010
18	12.637	9.25	201.00	0.657	12.07	64.07	124.87	0.00	0.009	0.176	0.472	0.000
19	13.160	9.39	218.13	0.712	9.20	67.33	141.60	0.00	0.006	0.185	0.521	0.000
23	7.250	6.18	121.73	0.271	9.33	40.47	71.60	0.33	0.007	0.077	0.186	0.001
24	7.744	6.22	165.80	0.390	14.27	61.73	89.60	0.20	0.009	0.135	0.245	0.001
25	7.874	6.39	162.07	0.375	17.00	51.73	93.27	0.07	0.012	0.109	0.254	0.000
26	8.136	6.39	186.40	0.469	18.20	59.20	109.00	0.00	0.011	0.124	0.333	0.000
27	7.065	8.10	215.47	0.482	25.80	155.87	33.73	0.07	0.018	0.370	0.094	0.000
28	6.633	7.48	171.27	0.291	81.27	44.67	45.33	0.00	0.054	0.103	0.135	0.000
29	7.666	7.95	175.40	0.474	11.33	73.40	90.67	0.00	0.010	0.187	0.277	0.000
30	5.366	6.79	159.07	0.375	23.20	89.47	46.40	0.00	0.016	0.223	0.137	0.000
31	7.252	7.69	185.60	0.493	14.07	77.33	94.20	0.00	0.012	0.195	0.287	0.000
33	10.378	7.51	190.00	0.539	39.60	35.00	90.87	24.53	0.025	0.039	0.356	0.119
35	8.252	7.29	206.67	0.727	19.80	46.07	140.73	0.07	0.010	0.128	0.589	0.000
42	8.269	8.10	209.67	0.615	9.73	55.80	144.13	0.00	0.008	0.129	0.478	0.000
44	9.540	7.18	200.80	0.592	20.00	40.00	140.73	0.07	0.012	0.089	0.490	0.000
45	9.044	7.53	187.20	0.413	31.40	81.07	74.67	0.07	0.026	0.137	0.250	0.000
47	10.353	7.81	221.00	0.749	5.87	47.80	167.27	0.07	0.004	0.128	0.616	0.001
49	10.083	7.62	233.27	0.830	6.87	59.07	167.33	0.00	0.005	0.173	0.653	0.000
50	7.922	7.69	177.27	0.472	16.47	37.13	123.67	0.00	0.010	0.079	0.383	0.000
51	8.841	7.23	196.60	0.601	28.13	69.20	99.13	0.13	0.019	0.203	0.379	0.001
52	6.233	6.34	190.80	0.508	21.47	114.87	54.47	0.00	0.016	0.316	0.177	0.000
53	9.988	8.02	227.60	0.791	23.60	55.53	148.40	0.07	0.017	0.162	0.612	0.000
54	8.836	7.79	187.80	0.523	8.87	30.73	147.27	0.93	0.006	0.059	0.455	0.003
55	7.563	7.09	185.87	0.494	16.40	52.27	117.13	0.07	0.010	0.109	0.375	0.000
56	10.581	7.19	183.13	0.595	10.47	36.80	133.60	2.27	0.009	0.079	0.499	0.008
57	6.771	7.49	139.13	0.385	12.93	28.07	98.13	0.00	0.008	0.046	0.331	0.000
58	6.342	6.29	199.53	0.536	28.53	92.33	78.67	0.00	0.016	0.252	0.268	0.000
59	9.108	6.81	181.40	0.631	13.80	51.80	115.80	0.00	0.010	0.139	0.482	0.000
60	10.286	8.69	242.67	0.736	14.47	101.20	127.00	0.00	0.010	0.271	0.455	0.000
61	10.771	8.59	256.27	0.753	22.53	110.33	123.40	0.00	0.016	0.296	0.441	0.000
62	14.244	9.25	239.47	1.087	5.20	21.87	184.93	27.47	0.005	0.046	0.884	0.152
63	8.583	7.77	187.60	0.692	7.53	34.60	145.47	0.00	0.005	0.085	0.602	0.000
64	5.379	6.31	162.33	0.351	39.00	83.33	40.00	0.00	0.018	0.196	0.137	0.000
65	6.058	6.78	176.33	0.347	47.67	81.00	47.67	0.00	0.023	0.178	0.146	0.000
66	4.362	6.25	151.13	0.276	51.27	77.07	22.80	0.00	0.022	0.187	0.067	0.000
67	10.115	7.90	184.60	0.631	13.13	37.60	128.87	5.00	0.008	0.061	0.538	0.024
68	8.858	7.32	163.20	0.468	7.00	37.00	115.33	3.87	0.005	0.059	0.388	0.017
69	10.564	8.95	214.47	0.553	16.27	88.73	109.40	0.07	0.011	0.208	0.333	0.000
70	9.971	8.65	213.80	0.563	17.53	95.13	101.07	0.07	0.013	0.220	0.331	0.000
Mean	8.786	7.57	191.64	0.551	20.62	60.82	108.59	1.61	0.013	0.144	0.386	0.008

Table IX. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., for individual trees in the spruce sample plot at Kvikkjokk in the year 1954.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. of seeds				Weight of seeds in gram			
					≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.	≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.
1	9.013	7.74	162.13	0.567	18.00	33.73	110.40	0.00	0.010	0.074	0.483	0.000
2	4.355	6.29	177.47	0.406	17.40	63.40	96.67	0.00	0.009	0.131	0.265	0.000
3	6.930	6.91	204.20	0.425	76.33	21.27	106.20	0.40	0.040	0.040	0.343	0.002
4	5.103	6.39	150.67	0.372	13.67	73.00	64.00	0.00	0.009	0.175	0.188	0.000
5	4.643	6.16	183.73	0.337	43.93	115.13	24.67	0.00	0.029	0.232	0.075	0.000
6	6.829	7.65	152.40	0.489	27.73	28.33	96.33	0.00	0.015	0.078	0.396	0.000
7	6.649	7.41	164.80	0.341	12.93	80.33	71.53	0.00	0.008	0.160	0.173	0.000
8	9.128	7.65	190.67	0.724	7.33	27.13	129.47	26.73	0.005	0.050	0.536	0.134
9	7.324	6.61	130.40	0.389	12.00	41.53	76.80	0.07	0.007	0.099	0.282	0.0002
10	7.051	7.47	173.93	0.592	18.27	34.13	118.53	3.00	0.016	0.066	0.496	0.014
11	4.487	6.49	172.20	0.489	19.07	58.67	94.47	0.00	0.011	0.140	0.338	0.000
12	6.612	7.01	183.40	0.207	63.87	75.33	44.20	0.00	0.034	0.080	0.093	0.000
13	5.571	6.61	180.93	0.389	17.07	153.87	10.00	0.00	0.012	0.347	0.030	0.000
14	3.391	5.93	140.60	0.313	15.13	79.27	46.20	0.00	0.010	0.170	0.133	0.000
15	4.909	6.89	161.07	0.416	15.20	97.20	48.66	0.00	0.012	0.247	0.157	0.000
16	6.636	6.75	181.47	0.517	17.67	26.93	132.73	4.13	0.011	0.040	0.449	0.017
17	6.503	7.31	191.67	0.432	73.80	61.27	54.47	2.13	0.053	0.153	0.215	0.011
18	6.921	7.66	185.47	0.369	61.33	48.53	74.73	0.87	0.036	0.101	0.227	0.003
19	4.301	6.41	142.73	0.281	19.87	59.40	63.40	0.07	0.012	0.112	0.158	0.0001
20	4.534	6.32	122.67	0.246	11.67	66.13	44.87	0.00	0.009	0.119	0.119	0.000
21	6.380	7.19	151.20	0.500	7.73	18.13	114.47	10.87	0.005	0.033	0.411	0.051
22	7.114	6.06	216.33	0.538	27.40	99.73	88.33	0.87	0.020	0.242	0.273	0.004
23	5.976	6.98	146.87	0.225	52.53	86.13	8.20	0.00	0.032	0.166	0.027	0.000
24	6.058	7.87	155.87	0.395	16.87	107.33	31.67	0.00	0.015	0.274	0.106	0.000
25	6.055	7.01	169.93	0.475	17.60	53.07	99.00	0.27	0.010	0.122	0.341	0.001
26	8.158	7.87	177.20	0.477	50.40	60.00	66.73	0.07	0.048	0.174	0.255	0.0002
27	4.884	6.46	146.60	0.394	25.13	50.07	71.40	0.00	0.016	0.133	0.245	0.000
28	4.862	6.40	125.53	0.392	12.13	51.00	62.40	0.00	0.008	0.151	0.233	0.000
29	7.241	7.41	171.40	0.521	25.20	102.93	43.27	0.00	0.021	0.330	0.171	0.000
30	4.126	6.06	193.07	0.418	55.07	124.33	13.60	0.07	0.034	0.340	0.045	0.0002
31	4.601	6.29	181.00	0.424	49.00	110.53	21.47	0.00	0.030	0.320	0.074	0.000
32	5.084	6.23	166.93	0.244	97.93	49.60	19.07	0.33	0.061	0.123	0.059	0.001
33	4.735	6.59	150.07	0.382	12.60	91.93	45.53	0.00	0.011	0.223	0.148	0.000
34	3.966	6.65	126.40	0.249	50.60	33.73	41.87	0.20	0.030	0.067	0.151	0.001
35	8.816	8.21	189.47	0.580	48.20	35.67	104.40	1.20	0.038	0.078	0.458	0.007
36	9.783	8.36	188.00	0.481	22.73	79.40	85.53	0.33	0.016	0.151	0.313	0.001
37	7.320	7.71	149.73	0.417	22.67	73.67	53.40	0.00	0.019	0.207	0.191	0.000
38	5.678	6.69	162.20	0.412	19.47	111.33	31.40	0.00	0.012	0.293	0.106	0.000
39	8.257	7.75	202.60	0.822	11.67	39.07	151.87	0.00	0.009	0.114	0.699	0.000
40	6.881	6.97	154.87	0.495	12.67	74.20	68.00	0.00	0.010	0.215	0.270	0.000
41	6.562	7.25	184.47	0.234	105.93	55.73	22.80	0.00	0.056	0.114	0.063	0.000
42	4.922	6.93	173.67	0.493	22.40	114.67	36.60	0.00	0.018	0.341	0.134	0.000
44	5.236	6.49	179.07	0.540	12.87	97.20	69.00	0.00	0.010	0.274	0.255	0.000
45	5.257	6.37	152.53	0.396	19.80	88.73	44.00	0.00	0.015	0.237	0.144	0.000
46	5.277	6.78	118.33	0.273	17.40	100.87	0.07	0.00	0.020	0.253	0.0003	0.000
47	7.314	7.07	185.73	0.461	16.53	98.07	71.13	0.00	0.014	0.228	0.219	0.000
48	5.893	6.95	159.87	0.377	29.33	87.47	43.07	0.00	0.018	0.201	0.158	0.000
49	4.964	6.24	132.33	0.347	29.73	51.40	51.20	0.00	0.018	0.131	0.198	0.000
50	6.352	7.21	121.00	0.327	16.07	74.33	30.60	0.00	0.011	0.207	0.109	0.000
51	5.227	6.62	174.13	0.545	14.87	104.40	54.87	0.00	0.012	0.311	0.222	0.000
Mean	6.077	6.93	165.18	0.423	29.70	71.39	63.06	1.03	0.020	0.173	0.225	0.005

Table X. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., for individual trees in the spruce sample plot at Gällivare in the year 1954.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. of seeds				Weight of seeds in gram			
					≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.	≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.
1	7.546	7.61	177.87	0.414	92.67	9.73	72.27	3.20	0.064	0.026	0.307	0.017
2	6.454	7.58	192.27	0.501	49.13	52.40	88.60	2.13	0.041	0.102	0.350	0.008
3	5.270	7.03	143.40	0.306	34.27	73.53	35.00	0.60	0.033	0.164	0.107	0.002
4	4.403	6.54	129.19	0.463	20.53	13.93	94.33	0.40	0.017	0.040	0.403	0.003
5	5.948	6.87	181.60	0.710	24.73	27.47	124.27	5.13	0.053	0.089	0.542	0.027
6	4.203	6.54	102.60	0.364	9.87	27.73	64.93	0.07	0.012	0.077	0.275	0.0004
7	4.602	6.53	131.53	0.209	58.67	35.13	37.73	0.00	0.051	0.052	0.106	0.000
10	6.270	7.37	150.60	0.407	18.07	82.60	49.73	0.20	0.020	0.220	0.167	0.0004
11	6.569	7.17	167.13	0.450	62.80	17.80	73.40	13.13	0.055	0.023	0.301	0.071
14	7.462	7.35	174.53	0.611	22.33	16.40	133.87	1.93	0.032	0.043	0.527	0.010
18	7.586	7.19	167.27	0.504	37.13	41.07	88.67	0.40	0.046	0.095	0.362	0.001
19	7.473	7.19	199.66	0.355	25.27	163.33	10.73	0.33	0.018	0.313	0.023	0.001
21	6.735	6.43	172.60	0.394	90.40	5.20	71.60	5.40	0.060	0.013	0.298	0.024
25	5.968	7.54	151.34	0.504	27.67	24.27	97.00	2.40	0.023	0.067	0.406	0.008
26	5.778	7.05	154.73	0.447	22.00	58.93	72.53	1.27	0.025	0.164	0.254	0.005
27	6.062	7.01	136.47	0.349	23.73	72.20	39.40	1.13	0.023	0.186	0.136	0.004
28	5.717	6.31	162.73	0.461	19.67	45.60	95.53	1.93	0.019	0.102	0.333	0.007
31	4.996	6.31	117.40	0.259	31.80	42.47	42.20	0.94	0.026	0.102	0.128	0.003
32	5.485	6.81	183.13	0.496	22.47	130.73	29.93	0.00	0.025	0.369	0.103	0.000
36	5.448	6.31	139.80	0.257	73.67	25.47	40.26	0.40	0.058	0.049	0.149	0.001
37	4.958	6.39	109.87	0.218	45.00	25.40	38.20	1.27	0.039	0.059	0.116	0.005
40	5.563	7.03	184.13	0.461	40.06	70.47	71.40	2.20	0.033	0.201	0.219	0.008
41	7.217	7.90	149.33	0.483	27.53	43.33	77.73	0.73	0.034	0.128	0.318	0.003
42	5.578	6.84	149.93	0.405	24.40	63.13	61.87	0.53	0.025	0.168	0.210	0.002
43	5.210	6.70	161.00	0.475	23.93	66.47	69.73	0.87	0.030	0.192	0.249	0.004
44	1.489	4.35	92.73	0.161	21.20	58.20	13.33	0.00	0.019	0.112	0.030	0.000
47	4.665	6.09	141.40	0.388	22.20	48.40	70.13	0.67	0.028	0.123	0.235	0.002
50	3.837	6.39	134.73	0.315	15.20	45.67	73.33	0.53	0.016	0.099	0.198	0.002
75	4.898	6.51	154.13	0.436	18.73	61.73	72.93	0.73	0.025	0.162	0.247	0.002
77	4.379	6.65	135.73	0.358	28.73	75.73	30.93	0.33	0.054	0.205	0.097	0.002
78	4.251	5.75	131.27	0.344	28.00	46.87	55.73	0.67	0.034	0.123	0.184	0.003
79	5.371	5.85	178.66	0.491	47.80	49.13	81.40	0.33	0.037	0.144	0.310	0.001
81	5.043	5.68	128.67	0.420	19.53	56.07	52.60	0.47	0.023	0.183	0.216	0.002
84	4.174	6.96	135.20	0.419	18.40	44.53	70.40	1.87	0.024	0.118	0.267	0.010
88	3.348	4.89	88.07	0.259	13.40	18.13	54.87	1.67	0.013	0.039	0.199	0.008
97	5.859	7.00	166.87	0.448	34.73	32.73	98.20	1.20	0.034	0.085	0.325	0.004
98	4.362	6.25	158.07	0.467	19.27	76.27	62.53	0.00	0.019	0.226	0.222	0.000
99	5.855	7.39	200.07	0.153	173.73	12.40	13.80	0.13	0.105	0.019	0.029	0.001
100	4.535	7.50	154.60	0.372	45.73	30.00	76.73	2.13	0.035	0.072	0.258	0.008
101	5.115	6.17	153.60	0.422	22.60	74.80	55.60	0.60	0.027	0.204	0.189	0.002
102	6.640	7.69	151.67	0.460	17.87	95.33	37.40	1.07	0.024	0.297	0.135	0.003
103	7.134	6.68	143.87	0.491	15.93	26.53	99.40	2.00	0.018	0.059	0.402	0.011
105	4.409	6.26	130.00	0.295	40.80	45.13	43.67	0.40	0.021	0.120	0.152	0.002
106	5.967	6.53	170.00	0.281	96.40	31.27	41.66	0.67	0.064	0.079	0.136	0.002
108	6.854	6.91	192.27	0.612	21.00	88.67	82.13	0.47	0.022	0.265	0.324	0.002
109	6.518	6.66	148.80	0.420	14.67	65.27	68.13	0.73	0.010	0.173	0.235	0.002
113	6.302	6.79	141.33	0.442	31.80	26.93	82.13	0.47	0.040	0.066	0.334	0.002
117	5.495	6.97	142.13	0.531	12.93	22.07	106.27	0.87	0.013	0.059	0.456	0.004
1001	4.383	6.37	121.60	0.249	9.07	45.67	66.00	0.87	0.008	0.081	0.158	0.002
1002	3.095	5.14	142.07	0.342	19.80	40.80	81.40	0.07	0.019	0.088	0.235	0.0002
Mean	5.450	6.66	150.55	0.402	34.75	49.06	65.43	1.31	0.032	0.125	0.239	0.006

Table XI. Mean values of cone weight, cone length, total no. of seeds per cone, and weight of all seeds per cone etc., for individual trees in the spruce sample plot at Pajala in the year 1954.

Tree No.	Mean cone weight in gram	Mean cone length in cm.	Total no. of seeds per cone	Total weight of all seeds in the average cone (in g.)	No. of seeds				Weight of seeds in gram			
					≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.	≦1.0 mm.	>1.0 ≦1.5	>1.5 ≦2.0	>2.0 mm.
1	6.696	7.19	137.60	0.410	6.80	14.33	108.73	7.73	0.004	0.019	0.357	0.030
2	4.905	5.75	172.73	0.321	33.33	84.00	55.27	0.13	0.022	0.139	0.160	0.000
3	4.647	5.87	172.20	0.331	24.07	88.87	59.07	0.20	0.012	0.145	0.174	0.001
4	6.874	6.92	178.60	0.518	15.73	26.33	131.73	4.80	0.011	0.054	0.434	0.019
5	8.010	7.15	163.73	0.644	7.27	10.20	136.20	10.07	0.004	0.016	0.574	0.050
6	5.506	6.47	158.80	0.331	13.40	82.87	62.47	0.07	0.009	0.154	0.167	0.000
7	3.513	5.16	163.20	0.267	34.40	111.47	17.33	0.00	0.023	0.195	0.049	0.000
8	6.839	6.52	177.27	0.644	14.53	59.07	102.73	0.93	0.009	0.197	0.433	0.004
9	5.455	6.66	171.73	0.441	13.40	49.80	108.07	0.47	0.008	0.096	0.336	0.002
10	4.791	6.08	137.20	0.338	6.33	41.60	89.27	0.00	0.004	0.075	0.259	0.000
11	6.776	7.26	159.60	0.484	10.87	104.40	44.13	0.20	0.008	0.303	0.172	0.001
12	6.344	7.04	208.20	0.673	16.60	110.13	81.47	0.00	0.011	0.322	0.339	0.000
13	3.984	6.18	136.80	0.273	10.00	29.00	97.00	0.80	0.006	0.052	0.213	0.002
14	7.729	7.22	160.67	0.574	8.93	19.93	128.20	3.60	0.006	0.036	0.512	0.020
15	5.628	7.03	179.07	0.411	40.73	78.33	60.00	0.00	0.026	0.171	0.215	0.000
16	8.930	7.59	150.60	0.393	8.73	44.60	92.73	4.53	0.005	0.058	0.308	0.022
17	6.197	6.55	179.53	0.348	62.40	43.60	73.27	0.27	0.033	0.059	0.255	0.001
18	7.332	7.54	194.40	0.546	24.13	46.27	122.93	1.07	0.013	0.087	0.442	0.004
19	6.730	7.01	219.53	0.325	54.07	109.73	55.67	0.07	0.028	0.144	0.153	0.000
20	8.305	7.23	178.07	0.516	12.80	18.13	142.53	4.60	0.007	0.028	0.458	0.022
21	7.053	6.76	150.87	0.611	10.73	19.27	120.40	0.47	0.006	0.041	0.562	0.002
22	7.217	7.67	195.07	0.436	59.60	50.33	83.93	1.20	0.038	0.051	0.340	0.006
23	8.366	8.14	208.93	0.634	17.80	68.47	118.67	4.00	0.012	0.105	0.499	0.019
24	6.924	6.93	202.73	0.705	22.73	28.80	151.00	0.20	0.012	0.070	0.622	0.001
25	4.689	5.99	153.33	0.396	17.60	22.80	112.93	0.00	0.010	0.040	0.346	0.000
26	6.310	7.25	161.80	0.362	11.53	81.93	68.33	0.00	0.006	0.151	0.205	0.000
27	5.878	6.10	196.60	0.334	78.40	65.73	52.47	0.00	0.042	0.092	0.199	0.000
28	7.939	7.62	181.93	0.478	10.73	17.33	148.93	4.93	0.008	0.025	0.429	0.017
29	7.149	7.45	188.93	0.608	21.80	35.87	129.93	1.33	0.017	0.067	0.517	0.007
30	9.795	7.94	216.93	0.744	14.80	37.87	164.13	0.13	0.009	0.077	0.657	0.001
31	7.203	6.27	184.73	0.528	24.93	91.13	68.67	0.00	0.019	0.253	0.257	0.000
32	7.051	7.03	167.47	0.375	25.87	42.27	99.27	0.07	0.012	0.069	0.294	0.000
33	7.448	7.07	140.27	0.475	5.47	14.13	119.40	1.27	0.003	0.020	0.448	0.004
34	5.931	6.73	178.00	0.349	22.47	113.47	42.07	0.00	0.014	0.213	0.122	0.000
35	6.859	6.69	183.00	0.597	21.93	29.13	131.67	0.27	0.015	0.064	0.517	0.001
36	2.606	5.75	143.93	0.151	50.87	80.47	12.60	0.00	0.033	0.098	0.020	0.000
37	6.735	6.62	164.20	0.505	14.47	15.07	130.20	4.47	0.011	0.023	0.453	0.018
38	4.560	5.27	147.07	0.345	10.67	41.93	94.33	0.13	0.006	0.073	0.265	0.001
39	4.794	5.95	178.13	0.320	13.20	93.67	71.27	0.00	0.008	0.145	0.168	0.000
40	3.477	6.67	146.80	0.231	18.33	67.60	60.87	0.00	0.010	0.098	0.123	0.000
41	4.742	6.27	175.80	0.330	20.07	116.73	39.00	0.00	0.011	0.229	0.091	0.000
42	6.362	6.73	171.27	0.415	21.33	63.80	86.13	0.00	0.013	0.131	0.271	0.000
43	6.383	6.40	161.13	0.451	20.00	19.40	121.27	0.47	0.010	0.030	0.410	0.002
44	5.315	6.60	133.53	0.210	57.27	38.73	37.53	0.00	0.034	0.059	0.117	0.000
45	4.423	6.63	133.53	0.358	18.33	34.07	81.13	0.00	0.010	0.072	0.276	0.000
46	8.079	7.11	173.27	0.412	16.07	68.87	88.33	0.00	0.009	0.139	0.264	0.000
47	8.129	6.89	225.67	0.564	22.27	111.27	92.07	0.07	0.012	0.159	0.392	0.000
48	8.958	8.06	202.80	0.848	27.73	27.47	146.60	1.00	0.020	0.056	0.767	0.006
49	8.121	5.90	183.20	0.536	24.60	65.93	91.20	1.47	0.016	0.143	0.370	0.007
50	5.015	7.63	150.13	0.296	4.67	20.80	121.73	2.93	0.003	0.025	0.260	0.008
Mean	6.374	6.77	172.01	0.448	22.49	55.14	93.10	1.28	0.014	0.103	0.325	0.006

Table XII. Seven sets of regression coefficients for individual trees at Stjernarp for the year 1948.

Regression of \ Tree No.	3	9	11	40	51	52	53	54	55	56	57	58	59	60	61	62	63
X_3 on X_2	0.382	0.389	0.592	0.324	0.518	0.616	0.433	0.373	0.253	0.548	0.353	0.359	0.452	0.535	0.701	0.498	0.377
X_4 on X_2	1.542	1.908	1.693	1.831	2.151	2.298	2.485	1.644	1.570	4.302	2.168	1.502	1.491	2.317	3.152	1.137	1.384
X_4 on X_3	3.961	3.658	1.715	8.134	4.169	3.475	5.881	4.449	4.934	8.158	5.484	4.064	3.815	2.876	2.896	2.400	4.088
X_7 on X_3	29.321	36.156	29.413	44.528	48.797	33.780	48.275	40.672	49.320	20.761	48.128	36.244	51.336	56.222	19.484	3.753	43.404
X_8 on X_3	2.686	4.135	1.793	7.175	4.260	3.246	5.876	4.807	4.837	1.034	5.235	3.849	3.883	2.645	2.864	2.900	3.665
X_8 on X_4	0.401	0.998	0.942	0.891	1.032	0.931	1.000	1.031	1.001	0.116	0.933	0.952	0.960	0.960	0.895	1.336	0.906
X_9 on X_7	0.880	1.001	1.005	0.987	1.001	0.989	0.997	1.003	0.995	0.997	0.997	0.996	1.000	0.993	0.981	1.116	0.982

Regression of \ Tree No.	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
X_3 on X_2	0.579	0.599	0.397	0.498	0.386	0.390	0.350	0.411	0.270	0.406	0.161	0.265	0.468	0.488	0.550	0.420	0.322
X_4 on X_2	1.009	1.581	3.362	0.548	2.739	1.180	2.644	1.852	1.011	2.956	1.753	1.534	2.115	2.812	1.991	0.935	2.794
X_4 on X_3	2.374	2.136	9.340	0.676	5.859	1.819	6.295	4.922	1.067	5.798	6.628	4.400	4.151	5.534	4.219	1.806	7.426
X_7 on X_3	28.222	21.042	52.552	18.941	50.223	27.598	26.541	41.505	20.802	38.110	46.108	49.628	50.009	43.688	36.410	44.259	49.584
X_8 on X_3	2.296	2.411	5.807	1.002	5.545	1.852	6.247	4.982	1.612	4.509	6.014	4.401	4.196	5.409	4.157	2.048	7.583
X_8 on X_4	1.017	0.975	0.556	0.878	0.952	0.896	0.954	0.981	0.927	0.588	0.715	0.801	1.088	0.940	0.947	0.873	0.968
X_9 on X_7	1.006	1.015	0.943	1.001	0.999	1.003	0.995	0.999	1.042	0.926	0.984	1.015	1.009	0.992	0.997	0.995	0.997

Regression of \ Tree No.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	
X_3 on X_2	0.730	0.407	0.559	0.500	0.440	0.537	0.336	0.601	0.384	0.382	0.468	0.542	0.267	0.407	0.442	0.428	
X_4 on X_2	2.162	1.684	1.224	2.023	2.026	1.984	1.548	1.879	2.562	1.667	1.609	1.862	1.449	1.987	2.001	2.637	
X_4 on X_3	3.835	3.275	2.129	2.372	5.281	3.280	3.002	2.005	5.602	4.322	3.787	2.754	5.569	4.671	4.433	6.288	
X_7 on X_3	36.742	49.149	40.801	18.292	25.853	48.068	34.089	41.205	33.832	41.207	36.796	28.564	69.703	41.930	40.870	41.181	
X_8 on X_3	3.957	3.254	1.763	2.007	4.562	3.169	3.184	2.311	5.586	4.166	4.160	2.533	5.871	4.504	5.136	6.130	
X_8 on X_4	0.985	0.980	0.852	0.864	0.907	0.957	0.934	0.981	0.987	0.906	1.087	0.947	0.933	0.955	0.994	0.973	
X_9 on X_7	1.002	0.995	0.990	0.980	0.987	1.003	1.000	0.992	0.998	1.004	1.019	1.003	0.995	1.004	1.011	0.996	

X_2 = cone length in mm.
X_3 = cone weight in g.
X_4 = the total number of seeds per cone
X_7 = the weight in mg. of all seeds per cone
X_8 = the number of seeds > 1 mm. per cone
X_9 = the weight in mg. of seeds > 1 mm. per cone

Table XIII. Seven sets of regression coefficients for individual trees at Härryda for the year 1948.

