Effects of Clone and Fertilization on the Seed and Foliar Chemical Composition of Scots Pine (*Pinus sylvestris*) Grafts

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Effects of clone and fertilization on the seed and foliar nutrient concentrations of Scots pine grafts were investigated in a seed orchard in southern Finland.

The seed and foliar samples for chemical analyses were collected during winters 1985–86 and 1988–89 from 39 grafts per clone fertilized in spring 1986. There were 6 clones and 13 treatments for each clone with three replications. The treatments consisted of N, P, K in various combinations, micronutrients, wood ash and grass control. Macro- (N, P, K, Ca, Mg) and micronutrients (Cu, Zn, B) were analysed.

There were statistically significant differences between the clones in seed nutrient concentrations. The variation of the K, Mg, Ca, Zn and Cu concentrations between the two study years was considerably larger in the seeds than in the needles. The concentrations of these elements in the seeds were low in the year of an abundant seed crop in spite of fertilization. This had, however, no negative effects on germination of seeds. The proportions of crude fat and crude protein were high in both years (34 % and 35 % in 1985 ; 33 % and 38 % in 1988). Fertilization had only minor or no effect at all on the seed chemical composition in the orchard with a satisfactory nutrient status of the soil. Also on the foliar nutrient concentrations the effect of the clone was stronger than that of fertilization. Grafts with large needles produced heavy seeds, which had more storage proteins than the lighter seeds.

Keywords needles, seeds, Scots pine, nutrient concentration, seed orchards
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1 Introduction

The production of fruit and seed crops requires large amounts of nutrients. In an abundant seed year of pine and spruce the increased requirement for nutrients can be seen as reduced radial growth (Pukkala 1987). A plant tends to supply its seeds with mineral nutrients and organic substances even at the expense of other plant organs (Mengel and Kirkby 1982). Nutrients for developing pine seeds are, in part, mobilized from reserves in the old shoots and needles, as well as from senescing cones (Dickmann and Kozlowski 1969).

Soil fertility is considered to be important for the seed production of Scots pine (Sarvas 1962). On fertile sites flowering is more abundant and seed production considerably heavier than on barren sites. That is why seed orchards (seed-producing populations consisting of grafts derived from selected mother trees) are recommended to be established on fertile sites (Sarvas 1970, Werner 1975). Fertilization can also be assumed to increase the seed crop.

The accumulation of a seed reserve as indicated by the rapid growth of the dry mass of Scots pine seeds occurs after syngamy during the second year of development (Nygren and Pulkkinen 1994). Lipids and proteins are the main storage substances in Scots pine seeds, while the levels of carbohydrates are low (Räder-Roitzsch 1957, Pulliainen and Lajunen 1984). Nutrients, in order of magnitude, accumulate in pine seeds as follows: N, P, K, Mg and Ca (Crooke et al. 1964; Dickmann and Kozlowski 1969; Pulliainen and Lajunen 1984; West and Lott 1993). The seeds of *Pinus* spp. are particularly high in N but very low in Ca (Crooke et al. 1964).

A large number of factors affect the concentration of elements in needles (Raitio 1995). The N, P and K concentrations in pine needles are usually high in seed orchards (Beloborodov et al. 1983; Danusjavitshjus 1982). Differences in the foliar nutrient concentrations among Scots pine provenances are well-established (Steinbeck 1966). According to McLean and El-Kassaby (1986) the nutrient concentrations also in Douglas fir seeds are under genetic control. There are no investigations dealing with the effect of the mother tree on the mineral nutrient uptake of Scots pine seeds and the correlation of seed and needle nutrient concentrations.

This study is a part of a larger investigation where the effect of fertilization on flowering and seed crop in Scots pine seed orchards was studied (Saarsalmi et al. 1994). The aim of the study was to investigate the effect of clone and fertilization on the seed and foliar chemical composition of Scots pine grafts in a seed orchard in southern Finland.

