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External factors influencing female flowering in *Picea abies* (L.) Karst.

Inverkan av yttre faktorer på honblomningen hos gran

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Abstract

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Inventories of the cone crop in the vicinity of meteorological stations in southern Sweden were made in the years 1973—1975. Correlations between cone crop and the following variables for the year of flower primordia initiation—cone crop, some temperature variables and precipitation—were calculated. The relationship between cone crop and some other factors was studied briefly. The investigation revealed that high temperature during the middle or end of June provokes increased flowering, on the condition that the cone crop during the year of flower primordia initiation is scanty. High precipitation during June may have a negative effect on the flowering.

Similar studies on the relationship between cone crop and temperature, precipitation and cone crop in the year of bud differentiation were conducted using the data collected by the National Forest Survey during the years 1961—1974. These correlations supported the observations made in our own inventories.

Concerning the location of seed orchards of Picea abies, *the results suggest that the south-eastern part of Sweden is most suitable.*

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1 Introduction

During recent years discussions concerning the establishment of new seed orchards of *Picea abies* in southern Sweden have taken place. It is therefore important that information be obtained concerning the optimum location of these future seed orchards. From earlier investigations (Tirén 1935, Hagner 1965b, Eriksson *et al.* 1975) it is known that there is a periodicity in the flowering of *Picea abies*. Tirén (1935) and Eriksson *et al.* (1975) suggested that the weather conditions during flower primordia initiation were of decisive importance to flowering frequency. A definite evaluation of the effect of weather conditions in this respect should therefore be of value. Since inventories of the cone crop were carried out by the National Forest Survey from 1953 onwards, we started an analysis of the relationship of the cone crop and the weather conditions during the year of flower primordia initiation, making use of the data on cone crops collected by the National Forest Survey during 1961—1974.

This material suffered from some shortcomings, the most important being the absence of examinations of the same stands each year. With this in mind, the preliminary reports of a great variation in the cone crop in different parts of southern Sweden in 1973 were taken as an indication that a new inventory would be worthwhile. Accordingly, an inventory was planned which would include stands of *Picea abies* growing in the vicinity of meteorological stations in southern Sweden. This would provide the best opportunity to study the relationship of the cone crop and the weather conditions at the time of flower primordia initiation. Inventories of the same stands were carried out during the three-year period, 1973—1975.

1.1 **Literature review**

1.1.1 *Initiation and development of the buds*

The proportion of bud primordia which differentiates in a generative direction is of the greatest importance to cone production. It is now generally accepted that there is no fundamental difference between the meristems producing primordia which become floral and those which remain vegetative.

Thus, all buds, after a similar initial stage, will subsequently differentiate. Tirén (1935) assumed that the time for differentiation into generative and vegetative buds in Norway spruce took place during August. Brunkener (1973) performed a microscopic investigation of material collected in Stockholm and its environs. For *Picea abies* he observed the following as periods during which it was possible to identify certain steps in the generative bud development:

	Primordium	
	Megasporangiate	Microsporangiate
Ovuliferous scales began to appear	20.7—5.8	
Sporangium began to develop	27.8—10.9	1.8—15.8
Spore mother cells developed	1.9—5.10	October
Integument began to grow out	10.4—1.5	
Meiosis (metaphase I) was detected	20.4—10.5	22.4—9.5

The author pointed out that it was rather difficult to identify the time at which the

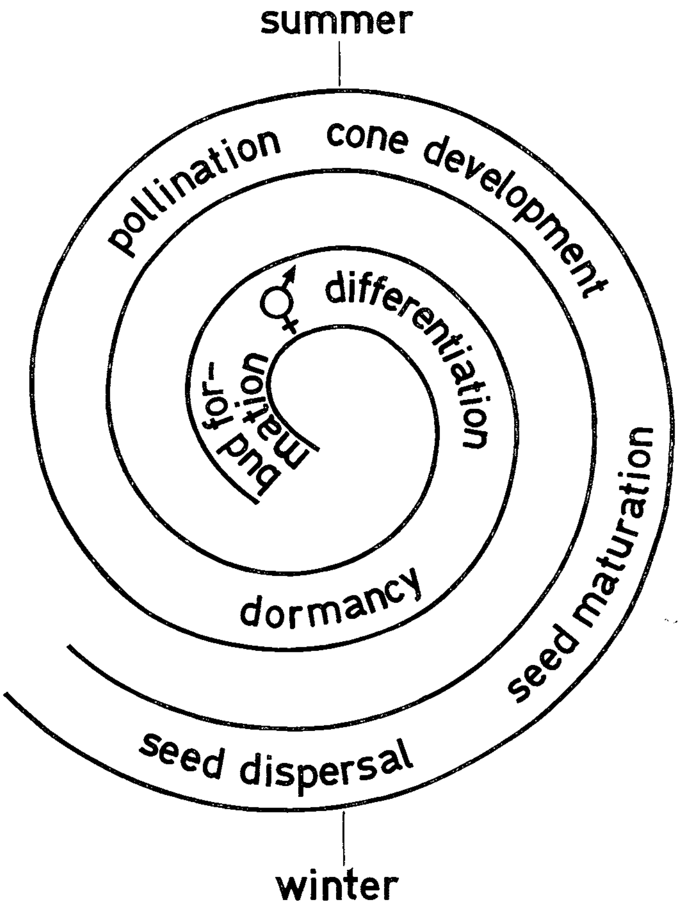


Figure 1. Schematic illustration of the generative development in *Picea abies*.

megasporangium development started and, in the case of the development of the microspore mother cells, even more difficult; consequently in the latter case he gave only the month in which he observed the onset of the development. Similar results were obtained by Laura (1975) for *Picea abies* growing in Latvia.

Varnell and Romberger (1967) noted that by late summer *Picea abies* male strobili are smooth hemispheres while vegetative buds and female strobili are parabolic. The vegetative and female buds remain superficially similar until winter, when ovuliferous scale primordia appear in the strobilus. The apical meristems of these two remain unchanged throughout the winter, but the male meristem declines and practically disappears in the autumn.

As regards other spruce species and Douglas fir, flower bud initiation also occurs during the growing season preceding that in which flowering occurs. The bud differentiation in *Picea glauca* and *Picea mariana* was described by Fraser (1962, 1966) and Eis (1967) and in *Picea sitchensis* by Moir and Fox (1975) and Owens and Molder (1976). The initiation and the development of buds of *Pseudotsuga menziesii* were described by Allen (1963), Owens and Smith (1964, 1965) and Brunkener (1973).

In Figure 1 the whole cycle of development from bud differentiation to seed dispersal in *Picea abies* is illustrated.

The differentiated buds are situated in different parts of the crown. The female buds are usually located in the upper exposed part, the male buds largely in the upper two-thirds of the crown, and the vegetative ones in the lowest part of the tree (cf. Eliason and Carlson 1969).

Female flowers develop from terminal buds, male flowers both from side-buds and from terminal ones. Each strobilus in an apical position causes a definite stop in the further growth of this shoot after flowering. Thus, prolific flowering of the spruce reduces the number of buds capable of vegetative development and causes difficulties in the regeneration of the shoot system; accordingly, the ability to initiate flower primordia is also reduced. This phenomenon of bud-reduction creates conditions for the periodicity of the cone crop in Norway spruce (Tirén 1935). Thus, the more abundant the flowering in a certain year, the fewer will be the flowers produced in the following year, even if all external factors for abundant flowering are optimum. Conversely, a year with poor flowering may be followed by a year with prolific flowering provided that optimum conditions exist for initiation of flower primordia.

1.1.2 *Factors affecting seed production*

Factors affecting flower initiation and the production of seed in forest trees have been reviewed by Kramer and Kozlowski (1960), Matthews (1963), Romberger (1967), Brøndbo (1968), Jackson and Sweet (1972) and Sweet (1975), among others.

Some factors which influence flowering and cone production will be discussed below.

1.1.2.1 Effects of age, tree size and crown exposure

Most trees are unable to flower until they have passed a juvenile period and attained the stage of maturity. There are great differences in the age at which different species start to flower. In Sweden, the flowering of Norway spruce in some cases may not appear until the trees have reached an age of 40—50 years. Uskov (1962) reported that in the region of Kharovsk, in Russia, the cone production in Norway spruce starts at an age of 80 years. Trees older than 220 years showed a decrease in cone production. Similarly, trees at an age of 120—280 years, studied by Hagner (1955), showed a decrease in cone production with increasing age.

Mature trees generally have a greater crown volume and more branch tips and are thus capable of producing a greater number of flower buds. A positive relationship between cone production and stem diameter was observed by Hagner (1955, 1958, 1959), Uskov (1962) and Giertych (1972). The flowering also increased when the dominant height of the stand increased (Sarvas 1968). The same was true for the height of the trees (Uskov 1962 and Giertych 1972) and the height of grafts (Eriksson *et al.* 1973 and Remröd 1973). However, height seems to have less effect on seed production than stem diameter. Eliason and Carlson (1969) found that the trees which produced most cones were somewhat larger and later in flushing than the non-productive trees. Furthermore, Uskov (1962) reported that trees exceeding 36 cm in diameter and 21 m in height showed a diminished cone production.

In the forest, most seeds are produced by dominant and co-dominant trees, which have the greatest exposure to sunshine and warmth. Intermediate and suppressed trees are such poor seeders that they can be disregarded with respect to having any significant role in seed production (Fowells and Schubert 1956 and Hagner 1958). Hagner (1955) observed that most of the cones were located on the southern side of the trees.

1.1.2.2 Effects of weather conditions

Weather conditions affect seed production by influencing flower bud initiation.

A certain minimum of heat is apparently necessary for flower bud initiation, probably higher than that required for the formation of vegetative buds. The importance of a warm and dry summer in the year before cone maturation in *Picea abies* was reported by Tirén (1935), Uskov (1962), la Bastide and van Vredenburch (1970) and

Eriksson *et al.* (1975). Eklund (1957) showed that the size of the cone crop in *Picea abies* was dependent on the amount of heat in the second half of June and in the first half of July, the most important factor being the number of days in that period with a maximum temperature exceeding +20°C. Brøndbo (1970) estimated the thermal influence occurring during the period of June 10—July 9. A high air temperature in this period, in the year before flowering, has a positive effect, while a high temperature sum during the growing seasons two years before flowering has a negative effect on female flowering. Remröd (1973) has produced stimulation of both female and male flowering and Dunberg (1976) produced stimulation of male flowering by increasing the temperature for the time during which the spruce grafts were surrounded by plastic tents. According to Dunberg, the most sensitive time was the latter part and the end of the period of side shoot elongation. Giertych (1972) claimed that, in addition to high air temperatures in late June and early July, a minimum of 9 hours of sunshine per day in June is required for abundant flower initiation. This observation is in agreement with the findings of Fraser (1958) with respect to *Picea glauca.* Sarvas (1957) studied meteorological data on growing seasons preceding years of heavy flowering between 1900 and 1955. He noted that there had been a high incidence of years with high temperatures in association with summer droughts, which were not followed by abundant flowering (only five years with an abundant cone crop were recorded). Therefore, he concluded that the temperature-drought factor could hardly be regarded as a factor of decisive importance but rather as a factor providing the impulse for the occurrence of years with good spruce seed crops.

The relationship between meteorological factors and the cone crop of Douglas fir was investigated by Lowry (1966), who found that an abundant cone crop in a certain autumn requires a warm January in the same year, a March—April period with high precipitation in the year of bud initiation, and a cool July two years before harvest. Van Vredenburch and la Bastide (1969) and la Bastide and van Vredenburch (1970) showed that a wet March and a sunny, warm and dry summer the previous year is important to an abundant cone crop in the following year.

The weather conditions during flower and cone development may also influence the seed crop. Uskov (1962) reported that spring frosts one year reduced the spruce cone crop by about 60 %. Eriksson *et al.* (1973) reported losses of female flowers in a clone trial as a result of spring frosts. Giertych (1972) found that a certain positive influence was exerted by low April temperatures on the cone crop of *Picea abies.*

Prolonged cold and moist weather in the spring may adversely affect pollen development and dispersal.

The weather conditions after flowering certainly influence the production of good seeds. If the summer and autumn are cool, the seeds may not mature properly, and this will be reflected by a high proportion of embryos that have not fully developed, a low yield of extraction, low germination and low germination energy.

1.1.2.3 Effects of nutrition and growth regulators

Seed production requires large quantities of minerals. Therefore, it seems probable that vigorous, fast growing trees that are growing in soil of high fertility and trees that are growing without competition will usually be better seed producers than small ones, or trees growing in stands and thus competing with other trees. The hypothesis has been stated that relatively high concentrations of carbohydrates as compared to available nitrogen (C/N ratio) promote flower initiation. Excessive fertilization with nitrogen might divert such a large proportion of the carbohydrates to vegetative growth that flowering and seed production might be reduced. However, forest soils usually lack available nitrogen; therefore, moderate fertilization, if applied at the proper time, may increase seed production of forest trees (Kramer and Kozlowski 1960).

Giertych (1972) did not obtain any positive effect on the cone production of *Picea abies* from treatment with various combinations of nitrogen, phosphorus and potassium fertilizers.

Holst (1961) treated 10-year-old seedlings of *Picea glauca* with three doses of ammonium nitrate fertilizer applied on May 30. Only the highest dose had a positive effect. When he coupled fertilization with root pruning on April 30 or June 7, a distinct increase in flowering was obtained from all of the doses.

Stoate *et al.* (1961) reported that a large initiation of flower buds in *Pseudotsuga menziesii* occurred after the spring application of ammonium nitrate at the time of flushing or vegetative bud opening. This period lasted for about two weeks and usually occurred at the end of May. Ebell (1970) obtained a fivefold increase in cone production of 20-year-old trees of *Pseudotsuga menziesii,* and a tenfold increase in 13-year-old trees by nitrate nitrogen treatment in May, while the influence of ammonium nitrogen treatment was negligible. The application of nitrate nitrogen favoured the accumulation of arginine, lysine and several guanidines, whereas trees treated with ammonium nitrogen favoured the accumulation of protein. Ebell claimed that differences in cone production owing to nitrogen fertilization with different types of nitrogen may be caused by differences in assimilation patterns during a critical period, rather than improved mineral nutrition or responses connected with growth and vigour.

Dunberg (1974, 1976) isolated gibberellin-like substances in *Picea abies.* His experiments with growth retardants indicated that endogenous gibberellins participate in the natural process of flower bud initiation. The measurements of gibberellin activity in spruce clones of different flowering ability showed that during the probable time of flower bud initiation the gibberellin activity increased in the flowering clones but dropped sharply in the non-flowering clone. Dunberg claims that the flowering of *Picea abies* can be stimulated by the application of gibberellin, provided that the proper giberellin is available.

1.1.2.4 Effects of root and stem treatment

The increased flowering after the mechanical treatment (injury) of trees is often believed to be due to increased carbohydrate levels provoked in this way.

The kinds of treatment included in this category can be effective if applied at the correct time, but in the long run there are great objections to them because of their negative effect on the health and condition of the trees.

Faulkner (1966) reported that the severest root-pruning treatment of nine-year-old *Picea omorica* trees favoured female flower production in 1961 and 1962, but reduced the male flowering in all of the three years, 1961—1963. He concluded that root pruning does not seem to be suitable treatment to increase flowering. Holst (1961) carried out root pruning of 10-year-old trees of *Picea glauca* on various dates. When this treatment was applied on April 30 (before initiation of growth), female flowering increased slightly in the following year.