Regression of \ Tree No.	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
X_3 on X_2	0.404	0.400	0.251	0.328	0.403	0.482	0.424	0.562	0.561	0.664	0.375	0.435	0.657	0.554	0.468	0.483	0.262
X_4 on X_2	1.715	2.733	1.464	1.552	1.810	2.565	1.896	3.241	2.009	2.037	0.720	2.033	2.693	2.580	2.153	0.318	1.720
X_4 on X_3	3.678	6.916	5.923	5.260	4.707	4.106	4.103	5.372	3.435	2.197	1.680	4.826	3.844	3.896	4.601	1.715	6.939
X_7 on X_3	39.229	48.430	51.862	59.334	39.903	31.891	39.284	38.675	39.219	12.270	21.641	28.910	32.885	34.356	56.886	12.284	25.546
X_8 on X_3	3.728	6.906	6.843	4.978	4.988	3.999	3.944	5.212	3.135	2.062	2.013	4.127	3.768	4.171	4.506	0.399	2.545
X_8 on X_4	0.962	0.996	1.081	0.958	1.021	0.932	0.939	0.928	0.915	1.026	0.960	0.871	0.925	1.001	0.966	0.432	0.444
X_9 on X_7	0.998	1.001	1.027	0.992	1.010	0.992	0.998	0.992	0.997	1.002	1.001	0.975	0.998	1.001	0.991	0.809	0.887

Regression of \ Tree No.	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
X_3 on X_2	0.403	0.484	0.200	0.533	0.391	0.309	0.521	0.342	0.311	0.484	0.418	0.515	0.518	0.494	0.311	0.552	0.290
X_4 on X_2	3.594	1.944	0.514	2.522	1.924	1.714	3.330	3.170	3.047	3.508	1.066	1.875	2.295	2.156	2.514	3.681	1.931
X_4 on X_3	9.633	3.572	4.880	4.221	5.674	1.401	5.864	7.826	6.991	6.146	1.668	3.089	4.511	4.290	6.718	6.477	8.623
X_7 on X_3	55.095	21.827	23.626	29.766	57.908	12.660	49.337	48.727	56.746	38.145	19.943	42.636	28.723	44.777	51.211	32.398	46.274
X_8 on X_3	9.425	3.358	4.069	2.209	6.498	1.612	5.549	7.595	7.085	5.950	1.599	2.945	4.275	4.285	6.767	6.820	7.570
X_8 on X_4	0.989	0.913	0.632	0.607	0.980	0.979	0.979	0.955	0.989	0.963	0.913	0.957	0.899	0.959	0.981	1.006	0.940
X_9 on X_7	0.999	0.993	0.967	0.942	1.002	1.000	0.995	0.997	0.994	0.997	0.981	1.002	0.994	0.997	0.995	0.997	0.987

Regression of \ Tree No.	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	
X_3 on X_2	0.473	0.443	0.460	0.297	0.515	0.313	0.453	0.592	0.440	0.366	0.344	0.598	0.459	0.545	0.611	0.556	
X_4 on X_2	1.819	1.885	2.861	2.104	2.578	0.117	1.517	3.996	3.675	3.038	3.151	1.357	3.665	0.872	1.853	3.227	
X_4 on X_3	3.219	4.375	6.956	6.866	4.363	0.855	3.447	6.273	6.914	9.544	8.007	2.292	6.156	1.476	5.664	4.842	
X_7 on X_3	26.727	38.988	44.521	37.081	56.037	6.749	44.502	53.598	57.575	58.859	32.235	21.197	36.268	36.097	54.011	44.115	
X_8 on X_3	3.294	4.126	6.447	6.743	4.103	1.101	3.540	6.559	6.714	9.396	7.901	2.372	5.903	1.554	5.293	4.887	
X_8 on X_4	0.977	0.966	0.917	0.986	0.921	0.982	0.968	1.075	0.951	0.948	0.969	1.049	0.987	0.983	0.929	1.019	
X_9 on X_7	1.004	0.992	0.988	0.995	0.993	0.998	1.001	1.013	0.991	0.997	0.995	1.004	0.999	1.000	0.982	1.004	

X_2 = cone length in mm.
X_3 = cone weight in g.
X_4 = the total number of seeds per cone
X_7 = the weight in mg. of all seeds per cone
X_8 = the number of seeds > 1 mm. per cone
X_9 = the weight in mg. of seeds > 1 mm. per cone.

Table XIV. Seven sets of regression coefficients for individual trees at Gunnarskog for the year 1948.

Regression of \ Tree No.	302	312	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365
X_3 on X_2	0.453	0.362	0.342	0.518	0.404	0.345	0.366	0.334	0.265	0.336	0.403	0.587	0.554	0.297	0.225	0.359	0.387
X_4 on X_2	0.099	3.615	—1.273	0.377	—1.321	1.250	0.228	1.345	0.049	—0.272	2.102	4.049	1.410	2.721	2.211	1.024	—0.157
X_4 on X_3	3.103	10.983	—3.274	1.450	—0.551	3.471	1.733	3.707	5.709	—0.569	3.578	5.526	1.623	7.879	17.252	5.582	1.193
X_7 on X_3	20.172	63.210	4.666	23.926	11.479	24.650	29.118	17.780	28.724	21.099	44.449	39.961	18.881	48.454	94.071	37.704	27.759
X_8 on X_3	3.383	12.237	—2.850	1.451	—0.045	3.318	2.944	2.263	5.460	—0.406	3.895	5.176	1.493	7.963	16.189	5.092	1.153
X_8 on X_4	0.958	1.072	0.937	0.879	0.864	0.899	0.650	0.578	0.913	0.950	0.888	0.933	0.984	1.007	0.968	0.930	0.994
X_9 on X_7	1.000	1.030	0.992	1.009	0.986	0.978	0.970	0.865	0.978	0.988	1.011	0.980	0.996	0.999	0.990	0.985	0.995

Regression of \ Tree No.	366	367	368	369	370	371	372	373	374	375	377	378	379	380	381	382	383
X_3 on X_2	0.320	0.520	0.291	0.400	0.502	0.273	0.375	0.292	0.614	0.387	0.296	0.346	0.468	0.583	0.493	0.398	0.128
X_4 on X_2	3.517	—0.997	0.817	2.389	1.278	—1.937	—1.289	—1.854	1.603	—0.024	—1.405	0.932	0.541	0.487	4.484	2.005	—0.156
X_4 on X_3	8.030	0.496	3.868	6.245	2.649	1.900	—1.133	—1.070	2.366	1.179	—2.600	1.960	1.804	1.753	8.006	5.657	2.909
X_7 on X_3	46.571	8.076	23.073	56.993	12.887	13.330	—2.588	2.902	26.076	23.576	—3.006	14.075	26.655	16.703	47.426	37.908	16.582
X_8 on X_3	6.892	0.135	4.113	6.002	2.639	1.609	—1.218	—0.246	2.673	1.805	—1.940	1.744	1.770	1.682	7.487	5.331	0.902
X_8 on X_4	0.946	0.989	0.923	0.950	0.961	0.915	0.853	0.742	1.003	0.991	0.908	0.962	0.967	0.953	0.928	0.934	0.646
X_9 on X_7	0.988	0.995	0.986	0.990	1.000	0.976	0.981	0.916	1.008	1.047	0.971	0.993	0.993	0.990	0.976	0.991	0.873

Regression of \ Tree No.	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	
X_3 on X_2	0.449	0.421	0.454	0.403	0.298	0.398	0.519	0.372	0.474	0.344	0.475	0.479	0.377	0.547	0.450	0.526	
X_4 on X_2	0.991	1.334	2.483	—0.825	1.110	0.917	2.385	—0.245	2.643	—1.048	2.470	1.221	0.233	0.897	—1.426	1.531	
X_4 on X_3	1.679	3.254	5.669	—0.511	5.055	0.444	5.209	2.806	2.979	—2.240	4.293	3.011	3.121	1.760	—2.448	3.707	
X_7 on X_3	23.928	30.793	43.416	6.788	36.204	12.742	29.817	32.136	28.199	—9.807	26.892	32.568	23.628	23.337	—4.845	27.752	
X_8 on X_3	1.597	3.410	5.477	—0.144	5.293	0.543	5.217	2.600	2.715	—2.229	4.130	2.536	3.346	1.523	—2.310	3.619	
X_8 on X_4	0.986	0.977	0.964	0.979	0.969	0.941	0.963	0.906	0.941	0.970	0.968	0.969	0.976	0.970	0.943	0.988	
X_9 on X_7	1.001	0.998	0.990	0.999	0.996	0.982	0.991	0.983	0.990	0.996	1.005	0.990	0.994	0.993	0.988	0.994	

X_2 = cone length in mm.
X_3 = cone weight in g.
X_4 = the total number of seeds per cone
X_7 = the weight in mg. of all seeds per cone
X_8 = the number of seeds > 1 mm. per cone
X_9 = the weight in mg. of seeds > 1 mm. per cone

Table XV. Seven sets of regression coefficients for individual trees at Höljes for the year 1948.

Regression of \ Tree No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
X_3 on X_2	0.394	0.301	0.278	0.256	0.312	0.357	0.479	0.201	0.261	0.366	0.263	0.339	0.181	0.416	0.246	0.478	0.273
X_4 on X_2	2.303	1.309	2.493	1.411	2.482	2.759	1.293	1.733	1.171	1.743	−0.825	3.596	2.786	3.143	1.815	2.888	−0.801
X_4 on X_3	4.982	4.094	4.863	5.340	7.533	6.857	2.333	6.199	3.922	5.065	−3.766	8.849	12.051	8.058	5.908	0.548	0.698
X_7 on X_3	42.332	39.924	38.280	53.057	53.668	42.495	31.967	29.757	23.366	33.123	−6.605	43.505	29.018	37.469	48.542	34.752	12.686
X_8 on X_3	5.598	4.009	4.350	5.739	7.473	4.652	1.995	2.973	3.882	5.473	−3.094	7.264	5.092	6.810	6.353	5.626	4.768
X_8 on X_4	0.859	0.944	0.870	0.850	0.962	0.668	0.816	0.399	0.864	0.962	0.860	0.858	0.361	0.855	0.944	0.930	0.617
X_9 on X_7	0.999	0.998	0.983	0.977	0.999	0.927	0.977	0.877	1.005	0.999	0.955	0.976	0.780	0.953	0.999	0.992	1.085

Regression of \ Tree No.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
X_3 on X_2	0.149	0.355	0.272	0.458	0.349	0.286	0.254	0.172	0.233	0.549	0.269	0.300	0.371	0.391	0.197	0.311	0.251
X_4 on X_2	1.494	0.916	1.418	2.412	1.869	2.501	2.710	2.447	3.391	3.456	1.058	0.120	1.657	0.482	3.221	2.163	3.374
X_4 on X_3	3.632	3.495	5.516	4.749	4.033	10.564	9.143	10.054	11.941	5.358	3.942	1.987	3.636	0.768	11.635	6.423	9.281
X_7 on X_3	28.464	49.240	24.450	40.291	35.028	59.019	58.118	61.650	61.387	39.325	34.901	32.914	42.138	21.772	46.200	39.007	46.835
X_8 on X_3	3.906	3.561	0.975	4.363	3.531	8.848	9.203	9.229	12.995	5.689	1.286	2.379	3.755	1.187	11.816	6.236	9.039
X_8 on X_4	0.882	0.923	0.671	0.889	0.869	0.838	0.886	0.878	0.881	1.074	1.040	0.944	0.848	0.967	0.918	0.861	0.976
X_9 on X_7	0.978	0.995	0.936	0.985	0.984	0.965	1.000	0.986	0.987	1.004	1.008	1.005	1.000	1.004	0.982	0.974	1.002

Regression of \ Tree No.	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
X_3 on X_2	0.432	0.299	0.444	0.147	0.227	0.462	0.439	0.196	0.264	0.414	0.369	0.242	0.503	0.469	0.247	0.330	
X_4 on X_2	2.854	−0.627	2.782	1.077	0.536	3.257	2.030	0.601	2.25[illegible]	0.031	0.994	2.150	2.115	3.164	2.322	2.425	
X_4 on X_3	0.938	−1.250	6.282	6.098	2.619	5.958	4.278	3.451	7.423	−0.252	4.410	6.500	3.403	7.972	5.049	6.103	
X_7 on X_3	15.683	5.884	43.763	35.519	15.391	26.806	32.487	28.448	41.490	0.362	38.217	47.323	14.853	52.323	50.662	49.834	
X_8 on X_3	1.253	−1.417	5.492	6.118	4.378	4.131	3.435	3.569	7.667	−0.614	5.533	6.408	3.314	9.901	7.105	6.072	
X_8 on X_4	0.969	0.828	0.888	0.721	0.859	0.647	0.890	1.259	0.983	0.969	1.001	0.928	0.837	1.031	1.070	0.890	
X_9 on X_7	0.992	0.950	0.985	0.974	1.015	0.948	0.991	1.064	1.001	1.003	1.012	1.001	0.983	1.025	1.032	0.983	

X_2 = cone length in mm.
X_3 = cone weight in g.
X_4 = the total number of seeds per cone
X_7 = the weight in mg. of all seeds per cone
X_8 = the number of seeds > 1 mm. per cone
X_9 = the weight in mg. of seeds > 1 mm. per cone

Table XVI. Seven sets of regression coefficients for individual trees at Skalstugan for the year 1948.

Regression of \ Tree No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
X_3 on X_2	0.246	0.181	0.262	0.253	0.262	0.180	0.337	0.238	0.189	0.224	0.287	0.228	0.208	0.191	0.213	0.304	0.217
X_4 on X_2	2.197	3.524	3.207	3.476	2.009	2.529	2.958	4.366	3.382	1.693	3.179	2.258	2.776	3.434	3.376	2.061	2.651
X_4 on X_3	7.762	17.798	7.714	13.129	6.751	10.151	7.389	16.992	15.296	4.152	10.823	7.311	10.121	16.351	16.035	6.033	7.550
X_7 on X_3	34.895	55.264	34.988	53.661	31.420	38.226	36.391	35.127	45.185	9.301	47.131	31.704	26.378	33.239	74.128	21.473	23.061
X_8 on X_3	7.142	16.194	6.955	10.297	6.303	10.318	7.736	15.228	13.160	2.425	9.892	7.110	8.813	14.219	14.333	5.875	7.771
X_8 on X_4	0.917	0.764	0.959	0.654	0.783	0.753	0.838	0.910	0.832	0.956	0.848	0.840	0.812	0.764	0.923	0.827	0.843
X_9 on X_7	0.993	0.932	0.996	0.952	0.990	1.008	0.967	0.996	0.933	0.992	0.978	0.981	0.920	0.942	0.988	0.955	0.981

Regression of \ Tree No.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
X_3 on X_2	0.042	0.238	0.331	0.220	0.259	0.178	0.257	0.182	0.262	0.403	0.179	0.297	0.251	0.212	0.237	0.122	0.133
X_4 on X_2	0.240	4.274	2.701	2.652	2.689	3.374	2.278	4.033	2.430	5.464	2.053	3.308	−0.894	1.432	4.065	2.037	3.209
X_4 on X_3	3.067	17.777	6.320	8.400	7.997	17.409	8.573	15.440	9.483	12.761	10.091	10.811	−2.237	1.777	11.122	6.000	18.800
X_7 on X_3	14.917	52.943	37.962	33.350	24.103	47.510	35.917	40.120	41.677	46.877	42.068	44.769	9.756	24.883	47.027	31.318	57.500
X_8 on X_3	2.267	14.692	6.505	9.050	3.610	16.307	9.663	15.514	8.924	10.470	9.994	10.348	−0.809	2.588	10.641	8.409	17.113
X_8 on X_4	0.818	0.809	0.911	0.795	0.369	0.933	0.972	0.919	0.905	0.844	0.898	0.911	0.833	0.950	0.935	0.953	0.800
X_9 on X_7	0.957	0.967	0.987	0.956	0.840	0.983	0.990	0.983	0.981	0.963	0.989	0.987	0.967	0.992	0.982	0.989	0.971

Regression of \ Tree No.	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
X_3 on X_2	0.186	0.193	0.144	0.208	0.217	0.314	0.198	0.230	0.237	0.195	0.178	0.181	0.251	0.224	0.124	0.203	
X_4 on X_2	2.968	3.343	0.712	2.940	3.179	2.849	1.577	1.626	1.310	0.952	1.443	1.864	2.460	2.795	2.106	3.664	
X_4 on X_3	14.909	12.165	−0.670	5.789	10.868	7.685	11.137	7.186	4.942	3.063	5.999	6.131	9.260	14.128	5.953	15.201	
X_7 on X_3	31.831	45.709	13.937	32.231	36.325	31.786	6.100	40.722	36.370	21.241	20.963	19.847	42.586	39.188	15.234	38.689	
X_8 on X_3	10.660	11.904	0.500	5.672	10.547	1.080	10.827	6.599	5.414	2.609	5.750	6.538	9.033	13.860	5.168	14.233	
X_8 on X_4	0.793	0.930	0.952	0.917	1.020	0.714	0.957	0.799	0.988	0.935	0.844	0.892	0.968	0.936	0.831	0.751	
X_9 on X_7	0.914	0.985	0.981	0.981	0.992	0.995	0.997	0.957	0.990	0.968	0.978	0.994	0.997	0.987	0.959	0.969	

X_2 = cone length in mm.
X_3 = cone weight in g.
X_4 = the total number of seeds per cone
X_7 = the weight in mg. of all seeds per cone
X_8 = the number of seeds > 1 mm. per cone
X_9 = the weight in mg. of seeds > 1 mm. per cone

Table XVII A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Stjernarp in the year 1948.

Tree No.	Total number of seeds for 25 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
3	6720	60.5	—	—	—	—	0.5	34.5	4.0	0.5
9	5877	81.5	—	—	—	—	—	16.5	—	2.0
11	6058	79.0	—	—	—	—	0.5	20.0	—	0.5
40	5035	77.5	—	0.5	—	—	—	21.5	0.5	—
51	6864	78.0	—	—	—	—	—	21.5	—	0.5
52	6088	65.5	—	—	—	—	1.5	21.5	11.0	0.5
53	7627	51.5	—	—	0.5	0.5	0.5	46.0	—	1.0
54	8426	43.5	—	—	—	—	—	56.5	—	—
55	6841	66.0	—	—	—	—	—	33.0	0.5	0.5
56	5044	81.0	—	—	—	—	—	16.0	0.5	2.5
57	6962	56.5	—	—	—	—	—	43.0	0.5	—
58	7102	65.5	—	—	—	—	—	31.0	2.5	1.0
59	8102	55.5	—	—	—	—	—	44.0	0.5	—
60	7016	56.5	—	—	—	—	—	42.0	0.5	1.0
61	6620	54.5	—	—	1.5	0.5	—	37.5	1.0	5.0
62	6703	56.5	—	—	1.0	—	0.5	40.5	0.5	1.0
63	5691	72.5	—	—	1.0	—	—	25.0	1.0	0.5
64	6127	68.0	—	—	1.5	—	—	28.0	0.5	2.0
65	6982	63.0	—	—	—	—	—	36.5	0.5	—
66	5983	71.5	—	—	1.0	—	1.5	23.0	3.0	—
67	5529	49.5	—	—	—	0.5	—	49.0	1.0	—
68	6391	55.5	—	—	—	0.5	—	40.5	3.5	—
69	5344	46.5	—	—	0.5	0.5	—	52.0	—	0.5
70	4688	60.0	—	0.5	—	1.0	—	38.0	—	0.5
72	5793	57.5	—	0.5	—	—	7.0	14.0	20.5	0.5
73	6603	66.0	—	—	0.5	—	0.5	32.5	—	0.5
74	6040	65.5	—	—	1.5	—	0.5	32.5	—	—
75	5874	68.5	—	1.0	0.5	—	0.5	27.0	2.0	0.5
76	7091	69.0	—	—	—	0.5	—	30.0	—	0.5
77	5655	46.0	0.5	—	1.5	—	2.0	50.0	—	—
78	6486	51.0	—	—	—	0.5	—	44.5	—	4.0
79	6658	69.5	—	—	—	—	—	30.0	0.5	—
80	5134	61.5	—	—	—	—	—	38.5	—	—
81	5434	57.0	—	—	0.5	—	1.5	34.0	7.0	—
82	5234	44.5	—	—	2.0	—	1.5	48.5	3.0	0.5
83	6613	67.0	—	—	—	—	—	33.0	—	—
84	6824	77.0	—	—	—	—	—	22.5	—	0.5
85	4992	84.0	—	—	—	—	—	16.0	—	—
87	6612	47.0	—	—	—	—	—	52.0	0.5	0.5
88	6370	62.0	—	—	—	—	—	36.0	1.5	0.5
89	5384	61.0	—	—	2.5	—	4.0	26.5	5.5	0.5
90	6811	86.5	—	—	1.0	—	—	9.5	0.5	2.5
91	4474	51.5	—	—	—	0.5	0.5	45.0	0.5	2.0
92	6225	67.0	—	—	—	—	—	32.5	—	0.5
93	5678	67.0	—	—	—	—	—	32.0	—	1.0
94	5626	34.5	—	—	0.5	—	—	64.0	—	1.0
95	6094	46.0	—	—	0.5	0.5	1.0	47.0	2.5	2.5
96	5933	33.5	—	—	—	—	0.5	64.5	0.5	1.0
Tree mean value (%):		61.57	0.01	0.05	0.38	0.12	0.51	34.98	1.58	0.80

Table XVII B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Stjernarp in the year 1948.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects: embryo type 0	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects: embryo type 0+I	Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
3	60.8	60.8	37.5	37.7	96.2	1.5	3.8
9	83.2	83.2	16.0	16.3	97.0	0.5	3.0
11	79.4	79.4	19.8	19.9	96.6	0.7	3.4
40	77.5	77.5	21.5	21.5	95.6	1.0	4.4
51	78.4	78.4	20.9	21.0	97.2	0.6	2.8
52	65.8	65.8	32.0	32.2	94.1	2.0	5.9
53	52.0	52.0	45.5	46.0	95.8	2.0	4.2
54	43.5	43.5	54.8	54.8	97.0	1.7	3.0
55	66.3	66.3	32.5	32.7	97.0	1.0	3.0
56	83.1	83.1	16.0	16.4	97.0	0.5	3.0
57	56.5	56.5	42.2	42.2	97.0	1.3	3.0
58	66.2	66.2	32.4	32.7	96.7	1.1	3.3
59	55.5	55.5	43.1	43.1	96.9	1.4	3.1
60	57.1	57.1	41.2	41.6	96.9	1.3	3.1
61	57.4	57.4	37.9	39.9	93.6	2.6	6.4
62	57.1	57.1	40.3	40.7	94.8	2.2	5.2
63	72.9	72.9	25.3	25.4	93.7	1.7	6.3
64	69.4	69.4	27.8	28.4	92.7	2.2	7.3
65	63.0	63.0	35.9	35.9	97.0	1.1	3.0
66	71.5	71.5	26.3	26.3	92.3	2.2	7.7
67	49.5	49.5	48.9	48.9	96.8	1.6	3.2
68	55.5	55.5	42.9	42.9	96.4	1.6	3.6
69	46.7	46.7	50.9	51.2	96.0	2.1	4.0
70	60.3	60.3	37.9	38.1	95.9	1.6	4.1
72	57.8	57.8	37.5	37.7	89.3	4.5	10.7
73	66.3	66.3	32.0	32.2	95.5	1.5	4.5
74	65.5	65.5	32.1	32.1	93.0	2.4	7.0
75	68.8	68.8	28.8	28.9	92.9	2.2	7.1
76	69.3	69.3	29.5	29.6	96.7	1.0	3.3
77	46.0	46.5	50.1	50.1	92.8	3.9	7.2
78	53.1	53.1	43.6	45.4	96.9	1.4	3.1
79	69.5	69.5	29.6	29.6	97.0	0.9	3.0
80	61.5	61.5	37.3	37.3	96.9	1.2	3.1
81	57.0	57.0	40.6	40.6	94.4	2.4	5.6
82	44.7	44.7	51.2	51.5	93.1	3.8	6.9
83	67.0	67.0	32.0	32.0	97.0	1.0	3.0
84	77.4	77.4	21.8	21.9	96.9	0.7	3.1
85	84.0	84.0	15.5	15.5	96.9	0.5	3.1
87	47.2	47.2	50.9	51.2	97.0	1.6	3.0
88	62.3	62.3	36.3	36.5	96.8	1.2	3.2
89	61.3	61.3	34.0	34.2	88.3	4.5	11.7
90	88.7	88.7	9.8	10.1	89.1	1.2	10.9
91	52.6	52.6	44.9	45.8	96.6	1.6	3.4
92	67.3	67.3	31.5	31.7	96.9	1.0	3.1
93	67.7	67.7	31.0	31.3	96.9	1.0	3.1
94	34.8	34.8	62.2	62.8	96.4	2.3	3.6
95	47.1	47.1	49.1	50.4	95.3	2.4	4.7
96	33.8	33.8	63.4	64.0	96.8	2.1	3.2
Tree mean value (%):	62.07	62.08	35.92	36.21	95.41	1.70	4.59

Table XVIII A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Härryda in the year 1948.