2 Material and Methods

The study was carried out in a Scots pine (*Pinus sylvestris* L.) seed orchard No. 249 (Metsäväärä) in Pertunmaa owned by the Finnish Forest and Park Service (Fig. 1). The orchard was established on forest land where grafts were planted in 1971 and 1972 using a spacing of 3.5 m × 7 m. The soil consisted of fine sand till. The original forest site type appears to have been of the *Myrtillus* type. The nutrient concentrations and the pH of the soil were equal or slightly better than the average nutrient concentrations for seed orchards established on mineral soil (Lipas 1986). The soil properties and weather conditions during the study period have been described in detail by Saarsalmi et al. (1994).

Six clones, and 39 grafts from each clone, were randomly selected in the orchard for the fertilization experiment. The experimental layout was a completely randomized factorial (2^3) experiment with five additional treatments. There were 13 treatments per clone, with three replications.

The treatments included in the factorial experiment were gm, Ngm, Pgm, Kgm, NPgm, NKgm, PKgm, NPKgm with the additional treatments of 0, g, ga, NPKg, N_2PKgm. The additional treatments were included in order to study the effect of nitrogen dose, the effect of grass control per se and the suitability of wood ash as a fertilizer in the seed orchard.

Explanation to the symbols:

0: no treatment

g: grass control Gardoprim 80 26 kg/ha

m: micronutrient fertilizer 255 kg/ha (Mn 20, Cu 10, Zn 22, Fe 18, B 04, Se 0.006, Mo 0.4 g/kg)

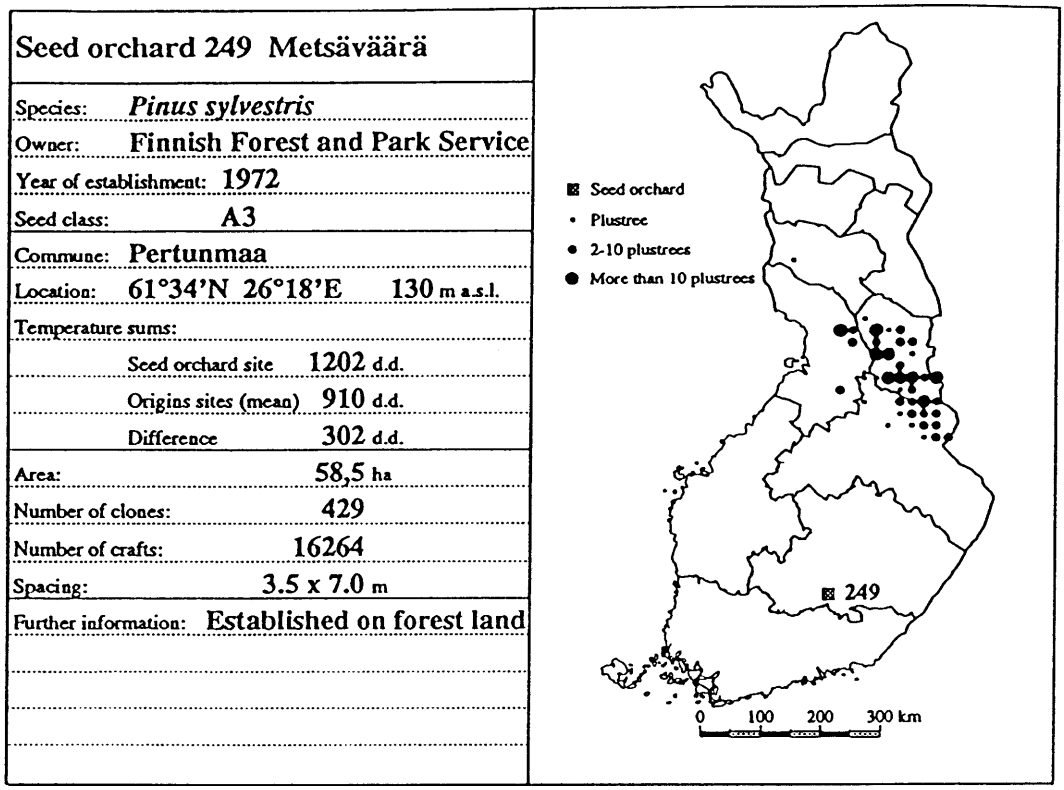

Fig. 1. Basic information about the seed orchard.