Stem girdling at breast height (Hagner 1965a) did not improve the cone crop of *Picea abies.* Positive results from the stem girdling of *Picea omorica* were reported by Faulkner (1966) and by Ebell (1970) in respect of *Pseudotsuga menziesi.* The best time for the girdling treatment was about one month before vegetative bud break (Ebell 1970).

2 Material and methods

This investigation comprises data from our own inventories of cone occurrence in stands in southern and central Sweden in 1973—1975 and similar data from inventories carried out by the National Forest Survey in 1961—1974.

For the majority of the meteorological stations included in the investigation the mean five-day (pentad) temperature was obtained from the Swedish Meteorological and Hydrological Institute (SMHI). For four years the pentad temperatures were calculated from the daily observations recorded by SMHI. For some of the larger meteorological stations the pentad temperatures were obtained from yearly reports published by SMHI.

The precipitation figures were obtained from yearly reports. The grants allocated to this project were too limited to allow us to purchase records of pentad precipitation. Therefore, we had to rely on the total precipitation during each month.

In the regression analyses the square root of cones per tree and the square root of precipitation in June (except for Table 1) were always used instead of cones per tree and precipitation, respectively. A prerequisite for making a linear regression analysis is that the experimental error is constant. Through use of the square root, the experimental error will be approximately constant.

The results are often presented with significance levels but it must be emphasized that these should not be taken too literally since all stations and all years used in the calculations are not independent.

2.1 **Our own inventories for 1973—1975**

In the years 1973—1975 our own inventories of the cone crop comprised 31 stands located in the vicinity of meteorological stations in southern and central Sweden (these stands are printed in italics in Table 4). Each year the inventories were made in the same stands (except for two localities which were clear-cut in 1974 and for which new stands had to be selected). The trees examined in 1974 and 1975 were the same except in a few cases where some of the trees had blown down or had been felled. The following criteria governed the selection of a stand for further study: the stand should be situated as near to the meteorological station as possible; the stand should consist mainly of mature trees of Norway spruce, able to produce cones; the stand should be closed without gaps in regeneration. The sample plots selected within the stands were 100 m long and 5 m in width. Trees shorter than 5 m were not examined. In 1974 and 1975 trees with a diameter of less than 10 cm at breast height were omitted in accordance with the inventory performed by the National Forest Survey. Thus, there was a slight difference between the techniques used in 1973 and in 1974—1975, respectively. In 1973, diameter was not used for the classification of trees and, therefore, the suppressed trees were omitted from the calculations of cones per tree for the individual stands. The lowest number of trees investigated per locality and year was 14 and the highest 42. The cones on every tenth tree were counted with the aid of binoculars. On the other trees in the sample plot the cones were counted or estimated and recorded in one of the following classes:

No. of cones: 0; 1—10; 11—25; 26—50; 51—100; 101—175; 176—250; 251 →

When the mean number of cones per tree and per station was calculated a mean value of 300 was used for the class with more than 250 cones. For the other classes the mean value of the class was taken.

In addition to cone counts, the trees were classified as dominant, codominant, intermediate or suppressed. The dominant height, the basal area of the stand, the site quality class, the density of the stand, the proportion of spruce in mixed stands, the altitude and the exposure of the stand were estimated. Soil samples were collected in all stands. Increment cores were taken from some trees of the stands.

The relationship between cones per tree (cone crop) on the one hand and temperature, precipitation and cones per tree in the year of flower primordia initiation as well as most of the variables mentioned above on the other was studied by means of simple linear regression analysis (one independent variable). The multiple regression analyses (two or three independent variables) mostly comprised the precipitation in June, cones per tree during the year of flower primordia initiation and one of the temperature variables listed below.

The following temperature variables were used in the investigation:

1. Mean temperature during different pentads or other periods.
2. Temperature sums with varying threshold temperatures (0°, +2°, +4°, +6° or +9°C).
3. Mean temperature at different temperature sums.
4. Number of days during a certain period, with a maximum temperature of +20°C or higher.

The reason for using one or other of these temperature variables will be dealt with in the discussion of the results obtained. For a discussion of the concept of temperature sum the reader is referred to Sarvas (1967). In the present investigation the pentad temperature sums were calculated from April 1. The temperature (within a pentad) at which a certain temperature sum was reached was calculated through interpolation of the mean pentad temperatures.

2.2 **Inventories carried out by the National Forest Survey**

Since 1953, yearly inventories of the cone crop of *Picea abies* have been carried out by the National Forest Survey. The principles of the survey were described by Hagner (1958 and 1965b). The cone counts were made by binocular observations of sample trees larger than 10 cm in diameter at breast height and older than 40 years, in circular sample plots with a 6.64-m radius, selected at random. Each year different trees were examined. The cones were counted on the most easily surveyed half of the tree crown. The following classification was used:

Cone class	1	2	3	4	5	6
No. of cones	0—10	10—50	50—100	100—200	200 →	
					200—400	400 →

Class 5 was subdivided into classes 5 and 6 from 1964 onwards.

When the number of cones per tree was calculated, based on these records, the mean value of the class was used and this value was multiplied by 1.88. The reason for not using the factor 2 was that there was a tendency to include in the counts some of the cones which were located in the other half of the crown and also that the most easily surveyed part of the crown usually had more cones than the opposite one. The mean value of the classes over 200 and over 400 was taken as 250 and 430, respectively.

In the present study calculations of cones per tree each year from 1953—1974 were carried out for 42 areas in southern Sweden (Table 7). Each area was a circle with a meteorological station at its centre (Table 4). The radius was usually 19 km but in some cases 14 km. The number of cones per tree for the area was based on the number of sample trees within the area. On an average there were 20 sample trees per area per year.

For some of the areas and years no trees were examined or the number of trees examined was too low (<5), as a result of which no reliable estimate of the cone crop could be made. Cone counts were not included in the survey of sample plots in those years when the survey was performed before July 1, owing to the small size of the cones before that date. The sample plots examined varied from year to year. A correction of the cone crop was made by means of the data from one or more neighbouring areas. The data from the area being studied was given double the weight in the calculation of the number of cones per tree for areas with too few trees examined. The cone crop data derived in this way are printed in italics in Table 7.

For some of the meteorological stations, temperature recordings were not carried out for all 14 years during the period 1960—1973. Furthermore, some recordings were inaccessible for different years for different stations. For these stations the relationship between the individual pentad temperatures from the station concerned and from one or two neighbouring stations in the years when recordings were made was determined. In that way a correction factor could be arrived at and missing temperature records estimated.

In principle, the regression analyses were carried out as for the data from our own inventory. The main difference lay in the study of the relationship between cone crop of individual stations during the period 1961—1974 and the meteorological variables at these stations during 1960—1973. Furthermore, temperature variables 2 and 4 above were not used for this material.

3 Results and discussion

Earlier inventories of the cone crop revealed that the cone production of Norway spruce varies somewhat in different parts of Sweden. Figure 2 illustrates the number of cones per tree for five regions of Sweden and is based on data compiled by Hagner (1965b), Huss (1967) and Simak (1967). As a complement to the earlier compilations, cone crop data from the National Forest Survey, comprising the mean number of cones per tree for 42 localities in southern Sweden during the period 1953—1974 (except for 1957), is given in Figures 3 and 4 (dashed line).

Yearly data for region IV were obtained from the three papers quoted above and are illustrated in Figure 4 (solid line). There is a considerable fluctuation in cone production from year to year. Thus, a year with an abundant cone crop is usually followed by at least one year of no or low cone production (see also Figure 5).

3.1 **Our own inventories for 1973—1975**

The reason for the initiation of the present investigation was outlined in the Introduction. The inventory was planned to take place during three consecutive years. This plan was achieved as may be seen from Figures 6, 8 and 10 in which the cone crop in different localities is demonstrated. All localities are situated in the vicinity of a meteorological station (the ones printed in italics in Table 4).

From Figure 6 it may be seen that there was a great difference between the eastern and western parts of southern Sweden in 1973, as suggested by the preliminary reports (cf. Introduction). The eastern part exhibited the most frequent flowering. In contrast to this, Figure 8 reveals that the flowering was most abundant in the western part of southern Sweden during 1974. Finally, it may be seen from Figure 10 that there was very poor flowering in most of the stands investigated during 1975.

A summary of the cone crops for these

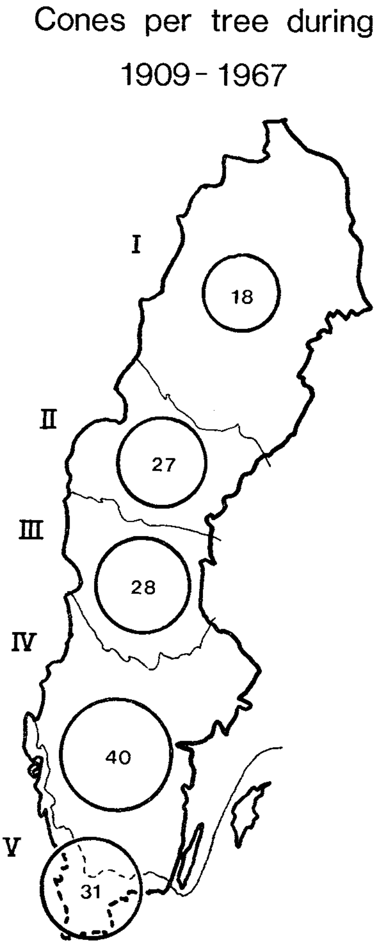


Figure 2. The average number of cones per tree in the years, 1909—1967, for five different regions in Sweden. The figure is based on data compiled by Hagner (1965b), Huss (1967) and Simak (1967).

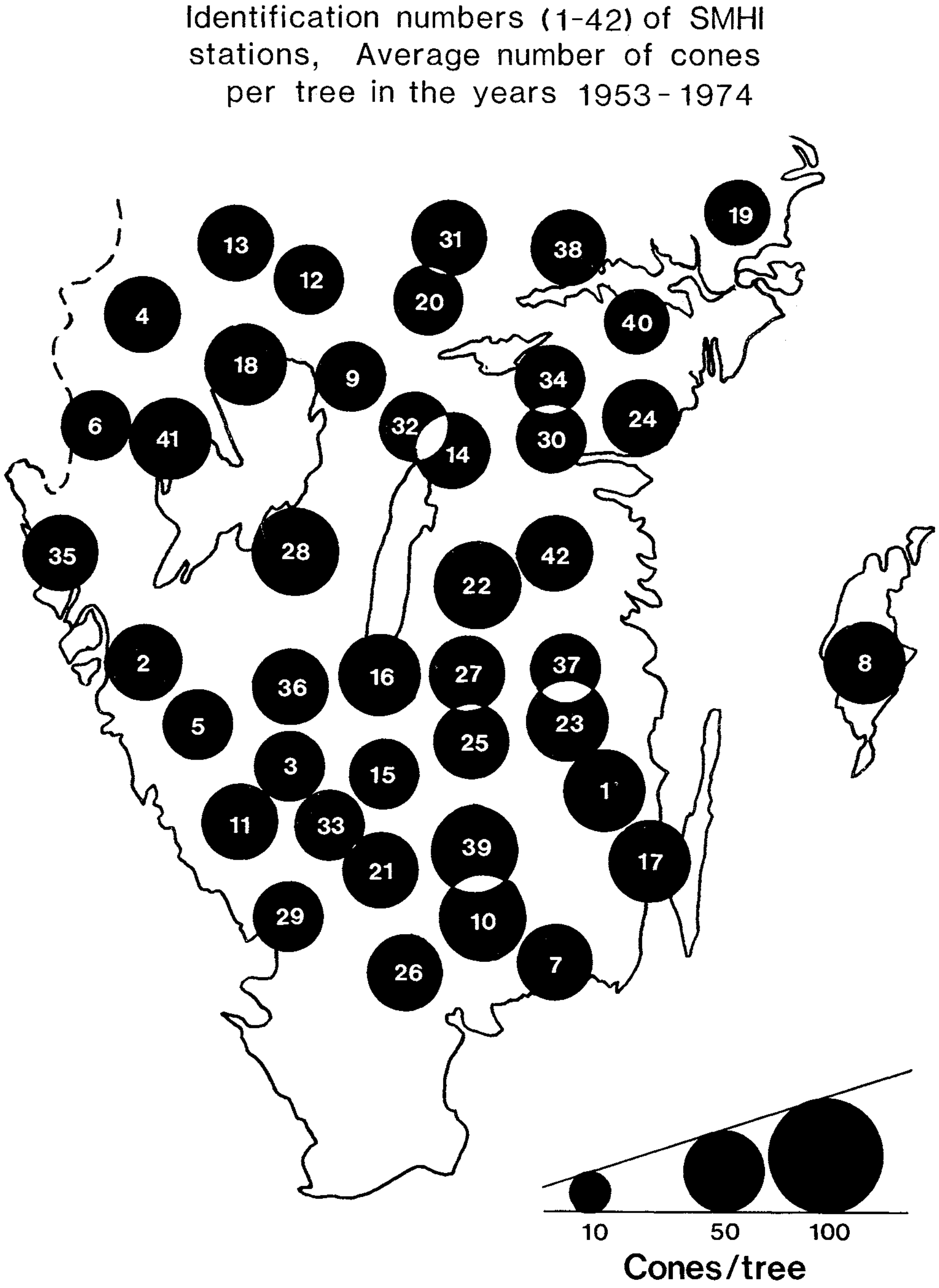


Figure 3. The average number of cones per tree in the years, 1953—1974 (except for 1957), in stands growing in the neighbourhood of meteorological stations. The size of the circles are proportional to the number of cones per tree. The figures in the circles refer to the identification numbers of the Swedish meteorological and hydrological institute (SMHI) as they are listed in Table 4.

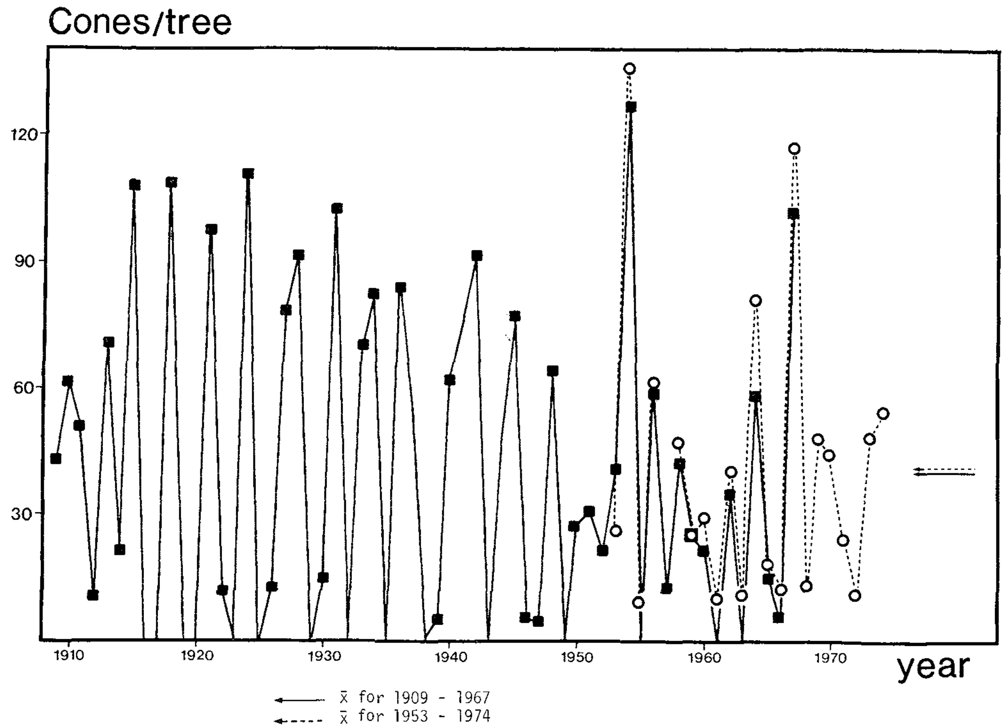


Figure 4. The mean number of cones per tree in 1909—1967 (■) for region IV (cf. Figure 2) based on data compiled by Hagner (1965b), Huss (1967) and Simak (1967), and the number of cones per tree in 1953—1974 (1957 is missing) for the 42 areas (○) shown in Figure 3 based on data obtained from the National Forest Survey.

three years and determination of the average cone crop per year would suggest a relatively even distribution of the flowering throughout southern Sweden (cf. Figure 11). Several objections to conclusions drawn from such a calculation must be raised. The number of years is too limited. The negative correlation between flowering in two consecutive years (cf. Eriksson *et al.* 1975) is another factor which must be considered. Such sources of error have to be considered before the relationship between weather factors and the cone crop can be analysed in detail.