Tree No.	Total number of seeds for 25 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								Seeds damaged by insects
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						
		0	I	II A	II B	III A	III B	IV A	IV B	
51	5834	43.5	—	—	—	—	—	51.5	0.5	4.5
52	6232	41.0	—	—	—	—	—	57.5	—	1.5
53	6044	26.0	—	—	—	—	0.5	69.0	0.5	4.0
54	5666	41.5	—	—	—	—	—	58.0	0.5	—
55	7284	26.0	—	—	0.5	0.5	—	72.0	0.5	0.5
56	6589	41.0	—	—	—	0.5	—	56.5	0.5	1.5
57	7431	32.5	—	—	1.0	0.5	1.0	58.5	2.0	4.5
58	6731	32.0	—	—	2.5	0.5	0.5	57.0	—	7.5
59	8347	43.0	—	—	—	—	—	55.0	—	2.0
60	5823	80.0	—	—	—	—	—	17.0	—	3.0
61	5846	33.0	—	—	2.5	—	2.5	57.0	2.0	3.0
62	6088	40.5	—	—	3.5	1.0	4.5	33.0	17.0	0.5
63	8026	50.0	—	—	2.0	—	0.5	46.0	—	1.5
64	7363	18.5	—	—	—	—	—	78.0	—	3.5
65	7217	49.5	—	—	—	—	0.5	48.5	—	1.5
66	6324	63.5	—	—	0.5	—	—	35.5	—	0.5
67	5792	80.5	—	0.5	—	—	—	18.5	—	0.5
68	6363	31.5	—	1.0	2.0	8.5	1.5	55.0	—	0.5
69	4652	71.5	—	—	—	—	—	25.5	—	3.0
70	6171	51.0	—	—	—	—	—	48.5	—	0.5
71	6155	48.0	—	—	—	—	—	50.0	—	2.0
72	6327	40.0	—	—	—	—	0.5	58.0	—	1.5
73	6651	41.5	—	—	—	—	—	56.5	—	2.0
74	6123	23.0	—	—	—	0.5	—	69.5	0.5	6.5
75	5153	48.0	—	—	—	—	—	48.5	—	3.5
76	5272	71.5	—	—	—	—	—	27.5	—	1.0
77	5522	35.0	—	—	—	—	—	62.5	0.5	2.0
78	5892	17.0	0.5	—	2.0	—	0.5	74.5	1.5	4.0
79	6809	23.5	—	—	—	—	0.5	73.0	0.5	2.5
80	5155	18.0	—	—	—	—	—	78.0	—	4.0
81	5219	25.5	—	—	0.5	—	—	69.5	—	4.5
82	5964	27.5	—	—	0.5	—	—	70.0	—	2.0
83	7519	74.0	—	—	—	—	—	24.5	—	1.5
84	5567	35.5	—	—	—	—	—	61.0	0.5	3.0
85	4899	34.5	—	—	—	—	—	64.5	0.5	0.5
86	6809	20.5	—	—	0.5	—	—	70.5	1.5	7.0
87	4706	16.5	—	—	2.0	—	1.0	77.5	1.0	2.0
88	5541	23.5	—	—	—	—	—	68.5	0.5	7.5
89	6552	23.5	—	—	0.5	1.0	—	74.5	—	0.5
90	5093	49.5	—	—	—	—	1.0	44.5	0.5	4.5
91	6457	11.0	—	—	—	—	—	83.5	—	5.5
92	6964	12.0	—	—	—	—	—	87.5	—	0.5
93	4419	18.5	—	—	0.5	—	—	78.5	—	2.5
94	4944	57.0	—	—	—	—	1.0	41.5	—	0.5
95	5305	81.5	—	—	—	—	—	17.5	—	1.0
96	5772	23.5	—	—	—	—	—	69.5	—	7.0
97	3244	21.5	—	—	—	—	2.5	69.0	—	7.0
98	5741	8.5	—	—	0.5	—	—	82.5	4.5	4.0
Tree mean value (%):		38.03	0.01	0.03	0.45	0.27	0.39	57.29	0.74	2.79

Table XVIII B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Härryda in the year 1948.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
51	45.5	45.5	50.4	52.8	96.9	1.6	3.1
52	41.6	41.6	55.8	56.6	97.0	1.7	3.0
53	27.1	27.1	67.7	70.5	96.7	2.3	3.3
54	41.5	41.5	56.7	56.7	96.9	1.8	3.1
55	26.1	26.1	70.8	71.2	96.3	2.7	3.7
56	41.6	41.6	55.7	56.5	96.9	1.8	3.1
57	34.0	34.0	59.9	62.7	95.1	3.1	4.9
58	34.6	34.6	56.4	61.0	93.2	4.1	6.8
59	43.9	43.9	53.4	54.5	97.1	1.6	2.9
60	82.5	82.5	16.5	17.0	97.1	0.5	2.9
61	34.0	34.0	59.3	61.1	92.7	4.7	7.3
62	40.7	40.7	52.2	52.5	88.5	6.8	11.5
63	50.8	50.8	45.3	46.0	93.4	3.2	6.6
64	19.2	19.2	75.7	78.4	97.1	2.3	2.9
65	50.3	50.3	47.4	48.1	96.7	1.6	3.3
66	63.8	63.8	34.5	34.7	95.8	1.5	4.2
67	80.9	80.9	18.1	18.2	95.3	0.9	4.7
68	31.7	31.7	62.0	62.3	91.2	6.0	8.8
69	73.7	73.7	24.7	25.5	96.9	0.8	3.1
70	51.3	51.3	47.0	47.2	96.9	1.5	3.1
71	49.0	49.0	48.5	49.5	97.0	1.5	3.0
72	40.6	40.6	56.6	57.5	96.8	1.9	3.2
73	42.3	42.3	54.8	55.9	97.0	1.7	3.0
74	24.6	24.6	68.3	73.0	96.9	2.2	3.1
75	49.7	49.7	47.0	48.7	96.9	1.5	3.1
76	72.2	72.2	26.7	27.0	97.1	0.8	2.9
77	35.7	35.7	61.1	62.3	97.0	1.9	3.0
78	17.7	18.2	74.3	77.4	94.6	4.2	5.4
79	24.1	24.1	71.6	73.4	96.8	2.4	3.2
80	18.8	18.8	75.7	78.9	97.1	2.3	2.9
81	26.7	26.7	67.5	70.7	96.4	2.5	3.6
82	28.1	28.1	68.0	69.4	96.5	2.5	3.5
83	75.1	75.1	23.8	24.2	97.1	0.7	2.9
84	36.6	36.6	59.6	61.4	96.9	1.9	3.1
85	34.7	34.7	63.0	63.3	96.9	2.0	3.1
86	22.0	22.0	69.8	75.1	96.3	2.7	3.7
87	16.8	16.8	77.1	78.7	94.6	4.4	5.4
88	25.4	25.4	66.9	72.3	97.0	2.1	3.0
89	23.6	23.6	73.2	73.6	96.3	2.8	3.7
90	51.8	51.8	44.3	46.4	96.3	1.7	3.7
91	11.6	11.6	81.0	85.7	97.0	2.5	3.0
92	12.1	12.1	84.9	85.3	97.0	2.6	3.0
93	19.0	19.0	76.2	78.2	96.5	2.8	3.5
94	57.3	57.3	41.0	41.2	96.5	1.5	3.5
95	82.3	82.3	17.0	17.2	97.1	0.5	2.9
96	25.3	25.3	67.4	72.5	97.0	2.1	3.0
97	23.1	23.1	68.7	73.9	96.1	2.8	3.9
98	9.0	9.0	84.2	87.7	96.2	3.3	3.8
Tree mean value (%):	38.96	38.97	56.83	58.62	96.10	2.34	3.90

Table XIX A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Gunnarskog in the year 1948.

Tree No.	Total number of seeds for 25 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
302	4206	41.5	—	—	1.0	0.5	0.5	44.0	4.0	8.5
312	6631	62.5	0.5	—	1.0	—	0.5	24.5	0.5	10.5
351	3739	33.0	1.0	—	0.5	—	—	58.0	1.5	6.0
352	6274	39.0	—	—	0.5	—	—	49.5	0.5	10.5
353	3798	48.0	0.5	—	—	—	—	42.5	0.5	8.5
354	4355	50.5	—	—	—	—	—	49.0	—	0.5
355	4682	49.0	—	0.5	0.5	—	1.0	43.5	1.0	4.5
356	4442	78.0	—	—	—	—	—	15.0	—	7.0
357	4273	75.0	—	—	—	—	—	21.0	—	4.0
358	4733	32.0	—	—	0.5	—	—	54.0	1.0	12.5
359	4868	60.0	—	0.5	—	—	—	35.0	—	4.5
360	4364	28.0	—	—	—	—	1.0	54.5	1.5	15.0
361	4911	63.5	—	—	—	—	—	32.0	1.0	3.5
362	5737	70.5	—	—	1.5	—	—	15.5	5.5	7.0
363	3676	52.0	—	—	0.5	—	—	36.0	—	11.5
364	3678	51.0	—	—	—	0.5	—	40.5	—	8.0
365	4136	28.5	—	—	0.5	0.5	0.5	52.5	1.0	16.5
366	6307	34.0	0.5	—	1.5	—	—	57.5	—	6.5
367	5142	43.0	—	—	—	0.5	—	51.0	—	5.5
368	2922	24.0	—	—	—	0.5	—	60.5	—	15.0
369	5269	36.5	—	—	—	1.0	1.5	58.5	—	2.5
370	4121	48.0	—	—	—	—	—	37.5	—	14.5
372	3195	65.5	—	—	1.5	—	—	24.5	2.0	6.5
373	2721	67.5	—	0.5	0.5	—	—	24.0	—	7.5
374	5443	44.5	—	—	0.5	1.0	1.5	36.0	2.0	14.5
375	4170	54.5	—	—	—	—	0.5	30.0	—	15.0
378	4268	48.0	—	—	0.5	—	1.0	43.5	—	7.0
379	4963	32.5	0.5	0.5	0.5	0.5	—	61.0	—	4.5
380	4278	42.0	0.5	—	—	—	0.5	48.0	0.5	8.5
381	7028	69.0	—	—	—	—	—	23.0	0.5	7.5
382	5029	51.0	—	0.5	—	—	0.5	27.5	—	20.5
383	4973	86.0	—	—	—	0.5	1.0	9.0	0.5	3.0
384	6769	40.0	—	—	—	—	—	37.0	—	23.0
385	4482	33.5	—	—	—	—	0.5	48.0	0.5	17.5
386	5024	40.5	—	—	1.5	0.5	3.0	43.0	2.5	9.0
387	3151	41.0	0.5	—	0.5	—	—	48.5	1.0	8.5
388	3373	43.0	—	—	0.5	0.5	2.5	49.0	2.5	2.0
389	4917	72.0	—	—	—	—	—	26.0	0.5	1.5
390	5871	60.0	—	—	0.5	—	1.0	22.5	8.5	7.5
391	4164	45.5	—	—	—	—	0.5	48.0	—	6.0
392	4903	55.0	—	—	1.5	0.5	1.5	39.0	—	2.5
393	2975	45.5	0.5	—	—	1.0	0.5	48.5	1.0	3.0
394	6716	76.5	—	—	—	—	—	20.5	0.5	2.5
395	5009	60.0	—	—	0.5	—	1.0	25.0	—	13.5
396	3150	55.5	0.5	—	1.0	0.5	—	35.5	0.5	6.5
397	5959	41.0	—	—	—	—	—	48.5	1.0	9.5
398	2551	26.5	—	—	—	—	—	63.0	0.5	10.0
399	6442	59.0	—	—	0.5	—	0.5	35.0	0.5	4.5
Tree mean value (%):		50.05	0.10	0.05	0.37	0.18	0.44	39.49	0.90	8.42

Table XIX B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Gunnarskog in the year 1948.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects: embryo type 0	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects: embryo type 0+I	Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
302	45.4	45.4	47.3	51.7	94.6	2.7	5.4
312	69.8	70.4	24.7	27.6	93.2	1.8	6.8
351	35.1	36.2	57.7	61.4	96.2	2.3	3.8
352	43.6	43.6	48.6	54.3	96.2	1.9	3.8
353	52.5	53.0	41.7	45.6	97.0	1.3	3.0
354	50.8	50.8	47.5	47.7	96.9	1.5	3.1
355	51.3	51.3	44.1	46.2	94.8	2.4	5.2
356	83.9	83.9	14.6	15.7	97.3	0.4	2.7
357	78.1	78.1	20.4	21.3	97.1	0.6	2.9
358	36.6	36.6	53.4	61.0	96.2	2.1	3.8
359	62.8	62.8	34.1	35.7	96.1	1.4	3.9
360	32.9	32.9	55.0	64.7	96.5	2.0	3.5
361	65.8	65.8	32.0	33.2	97.0	1.0	3.0
362	75.8	75.8	20.3	21.8	90.2	2.2	9.8
363	58.8	58.8	35.0	39.5	95.9	1.5	4.1
364	55.4	55.4	39.7	43.2	96.8	1.3	3.2
365	34.1	34.1	52.7	63.1	95.8	2.3	4.2
366	36.4	36.9	56.0	59.9	94.9	3.0	5.1
367	45.5	45.5	49.9	52.8	96.9	1.6	3.1
368	28.2	28.2	59.1	69.5	96.9	1.9	3.1
369	37.4	37.4	58.6	60.1	96.1	2.4	3.9
370	56.1	56.1	36.4	42.6	97.1	1.1	2.9
372	70.1	70.1	25.8	27.6	92.1	2.2	7.9
373	73.0	73.0	23.5	25.4	94.0	1.5	6.0
374	52.0	52.0	38.7	45.3	94.4	2.3	5.6
375	64.1	64.1	29.5	34.7	96.7	1.0	3.3
378	51.6	51.6	43.0	46.2	95.6	2.0	4.4
379	34.0	34.6	59.8	62.6	95.7	2.7	4.3
380	45.9	46.4	47.4	51.8	96.7	1.6	3.3
381	74.6	74.6	22.8	24.6	97.0	0.7	3.0
382	64.2	64.2	27.2	34.2	95.4	1.3	4.6
383	88.7	88.7	10.3	10.6	93.6	0.7	6.4
384	51.9	51.9	35.9	46.6	97.0	1.1	3.0
385	40.6	40.6	47.4	57.5	96.7	1.6	3.3
386	44.5	44.5	46.8	51.4	92.7	3.7	7.3
387	44.8	45.4	48.0	52.5	96.0	2.0	4.0
388	43.9	43.9	52.1	53.2	94.7	2.9	5.3
389	73.1	73.1	25.7	26.1	97.0	0.8	3.0
390	64.9	64.9	30.4	32.9	93.5	2.1	6.5
391	48.4	48.4	46.9	49.9	96.7	1.6	3.3
392	56.4	56.4	39.5	40.5	92.9	3.0	7.1
393	46.9	47.4	49.1	50.6	96.3	1.9	3.7
394	78.5	78.5	20.3	20.8	96.7	0.7	3.3
395	69.4	69.4	25.0	28.9	94.3	1.5	5.7
396	59.4	59.9	35.5	38.0	94.7	2.0	5.3
397	45.3	45.3	48.0	53.0	97.0	1.5	3.0
398	29.4	29.4	61.6	68.4	97.0	1.9	3.0
399	61.8	61.8	34.8	36.4	95.3	1.7	4.7
Tree mean value (%):	54.45	54.56	39.66	43.51	95.61	1.77	4.39

Table XX A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Höljes in the year 1948.

Tree No.	Total number of seeds for 25 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
1	3341	54.0	—	1.0	—	—	1.5	42.0	1.5	—
2	3736	30.5	0.5	—	3.0	—	1.5	63.5	—	1.0
3	3148	40.5	—	—	6.5	—	1.0	48.0	3.0	1.0
4	2754	63.5	—	—	9.5	—	1.5	24.5	0.5	0.5
5	3536	31.5	—	—	2.5	1.0	—	63.0	2.0	—
6	3790	47.0	—	—	0.5	1.5	—	50.5	—	0.5
7	4503	31.5	—	0.5	1.5	1.5	2.5	60.5	1.0	1.0
8	3587	29.5	—	—	1.0	—	1.5	65.5	1.5	1.0
9	3849	30.5	—	—	0.5	—	0.5	66.5	2.0	—
10	3784	37.5	1.0	1.0	0.5	1.0	—	58.0	0.5	0.5
11	1444	48.0	—	—	—	0.5	1.5	48.0	1.5	0.5
12	3381	46.5	1.0	—	0.5	1.0	0.5	50.0	0.5	—
13	3875	48.0	—	—	2.0	2.0	1.0	45.0	1.5	0.5
14	3351	50.0	0.5	—	—	—	—	47.5	1.0	1.0
15	4120	26.0	—	—	—	—	0.5	71.5	—	2.0
16	3887	67.5	—	0.5	0.5	—	—	27.5	0.5	3.5
17	2582	68.5	—	—	0.5	1.0	—	27.5	1.0	1.5
18	2591	44.5	—	—	0.5	1.0	—	51.5	0.5	2.0
19	3054	44.5	2.0	3.5	5.5	1.5	3.5	32.5	5.5	1.5
20	2647	54.0	1.5	—	—	0.5	—	1.0	42.5	0.5
21	5319	57.0	—	—	—	0.5	—	40.5	1.0	1.0
22	4364	35.0	—	—	—	—	—	59.0	1.5	4.5
23	4472	46.5	—	1.0	1.0	1.0	—	49.5	0.5	0.5
25	3850	73.5	—	—	—	1.5	—	23.5	0.5	1.0
26	3955	63.0	—	—	0.5	0.5	—	36.0	—	—
28	2542	18.5	0.5	—	—	—	—	74.0	0.5	6.5
29	3022	51.5	0.5	—	1.0	0.5	0.5	43.5	1.5	1.0
30	4658	39.5	—	—	0.5	2.0	—	55.0	1.5	1.5
31	3468	50.5	—	—	—	—	—	48.0	—	1.5
32	2392	53.0	0.5	—	1.0	—	0.5	44.5	—	0.5
33	2274	65.5	2.5	—	1.5	—	—	30.5	—	—
34	3126	67.0	—	—	4.0	—	1.5	25.0	1.5	1.0
35	3749	70.5	—	—	—	—	3.5	24.0	2.0	—
36	2963	46.0	—	—	6.5	—	5.0	42.0	—	0.5
37	5139	54.0	—	—	1.0	—	0.5	44.5	—	—
38	3161	23.5	—	—	1.0	0.5	2.0	72.0	0.5	0.5
39	4332	63.0	—	—	—	—	—	34.0	0.5	2.5
40	4437	47.5	—	—	2.0	—	0.5	48.0	1.5	0.5
41	4846	73.0	—	—	—	—	—	25.5	—	1.5
42	4679	56.0	—	—	1.5	—	0.5	38.0	0.5	3.5
43	4107	40.5	—	—	0.5	—	—	56.0	2.5	0.5
44	3275	58.5	—	—	0.5	—	0.5	40.0	—	0.5
45	4302	42.0	—	—	0.5	0.5	1.0	53.0	1.5	1.5
46	3240	53.0	—	—	0.5	—	—	46.5	—	—
47	5169	67.5	—	—	0.5	—	—	30.5	0.5	1.0
48	4095	76.0	0.5	—	0.5	0.5	0.5	21.0	0.5	0.5
49	3485	47.5	0.5	—	0.5	—	0.5	49.0	1.5	0.5
50	5136	20.0	—	1.0	1.0	—	0.5	75.0	0.5	2.0
Tree mean value (%):		49.01	0.24	0.18	1.27	0.42	0.72	45.25	1.81	1.10

Table XX B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Höljes in the year 1948.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
1	54.0	54.0	43.5	43.5	94.6	2.5	5.4
2	30.8	31.3	63.1	63.7	92.8	4.9	7.2
3	40.9	40.9	51.0	51.5	87.2	7.5	12.8
4	63.8	63.8	26.7	26.8	74.2	9.3	25.8
5	31.5	31.5	64.1	64.1	93.6	4.4	6.4
6	47.2	47.2	50.3	50.6	95.8	2.2	4.2
7	31.8	31.8	63.0	63.6	93.3	4.5	6.7
8	29.8	29.8	66.1	66.8	95.1	3.4	4.9
9	30.5	30.5	66.8	66.8	96.1	2.7	3.9
10	37.7	38.7	58.0	58.3	95.1	3.0	4.9
11	48.2	48.2	49.4	49.6	95.9	2.1	4.1
12	46.5	47.5	50.2	50.2	95.6	2.3	4.4
13	48.2	48.2	47.7	47.9	92.6	3.8	7.4
14	50.5	51.0	47.0	47.5	95.9	2.0	4.1
15	26.5	26.5	69.7	71.1	96.8	2.3	3.2
16	69.9	69.9	27.4	28.4	94.5	1.6	5.5
17	69.5	69.5	28.5	28.9	95.0	1.5	5.0
18	45.4	45.4	51.3	52.3	95.9	2.2	4.1
19	45.2	47.2	42.4	43.0	81.5	9.6	18.5
20	54.3	55.8	40.5	40.7	92.0	3.5	8.0
21	57.6	57.6	40.6	41.0	96.7	1.4	3.3
22	36.6	36.6	58.6	61.4	96.9	1.9	3.1
23	46.7	46.7	49.8	50.1	94.0	3.2	6.0
25	74.2	74.2	24.5	24.7	96.1	1.0	3.9
26	63.0	63.0	35.4	35.4	95.7	1.6	4.3
28	19.8	20.3	72.2	77.2	96.9	2.3	3.1
29	52.0	52.5	44.5	44.9	94.7	2.5	5.3
30	40.1	40.1	56.4	57.3	95.6	2.6	4.4
31	51.3	51.3	46.6	47.3	97.1	1.4	2.9
32	53.3	53.8	43.7	43.9	95.0	2.3	5.0
33	65.5	68.0	29.8	29.8	93.1	2.2	6.9
34	67.7	67.7	27.3	27.6	85.3	4.7	14.7
35	70.5	70.5	27.6	27.6	93.6	1.9	6.4
36	46.2	46.2	45.3	45.5	84.7	8.2	15.3
37	54.0	54.0	43.7	43.7	95.0	2.3	5.0
38	23.6	23.6	72.3	72.7	95.1	3.7	4.9
39	64.6	64.6	33.4	34.3	96.8	1.1	3.2
40	47.7	47.7	48.6	48.8	93.5	3.4	6.5
41	74.1	74.1	24.7	25.1	96.9	0.8	3.1
42	58.0	58.0	37.9	39.3	93.6	2.6	6.4
43	40.7	40.7	56.7	57.0	96.1	2.3	3.9
44	58.8	58.8	39.2	39.4	95.6	1.8	4.4
45	42.6	42.6	54.0	54.8	95.6	2.5	4.4
46	53.0	53.0	45.2	45.2	96.1	1.8	3.9
47	68.2	68.2	30.1	30.4	95.6	1.4	4.4
48	76.4	76.9	21.7	21.8	94.3	1.3	5.7
49	47.7	48.2	49.3	49.5	95.7	2.2	4.3
50	20.4	20.4	74.1	75.6	95.0	3.9	5.0
Tree mean value (%):	49.51	49.75	46.66	47.22	93.83	2.99	6.17

Table XXI A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Skalstugan in the year 1948.

Tree No.	Total number of seeds for 25 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
1	2449	63.5	5.5	9.5	13.0	1.5	0.5	—	—	6.5
2	3313	76.0	3.5	2.0	14.5	—	0.5	0.5	0.5	2.5
3	3490	77.5	0.5	5.5	10.5	—	2.0	—	4.0	—
4	4317	60.0	5.0	3.0	29.0	—	1.5	—	—	1.5
5	3799	29.5	1.5	37.5	21.5	5.0	2.5	—	—	2.5
6	3332	50.5	14.0	4.0	25.0	0.5	0.5	—	0.5	5.0
7	3376	50.0	4.5	12.5	27.5	2.0	1.5	—	—	2.0
8	3601	82.0	0.5	3.5	8.0	1.0	1.5	—	—	3.5
9	2542	75.5	7.0	2.0	12.5	—	1.0	—	—	2.0
10	2390	57.0	2.5	9.5	18.0	1.5	3.5	0.5	7.5	—
11	2705	70.5	3.0	4.0	15.0	—	2.5	0.5	0.5	4.0
12	4089	59.5	2.0	23.5	9.5	4.5	0.5	0.5	—	—
13	2241	71.0	4.5	6.0	16.0	—	—	—	—	2.5
14	2434	62.5	3.5	14.5	9.0	4.0	2.0	1.0	—	3.5
15	3749	91.5	—	—	4.5	—	—	—	—	4.0
16	2384	88.5	—	1.0	6.0	—	—	—	—	4.5
17	3918	91.0	2.0	0.5	2.0	—	—	1.0	—	3.5
18	1352	55.5	6.0	5.0	20.5	5.5	1.0	2.0	—	4.5
19	2041	72.0	13.0	5.5	7.5	—	0.5	—	—	1.5
20	3112	58.5	11.0	16.0	6.5	3.5	0.5	0.5	—	3.5
21	3139	40.4	26.5	12.5	17.5	1.0	—	—	—	2.5
22	3764	73.0	4.0	8.0	11.0	1.0	1.0	—	—	2.0
23	1789	77.0	7.0	2.0	11.0	—	0.5	—	—	2.5
24	3648	81.0	8.0	1.0	6.5	—	1.5	—	—	2.0
25	2720	74.0	9.0	4.0	8.0	0.5	2.0	—	—	2.5
26	2954	40.5	9.0	13.5	34.5	—	0.5	—	—	2.0
27	3311	85.0	4.5	0.5	6.0	0.5	1.0	—	—	2.5
28	2500	71.5	9.5	5.5	9.5	0.5	0.5	—	—	3.0
29	4121	59.0	9.0	5.5	19.0	—	1.5	—	—	6.0
30	1785	42.5	7.0	30.0	11.5	3.0	0.5	0.5	—	5.0
31	3061	41.0	15.0	13.5	18.0	4.5	1.0	—	0.5	6.5
32	3184	57.5	3.5	15.0	7.0	7.5	4.0	1.0	1.0	3.5
33	2881	33.5	17.5	17.0	26.5	2.0	1.0	—	—	2.5
34	2978	64.5	10.0	8.0	9.5	2.5	0.5	—	—	5.0
35	2941	62.5	3.5	—	24.5	—	1.0	—	—	8.5
36	3046	47.0	5.0	8.0	33.0	—	0.5	—	—	6.5
37	2217	68.0	1.5	3.0	16.0	1.0	1.0	0.5	—	9.0
38	2185	57.5	4.5	12.0	16.5	2.0	0.5	—	—	7.0
39	1995	46.0	13.0	11.0	23.0	1.0	1.5	—	—	4.5
40	2568	71.5	12.0	2.0	6.5	—	—	—	—	8.0
41	2191	74.0	6.0	1.5	10.5	0.5	2.5	—	—	5.0
42	2132	44.7	6.6	11.2	28.4	0.5	1.5	—	—	7.1
43	2094	50.5	4.0	12.5	19.0	4.5	5.0	—	—	4.5
44	1593	77.5	2.0	7.0	8.0	—	0.5	1.0	—	4.0
45	2000	68.5	4.5	1.5	10.5	1.5	4.0	3.5	2.0	4.0
46	1643	75.0	6.0	2.0	5.0	2.5	2.0	1.5	1.0	5.0
47	1911	53.0	1.0	4.0	20.5	1.5	2.0	—	0.5	17.5
48	1496	47.5	6.0	5.5	35.5	0.5	1.0	—	—	4.0
Tree mean value (%):		63.03	6.35	7.96	15.17	1.41	1.26	0.30	0.37	4.15