a: wood ash 3000 kg/ha (P 4, K 11, Ca 128, Mg 8, Mn 6, Cu 0.06, Zn 2, Fe 8, B 15 g/kg)
N: ammonium nitrate with lime 150 kg N/ha (N 280, Ca 40, Mg 20 g/kg)
N_2: as above, with 300 kg N/ha
P: superphosphate 100 kg P/ha (P 90 g/kg)
K: potassium sulphate 200 kg K/ha (K 420 g/kg)

Grafts were fertilized in spring 1986. The fertilizers were applied in a circular area (radius 3.5 m) around each graft, a 3.5-m-wide unfertilized area being left between each treatment. A solution of Gardoprim was applied as grass control in summer 1986, and repeated in summer 1988.

The first sampling of seeds and needles was carried out before fertilization during winter 1985–86. Cones were collected from replication 1 in October, from replication 2 in January and from replication 3 in March. The collection year was defined as the year when the seed was ripened. The three collection times were for the purposes of another study, the results of which will be published later. Seeds collected at different times of the year were treated together in the nutrient analysis.

Needle samples were taken from each graft in March 1986. The needle samples contained 80–100 g of the youngest needles from the southern side of the 3rd to 5th branch whorl from the top down. Cone and needle samples were collected again in 1988–89 three years after fertilization using the same procedure as before fertilization. The needles from the grafts with no seeds were excluded from this study.

Seeds were extracted from the cones and the mass of the seed crop and the nutrient concentrations of the seeds were determined for each graft separately. The 1,000-seed mass and the germination percentage of seeds were determined in accordance with the forest tree seed handling

and analysis instructions (Metsäpuiden... 1980). Analysis of seed germination includes only those seeds collected from replication 1 in October. The dry mass of 1,000 needles and the nutrient concentrations of the needles were determined for each graft separately (70 °C for 48 hours).

The concentrations of P, K, Ca, Mg, Mn, Cu, Zn and B were determined from finely ground needles and seeds by dry ashing and extraction with HCl, excluding B which was extracted with a mixture of sulphuric and phosphoric acid. The methods used are described by Halonen et al. (1983). The filtered solutions were analysed by the flame atomic absorption spectrophotometry, except for P and B which were determined colorimetrically. The total N was determined by the Kjeldahl method. The values for crude protein have been obtained by using coefficient 6.25 (Salmia 1981). Crude fat was determined with a slight modification according to Troeng (1955). In place of petroleum ether a mixture of heptane and ethanol 99.5 % (3+1 vols) was used for extraction.

The analysis of variance and regression analysis were used in the statistical treatment of the results (BMDP 1985). The pairwise comparison of differences in seed crop between the clones was performed by means of the Tukey test.

3 Results

The seed crop in 1988 was better than that in 1985, the year when many grafts did not produce seeds at all (Fig. 2). Fertilization had no statistically significant effect on the seed crop (Saarsalmi et al. 1994). The seed crop data is described in detail by Saarsalmi et al. (1994).

Nutrients were accumulated by the seeds in the following order: N>K>P>Mg>Ca>Zn>Cu>B (in 1988 P>K and B>Cu) (Fig. 3). The seeds contained N, K, P, Mg and Ca in the following proportions on average: 100 : 17 : 15 : 10 : 0.8.

In 1988 the average N and P concentrations of the seeds were higher but those of the other nutrients lower than in 1985 (Fig. 3). Excluding boron, the decrease was considerable; e.g. Mg, Cu and Zn concentrations in the seeds were only about half the concentrations in 1985. The differences between the clones in the 1,000-seed mass, seed crude fat and protein percentages and the 1,000-needle mass, were statistically significant ($p < 0.001$) in both years (Table 1).

