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SOME RESULTS ON THE REGULARITIES OF SEED CROPS IN SCOTS PINE SEED ORCHARDS

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SELOSTE:

MÄNNYN SIEMENVILJELYSTEN SIEMENSATOON VAIKUTTAVISTA TEKIJÖISTÄ

The establishment of a permanent source of genetically improved seed which started in the USSR in the 60's and which has developed especially during the past 5–7 years is of great importance in the programme of forest improvement through the methods of genetics and forest tree breeding. It is proposed that after 10–15 years, the area of seed orchards, mainly consisting of coniferous species, will be increased up to 21 000 ha, and that the genetically improved seed share of the total seed production will reach 50 % (Vorobyov, 1974). Research aimed at determining the factors of seed yield formation in seed orchards and at developing stimulating measures for seed-bearing is, therefore, particularly topical.

A restricted set of genotypes, a low planting density and intensive soil maintenance call for a new approach to the analysis of the generative development of trees in seed orchards. The main targets of research are: 1) to determine the potential and actual crop capacity of seed orchards of different age and with different methods of establishment; 2) to study the flowering process and the regularities of yield formation in connection with environmental factors and the individual characteristics of trees; 3) to determine the physiological characteristics of the trees of different generative type and different reproductive capacity; 4) to study the reaction of seed production trees to experimental treatments. The results obtained will make it possible to solve a number of practical problems of seed growing, for instance, the elaboration of methods for the prediction and calculation of seed yield, stimulation of seed-bearing, selection of clones for the establishment of second-generation seed orchards, planning of the working phases in the establishment of seed orchards, etc.

In the central part of the forest-steppe of the European part of the RSFSR, the seed orchards of Scots pine are established by two different methods: by grafting (clonal seed orchards) and by planting seedlings which have been grown from the seed of plus trees (seedling seed orchards or half-sib family seed orchards). It has been found that the age dynamics of the flowering of the grafted and ungrafted trees have different characteristics. Grafts made with scions from physiologically mature trees begin flowering relatively early, within two or three years after grafting. However, during the first 5–7 years only a few individual trees flower, and the number of flowers is limited. Only at the age of 8–10 years seed crops become relatively regular and abundant. In the second decade (11–16 years of age) seed yields may be 5–6 kg/ha (at the density of 400 trees per ha) in some years.

Some trees in the seedling seed orchards also begin flowering relatively early – at the age of 5–6 years – thanks to favourable growth conditions. However, the seed yield is of economic importance only at a later age: 2–3 years later than in clonal orchards. During a period of seven years (from 10 to 16 years of age) the cone yield of clonal orchards is 13 % higher than that in the seedling seed orchards. When also taking into account the crops during the first ten years, the advantages of grafting become even more appreciable. With increasing age, however, the yields of seed orchards established by different methods tend to become more or less equal.

The conditions in the central part of the forest-steppe are favourable for the growth of Scots pine. Absolute seed failures are practically nonexistent. Scots pine is flowering every year, but the intensity of flowering and the quantity of seed yield are subject to great fluctuations. The reasons for the irregularities in seed-bearing are – as determined by correlation analysis – weather conditions (temperature, humidity, precipitation) at different phases of the generative cycle, especially at the critical periods of the reproduction process: the period of the induction of generative organs and the period of flowering. Good yields are preceded by the following combination of weather conditions: warm and dry summer (June–July) in the year of the formation of generative buds, lack of rain at the period of pollen dispersal (May), hot and dry weather after the end of flowering (June).

A biological precondition for the formation of high seed yields in seed orchards is an abundant female flowering and a balanced relation between the quantity of female and male inflorescences, which contibutes to normal pollination. As is generally known, in the classification of Correns (1928), Scots pine falls under the monoecious, unisexual species, where the determination of sex takes place on the basis of phenotype. It is a characteristic of Scots pine that the organs of the different sexes are differentiated in the crown. T. P. Nekrasova (1960, 1972) separates the following generative crown layers in mature trees: female, mixed, male and vegetative layer.