Table XXI B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Skalstugan in the year 1948.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
1	67.9	73.8	7.0	7.5	28.6	17.5	71.4
2	77.9	81.5	4.2	4.3	23.3	13.8	76.7
3	77.5	78.0	8.7	8.7	39.5	13.3	60.5
4	60.9	66.0	6.5	6.6	19.4	27.0	80.6
5	30.3	31.8	22.6	23.2	34.0	43.9	66.0
6	53.2	67.9	6.4	6.7	21.0	24.1	79.0
7	51.0	55.6	11.3	11.5	26.0	32.2	74.0
8	85.0	85.5	4.3	4.5	30.7	9.7	69.3
9	77.0	84.2	3.3	3.4	21.3	12.2	78.7
10	57.0	59.5	17.2	17.2	42.5	23.3	57.5
11	73.4	76.6	6.4	6.7	28.4	16.1	71.6
12	59.5	61.5	14.4	14.4	37.4	24.1	62.6
13	72.8	77.4	4.6	4.7	20.9	17.4	79.1
14	64.8	68.4	12.2	12.6	40.0	18.3	60.0
15	95.3	95.3	0.7	0.7	15.6	3.8	84.4
16	92.7	92.7	1.3	1.4	18.6	5.7	81.4
17	94.3	96.4	1.5	1.6	42.9	2.0	57.1
18	58.1	64.4	12.0	12.6	35.3	22.0	64.7
19	73.1	86.3	3.5	3.6	25.9	10.0	74.1
20	60.6	72.0	10.4	10.8	38.5	16.6	61.5
21	41.0	68.2	7.9	8.1	25.8	22.7	74.2
22	74.5	78.6	6.1	6.2	29.0	14.9	71.0
23	79.0	86.2	2.7	2.8	20.0	10.8	80.0
24	82.7	90.8	2.4	2.4	26.7	6.6	73.3
25	75.9	85.1	4.5	4.6	31.0	10.0	69.0
26	41.3	50.5	10.4	10.6	21.4	38.1	78.6
27	87.2	91.8	2.2	2.3	27.5	5.8	72.5
28	73.7	83.5	4.2	4.3	26.3	11.8	73.7
29	62.8	72.3	5.9	6.3	22.7	20.1	77.3
30	44.7	52.1	15.8	16.6	34.7	29.7	65.3
31	43.9	59.9	12.4	13.3	33.1	25.1	66.9
32	59.6	63.2	17.3	17.9	48.7	18.2	51.3
33	34.4	52.3	12.4	12.7	26.7	34.1	73.3
34	67.9	78.4	6.7	7.1	32.7	13.8	67.3
35	68.3	72.1	4.4	4.8	17.3	21.1	82.7
36	50.3	55.6	8.2	8.8	19.8	33.3	80.2
37	74.7	76.4	5.5	6.0	25.6	16.0	74.4
38	61.8	66.7	8.8	9.5	28.4	22.2	71.6
39	48.2	61.8	9.3	9.7	25.5	27.2	74.5
40	77.7	90.8	1.7	1.8	20.0	6.8	80.0
41	77.9	84.2	4.3	4.5	28.7	10.7	71.3
42	48.1	55.2	9.8	10.5	23.6	31.8	76.4
43	52.9	57.1	14.6	15.3	35.6	26.4	64.4
44	80.7	82.8	5.0	5.2	30.3	11.5	69.7
45	71.4	76.0	11.4	11.9	49.6	11.6	50.4
46	78.9	85.3	7.3	7.7	52.1	6.7	47.9
47	64.2	65.5	7.6	9.2	26.7	20.9	73.3
48	49.5	55.7	8.4	8.8	19.8	34.1	80.2
Tree mean value (%):	65.74	72.35	7.83	8.16	29.15	18.64	70.85

Table XXII A. Regression of X_{13} on X_1 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2{}_{(13)1}$ in %
Stjernarp.........	$X_{13} = 183.8338 + 0.7303\ X_1$	48.5
,, ...	$X_{13} = -175.6219 + 2.6429\ X_1 - 0.0023843\ X_1^2$	54.3
,, ...	$X_{13} = 335.5801 - 1.4791\ X_1 + 0.0082048\ X_1^2 - 0.0000086778\ X_1^3$	55.4
Gunnarskog......	$X_{13} = 114.7425 + 0.7264\ X_1$	28.0
,, ...	$X_{13} = 89.1270 + 0.8618\ X_1 - 0.00017079\ X_1^2$	28.0
,, ...	$X_{13} = 148.7409 + 0.3490\ X_1 + 0.00121548\ X_1^2 - 0.0000011906\ X_1^3$	28.0
Skalstugan.......	$X_{13} = 131.9488 + 0.7055\ X_1$	37.2
,, ...	$X_{13} = -297.1860 + 3.7346\ X_1 - 0.005149\ X_1^2$	50.1
,, ...	$X_{13} = -751.3906 + 8.4827\ X_1 - 0.021074\ X_1^2 + 0.000017160255\ X_1^3$	51.2
Kvikkjokk........	$X_{13} = -13.4750 + 1.0906\ X_1$	18.4
,, ...	$X_{13} = 140.6506 - 0.1910\ X_1 + 0.0025182\ X_1^2$	19.1
,, ...	$X_{13} = 289.0409 - 2.1680\ X_1 + 0.0106896\ X_1^2 - 0.000010609\ X_1^3$	19.2
Gällivare.........	$X_{13} = 45.9913 + 0.7390\ X_1$	36.6
,, ...	$X_{13} = -34.2030 + 1.4027\ X_1 - 0.0012894\ X_1^2$	37.8
,, ...	$X_{13} = -69.7348 + 1.9263\ X_1 - 0.0035803\ X_1^2 + 0.00000307998\ X_1^3$	37.8
Pajala...........	$X_{13} = 114.9581 + 0.9299\ X_1$	45.5
,, ...	$X_{13} = -49.3359 + 2.2630\ X_1 - 0.0025102\ X_1^2$	47.9
,, ...	$X_{13} = -161.3354 + 3.6946\ X_1 - 0.0082081\ X_1^2 + 0.00000712344\ X_1^3$	48.1
For the six populations.....	$X_{13} = 72.8953 + 0.8809\ X_1$	41.8
,, ...	$X_{13} = -6.4162 + 1.3932\ X_1 - 0.0007561\ X_1^2$	42.4
,, ...	$X_{13} = 39.7120 + 0.9154\ X_1 + 0.0007579\ X_1^2 - 0.0000014558\ X_1^3$	42.4

X_1 = thousand-grain weight in centigram of all seeds per cone

X_{13} = germination rate (in the JACOBSEN germinator) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular value by the formula, angle = $\arcsin \sqrt{\text{per mille}/1000}$)

Table XXII B. Regression of X_{13} on X_2 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2{}_{(13)2}$ in %
Stjernarp......	$X_{13} = 211.0838 + 0.2376\ X_2$	8.1
"	$X_{13} = 440.1003 - 0.1978\ X_2 + 0.00020398\ X_2^2$	8.3
"	$X_{13} = 1{,}226.9423 - 2.4306\ X_2 + 0.00228409\ X_2^2 - 0.0000006357\ X_2^3$	8.3
Gunnarskog....	$X_{13} = 125.6344 + 0.3006\ X_2$	6.0
"	$X_{13} = 1{,}298.0753 - 2.1357\ X_2 + 0.001253\ X_2^2$	6.9
"	$X_{13} = -8{,}842.5067 + 29.2519\ X_2 - 0.030929\ X_2^2 + 0.0000109312\ X_2^3$	7.6
Skalstugan....	$X_{13} = 226.8345 + 0.1388\ X_2$	3.2
"	$X_{13} = -892.2251 + 3.0981\ X_2 - 0.001934\ X_2^2$	9.6
"	$X_{13} = -14{,}147.9678 + 55.6576\ X_2 - 0.070712\ X_2^2 + 0.0000297093\ X_2^3$	18.2
Kvikkjokk.....	$X_{13} = -34.7353 + 0.4333\ X_2$	2.9
"	$X_{13} = -1{,}889.8810 + 5.7273\ X_2 - 0.003749\ X_2^2$	3.8
"	$X_{13} = -23{,}982.0897 + 99.8547\ X_2 - 0.136742\ X_2^2 + 0.0000623125\ X_2^3$	4.9
Gällivare......	$X_{13} = 163.3979 + 0.1215\ X_2$	1.2
"	$X_{13} = -604.8701 + 2.5912\ X_2 - 0.00196\ X_2^2$	5.2
"	$X_{13} = -4{,}353.0672 + 21.3871\ X_2 - 0.03277\ X_2^2 + 0.000016563\ X_2^3$	7.4
Pajala........	$X_{13} = 150.1958 + 0.3031\ X_2$	4.4
"	$X_{13} = 877.8544 - 1.8900\ X_2 + 0.0016358\ X_2^2$	5.3
"	$X_{13} = 1{,}297.2933 - 3.8100\ X_2 + 0.0045373\ X_2^2 - 0.0000014483\ X_2^3$	5.3
For the six populations..	$X_{13} = 18.8561 + 0.4089\ X_2$	27.5
" ..	$X_{13} = -3.4169 + 0.4630\ X_2 - 0.000031447 X_2^2$	27.5
" ..	$X_{13} = 214.2772 - 0.3134\ X_2 + 0.000862118 X_2^2 - 0.000000332051\ X_2^3$	27.6

X_2 = cone length in tenths of a millimetre

X_{13} = germination rate (in the JACOBSEN germinator) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular value by the formula, angle $= \arcsin \sqrt{\text{per mille}/1000}$)

Table XXII C. Regression of X_{13} on X_3 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2_{(13)3}$ in %
Stjernarp.......	$X_{13} = 383.0817 + 0.0470\ X_3$	4.0
,, ...	$X_{13} = 448.0404 - 0.0301\ X_3 + 0.00002090 X_3^2$	4.5
,, ...	$X_{13} = 737.4001 - 0.5577\ X_3 + 0.00031888 X_3^2 - 0.0000000515796 X_3^3$	5.5
Gunnarskog.....	$X_{13} = 244.0941 + 0.1219\ X_3$	10.0
,, ...	$X_{13} = 322.8123 + 0.0048\ X_3 + 0.0000416\ X_3^2$	10.1
,, ...	$X_{13}\ \ 962.1067 - 1.4412\ X_3 + 0.0010924\ X_3^2 - 0.00000024608\ X_3^3$	10.6
Skalstugan.....	$X_{13} = 254.0671 + 0.0887\ X_3$	7.8
,, ...	$X_{13} = 62.5182 + 0.5289\ X_3 - 0.00024022 X_3^2$	12.7
,, ...	$X_{13} = -75.9253 + 1.0242\ X_3 - 0.00079985 X_3^2 + 0.000000200412\ X_3^3$	12.9
Kvikkjokk.....	$X_{13} = 160.8146 + 0.1721\ X_3$	2.7
,, ...	$X_{13} = -61.6005 + 0.8994\ X_3 - 0.0005625\ X_3^2$	3.6
,, ...	$X_{13} = -1{,}629.1822 + 8.6526\ X_3 - 0.0128004\ X_3^2 + 0.0000061754\ X_3^3$	6.6
Gällivare.......	$X_{13} = 148.9939 + 0.1749\ X_3$	8.0
,, ...	$X_{13} = 21.3982 + 0.7018\ X_3 - 0.00051079 X_3^2$	10.5
,, ...	$X_{13} = 37.0144 + 0.5776\ X_3 - 0.00022408 X_3^2 - 0.000000201727\ X_3^3$	10.5
Pajala.........	$X_{13} = 173.1536 + 0.2859\ X_3$	20.6
,, ...	$X_{13} = 85.8766 + 0.5857\ X_3 - 0.0002412\ X_3^2$	21.2
,, ...	$X_{13} = -442.7217 + 3.4574\ X_3 - 0.0051048\ X_3^2 + 0.00000260085\ X_3^3$	24.1
For the six populations...	$X_{13} = 202.0075 + 0.1531\ X_3$	29.7
,, ...	$X_{13} = 139.5503 + 0.2827\ X_3 - 0.00005397\ X_3^2$	31.6
,, ...	$X_{13} = 90.9422 + 0.4232\ X_3 - 0.00016466\ X_3^2 + 0.000000024569\ X_3^3$	31.8

X_3 = cone weight in centigram

X_{13} = germination rate (in the JACOBSEN germinator) in per mille of all seeds not damaged by insects (the per mille data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per mille}/1000}$)

Table XXII D. Regression of X_{13} on X_4 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2_{(13)4}$ in %
Stjernarp....	$X_{13} = 649.9093 - 0.7068\ X_4$	3.2
,, ...	$X_{13} = -477.7903 + 7.4719\ X_4 - 0.014707\ X_4^2$	4.2
,, ...	$X_{13} = 18{,}252.4481 - 196.8384\ X_4 + 0.723566\ X_4^2 - 0.000883809\ X_4^3$	7.0
Gunnarskog .	$X_{13} = 293.9073 + 0.4563\ X_4$	1.7
,, .	$X_{13} = 1{,}318.3721 - 7.4398\ X_4 + 0.014980\ X_4^2$	4.8
,, .	$X_{13} = 3{,}561.6719 - 33.3667\ X_4 + 0.113475\ X_4^2 - 0.0001230356\ X_4^3$	5.3
Skalstugan ..	$X_{13} = 146.8533 + 0.9660\ X_4$	16.5
,, ..	$X_{13} = -40.1328 + 2.9460\ X_4 - 0.00514\ X_4^2$	17.2
,, ..	$X_{13} = 1{,}025.2505 - 14.6978\ X_4 + 0.09009\ X_4^2 - 0.000167713\ X_4^3$	18.3
Kvikkjokk ..	$X_{13} = 287.8018 - 0.1355\ X_4$	0.04
,, ..	$X_{13} = 278.4118 - 0.0176\ X_4 - 0.000363\ X_4^2$	0.04
,, ..	$X_{13} = 5{,}685.2589 - 101.5828\ X_4 + 0.624652\ X_4^2 - 0.001261817\ X_4^3$	2.1
Gällivare....	$X_{13} = 191.7418 + 0.3493\ X_4$	1.4
,, ...	$X_{13} = -310.3051 + 7.3321\ X_4 - 0.023560\ X_4^2$	8.7
,, ...	$X_{13} = 1{,}248.7597 - 27.0612\ X_4 + 0.220841\ X_4^2 - 0.000561601\ X_4^3$	12.4
Pajala......	$X_{13} = 150.2098 + 1.1926\ X_4$	8.0
,, ...	$X_{13} = 103.8487 + 1.7299\ X_4 - 0.001529\ X_4^2$	8.0
,, ...	$X_{13} = 6{,}626.9463 - 111.6899\ X_4 + 0.646518\ X_4^2 - 0.001217007\ X_4^3$	11.3
For the six populations	$X_{13} = 102.8925 + 1.1889\ X_4$	25.9
,,	$X_{13} = -9.6379 + 2.3090\ X_4 - 0.0025956\ X_4^2$	26.3
,,	$X_{13} = 375.5737 - 3.6334\ X_4 + 0.0265114\ X_4^2 - 0.0000153494\ X_4^3$	26.8

X_4 = the total number of seeds per cone

X_{13} = germination rate (in the JACOBSEN germinator) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per mille}/1000}$)

Table XXII E. Regression of X_{13} on X_7 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2_{(13)7}$ in %
Stjernarp.........	$X_{13} = 200.5441 + 0.2469\, X_7$	42.6
,, ...	$X_{13} = -95.5628 + 0.8099\, X_7 - 0.0002508\, X_7^2$	47.7
,, ...	$X_{13} = 385.3626 - 0.6137\, X_7 + 0.0010817\, X_7^2 - 0.000000394435\, X_7^3$	49.2
Gunnarskog......	$X_{13} = 148.9001 + 0.2457\, X_7$	28.7
,, ...	$X_{13} = 2.4684 + 0.5326\, X_7 - 0.00013281\, X_7^2$	29.7
,, ...	$X_{13} = 130.4138 + 0.0962\, X_7 + 0.00032731\, X_7^2 - 0.000000151798\, X_7^3$	29.8
Skalstugan.......	$X_{13} = 208.8007 + 0.2234\, X_7$	31.8
,, ...	$X_{13} = 30.7540 + 0.8708\, X_7 - 0.00054182\, X_7^2$	43.5
,, ...	$X_{13} = -147.7500 + 1.8320\, X_7 - 0.00212167\, X_7^2 + 0.0000007976\, X_7^3$	44.9
Kvikkjokk.......	$X_{13} = 72.5199 + 0.4564\, X_7$	13.3
,, ...	$X_{13} = 190.7350 - 0.0954\, X_7 + 0.00059486\, X_7^2$	14.2
,, ...	$X_{13} = -88.1275 + 1.9053\, X_7 - 0.00378322\, X_7^2 + 0.00000293324\, X_7^3$	14.8
Gällivare.........	$X_{13} = 87.5447 + 0.3904\, X_7$	32.9
,, ...	$X_{13} = -19.3941 + 0.9715\, X_7 - 0.0007270\, X_7^2$	36.1
,, ...	$X_{13} = -18.7002 + 0.9656\, X_7 - 0.0007119 X_7^2 - 0.00000001180167 X_7^3$	36.1
Pajala...........	$X_{13} = 150.8191 + 0.4569\, X_7$	47.1
,, ...	$X_{13} = 84.6004 + 0.7608\, X_7 - 0.0003148\, X_7^2$	47.8
,, ...	$X_{13} = -128.1966 + 2.2985\, X_7 - 0.0036908\, X_7^2 + 0.00000227811\, X_7^3$	49.7
For the six populations.....	$X_{13} = 181.6457 + 0.2482\, X_7$	43.2
,, ...	$X_{13} = 116.2017 + 0.4522\, X_7 - 0.00012498\, X_7^2$	44.7
,, ...	$X_{13} = 58.0004 + 0.7264\, X_7 - 0.00048656\, X_7^2 + 0.000000138396\, X_7^3$	45.1

X_7 = the weight in milligram of all seeds per cone

X_{13} = germination rate (in the JABOBSEN germinator) in per mille of all seeds not damaged by insects
(the per mille data transformed to corresponding angular value by the formula, angle = $\arcsin \sqrt{\text{per mille}/1000}$)

Table XXIII. Percentage of seed germination of different seed sizes and of total number of seeds for individual trees (after 30 days in Jacobsen's apparatus) at Stjernarp in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Seeds ≦1.0 mm.		Seeds >1.0 ≦1.5 mm.		Seeds >1.5 ≦2.0 mm.		Seeds >2.0 mm.		Average germination rate in per cent of all seeds
		Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	
1	4079	181	2.0	152	22.8	3735	69.0	11	63.6	64.3
2	3462	227	1.0	98	22.0	3054	71.0	83	88.0	65.4
3	4618	2763	0.0	185	66.0	1654	91.0	16	100.0	35.6
4	4167	776	1.0	45	15.6	2858	77.0	488	84.0	63.0
5	3946	393	1.0	101	56.8	3327	83.2	125	79.0	74.2
6	3691	596	0.0	84	23.8	2701	54.0	310	42.4	43.6
7	3579	341	0.0	246	44.0	2985	73.0	7	28.6	64.0
8	4543	453	1.0	42	16.7	1757	71.0	2291	76.2	66.1
9	4196	451	1.0	128	13.9	3537	81.0	80	58.0	70.0
11	4078	521	0.0	805	17.2	2699	29.0	53	30.0	23.0
27	4638	557	1.0	1039	70.0	3041	72.7	1	100.0	63.5
29	4097	268	1.0	811	48.0	3011	81.0	7	71.4	69.2
40	4176	702	0.0	250	41.0	3199	63.0	25	28.0	50.9
51	4141	316	2.0	288	18.8	3533	29.7	4	75.0	26.9
55	4093	564	2.0	1377	60.0	2152	49.0	—	—	46.2
56	4077	2133	0.0	30	36.7	1823	55.0	91	38.7	25.7
57	4401	544	0.0	2418	80.2	1436	89.0	3	66.7	73.2
59	4167	587	0.0	70	11.1	2816	69.7	694	84.0	61.3
60	4552	665	0.0	731	32.0	3153	48.5	3	33.3	38.8
61	3760	539	0.0	301	72.0	2911	85.0	9	55.6	71.7
63	3896	983	0.0	1283	40.0	1620	49.0	10	40.0	33.7
64	4363	1112	1.0	1550	64.0	1701	70.5	—	—	50.5
65	4617	1274	2.0	1953	48.0	1383	62.0	7	42.9	39.5
66	3767	1428	0.0	694	45.0	1642	36.0	3	33.3	24.0
67	3853	317	0.0	802	50.5	2733	44.0	1	0.0	41.7
68	4524	582	3.0	799	54.0	3136	73.0	7	66.7	60.6
69	3662	205	1.0	1008	76.2	2449	86.1	—	—	78.6
70	3914	460	6.0	1111	70.0	2342	79.0	1	0.0	67.9
71	4353	661	0.0	298	56.0	3384	50.0	10	16.7	42.7
72	3986	333	2.0	809	65.0	2844	56.0	—	—	53.3
73	4880	2388	0.0	494	35.0	1987	60.0	11	72.7	28.1
75	4460	1672	0.0	181	18.0	2599	46.5	8	20.0	27.9
76	4381	596	0.0	1040	34.0	2745	52.0	—	—	40.7
77	3523	464	0.0	650	60.0	2405	79.0	4	66.7	65.1
78	4654	453	0.0	523	79.0	3673	86.0	5	100.0	76.9
79	4157	786	0.0	362	58.0	3009	67.0	—	—	53.6
80	3482	876	0.0	570	46.0	2030	53.0	6	60.0	38.5
81	3885	378	0.0	53	47.0	3338	81.0	116	87.0	72.8
83	4972	1165	3.0	2041	41.0	1761	52.0	5	40.0	36.0
84	4704	604	0.0	842	36.6	3252	48.5	6	33.3	40.1
85	3853	772	0.0	726	21.0	2351	24.8	4	0.0	19.1
86	3717	499	0.0	126	13.0	1974	35.4	1118	59.0	37.0
87	3989	708	20.0	910	67.0	2371	78.0	—	—	65.2
88	4618	609	0.0	143	47.0	3833	71.0	33	55.0	60.8
89	4744	981	0.0	422	28.0	3328	25.0	13	11.1	20.1
90	4182	716	0.0	729	49.0	2729	68.7	8	16.7	53.4
92	4243	468	1.0	2652	51.0	1123	61.0	—	—	48.1
93	4098	784	0.0	98	25.7	3187	54.0	29	40.0	42.9
94	3554	1024	4.0	2099	65.0	431	82.0	—	—	49.5
95	4164	691	1.0	575	54.5	2894	85.9	4	75.0	67.5
Tree mean value (%):	4153.12	751.32	1.14	694.88	44.26	2592.72	63.16	114.20	42.77	50.65

Table XXIV. Percentage of seed germination of different seed sizes and of total number of seeds for individual trees (after 30 days in Jacobsen's apparatus) at Gunnarskog in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Seeds ≦1.0 mm.		Seeds >1.0 ≦1.5 mm.		Seeds >1.5 ≦2.0 mm.		Seeds >2.0 mm.		Average germination rate in per cent of all seeds
		Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	
178	3412	126	2.0	365	31.0	2162	40.0	759	56.0	41.2
182	3614	143	0.0	1167	8.0	2301	42.0	3	0.0	29.3
183	3730	228	6.0	1341	25.0	2161	26.0	—	—	24.4
189	3513	752	0.0	1706	0.0	1021	43.0	34	72.0	13.2
301	4253	354	1.0	984	25.0	2915	27.0	—	—	24.4
302	3854	208	1.0	1526	27.0	2116	53.0	4	0.0	39.8
303	4757	844	3.0	486	36.0	3422	76.0	5	0.0	58.9
304	4412	511	2.0	209	29.0	3661	32.0	31	56.0	28.6
305	4202	135	0.0	490	6.0	3418	2.0	159	42.0	3.9
306	4104	124	1.0	1096	15.0	2884	24.0	—	—	20.9
307	3098	291	1.0	973	36.0	1831	34.0	3	66.7	31.6
308	4143	59	1.0	454	50.0	3603	80.0	27	72.0	75.5
309	4211	386	4.0	2862	43.0	962	25.0	1	0.0	35.3
310	4812	445	0.0	2390	13.0	1975	73.0	2	100.0	36.5
311	3635	149	1.0	1018	66.0	2468	67.0	—	—	64.0
312	4299	244	0.0	772	23.0	3272	45.0	11	60.0	38.5
313	3635	120	0.0	699	12.0	2807	69.0	9	87.5	55.8
314	4081	216	9.0	2552	55.0	1313	74.0	—	—	58.7
315	3657	84	8.0	673	66.0	2897	84.0	3	100.0	79.0
317	5172	819	3.0	1957	45.0	2396	87.0	—	—	57.8
318	4406	82	2.0	572	67.0	3749	78.0	3	100.0	75.2
319	3909	297	4.0	129	39.0	3045	58.0	438	83.0	56.1
320	3948	68	9.0	863	31.0	3008	61.0	9	87.5	53.6
321	4043	456	4.0	915	23.0	2672	23.0	—	—	20.9
322	3732	168	7.0	624	74.0	2917	55.0	23	80.0	56.2
323	3751	163	0.0	1356	59.0	2232	77.0	—	—	67.2
324	4084	435	5.0	345	40.0	3291	42.0	13	70.0	38.0
325	3339	124	0.0	359	21.0	2855	16.0	1	0.0	16.0
326	4181	75	2.0	450	21.0	3631	62.0	25	32.0	56.3
327	3093	230	0.0	610	50.0	2247	37.0	6	33.3	36.8
328	4513	189	1.0	1556	41.0	2768	48.0	—	—	43.6
329	3247	120	1.0	1678	54.0	1447	57.0	2	50.0	53.4
330	3573	396	1.0	2488	10.0	689	30.0	—	—	12.9
331	3651	136	0.0	489	36.0	3026	49.0	—	—	45.4
332	4066	110	1.0	2274	36.0	1682	51.0	—	—	41.3
333	3179	191	0.0	1051	17.0	1937	32.0	—	—	25.1
334	3947	769	4.0	1486	40.0	1692	40.0	—	—	33.0
335	4493	586	1.0	334	42.0	3526	76.0	47	95.0	63.9
336	4642	328	3.0	1084	56.0	3226	81.0	4	100.0	69.7
337	3644	148	0.0	1005	19.0	2490	32.0	1	0.0	27.1
338	3072	242	2.0	1425	62.0	1405	70.0	—	—	60.9
339	2912	145	0.0	429	51.0	2337	75.0	1	0.0	67.7
340	3660	190	9.0	2653	47.0	817	57.0	—	—	47.3
341	4554	413	15.0	572	73.0	3564	67.0	5	80.0	63.1
342	3691	266	2.0	2857	37.0	568	65.0	—	—	38.8
343	3716	250	5.0	2549	44.0	917	62.0	—	—	45.8
344	3558	174	0.0	1394	42.0	1990	36.0	—	—	36.6
345	4298	93	0.0	374	8.0	1923	41.0	1908	35.0	34.6
346	3661	223	2.0	1063	48.0	2375	58.0	—	—	51.7
347	4188	111	1.0	853	8.0	3224	16.0	—	—	14.0
Tree mean value (%):	3906.90	268.32	2.48	1151.14	36.14	2416.70	51.10	70.74	31.16	43.39