The differences in the chemical composition of seeds, apart from Cu in 1988, between the clones were statistically highly significant in both years. In contrast, fertilization had no clear effect on the chemical composition and the 1,000-

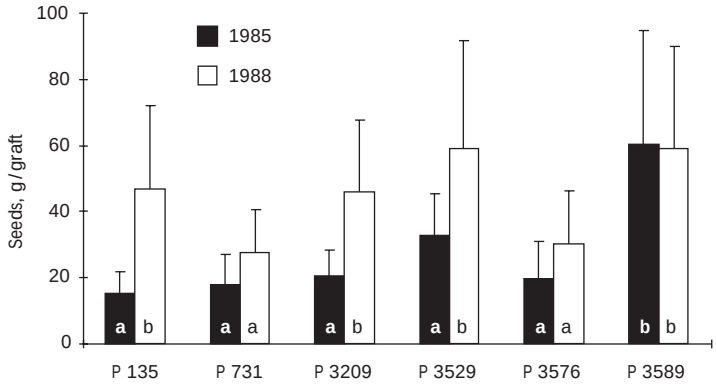

Fig. 2. Mean seed crop in 1985 and 1988 of different clones. Standard errors of the mean are indicated by vertical bars. The seed crops that do not differ statistically significantly at 5 % probability are marked with the same letter.

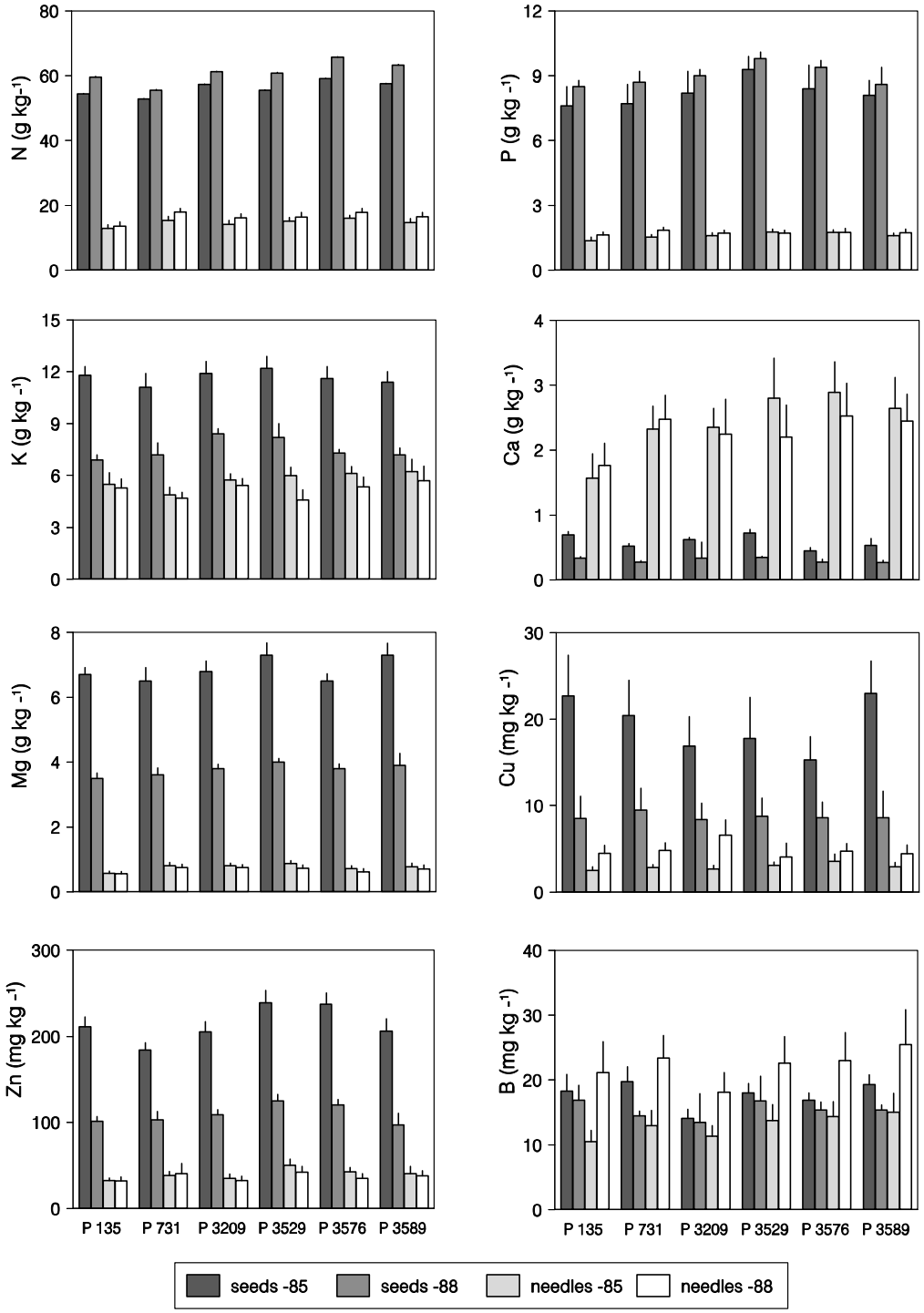

Fig. 3. Mineral nutrient concentrations in seeds and needles in different clones.