Young trees in seed orchards also have spatially differentiated generative organs, but with some special features due to their age and the methods of the establishment of seed orchards. Consequently, 11 year-old grafted trees have only two layers: a female layer, which is situated on the four uppermost whorls of shoots and a mixed one, which takes up the rest of the crown, but the bulk of the female inflorescences is situated on the lower layer (whorls 6–9). Grafts of this age do not have separate male or vegetative layers. In the case of ungrafted trees of the same age most of the crown is taken up by the mixed layer (from the second whorl till the eighth), and female inflorescences dominate on the upper shoots (whorls 2–6). Female, male and vegetative (»nonsexual» according to Minina 1975) layers may also be distinguished (Table 1).

Consequently, it is typical for young ungrafted plants to have the same kind of differentiation of the generative organs of the different sexes as the mature trees have. In the case of grafts, female flowering appears throughout the whole crown.

In the seed orchards of Scots pine female flowering prevails till the age of 10–11. Later, with the development of the crown and the appearance of a greater number of depressed shoots, male flowering becomes more intensive and stable. The number of female inflorescences in a clone orchard at the age of eleven was 2.6 times higher than that of male inflorescences, but an opposite relation was to be noted at the age of 16. At this age, 210 000–267 000 male inflorescences are formed on one hectare of seed orchard, which means that the seed orchards may be regarded as self-supporting with respect to pollen.

As a whole, grafted trees have more female inflorescences and less male ones than ungrafted trees of the same age.

As we know, the sexuality of conifers is substantially influenced by environmental

Table 1. The distribution of generative organs in the crown of 11 year-old trees of Scots pine in seed orchards.

Whorls (from above)	Average number of generative organs					
	Grafted trees			Ungrafted trees		
	Male	Female	Conelets	Male	Female	Conelets
1	0	0,6	0,7	0	6,2	4,9
2	0	3,1	3,6	0,1	18,8	17,4
3	0	9,0	8,4	3,6	36,0	35,5
4	0	17,3	13,7	31,0	49,4	46,5
5	2,0	26,2	22,5	38,1	28,8	29,8
6	6,0	35,3	32,2	31,2	12,8	12,2
7	12,0	46,1	43,8	17,1	5,2	5,0
8	27,0	41,8	43,0	3,7	0,7	0,7
9	24,0	30,9	32,5	0,2	0,1	0
10	16,0	15,8	17,0	0	0	0

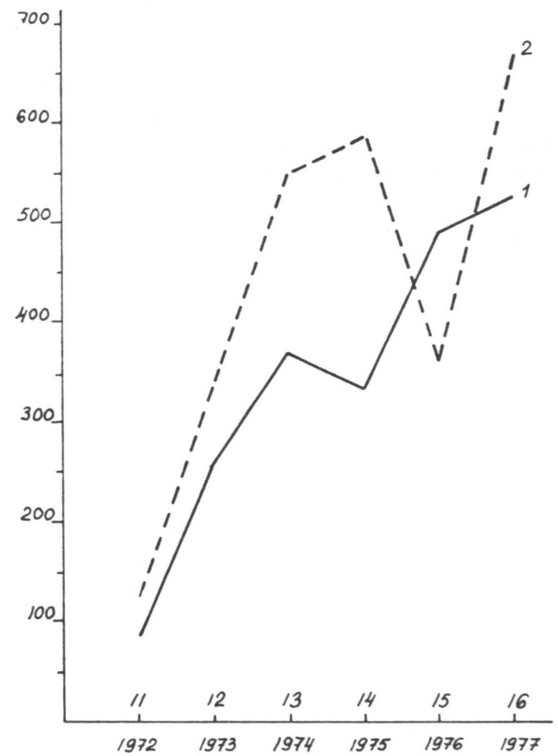

Figure 1. Average number of male inflorescences in grafted (1) and ungrafted (2) trees of Scots pine.

factors (Minina 1960, Brøndbo 1969, Nekrasova 1972, Kozubov and others 1974). We also know that male sexuality of Scots pine in the central forest-steppe is increased if at the period of the formation of flower primordia (June–July) the temperature of the air is lower and the humidity higher than the long-term average. Warm and dry weather at this period contributes to female flowering.

The trees in seed orchards have marked individual variability in flowering. In clonal orchards, trees with a mixed type of flowering prevail. But one can also find clones, in which either male or female inflorescences are relatively more abundant. There are also functionally vegetative trees, which have a few male and female generative organs only.

The type of flowering is characterized by temporal constancy. The correlation coefficient between the average quantity of inflorescences of one sex in different years varies between +0.77 and +0.98. The same is typical for ungrafted trees, too. This fact testifies to the genetic nature of the characteristic.