3.1.1 *Relationship between cone crop and the temperature, precipitation and cone crop in the preceding year*

3.1.1.1 Cone crop, 1973

The year 1973 is a very suitable one for analysis of the relationship between cone crop and weather factors, since it was preceded by some years of poor flowering (cf. Figure 4). This makes the analysis of such a relationship reliable.

The first approach was to calculate the correlation coefficients between the cone crop in 1973 and the temperature and the precipitation during the twelve months of 1972. The results are presented in Table 1. As regards temperature, the table reveals that there is a strong negative correlation in May, whereas June—August show high positive correlations. As regards precipita-

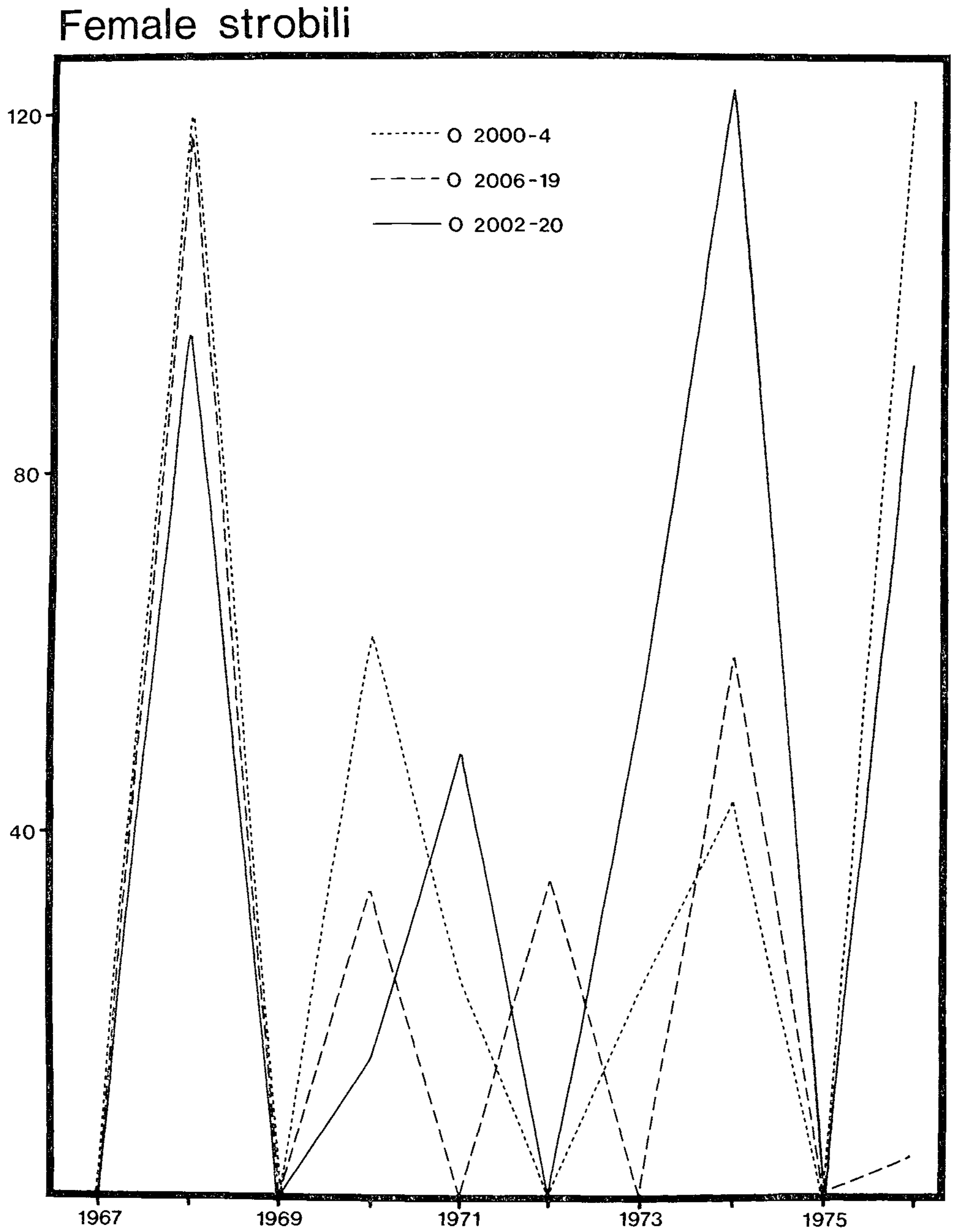


Figure 5. Three grafts growing in a clone trial outside Stockholm are used to illustrate the annual fluctuation in female flowering for a ten-year period.

tion, high negative correlations were noted for the months April—June. As is well known, high temperatures during the growing season are mostly accompanied by low precipitation. Therefore, it is difficult to decide whether the temperature or the precipitation is the crucial factor.

A more detailed regression analysis was carried out for individual pentads making use of the mean temperatures of individual

Table 1. The correlation coefficients and their significance levels for the relationship between cone crop of *Picea abies* in 1973 at 31 localities in southern Sweden and the average monthly temperature and precipitation in 1972. In all tables (except Table 7) cone crop and cones per tree refer to the square root of cones per tree. The significance levels are: *** = $P < .001$; ** = $.001 < P < .01$; * = $.01 < P < .05$ in a two-sided test.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Temperature 1972	.024	−.075	−.287	−.244	−.742***	.675***	.641***	.531**	.421*	−.111	.027	.164
Precipitation 1972	.334	.369*	−.250	−.647***	−.686***	−.813***	−.258	−.156	.523**	−.121	−.727***	−.796***

Table 2. The correlation coefficients for the relationship between the cone crop and the temperature of individual pentads during the previous year.

Day, Month	Pentad No.	Cone crop	
		1973	1974
1—5 May	25	−.72***	−.11
6—10	26	−.82***	−.54**
11—15	27	−.79***	−.77***
16—20	28	−.41*	.69***
21—25	29	−.10	−.00
26—30	30	.32*	.39*
31—4 June	31	.14	−.68***
5—9	32	.25	−.59***
10—14	33	.70***	−.74***
15—19	34	.69***	.34
20—24	35	.53**	−.22
25—29	36	.44*	−.69***
30—4 July	37	.66***	−.57***
5—9	38	.70***	−.80***
10—14	39	.64***	−.59***
15—19	40	−.18	−.79***
20—24	41	.02	−.65***
25—29	42	.52**	−.36*

pentads. The results are presented in Table 2. Strong positive correlations were obtained for pentads 33 and 34 (June 10—19) and 37—39 (June 30—July 14), respectively.

Since the present investigation covered the whole of southern Sweden, it may be assumed that the critical period for flower primordia differentiation will appear at different dates at the different localities depending on differences in latitude and altitude, local topography, other site conditions and weather conditions. One way of circumventing such complications is to calculate temperature sums. The calculation of correlation coefficients between cone crops and temperature sums with various threshold temperatures was carried out for four different periods, as is demonstrated in Table 3. (A study of the time at which different temperature sums were reached in different localities and in varying years in southern Sweden was presented by Lindgren and Lindgren (1976a).) Table 3 shows that the temperature during June and July is of greater importance to the initiation of

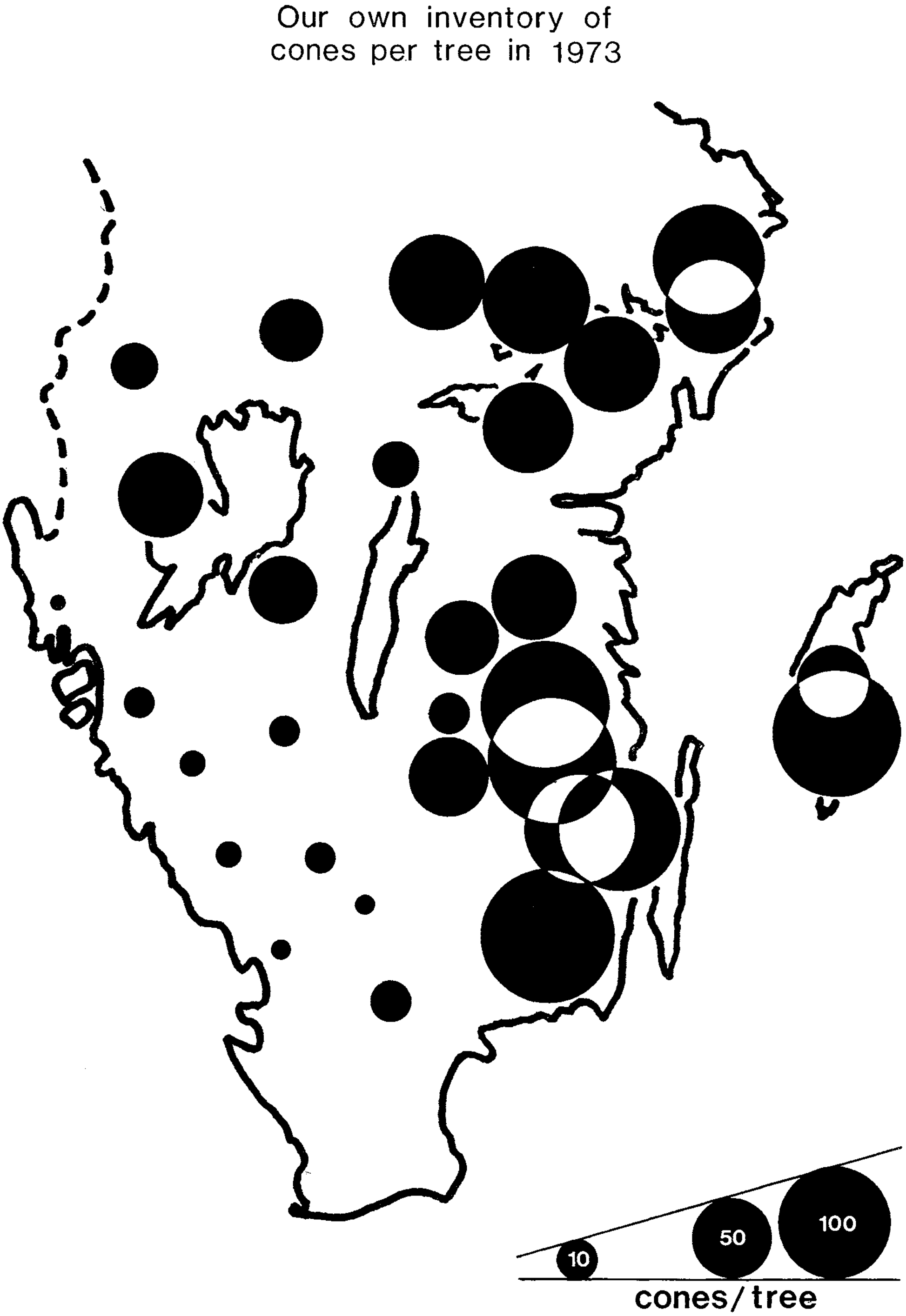


Figure 6. The number of cones per tree in 31 stands growing in the vicinity of meteorological stations based on our own inventory in 1973. The sizes of the circles are proportional to the number of cones per tree.

