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Cone and seed properties in a young and an old stand of *Pinus sylvestris* L.

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Studia Forestalia Suecica
No. 168 · 1985

ISSN 0039-3150
ISBN 91-576-2282-5

Abstract

Bergsten, U. 1983. *Cone and seed properties in a young and an old stand of* Pinus sylvestris L. Studia Forestalia Suecica 168. 13 pp. ISSN 0039-3150. ISBN 91-576-2282-5.

Cones from a young (24–28 years) and an old stand (120–280 years) of *Pinus sylvestris* L., originating from Lycksele in north Sweden (N 64° 30', E 18° 45', Alt. 310 m) were examined in the laboratory to establish whether there are biological restrictions on the use of seeds from young stands. The number of cones per ha was approximately 71 000 in the old stand and about 29 000 in the young stand, which corresponded to 4.3 respectively 2.1 kg of filled seeds. Cones from the young stand exceeded cones from the old stand in length, volume and dry weight; consequently the seeds from the young stand were heavier than those from the old stand. There were no differences between the two stands in other properties, such as germination rate and capacity, number of seeds per cone, percentage of empty seeds and extractability. There appears to be no biological reason for restricting cone collection from a young stand of the above age.

Key words: Pinus sylvestris, cones, seeds, young stand, old stand.
ODC 232.319

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Contents

MS. accepted 8 February 1985

016.10 Tofters tryckeri ab, Östervåla 1985

Introduction

As the demand for pine seed in parts of Sweden, especially in the north of the country, cannot be totally supplied by seed from seed orchards, cone picking from stands is necessary. This demand will increase if sowing as a method for regeneration is used to a greater extent than now (Gustafson, 1980).

Flowering, pollination, cone setting and seed development are strongly influenced by weather conditions, especially by the temperature (cf. Sarvas, 1962; Simak, 1972; Bergman, 1976; Ihlstedt, 1982:1, etc.).

Cone setting is greatly dependent on the weather during the induction of flower-buds, i.e. the year before flowering. As against this, the seed quality is determined by the weather during the embryo development, which for Scots pine (*Pinus sylvestris* L.) is the year after flowering. If both cone setting and seed quality are taken into account, the interval between years with abundant cone setting combined with high seed quality is considerable, above all at high altitudes and latitudes. According to calculations by Kohh (1968), at Jokkmokk (Lat. 66° 36′, Alt. 262 m) for example, the frequency of years with cone setting of at least 80 cones/tree and a germinating percentage of 90 is only about 3%. Therefore, in many years, there is a shortage of seed in north Sweden.

As it is possible to store seed of high quality for a long time without risking a significant decrease in germinability (Huss, 1967), in years with good cone setting and seed ripening, cone picking should be done on a large scale. One way of meeting the demand for seed and increasing the cone collection during such years could be to collect cones in young stands, too.

Cone picking from standing trees is now being tested with promising results as an alternative to collection from clear-felled areas (Brunberg, 1982 - pers. comm.). Methods for cone collection from standing trees should make it possible to collect cones more than one year from each stand and not only at the clear-felling. Such methods should be easier to improve, if the trees are short, i.e. young.

The number of stands suitable for potential cone picking will increase significantly if young stands are also considered. As an example it may be mentioned that in north Sweden about 20% of the forests are between 21 and 50 years old (Svensson, 1983).

No direct comparisons of seed and cone properties in young and old stands of Scots pine have been found in the literature, though comparisons between *single trees* of different age *within a stand* have been made. According to Holmerz (1900), Lindroth (1953) and Mork (1957) there is no connection between germination capacity and the age of the mother tree if single trees of different age are compared. Old trees may produce more but smaller cones than young ones (Holmerz 1900, Lindroth 1953). Pines between 26 and 35 years of age produce about the same ammount of seeds (Rogozin 1978).

Rohmeder (1972) summarizes a review concerning the connection between the age of the mother tree and the cone, the seed and the plant quality as follows:

- From a genetical point of view, the age of the mother tree has no importance.
- The seed quality, for instance seed weight and germination capacity, is in general not considerable affected by the age of the mother tree.
- Plant development has not proved to be affected by the age of the mother tree.

Since the above investigations were made on single trees of different age within a stand, the value of this information—from a practical point of view—is limited. Cone and seed properties of young trees may depend on whether the trees are suppressed by competition, as may be the case in an uneven-aged stand or whether they are dominant as in an even-aged stand. On a practical scale, cones from young trees will probably be collected only in even-aged young stands. Therefore, the present examination focuses on cone and seed properties in two adjacent *stands* of Scots pine—a young and an old stand. The study was made to establish whether there are biological restrictions on the use of seeds from young stands.