Table XXV. Percentage of seed germination of different seed sizes and of total number of seeds for individual trees (after 30 days in Jacobsen's apparatus) at Skalstugan in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Seeds ≦1.0 mm.		Seeds >1.0 ≦1.5 mm.		Seeds >1.5 ≦2.0 mm.		Seeds >2.0 mm.		Average germination rate in per cent of all seeds
		Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	
2	2785	80	0.0	841	28.0	1862	42.0	2	50.0	36.6
3	3570	680	0.0	1180	45.0	1705	63.0	5	20.0	45.0
4	3006	170	0.0	566	17.0	2155	29.0	115	5.5	24.2
7	3221	288	0.0	572	21.0	2343	27.0	18	22.2	23.5
9	3085	214	0.0	879	17.0	1992	33.0	—	—	26.2
10	2892	253	0.0	757	21.0	1881	56.0	1	0.0	41.9
11	2782	290	0.0	1386	14.0	1106	49.0	—	—	26.5
12	2594	315	0.0	1023	35.0	1255	28.0	1	0.0	27.4
13	2810	161	0.0	372	20.0	2243	44.0	34	35.7	38.2
15	2338	1012	0.0	286	26.0	1018	46.0	22	27.3	23.5
16	2572	134	0.0	450	18.0	1957	45.0	31	18.2	37.6
18	3015	181	0.0	961	28.0	1873	20.0	—	—	21.4
19	3272	138	0.0	1010	24.0	2124	39.0	—	—	32.7
23	1826	140	0.0	607	13.0	1074	18.0	5	0.0	14.9
24	2487	214	0.0	926	19.0	1344	19.0	3	33.3	17.4
25	2431	255	0.0	776	11.0	1399	21.0	1	0.0	15.6
26	2796	273	0.0	888	16.0	1635	23.0	—	—	18.5
27	3232	387	0.0	2338	27.0	506	31.0	1	0.0	24.4
28	2569	1219	0.0	670	9.0	680	14.0	—	—	6.1
29	2631	170	0.0	1101	21.0	1360	15.0	—	—	16.5
30	2386	348	0.0	1342	29.0	696	44.0	—	—	29.2
31	2784	211	0.0	1160	24.0	1413	35.0	—	—	27.8
33	2850	594	0.0	525	7.0	1363	39.0	368	33.0	24.2
35	3100	297	0.0	691	41.0	2111	68.0	1	0.0	55.4
42	3145	146	0.0	837	32.0	2162	29.0	—	—	28.5
44	3012	300	0.0	600	36.0	2111	45.0	1	0.0	38.7
45	2808	471	0.0	1216	24.0	1120	28.0	1	0.0	21.6
47	3315	88	0.0	717	33.0	2509	33.0	1	0.0	32.1
49	3499	103	0.0	886	30.0	2510	41.0	—	—	37.0
50	2659	247	0.0	557	23.0	1855	35.0	—	—	29.2
51	2949	422	0.0	1038	39.0	1487	43.0	2	0.0	35.4
52	2862	322	0.0	1723	45.0	817	40.0	—	—	38.5
53	3414	354	0.0	833	28.0	2226	34.0	1	0.0	29.0
54	2817	133	0.0	461	26.0	2209	31.0	14	0.0	28.6
55	2788	246	0.0	784	30.0	1757	62.0	1	0.0	41.5
56	2747	157	0.0	552	25.0	2004	40.0	34	35.7	34.7
57	2087	194	0.0	421	24.0	1472	56.0	—	—	44.3
58	2993	428	0.0	1385	38.0	1180	54.0	—	—	38.9
59	2721	207	0.0	777	34.0	1737	40.0	—	—	35.2
60	3640	217	0.0	1518	31.0	1905	38.0	—	—	32.8
61	3844	338	0.0	1655	40.0	1851	35.0	—	—	34.1
62	3592	78	0.0	328	20.0	2774	40.0	412	10.0	33.9
63	2814	113	0.0	519	24.0	2182	37.0	—	—	33.1
64	2435	585	0.0	1250	17.0	600	46.0	—	—	20.1
65	2645	715	0.0	1215	32.0	715	26.0	—	—	21.7
66	2267	769	0.0	1156	11.0	342	42.0	—	—	12.0
67	2769	197	0.0	564	10.0	1933	60.0	75	23.3	44.6
68	2448	105	0.0	555	7.0	1730	27.0	58	44.4	21.7
69	3217	244	0.0	1331	15.0	1641	37.0	1	0.0	25.1
70	3207	263	0.0	1427	25.0	1516	41.0	1	0.0	30.5
Tree mean value (%):	2874.56	309.32	0.0	912.24	24.60	1628.80	37.76	24.20	7.17	29.55

Table XXVI. Percentage of seed germination of different seed sizes and of total number of seeds for individual trees (after 30 days in Jacobsen's apparatus) at Kvikkjokk in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Seeds ≦1.0 mm.		Seeds >1.0 ≦1.5 mm.		Seeds >1.5 ≦2.0 mm.		Seeds >2.0 mm.		Average germination rate in per cent of all seeds
		Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	
1	2432	270	0.0	506	20.0	1656	39.0	—	—	30.7
2	2662	261	0.0	951	31.0	1450	23.0	—	—	23.6
3	3063	1145	0.0	319	12.0	1593	19.0	6	0.0	11.1
4	2260	205	0.0	1095	10.0	960	17.0	—	—	12.1
5	2756	659	0.0	1727	29.0	370	24.0	—	—	21.4
6	2286	416	0.0	425	35.0	1445	54.0	—	—	40.6
7	2472	194	0.0	1205	14.0	1073	20.0	—	—	15.5
8	2860	110	0.0	407	1.0	1942	10.0	401	10.1	8.4
9	1956	180	0.0	623	4.0	1152	4.0	1	0.0	3.6
10	2609	274	0.0	512	22.0	1778	48.0	45	31.1	37.6
11	2583	286	1.0	880	21.0	1417	26.0	—	—	21.5
12	2751	958	0.0	1130	8.0	663	6.0	—	—	4.7
13	2714	256	0.0	2308	0.0	150	0.0	—	—	0.0
14	2109	227	0.0	1189	0.0	693	6.0	—	—	2.0
15	2416	228	0.0	1458	3.0	730	1.0	—	—	2.1
16	2722	265	0.0	404	2.0	1991	24.0	62	14.5	18.2
17	2875	1107	0.0	919	6.0	817	2.0	32	0.0	2.5
18	2782	920	0.0	728	1.0	1121	7.0	13	0.0	3.1
19	2141	298	0.0	891	1.0	951	3.0	1	0.0	1.8
20	1840	175	0.0	992	2.0	673	14.0	—	—	6.2
21	2268	116	0.0	272	0.0	1717	3.0	163	5.0	2.6
22	3245	411	0.0	1496	4.0	1325	8.0	13	7.7	5.1
23	2203	788	0.0	1292	13.0	123	24.0	—	—	9.0
24	2338	253	0.0	1610	11.0	475	10.0	—	—	9.6
25	2549	264	0.0	796	7.0	1485	6.0	4	0.0	5.7
26	2658	756	0.0	900	7.0	1001	17.0	1	0.0	8.8
27	2199	377	0.0	751	6.1	1071	11.9	—	—	7.9
28	1883	182	0.0	765	12.0	936	23.0	—	—	16.3
29	2571	378	0.0	1544	10.0	649	20.0	—	—	11.1
30	2896	826	0.0	1865	13.0	204	16.0	1	0.0	9.5
31	2715	735	0.0	1658	17.0	322	18.0	—	—	12.5
32	2504	1469	0.0	744	21.0	286	18.0	5	20.0	8.3
33	2251	189	0.0	1379	7.0	683	8.0	—	—	6.7
34	1896	759	0.0	506	7.0	628	14.0	3	33.3	6.6
35	2842	723	0.0	535	10.0	1566	31.0	18	50.0	19.3
36	2820	341	0.0	1191	15.8	1283	51.6	5	60.0	30.3
37	2246	340	1.0	1105	43.0	801	60.0	—	—	42.7
38	2433	292	4.0	1670	51.0	471	67.0	—	—	48.5
39	3039	175	0.0	586	54.0	2278	84.0	—	—	73.4
40	2323	190	0.0	1113	60.0	1020	72.0	—	—	60.4
41	2767	1589	1.0	836	49.0	342	41.0	—	—	20.5
42	2605	336	5.0	1720	54.0	549	67.0	—	—	50.4
44	2686	193	4.0	1458	53.0	1035	54.0	—	—	49.9
45	2288	297	1.0	1331	44.0	660	49.0	—	—	39.9
46	1775	261	9.0	1513	66.0	1	0.0	—	—	57.6
47	2786	248	3.0	1471	37.0	1067	41.0	—	—	35.5
48	2398	440	0.0	1312	54.0	646	66.0	—	—	47.3
49	1985	446	0.0	771	56.0	768	67.0	—	—	47.7
50	1815	241	0.0	1115	48.0	459	63.0	—	—	45.4
51	2612	223	2.0	1566	83.0	823	83.7	—	—	76.3
Tree mean value (%):	2477.70	445.44	0.62	1070.80	22.70	945.98	28.82	15.48	4.63	22.63

Table XXVII. Percentage of seed germination of different seed sizes and of total number of seeds for individual trees (after 30 days in Jacobsen's apparatus) at Gällivare in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Seeds ≦1.0 mm.		Seeds >1.0 ≦1.5 mm.		Seeds >1.5 ≦2.0 mm.		Seeds >2.0 mm.		Average germination rate in per cent of all seeds
		Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	
1	2668	1390	0.0	146	24.0	1084	10.0	48	22.9	11.2
2	2884	737	0.0	786	6.0	1329	14.0	32	9.4	6.7
3	2151	514	0.0	1103	2.0	525	17.0	9	12.5	5.2
4	1938	308	0.0	209	25.0	1415	47.0	6	0.0	37.0
5	2724	371	1.0	412	25.0	1864	17.0	77	29.6	16.4
6	1539	148	3.0	416	7.0	974	8.0	1	0.0	7.2
7	1973	880	1.0	527	2.0	566	15.0	—	—	5.3
10	2259	271	0.0	1239	19.0	746	9.0	3	0.0	13.4
11	2507	942	0.0	267	3.0	1101	21.0	197	41.0	12.8
14	2618	335	2.0	246	12.0	2008	26.0	29	20.7	21.6
18	2509	557	0.0	616	0.0	1330	15.8	6	0.0	8.4
19	2995	379	1.0	2450	13.0	161	12.0	5	0.0	11.4
21	2589	1356	0.0	78	16.9	1074	51.0	81	56.8	23.4
25	2270	415	3.0	364	25.0	1455	34.0	36	9.7	26.5
26	2321	330	0.0	884	20.0	1088	28.0	19	5.3	20.8
27	2047	356	3.0	1083	17.0	591	24.0	17	5.9	16.5
28	2441	295	0.0	684	18.0	1433	32.3	29	7.1	24.1
31	1761	477	0.0	637	7.0	633	11.0	14	0.0	6.5
32	2747	337	0.0	1961	26.0	449	48.0	—	—	26.4
36	2097	1105	0.0	382	19.4	604	37.0	6	33.3	14.3
37	1648	675	0.0	381	13.3	573	27.0	19	44.4	13.0
40	2762	601	0.0	1057	22.0	1071	12.0	33	6.3	13.2
41	2240	413	3.0	650	26.0	1166	31.0	11	9.1	24.3
42	2249	366	2.0	947	6.0	928	3.0	8	12.5	4.1
43	2415	359	0.0	997	38.0	1046	37.0	13	7.7	31.8
44	1391	318	0.0	873	2.0	200	10.0	—	—	2.7
47	2121	333	0.0	726	22.0	1052	30.0	10	12.5	22.5
50	2021	228	0.0	685	11.0	1100	19.0	8	0.0	14.1
75	2312	281	5.0	926	15.0	1094	17.0	11	0.0	14.7
77	2036	431	2.0	1136	15.0	464	15.0	5	0.0	12.2
78	1969	420	0.0	703	7.0	836	22.0	10	0.0	11.8
79	2680	717	0.0	737	30.0	1221	29.0	5	0.0	21.5
81	1930	293	0.0	841	26.0	789	32.0	7	28.6	24.5
84	2028	276	0.0	668	22.0	1056	12.0	28	7.1	13.6
88	1321	201	3.0	272	17.0	823	14.0	25	8.3	12.8
97	2503	521	1.0	491	36.0	1473	26.0	18	5.6	22.6
98	2371	289	1.0	1144	4.0	938	7.0	—	—	4.8
99	3001	2606	0.0	186	0.0	207	1.0	2	0.0	0.7
100	2319	686	1.0	450	18.0	1151	15.0	32	12.5	11.4
101	2304	339	0.0	1122	18.0	834	20.0	9	33.3	16.1
102	2275	268	3.0	1430	16.0	561	25.0	16	0.0	16.6
103	2158	239	2.0	398	10.0	1491	38.0	30	19.2	28.6
105	1950	612	0.0	677	16.0	655	11.0	6	0.0	9.3
106	2550	1446	0.0	469	23.0	625	54.0	10	20.0	17.5
108	2884	315	0.0	1330	46.0	1232	45.0	7	28.6	40.5
109	2232	220	0.0	979	19.0	1022	16.0	11	0.0	15.7
113	2120	477	0.0	404	6.0	1232	28.0	7	57.1	17.6
117	2132	194	0.0	331	24.0	1594	21.0	13	7.7	19.5
1001	1824	136	0.0	685	2.0	990	1.0	13	0.0	1.3
1002	2131	297	0.0	612	13.0	1221	10.0	1	0.0	9.5
Tree mean value (%):	2258.30	521.20	0.74	735.94	16.21	981.50	22.10	19.66	11.49	15.67

Table XXVIII. Percentage of seed germination of different seed sizes and of total number of seeds for individual trees (after 30 days in Jacobsen's apparatus) at Pajala in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Seeds ≦1.0 mm.		Seeds >1.0 ≦1.5 mm.		Seeds >1.5 ≦2.0 mm.		Seeds >2.0 mm.		Average germination rate in per cent of all seeds
		Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	Number of seeds	Germinated in %	
1	2064	102	0.0	215	20.0	1631	23.0	116	6.3	20.6
2	2591	500	0.0	1260	10.0	829	26.0	2	0.0	13.2
3	2583	361	0.0	1333	28.0	886	52.0	3	0.0	32.3
4	2679	236	0.0	395	5.0	1976	13.0	72	5.0	10.5
5	2456	109	1.0	153	11.0	2043	41.0	151	7.4	35.3
6	2382	201	0.0	1243	17.0	937	40.0	1	0.0	24.6
7	2448	516	0.0	1672	46.0	260	53.0	—	—	37.1
8	2659	218	1.0	886	65.0	1541	61.0	14	21.4	57.2
9	2576	201	2.0	747	34.0	1621	31.0	7	14.3	29.6
10	2058	95	1.0	624	20.0	1339	45.0	—	—	35.4
11	2394	163	0.0	1566	59.0	662	47.0	3	33.3	51.6
12	3123	249	0.0	1652	57.0	1222	77.0	—	—	60.3
13	2052	150	0.0	435	32.0	1455	19.0	12	0.0	20.3
14	2410	134	0.0	299	24.0	1923	46.0	54	57.1	42.0
15	2686	611	0.0	1175	48.0	900	69.0	—	—	44.1
16	2259	131	0.0	669	9.0	1391	19.0	68	12.5	14.7
17	2693	936	0.0	654	23.0	1099	64.0	4	50.0	31.8
18	2916	362	0.0	694	33.0	1844	55.0	16	6.3	42.7
19	3293	811	0.0	1646	12.0	835	21.0	1	0.0	11.3
20	2671	192	0.0	272	27.0	2138	27.0	69	9.1	24.6
21	2263	161	0.0	289	63.0	1806	35.0	7	42.9	36.1
22	2926	894	0.0	755	6.0	1259	58.0	18	30.8	26.7
23	3134	267	0.0	1027	11.0	1780	63.0	60	16.7	39.7
24	3041	341	1.0	432	53.0	2265	48.0	3	0.0	43.4
25	2300	264	0.0	342	31.0	1694	33.0	—	—	28.9
26	2427	173	0.0	1229	22.0	1025	36.0	—	—	26.3
27	2949	1176	0.0	986	14.0	787	65.0	—	—	22.0
28	2729	161	1.0	260	14.0	2234	24.0	74	23.8	21.7
29	2834	327	0.0	538	22.0	1949	67.0	20	65.0	50.7
30	3254	222	0.0	568	25.0	2462	75.0	2	50.0	61.1
31	2771	374	3.0	1367	54.0	1030	67.0	—	—	52.0
32	2512	388	0.0	634	26.0	1489	55.0	1	0.0	39.2
33	2104	82	0.0	212	16.0	1791	64.0	19	42.1	56.5
34	2670	337	3.0	1702	28.0	631	57.0	—	—	31.7
35	2745	329	0.0	437	44.0	1975	43.0	4	25.0	38.0
36	2159	763	0.0	1207	7.0	189	10.0	—	—	4.8
37	2463	217	0.0	226	8.0	1953	38.0	67	31.4	31.7
38	2206	160	3.0	629	30.0	1415	49.0	2	0.0	40.2
39	2672	198	2.0	1405	30.0	1069	31.0	—	—	28.3
40	2202	275	0.0	1014	10.0	913	10.0	—	—	8.8
41	2637	301	3.0	1751	28.0	585	36.0	—	—	26.9
42	2569	320	0.0	957	26.0	1292	34.0	—	—	26.8
43	2417	300	0.0	291	14.0	1819	50.0	7	28.6	39.4
44	2003	859	0.0	581	26.0	563	39.0	—	—	18.5
45	2003	275	0.0	511	53.0	1217	63.0	—	—	51.8
46	2599	241	0.0	1033	31.0	1325	60.0	—	—	42.9
47	3385	334	1.0	1669	16.0	1381	72.0	1	0.0	37.4
48	3042	416	0.0	412	42.0	2199	73.0	15	60.0	58.8
49	2748	369	0.0	989	32.0	1368	61.0	22	45.5	42.3
50	2252	70	7.6	312	6.0	1826	8.0	44	3.6	7.6
Tree mean value (%):	2580.18	337.44	0.59	827.10	27.36	1396.46	45.06	19.18	13.76	33.59

Table XXIX A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Stjernarp in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
1	4079	29.1	—	—	1.2	—	3.8	62.9	3.0	—
2	3462	24.3	—	—	0.1	—	0.3	68.8	6.5	—
3	4618	63.1	—	—	—	—	—	33.5	3.4	—
4	4167	36.1	—	—	—	—	—	63.3	0.6	—
5	3946	22.8	—	—	—	0.1	0.9	74.9	1.1	0.2
6	3691	54.9	—	—	—	—	—	45.1	—	—
7	3579	35.1	—	—	—	0.8	—	63.3	0.8	—
8	4543	27.0	—	—	1.9	—	3.4	9.4	58.3	—
9	4196	24.9	—	—	—	—	0.8	69.1	5.1	0.1
11	4078	77.0	—	—	—	0.2	—	22.8	—	—
27	4638	20.0	—	—	—	—	—	78.7	1.3	—
29	4097	30.0	—	—	—	—	—	67.3	2.7	—
40	4176	44.5	—	—	—	0.8	—	53.8	0.9	—
51	4141	68.0	0.9	—	0.9	0.9	—	27.5	1.8	—
55	4093	53.7	—	—	—	—	—	45.8	0.5	—
56	4077	72.7	—	—	0.4	—	—	24.6	2.3	—
57	4401	26.4	—	—	—	—	—	72.5	—	1.1
59	4167	34.5	—	—	0.7	—	—	62.8	2.0	—
60	4552	59.4	—	—	0.7	—	0.7	38.0	1.0	0.2
61	3760	22.0	—	—	0.2	—	1.6	73.5	1.6	1.1
63	3896	63.2	—	—	0.3	—	0.4	35.5	—	0.6
64	4363	47.5	—	—	0.4	0.4	—	50.4	—	1.3
65	4617	60.5	—	—	—	—	0.4	39.1	—	—
66	3767	71.8	—	—	1.2	0.4	1.2	22.4	3.0	—
67	3853	54.5	—	—	—	0.9	—	43.8	0.4	0.4
68	4524	32.8	—	—	1.6	—	1.6	62.9	0.8	0.3
69	3662	18.9	—	0.3	—	—	—	79.5	0.8	0.5
70	3914	31.5	—	—	—	—	—	67.9	0.6	—
71	4353	53.9	—	—	1.0	0.1	3.2	38.4	3.4	—
72	3986	46.5	—	—	0.2	—	—	53.3	—	—
73	4880	71.5	—	0.4	—	0.1	—	27.6	—	0.4
75	4460	71.5	—	—	—	—	—	28.2	—	0.3
76	4381	58.6	—	—	—	—	—	40.4	0.9	0.1
77	3523	32.0	—	—	0.7	—	1.0	57.8	8.5	—
78	4654	22.6	—	—	0.1	1.6	—	74.6	0.8	0.3
79	4157	42.8	—	—	—	—	—	56.4	—	0.8
80	3482	59.6	—	—	—	—	—	40.3	0.1	—
81	3885	26.3	—	—	—	0.9	—	72.8	—	—
83	4972	61.6	—	—	—	0.4	0.4	35.1	—	2.5
84	4704	58.9	—	—	—	—	0.2	38.8	1.7	0.4
85	3853	80.9	—	—	—	—	—	19.1	—	—
86	3717	60.8	—	—	—	—	—	36.1	3.0	0.1
87	3989	34.8	—	—	—	—	—	65.2	—	—
88	4618	33.9	—	—	0.9	—	—	61.5	3.6	0.1
89	4744	57.7	0.8	—	8.2	—	4.7	24.4	4.2	—
90	4182	43.3	—	—	—	—	0.7	52.6	3.4	—
92	4243	49.1	—	—	—	—	0.6	49.1	—	1.2
93	4098	57.1	—	—	—	—	0.1	41.2	1.6	—
94	3554	49.6	—	—	—	0.6	—	49.8	—	—
95	4164	29.5	—	—	0.1	0.7	—	68.7	1.0	—
Tree mean value (%):		46.17	0.04	0.01	0.41	0.18	0.52	49.81	2.62	0.24

Table XXIX B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Stjernarp in the year 1954.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
1	29.1	29.1	66.7	66.7	94.1	4.2	5.9
2	24.3	24.3	72.9	72.9	96.3	2.8	3.7
3	63.1	63.1	35.6	35.6	96.5	1.3	3.5
4	36.1	36.1	62.0	62.0	97.0	1.9	3.0
5	22.8	22.8	74.4	74.5	96.6	2.6	3.4
6	54.9	54.9	43.7	43.7	96.9	1.4	3.1
7	35.1	35.1	62.8	62.8	96.8	2.1	3.2
8	27.0	27.0	65.5	65.5	89.7	7.5	10.3
9	24.9	24.9	72.3	72.4	96.4	2.7	3.6
11	77.0	77.0	22.3	22.3	97.0	0.7	3.0
27	20.0	20.0	77.5	77.5	96.9	2.5	3.1
29	30.0	30.0	67.8	67.8	96.9	2.2	3.1
40	44.5	44.5	53.7	53.7	96.8	1.8	3.2
51	68.0	68.9	29.2	29.2	93.9	1.9	6.1
55	53.7	53.7	44.9	44.9	97.0	1.4	3.0
56	72.7	72.7	26.0	26.0	95.2	1.3	4.8
57	26.7	26.7	70.3	71.1	97.0	2.2	3.0
59	34.5	34.5	62.9	62.9	96.0	2.6	4.0
60	59.5	59.5	38.4	38.5	95.0	2.0	5.0
61	22.2	22.2	73.9	74.7	96.1	3.0	3.9
63	63.6	63.6	34.8	35.0	96.1	1.4	3.9
64	48.1	48.1	49.3	49.9	96.3	1.9	3.7
65	60.5	60.5	38.2	38.2	96.7	1.3	3.3
66	71.8	71.8	25.8	25.8	91.5	2.4	8.5
67	54.7	54.7	43.6	43.8	96.7	1.5	3.3
68	32.9	32.9	63.1	63.3	94.3	3.8	5.7
69	19.0	19.0	78.0	78.4	96.8	2.6	3.2
70	31.5	31.5	66.4	66.4	96.9	2.1	3.1
71	53.9	53.9	42.9	42.9	93.1	3.2	6.9
72	46.5	46.5	51.7	51.7	96.6	1.8	3.4
73	71.8	71.8	27.0	27.1	96.1	1.1	3.9
75	71.7	71.7	27.4	27.5	97.2	0.8	2.8
76	58.7	58.7	40.0	40.0	96.9	1.3	3.1
77	32.0	32.0	64.7	64.7	95.1	3.3	4.9
78	22.7	22.7	74.4	74.6	96.5	2.7	3.5
79	43.1	43.1	54.7	55.1	97.0	1.7	3.0
80	59.6	59.6	39.2	39.2	97.0	1.2	3.0
81	26.3	26.3	71.4	71.4	96.9	2.3	3.1
83	63.2	63.2	34.7	35.6	96.7	1.2	3.3
84	59.1	59.1	39.3	39.5	96.6	1.4	3.4
85	80.9	80.9	18.5	18.5	96.9	0.6	3.1
86	60.9	60.9	37.8	37.8	96.7	1.3	3.3
87	34.8	34.8	63.2	63.2	96.9	2.0	3.1
88	33.9	33.9	63.1	63.2	95.6	2.9	4.4
89	57.7	58.5	32.1	32.1	77.3	9.4	22.7
90	43.3	43.3	54.6	54.6	96.3	2.1	3.7
92	49.7	49.7	48.1	48.7	96.8	1.6	3.2
93	57.1	57.1	41.5	41.5	96.7	1.4	3.3
94	49.6	49.6	48.8	48.8	96.8	1.6	3.2
95	29.5	29.5	68.1	68.1	96.6	2.4	3.4
Tree mean value (%):	46.28	46.32	51.30	51.43	95.71	2.25	4.29