Table 1. Mean needle dry mass and seed quality in 1985 (n = 128, crude fat n = 121) and 1988 (n = 222).

Clone	Mass, g/1000 needles		Mass, g/1000 seeds		Germination, %		Crude fat, %		Crude protein, %	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
					1985					
P135	22.5	3.8	5.2	0.4	97.9	1.7	33.5	1.4	34.0	0.7
P731	24.2	2.5	5.5	0.4	94.8	4.4	34.3	1.0	33.0	0.7
P3209	30.2	4.9	6.2	0.4	97.3	2.3	33.2	0.9	35.8	0.9
P3529	25.1	3.0	5.2	0.4	97.6	1.8	34.3	1.9	34.7	0.7
P3576	22.5	4.5	5.8	0.4	92.4	5.7	32.8	0.7	36.9	0.9
P3589	23.3	3.4	6.2	0.4	97.9	1.8	35.8	1.0	36.0	0.6
Average	25.8	4.8	5.8	0.6	96.5	3.7	34.2	1.6	35.3	1.5
					1988					
P135	28.0	4.5	5.6	0.3	97.9	2.0	33.1	0.7	37.3	1.4
P731	27.7	2.2	5.7	0.3	95.1	5.2	32.6	0.6	34.7	1.7
P3209	33.7	4.5	6.5	0.3	98.2	1.4	32.1	0.7	38.2	1.5
P3529	34.4	6.5	5.7	0.3	98.8	1.5	32.5	1.0	38.1	1.1
P3576	40.8	7.0	6.3	0.4	96.4	3.1	31.2	0.8	41.1	1.2
P3589	33.4	7.0	6.8	0.5	98.4	1.2	34.0	0.6	39.6	1.0
Average	33.1	7.1	6.1	0.6	97.5	3.0	32.6	1.2	38.2	2.4

seed mass of seeds. The difference in the Cu concentrations between the treatments was, however, significant (Table 2). The lowest Cu concentrations of the seeds were in the treatments including nitrogen (Table 3). No other statistically significant effect of fertilization on the seeds could be found either when including all the treatments or when only the factorial part of the experiment was included.

The Ca concentrations in the needles far exceeded those in the seeds (Fig. 3). In 1988 also the boron concentrations were higher in the needles than in the seeds. Compared to the seeds, the concentrations of all other nutrients were lower in the needles. The needles contained N, K, P, Mg and Ca in the following proportions on average: 100 : 36 : 11 : 5 : 16. It is noteworthy that in relation to N the concentration of Ca in the needles was 20 times higher than the corresponding nutrient concentration in the seeds.

In 1988 the mean foliar N, Cu and B concentrations were higher than those in 1985. This was also the case when only treatment 0 was included. No differences as clear as those in the seeds could be found in the concentrations of the other nutrients between the years.

As in the seeds, statistically highly significant differences between the clones in relation to the foliar nutrient concentrations were found in both years. In contrast to the seeds, also the effect of fertilization could be recognised. After fertilization statistically significant differences between the treatments were found when handling all treatments together, in the foliar P, Mg, Cu, Zn and B concentrations (Table 2). The highest P concentrations of the needles were detected in the treatments including P and the highest B concentrations in the treatments including micronutrients (Table 4). The treatment including ash had the highest Mg concentrations. Fewer differences between the treatments were found when only the treatments in the factorial part of the experiment were included i.e. in the P ($p < 0.001$) and Cu ($p = 0.049$) concentrations.

The correlation between the foliar nutrient concentration with the corresponding seed nutrient concentration was mostly weak (Table 5). The 1,000-seed mass correlated positively with the seed N concentration and in 1988 positively also with the needle N concentrations. The 1,000-

Table 2. Two-way ANOVA table of seed and needle nutrient concentrations in 1988.