Material and methods

Field methods

An inventory and cone collection was made in November 1980 of a young (24–28 years) and an old stand (120–280 years) of Scots pine *(Pinus sylvestris* L.). The two stands are situated 2 km west of Lycksele (N 64° 30′, E 18° 45′) at an altitude of about 310 metres. Both stands arose by natural regeneration, the young stand probably from the old one.

At the time of the inventory most of the trees in the old stand had been clear-felled by a feller-buncher and a processor. In the investigated area, Fig. 1, in which the trees were felled but not limbed, 20 circular sample plots (100 m^2) were laid out at a distance of 40×40 metres from each other. In the young stand, about 50 metres west of the old stand, 16 sample plots (100 m^2) were laid out at a spacing of 50×50 metres. On each plot a sample tree was selected and the properties of the site, the stand and the sample tree were described.

The site data were almost the same in the two stands. The old stand was exposed to the south, south-east and the young stand to the north, north-east. This difference in exposure will probably be of no importance, as the slope was gentle, <1:10. The soil was till, sand-fine sand with mesic-moist soil and surface/subsurface water flow during short periods. The ground flora was of *Vaccinium myrtillus* type in the old stand and of *Vaccinium myrtillus* and, to a small extent, *Ledum palustre-Vaccinium uliginosum* type in the young stand.

Both stands consisted of Scots pine, Norway spruce *(Picea abies* (L.) (Karst) and Birch *(Betula pubescens* Ehrh.), with Scots pine as the dominant species (Table 1). The number of trees per ha in both stands is representative of this part of north Sweden. The trees in the young stand were on the average 26 years old, showing a small variation in age. In the old stand the age varied considerably, from 120 to 280 years, with a mean age of 230 years.

The sample trees in the old stand were almost twice as tall as those in the young stand, 14 m on the average, compared to 8 m. The difference in diameter was also twofold, 28 cm and 14 cm. The cones on the sample tree were collected by an SFI-picker in the old stand and by hand in the young stand. As the trees in the old stand had been felled by a feller-buncher, the trees were to some extent gathered into bunches. The nearest pine with any part inside the plot was therefore selected as sample tree. In the old stand the number of cones on the sample trees was used to calculate the average amount of cones per tree and per hectare.

In the young stand the nearest tree with cones, counted from the centre of the plot, was selected as sample tree. In contrast to the old stand, in the young stand there were trees without cones. For estimating the average number of cones per tree and per hectare, the cone setting of each tree inside the sample plot was ocularly determined and assigned to one of six classes of cone setting. Since the cones of each sample tree were counted in the laboratory, this ocular classification was calibrated. The crowns of the sample trees in the young stand were too weak to permit

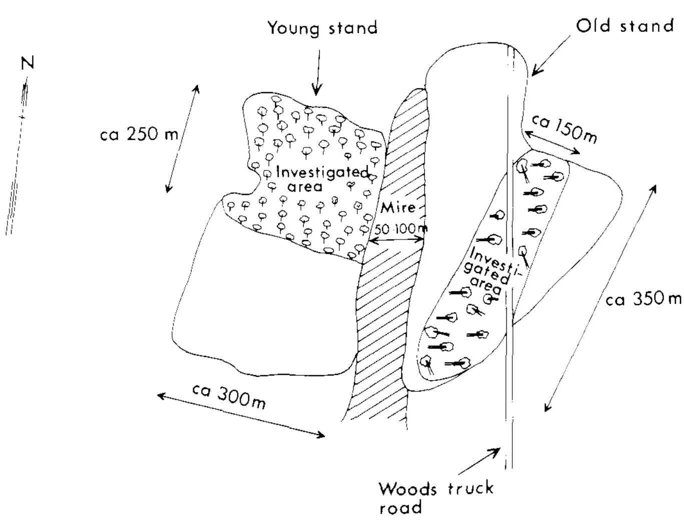


Fig. 1. Sketch of the investigated stands.

Table 1. *Stand and sample tree data with standard error described as ± s.e. %*

		Old stand	Young stand
Total number of trees/ha [a]		500±6%	910±9%
Number of Scots pine/ha [a]		390±7%	840±10%
Age of sample trees (year)	mean	230±4%	26±1%
	min.-max.	120–280	24–28
Height of sample trees (m)	mean	14±3%	8±5%
	min.-max.	11–17	5–11
Diameter of sample trees (cm)	mean	28±4%	14±5%
	min.-max.	18–37	8–17

[a] Calculated from a stump inventory on the plots, involving the risk of an underestimate as the stumps were covered by snow, ice and felled trees.

climbing to the top of the tree, which had the consequence that 12% (s.e.=20%) of the cones, though counted, could not be collected.