Table XXX A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Gunnarskog in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
178	3412	56.9	—	—	0.1	—	—	41.7	0.6	0.7
182	3614	67.4	—	—	—	—	—	31.9	—	0.7
183	3730	73.1	—	—	0.4	0.4	0.6	22.9	0.7	1.9
189	3513	84.7	—	—	0.1	0.3	0.9	13.1	0.6	0.3
301	4253	40.7	—	—	13.7	0.7	4.5	25.8	4.5	10.1
302	3854	57.2	—	—	0.8	—	—	40.2	0.4	1.4
303	4757	33.6	—	—	—	—	1.6	56.6	0.7	7.5
304	4412	65.8	—	—	—	—	—	27.5	1.9	4.8
305	4202	93.0	—	—	0.1	—	—	5.1	0.1	1.7
306	4104	75.9	—	—	—	—	—	22.9	—	1.2
307	3098	67.7	—	—	—	—	—	32.3	—	—
308	4143	23.0	—	—	—	0.1	—	75.1	—	1.8
309	4211	62.9	—	—	—	0.7	—	35.9	0.1	0.4
310	4812	62.3	—	—	—	0.8	—	36.5	—	0.4
311	3635	61.5	—	—	—	1.4	0.7	35.1	0.3	1.0
312	4299	36.9	—	—	—	0.4	—	62.7	—	—
313	3635	37.9	—	—	—	0.8	1.0	54.8	0.8	4.7
314	4081	37.8	—	—	—	0.6	1.9	58.1	—	1.6
315	3657	17.5	—	—	—	—	0.1	74.9	4.3	3.2
317	5172	40.3	—	0.5	—	1.3	0.8	56.8	—	0.3
318	4406	22.3	—	—	0.9	0.3	0.1	74.5	1.1	0.8
319	3909	42.4	—	—	—	0.1	0.1	55.4	0.1	1.9
320	3948	43.7	—	—	2.3	0.2	1.5	49.8	0.8	1.7
321	4043	73.5	—	—	0.2	—	—	21.9	—	4.4
322	3732	41.6	—	—	0.8	—	—	55.6	0.2	1.8
323	3751	31.4	—	—	—	1.6	—	65.8	0.8	0.4
324	4084	59.2	—	—	—	—	—	37.4	—	3.4
325	3339	47.0	—	—	—	—	0.4	15.9	34.5	2.2
326	4181	40.9	—	—	—	1.8	—	55.3	—	2.0
327	3093	59.6	—	—	3.7	1.8	0.2	33.1	—	1.6
328	4513	54.7	0.7	—	0.3	0.6	—	42.7	0.3	0.7
329	3247	42.8	—	—	0.5	2.4	0.4	51.0	0.4	2.5
330	3573	86.0	—	—	0.9	—	—	10.2	2.7	0.2
331	3651	49.9	—	0.8	0.8	0.8	—	45.4	0.8	1.5
332	4066	54.8	—	—	—	—	—	41.8	0.4	3.0
333	3179	72.4	—	—	—	—	1.5	23.9	—	2.2
334	3947	65.9	—	0.4	0.9	—	0.4	31.2	1.2	—
335	4493	35.0	—	0.8	—	0.9	0.1	62.1	0.1	1.0
336	4642	26.5	—	—	0.5	—	0.5	67.3	2.9	2.3
337	3644	72.2	—	—	—	—	0.7	25.7	1.4	—
338	3072	28.2	—	—	—	0.9	0.5	70.2	0.1	0.1
339	2912	30.6	—	—	—	—	—	68.5	0.1	0.8
340	3660	52.2	—	—	—	—	—	47.8	—	—
341	4554	34.5	—	—	—	0.1	0.1	64.4	0.3	0.6
342	3691	60.0	—	—	0.8	0.2	—	38.5	0.5	—
343	3716	53.4	—	—	0.1	—	0.7	45.3	0.5	—
344	3558	59.0	—	—	0.6	—	0.6	37.5	0.6	1.7
345	4298	63.0	—	—	—	—	—	33.9	—	3.1
346	3661	40.5	—	—	—	0.3	0.1	58.2	0.6	0.3
347	4188	62.7	—	—	—	—	—	36.9	—	0.4
Tree mean value (%):		52.04	0.01	0.05	0.57	0.39	0.40	43.54	1.31	1.69

Table XXX B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Gunnarskog in the year 1954.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
178	57.3	57.3	41.0	41.3	96.7	1.4	3.3
182	67.9	67.9	30.9	31.1	96.9	1.0	3.1
183	74.5	74.5	23.7	24.2	94.8	1.3	5.2
189	84.8	84.8	14.2	14.2	94.7	0.8	5.3
301	45.3	45.3	35.0	38.9	71.1	14.2	28.9
302	58.0	58.0	39.5	40.1	95.4	1.9	4.6
303	36.3	36.3	56.7	61.3	96.3	2.2	3.7
304	69.1	69.1	28.4	29.8	96.6	1.0	3.4
305	94.6	94.6	5.1	5.2	96.2	0.2	3.8
306	76.8	76.8	22.2	22.5	96.9	0.7	3.1
307	67.7	67.7	31.3	31.3	96.9	1.0	3.1
308	23.4	23.4	72.9	74.2	96.9	2.3	3.1
309	63.2	63.2	35.5	35.6	96.7	1.2	3.3
310	62.6	62.6	36.1	36.2	96.8	1.2	3.2
311	62.1	62.1	36.0	36.4	96.0	1.5	4.0
312	36.9	36.9	61.1	61.1	96.8	2.0	3.2
313	39.8	39.8	55.3	58.0	96.3	2.1	3.7
314	38.4	38.4	58.2	59.1	96.0	2.4	4.0
315	18.1	18.1	76.7	79.2	96.7	2.6	3.3
317	40.4	40.4	56.9	57.1	95.8	2.5	4.2
318	22.5	22.5	73.7	74.3	95.8	3.2	4.2
319	43.2	43.2	54.0	55.0	96.9	1.7	3.1
320	44.5	44.5	50.6	51.5	92.7	4.0	7.3
321	76.9	76.9	21.3	22.3	96.4	0.8	3.6
322	42.4	42.4	54.2	55.2	95.8	2.4	4.2
323	31.5	31.5	65.9	66.2	96.6	2.3	3.4
324	61.3	61.3	36.3	37.6	97.1	1.1	2.9
325	48.1	48.1	47.4	48.5	93.3	3.4	6.7
326	41.7	41.7	55.1	56.2	96.5	2.0	3.5
327	60.6	60.6	34.3	34.9	88.4	4.5	11.6
328	55.1	55.8	42.2	42.5	96.1	1.7	3.9
329	43.9	43.9	52.2	53.5	95.4	2.5	4.6
330	86.2	86.2	12.5	12.5	90.6	1.3	9.4
331	50.7	50.7	45.8	46.5	94.2	2.8	5.8
332	56.5	56.5	40.9	42.2	96.9	1.3	3.1
333	74.0	74.0	24.2	24.7	95.3	1.2	4.7
334	65.9	65.9	31.9	31.9	93.5	2.2	6.5
335	35.4	35.4	61.4	62.0	95.9	2.6	4.1
336	27.1	27.1	68.4	70.0	96.1	2.8	3.9
337	72.2	72.2	26.7	26.7	96.0	1.1	4.0
338	28.2	28.2	69.3	69.4	96.7	2.4	3.3
339	30.8	30.8	66.5	67.0	96.9	2.1	3.1
340	52.2	52.2	46.4	46.4	97.1	1.4	2.9
341	34.7	34.7	62.9	63.3	96.9	2.0	3.1
342	60.0	60.0	38.1	38.1	95.3	1.9	4.7
343	53.4	53.4	44.9	44.9	96.4	1.7	3.6
344	60.0	60.0	37.4	38.0	95.2	1.9	4.8
345	65.0	65.0	32.9	34.0	97.1	1.0	2.9
346	40.6	40.6	57.3	57.5	96.8	1.9	3.2
347	62.9	62.9	35.8	35.9	97.0	1.1	3.0
Tree mean value (%):	52.89	52.91	44.14	44.91	95.31	2.12	4.69

Table XXXI A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Skalstugan in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
2	2785	38.7	2.9	9.7	23.3	7.8	7.8	1.0	3.9	4.9
3	3570	24.0	4.9	45.3	3.2	12.1	0.8	3.2	0.8	5.7
4	3006	50.0	—	27.4	11.3	5.7	1.9	0.9	0.9	1.9
7	3221	26.3	11.0	29.1	18.2	2.7	6.4	2.7	2.7	0.9
9	3085	80.5	1.9	6.5	9.3	—	0.9	—	—	0.9
10	2892	39.7	5.5	31.9	14.6	3.7	3.7	—	—	0.9
11	2782	71.4	—	10.7	11.6	1.8	2.7	—	—	1.8
12	2594	73.7	—	10.5	7.9	4.4	—	—	—	3.5
13	2810	35.9	1.9	20.7	29.2	4.7	5.7	—	—	1.9
15	2338	53.4	0.6	17.6	21.0	1.7	1.1	1.7	0.6	2.3
16	2572	31.9	9.5	19.9	23.7	5.7	4.7	2.8	0.9	0.9
18	3015	34.3	5.6	28.2	4.7	5.6	0.9	4.7	—	16.0
19	3272	32.0	1.9	34.5	9.6	4.8	0.9	4.8	—	11.5
23	1826	67.7	2.8	8.3	15.7	0.9	—	—	—	4.6
24	2487	47.9	0.9	13.7	30.2	3.7	1.8	—	1.8	—
25	2431	59.7	2.7	9.8	18.8	4.5	2.7	0.9	—	0.9
26	2796	53.2	0.9	10.8	18.0	6.3	2.7	1.8	1.8	4.5
27	3232	64.8	2.6	—	30.8	—	0.9	—	—	0.9
28	2569	68.0	3.7	2.6	23.1	0.5	0.5	—	0.5	1.1
29	2631	56.7	5.2	2.9	31.4	0.9	—	—	0.9	2.0
30	2386	31.7	7.7	3.4	53.8	—	1.7	—	—	1.7
31	2784	48.3	4.6	7.4	36.0	—	0.9	—	—	2.8
33	2850	40.2	2.8	19.9	32.3	0.2	3.0	—	1.4	0.2
35	3100	19.6	4.5	38.9	31.6	1.8	1.8	—	—	1.8
42	3145	40.0	1.9	5.7	41.0	—	—	—	—	11.4
44	3012	35.3	1.8	26.2	33.9	0.8	0.9	—	0.9	0.2
45	2808	45.1	0.8	16.6	32.5	1.7	2.5	—	—	0.8
47	3315	48.5	1.9	8.8	25.3	7.8	1.9	1.0	1.9	2.9
49	3499	49.6	1.9	15.5	20.4	2.9	6.8	—	—	2.9
50	2659	41.1	1.0	18.1	31.7	0.9	2.7	—	—	4.5
51	2949	27.2	0.9	30.8	22.3	7.7	5.1	1.7	—	4.3
52	2862	36.9	2.7	25.7	19.5	8.0	2.7	2.7	—	1.8
53	3414	50.7	0.9	8.1	15.2	7.2	—	2.7	—	15.2
54	2817	56.3	3.9	11.4	18.1	2.6	1.0	—	1.0	5.7
55	2788	23.4	3.6	43.8	24.6	4.6	—	—	—	—
56	2747	47.2	1.9	9.4	23.6	5.7	2.8	3.8	0.9	4.7
57	2087	34.7	9.1	8.2	42.6	—	1.8	—	—	3.6
58	2993	20.2	6.9	30.9	35.1	4.3	1.7	—	—	0.9
59	2721	15.0	5.5	53.6	18.5	2.8	1.8	—	—	2.8
60	3640	17.3	7.6	24.5	45.1	2.8	0.9	0.9	—	0.9
61	3844	32.5	—	11.9	48.3	4.6	1.8	—	0.9	—
62	3592	6.0	5.8	46.7	36.5	2.0	0.9	—	—	2.1
63	2814	12.7	3.8	47.0	27.8	2.9	1.9	1.0	—	2.9
64	2435	45.3	—	12.1	27.3	8.4	4.6	—	—	2.3
65	2645	53.3	1.5	13.1	24.8	2.9	2.9	—	1.5	—
66	2267	47.7	4.0	14.5	31.1	0.7	0.7	—	—	1.3
67	2769	42.4	1.9	20.4	24.2	7.4	2.8	—	—	0.9
68	2448	48.2	—	24.9	21.1	1.9	1.0	—	1.0	1.9
69	3217	28.8	3.7	17.6	43.4	0.9	2.8	—	—	2.8
70	3207	26.5	2.8	29.4	34.0	5.5	0.9	—	—	0.9
Tree mean value (%):		41.63	3.20	19.69	25.54	3.53	2.13	0.77	0.48	3.03

Table XXXI B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Skalstugan in the year 1954.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
2	40.7	43.7	23.5	24.7	43.9	30.0	56.1
3	25.5	30.6	31.1	33.0	47.6	34.3	52.4
4	50.9	50.9	19.3	19.7	40.1	28.8	59.9
7	26.5	37.6	25.1	25.3	40.6	36.7	59.4
9	81.2	83.1	4.4	4.4	26.3	12.3	73.7
10	40.1	45.6	19.3	19.5	35.8	34.6	64.2
11	72.7	72.7	9.0	9.2	33.6	17.8	66.4
12	76.4	76.4	8.6	8.9	37.7	14.2	62.3
13	36.6	38.4	19.7	20.1	32.7	40.6	67.3
15	54.7	55.3	13.9	14.2	31.8	29.8	68.2
16	32.2	41.8	22.3	22.5	38.6	35.4	61.4
18	40.8	47.5	20.6	24.5	46.7	23.5	53.3
19	36.2	38.3	23.1	26.1	42.3	31.5	57.7
23	71.0	73.9	6.1	6.4	24.5	18.8	75.5
24	47.9	48.8	15.4	15.4	30.1	35.8	69.9
25	60.3	63.0	12.8	12.9	34.9	23.9	65.1
26	55.7	56.6	17.1	17.9	41.3	24.3	58.7
27	65.4	68.0	5.3	5.3	16.7	26.4	83.3
28	68.8	72.5	5.6	5.7	20.6	21.6	79.4
29	57.9	63.2	7.3	7.4	20.2	28.8	79.8
30	32.2	40.1	10.5	10.7	17.8	48.4	82.2
31	49.7	54.4	8.7	9.0	19.6	35.6	80.4
33	40.3	43.1	15.6	15.6	27.5	41.2	72.5
35	20.0	24.5	21.5	21.9	29.0	52.6	71.0
42	45.1	47.3	8.2	9.3	17.6	38.5	82.4
44	35.4	37.2	16.6	16.6	26.5	46.1	73.5
45	45.5	46.0	14.0	14.1	26.3	39.3	73.7
47	49.9	51.9	17.4	17.9	37.3	29.3	62.7
49	51.1	53.0	15.8	16.3	34.6	29.8	65.4
50	43.0	44.1	13.9	14.6	26.0	39.5	74.0
51	28.4	29.4	26.0	27.2	38.5	41.6	61.5
52	37.6	40.3	23.3	23.7	39.8	35.3	60.2
53	59.8	60.8	13.7	16.2	41.3	19.5	58.7
54	59.7	63.8	10.6	11.3	31.1	23.5	68.9
55	23.4	27.0	23.2	23.2	31.8	49.8	68.2
56	49.5	51.5	18.1	19.0	39.2	28.1	60.8
57	36.0	45.4	10.6	11.0	20.2	42.0	79.8
58	20.4	27.3	21.1	21.3	29.3	50.9	70.7
59	15.4	21.1	25.6	26.3	33.4	51.1	66.6
60	17.5	25.1	19.4	19.6	26.1	54.8	73.9
61	32.5	32.5	17.4	17.4	25.8	50.1	74.2
62	6.1	12.1	24.6	25.1	28.6	61.5	71.4
63	13.1	17.0	25.8	26.6	32.0	54.8	68.0
64	46.4	46.4	18.8	19.2	35.9	33.6	64.1
65	53.3	54.8	14.3	14.3	31.6	30.9	68.4
66	48.3	52.4	11.0	11.1	23.4	36.0	76.6
67	42.8	44.7	19.0	19.2	34.7	35.8	65.3
68	49.1	49.1	15.3	15.6	30.7	34.6	69.3
69	29.6	33.4	15.6	16.0	24.1	49.1	75.9
70	26.7	29.6	20.0	20.2	28.7	49.8	71.3
Tree mean value (%):	42.99	46.26	16.50	17.05	31.49	35.64	68.51

Table XXXII A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Kvikkjokk in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
1	2432	30.8	6.0	13.1	5.0	38.7	2.1	1.1	—	3.2
2	2662	47.6	4.6	11.7	5.7	13.7	3.8	8.3	2.3	2.3
3	3063	72.1	1.0	9.3	6.5	7.5	2.4	0.6	0.3	0.3
4	2260	38.7	11.7	17.6	14.0	12.2	2.3	0.5	1.5	1.5
5	2756	50.1	5.2	10.7	15.3	3.8	2.4	3.5	0.9	8.1
6	2286	46.9	0.7	7.0	2.2	23.0	1.0	18.6	0.2	0.4
7	2472	57.7	3.9	5.7	11.9	9.6	3.3	2.7	0.9	4.3
8	2860	18.4	15.6	27.2	35.9	1.3	0.4	0.2	—	1.0
9	1956	20.3	8.9	29.8	33.5	2.7	2.2	0.9	0.3	1.4
10	2609	39.3	2.1	16.4	12.1	19.6	3.2	4.3	0.1	2.9
11	2583	13.1	10.9	34.8	35.1	4.4	1.4	—	0.3	—
12	2751	80.4	1.3	6.8	7.2	0.5	1.9	—	1.5	0.4
13	2714	12.1	13.6	18.7	44.8	1.8	4.0	—	0.9	4.1
14	2109	29.9	10.3	3.8	44.9	1.1	7.1	—	1.2	1.7
15	2416	7.9	8.9	—	78.5	—	3.2	—	0.7	0.8
16	2722	26.5	12.7	21.0	36.8	—	1.8	—	—	1.2
17	2875	52.1	5.1	10.8	19.6	6.1	3.5	—	0.6	2.2
18	2782	52.7	4.0	17.7	19.6	1.2	2.5	—	0.3	2.0
19	2141	40.0	7.7	5.8	27.6	0.4	15.6	—	2.1	0.8
20	1840	49.5	8.9	18.9	18.1	—	2.3	—	1.4	0.9
21	2268	24.2	7.0	9.8	42.9	0.8	9.3	—	3.3	2.7
22	3245	39.4	18.5	14.1	22.9	0.8	3.2	—	—	1.1
23	2203	62.6	2.8	20.4	8.4	5.1	0.1	0.6	—	—
24	2338	37.0	2.0	21.2	36.1	1.1	0.8	0.2	0.2	1.4
25	2549	20.6	1.8	4.3	71.0	—	2.1	—	—	0.2
26	2658	37.0	0.8	4.7	48.5	—	4.3	—	—	4.7
27	2199	22.6	1.3	22.1	51.0	—	2.5	—	0.3	0.2
28	1883	10.0	2.3	37.4	44.2	3.1	2.9	—	0.1	—
29	2571	13.8	1.6	14.1	52.6	0.4	8.6	—	3.9	5.0
30	2896	27.4	—	16.7	49.3	0.9	2.6	1.4	0.7	1.0
31	2715	28.5	—	18.9	50.5	0.1	1.4	—	—	0.6
32	2504	71.4	0.2	8.8	15.6	2.0	0.1	0.3	0.3	1.3
33	2251	26.3	1.8	4.3	67.4	—	—	—	—	0.2
34	1896	55.9	0.7	1.0	37.4	—	1.1	—	—	3.9
35	2842	38.4	0.6	16.8	37.5	4.2	—	0.7	0.6	1.2
36	2820	65.1	—	1.3	2.0	4.3	0.5	18.3	2.3	6.2
37	2246	34.3	0.9	10.4	15.5	18.5	1.3	15.4	1.5	2.2
38	2433	36.3	—	3.4	12.0	11.3	17.2	6.4	12.6	0.8
39	3039	13.4	0.2	0.6	5.4	4.6	17.1	18.2	30.1	10.4
40	2323	18.2	—	0.2	14.5	13.7	11.1	25.5	11.5	5.3
41	2767	68.3	—	0.1	4.5	1.4	7.0	5.0	11.5	2.2
42	2605	23.3	0.2	5.6	15.2	12.1	16.2	15.7	8.6	3.1
44	2686	27.9	0.1	1.1	16.0	12.9	23.7	7.6	9.7	1.0
45	2288	35.5	0.3	4.9	32.2	7.4	16.9	1.2	1.6	—
46	1775	17.9	1.3	13.1	11.5	23.7	10.3	15.6	5.3	1.3
47	2786	57.5	0.1	2.2	6.8	9.0	9.3	4.6	5.3	5.2
48	2398	30.1	0.2	1.0	15.4	10.6	21.8	9.0	7.8	4.1
49	1985	33.9	0.4	5.0	11.4	22.9	20.2	3.1	2.7	0.4
50	1815	33.7	0.6	1.8	11.7	8.5	17.6	12.1	8.8	5.2
51	2612	8.1	0.6	2.3	11.7	7.6	46.4	5.5	13.8	4.0
Tree mean value (%):		36.09	3.79	11.09	25.91	6.69	6.84	4.14	3.16	2.29

Table XXXII B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Kvikkjokk in the year 1954.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0—I					
1	31.8	38.0	39.8	41.1	66.3	20.2	33.7
2	48.7	53.3	29.2	29.9	64.2	16.3	35.8
3	72.3	73.3	13.0	13.0	48.9	13.6	51.1
4	39.3	51.2	21.9	22.2	45.5	26.2	54.5
5	54.5	60.2	15.2	16.5	41.5	21.4	58.5
6	47.1	47.8	40.6	40.8	78.1	11.4	21.9
7	60.3	64.4	17.5	18.3	51.3	16.6	48.7
8	18.6	34.3	16.7	16.9	25.7	48.3	74.3
9	20.6	29.6	20.7	21.0	29.8	48.7	70.2
10	40.5	42.6	30.3	31.2	54.4	25.4	45.6
11	13.1	24.0	22.7	22.7	29.9	53.3	70.1
12	80.7	82.0	6.7	6.7	37.4	11.2	62.6
13	12.6	26.8	18.6	19.4	26.5	51.6	73.5
14	30.4	40.9	15.2	15.5	26.2	42.9	73.8
15	8.0	16.9	14.7	14.8	17.8	67.7	82.2
16	26.8	39.7	14.4	14.6	24.2	45.2	75.8
17	53.3	58.5	14.9	15.2	36.7	25.7	63.3
18	53.8	57.9	12.3	12.6	29.8	29.0	70.2
19	40.3	48.1	19.6	19.8	38.1	31.9	61.9
20	49.9	58.9	12.4	12.5	30.5	28.3	69.5
21	24.9	32.1	20.3	20.9	30.7	45.8	69.3
22	39.8	58.5	11.4	11.5	27.8	29.6	72.2
23	62.6	65.4	13.4	13.4	38.7	21.2	61.3
24	37.5	39.6	14.9	15.1	25.0	44.7	75.0
25	20.6	22.4	13.7	13.7	17.7	63.7	82.3
26	38.8	39.6	12.0	12.6	20.9	45.5	79.1
27	22.6	23.9	17.7	17.7	23.3	58.2	76.7
28	10.0	12.3	24.8	24.8	28.3	62.9	71.7
29	14.5	16.2	23.0	24.2	28.9	56.6	71.1
30	27.7	27.7	18.0	18.2	25.1	53.6	74.9
31	28.7	28.7	15.5	15.6	21.9	55.4	78.1
32	72.3	72.5	7.8	7.9	28.8	19.3	71.2
33	26.4	28.2	11.7	11.7	16.3	60.0	83.7
34	58.2	58.9	6.8	7.1	17.2	32.7	82.8
35	38.9	39.5	16.3	16.5	27.3	43.5	72.7
36	69.4	69.4	24.5	26.1	85.4	4.2	14.6
37	35.1	36.0	38.5	39.4	61.5	24.1	38.5
38	36.6	36.6	42.3	42.6	67.2	20.6	32.8
39	15.0	15.2	62.3	69.5	82.0	13.7	18.0
40	19.2	19.2	56.7	59.9	74.1	19.8	25.9
41	69.8	69.8	22.3	22.8	75.6	7.2	24.4
42	24.0	24.2	48.9	50.5	66.6	24.5	33.4
44	28.2	28.3	46.5	47.0	65.5	24.5	34.5
45	35.5	35.8	27.3	27.3	42.5	36.9	57.5
46	18.1	19.5	53.2	53.9	66.9	26.3	33.1
47	60.7	60.8	25.1	26.5	67.5	12.1	32.5
48	31.4	31.6	42.7	44.5	65.1	22.9	34.9
49	34.0	34.4	42.1	42.3	64.5	23.2	35.5
50	35.5	36.2	41.7	44.0	68.9	18.8	31.1
51	8.4	9.0	59.8	62.3	68.5	27.5	31.5
Tree mean value (%):	36.94	40.80	25.15	25.88	44.05	32.68	55.95

Table XXXIII A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Gällivare in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
1	2668	61.8	0.6	0.6	4.6	0.5	4.6	12.7	4.7	9.9
2	2884	56.6	0.9	1.6	5.9	2.9	4.1	7.6	3.6	16.8
3	2151	63.8	0.8	5.6	8.4	4.6	3.1	4.3	2.4	7.0
4	1938	34.5	—	8.6	6.0	24.4	3.4	13.4	3.2	6.5
5	2724	24.0	4.2	20.4	9.7	15.0	2.4	2.6	2.9	18.8
6	1539	49.6	2.8	10.7	16.2	8.9	3.3	3.1	3.0	2.4
7	1973	71.1	0.9	3.1	7.2	2.3	0.6	3.7	0.3	10.8
10	2259	65.1	3.0	9.5	4.4	10.3	0.5	4.7	0.2	2.3
11	2507	64.7	0.7	4.2	3.8	8.0	1.5	6.9	0.5	9.7
14	2618	33.9	6.0	8.1	12.9	10.6	3.7	18.7	1.9	4.2
18	2509	53.3	4.8	4.2	10.2	11.9	4.4	2.7	2.9	5.6
19	2995	65.1	5.4	4.4	7.7	5.9	3.0	2.0	3.8	2.7
21	2589	68.7	0.7	5.9	1.9	13.3	1.5	5.9	—	2.1
25	2270	54.1	—	1.8	2.2	8.4	1.2	20.2	1.8	10.3
26	2321	32.5	2.7	6.3	7.2	27.1	1.9	9.2	0.6	12.5
27	2047	41.5	3.0	1.6	6.2	4.5	4.4	10.3	4.0	24.5
28	2441	26.0	4.1	8.6	9.1	17.3	2.0	4.6	0.3	28.0
31	1761	62.9	3.9	1.4	5.3	2.5	0.6	4.3	0.4	18.7
32	2747	19.6	5.1	17.2	6.4	19.0	1.0	19.7	0.7	11.3
36	2097	67.2	1.7	7.2	2.3	10.0	1.1	2.7	—	7.8
37	1648	64.2	1.3	2.2	6.8	8.7	1.5	6.1	0.8	8.4
40	2762	27.9	1.6	14.0	18.4	9.3	3.3	10.0	2.5	13.0
41	2240	19.4	2.4	8.4	6.9	18.9	4.6	15.6	1.1	22.7
42	2249	23.0	9.6	18.1	23.8	9.5	4.8	0.8	0.4	10.0
43	2415	27.2	2.7	13.2	9.3	12.8	4.3	10.9	4.3	15.3
44	1391	23.2	10.4	18.3	17.2	13.1	1.1	0.9	0.1	15.6
47	2121	31.7	6.1	11.3	18.1	19.4	2.2	4.3	—	6.9
50	2021	41.1	2.8	3.3	13.4	7.3	7.2	4.0	1.6	19.3
75	2312	61.8	4.5	3.6	8.3	9.6	1.3	6.8	0.2	3.9
77	2036	34.7	5.5	5.1	10.0	11.7	2.5	6.1	1.3	23.1
78	1969	35.3	4.6	6.7	15.2	15.8	1.8	4.8	0.4	15.4
79	2680	45.6	9.3	10.0	11.5	11.4	3.2	3.5	0.7	4.8
81	1930	53.1	0.5	3.6	4.6	11.7	1.0	15.5	0.8	9.2
84	2028	26.7	2.5	3.5	7.7	4.0	2.2	11.7	2.1	39.6
88	1321	33.2	3.3	4.2	4.1	9.8	3.6	5.2	1.5	35.1
97	2503	46.4	2.2	3.8	7.4	6.9	0.4	15.1	0.8	17.0
98	2371	13.5	4.5	22.1	12.0	28.6	2.8	5.3	0.4	10.8
99	3001	98.6	0.6	—	0.5	—	0.1	0.1	—	0.1
100	2319	61.9	1.5	1.8	10.5	4.0	5.2	7.9	3.6	3.6
101	2304	23.9	4.2	15.7	7.1	26.9	4.6	7.0	3.5	7.1
102	2275	19.1	5.0	12.1	8.9	22.8	5.4	3.7	3.7	19.3
103	2158	18.0	3.3	2.5	12.3	14.3	5.3	17.1	2.0	25.2
105	1950	48.1	2.0	3.1	7.8	5.8	9.2	2.7	5.2	16.1
106	2550	59.2	3.1	5.2	6.0	7.4	1.7	11.9	0.5	5.0
108	2884	29.0	2.0	11.7	8.2	26.8	3.1	14.7	1.0	3.5
109	2232	45.6	3.1	7.1	7.7	13.0	2.8	7.1	2.8	10.8
113	2120	43.3	3.9	6.0	5.4	16.8	3.3	12.6	1.4	7.3
117	2132	54.6	2.8	3.8	7.8	13.6	2.7	8.3	2.7	3.7
1001	1824	69.3	4.4	1.5	15.8	2.0	1.3	0.1	0.1	5.5
1002	2131	34.8	4.4	10.2	17.7	11.5	5.2	10.9	3.4	1.9
Tree mean value (%):		44.59	3.31	7.26	8.96	11.62	2.92	7.80	1.72	11.82