Trees with exclusively male or female generative organs have not been found in seed orchards. Lack of clearly expressed sexual dimorphism with Scots pine has also been found in seed collection stands by D.Ya. Girgidov.

Concerning sexual dimorphism, the scions in one clone are not uniform. However, the stability of the type of flowering of separate scions is lower, than with clones as a whole ($r = 0.30-0.66$).

The shoots of different sexuality in a tree are morphologically and biologically different. Female shoots are distinguished from vegetative and male shoots due to higher growth energy and a greater content of soluble carbohydrates, amino-acids and growth substances, a higher rate of nucleid acid synthesis (mainly DNA) and a greater intensity of metabolic processes during the entire vegetation period (Shirnin and Efimov 1977, Samsonova, Efimov and Bolgova 1977). It is not impossible that the direction of metabolic processes is preserved to some extent in different types of shoots after grafting. This fact may be reflected in the character of the sexuality of the grafted trees.

It can be supposed that in the case of vegetative propagation the generative type of the onset basically remains prevalent, but in each clonal offspring the type of flowering may vary among separate scions, depending on different factors, e.g. the sex of the scion, the influence of the grafting stock, nutrition and light conditions. In this connection, a favourable ratio between female and male flowering may be regulated to some extent by selecting suitable mother trees and by grafting scions of different type of sex as well as by selecting grafting stocks, by varying nutrition conditions and by adjusting other factors which have an influence on metabolic processes.

The cone yield in young seed orchards of Scots pine is characterized by exceptionally high variability (Table 2). At the same time, with respect to the intensity of seed-bearing, the relative distribution of clones or ungrafted trees remains stable for several years (Figure 2). The correlation coefficients between the yields of cones of the same trees (clones) in different years vary from 0.78 to 0.89. At the same time, correlation analysis has shown a weak relation or no correlation at all between the yield of cones and the size of trees (height and diameter of stem and crown). This is indicative of the genetic nature of the

Table 2. The variation in cone crops in Scots pine seed orchards.

Year	Clonal seed orchards			Seedling seed orchards		
	Number of cones		Variation coefficient	Number of cones		Variation coefficient
	Average	Range	%	Average	Range	%
1971	37	0–781	176,6	5	0–96	213,5
1972	47	0–620	123,0	34	0–555	131,7
1973	127	0–1508	116,0	103	0–840	102,9
1974	61	0–656	130,5	15	0–189	165,9
1975	38	0–266	112,2	79	0–730	124,1
1976	121	0–745	202,4	165	0–634	85,6
1977	171	1–659	65,4	114	2–402	66,6