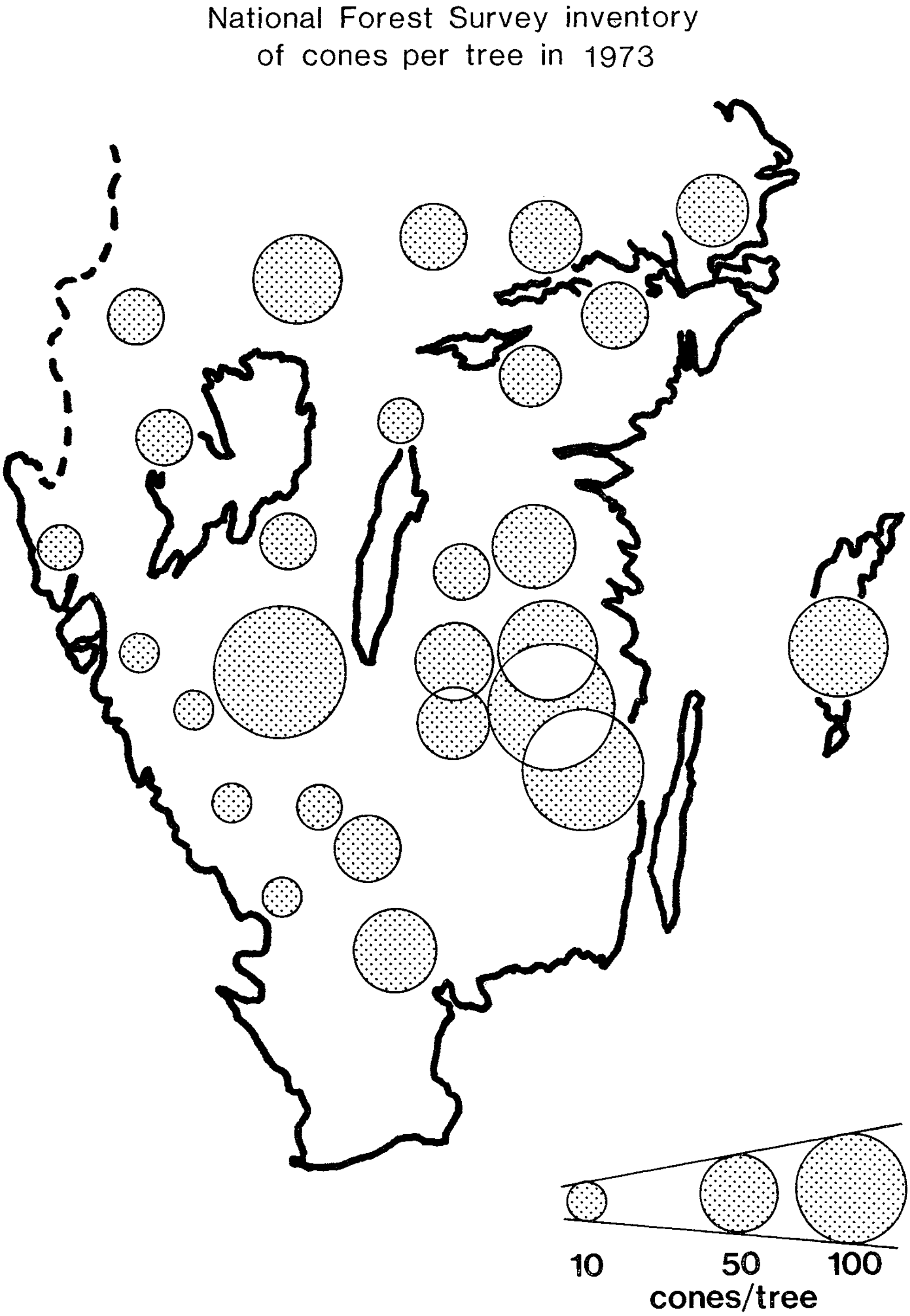
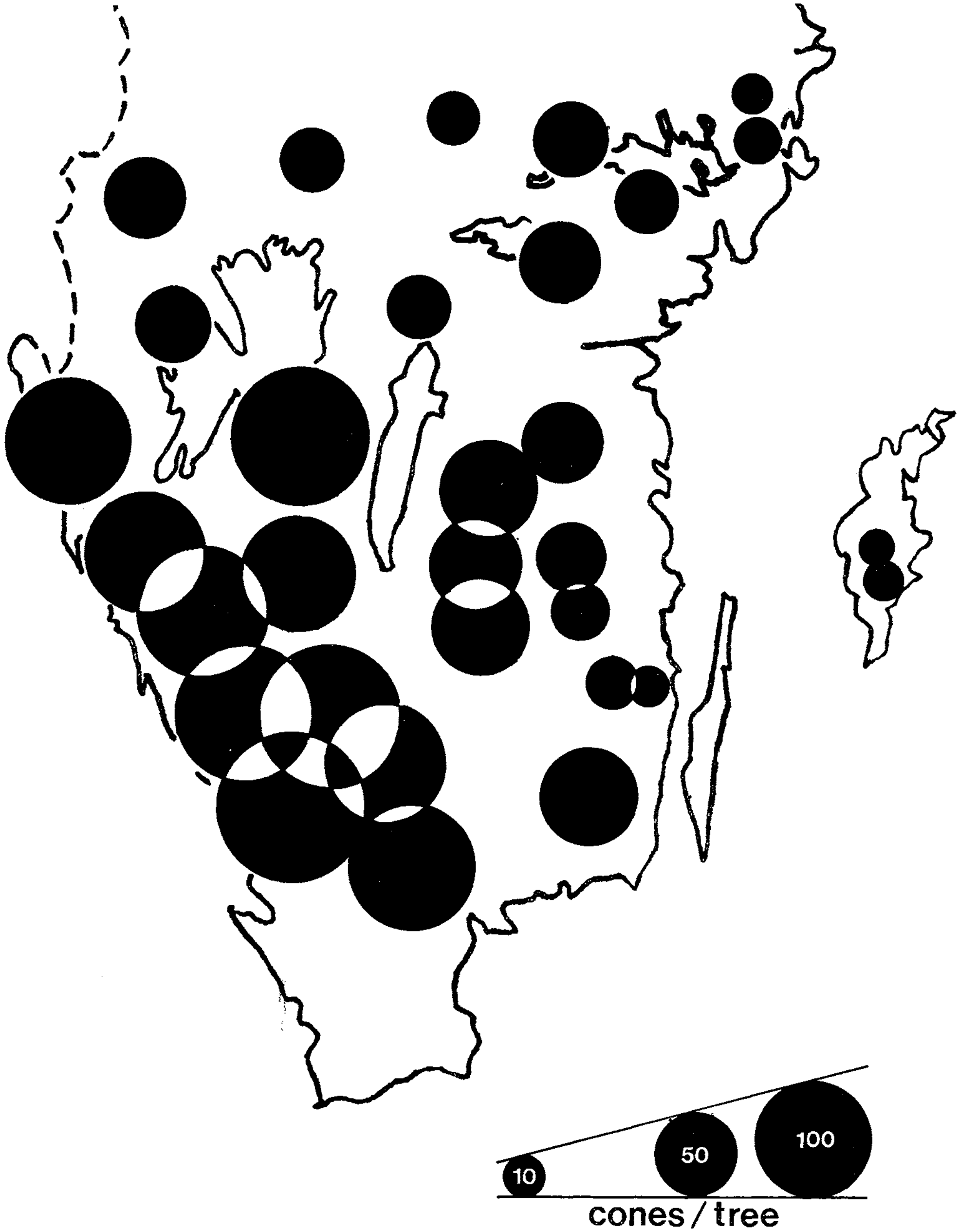


Figure 7. The number of cones per tree in stands in the neighbourhood (maximum distance = 19 kilometres) of the meteorological stations shown in Figure 6. The figures are based on the inventory carried out by the National Forest Survey in 1973.



Our own inventory of cones per tree in 1974

Figure 8. The number of cones per tree in 31 stands growing in the vicinity of meteorological stations based on our own inventory in 1974.

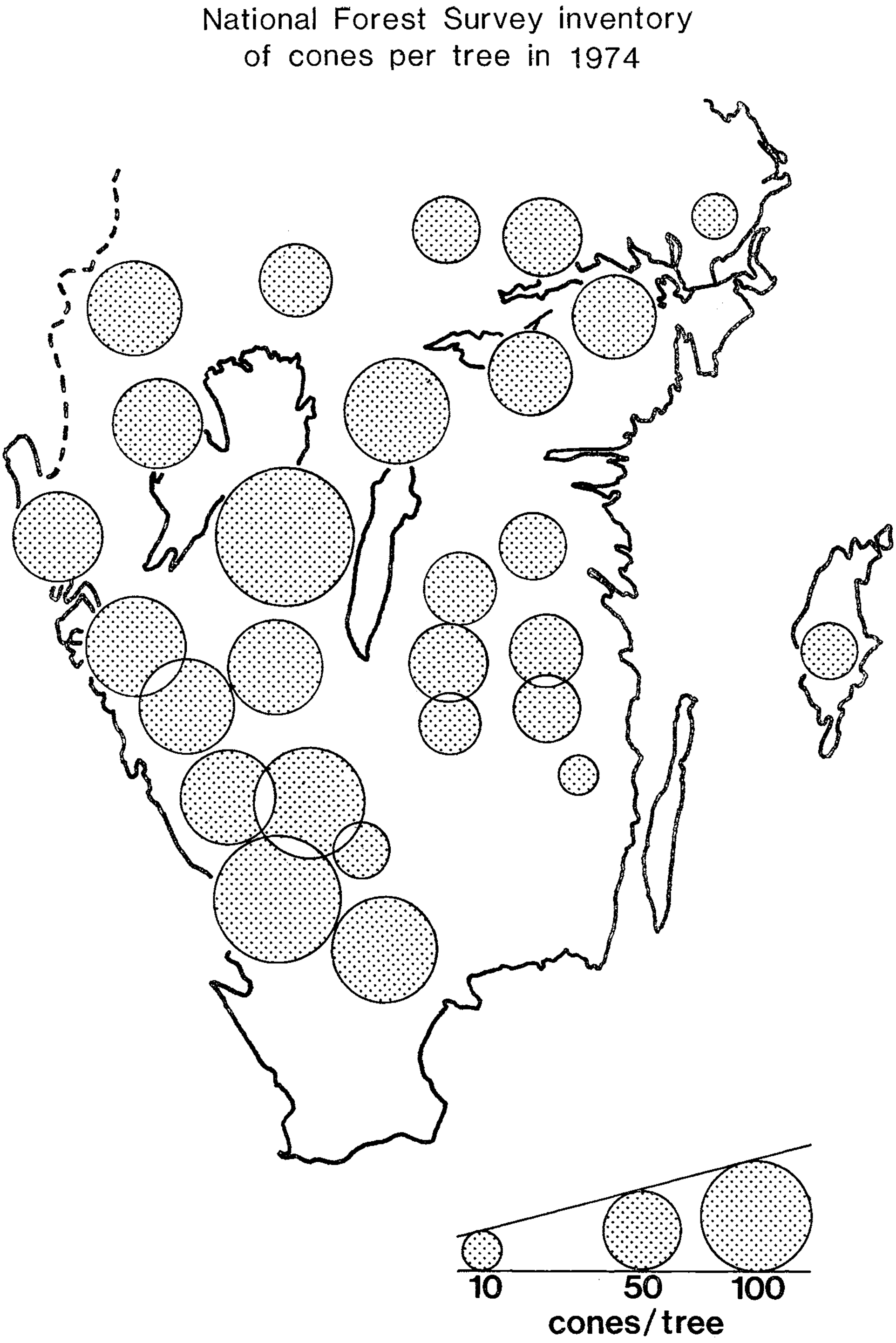


Figure 9. The number of cones per tree in stands in the neighbourhood (maximum distance = 19 kilometres) of the meteorological stations shown in Figure 8. The figures are based on the inventory carried out by the National Forest Survey in 1974.

Figure 10. The number of cones per tree in 31 stands growing in the vicinity of meteorological stations based on our own inventory in 1975.

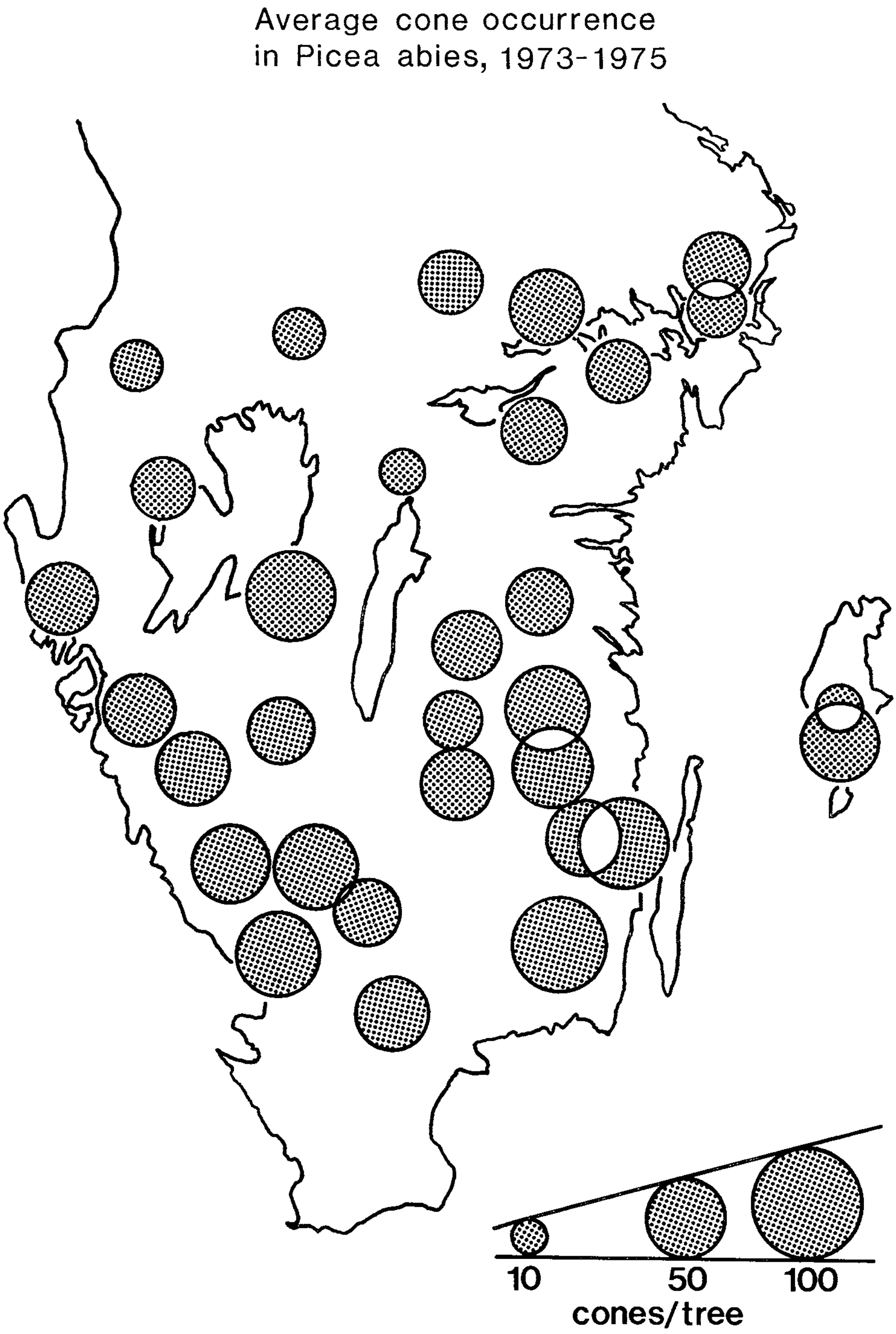


Figure 11. The average number of cones per tree for the years 1973—1975 in 31 stands growing in the vicinity of meteorological stations in southern Sweden. The figure is based on our own inventories.

Table 3. Correlation coefficients for the relationship between cones per tree 1973 and 1974 and the temperature sums of pentads, 19—42 and 29—42 (1972—1973), respectively, at threshold temperature (t_o) 0°, 2°, 4°, 6° and 9°C. In addition the correlations for cones per tree and temperature sums during pentads, 33—35 and 37—39, are given.

Date	1 April—29 July					21 May—29 July					10—24 June	30 June—14 July
Pentad	19—42					29—42					33—35	37—39
Year t_o	0°	2°	4°	6°	9°	0°	2°	4°	6°	9°	—	—
1973	.167	.184	.212	.299	.519**	.610***	.614***	.616***	.616***	.616***	.715***	.682***
1974	–.539**	–.546**	–.587***	–.664***	–.699***	–.682***	–.656***	–.682***	–.682***	–.682***	–.314	–.725***

flowering than the temperature during April—May.

Still another approach is to relate the cone crop to varying temperatures at various temperature sums. Since preliminary calculations did not suggest that any of the threshold temperatures, +4°, +6° or +9°C, was to be preferred as the critical temperature, +6°C was selected for the further calculations.

A comparison of the results presented in Tables 2 (pentad temperatures) and 5 (temperatures at various temperature sums) shows that there is an agreement between the two methods of tracing the sensitive period(s) for the initiation of flowering primordia. The relationship between the square root of the number of cones per tree in 1973 and the temperature during the period of temperature sums, 45—70 degree pentads in 1972 is illustrated in Figure 12. The reason that such a wide variation in the temperature sum was used is that there are differences in temperature requirement (to provoke flowering) between various populations. As is evident from Figure 12, the correlation is fairly strong. It is worth mentioning that the points marked as squares refer to south-eastern stands. To illustrate the variation in the dates at which four different temperature sums, 45, 55, 65 and 70 degree pentads were reached, Table 4 can be consulted. It was assumed that the attainment of temperature sums, 45 and 70, formed the limits of the critical period for the initiation of flower primordia.

The exclusion of pentads, 37—39 (June 30—July 14), from the critical period was based on data presented in 3.2. Moreover, it must be assumed that the influence on the initiation of flower primordia must take place some time before any visible differentiation can be distinguished, which may be in late July (cf. Brunkener 1973). The maximum difference between the localities did not, in any case, exceed 10 days (cf. Table 4). Therefore, it is not expected that the critical time of flower primordia differentiation will vary considerably between the localities.

From Table 5 it may also be seen that

Table 4. Geographic data of meteorological stations and the day in June when temperature sums, 45 and 70, were reached in 1972 and when temperature sums, 45, 55 and 65, were reached on an average, based on temperature data for periods, 1960—1973 and 1960—1974. The threshold temperature = +6°C. The stations printed in italics were included in our own inventories.