Dependent	Source	Seed nutrient				Needle nutrient			
		df	MS	F	p	df	MS	F	p
N	Treatment (T)	12	3.4	0.8	0.649	12	1.3	0.8	0.634
	Clone (C)	5	437	104.0	0.000	5	88.9	54.0	0.000
	T × C	60	5.6	1.3	0.082	60	1.2	0.7	0.901
	Error	144	4.2			144	1.6		
P	Treatment (T)	12	0.19	0.9	0.543	12	0.10	5.1	0.000
	Clone (C)	5	9.29	44.8	0.000	5	0.19	9.8	0.000
	T × C	60	0.21	1.0	0.492	60	0.02	0.9	0.662
	Error	144	0.21			144	0.02		
K	Treatment (T)	12	0.20	0.8	0.686	12	0.44	1.3	0.226
	Clone (C)	5	13.11	49.7	0.000	5	6.66	19.8	0.000
	T × C	60	0.13	0.5	0.999	60	0.31	0.9	0.624
	Error	144	0.26			144	0.34		
Ca	Treatment (T)	12	0.001	1.0	0.485	12	0.09	0.4	0.962
	Clone (C)	5	0.049	54.0	0.000	5	2.90	12.4	0.000
	T × C	60	0.001	0.8	0.879	60	0.14	0.6	0.982
	Error	144	0.001			144	0.23		
Mg	Treatment (T)	12	0.04	0.9	0.535	12	0.02	1.8	0.047
	Clone (C)	5	1.35	30.6	0.000	5	0.21	24.3	0.000
	T × C	60	0.05	1.1	0.364	60	0.01	1.2	0.184
	Error	144	0.04			144	0.01		
Cu	Treatment (T)	12	13.5	2.8	0.002	12	3.2	2.0	0.027
	Clone (C)	5	4.3	0.9	0.485	5	28.5	17.9	0.000
	T × C	60	6.1	1.3	0.133	60	0.9	0.6	0.988
	Error	144	4.8			144	1.6		
Zn	Treatment (T)	12	108	1.4	0.161	12	90	1.8	0.048
	Clone (C)	5	4676	61.6	0.000	5	623	12.7	0.000
	T × C	60	71	0.9	0.615	60	41	0.8	0.796
	Error	144	76			144	49		
B	Treatment (T)	12	6.3	0.9	0.540	12	142	14.3	0.000
	Clone (C)	5	65.7	9.5	0.000	5	226	22.9	0.000
	T × C	60	6.8	1.0	0.517	60	12.6	1.3	0.125
	Error	141	6.9			144	9.9		

needle mass correlated positively with the 1,000-seed mass, with the seed N concentration and in 1988 also with the needle N concentration. Although the needle N concentration correlated positively with the 1,000-seed mass in 1988, there was a negative correlation ($p < 0.01$) between the seed crop and the needle N concentration.

4 Discussion

The importance of heritability in the growth, flowering and cone and seed crop of the Scots pine grafts in our study has become apparent earlier (Saarsalmi et al. 1994). According to the results of this study there were significant differences in the foliar and seed nutrient concentrations between the clones as well. The effect of the clone proved to be more pronounced than

Table 3. Seed mineral nutrient concentrations in different treatments in 1988 (n = 222). g = grass control, a = wood ash, m = micronutrient fertilizer.