As the trees in the old stand had been felled, the cones from the underside of the crowns could not be picked. The total number of cones per tree was derived from an ocular estimate of the fraction of the crown that was hidden, on the average about 14%.

The cones from the north and the south sides of each tree in the young stand were counted and collected separately. This was not possible in the old stand, as the trees there had been felled and moved.

The collected cones were kept in special net sacks at 4°C in the cone store at the seed laboratory, until extraction was done in March 1981.

Cone and seed analyses

Cones from each tree were examined separately according to Fig. 2.

The length of the cones was measured in 18 classes of 2.5 mm respectively, from 15.0 to 60.0 mm. For further examination these 18 classes were united into 6 length classes (cf. Fig. 3).

The volume of the cones was determined by xylometer. If the number of cones per length class exceeded 50, the determination of volume and further examination was made on a sample lot of 30 cones.

The extraction was performed at 53°C for 16 hours. The degree of opening of the cones was determined according to Simak (1966). For the extracted seeds the percentage of empty seeds, anatomical development, thousand-grain weight and germination capacity were determined. The percentage of empty seeds and the anatomical development was established by radiograph (Simak, 1980). As the seeds were individually x-rayed, all the empty seeds could be removed. The remaining filled seeds gave thousand-grain weight and were used for the germination analysis which was carried out at 20°C according to

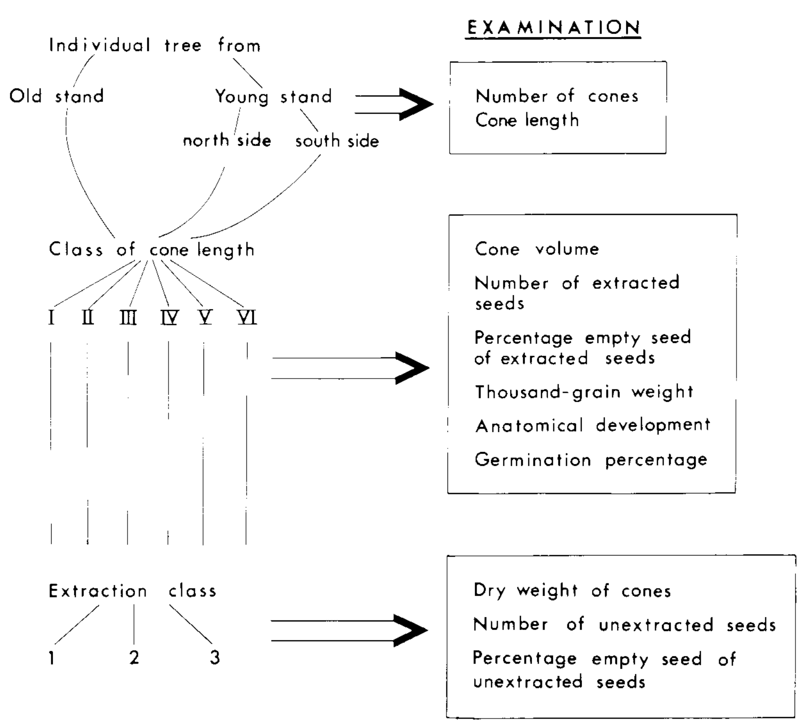


Fig. 2. Procedure for cone and seed analyses.

the ISTA-rules (1976). The analysis was performed with replications of 100 seeds with a maximum of 3×100 seeds per length class and tree. The extracted cones were manually divided into pieces, and the number of seeds that did not fall out during the extraction ("unextracted seeds") was determined. As these seeds were x-rayed, the percentage of empty seeds could be determined for this fraction, too. The cone parts were dried for 16 hours at 105°C for determination of dry weight.

The results presented include all material. No corrections or transformations were made, in spite of the fact that the number of cones and seeds was high for some trees and low for others. Differences in seed and cone properties between the stands were tested statistically with Student's *t*-test. The paired *t*-test was used when testing differences in properties for cones and seeds from different sides of the crown in the young stand.

The following levels of significance were used:
* = $p<0.05$ ** = $p<0.01$ *** = $p<0.001$
The standard error is presented as ± s.e.%

Results

Cone setting

On the sample trees in the old stand the average number of cones per tree was 183, in the young stand the average was 92. The south side of the crowns of the sample trees in the young stand contained 42% more cones than the north side of the crowns, 54 cones compared to 38 (Table 2).

By multiplying the number of cones per sample tree by the number of pines per hectare, the number of cones per hectare in the old stand was estimated at approximately 71 000.

Since in the young stand, only trees with cones were selected as sample trees, the estimation of the number of cones per hectare was based on the ocular determination of cone setting for every tree inside the sample plot. The frequency of pines in different classes of cone setting is shown in Table 3. The number of cones per hectare in the young stand, based on this estimation, was about 26 000. By comparing the counted number with the estimated number of cones on the sample tree, this value was calibrated to about 28 600 cones per hectare.