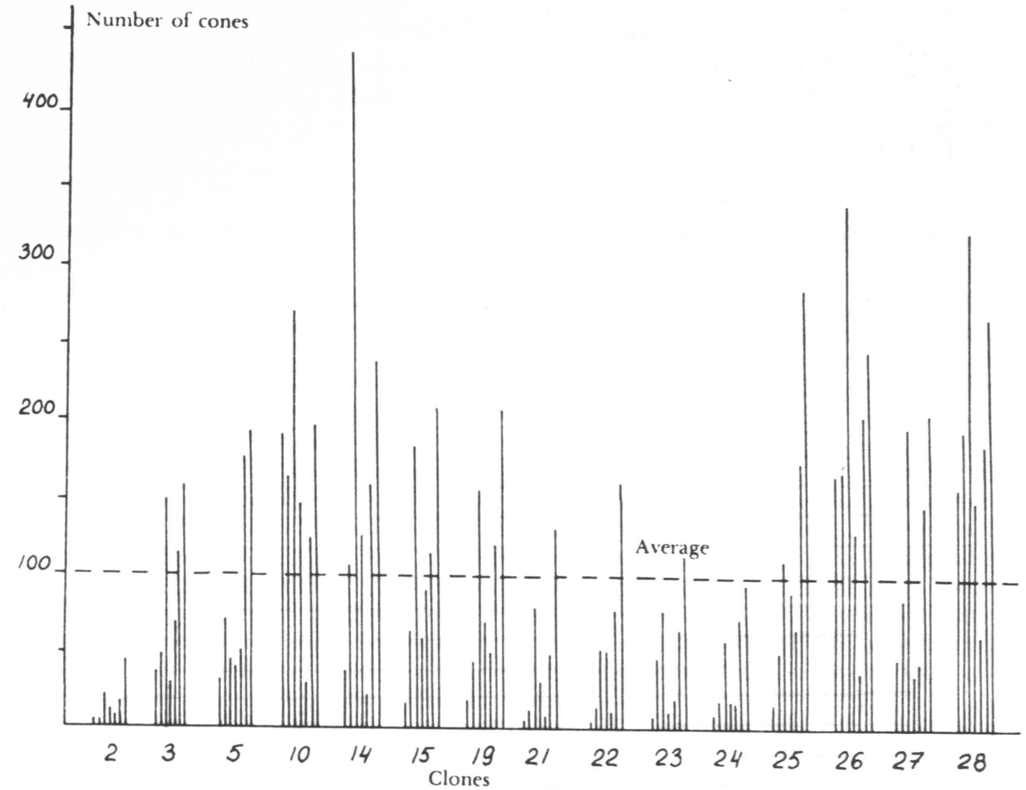

Figure 2. The dynamics of the average yield of cones of single trees in some Scots pine clones (1971–1977)

differences in reproductive capacity and its heritability in the case of vegetative propagation. The latters is confirmed by the coefficient of heritability h^2, which has been calculated on the basis of variance analysis. In clone orchards, h^2 concerning the yield of cones, varies in different years from 0.39 to 0.46.

Similarly to flowering, the yield of cones also varies among clones. The stability of the relative productivity of scions in different clones is unequal (r varies between 0.06 and 0.98), i.e. the factors determining their productivity may in many cases be stable for several years. More often, the stability of this trait in the scions is characterized by medium or low values and thus reflects the natural inconsistency of seed-bearing with time.

Analysis of the biological qualities of Scots pine trees with different reproductive powers showed that trees with a high seed yield, as compared to trees of the same size with a low yield were characterized by a higher physiological and biochemical activity, a higher content of nucleic acids and growth substances in needles and buds, and a more clearly expressed differentiation of shoots into different sexual type. It is to be supposed that the difference in the reproductive power of trees is determined by the genetically controlled activity of their metabolic processes.

Trees (clones) show a considerable variability in biological and morphological characteristics of cones and seed (e.g. size, weight, colour, seed yield from cones, amount of viable seeds, germination etc.). The variability of some indices is to a great extent dependent on genetic factors. In a clonal orchard, h^2 with regard to the length of cones, number of cone scales, and seed yield varies between 0.36 and 0.54. There are clones with a stable high or low seed yield, high or low amount of viable seeds, the differences being considerable (Figure 3).

One of the reasons for a high amount of empty seeds is the difference in the periods of flowering. For instance, the late flowering clone 3, shown in Fig. 3, in which the receptive stage occurs 2—3 days later than the bulk of the other clones and therefore does not coincide with the mass dispersal of pollen, has a consistently low amount of viable seeds, apparently due to insufficient pollination or self-pollination.

It has to be noted that the quality of seed does not depend on the size of the yield of cones. As a result, the ranks of