	Meteorological station	Lat.	Long.	Alt. m	1972		Average 1960—1973	Average 1960—1974	
					T 45	T 70	T 45	T 55	T 65
1	*Allgunnen*	57°04′	15°58′	115	14	27	9	15	21
2	*Alvhem*	58°01′	12°09′	5	8	25	7	13	18
3	Ambjörnarp	57°25′	13°17′	220	14	29	12	18	24
4	*Arvika*	59°40′	12°35′	73	10	25	10	15	21
5	*Bollebygd*	57°40′	12°34′	75	10	27	9	15	20
6	Bredviken	59°13′	11°59′	100	17	2*	14	20	25
7	Bredåkra	56°16′	15°17′	58	13	27	9	15	21
8	*Buttle*	57°24′	18°30′	45	16	29	13	19	25
9	Degerfors	59°14′	14°27′	85	10	25	10	15	20
10	Ekefors	56°33′	14°45′	145	13	28	10	17	23
11	*Fagered*	57°12′	12°49′	110	12	29	11	17	23
12	*Filipstad*	59°43′	14°10′	141	12	27	11	16	21
13	Forshult	59°58′	13°31′	125	14	28	13	19	25
14	Godegård	58°48′	15°10′	130	15	29	13	19	24
15	Hagshult	57°18′	14°08′	169	16	2*	13	20	26
16	Jönköping	57°46′	14°05′	226	16	30	13	19	24
17	Kalmar	56°41′	16°18′	6	11	26	13	20	25
18	Karlstad	59°22′	13°28′	46	11	27	11	16	22
19	*Kårsta*	59°40′	18°17′	20	14	27	12	18	23
20	Lindesberg	59°35′	15°14′	70	14	28	11	16	22
21	*Ljungby*	56°50′	13°55′	155	9	25	9	15	20
22	*Malexander*	58°04′	15°13′	153	14	28	12	18	23
23	*Målilla*	57°24′	15°50′	100	14	28	10	16	22
24	Nyköping	58°47′	16°55′	42	18	1*	14	21	26
25	*Nävelsjö*	57°24′	14°53′	215	16	30	12	19	25
26	*Osby*	56°22′	13°57′	83	11	26	9	15	21
27	*Prästkulla*	57°44′	14°59′	300	17	1*	14	21	27
28	*Remningstorp*	58°27′	13°40′	133	11	27	10	15	21
29	*Simlångsdalen*	56°43′	13°08′	75	9	26	9	15	21
30	Simonstorp	58°47′	16°10′	65	13	27	10	16	21
31	*Skinnskatteberg*	59°50′	15°41′	113	16	28	12	17	23
32	*Snavlunda*	58°58′	14°54′	140	14	29	12	18	24
33	*Stora Segerstad*	57°09′	13°34′	170	12	28	11	17	23
34	*Strängstorp*	59°03′	16°13′	62	14	27	10	16	21
35	*Svarteborg*	58°34′	11°33′	70	12	27	13	18	24
36	*Ulricehamn*	57°47′	13°26′	290	15	1*	14	20	26
37	*Vimmerby*	57°40′	15°51′	135	13	26	9	15	20
38	*Västerås*	59°35′	16°38′	6	10	22	7	12	17
39	Växjö	56°52′	14°48′	166	10	25	8	13	19
40	*Åkers Styckebruk*	59°15′	17°06′	20	12	25	9	14	20
41	*Åmål*	59°03′	12°42′	60	13	28	12	17	23
42	*Åtvidaberg*	58°12′	15°59′	100	13	27	9	15	20
	Hemse	57°14′	18°23′	25	18	30			
	Rörsbo	56°36′	15°31′	140	15	29			
	Röskär	59°25′	18°10′	15	14	27			
	Sandbäckhult	57°00′	16°18′	37	17	30			
	earliest date June				8	22	7	12	17
	latest date June				18	2*	14	21	27

* = July.

Table 5. The correlation coefficients (r) for the relationship between cones/tree in 1973 and 1974, respectively, and the three different independent variables: temperature, precipitation and cones/tree, in the year of flower bud initiation. Also, the average day in May—July when a certain temperature sum at a threshold temperature of +6°C was reached is given.

Independent variables	Cones/tree 1973		Cones/tree 1974	
	r	Date 1972	r	Date 1973
Temperature at T				
5	–.72***	4 May	–.49**	10 May
10	–.49**	14	.41	20
15	.66***	21	.35	24
20	–.22	27	.35	28
25	.58***	1 June	–.33	31
30	.73***	5	–.72***	3 June
35	.50**	8	–.67***	5
40	.06	10	–.59***	8
45	.47**	13	–.52**	11
50	.58***	16	.07	15
55	.35	19	.46**	18
60	.35	23	.28	21
65	.48**	25	–.05	23
70	.42*	28	–.49**	25
75	.45*	30	–.73***	27
80	.56***	2 July	–.71***	29
85	.65***	4	–.71***	30
90	.67***	6	–.68***	2 July
95	.63***	9	–.71***	4
100	.47**	11	–.72***	6
45—70	.80***	13—28 June	.06	11—25 June
Precipitation	–.80***	June	.01	June
Cones/tree	—	—	–.76***	1973

there is a strong negative correlation (r = –0.80***) between the cone crop of 1973 and the square root of the precipitation during June 1972.

A linear multiple regression analysis was also carried out using the temperature at varying temperature sums and the precipitation. The results are compiled in Table 6. From this table it may be seen that the correlation coefficients are fairly high when both temperature and precipitation are included in the linear multiple regression analysis. Approximately 66 per cent (temperature sum 65) of the variation in cone crop is explained by these two factors. It may be added that the strength of the correlation was improved by including the precipitation (cf. Tables 5 and 6). However, it must be recalled that the temperature alone during the period for temperature sums, 45—70, also gave a good correlation (r = 0.80***), which explains 64 per cent of the variation of the cone crop (Figure 12). The results obtained indicate that there is a sensitive period during June lasting no more than two weeks in each stand (cf. Table 4). As pointed out above, it is probable that different populations are adapted to different temperature sums. This means that an analysis of all populations taken together will complicate the interpretation of the data.

According to Eklund (1957) there was a strong correlation between cone crop and days with a maximum temperature above +20°C. A similar study of the relationship from our material was carried out for the period June 16—July 15. The correlation coefficient for days above +20°C was slightly higher (r = 0.82***) than the one obtained for temperature sums, 45—70, in Table 5. Furthermore, a multiple regression analysis was performed. These results supported those obtained in the above regression analyses. Thus, once more it was shown that the temperature and the precipitation influence the initiation of flower primordia formation.

3.1.1.2 Cone crop, 1974

As demonstrated earlier, a strong relationship between the cone crop and the temperature and/or precipitation was not expected for 1974, owing to so-called bud reduction (cf. Tirén 1935). Thus a strong negative relationship was observed between the cone crops of 1973 and 1974, as is illustrated in Figure 13. The correlation coefficients presented in Tables 5 and 6 show that the cone crop in the year of flower primordia initiation completely dominates over temperature and precipitation as the reason for the variation in cone crop. The negative effects of heavy cone crop in the year of flower bud initiation on the cone crop in the following year have also been reported by Eklund (1954) and Brøndbo (1970).

A good illustration of the negative relationship between the cone crop in two consecutive years is illustrated in Figure 5. In this figure the number of female strobili for three grafts during the ten-year period, 1967—1976, is demonstrated. The grafting was carried out in 1955 and the grafts were planted in 1959 in a clone trial at Grabbtorp, nine kilometres outside Stockholm (cf. Eriksson *et al.* 1975). This figure clearly shows that a year of abundant flowering is always followed by a year of no flowering (cf. the two-year periods 1968—1969 and 1974—1975, respectively). The same tendency is also evident for the years with moderate flowering. This example clearly

Table 6. Multiple correlation coefficients for the relationship between cones per tree for years, 1973 and 1974, and temperature and precipitation in June and cones per tree in the year of flower primordia initiation. T = temperature sum with a threshold temperature of +6°C. The significances for multiple correlation coefficients were obtained by F-analyses based on the regression mean square divided by the residual mean square.

Cones/tree	Independent variables during the year of flower primordia initiation											
Year	Precipitation and temperature at T				Cones/tree and temperature at T				Precipitation and cones/tree and temperature at T			
	55	60	65	45—70	55	60	65	45—70	55	60	65	45—70
1973	.804***	.803***	.814***	.841***	—	—	—	—	—	—	—	—
1974	.474*	.295	.048	.204	.759***	.759***	.767***	.776***	.776***	.774***	.778***	.795***

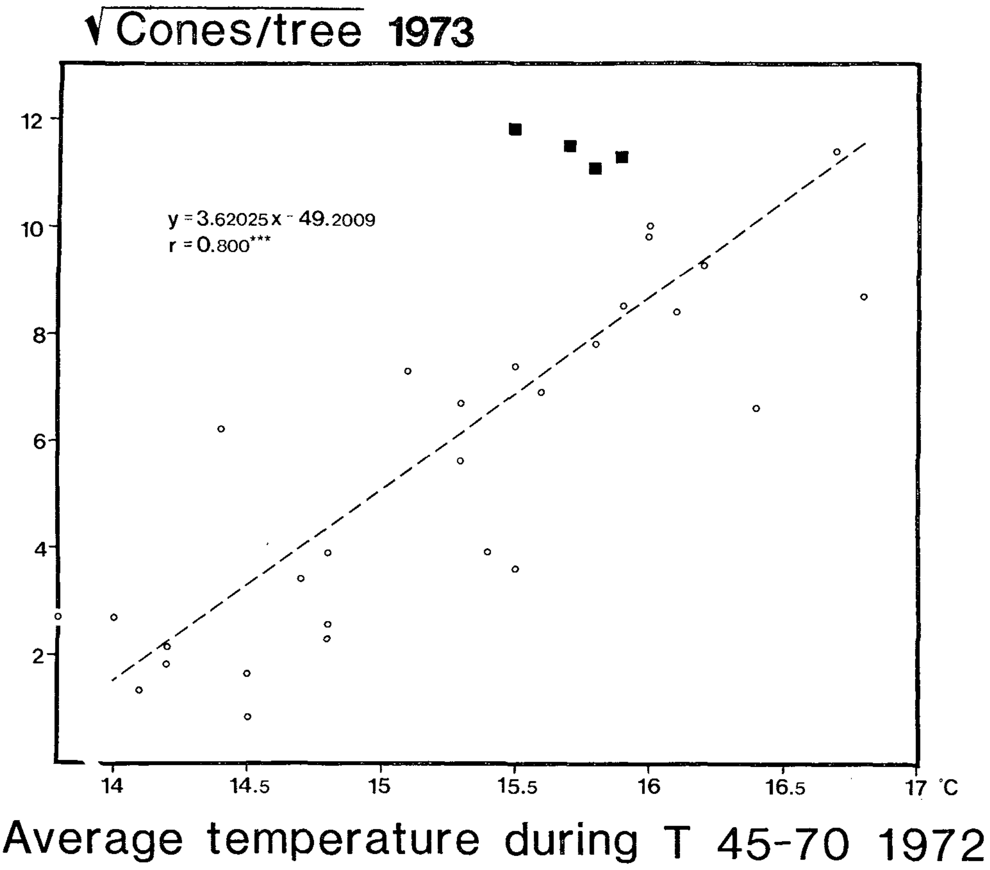


Figure 12. The relationship between the square root of cones per tree in 1973 and the mean temperature at temperature sums (T), 45—70 (June 13—28), in 1972. The stands shown as squares are all located in south-east Sweden.

establishes that "bud reduction" is responsible for the periodicity of flowering of Norway spruce (cf. Figure 4).

3.1.1.3 Cone crop, 1975

As mentioned above, no regression analyses were carried out for 1975 owing to the extremely poor flowering in that year.

3.1.2 *Other factors which may influence the cone crop*

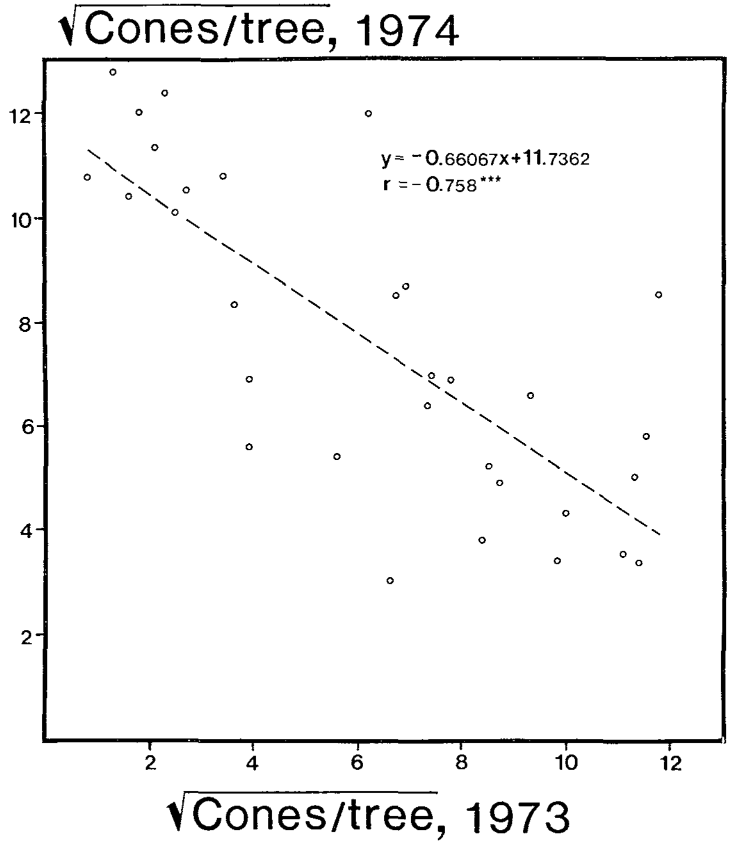
The factors included in this section will only be discussed in brief, since the material is not suitable for detailed study.

3.1.2.1 Stand characteristics

The majority of cones were produced by *dominant and codominant trees.* The average number of cones per tree per stand for the 31 stands investigated is given in the table below:

Year	Tree class			
	dominant	codominant	intermediate	suppressed
1973	83	36	10	0
1974	110	54	14	1

Figure 13. The relationship between the number of cones per tree in 1973 and in 1974.



Evidently the dominant trees produced considerably more offspring than trees of poor development. This fact has to be taken into consideration in a discussion of the genetic structure of the populations and the possibilities of breeding for height growth.

No significant correlations were obtained between cone crop and the independent variables: height, age, basal area, stand density or the proportion of spruce in mixed stands.

3.1.2.2 Site characteristics

Soil samples from 31 localities were collected and analysed for distribution of particle size. No significant correlation between average cone crop in 1973—75 and the percentage of clay, fine silt, coarse silt, very fine sand, medium sand and coarse sand was detected. A significant relationship was obtained only in the case of fine sand ($r = 0.475^{**}$), which means that this type of soil material may favour flowering.

Concerning the independent variables: site quality class and altitude of the stand, no significant relationship to cone crop was found.

As regards the influence of exposure on cone crop, Figure 14 shows that there is probably a more abundant flowering on slopes facing south or west, which indirectly suggests that the favourable temperature conditions are responsible for the increased flowering.

3.2 Inventories carried out by the National Forest Survey

To be able to determine the relationship between cone crop and external factors, it is necessary to test whether the data col-

Table 7. The observed number of cones per tree in 1953—1974 (except 1957) for 42 meteorological stations is given. Numbers in italics designate cones per tree estimated from cone crop data of neighbouring stations (cf. Material and methods).