The calculation showed that the number of cones per hectare was almost three times as high in the old stand as in the young stand.

Length, volume and dry weight per cone

Cones from the young stand were significantly larger (18% in length, 47% in volume) and heavier than cones from the old stand (Table 4).

Cones from the south side of the crowns in the young stand were larger (3% in length, 16% in volume) and heavier (14%) than those from the north side of the crowns. The differences in length are illustrated in Fig. 3 which shows the average number of cones of different length per tree. The variation seems to be normally distributed in both stands.

Cone extractability

In Fig. 4 the result from the ocular estimation of extractability is shown.

The differences in extractability between cones from the two stands shown by this method were not significant.

Table 2. *The number of cones per sample tree*

	Old stand	Young stand			
	Total	Total	South side	*t*-test	North side
Mean	183±24%	92±16%	54±17%	**	38±20%
Min.-max.	16–722	17–209	10–134		1–105

Table 3. *The average number of pines per hectare in different classes of cone setting in the young stand*

	Number of cones					
	0–10	10–50	50–100	100–200	200–400	400+
Number of trees/ha	480±17%	225±14%	105±24%	25±45%	5±100%	0

Table 4. *Length, volume and dry weight per cone and tree*

	Old stand		Young stand			
	Total	*t*-test	Total	South side	*t*-test	North side
Length/cone and tree (mm) mean	28±2%	**	33±4%	33	**	32
min.-max.	21–32		25–44			
Volume/cone and tree (cm^3) mean	3.2±6%	**	4.7±9%	5.1	**	4.4
min.-max.	1.5–4.2		2.2–8.5	2.2–9.2		2.1–7.5
Dry weight/cone and tree (g) mean	2.72±5%	**	2.97±9%	3.15	**	2.77
min.-max.	0.96–2.88		1.49–5.38	1.53–5.98		1.46–4.95