Table XXXIII B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Gällivare in the year 1954.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
1	68.6	69.2	21.2	23.5	76.5	6.5	23.5
2	68.0	69.1	17.4	20.9	67.7	8.3	32.3
3	68.6	69.5	15.6	16.8	54.9	12.8	45.1
4	36.9	36.9	42.4	45.3	71.9	16.6	28.1
5	29.6	34.7	28.0	34.5	52.8	25.0	47.2
6	50.8	53.7	21.7	22.2	48.0	23.5	52.0
7	79.7	80.7	8.4	9.4	48.8	8.8	51.2
10	66.6	69.7	17.6	18.0	59.5	12.0	40.5
11	71.7	72.4	16.9	18.7	67.9	8.0	32.1
14	35.4	41.6	36.1	37.7	64.6	19.8	35.4
18	56.5	61.5	21.2	22.5	58.4	15.1	41.6
19	66.9	72.5	15.1	15.5	56.3	11.7	43.7
21	70.2	70.9	20.1	20.5	70.5	8.4	29.5
25	60.3	60.3	30.0	33.4	84.3	5.5	15.4
26	37.1	40.2	36.4	41.6	69.6	15.9	30.4
27	55.0	58.9	22.0	29.1	71.0	9.0	29.0
28	36.1	41.8	24.8	34.4	59.2	17.1	40.8
31	77.4	82.2	8.3	10.2	57.2	6.2	42.8
32	22.1	27.8	43.2	48.7	67.5	20.8	32.5
36	72.9	74.7	14.5	15.7	62.2	8.8	37.8
37	70.1	71.5	16.7	18.2	64.0	9.4	36.0
40	32.1	33.9	29.8	34.3	51.8	27.7	48.2
41	25.1	28.2	39.0	50.5	70.3	16.5	29.7
42	25.5	36.2	22.4	24.9	39.0	35.0	61.0
43	32.1	35.3	34.2	40.4	62.4	20.6	37.6
44	27.5	39.8	21.7	25.7	42.7	29.1	57.3
47	34.0	40.6	28.4	30.5	51.4	26.9	48.6
50	50.9	54.4	19.6	24.3	53.3	17.2	46.7
75	64.3	69.0	18.1	18.8	60.7	11.7	39.3
77	45.1	52.3	21.8	28.3	59.4	14.9	40.6
78	41.7	47.2	23.9	28.3	53.5	20.8	46.5
79	47.9	57.7	21.0	22.1	52.1	19.3	47.9
81	58.5	59.0	28.1	30.9	75.5	9.1	24.5
84	44.2	48.3	20.5	33.9	65.7	10.7	34.3
88	51.2	56.2	19.1	29.4	67.3	9.3	32.7
97	55.9	58.6	23.8	28.9	69.2	10.7	31.1
98	15.1	20.2	40.7	45.6	57.2	30.5	42.8
99	98.7	99.3	0.2	0.2	28.6	0.5	71.4
100	64.2	65.8	20.2	21.0	61.2	12.8	38.8
101	25.7	30.2	42.1	45.3	65.0	22.7	35.0
102	23.7	29.9	35.2	43.6	62.2	21.4	37.8
103	24.1	28.5	36.7	49.1	68.6	16.8	31.4
105	57.3	59.7	21.0	25.0	62.1	12.8	37.9
106	62.3	65.7	22.1	23.3	67.6	10.6	32.4
108	30.1	32.1	44.8	46.4	68.4	20.7	31.6
109	51.1	54.6	25.8	28.9	63.7	14.7	36.3
113	46.7	50.9	32.6	35.2	71.6	12.9	28.4
117	56.7	59.6	26.1	27.1	67.1	12.8	32.9
1001	73.3	78.0	5.7	6.0	27.4	15.1	72.6
1002	35.5	40.0	33.2	33.8	56.4	25.7	43.6
Tree mean value (%):	50.02	53.82	24.71	28.37	60.68	15.57	39.32

Table XXXIV A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Pajala in the year 1954.

Tree No.	Total number of seeds for 15 cones per tree	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
1	2064	65.3	—	0.5	12.3	2.4	3.3	6.2	5.7	4.3
2	2591	78.7	—	0.4	6.0	1.6	1.2	7.7	0.4	4.0
3	2583	62.0	—	0.7	9.8	3.9	2.9	17.2	1.2	2.3
4	2679	45.1	6.3	0.2	24.0	0.2	8.4	8.8	1.6	5.4
5	2456	49.4	1.1	0.9	9.1	—	2.0	26.2	5.8	5.5
6	2382	51.8	0.9	1.0	14.6	0.9	4.2	18.0	6.7	1.9
7	2448	65.7	0.4	—	7.1	1.2	3.6	18.1	3.9	—
8	2659	27.9	0.5	—	6.6	2.3	0.9	58.8	1.8	1.2
9	2576	50.0	0.5	1.4	11.5	0.9	1.4	28.6	1.8	3.9
10	2058	27.4	1.0	1.4	12.2	2.5	9.8	34.2	7.3	4.2
11	2394	46.4	0.8	0.7	5.2	0.7	3.7	31.0	1.7	9.8
12	3123	20.6	0.8	1.4	12.6	2.9	5.1	50.6	4.6	1.4
13	2052	76.1	3.6	—	8.7	0.4	3.8	4.9	1.6	0.9
14	2410	35.0	—	—	9.2	0.8	4.4	36.5	10.8	3.3
15	2685	49.8	0.4	0.4	1.9	0.4	4.2	34.4	6.6	1.9
16	2259	65.6	3.3	—	10.8	—	5.2	4.7	5.7	4.7
17	2693	67.4	0.3	—	1.6	—	0.3	27.1	2.0	1.3
18	2916	61.4	0.9	0.3	9.2	0.4	4.8	9.6	6.6	6.8
19	3293	68.8	3.0	0.5	12.6	0.5	0.8	11.3	1.3	1.2
20	2671	64.9	0.9	—	7.2	0.9	2.0	10.8	2.7	10.6
21	2263	32.9	0.8	0.9	1.5	2.5	3.3	47.2	6.0	4.9
22	2926	72.2	—	—	4.0	—	0.4	17.3	3.5	2.6
23	3134	50.6	1.4	—	5.0	—	1.4	27.4	13.3	0.9
24	3041	57.0	—	—	2.1	1.9	0.9	34.5	3.6	—
25	2300	75.4	0.9	—	2.7	0.4	2.7	11.9	2.7	3.3
26	2427	72.1	—	—	21.4	0.9	2.3	0.5	0.9	1.9
27	2949	70.5	—	0.6	2.7	3.3	1.5	20.8	0.6	—
28	2729	33.4	0.5	—	33.4	—	8.0	15.1	3.3	6.3
29	2834	60.0	—	—	10.2	3.1	4.6	19.0	0.4	2.7
30	3254	45.7	0.9	1.4	7.7	4.7	8.4	21.6	2.3	7.3
31	2771	41.5	—	1.1	2.2	3.3	3.0	46.3	0.9	1.7
32	2512	59.1	—	0.4	14.0	0.7	6.3	14.0	3.4	2.1
33	2104	30.9	1.9	1.0	12.6	1.0	6.7	30.9	8.3	6.7
34	2670	59.9	0.4	0.7	10.8	0.4	5.7	17.7	3.5	0.9
35	2745	47.0	0.7	0.4	2.1	3.5	—	42.2	0.2	3.9
36	2159	94.1	1.3	—	4.6	—	—	—	—	—
37	2463	65.8	2.3	0.9	9.6	0.9	5.5	9.1	0.9	5.0
38	2206	60.8	1.4	0.9	10.5	3.2	1.4	15.3	2.3	4.2
39	2672	60.0	2.8	0.5	15.6	1.4	6.0	9.3	2.9	1.5
40	2202	67.6	1.3	—	22.3	—	5.3	—	3.1	0.4
41	2637	68.1	1.3	4.9	9.8	2.6	1.8	11.1	0.4	—
42	2569	64.5	0.4	0.9	4.8	1.8	2.2	22.3	1.8	1.3
43	2417	56.8	—	1.3	7.7	1.8	4.4	25.8	—	2.2
44	2003	67.8	0.6	—	7.5	—	2.8	11.2	5.8	4.3
45	2003	50.6	—	—	2.1	1.3	2.6	39.1	1.7	2.6
46	2599	71.4	0.4	0.5	6.0	0.9	3.2	10.0	5.4	2.2
47	3385	76.8	—	—	1.3	2.3	1.3	15.8	0.9	1.6
48	3048	33.3	—	0.4	2.9	2.6	1.7	49.6	2.2	7.3
49	2748	50.1	—	1.3	1.6	3.9	0.9	39.8	0.4	2.0
50	2252	76.3	1.4	—	7.6	1.9	1.5	6.8	1.5	3.0
Tree mean value (%):		57.03	0.91	0.56	8.77	1.46	3.36	21.52	3.24	3.15

Table XXXIV B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Pajala in the year 1954.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
1	68.2	68.2	17.6	18.4	57.9	12.8	42.1
2	82.0	82.0	11.0	11.5	63.6	6.3	36.4
3	63.5	63.5	24.8	25.4	69.5	10.9	30.5
4	47.7	54.3	19.8	20.9	45.8	23.4	54.2
5	52.3	53.4	33.9	35.9	77.0	10.1	23.0
6	52.8	53.7	29.9	30.5	65.9	15.5	34.1
7	65.7	66.1	25.8	25.8	76.1	8.1	23.9
8	28.2	28.7	62.2	63.0	88.4	8.2	11.6
9	52.0	52.5	33.4	34.8	73.2	12.2	26.8
10	28.6	29.6	51.2	53.4	76.0	16.2	24.0
11	51.4	52.3	35.9	39.8	83.5	7.1	16.5
12	20.6	21.4	61.7	62.6	79.9	15.5	20.1
13	76.8	80.4	10.6	10.7	54.6	8.8	45.4
14	36.2	36.2	50.5	52.2	81.8	11.2	18.2
15	50.8	51.2	43.2	44.0	90.2	4.7	9.8
16	68.8	72.3	15.1	15.8	57.2	11.3	42.8
17	68.3	68.6	28.6	29.0	92.3	2.4	7.7
18	65.9	66.8	20.6	22.1	66.7	10.3	33.3
19	69.6	72.7	15.2	15.4	56.3	11.8	43.7
20	72.6	73.6	16.2	18.1	68.6	7.4	31.4
21	34.6	35.4	56.2	59.1	91.5	5.2	8.5
22	74.1	74.1	20.9	21.5	82.9	4.3	17.1
23	51.1	52.5	40.6	41.0	86.2	6.5	13.8
24	57.0	57.0	39.3	39.3	91.4	3.7	8.6
25	78.0	78.9	16.7	17.3	81.9	3.7	18.1
26	73.5	73.5	6.9	7.0	26.5	19.1	73.5
27	70.5	70.5	25.1	25.1	85.1	4.4	14.9
28	35.6	36.2	28.4	30.3	47.5	31.4	52.5
29	61.7	61.7	26.1	26.8	70.0	11.2	30.0
30	49.3	50.3	34.5	37.2	74.8	11.6	25.2
31	42.2	42.2	51.3	52.2	90.3	5.5	9.7
32	60.4	60.4	24.0	24.5	61.9	14.8	38.1
33	33.1	35.2	45.4	48.7	75.0	15.1	25.0
34	60.4	60.8	26.6	26.8	68.6	12.2	31.4
35	48.9	49.6	44.4	46.2	91.7	4.0	8.3
36	94.1	95.4	0.7	0.7	15.2	3.9	84.8
37	69.3	71.7	16.1	16.9	59.9	10.8	40.1
38	63.5	64.9	22.5	23.5	67.0	11.1	33.0
39	60.9	63.8	19.6	19.9	54.9	16.1	45.1
40	67.9	69.2	10.0	10.0	32.6	20.7	67.4
41	68.1	69.4	17.8	17.8	58.2	12.8	41.8
42	65.3	65.8	27.4	27.8	81.1	6.4	18.9
43	58.1	58.1	31.2	31.9	76.1	9.8	23.9
44	70.8	71.5	19.3	20.2	70.7	8.0	29.3
45	52.0	52.0	42.7	43.8	91.2	4.1	8.8
46	73.0	73.4	18.8	19.2	72.3	7.2	27.7
47	78.0	78.0	19.2	19.5	88.9	2.4	11.1
48	35.9	35.9	54.1	58.4	91.1	5.3	8.9
49	51.1	51.1	43.5	44.4	90.8	4.4	9.2
50	78.7	80.1	11.7	12.1	60.6	7.6	39.4
Tree mean value (%):	58.78	59.72	28.96	29.97	71.21	9.95	28.79

Table XXXV A. Regression of X_{12} on X_1 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2{}_{(12)1}$ in %
Stjernarp.........	$X_{12} = 717.5948 - 0.7832\ X_1$	52.0
,, ...	$X_{12} = 1{,}067.8852 - 2.6470\ X_1 + 0.002323\ X_1^2$	57.0
,, ...	$X_{12} = 417.5779 + 2.5966\ X_1 - 0.011147\ X_1^2 + 0.000011039\ X_1^3$	58.7
Gunnarskog.......	$X_{12} = 734.7315 - 0.6484\ X_1$	25.2
,, ...	$X_{12} = 847.1249 - 1.2428\ X_1 + 0.0007494\ X_1^2$	25.7
,, ...	$X_{12} = 896.4111 - 1.6668\ X_1 + 0.0018955\ X_1^2 - 0.00000098435\ X_1^3$	25.7
Skalstugan.......	$X_{12} = 680.1331 - 0.8928\ X_1$	28.2
,, ...	$X_{12} = 725.9451 - 1.2161\ X_1 + 0.0005497\ X_1^2$	28.2
,, ...	$X_{12} = 1{,}223.1531 - 6.4138\ X_1 + 0.0179824\ X_1^2 - 0.00001878497\ X_1^3$	28.9
Kvikkjokk.......	$X_{12} = 713.2032 - 1.2505\ X_1$	45.3
,, ...	$X_{12} = 1{,}003.6919 - 3.6661\ X_1 + 0.0047462\ X_1^2$	50.4
,, ...	$X_{12} = 910.0895 - 2.4191\ X_1 - 0.0004082\ X_1^2 + 0.000006692\ X_1^3$	50.5
Gällivare.........	$X_{12} = 772.4752 - 1.1089\ X_1$	39.4
,, ...	$X_{12} = 1{,}065.5435 - 3.5344\ X_1 + 0.00471199\ X_1^2$	46.6
,, ...	$X_{12} = 1{,}098.6456 - 4.0223\ X_1 + 0.00684628\ X_1^2 - 0.00000286937\ X_1^3$	46.6
Pajala...........	$X_{12} = 747.4290 - 0.9216\ X_1$	44.9
,, ...	$X_{12} = 800.1751 - 1.3496\ X_1 + 0.0008059\ X_1^2$	45.1
,, ...	$X_{12} = 1{,}071.9231 - 4.8232\ X_1 + 0.0146309\ X_1^2 - 0.0000172838\ X_1^3$	46.1
For the six populations.....	$X_{12} = 610.7006 - 0.5223\ X_1$	19.6
,, ...	$X_{12} = 813.1133 - 1.8298\ X_1 + 0.00192978\ X_1^2$	24.2
,, ...	$X_{12} = 1{,}096.9455 - 4.7699\ X_1 + 0.01124584\ X_1^2 - 0.0000090794\ X_1^3$	26.2

X_1 = thousand-grain weight in centigram of all seeds per cone

X_{12} = empty seeds (not damaged by insects) in per mille of all seeds not damaged by insects

(the per mille data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per mille}/1000}$)

Table XXXV B. Regression of X_{12} on X_2 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2_{(12)2}$ in %
Stjernarp.......	$X_{12} = 681.1022 - 0.2477\ X_2$	8.1
,, ...	$X_{12} = 358.2223 + 0.3661\ X_2 - 0.00028758\ X_2^2$	8.6
,, ...	$X_{12} = 261.4313 + 0.6408\ X_2 - 0.00054349\ X_2^2 + 0.000000078215\ X_2^3$	8.6
Gunnarskog.....	$X_{12} = 694.3939 - 0.2363\ X_2$	4.2
,, ...	$X_{12} = 78.7342 + 1.0431\ X_2 - 0.000658\ X_2^2$	4.5
,, ...	$X_{12} = 15{,}687.3931 - 47.2687\ X_2 + 0.048876\ X_2^2 - 0.000016825\ X_2^3$	6.3
Skalstugan.....	$X_{12} = 532.6233 - 0.1394\ X_2$	1.5
,, ...	$X_{12} = -406.8617 + 2.3450\ X_2 - 0.00162328\ X_2^2$	3.7
,, ...	$X_{12} = 19{,}068.2091 - 74.8735\ X_2 + 0.09942385\ X_2^2 - 0.000043647\ X_2^3$	12.5
Kvikkjokk.....	$X_{12} = 285.8425 + 0.1553\ X_2$	0.7
,, ...	$X_{12} = 2{,}444.4784 - 6.0047\ X_2 + 0.004362\ X_2^2$	3.0
,, ...	$X_{12} = 9{,}532.0811 - 36.2022\ X_2 + 0.047028\ X_2^2 - 0.00001999\ X_2^3$	3.1
Gällivare.......	$X_{12} = 342.4603 + 0.1988\ X_2$	1.6
,, ...	$X_{12} = 59.9105 + 1.1071\ X_2 - 0.0007190\ X_2^2$	1.8
,, ...	$X_{12} = 1{,}233.2574 - 4.7769\ X_2 + 0.0089276\ X_2^2 - 0.00000518511\ X_2^3$	1.9
Pajala.........	$X_{12} = 731.1608 - 0.3280\ X_2$	5.1
,, ...	$X_{12} = 1{,}303.9304 - 2.0543\ X_2 + 0.001288\ X_2^2$	5.7
,, ...	$X_{12} = 3{,}939.4664 - 14.1183\ X_2 + 0.019519\ X_2^2 - 0.00000910015\ X_2^3$	6.0
For the six populations...	$X_{12} = 510.0890 - 0.0756\ X_2$	1.3
,, ...	$X_{12} = 345.8429 + 0.3233\ X_2 - 0.0002319\ X_2^2$	1.7
,, ...	$X_{12} = 848.8229 - 1.4705\ X_2 + 0.0018327\ X_2^2 - 0.0000007672\ X_2^3$	2.2

X_2 = cone length of tenths of a millimetre

X_{12} = empty seeds (not damaged by insects) in per mille of all seeds not damaged by insects

(the per mille data transformed to corresponding angular value by the formula, angle = $\arcsin \sqrt{\text{per mille}/1000}$)

Table XXXV C. Regression of X_{12} on X_3 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2{}_{(12)3}$ in %
Stjernarp........	$X_{12} = 508.1110 - 0.0532\ X_3$	4.8
”	$X_{12} = 434.2663 + 0.0344\ X_3 - 0.0000238\ X_3^2$	5.3
”	$X_{12} = 242.9218 + 0.3833\ X_3 - 0.0002208\ X_3^2 + 0.000000034108\ X_3^3$	5.7
Gunnarskog.....	$X_{12} = 617.4014 - 0.1075\ X_3$	8.8
”	$X_{12} = 694.5924 - 0.2223\ X_3 + 0.00004075\ X_3^2$	8.9
”	$X_{12} = 577.7930 + 0.0419\ X_3 - 0.00015125\ X_3^2 + 0.0000000449599\ X_3^3$	9.0
Skalstugan......	$X_{12} = 546.8836 - 0.1364\ X_3$	8.7
”	$X_{12} = 444.3587 + 0.0992\ X_3 - 0.0001286\ X_3^2$	9.4
”	$X_{12} = 245.9277 + 0.8091\ X_3 - 0.0009307\ X_3^2 + 0.00000028725\ X_3^3$	9.6
Kvikkjokk......	$X_{12} = 326.2142 + 0.1106\ X_3$	2.1
”	$X_{12} = 343.0929 + 0.0554\ X_3 + 0.0000427\ X_3^2$	2.1
”	$X_{12} = 711.8976 - 1.7687\ X_3 + 0.0029219\ X_3^2 - 0.000001453\ X_3^3$	2.4
Gällivare........	$X_{12} = 443.9838 + 0.0566\ X_3$	0.4
”	$X_{12} = 293.0014 + 0.6800\ X_3 - 0.0006044\ X_3^2$	2.1
”	$X_{12} = 275.7904 + 0.8168\ X_3 - 0.0009204\ X_3^2 + 0.00000022233\ X_3^3$	2.1
Pajala..........	$X_{12} = 658.9095 - 0.2350\ X_3$	14.0
”	$X_{12} = 932.1889 - 1.1736\ X_3 + 0.000755\ X_3^2$	19.3
”	$X_{12} = 1{,}308.6784 - 3.2189\ X_3 + 0.004219\ X_3^2 - 0.0000018524\ X_3^3$	20.8
For the six populations....	$X_{12} = 479.3203 - 0.0317\ X_3$	1.7
”	$X_{12} = 461.0536 + 0.0062\ X_3 - 0.00001578\ X_3^2$	1.9
”	$X_{12} = 476.6112 - 0.0387\ X_3 + 0.00001964\ X_3^2 - 0.0000000078637\ X_3^3$	1.9

X_3 = cone weight in centigram

X_{12} = empty seeds (not damaged by insects) in per mille of all seeds not damaged by insects

(the per mille data transformed to corresponding angular value by the formula, angle = $\arcsin \sqrt{\text{per mille}/1000}$)

Table XXXV D. Regression of X_{12} on X_4 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2_{(12)4}$ in %
Stjernarp.......	$X_{12} = 267.3637 + 0.5788\ X_4$	2.0
,, ...	$X_{12} = 976.1953 - 4.5620\ X_4 + 0.009244\ X_4^2$	2.4
,, ...	$X_{12} = -23{,}937.5185 + 267.2005\ X_4 - 0.972766\ X_4^2 + 0.0011756\ X_4^3$	6.9
Gunnarskog.....	$X_{12} = 587.6677 - 0.4568\ X_4$	1.9
,, ...	$X_{12} = -464.8098 + 7.6552\ X_4 - 0.015389\ X_4^2$	5.7
,, ...	$X_{12} = -4{,}675.4912 + 56.3201\ X_4 - 0.200265\ X_4^2 + 0.000230936\ X_4^3$	7.4
Skalstugan....	$X_{12} = 674.5251 - 1.2916\ X_4$	13.9
,, ...	$X_{12} = 720.8418 - 1.7821\ X_4 + 0.001273\ X_4^2$	13.9
,, ...	$X_{12} = 2{,}294.5488 - 27.8442\ X_4 + 0.141938\ X_4^2 - 0.000247733\ X_4^3$	15.1
Kvikkjokk......	$X_{12} = 217.8711 + 1.0629\ X_4$	4.9
,, ...	$X_{12} = 713.1954 - 5.1574\ X_4 + 0.019129\ X_4^2$	6.1
,, ...	$X_{12} = 133.0204 + 5.7409\ X_4 - 0.047937\ X_4^2 + 0.000135397\ X_4^3$	6.1
Gällivare.......	$X_{12} = 460.6837 + 0.0940\ X_4$	0.05
,, ...	$X_{12} = 1{,}059.2811 - 8.2318\ X_4 + 0.028090\ X_4^2$	5.1
,, ...	$X_{12} = -3{,}379.5400 + 89.6896\ X_4 - 0.667744\ X_4^2 + 0.001598938\ X_4^3$	19.4
Pajala.........	$X_{12} = 606.7144 - 0.5674\ X_4$	1.8
,, ...	$X_{12} = 939.4376 - 4.4229\ X_4 + 0.0109706\ X_4^2$	2.3
,, ...	$X_{12} = -7{,}591.1809 + 143.9024\ X_4 - 0.8365159\ X_4^2 + 0.001591548\ X_4^3$	8.1
For the six populations...	$X_{12} = 473.0382 - 0.1139\ X_4$	0.3
,, ...	$X_{12} = 495.9057 - 0.3415\ X_4 + 0.0005275\ X_4^2$	0.3
,, ...	$X_{12} = 563.8826 - 1.3901\ X_4 + 0.0056639\ X_4^2 - 0.0000080026\ X_4^3$	0.4

X_4 = the total number of seeds per cone

X_{12} = empty seeds (not damaged by insects) in per mille of all seeds not damaged by insects

(the per mille data transformed to corresponding angular value by the formula, angle = $\arcsin \sqrt{\text{per mille}/1000}$)

Table XXXV E. Regression of X_{12} on X_7 for the six populations: Stjernarp, Gunnarskog, Skalstugan, Kvikkjokk, Gällivare and Pajala in the year 1954.

Population	Linear, quadratic and cubic regression equations	$R^2{}_{(12)7}$ in %
Stjernarp.........	$X_{12} = 703.4910 - 0.2685\,X_7$	46.9
,, ...	$X_{12} = 991.2181 - 0.8156\,X_7 + 0.0002437\,X_7^2$	51.4
,, ...	$X_{12} = 416.7925 + 0.8849\,X_7 - 0.0013479\,X_7^2 + 0.00000047112\,X_7^3$	53.3
Gunnarskog.......	$X_{12} = 704.2880 - 0.2194\,X_7$	25.9
,, ...	$X_{12} = 935.5814 - 0.6725\,X_7 + 0.00020978\,X_7^2$	28.5
,, ...	$X_{12} = 836.3888 - 0.3342\,X_7 - 0.00014694\,X_7^2 + 0.000000117685\,X_7^3$	28.6
Skalstugan.......	$X_{12} = 592.0811 - 0.2994\,X_7$	27.0
,, ...	$X_{12} = 648.4924 - 0.5045\,X_7 + 0.00017167\,X_7^2$	27.6
,, ...	$X_{12} = 836.7046 - 1.5180\,X_7 + 0.00183744\,X_7^2 - 0.00000084098\,X_7^3$	28.4
Kvikkjokk.......	$X_{12} = 572.1310 - 0.4228\,X_7$	21.4
,, ...	$X_{12} = 746.7817 - 1.2380\,X_7 + 0.000879\,X_7^2$	25.2
,, ...	$X_{12} = 1{,}430.0325 - 6.1400\,X_7 + 0.011606\,X_7^2 - 0.000007187\,X_7^3$	31.6
Gällivare.........	$X_{12} = 698.7048 - 0.5573\,X_7$	32.0
,, ...	$X_{12} = 817.6649 - 1.2038\,X_7 + 0.0008087\,X_7^2$	33.9
,, ...	$X_{12} = 842.4892 - 1.4149\,X_7 + 0.0013476\,X_7^2 - 0.0000004222\,X_7^3$	34.0
Pajala...........	$X_{12} = 689.5887 - 0.4031\,X_7$	36.8
,, ...	$X_{12} = 779.0972 - 0.8139\,X_7 + 0.0004255\,X_7^2$	38.2
,, ...	$X_{12} = 925.1422 - 1.8692\,X_7 + 0.0027425\,X_7^2 - 0.0000015635\,X_7^3$	39.1
For the six populations.....	$X_{12} = 512.5631 - 0.0957\,X_7$	8.6
,, ...	$X_{12} = 550.6939 - 0.2145\,X_7 + 0.00007282\,X_7^2$	9.3
,, ...	$X_{12} = 754.4627 - 1.1749\,X_7 + 0.00133875\,X_7^2 - 0.00000048454\,X_7^3$	14.6

X_7 = the weight in milligram of all seeds per cone

X_{12} = empty seeds (not damaged by insects) in per mille of all seeds not damaged by insects

(the per mille data transformed to corresponding angular value by the formula, angle = arcsin $\sqrt{\text{per mille}/1000}$)

Table XXXVI A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Gällivare in the year 1960.