Station Year	1953	1954	1955	1956	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Allgunnen	34	160	*9*	134	144	9	36	9	45	9	19	31	13	94	27	27	17	44	9	120	12
Alvhem	9	111	*9*	52	86	*35*	16	9	16	9	*246*	45	9	51	11	61	22	15	13	9	78
Ambjörnarp	*27*	144	9	62	50	39	15	9	9	9	73	33	9	51	11	97	42	16	9	12	57
Arvika	9	*91*	9	34	32	*29*	9	9	80	9	*64*	9	9	306	9	*20*	39	13	9	21	67
Bollebygd	9	157	9	15	17	9	17	11	23	*9*	113	56	9	44	9	40	31	12	12	9	70
Bredviken	9	141	9	27	30	*34*	9	9	44	9	89	9	9	120	9	25	61	9	21	12	42
Bredåkra	37	123	*9*	51	75	9	42	9	42	40	45	11	23	64	9	40	67	12	17	33	75
Buttle	*81*	49	*9*	84	27	28	116	*9*	*72*	*9*	24	21	17	175	14	41	59	13	9	76	25
Degerfors	9	123	9	35	9	36	9	9	47	9	32	9	9	201	9	25	43	36	11	49	43
Ekefors	67	283	*9*	80	*79*	17	*49*	9	*44*	*9*	170	9	11	81	9	52	16	19	9	90	54
Fagered	25	264	9	54	61	17	21	12	9	9	84	9	9	43	9	57	32	44	12	11	73
Filipstad	15	131	9	42	14	25	13	*9*	14	9	39	9	10	184	21	22	40	12	*10*	63	40
Forshult	16	106	9	17	21	37	32	9	45	9	79	*9*	9	142	41	35	70	9	11	80	49
Godegård	33	142	9	65	57	48	14	9	49	9	36	23	17	76	10	60	45	14	9	31	89
Hagshult	*15*	105	*9*	74	*72*	9	*23*	10	25	*9*	117	*10*	9	64	*9*	57	13	39	9	13	10
Jönköping	40	231	*9*	41	41	15	16	*9*	16	*9*	177	11	9	55	9	100	62	21	9	28	50
Kalmar	28	183	*9*	84	115	9	53	9	*83*	9	62	31	9	57	12	*35*	17	9	9	*188*	9
Karlstad	28	77	9	17	*19*	39	*12*	9	*69*	*9*	51	9	*9*	450	*9*	43	*40*	24	9	18	61
Kårsta	25	128	15	87	9	*11*	9	9	15	9	33	18	14	101	20	27	31	23	15	41	13
Lindesberg	9	62	9	66	16	36	17	9	33	9	34	9	12	124	9	44	29	56	9	48	58
Ljungby	9	270	*9*	94	*60*	*20*	9	*9*	*25*	*9*	77	*9*	9	100	9	48	27	36	9	34	24
Malexander	82	172	9	84	67	12	23	9	*44*	9	138	9	11	142	9	47	138	33	11	24	42
Målilla	28	104	*9*	62	114	*12*	55	9	*123*	*9*	55	27	17	52	18	82	12	42	*9*	132	32
Nyköping	65	48	*9*	48	16	41	*42*	*9*	44	9	15	17	17	222	11	*34*	71	12	9	70	16
Nävelsjö	25	93	*9*	156	72	15	*21*	9	9	9	65	9	9	50	15	91	45	29	*9*	44	27
Osby	9	135	*9*	31	86	11	30	9	34	*20*	48	9	9	95	9	26	123	27	26	55	88
Prästkulla	66	162	*9*	73	48	15	19	*9*	11	9	112	9	9	28	16	44	46	26	9	48	46
Remningstorp	14	*195*	9	46	9	47	9	*9*	*104*	9	*234*	*9*	9	37	9	37	36	41	9	24	158
Simlångsdalen	*17*	*180*	*9*	*38*	17	9	*17*	15	*21*	9	78	9	9	77	9	*30*	29	46	*14*	10	130
Simonstorp	25	50	*9*	19	44	*35*	14	14	40	9	*32*	24	12	*94*	13	*44*	69	26	9	67	37

Skinnskatteberg	9	215	9	69	17	43	23	9	28	11	26	9	15	135	9	65	37	16	9	38	31
Snavlunda	*15*	99	9	27	*21*	25	30	*9*	23	19	154	9	9	85	*9*	31	52	17	9	15	90
Stora Segerstad	9	139	*9*	16	75	9	18	9	*20*	9	127	9	9	69	9	66	13	40	*9*	17	94
Strängstorp	*19*	75	9	92	30	37	82	9	25	9	38	9	10	48	11	72	88	15	9	29	52
Svarteborg	25	123	9	41	13	*30*	54	9	40	9	88	9	9	280	9	26	46	9	9	14	66
Ulricehamn	13	205	9	25	38	24	34	*9*	35	*9*	66	29	9	64	12	39	29	18	12	142	69
Vimmerby	33	119	*9*	117	34	20	30	9	39	*9*	24	9	18	54	14	83	*34*	20	9	80	40
Västerås	42	*87*	9	51	9	*80*	22	*9*	*48*	19	*22*	74	9	*67*	*50*	94	11	9	9	43	44
Växjö	9	*181*	*9*	148	90	9	*32*	*9*	*38*	9	*188*	*9*	9	165	9	49	*42*	36	*9*	53	73
Åkers styckebruk	*16*	47	*9*	50	35	17	*40*	11	25	9	112	9	14	59	11	43	25	9	9	38	51
Åmål	*26*	55	9	53	*18*	27	22	9	36	9	67	9	*9*	458	*9*	31	53	9	9	22	64
Åtvidaberg	*19*	128	*9*	95	83	9	46	19	*86*	9	26	9	36	83	25	25	56	38	9	57	32
Average	26.2	135.5	9.1	60.9	46.9	24.7	28.6	9.7	40.0	10.5	80.5	16.5	11.7	117.8	13.4	48.0	44.2	23.7	10.6	47.8	54.3

lected by the National Forest Survey permit such analysis. As may be recalled, the inventories carried out by the National Forest Survey did not comprise the same stands every year. The distance from the stands to the meteorological station varied (the maximum distance being 19 kilometres). Moreover, in years of scarce flowering the technique used for the classification of the cone crop exaggerated the true cone crop. Therefore, we found it worthwhile to test the agreement of our own data from 1973 and 1974 with those obtained by the National Forest Survey. This can be done by comparing Figure 6 with Figure 7 (1973), and Figure 8 with Figure 9 (1974). As seen from these figures, the agreement is not at all complete. Therefore, we suggest that the data from the National Forest Survey should only be used for the purpose of forecasts and not for detailed studies of the relationship between cone crop and other external factors. This means that the results presented below must be regarded only as supplementary to the results discussed in section 3.1.

The data of cones per tree, on which this section is based, are given in Table 7. The years 1953—1960 are not used in the regression analyses presented below but are included as additional information.

3.2.1 *Relationship between cone crop and pentad temperature*

The correlation between the mean temperature during a certain pentad and the number of cones per tree in the next year was calculated. This calculation was carried out for each of the pentads, 25—42 (May 1—July 29), for each year between 1960 and 1973 (i.e. the cone crop 1961—1974, Table 8), and each station (Table 9). These results are presented as significance levels of the corresponding correlation coefficients in Tables 8 and 9, respectively. The overall correlation was also calculated with each year and station being regarded as an independent observation. Overall and average correlation coefficients are also presented in Tables 8 and 9.

Table 8. Significance levels of the correlations between the cone crop each year from 1961—1974 1973). Corresponding correlation coefficients for the mean of all years, for the mean of the five tion, and the overall means are also given. Minus signs indicate the significance level of the negative

	Pentad temperature									
Date	May						June			
	1—5	6—10	11—15	16—20	21—25	26—30	31—4	5—9	10—14	15—19
Pentad	25	26	27	28	29	30	31	32	33	34
Year										
1960										
1961					***					**
1962									*	
1963			– –	– –						
1964		*		*		**		*		
1965	–				–					**
1966	– – –	–		– – –		**				
1967	–									
1968				–						
1969										
1970							–			
1971					*					
1972	–	– –	– – –	–					*	***
1973										**
mean values 60—73	–.113	–.026	–.106	–.051	.070	.051	.001	.037	.136	.190
mean values 61+63+ 66+68+ 72	–.191	–.076	–.209	–.282	.156	.037	.010	.038	.223	.301
overall	.374***	–.194***	–.323***	–.081*	.192***	.123**	–.031	.136**	.409***	.365***

Significance levels assuming 42 independent observations:
*** = .491 < r P < .001
** = .394 < r < .491 .001 < P < .01
* = .305 < r < .394 .01 < P < .05

Table 8 indicates that for pentads, 33—37 (June 10—July 4), there are significant positive correlations for several of the years. The other pentads show an irregular pattern, with the possible exception of pentads 27 (May 11—15) and 41 (July 20—24) which had relatively high overall correlations.

The mean correlation coefficients for years of high cone crop but with either no or a low cone crop in the preceding year are also shown in Table 8. These data also indicate that the temperature during the pentads, 33—37 (June 10—July 4), is of importance to the cone crop the following year.

The results presented in Table 9, which are based on individual stations, support the assumption that the most influential period comprises pentads 33—37 (June 10—July 4).

and different independent variables which refer to the year of flower primordia initiation (1960—
years which were characterized by a high cone crop and a low cone crop in the year of bud forma-
correlations.

July									June		
20—24	25—29	30—4	5—9	10—14	15—19	20—24	25—29	10—19	Mean temperature	Precipitation	Cones/tree
35	36	37	38	39	40	41	42	33 + 34			
**	***	**				***	**	**	**	– –	
		–	– – –	– –	–		– –				
			**								
**	*	*		*			**				
	*	*			*					– –	
*	*	*	*						*		
					–						
**			**				*	*	*	– –	
											– –
.111	.096	.122	.088	.066	.003	.063	.098	.148	.100	–.174	–.059
.105	.163	.160	.107	.026	–.023	–.004	.084	.261	.186	–.294	–.045
.217***	.237***	.511***	.182***	.033	.094*	.398***	.083*	.417***	.422***	–.217***	–.305***

Significance levels for overall correlation coefficients:
*** = $.139 < r$ $P < .001$
** = $.109 < r < .139$ $.001 < P < .01$
* = $.070 < r < .109$ $.01 < P < .05$

3.2.2 *Relationship between cone crop and temperature at a certain temperature sum*

The temperature at a certain temperature sum (T) was related to the cone crop in the same way as was the data from our own inventory. The results for the different years are presented in Table 10. The correlations are surprisingly low. However, especially if emphasis is on the mean of the years followed by good cone crop, T = 45—65 seems to be a period of importance to flower primordia initiation. The temperature sum, 45—65, corresponds on the average to June 11—22 (cf. Table 4).

When the individual stations are studied, stronger correlations are obtained (Table 11). Table 11 indicates that the temperature during T = 45—70 is most important to

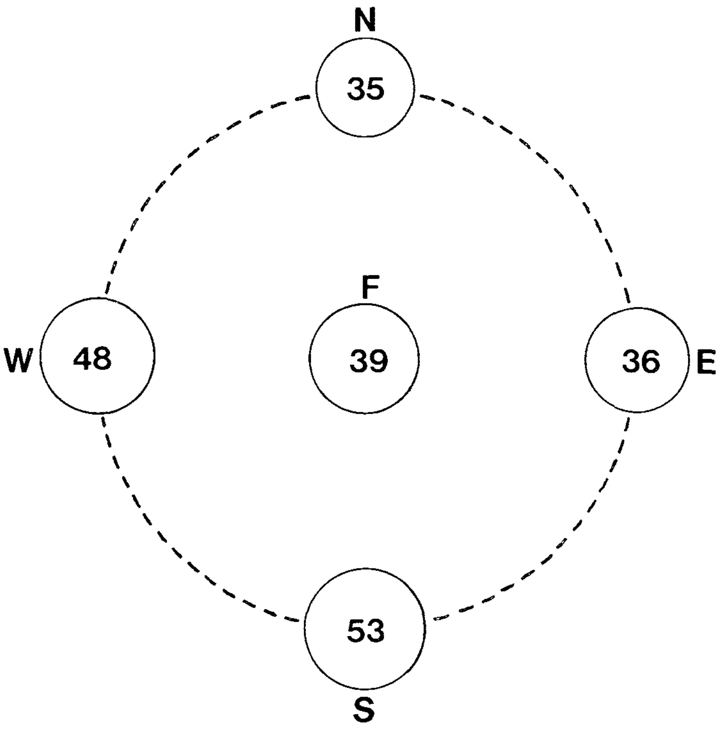


Figure 14. Mean values of cones per tree in stands located on northern (N), eastern (E), southern (S) and western (W) slopes or on more or less flat ground (F) in 1973—1975.

flower primordia induction, which agrees with the data presented in Table 10.

The overall correlations obtained with the temperature at different pentad temperature sums with a threshold temperature of +6°C are illustrated in Figure 15. This figure suggests that the temperature at temperature sums, 45—70, is of greatest importance to flower primordia initiation. This holds true even if precipitation and cones per tree are included in the multiple regression analyses.

3.2.3 *Dependence of precision on choice of independent variables*

Simple and multiple regression analyses of the relationship between cones per tree and the following independent variables were compared (all independent variables refer to the year of flower primordia initiation):

Mean temperature in June
Mean temperature during pentads 33 + 34
Mean temperature when T = 55—65 is reached
Mean temperature when T = 45—70 is reached
Precipitation in June
Cones per tree

These correlations were calculated to examine the gain in precision through the use of short periods instead of, for example, periods comprising a whole month, or through the use of one, two or three independent variables. The average simple and multiple correlation coefficients together with overall correlation coefficients are shown in Table 12 (cf. also Tables 8—11). When precipitation in June of the year of bud initiation was used as a second independent variable, almost no increase in the overall correlation coefficients was obtained, whereas a slight increase was observed in the mean correlation coefficients of stations and years compared with those calculated

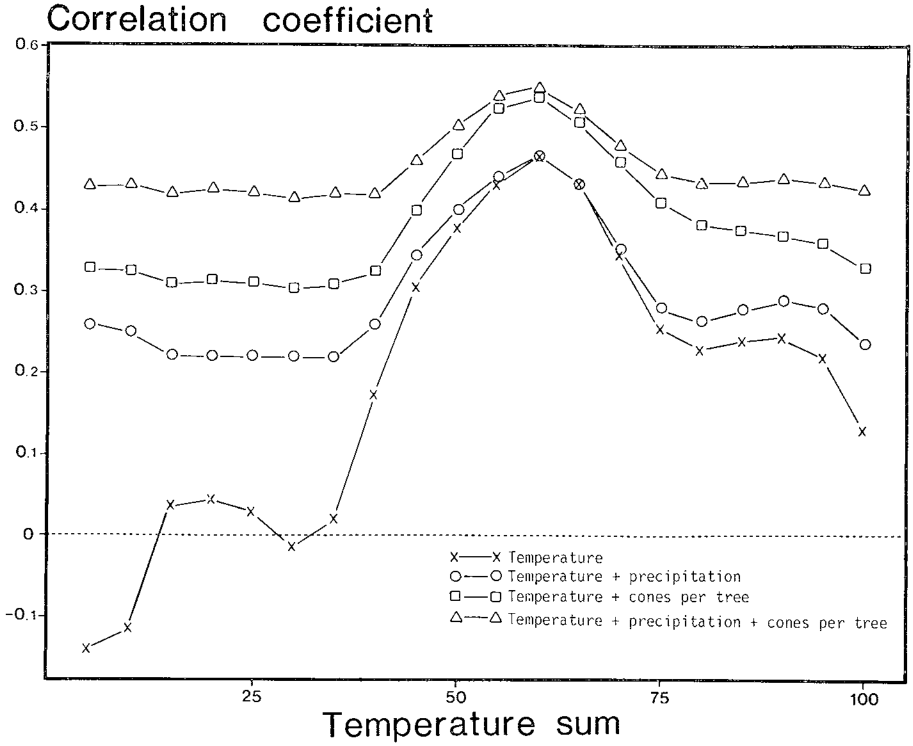


Figure 15. Correlation coefficients with the square root of cones per tree in 1961—1974 as the dependent variable and temperature at different pentad temperature sums, the square root of precipitation in June and the square root of cones per tree as independent variables. All independent variables refer to the year of flower primordia initiation. The correlations are calculated with each station and each year as an independent unit: "overall correlation."

for the temperature alone. An increase in the overall correlation coefficients was obtained when the number of cones per tree in the year of bud initiation was taken as a second independent variable. The results also indicate that the temperature, when a temperature sum of 45—70 is reached, is the most important one. As regards the overall correlations, the temperature explains about 24 % of the variation in cone crop, which increases to 31 % when the additional independent variable, cones per tree in the year of bud differentiation, is included. This percentage is almost unchanged if yet another independent variable, precipitation in June of the year of bud formation, is included.