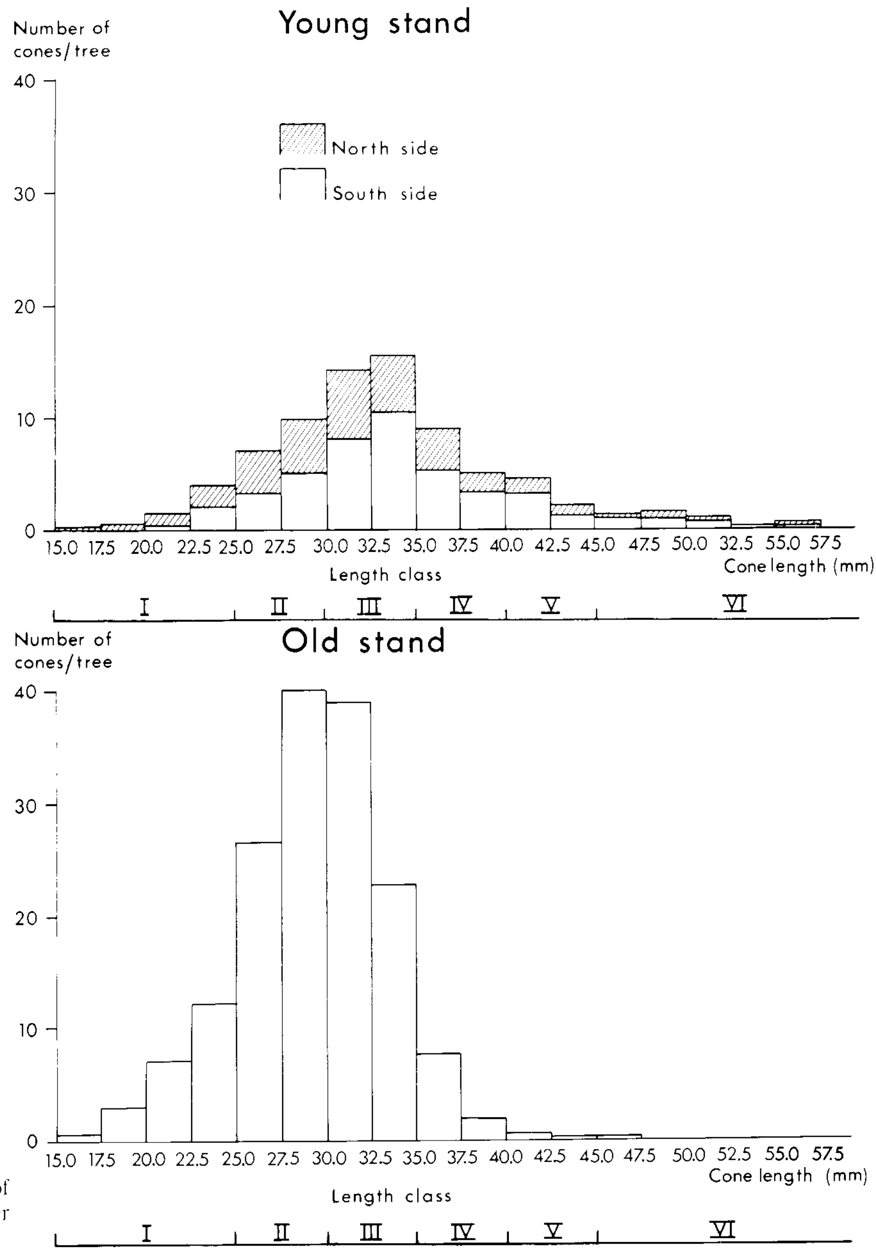


Fig. 3. The average number of cones of different length per tree.

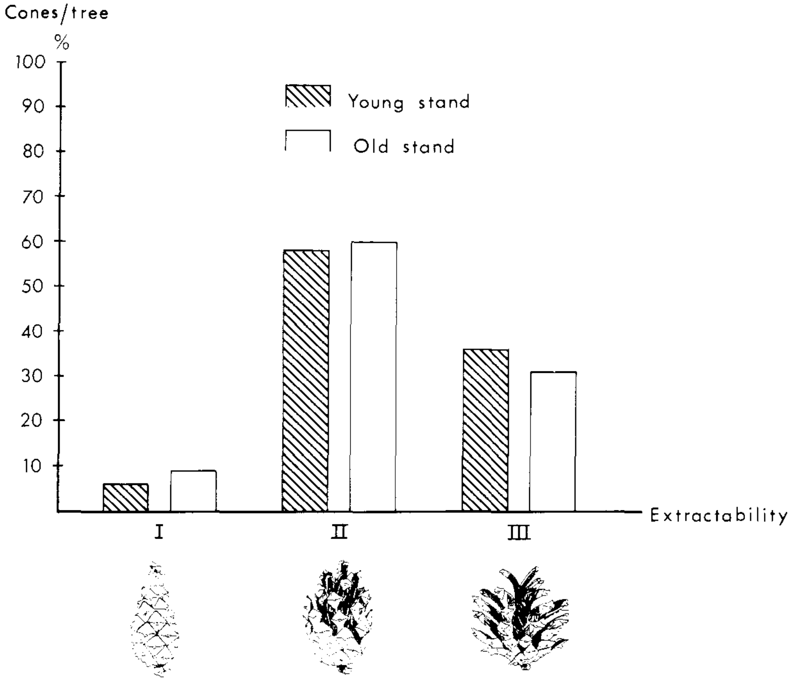


Fig. 4. Number of cones per tree in different classes of extractability.

As another value for extractability the number of extracted seeds was compared to the total number of seeds. On the average, 75% of the seeds from the young stand were extracted, compared to 66% extracted seeds from the old stand. However, the difference was not significant.

The number of extracted seeds may seem low, but must be seen in relation to the fact that only one extraction was made. In practice, the first extraction would probably have been succeeded by a second.

Number of seeds per cone, percentage of empty seeds and thousand-grain weight

Neither the percentage of empty seeds per tree nor the number of seeds per cone and tree differed significantly between the two stands (Table 5). Nor were these two parameters statistically different if cones and seeds from the north and the south sides of the crowns in the young stand were compared. The thousand-grain weight was 10% higher for seeds from the young stand, i.e. 4.20 g, compared to 3.82 g for seeds from the old stand. Seeds from south-exposed cones in the young stand were heavier than seeds from north-exposed cones, i.e. 4.32 g, compared to 4.03 g.

The percentage of empty seeds per tree was significantly lower ($p < 0.001$) for extracted seeds than for unextracted seeds in both stands, 16–17% compared to 22–23%.

The number of seeds per cone increased with the cone weight, as is shown in Fig. 5. At the same cone

Table 5. *Number of seeds per cone and tree, percentage of empty seeds per tree and thousand-grain weight per tree*

		Old stand		Young stand			
		Total	*t*-test	Total	South side	*t*-test	North side
Number of seeds/cone and tree	mean	19±6%	–	21±6%	22	–	20
	min.-max.	10–28		13–29	10–32		11–29
Empty seed/ tree (%)	mean	17±9%	–	18±17%	18	–	17
	min.-max.	4–37		8–52	7–52		6–52
Thousandgrain weight/tree (g)	mean	3.82±3%	*	4.20±4%	4.32	*	4.03
	min.-max.	2.91–4.64		3.48–5.66	3.52–5.61		3.25–5.75