Tree No.	Mean value of all seeds per cone	Embryo (0—IV) and endosperm types in per cent of all seeds									
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
5	180.7	38.7	—	0.7	0.4	2.0	0.3	7.7	0.3	49.9
10	124.0	43.9	0.2	0.5	1.1	1.8	0.2	23.8	—	28.5
12	86.4	49.2	0.3	0.2	1.2	1.7	0.6	23.1	1.1	22.6
17	152.4	46.8	—	0.2	9.2	1.7	0.9	10.9	0.2	30.1
18	126.7	45.7	0.2	1.1	3.2	2.9	2.2	14.3	0.8	29.6
19	142.1	62.1	0.7	0.2	6.6	1.0	1.5	16.5	0.4	11.0
21	137.7	74.4	0.8	0.7	0.6	6.5	0.4	12.2	0.2	4.2
22	121.4	48.0	0.2	0.6	20.9	2.3	4.8	7.7	0.5	15.0
31	68.0	32.4	0.3	0.2	1.8	0.2	0.2	0.2	—	64.7
75	133.2	45.6	0.2	0.6	3.9	0.4	0.5	9.5	—	39.3
99	141.6	95.3	0.2	—	0.3	—	—	—	—	4.2
102	140.8	27.0	0.1	0.2	2.2	2.6	1.3	3.4	—	63.2
103	115.4	18.1	—	1.0	1.6	0.9	0.6	9.8	—	68.0
104	104.5	28.7	0.7	0.7	2.9	1.7	1.2	13.6	0.2	50.3
110	83.3	33.3	—	7.5	9.2	10.8	1.6	17.1	1.8	18.7
113	122.4	55.1	0.2	0.2	6.0	0.4	1.8	8.8	0.3	27.2
119	139.5	42.2	0.2	—	3.1	0.7	0.9	12.5	0.4	40.0
122	113.3	48.7	0.7	0.9	2.2	1.6	1.4	27.1	1.2	16.2
124	95.7	73.8	0.6	0.1	1.6	0.5	0.2	12.2	0.3	10.7
125	103.4	45.7	—	—	0.9	1.5	1.2	1.2	0.2	49.3
176	123.9	45.7	0.8	0.2	8.4	2.7	1.1	14.8	—	26.3
186	46.9	65.5	—	0.6	20.1	0.3	0.6	1.9	0.9	10.1
194	57.4	73.1	—	0.4	0.7	0.3	—	1.1	0.3	24.1
195	155.3	58.8	—	0.9	2.7	—	0.9	17.5	0.6	18.6
Tree mean value (%):	117.33	49.91	0.27	0.74	4.62	1.85	1.01	11.12	0.40	30.08

Table XXXVI B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Gällivare in the year 1960.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
5	77.2	77.2	9.9	19.8	86.8	1.5	13.2
10	61.4	61.7	25.0	35.0	91.2	2.4	8.8
12	63.6	64.0	25.5	32.9	91.4	2.4	8.6
17	67.0	67.0	14.2	20.3	61.5	8.9	38.5
18	64.9	65.2	19.4	27.6	79.2	5.1	20.8
19	69.8	70.6	19.3	21.7	73.7	6.9	26.3
21	77.7	78.5	18.0	18.8	87.4	2.6	12.6
22	56.5	56.7	16.6	19.5	45.1	20.2	54.9
31	91.8	92.6	0.8	2.3	30.8	1.8	69.2
75	75.1	75.5	10.7	17.6	71.8	4.2	28.2
99	99.5	99.7	0.0	—	—	0.3	100.0
102	73.4	73.6	6.8	18.5	70.1	2.9	29.9
103	56.6	56.6	11.3	35.3	81.3	2.6	18.7
104	57.7	59.2	16.3	32.8	80.3	4.0	19.7
110	41.0	41.0	32.3	39.7	67.3	15.7	32.7
113	75.7	76.0	11.4	15.7	65.1	6.1	34.9
119	70.3	70.7	14.2	23.7	80.7	3.4	19.3
122	58.1	58.9	30.4	36.3	88.4	4.0	11.6
124	82.6	83.3	12.9	14.4	86.6	2.0	13.4
125	90.1	90.1	3.6	7.1	72.0	1.4	28.0
176	62.0	63.1	18.7	25.4	68.8	8.5	31.2
186	72.9	72.9	6.6	7.3	27.0	17.8	73.0
194	96.3	96.3	1.8	2.4	64.3	1.0	35.7
195	72.2	72.2	18.9	23.2	83.6	3.7	16.4
Tree mean value (%):	71.39	71.78	14.36	20.72	68.93	5.39	31.07

Table XXXVII A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Gällivare in the year 1961.

Tree No.	Mean value of all seeds per cone	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
5	199.1	19.6	1.3	7.3	7.1	13.3	11.0	6.4	5.0	29.0
7	168.9	23.7	—	—	0.2	0.4	0.9	0.9	—	73.9
12	108.3	6.8	—	0.9	2.8	—	—	0.5	0.5	88.5
17	175.3	11.9	—	1.9	5.8	2.8	2.7	2.5	2.1	70.3
18	158.1	39.6	—	3.4	5.1	6.3	6.7	3.0	3.8	32.1
19	181.8	20.1	—	4.7	4.7	2.0	2.2	4.9	4.9	56.5
20	133.3	24.2	—	0.7	3.1	1.4	0.4	0.7	0.7	68.8
21	211.9	68.1	2.2	3.3	5.4	5.2	3.3	5.4	2.8	4.3
22	95.1	25.6	0.5	2.8	14.6	0.5	2.5	0.9	1.5	51.1
31	125.4	36.0	0.3	2.3	6.1	1.2	1.2	0.8	—	52.1
75	164.1	32.1	1.1	5.1	9.4	6.4	5.8	1.4	2.1	36.6
84	124.5	31.1	0.4	1.8	3.1	0.4	2.2	0.9	0.9	59.2
97	159.2	12.4	0.4	—	1.1	0.9	0.9	0.4	2.2	81.7
98	153.4	19.4	—	4.4	10.0	3.6	8.9	1.3	5.8	46.6
99	193.2	85.5	—	—	0.8	—	1.2	—	0.2	12.3
100	159.7	42.5	0.3	0.6	4.4	1.5	2.1	3.9	2.4	42.3
101	164.3	13.7	0.4	22.9	11.6	24.2	6.2	9.1	3.1	8.8
102	188.5	7.8	0.5	3.1	5.6	9.8	6.2	2.0	3.4	61.6
103	132.9	7.7	—	4.1	6.1	7.6	5.8	8.8	0.9	59.0
104	118.3	23.6	0.4	4.4	8.7	3.1	3.5	1.3	1.8	53.2
105	119.0	48.8	—	2.6	5.4	1.6	5.9	1.6	3.3	30.8
116	127.0	15.8	—	1.4	5.6	2.7	2.7	6.3	0.9	64.6
123	177.1	18.3	0.9	5.1	12.4	6.0	4.6	1.4	0.9	50.4
125	149.8	17.2	—	—	1.9	0.4	—	0.8	1.6	78.1
176	90.3	27.8	—	3.1	8.7	1.5	4.7	0.8	0.8	52.6
188	52.0	51.4	0.8	2.3	12.2	0.4	1.5	—	0.8	30.6
189	85.0	51.2	—	—	4.9	—	1.7	—	0.5	41.7
190	105.8	16.2	0.4	4.2	15.3	2.6	7.3	1.3	1.3	51.4
192	77.4	33.9	2.1	2.9	12.7	5.1	2.8	2.1	2.5	35.9
193	57.5	18.3	—	—	2.6	—	—	—	0.9	78.2
194	57.8	32.9	0.4	3.6	5.4	1.5	4.3	0.4	4.4	47.1
195	124.2	28.7	0.8	6.7	2.7	4.3	8.5	0.4	1.9	46.0
197	105.0	25.5	2.8	6.0	11.7	8.4	4.9	6.0	5.1	29.5
1002	134.3	21.7	1.3	5.8	9.3	12.4	17.7	9.7	11.9	10.2
Tree mean value (%):	134.63	28.21	0.51	3.45	6.66	4.04	4.13	2.53	2.38	48.09

Table XXXVII B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Gällivare in the year 1961.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
5	27.6	29.4	33.2	46.8	66.3	16.9	33.7
7	90.8	90.8	1.9	7.3	79.2	0.5	20.8
12	59.1	59.1	1.7	14.8	36.2	3.0	63.8
17	40.1	40.1	10.1	34.0	56.7	7.7	43.3
18	58.3	58.3	18.3	27.0	64.7	10.0	35.3
19	46.2	46.2	14.9	31.3	63.7	8.5	36.3
20	77.6	77.6	3.5	11.2	50.0	3.5	50.0
21	71.2	73.5	16.4	17.1	64.6	9.0	35.4
22	52.4	53.4	7.6	15.5	33.3	15.2	66.7
31	75.2	75.8	4.4	9.2	37.9	7.2	62.1
75	50.6	52.4	15.9	25.1	52.6	14.3	47.4
84	76.2	77.2	4.7	11.5	50.5	4.6	49.5
97	67.8	69.9	4.0	21.9	72.7	1.5	27.3
98	36.3	36.3	19.0	35.6	55.9	15.0	44.1
99	97.5	97.5	1.2	1.4	54.5	1.0	45.5
100	73.7	74.2	9.6	16.6	64.4	5.3	35.6
101	15.0	15.5	45.9	50.3	59.5	31.2	40.5
102	20.3	21.6	19.5	50.8	64.8	10.6	35.2
103	18.8	18.8	22.1	53.9	66.4	11.2	33.6
104	50.4	51.3	10.8	23.1	47.4	12.0	52.6
105	70.5	70.5	11.8	17.1	57.8	8.6	42.2
116	44.6	44.6	12.4	35.0	63.3	7.2	36.7
123	36.9	38.7	14.1	28.4	46.4	16.3	53.6
125	78.5	78.5	2.9	13.2	61.7	1.8	38.3
176	58.6	58.6	8.5	17.9	43.4	11.1	56.6
188	74.1	75.2	4.8	6.9	27.9	12.4	72.1
189	87.8	87.8	2.4	4.1	33.8	4.7	66.2
190	33.3	34.1	13.6	28.0	42.5	18.4	57.5
192	52.9	56.2	13.5	21.1	48.0	14.6	52.0
193	83.9	83.9	1.2	5.5	34.3	2.3	65.7
194	62.2	62.9	10.8	20.4	55.1	8.8	44.9
195	53.1	54.6	14.5	26.9	59.2	10.0	40.8
197	36.2	40.1	24.8	35.2	58.8	17.4	41.2
1002	24.2	25.6	46.6	51.9	69.8	20.2	30.2
Tree mean value (%):	55.94	56.77	13.14	24.09	54.21	10.06	45.79

Table XXXVIII A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Kiruna in the year 1960.

Tree No.	Mean value of all seeds per cone	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
1	167.4	79.9	—	0.9	3.0	3.9	1.4	7.4	1.8	1.7
3	149.3	65.9	0.3	4.3	15.4	6.3	1.2	3.3	0.8	2.5
4	118.3	74.2	—	1.1	9.2	1.6	1.0	0.9	0.6	11.4
6	126.4	84.0	0.1	0.7	9.9	0.4	0.5	0.3	0.4	3.7
10	96.7	83.5	—	0.5	7.7	1.2	3.3	1.4	1.9	0.5
11	151.4	65.9	—	1.1	5.8	5.5	2.4	11.5	2.9	4.9
17	138.4	80.2	—	1.2	13.0	1.2	1.0	1.5	—	1.9
19	92.9	72.2	0.5	1.0	20.9	0.6	1.6	0.1	0.3	2.8
22	121.0	73.4	0.8	2.2	15.8	0.4	5.8	0.4	0.4	0.8
25	152.6	72.0	0.3	2.6	19.2	3.4	1.2	0.6	0.6	0.1
27	56.3	81.6	—	0.4	14.6	—	1.1	—	0.3	2.0
29	174.2	69.3	0.8	2.8	12.1	8.5	1.7	2.0	—	2.8
34	148.6	73.2	—	2.5	11.8	6.2	3.1	2.4	0.2	0.6
35	77.8	79.4	—	5.4	2.6	1.3	1.0	2.6	0.6	7.1
38	127.4	67.3	—	0.4	16.1	1.2	5.6	2.6	1.7	5.1
39	106.6	91.8	—	—	4.3	—	—	—	—	3.9
50	133.2	81.1	—	4.1	10.4	1.4	1.2	0.2	—	1.6
53	125.3	63.9	0.9	3.6	25.4	2.3	3.1	0.6	—	0.2
54	129.6	80.9	—	—	11.3	0.1	0.3	—	—	7.4
55	138.4	75.0	0.2	2.9	11.4	3.3	2.3	0.4	0.2	4.3
Tree mean value (%):	126.59	75.74	0.20	1.89	12.00	2.44	1.94	1.91	0.64	3.27

Table XXXVIII B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Kiruna in the year 1960.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
1	81.3	81.3	13.8	14.0	75.0	4.6	25.0
3	67.6	67.9	13.8	14.2	44.1	17.5	55.9
4	83.7	83.7	5.2	5.9	36.1	9.2	63.9
6	87.2	87.3	3.1	3.2	25.4	9.1	74.6
10	83.9	83.9	7.8	7.8	48.8	8.2	51.2
11	69.3	69.3	21.3	22.4	72.9	7.9	27.1
17	81.8	81.8	5.5	5.6	30.7	12.4	69.3
19	74.3	74.8	5.5	5.7	22.4	19.0	77.6
22	74.0	74.8	8.4	8.5	33.6	16.6	66.4
25	72.1	72.4	8.6	8.6	31.2	19.0	68.8
27	83.3	83.3	3.4	3.5	20.7	13.0	79.3
29	71.3	72.1	12.9	13.3	47.6	14.2	52.4
34	73.6	73.6	12.5	12.6	47.7	13.7	52.3
35	85.5	85.5	7.2	7.8	53.3	6.3	46.7
38	70.9	70.9	11.6	12.2	42.0	16.0	58.0
39	95.5	95.5	0.6	0.6	14.0	3.7	86.0
50	82.4	82.4	5.2	5.3	30.1	12.1	69.9
53	64.0	64.9	9.8	9.8	28.0	25.2	72.0
54	87.4	87.4	2.0	2.2	17.1	9.7	82.9
55	78.4	78.6	7.7	8.0	37.6	12.8	62.4
Tree mean value (%):	78.37	78.57	8.30	8.56	37.92	12.51	62.09

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Table XXXIX A. The distribution of all seeds per mean cone in per cent, into embryo and endosperm types and the group of seeds damaged by insects, for individual trees at Kiruna in the year 1961

Tree No.	Mean value of all seeds per cone	Embryo (0—IV) and endosperm types in per cent of all seeds								
		Empty seeds (not damaged by insects)		Seeds with embryo (not damaged by insects)						Seeds damaged by insects
		0	I	II A	II B	III A	III B	IV A	IV B	
1	182.6	44.3	—	5.0	39.5	—	4.5	—	0.7	6.0
3	166.7	9.0	—	9.4	73.5	0.9	4.0	0.5	1.8	0.9
4	85.3	73.0	0.3	2.5	23.3	—	0.6	—	0.3	—
5	94.0	84.4	0.5	—	6.0	—	—	—	—	9.1
6	174.8	36.7	—	4.6	56.4	—	1.1	—	0.4	0.8
7	118.2	78.2	—	—	20.2	—	1.2	—	—	0.4
8	125.6	36.9	0.4	5.9	44.4	—	1.7	—	—	10.7
13	83.0	65.8	—	—	32.9	—	0.4	—	—	0.9
18	81.5	78.8	—	1.2	13.2	1.2	1.2	0.4	0.4	3.6
22	42.1	70.7	—	—	23.5	—	4.7	—	0.4	0.7
25	107.9	55.6	1.8	4.5	34.0	0.9	1.4	0.4	0.5	0.9
29	155.2	31.0	1.2	0.4	65.9	—	0.4	—	—	1.1
30	146.3	49.0	1.3	6.9	38.9	—	2.3	—	—	1.6
34	170.6	18.3	4.0	2.2	71.2	—	1.8	—	0.5	2.0
35	82.3	62.4	—	0.3	30.6	—	0.9	—	—	5.8
39	51.6	82.9	—	—	15.8	—	—	—	—	1.3
40	63.7	68.6	—	—	29.8	—	1.1	—	—	0.5
47	117.4	27.8	—	0.4	66.9	—	0.4	—	—	4.5
49	104.7	14.7	2.0	4.5	71.7	—	1.2	—	—	5.9
50	131.6	51.3	—	0.4	41.5	—	3.2	—	0.4	3.2
51	109.2	68.2	—	—	28.9	—	0.4	—	—	2.5
52	100.2	41.8	1.7	4.6	44.8	—	0.8	—	—	6.3
54	63.9	84.9	—	—	10.2	—	0.7	—	—	4.2
55	80.1	70.2	0.4	—	25.4	—	2.0	—	—	2.0
Tree mean value (%):	109.94	54.35	0.57	2.20	37.85	0.13	1.50	0.05	0.23	3.12

Table XXXIX B. Empty seeds, seed germination rates and seeds with embryo unable to germinate at Kiruna in the year 1961.

(Calculated values)

Tree No.	Empty seeds (not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo
	embryo type 0	embryo type 0+I					
1	47.1	47.1	11.6	12.3	23.3	38.1	76.7
3	9.1	9.1	20.1	20.3	22.3	70.0	77.7
4	73.0	73.3	5.1	5.1	19.1	21.6	80.9
5	92.8	93.4	0.9	1.0	15.0	5.1	85.0
6	37.0	37.0	11.3	11.4	18.1	51.2	81.9
7	78.5	78.5	3.9	3.9	18.2	17.5	81.8
8	41.3	41.8	10.0	11.2	19.2	42.0	80.8
13	66.4	66.4	5.2	5.2	15.6	28.1	84.4
18	81.7	81.7	5.0	5.2	28.4	12.6	71.6
22	71.2	71.2	7.2	7.3	25.2	21.4	74.8
25	56.1	57.9	9.3	9.4	22.3	32.4	77.7
29	31.3	32.6	10.3	10.4	15.4	56.4	84.6
30	49.8	51.1	10.0	10.2	20.8	38.1	79.2
34	18.7	22.8	13.2	13.5	17.4	62.5	82.6
35	66.2	66.2	5.3	5.6	16.7	26.5	83.3
39	84.0	84.0	2.4	2.4	15.2	13.4	84.8
40	68.9	68.9	5.3	5.3	17.2	25.6	82.8
47	29.1	29.1	10.5	11.0	15.5	57.2	84.5
49	15.6	17.7	13.2	14.0	17.1	64.2	82.9
50	53.0	53.0	9.0	9.3	19.8	36.5	80.2
51	69.9	69.9	4.6	4.7	15.7	24.7	84.3
52	44.6	46.4	8.9	9.5	17.7	41.3	82.3
54	88.6	88.6	2.0	2.1	18.3	8.9	81.7
55	71.6	72.0	5.2	5.3	19.0	22.2	81.0
Tree mean value (%):	56.06	56.65	7.90	8.15	18.85	34.06	81.15

Table XL A. Distribution of seeds to embryo and endosperm classes in Norway spruce after open-pollination and selfing at Åkersberga in the year 1954.

(Calculated values)

Mother tree No.	Progeny No.	Cross type	Total number of seeds per 10 cones	Embryo (0—IV) and endosperm types and seeds damaged by insects in per cent of all seeds								
				Empty seeds (not damaged by insects)	Seeds with embryo (not damaged by insects)							Seeds damaged by insects
				0	I	II A	II B	III A	III B	IV A	IV B	
1	9 obtained after selfing = I_1	O.p.	2082	72.9	2.0	0.8	—	0.7	—	22.7	—	0.9
	9 I_1	selfed	2491	98.6	0.1	—	—	—	—	1.3	—	—
	15 I_1	O.p.	2941	44.1	0.9	—	—	—	—	52.3	—	2.7
	15 I_1	selfed	2791	99.9	—	—	—	—	—	0.1	—	—
3	21 I_1	O.p.	1531	86.6	—	—	—	—	—	10.9	—	2.5
	21 I_1	selfed	1433	100.0	—	—	—	—	—	—	—	—
	26 I_1	O.p.	2114	67.1	—	—	—	—	—	28.0	—	4.9
	26 I_1	selfed		Cones have not developed								
	31 I_1	O.p.	1507	50.4	—	—	—	—	—	48.8	—	0.8
	31 I_1	selfed	1540	99.6	—	—	—	—	—	0.4	—	—
1	47 O.p.	O.p.	1783	27.8	—	—	—	—	—	70.2	—	2.0
	47 O.p.	selfed	2162	98.7	—	—	—	—	—	1.3	—	—
3	87 O.p.	O.p.	2429	37.0	—	—	—	—	—	63.0	—	—
	87 O.p.	selfed	2149	97.1	—	—	—	—	—	2.9	—	—
1	49 obtained after O.p.	O.p.	2654	44.4	1.0	0.7	—	1.4	—	51.0	—	1.5
	53 "	O.p.	2933	51.2	1.1	0.7	—	2.8	—	43.2	—	1.0
	73 "	O.p.	2752	33.8	2.4	0.7	—	—	—	61.2	—	1.9
	78 "	O.p.	3105	25.3	0.1	—	—	—	—	72.1	—	2.5
3	82 obtained after O.p.	O.p.	1964	65.4	0.4	—	—	—	—	30.1	—	4.1
	92 "	O.p.	2317	35.5	1.0	—	—	—	—	62.5	—	1.0
	93 "	O.p.	2036	46.3	—	—	—	—	—	53.4	—	0.3
	96 "	O.p.	2473	31.0	0.8	1.7	—	1.7	—	64.8	—	—

O.p. = Open—pollinated

Table XL B. Percentage of empty seed, seed germination rate and seed (not damaged by insects) with embryo unable to germinate at Åkersberga in the year 1954.

(Calculated values)

Mother tree No.	Progeny No.	Cross type	Empty seeds not damaged by insects) in per cent of all seeds not damaged by insects		Germination rate in per cent of total number of seeds	Germination rate in per cent of all seeds not damaged by insects	Germination rate in per cent of all seeds (not damaged by insects) with embryo	Seeds (not damaged by insects) with embryo unable to germinate in per cent of total number of seeds	Seeds (not damaged by insects) with embryo unable to germinate in per cent of all seeds (not damaged by insects) with embryo	Number of seeds classified
			embryo type 0	embryo type 0+I						
1	9 obtained after selfing = I_1	O.p.	73.6	75.6	22.9	23.1	94.6	1.3	5.4	300
	9 I_1	selfed	98.6	98.7	1.3	1.3	100.0	—	—	300
	15 I_1	O.p.	45.3	46.2	50.7	52.1	96.9	1.6	3.1	300
	15 I_1	selfed	99.9	99.9	0.1	0.1	100.0	—	—	300
3	21 I_1	O.p.	88.8	88.8	10.6	10.9	97.2	0.3	2.8	300
	21 I_1	selfed	100.0	100.0	—	—	—	—	—	300
	26 I_1	O.p.	70.6	70.6	27.2	28.6	97.1	0.8	2.9	313
	26 I_1	selfed	Cones have not developed							
	31 I_1	O.p.	50.8	50.8	47.3	47.7	96.9	1.5	3.1	300
	31 I_1	selfed	99.6	99.6	0.4	0.4	100.0	—	—	300
1	47 O.p.	O.p.	28.4	28.4	68.1	69.5	97.0	2.1	3.0	300
	47 O.p.	selfed	98.7	98.7	1.3	1.3	100.0	—	—	300
3	87 O.p.	O.p.	37.0	37.0	61.1	61.1	97.0	1.9	3.0	300
	87 O.p.	selfed	97.1	97.1	2.8	2.8	96.6	0.1	3.4	300
1	49 obtained after O.p.	O.p.	45.1	46.1	50.9	51.7	95.9	2.2	4.1	300
	53 "	O.p.	51.7	52.8	44.5	44.9	95.3	2.2	4.7	400
	73 "	O.p.	34.5	36.9	59.6	60.8	96.3	2.3	3.7	300
	78 "	O.p.	25.9	26.1	69.9	71.7	96.9	2.2	3.1	300
3	82 obtained after O.p.	O.p.	68.2	68.6	29.2	30.4	97.0	0.9	3.0	299
	92 "	O.p.	35.9	36.9	60.6	61.2	97.0	1.9	3.0	300
	93 "	O.p.	46.4	46.4	51.8	52.0	97.0	1.6	3.0	300
	96 "	O.p.	31.0	31.8	64.9	64.9	95.2	3.3	4.8	264

O.p. = Open—pollinated

Table XLI. Germinating ability of all seeds and of all seeds not damaged by insects (after 30 days in the Jacobsen germinator), number of seeds per cone, and thousand-grain weight in cg. for induvidual trees and different cross types at Åkersberga in the year 1954.

Mother tree No.	Progeny No.	Cross type	Thousand-grain weight in cg.	Germination rate in per cent of all seeds	Germination rate in per cent of all seeds not damaged by insects
1	9 obtained after selfing = I_1	O.p.	288	22.2	22.4
	9 I_1	selfed	129	0.5	0.5
	15 I_1	O.p.	382	52.5	54.0
	15 I_1	selfed	91	0.1	0.1
3	21 I_1	O.p.	192	14.3	14.7
	21 I_1	selfed	115	—	—
	26 I_1	O.p.	284	25.7	27.0
	26 I_1	selfed	Cones have not developed		
	31 I_1	O.p.	318	46.5	46.9
	31 I_1	selfed	127	0.4	0.4
1	47 O.p.	O.p.	498	65.6	66.9
	47 O.p.	selfed	183	1.3	1.3
3	87 O.p.	O.p.	475	60.8	60.8
	87 O.p.	selfed	231	2.7	2.7
1	49 obtained after O.p.	O.p.	418	51.2	52.0
	53 »	O.p.	421	47.1	47.6
	73 »	O.p.	410	55.5	56.6
	78 »	O.p.	367	65.6	67.3
3	82 obtained after O.p.	O.p.	335	29.3	30.6
	92 »	O.p.	438	63.4	64.0
	93 »	O.p.	431	53.4	53.6
	96 »	O.p.	469	65.6	65.6

O.p. = Open-pollinated