3.3 Discussion and conclusions

In the above discussion, it was frequently emphasized that high correlations between the cone crop and weather conditions are not to be expected for the following reasons:

1. The appearance of the critical period(s) for flower primordia initiation may vary from locality to locality owing to:
   a) Variation in the onset of spring and summer.
   b) Variation in temperature requirement for initiation of flower primordia.
2. Flowering in a given year is negatively correlated with flowering in the following year.

Table 9. Significance levels of the correlations between the cone crop in the years 1961—1974 and for each station separately. Corresponding mean and overall correlation coefficients are also given.

	Temperature at pentad No.									
Station	25	26	27	28	29	30	31	32	33	34
1 Allgunnen	*									
2 Alvhem						**				
3 Ambjörnarp									*	
4 Arvika										
5 Bollebygd						**				
6 Bredviken										
7 Bredåkra			–							
8 Buttle	**									
9 Degerfors									*	*
10 Ekefors	*		–					*		
11 Fagered										
12 Filipstad									*	
13 Forshult										
14 Godegård			–						*	
15 Hagshult										
16 Jönköping										
17 Kalmar	*				*					
18 Karlstad									**	*
19 Kårsta										*
20 Lindesberg	*									
21 Ljungby	*	– –								*
22 Malexander									*	
23 Målilla	*		–					*		
24 Nyköping	*								*	*
25 Nävelsjö										*
26 Osby										
27 Prästkulla										
28 Remningstorp										
29 Simlångsdalen										
30 Simonstorp	*								*	
31 Skinnskatteberg									**	*
32 Snavlunda										
33 Stora Segerstad										
34 Strängstorp									*	
35 Svarteborg									*	
36 Ulricehamn	***									
37 Vimmerby	*		– –							
38 Västerås		–								
39 Växjö	*									
40 Åkers Styckebruk										
41 Åmål									*	
42 Åtvidaberg		–								
mean value	.398	–.230	–.356	–.101	.204	.110	–.042	.148	.431	.382
overall	.374***	–.194***	–.323***	–.081*	.192***	.123**	–.031	.136**	.409***	.365***

Significance levels assuming 14 independent observations:

*** = .780 < r P < .001
** = .661 < r < .780 .001 < P < .01
* = .532 < r < .661 .01 < P < .05

different independent variables which refer to the year of flower primordia initiation (1960—1973) Minus signs indicate the significance level of the negative correlations.

									June		
35	36	37	38	39	40	41	42	33 + 34	Mean temperature	Precipitation	Cones/ tree
						*					–
		*									
		*						*			
		*								–	
		*								–	
		*									
		*				*		*	*		
						*		*	*		
		*									
*		*							**		
						**		*			
		*				**					
		**							*	–	
									*		
		**									
						*					
								**	*		
						**		*			
		*						*	**		
						*		*	*		
		*						*	*		
		*									– –
						**					
		*						*	**		
		*				*					
		*									
		**									
*		**	*						*		
		*				*		**	**		
						*		**	*	–	
		**								–	
		**									
*		*						*	**	– –	
								*			
	*	*				*					
		**							*		
							*				
						*			*		
		**									
								*			
						*			*		
.225	.260	.546	.190	.008	.100	.417	.114	.441	.474	–.220	–.320
.217***	.237***	.511***	.182***	.033	.094*	.398***	.083*	.417***	.422***	–.217***	–.305***

Significance levels for overall correlation coefficients:
*** = .139 < r P < .001
** = .109 < r < .139 .001 < P < .01
* = .070 < r < .109 .01 < P < .05

Table 10. Significance levels of the correlations between the cone crop in 1961—1974 and the primordia initiation, 1960—1973, for each year separately and the corresponding mean and overall

Year	T 5	10	15	20	25	30	35	40	45	50
1960										
1961										
1962					---					**
1963										
1964	*				–			**	**	–
1965										
1966	---	***		---	***	**	*	**	***	**
1967	---									
1968	*									
1969			*							
1970										
1971										
1972	--		**			*				*
1973						--			–	
mean value 60—73	–.121	.031	.086	–.038	–.064	.041	.144	.122	.112	.081
mean value 61+63+66+68+72	–.228	.055	.088	–.095	.125	.134	.162	.166	.206	.195
overall	–.141***	–.116**	.036	.047	.027	–.014	.019	.176***	.306***	.379***

Significance levels assuming 42 independent observations:
*** = .491 < r   P < .001
** = .394 < r < .491   .001 < P < .01
* = .305 < r < .394   .01 < P < .05

3. The site conditions (particularly soil factors) may influence the number of female strobili, which may also be reduced by spring frost or other factors.

For the inventories carried out by the National Forest Survey additional causes prevail:

1. The stands surveyed vary from year to year.
2. The weather conditions at the stands examined are not exactly known.
3. The number of cones per tree in conjunction with low cone crops is probably exaggerated owing to the classification technique used.

In spite of all disturbing factors, both the data from our own inventory and those obtained from the National Forest Survey indicate that the period lasting from the middle to the end of June is important to flower primordia initiation.

According to Dunberg (1976), measurement of the growth of the terminal shoots on side branches should be a good criterion for the determination of the point of time of male flower primordia initiation. Covering grafts with plastic tents has verified that the maximum flowering stimulation is connected with the final growth period of the terminal shoots of side branches. This period of flower induction, thus revealed, empirically agrees well with the time sugtemperature at different temperature sums, T (threshold temperature + 6°C), in the year of flower correlations (cf. Table 8). Minus signs indicate the significance level of the negative correlations.

55	60	65	70	75	80	85	90	95	100	55—65	45—70
		*					***	***			
**	*		–							*	*
							– –	–			
			*					*			
**							**	*			*
	**	**	***	***			*	*		**	*
*						*		**		*	***
				–	– –	–	–				
.135	.120	.059	.037	.030	.028	.054	.083	.076	.004	.133	.165
.210	.173	.103	.086	.065	.097	.147	.178	.174	.077	.191	.255
.436***	.464***	.430***	.349***	.256***	.230***	.238***	.246***	.221**	.132**	.473***	.490***

Significance levels for overall correlation coefficients:
*** = .139 < r P < .001
** = .109 < r < .139 .001 < P < .01
* = .070 < r < .109 .01 < P < .05

gested by the data of the present investigation.

Whether or not there is a second period important to flowering cannot be determined. There is an indication that a high temperature later on during the summer is positively correlated with flowering. The biological explanation for this would be that high temperature prevents a reversion of flower primordia to vegetative ones as suggested by Ebell (1970).

The investigation indicates that there is a positive correlation between temperature and cone crop. (Similar conclusions were recently drawn by Zviedre (1976) for *Picea abies* in Latvia.) In recent investigations of *Picea abies* in which grafts were covered with plastic tents, an increase of flowering was provoked (Remröd 1973, Dunberg 1976, Wellendorf 1976), which may be attributed to the increased temperature during the treatment.

Earlier observations of the flowering after root pruning or stem strangulation suggest that such treatment causes an increase in flowering (cf. Matthews 1963). This also suggests that a water deficit would stimulate flowering. The present investigation supports this view. However, this may not be true in the case of artificial conditions. Thus, Olsen (personal communication) obtained a decrease in the flowering of potted grafts placed in a polythene house when the grafts were subjected to water stress. Ac-

Table 11. Significance levels of the correlations between the cone crop in 1961—1974 and the primordia initiation for each station separately. The corresponding mean and overall correlation stated. Minus signs indicate the significance level of the negative correlations.

Station	Temperature sum									
	5	10	15	20	25	30	35	40	45	50
1 Allgunnen										
2 Alvhem						**				
3 Ambjörnarp										*
4 Arvika									*	
5 Bollebygd										
6 Bredviken								*	*	*
7 Bredåkra							–			
8 Buttle					– –					
9 Degerfors										*
10 Ekefors										
11 Fagered										
12 Filipstad										
13 Forshult									*	
14 Godegård	–									
15 Hagshult									*	*
16 Jönköping										
17 Kalmar										
18 Karlstad									*	*
19 Kårsta										
20 Lindesberg				*						
21 Ljungby										
22 Malexander									**	**
23 Målilla		–								
24 Nyköping	–								*	
25 Nävelsjö										*
26 Osby										
27 Prästkulla										
28 Remningstorp										
29 Simlångsdalen										
30 Simonstorp										
31 Skinnskatteberg										*
32 Snavlunda										
33 Stora Segerstad										
34 Strängstorp										
35 Svarteborg									**	**
36 Ulricehamn										
37 Vimmerby										
38 Västerås										
39 Växjö										
40 Åkers Styckebruk										
41 Åmål										
42 Åtvidaberg										*
mean value	–.115	–.132	.019	.036	.018	.034	.020	.146	.298	.391
overall	–.141***	–.116***	.036	.047	.027	–.014	.019	.176***	.306***	.379***

Significance levels assuming 14 independent observations:

*** = .780 < r P < .001

** = .661 < r < .780 .001 < P < .01

* = .532 < r < .661 .01 < P < .05

temperature at different temperature sums, T (threshold temperature +6°C) in the year of flower coefficients are shown. The mean number of cones per tree in 1961—1974 for each station are also

55	60	65	70	75	80	85	90	95	100	55—65	45—70	Cones/ tree 1961—1974
												34
												42
**	**									**	*	31
	*									*	*	47
	*											32
												33
												35
	*	*								*	*	40
*	*	*	*							*	*	38
												42
*	*	*						*		*	*	30
*	*									*	*	34
												43
*	**									*	*	34
												28
				*								40
												38
**	*	*								**	**	58
	*	*	*							*	*	26
*	***	**	*							**	**	34
*	*	*	*							*	*	30
*	*	*								*	**	48
												44
												40
**	**	**	*							**	**	30
												41
												30
												52
	*	*	*	*						*	*	35
*	*	**	**	*						**	**	35
**	**	*								**	**	31
												38
												36
	**	***	**	*						**	**	30
*											*	44
	*								*			39
		*	**	*							*	32
												36
											*	50
									*			30
*	*									*	*	57
*										*	*	36
.454	.489	.463	.364	.275	.253	.261	.263	.240	.143	.500	.518	38
.436***	.464***	.430***	.349***	.256***	.230***	.238***	.246***	.221***	.137***	.473***	.490***	

Significance levels for overall correlation coefficients:
*** = .139 < r P < .001
** = .109 < r < .139 .001 < P < .01
* = .070 < r < .109 .01 < P < .05

Table 12. Average correlation coefficients and the overall correlation coefficients for the cone crop in 1961—1974 based on one, two or three independent variables. The significances for multiple, overall correlation coefficients were obtained by F-analyses based on the regression mean square divided by the residual mean square.

	Independent variables during the year of flower primordia initiation																
	Temperature during				Precipitation June + temperature				Cones/tree + temperature				Precipitation + cones/tree + temperature				Cones/tree + precipitation during June
	June	pentad 33 + 34	T 55—65	T 45—70	June	pentad 33 + 34	T 55—65	T 45—70	June	pentad 33 + 34	T 55—65	T 45—70	June	pentad 33 + 34	T 55—65	T 45—70	
Years 1960—1973	.100	.148	.133	.165	.285	.292	.281	.296	.233	.231	.241	.256	.318	.327	.319	.335	.251
Stations 1—42	.474	.441	.500	.518	.537	.509	.549	.572	.546	.553	.602	.607	.615	.614	.645	.652	.499
Overall	.422***	.417***	.473***	.490***	.426***	.429***	.473***	.490***	.485***	.498***	.551***	.558***	.503***	.526***	.558***	.563***	.416***

cording to Olsen the heat treatment (approximately +30°C) must be accompanied by abundant watering to stimulate flowering. If this is a general phenomenon it may explain the unexpectedly low cone crops sometimes obtained for grafts placed in polythene houses (Fletcher, Remröd; personal communications).

A positive and significant correlation was obtained between the cone crop and the proportion of fine sand. Earlier observations of grafts growing in heavy clay indicate that such types of soil material should be avoided when seed orchards are to be established.

From a summary of the facts which are known to be of importance to the location of *Picea abies* seed orchards in southern and central Sweden, it may be concluded that such orchards should be established in localities where there is a high probability of high temperatures being reached during June 10—June 30, which period coincides approximately with the last part of the growth period of the terminal shoots on side branches. Therefore, in the next section the temperature data for mid and late June in southern Sweden will be examined, to identify regions with a high probability of a high incidence of weather conditions conducive to flowering.

4 Location of seed orchards

From the above discussion, it is evident that the weather conditions during the last 20 days of June are important to the initiation of flower primordia. Therefore, the percentage of observations with a mean temperature equal to or above +15°C during the pentads, 33—37 (June 10—July 4), was calculated for the period, 1960—1973. Percentages thus obtained are illustrated in Figure 16. As may be seen from this map the highest percentages occur in the eastern part of the country.

Another approach was also used to identify regions with a high probability of frequent and abundant cone crop. In this case a percentage based on the number of occasions when the temperature was equal to or above +15°C at six distinctive temperature sums (45, 50, 55, 60, 65 and 70) at the different meteorological stations was calculated. Percentages thus obtained are illustrated in Figure 17. There is a fairly good correlation between the percentages in Figures 16 and 17. The highest percentage in both cases was noted for Västerås. This seems reasonable since many wild plants and trees which prefer heat are found in the valley of Lake Mälaren. In Figures 16 and 17 one of the stations (Alvhem) close to the west coast is characterized by a relatively high percentage. This station is situated in the valley of the "Göta älv" river, for which a forecast of warm weather could be expected.

Our results suggest that low precipitation is conducive to flower primordia initiation. Therefore the average precipitation for June during the period 1960—1973 was calculated. The results are illustrated in Figure 18. From this figure it may be seen that the lowest precipitation in June was noted for the stations in the south-eastern part of the country.

It may therefore be concluded that the south-eastern part of the country seems to be the most feasible for the location of *Picea abies* seed orchards (cf. Figures 16—18). This agrees with the observations from the seed orchards of *Picea abies* established earlier, cf. e.g. Eriksson *et al.* (1975). High average numbers of cones per tree in natural stands are also more frequent in this part of the country, as may be seen from Figure 3. If the establishment of a seed orchard in the south-western part of the country is nonetheless desired, the local conditions must be carefully considered. There are probably localities like Alvhem (cf. above) that will satisfy the meteorological prerequisites governing the location of the seed orchards, but they are certainly not as frequent as in the south-eastern part of Sweden.