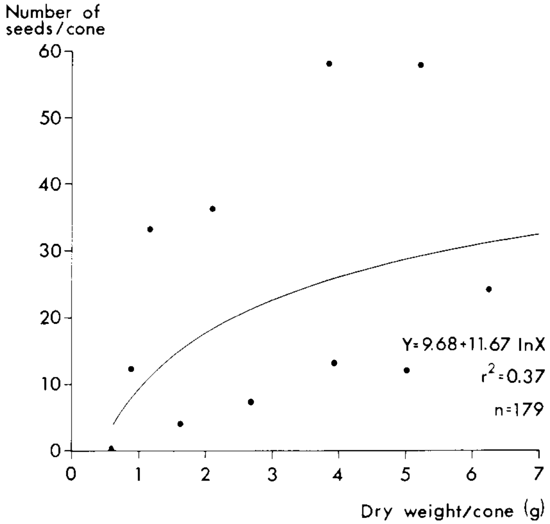
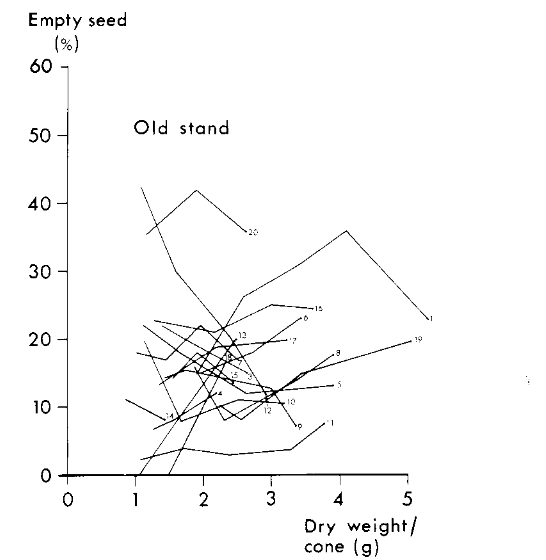


Fig. 5. Number of seeds per cone at different cone weights, old and young stand united. Dots indicate variation range for the observations.

weight there was no significant difference in the number of seeds per cone between the two stands. If individual trees were studied, a logarithmic curve provided the best fit. Since the variation between trees was very large, the correlation coefficient for the whole material united was low.

The percentage of empty seeds did not appear to increase or decrease with the cone weight (Fig. 6).

There was wide variation in percentage of empty seeds between different trees. For example, all values



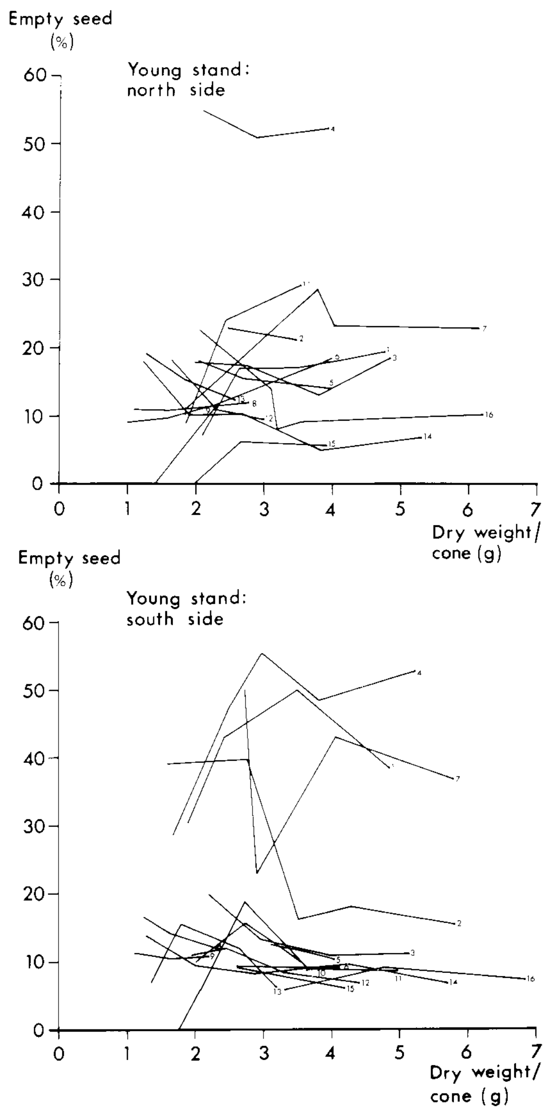


Fig. 6. Percentage of empty seeds at different cone weights for each tree. The values for each tree are represented by a line and a number.

for tree number 20 in the old stand were over 30% but for tree number 11 the percentage of empty seeds never exceeded 10%.