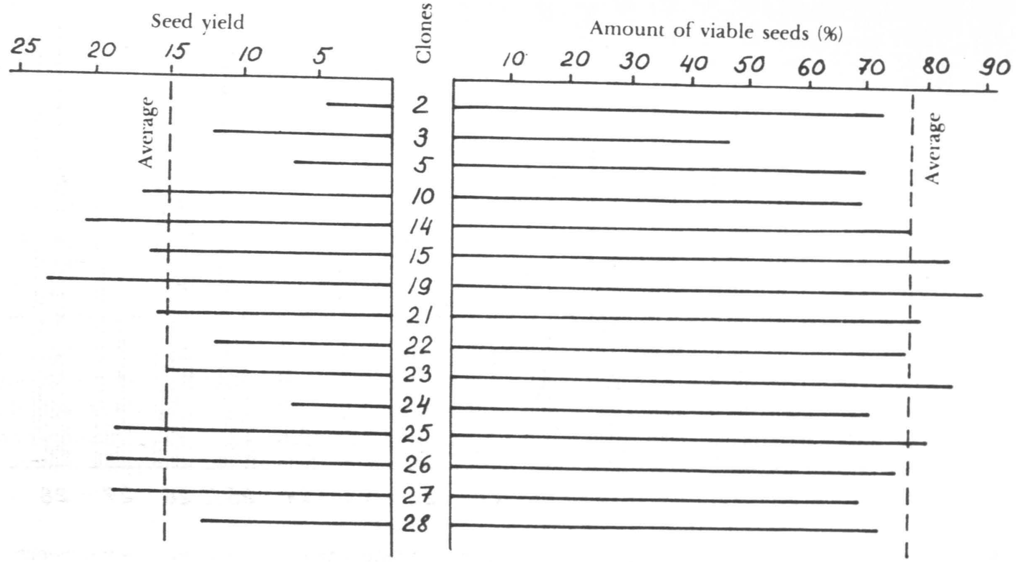

Figure 3. Seed yield and the amount of viable seeds per cone in some Scots pine clones (average in 1973—1976)

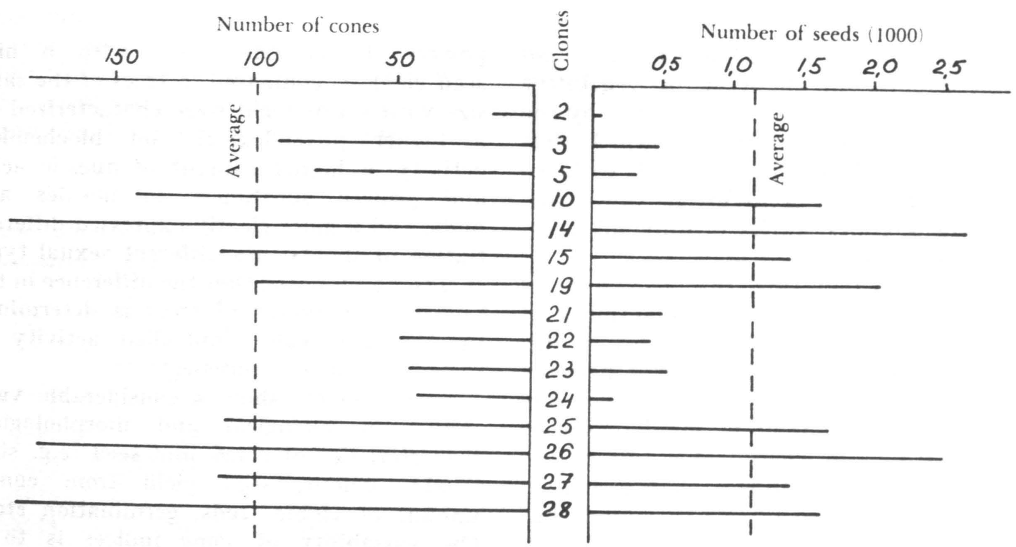

Figure 4. The yield of cones and the number of viable seeds of single trees, in some Scots pine clones (average in 1973—1976).

clones in seed orchards with regard to the average yield of cones are not identical with the ranks concerning the average quantity of germinating seeds in one tree (Figure 4). Concerning seed productivity, separate clones greatly differ from each other.

The results of the study of the regularities of seed-bearing of Scots pine in seed orchards determine the direction and character of the measures for the increase of seed yields. A well-kown method for increasing the seed crops of woody plants is to establish optimal conditions for their growth. These conditions are already secured to a great extent by establishing seed orchards on rich soil as well as by low planting density, tilling and weeding. As accumulated experience shows, these measures do not eliminate inconsistency in seed-bearing, and a good yield and a high quality of seed is not always guaranteed. A further improvement in the conditions of the environment, including fertilization, evidently has its limits, at least in regions with optimal growth conditions. The effectiveness of the use of fertilizers in seed orchards is often limited by the fact that some clones react only weakly to soil improvements. Therefore, at the time of the foundation of secong-generation seed orchards, the peculiarities of the generative activities of clones and their reaction to changes in the environmental conditions must be taken into account by taking an individual and selective approach to improvement measures.

The establishment of seed orchards with clones which have been selected for their genetic combining ability and which at the same time require similar measures for the stimulation of seed-bearing (fertilization, treatment with plant hormones, artificial additional pollination etc). improves the effectiveness of clones and improves the economics of their use. Clones with a genetically determined high reproductive power will deserve special attention. The use of these clones, even without any additional stimulating measures, secures high and consistent yields of high quality seed.