Treatment	N g/kg		P g/kg		K g/kg		Ca g/kg		Mg g/kg		Cu mg/kg		Zn mg/kg		B mg/kg	
	Average	s	Average	s	Average	s	Average	s	Average	s	Average	s	Average	s	Average	s
0	61.0	3.9	9.0	0.5	7.5	0.7	0.31	0.44	3.8	0.2	10.2	2.3	113	12	15.0	1.9
g	60.7	3.9	8.9	0.4	7.4	0.7	0.31	0.49	3.7	0.2	9.9	1.5	112	10	14.4	1.9
ga	60.8	3.7	8.8	0.9	7.4	0.7	0.29	0.51	3.7	0.3	8.6	2.5	106	19	15.9	5.5
gm	61.4	4.5	8.9	0.8	7.6	0.8	0.31	0.63	3.8	0.4	9.6	2.9	112	17	14.9	4.6
Ngm	60.8	3.1	9.0	0.6	7.6	0.7	0.31	0.37	3.7	0.2	8.2	2.4	109	14	16.0	2.3
Pgm	60.7	3.4	8.9	0.8	7.4	0.8	0.31	0.40	3.7	0.3	9.0	2.6	109	17	15.7	1.9
Kgm	61.8	3.5	9.1	0.5	7.7	0.6	0.30	0.43	3.8	0.3	9.6	1.4	112	10	14.7	2.5
PKgm	60.5	4.5	9.0	0.6	7.6	0.8	0.30	0.34	3.7	0.2	8.8	2.0	109	11	16.1	2.4
NKgm	61.4	3.7	8.8	0.9	7.4	0.8	0.29	0.49	3.7	0.3	8.1	2.4	105	14	15.6	4.0
NPgm	61.5	4.0	9.1	0.5	7.4	0.7	0.31	0.51	3.8	0.2	7.2	2.4	107	12	14.3	4.5
NPKg	60.8	4.3	9.0	0.6	7.6	0.7	0.30	0.36	3.8	0.2	8.5	1.6	108	13	14.1	4.4
NPKgm	61.9	3.4	9.2	0.6	7.6	0.8	0.30	0.42	3.8	0.2	8.3	2.3	109	12	16.2	3.3
N2PKgm	60.9	4.5	9.0	0.7	7.6	0.8	0.31	0.40	3.8	0.3	7.6	2.7	106	14	15.0	1.6

Table 4. Needle mineral nutrient concentrations in different treatments in 1988 (n = 222). g = grass control, a = wood ash, m = micronutrient fertilizer.

Treatment	N g/kg		P g/kg		K g/kg		Ca g/kg		Mg g/kg		Mn mg/kg		Cu mg/kg		Zn mg/kg		B mg/kg	
	Average	s	Average	s	Average	s	Average	s	Average	s	Average	s	Average	s	Average	s	Average	s
0	16.0	1.8	1.6	0.2	5.2	0.6	2.3	0.4	0.7	0.2	591	232	5.4	1.5	39.0	9.2	18.6	3.8
g	16.9	2.4	1.7	0.1	5.2	0.6	2.3	0.6	0.7	0.1	576	195	5.3	1.2	37.4	6.6	17.4	3.0
ga	16.3	1.6	1.7	0.2	5.0	0.7	2.3	0.4	0.8	0.1	540	155	5.1	1.7	38.3	7.6	19.6	3.2
gm	16.9	1.8	1.7	0.1	5.3	0.9	2.4	0.5	0.7	0.1	573	164	5.3	1.6	40.2	7.9	23.8	4.6
Ngm	16.7	1.9	1.7	0.1	5.2	0.6	2.3	0.4	0.6	0.1	737	200	5.3	1.5	41.8	11.7	23.7	5.0
Pgm	16.5	2.1	1.8	0.1	5.0	0.7	2.3	0.5	0.7	0.1	785	233	4.2	1.3	35.6	7.2	24.5	4.1
Kgm	16.7	1.7	1.7	0.2	5.0	0.6	2.1	0.5	0.7	0.1	633	200	4.6	1.2	35.0	8.0	24.5	4.3
PKgm	16.1	2.0	1.8	0.2	5.3	0.9	2.4	0.6	0.6	0.1	763	233	4.8	1.2	36.2	6.7	25.8	4.9
NKgm	16.3	1.5	1.6	0.1	5.3	0.7	2.2	0.6	0.6	0.1	636	176	5.2	1.3	36.2	5.6	23.3	3.1
NPgm	16.4	2.3	1.8	0.1	4.9	0.8	2.2	0.5	0.7	0.1	693	167	4.5	1.4	34.7	8.1	23.9	4.1
NPKg	16.1	2.1	1.8	0.1	5.4	0.7	2.3	0.6	0.7	0.1	634	208	4.7	2.0	34.8	5.8	18.0	3.4
NPKgm	16.4	1.6	1.8	0.1	5.3	0.7	2.2	0.5	0.7	0.1	755	183	4.2	0.9	36.4	9.6	24.5	4.0
N2PKgm	16.5	2.0	1.8	0.1	5.1	0.4	2.3	0.4	0.7	0.1	680	167	4.4	1.3	32.8	5.6	22.9	3.9

Table 5. Significant correlations between A) needle and seed nutrient and B) between needle and seed mass and N concentration (n = 125 in 1985, n = 222 in 1988).