The thousand-grain weight increased with cone weight (Fig. 7). There were no significant differences in average increase, neither when seeds from the two stands nor when seeds from different sides of the crown in the young stand were compared. This means that cones with the same weight from the two stands contained the same amount of seeds.

Anatomical development and germination capacity

The anatomical development was very high for seeds from both stands, almost 99% of the filled seeds

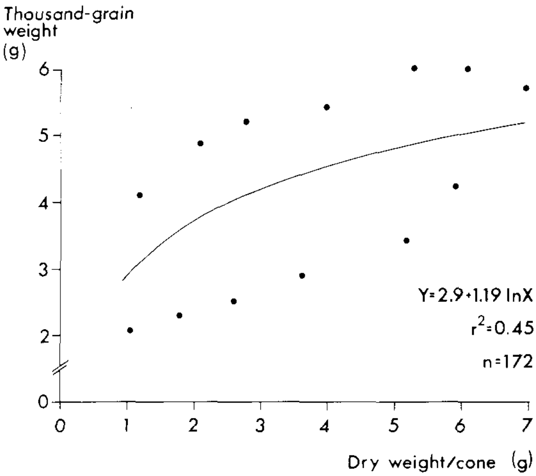


Fig. 7. Thousand-grain weight at different cone weights, old and young stand united. Dots indicate variation range for the observations.

belonged to embryo-class IV A, i.e. the embryo covered at least 75% of the length of the embryo cavity and the gametophyte was well developed.

Seeds from both south and north-exposed cones showed the same anatomical development. As the anatomical development was very high for almost every seed, no comparison was made between seeds from cones of different weight nor between seeds of different thousand-grain weight.

The germination capacity (Table 6) was also very high, 97–98% after 21 days, for seeds from both stands.

The germination capacity for seeds of different thousand-grain weight was compared after 7 days as well as after 21 days of germination. For all seeds irrespective of weight, the germination capacity after 21 days was very similar, close to the maximum, for seeds from both stands. The germination percentages after 7 days were more variable but there were no significant differences between seeds of different weight.

Table 6. *Germination capacity in per cent of filled seeds after 7 and 21 days. The values are mean per tree*

	Old stand		Young stand			
	Total	*t*-test	Total	South side	*t*-test	North side
7 days	64±8%	–	71±6%	72	–	68
21 days	97±1%	–	98±0.1%	98	–	97

Discussion

There were considerably more cones per tree as well as per hectare—almost threefold—in the old stand than in the young stand. The frequency of trees with cones was also higher in the old stand. However, the number of cones per hectare in the young stand corresponded to as much as 2.1 kg filled seed per hectare and the amount in the old stand to about 4.3 kg filled seed per hectare. For comparison, it may be mentioned that the cone harvest in seeds orchards in north Sweden in the season 1980/81 yielded 2.7 kg seed per hectare (Wilhelmsson, 1981).

It should be pointed out that the number of one-year-old cones in the young stand exceeded the number of cones produced during the collecting year, which indicates that the seed production in the young stand during favourable seed years could be higher than it was in this inventory.

The cones from the young stand exceeded cones from the old stand in length, volume and dry weight. South-exposed cones in the young stand were not only larger in size and weight than north-exposed cones but also more numerous. Although cone size is a feature that is genetically connected with the mother tree, it is also influenced by external factors, such as nutritional conditions (Bergman, 1954) and weather conditions, probably most by temperature. According to Bergman (1976) several investigations have shown that cone size will decrease if the temperature sum diminishes (among others Lähde, 1972, 1975). Johnsson et al. (1953) mentions that grafts grown in a better climate than that of the original tree produce larger cones, but that small differences occur if the grafts and the mother tree are exposed to the same climate.

The differences in cone size between the two stands may depend on differences in temperature sum, i.e. climatic conditions, but other factors may also be of importance. Rohmeder (1972) says that very young and very old trees are more affected by a shortage of photosynthate than trees of middle age, as far as cone and seed weight are concerned. According to Linder (1981) for the production of 75 cones on a 14-year-old Scots pine, just as much carbon was needed as the amount used for stem increment, which was 6% of the annual photosynthate production. This indicates that the amount of photosynthate needed for cone production is of great importance.

The differences in cone size between south and north-exposed cones may also be due to differences in temperature. As an example of this, Acatay (1938) measured a temperature that was 1.8°C higher in south-exposed than in north-exposed cones on a 40-year-old spruce during a clear day in August.

Since flowering is also dependent on temperature (Ihlstedt 1982), there is reason to believe that the differences in cone number between south and north-exposed crowns were related to differences in temperature sum. Bergman (1976) also pointed out that south-exposed cones are more numerous than north-exposed cones.