In order to obtain high temperatures it is preferable that the site be exposed to as little wind as possible. This is an argument against sites on flat agricultural land, although such a site may be attractive from other considerations, such as long distances to surrounding stands of Norway spruce.

As regards soil factors, the recommendations cannot be taken as definitive, since sufficient empirical data for reliable recommendations are lacking. In the present investigation, a positive correlation was found between cone crop and the proportion of fine sand in the soil. It may therefore be wise to select a site with a high proportion of fine sand or with a closely related soil material for the establishment of new seed orchards.

Finally, it may be questioned as to whether or not the male flowering responds to external factors in the same way as female flowering. In the present investigation no examination of the male flowering was made. However, a stimulation of male

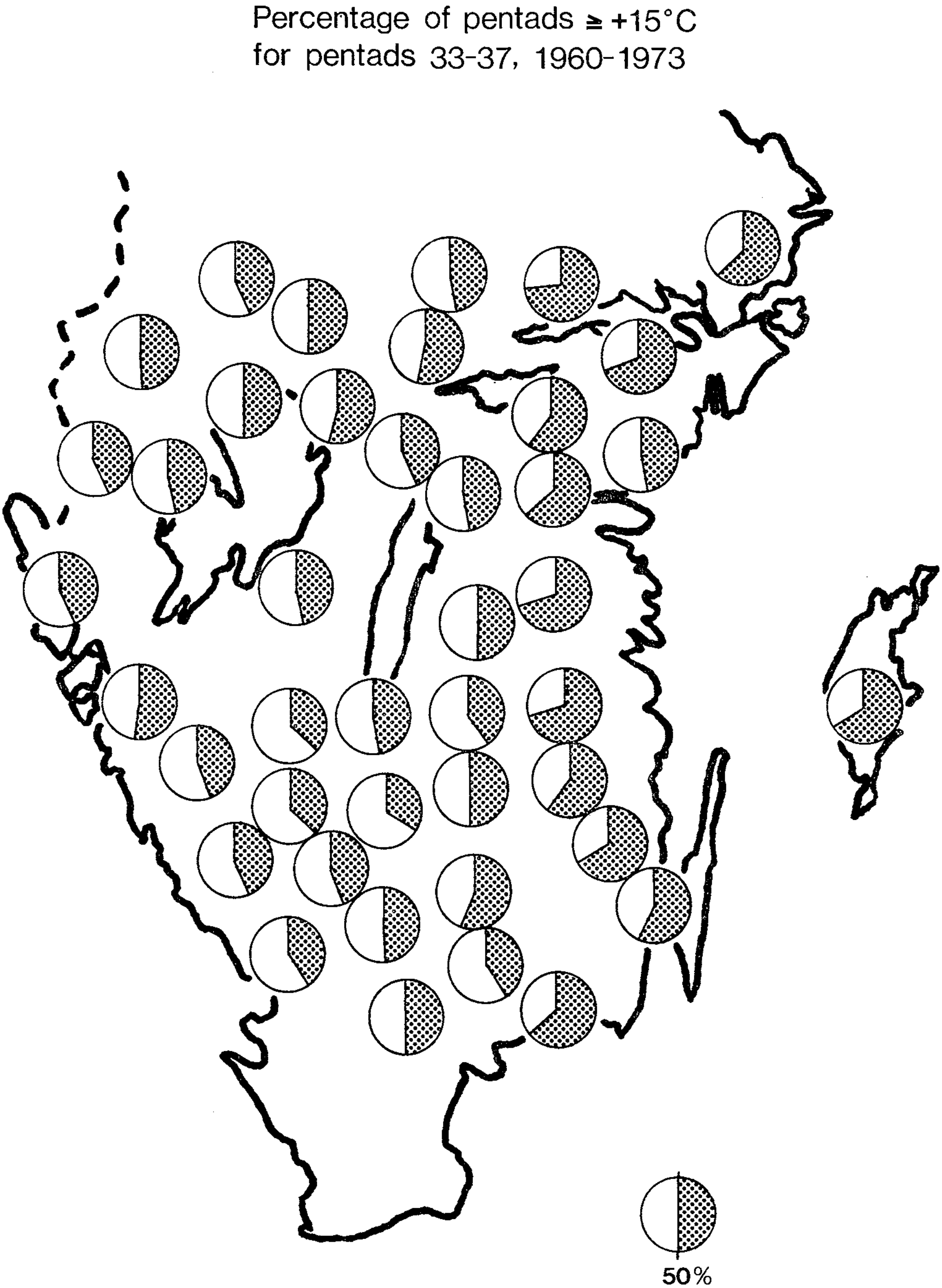


Figure 16. The percentage of pentads with a mean pentad temperature equal to or above +15°C during the pentads, 33—37, based on data for the period 1960—1973.

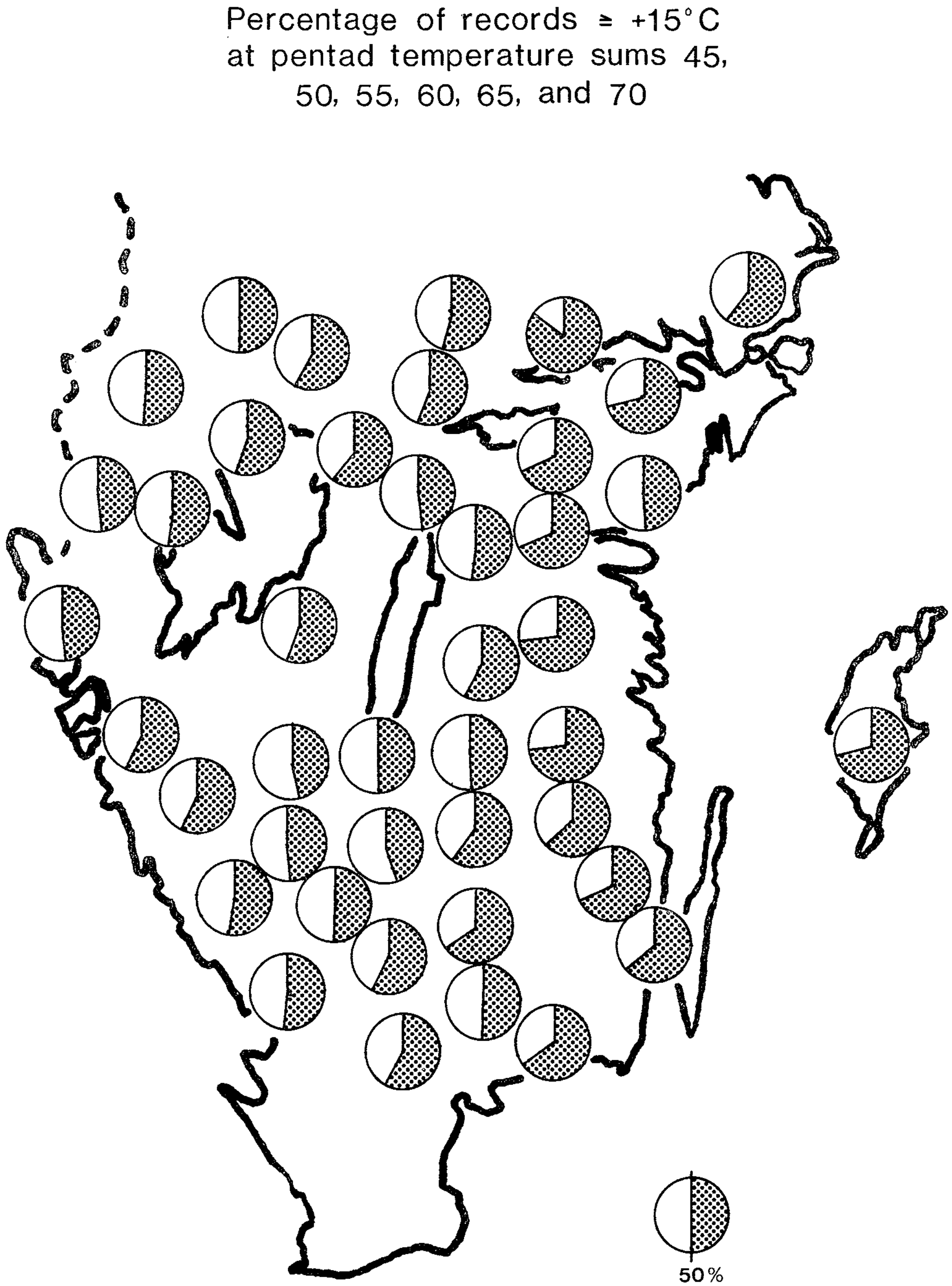


Figure 17. The percentage of records with a mean temperature equal to or above + 15°C at six distinct pentad temperature sums: 45, 50, 55, 60, 65 and 70 in 1960—1973.

Figure 18. The average precipitation for June based on monthly records during the period 1960—1973.

flowering by temperature treatment during the sensitive period of flower bud initiation was found by Brøndbo (1969, 1970), Remröd (1973) and Dunberg (1976). Furthermore, from the detailed investigation on male and female flowering in a clone trial outside Stockholm (Ekberg *et al.* 1977) and in a seed orchard at Jung (Lindgren and Lindgren 1976b), it seems clear that there is a fairly close analogy between female and male flowering as regards their cyclic appearance. Thus, current knowledge on male flowering does not contradict any of the above recommendations for the location of seed orchards. Moreover, the new concept of seed orchards, as presented by Sweet and Krugman (1977), implies that female and male orchards could be kept separate.

5 Sammanfattning

I samband med att anläggningen av nya fröplantager av gran tagits upp till diskussion har frågan om den optimala lokaliseringen av dessa fröplantager blivit aktuell. En fröplantage bör vara lokaliserad så att en riklig blomning inträffar så ofta som möjligt. I södra Sverige förekommer en riklig granblomning i genomsnitt vart 4:e år. Denna periodicitet i blomningen tyder på att yttre faktorer, såsom klimatförhållanden, kan spela en avgörande roll vid induceringen av blomanlagen. För att kunna ge tillförlitliga rekommendationer om var granfröplantagerna bör vara belägna måste en utvärdering av dessa yttre faktorers betydelse utföras.

Riksskogstaxeringen har sedan 1953 utfört årliga inventeringar av kottförekomsten. Det var därför naturligt att utnyttja dessa data för en analys av sambandet mellan kottförekomst och väderförhållanden under det år då blomanlagen initieras. Dessa data är emellertid inte helt idealiska för denna typ av analys bl.a. beroende på att olika bestånd inventerats olika år.

Det var därför angeläget att starta en egen inventering som utfördes under åren 1973—1975 i granbestånd belägna i närheten av meteorologiska stationer i södra och mellersta Sverige.

Den egna inventeringen omfattade 31 bestånd (kursiverade i tabell 4). Samma bestånd undersöktes de olika åren i fråga om antal kottar per träd. I figurerna 6, 8 och 10 har kottförekomsten hos de 31 bestånden illustrerats för åren 1973, 1974 och 1975. År 1973 kännetecknades av en riklig blomning i östra Sverige medan det under 1974 inträffade en riklig blomning i västra Sverige. År 1975 förekom däremot praktiskt taget ingen blomning hos de analyserade bestånden. Den genomsnittliga kottförekomsten under de tre åren blev därför utjämnad (figur 11).

Som en jämförelse har Riksskogstaxeringens inventering av kottförekomsten under 1973 och 1974 illustrerats i figurerna 7 och 9 för respektive år.

Med utnyttjande av data från den egna undersökningen har en analys utförts av sambandet mellan kottförekomst och följande yttre faktorer under det år då initieringen av blomanlagen äger rum: olika temperaturvariabler (se kapitel 2.1), nederbörd och kottförekomst. Vidare har sambandet mellan kottförekomst och olika bestånds- samt ståndortskarakteristika studerats.

Beträffande temperaturen erhölls ett starkt signifikant samband mellan hög temperatur under senare hälften av juni 1972 och en riklig kottförekomst året därpå (figur 12). Temperaturen ensam förklarade 64 % av variationen i kottförekomst.

Ett starkt samband förelåg mellan låg nederbörd i juni och hög kottförekomst året därpå (tabell 5).

En konsekvens av den typ av skottuppbyggnad som kännetecknar gran, där honblommorna bildas i skottspetsarna, är att en riklig honblomning ett år reducerar antalet skottspetsar som skulle kunna bilda honblommor nästa år. Som väntat erhölls också ett negativt samband mellan antalet kottar per träd 1973 och 1974, dvs. de bestånd som hade en god blomning 1973 uppvisade en sämre blomning 1974 (figur 13). Detta negativa samband illustreras även i figur 5 som visar kottsättningen hos tre granympar under 10 år. Ett mycket rikligt blomningsår åtföljdes alltid av ett år utan blomning. Till detta kan läggas att antal kottar under blomanläggningsåret dominerade över temperatur och nederbörd när det gällde att förklara orsakerna till variationen i kottförekomst år 1974 (tabell 5 och 6).

Av övriga faktorer som kunde förväntas påverka blomningen registrerades en signifikant bättre blomning hos de bestånd som växte på jord med en hög andel grovmo. Vidare uppvisade de största träden i bestånden den bästa kottproduktionen.

Riksskogstaxeringens insamlade data från 42 områden i södra Sverige med en radie av högst 19 km från närmaste meteorologiska station utnyttjades också vid analysen av väderlekens inverkan på blomningen. Det blev härigenom möjligt att utvidga analysen över en längre tidsperiod (tabell 7). Kottförekomsten under åren 1909 till 1967 för 5 regioner av Sverige visar att södra och mellersta regionen haft det genomsnittligt högsta antalet kottar per träd under denna tid (figur 2). En kraftig variation mellan olika år förekommer emellertid (figur 4).

Sambandet mellan kottförekomsten och den genomsnittliga temperaturen under olika pentader (5 dygn) samt temperaturen när en viss temperatursumma uppnåddes under blomanläggningsåret beräknades för vart och ett av åren 1960—1973 (tabell 8 och 10) och för vart och ett av de 42 områdena intill meteorologiska stationer (tabell 9 och 11).

Såväl de korrelationer som var baserade på enskilda år som de avseende enskilda områden bekräftade de resultat som erhållits i den egna undersökningen, nämligen att temperaturen under tiden strax före mitten av juni till början av juli är av största betydelse för induceringen av blomanlag och därmed för nästa års kottförekomst.

Multipla korrelationer, där förutom olika temperaturvariabler även nederbörden under juni och kottantal under blomanläggningsåret ingår, visade att perioden från strax före mitten till slutet av juni är av störst betydelse (tabell 12). Temperaturen under denna tidsperiod kunde ensam förklara 24 % av variationen i kottantal. Inkluderas även kottförekomsten under blomanläggningsåret kunde 31 % av variationen förklaras (se även figur 15).

De slutsatser man kan dra av dessa resultat är att väderleken och då främst temperaturen har ett betydelsefullt inflytande på initieringen av blomanlagen.

För att kunna identifiera regioner med hög sannolikhet för en riklig kottförekomst har procenttalet pentader med medeltemperaturer på +15°C eller däröver under tiden 10 juni till 4 juli beräknats för åren 1960—1973 (figur 16). Även procenttalet observationer av temperaturer på +15°C och däröver vid olika temperatursummor har beräknats (figur 17). I båda dessa beräkningar uppnåddes de högsta procenttalen i östra delen av landet.

Beträffande nederbörden under juni månad observerades de lägsta nederbördsmängderna i sydöstra delen av landet (figur 18).

De erhållna resultaten pekar således mot att granfröplantager företrädesvis bör anläggas i den sydöstra delen av Sverige. Men även utanför denna region bör det vara möjligt att finna platser med ett för fröplantager lämpligt lokalklimat.

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