SELOSTE:

MÄNNYN SIEMENVILJELYSTEN SIEMENSATOON VAIKUTTAVISTA TEKIJÖISTÄ

Kirjoituksessa selostetaan Neuvostoliiton euroopanpuoleisen metsäaroalueen keskiosissa saatuja kokemuksia männyn varttamalla perustettujen ja siementaimilla istutettujen siemenviljelysten kukinnan ja siementuoton kehityksestä. Vartteet kukkivat aikaisemmin ja runsaammin kuin siementaimet, mutta ero on vain 2—3 vuoden luokkaa ja tasoittuu myöhemmällä iällä. Siemensadon vuotuinen vaihtelu johtuu ilmastotekijöistä. Hyvän siemensadon kehittyminen edellyttää lämmintä ja kuivaa kesää kukka-aiheiden muodostumisvuonna, sateetonta kukinta-aikaa seuraavana keväänä sekä kuumia ja kuivia säitä kukinnan jälkeen. Biologisena edellytyksenä ovat runsas emikukinta sekä sopiva emi- ja hedekukinnan määrällinen suhde. Viimemainittuun vaikuttaa olennaisesti sukupuolisuuden kehittyminen siemenviljelyspuissa. Siementaimissa latvukseen kehittyy samantapainen koiras- ja naarassukupuolta edustava kerroksellisuus kuin täysikasvuisissa puissa vallitsee, mutta nuorissa vartteissa emikukkia esiintyy kaikkialla latvuksessa.

Ylimalkaan vartteissa on enemmän emikukkia ja vähemmän hedekukkia kuin samanikäisissä siementaimissa. Sukupuolisuus on havupuilla myös ympäristötekijöistä riippuvaa: viileät ja kosteat säät kukka-aiheiden muodostumisaikaan edistävät koiraspuolisuuden ilmenemistä, lämpimät ja kuivat taas naaraspuolisuutta. Sukupuolisuus on luonteeltaan myös geneettinen ominaisuus, ja siten vartetut kloonit voivat olla kukintatyypiltään lähinnä koiras- tai naaraspuolisia, näiden sekamuotoa tai vegetatiivista tyyppiä, ja säilyttää tämän taipumuksensa vuodesta toiseen. Vartteissa kukintatyyppiin vaikuttaa jossakin määrin sekin, mistä osasta emopuun latvusta varteoksat on otettu. Sukupuolisuudeltaan erilaiset versot eroavat toisistaan monella tavoin, sekä morfologisesti että fysiologisesti. Siemenviljelyksiä perustettaessa hede- ja emikukinnan määräsuhteita voidaan pyr-

kiä ennalta ohjaamaan valitsemalla ja varttamalla sopivia emopuita ja versoja.

Siemensadot vaihtelevat nuorilla mäntysiemenviljelyksillä paljon vuodesta toiseen, kuten kukintakin. Puiden keskinäisillä kokoeroilla ei ole satovaihtelun kannalta sanottavaa merkitystä. Eri kloonien tai puiden välinen satoisuusjärjestys sen sijaan pysyy vakaana eri vuosina, mikä kuvastaa geneettisten tekijöiden merkitystä siementuottokyvyn määrääjinä. Käpy- ja siemensato ovat kaksi eri asiaa, sillä siemenen laadun vaihtelun takia runsas kukinta ja käpysato ei aina takaa hyvää siemensatoa. Siemenen laatu vaihtelee paljon kloonien välillä. Eräs syy siihen, että jotkin kloonit tuottavat paljon tyhjää siementä, on kloonien kukinta-aikojen poikkeavuus.

Metsäpuiden siemenviljelyssä pyritään siementuotantoa lisäämään järjestämällä kasvuolosuhteet edullisiksi, mm. valitsemalla viljavat kasvupaikat, harvalla istutusvälillä, maanmuokkauksella ja kilpailevan kasvillisuuden torjunnalla. Yleisesti käytetyn lannoituksen mahdollisuuksia lisätä siemensatoa rajoittaa se, että jotkin kloonit reagoivat heikosti maanparannuksiin. Varsinkin toisen sukupolven siemenviljelyksiä perustettaessa eri kloonien lisääntymistoimintojen erikoispiirteet ja niiden erilaiset reaktiot ympäristötekijöiden muutoksiin olisi otettava huomioon.