According to Schotte (1905) and Lähde (1975) the larger the cones are, the better the extractability is. The extractability is also influenced by the degree of ripening (Stefansson, 1953). In this investigation, cones from the young stand, although larger, did not show significantly higher extractability than cones from the old stand, probably because the weather conditions had been very favourable during the time for cone ripening.

The number of seeds per cone, which on the average, was about the same in the two stands, clearly increased with cone weight (cf. Simak, 1953).

The thousand-grain weight showed a pattern similar to that of cone weight, i.e. seeds from the young stand were heavier than seeds from the old stand, and seeds from south-exposed cones in the young stand were heavier than seeds from north-exposed cones. The increase in seed weight with increasing cone weight, which is also described by Simak (1953) and Södersten & Österberg (1960), was similar in the two stands. Simak also mentions that at the same cone weight cones with many seeds produce smaller seeds than cones containing few seeds, if the cones originate from the same tree. Seed weight, like cone weight, is genetically conditioned, but also strongly affected by weather conditions, mainly temperature (Johnsson et al., 1953, Simak & Gustafsson, 1954). The superior weight of seeds from the young stand, due to large cones, indicates that the temperature sum during the year of ripening may have been higher in the crown of the young stand. As shown by e.g. Hadders (1967), heavy seeds will have a better plant development after germination. This lead is, however, according to Rohmeder (1972), made up for in about 3 to 4 years in Scots pine.

Pollinated ovules produce empty seeds, if the pollen is dead or dies before fertilization is completed. Beyond this, the occurrence of semi-lethal or lethal genes may lead to abortion of the embryo (Dogra, 1967) and the production of empty seeds. Therefore, the percentage of empty seeds is strongly influenced by pollen quality. According to Sarvas (1962), the main reason for the production of empty seeds in Scots pine is self-fertilization. One prerequisite for the production of empty seeds is, however, that pollination has taken place. Unpollinated ovules degenerate.

No difference was shown between the two stands in the frequency of empty seeds, though between trees the difference could be very large. On the average, the percentage was 17–18%, which can be considered normal. According to Kardell (1973), during 1963–1970 the mean value for seeds from a number of stands in the county of Västerbotten was 20–30%. The percentage of empty seeds in the seed orchards in north Sweden was 19% in season 1980/81 (Wilhelmsson, 1981).

Simak (1960) showed that the percentage of empty seeds in individual trees declines when the cone weight increases. In this investigation no connection was found between the number of empty seeds and the cone weight, even if seeds and cones from each tree were compared separately.

The anatomical development and the germination percentage were very high, close to the maximum, for seeds from both stands, in spite of the fact that the collecting area is situated at an altitude of 300 m in north Sweden. The year 1980 was very favourable for seed ripening and, in fact, the forecast for seed ripening by the Institute for Forest Tree Improvement was the most favourable ever made (Andersson & Ericsson, 1980).

According to Bergman (1976), significant differences in germination capacity between seeds from cones of different exposition may exist. In this investigation there were no differences in germination capability between seeds from south and north-exposed cones, probably because of high temperature sum during the ripening period.

Applications

The presented results have not shown any biological restrictions on the use of cones and seeds from a young stand, at least not in a year with favourable conditions for seed ripening. The seed production in young stands during favourable years seems to be high enough to consider cone collection.

In general, cone collection in a young stand, from the biological point of view, should therefore not be restricted. Besides, the decision to collect cones should always be based on a seed analysis by which the seed quality will be described. If the topography is rough, however, i.e. if depressions exist, low trees may be more frequently exposed to frost than tall trees. Night temperature especially is strongly influenced by topography in areas exposed to frost (Andersson, 1968; Odin, 1969).

Regenerations from the 1950s and the 1960s, i.e. when transfer of seeds/plants started on a large scale, have now reached the age at which cone production can begin. If cones are to be collected in these forests, the origin of the stand must be known. It must also be emphasized that if trees of different origin are situated close to one another the progeny will be hybrid, the properties of which will be difficult to predict. This concerns, of course, trees in both old and young stands.

One advantage, in northernmost Sweden especially, of collecting seeds from young pine stands which have arisen from transferred material may be the possibility of using the collected seed for regeneration at the same latitude as the collecting area. A prerequisite for this, of course, is that the transfer made when the young stand was created was carried out according to appropriate recommendations.

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Acknowledgements. The investigation was supported by grants from the Swedish Council for Forestry and Agricultural Research.

Mrs Gunvor Henriksson and Mr Rudolf Kollenmark participated in the field work and also, together with Mrs Margareta Söderström and Miss Szura Swiatycka, in the laboratory analyses.