A)		B	Mg	Zn	Ca	P	Cu
	1985	+0.33***	+0.24**	+0.54***	–0.18*	+0.24*	
	1988	+0.13*	+0.26***	+0.34***	–0.25***		+0.20***

B)		1,000-seed mass	seed-N	needle-N
1,000-seed mass	1985		+0.49***	
	1988		+0.48***	+0.28***
1,000-needle mass	1985	+0.25**	+0.28**	
	1988	+0.42***	+0.49***	+0.26***

that of fertilization in the seed orchard with a good nutrient status in the soil.

The correlations between the foliar and corresponding seed nutrient concentrations were mostly weak or totally lacking. As stated earlier, the nutrient status in the soil was high already at the start of the study. On a more barren soil or in case of a shortage of main nutrients the foliar nutrient concentrations may have had an influence on the seed nutrient concentrations. The weak correlation may also be due to the fact that the developing seeds generally obtain the minerals they require even when the plant is growing under conditions that are severe enough to cause mineral deficiency symptoms (Lott 1984).

The needles of the grafts were heavy, as is usual in seed orchards (Danusjavitshjus 1982, Rosvall and Untinen 1982) and much heavier than on average in pine stands in Finland (Mälkönen 1991). Grafts with large needles produce heavy seeds as was shown by the positive correlation between the 1,000-needle mass and the 1,000-seed mass. Heavy seeds had higher N concentration and accordingly more storage proteins than the light ones. The seed size is considered to be important because it is positively correlated with the initial development of pine transplants (Hadders 1963, Mikola 1980).

The magnitude of the accumulation of macronutrients in the seeds followed the order presented for pine in earlier studies (Crooke et al. 1964; Dickmann and Kozlowski 1969; Pulliainen and Lajunen 1984; West and Lott 1993). In this study as well as in all the above-mentioned studies the Ca concentrations in seeds were clearly lower than those of the other macronutrients.

With the exception of Ca, the macronutrient concentrations, especially the concentration of N, in the seeds were higher in the seed orchard than in *Pinus sylvestris* seeds in subarctic conditions in Finland (Pulliainen and Lajunen 1984). Although the plustrees, from which the grafts have been derived, are of northern origin, the seed orchard itself is situated in South Finland. Because of this the grafts are growing in a climatically much more favourable area than the corresponding plustrees. Also the nutrient status of the seed orchard was good. Excluding Mg, the macronutrient concentrations in the needles were higher than the average values presented for young or middle-aged, thinned pine stands in Finland (Mälkönen 1991), and clearly higher than the lower limit for the class “optimum” presented for Scots pine stands by Jukka (1988). Probably these factors led to higher macronutrient concentrations in the seeds in the seed orchard compared to natural stands in North Finland.

Beloborodov et al.(1983) found no reliable correlation between the cone crop and the needle nutrient concentrations. In this study, however, a

significant negative correlation between the seed crop and needle N concentrations was seen in the year when the seed crop was abundant. Similar to the results by Crooke et al. (1964), the needle N concentrations correlated positively with the mass of the needle, which again had a positive effect on the size of the seed.

The difference in the seed K, Ca, Mg, Cu and Zn concentrations between the two study years was considerable. The concentrations of these elements were low in the year when the grafts produced a lot of seeds. The decrease in concentrations was similar in all clones, also in the best-producing clone P 3589, although it had a good crop also in the first study year. The germinability of the seeds was, however, in all clones high in both years. Also Pulliainen and Lajunen (1984) report that the chemical composition of Scots pine seeds with the same 1,000-seed weight but representing crops of different years may vary. In contrast to their results, the annual variation in proportion to essential storage reserves, crude fat and crude protein, was less pronounced in our study.

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