SEED PRODUCTION IN SCOTS PINE SEED ORCHARDS

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Abstract

Earlier studies show that seed orchards have considerable heavier cones and seeds, but not necessarily more seeds per cone and fluctuations in seed production are smaller than in stands. Harvest statistics are often available for seed orchards; usually the amount of harvested cones and seeds drops by age of the orchard. However, the harvest statistics seldom reflects the actual biological seed production. Biological seed production in some Swedish Scots pine seed orchards was calculated. No decrease in seed production when the orchard gets old was indicated. A case was reported when dense spacing did not increase seed production at age 30. Few of the cones were registered in a fast cone count in two mature seed orchards, indicating that manual observations are unreliable. Reasonable estimates of variation in female fertility among grafts seem possible with simpler measures than actual seed count. A considerable variation in female fertility among grafts was observed. The variation in seed weight among ramets was rather moderate.

Keywords: Seed orchards, cone production, seed production, seed weight, fertility variation, visual estimation.

Introduction

Prognoses of seed set in seed orchards are needed for projections about future seed production, for operational decisions and also for estimates of effective population size. There exist, however, a considerable difference between different meanings of seed production, which complicates these procedures. Reports about seed orchard harvests are frequent, but actual seed production is more rarely reported. Even when seed production per graft is reported, it is seldom converted to area production and often considers young grafts where seed production per area still is raising. There is a biological seed production potential, but the seed available for operational harvest is another thing, harvest statistics further another, and seed production observed in experimental settings may not be representative for operational seed orchards. Here some aspects of this will be discussed. Some estimates of biological seed production in actual mature seed orchards will be presented. Methods for estimation will be discussed.

Seed production in nature and its relevance for seed orchards

The Scots pine stand seed production has been carefully investigated in Finland; the main important studies were initiated by Heikinheimo in 1920's (Heikinheimo 1932, 1937) and continued, by Sarvas (1962) and Koski and Tallqvist (1978). There are also important Swedish studies like Hagner (1957). In natural stands, seed crop (on areal basis) is higher in rather sparse seed tree stands as compared to dense forests (Heikinheimo 1937). The difference increases with time from the thinning treatment and is greater in poor seed years. On average 50 seeds/m^2 are produced in northern Finland, 100 in central Finland and 150 in southern Finland. In peak years it may be three times as high. Seed production increases with site class.

A comparison between natural stands and seed orchards reveals that there are at least sometimes differences in their cone and seed characteristics. The number of seeds per tree (graft) can be higher in seed orchards than in stands. The cone number and volume may be larger. Cone size is – not so surprisingly – clearly greater in seed orchards, but number of seeds per cone is about the same (20). Seed production per volume unit of cones is higher in stands than in seed orchards. Seed weight is considerably higher in seed orchards (see below). The annual variations are likely to be smaller in a seed orchard than in a stand.

There are differences between seed orchards and stands, which may explain differences in seed set. Scots pine seed orchards have often a more southern location than their utilization area, and a good site class; they are often situated on former farmland. Land preparation includes ditching and removal of competing vegetation. Sometimes they are fertilized. A natural stand under those conditions would probably produce 120-150 seeds/m^2. A mature seed orchard is similar to the top of an old stand, thus a similar seed production would be expected. Thus we may assume that biological seed production in old seed orchards would approach 120-150 seeds/m^2 (10 kg/ha in orchards, but only 6 in stands).

When trees are released in seed tree cuttings they react by setting more cones and producing more and heavier seeds (Karlsson 2000). The effect is largest 4-5 years after the release and may then pass 200 seeds/m^2. The seed production is still considerable higher 10 years after the release than before. Seed tree stand conditions may have some similarity with seed orchards.

Material

Observation of seed production

We report on seed production in mature Swedish Scots pine seed orchards. Information about the concerned seed orchards is given in Table 1.

Table 1. Basic information for considered Swedish Scots pine seed orchards

Seed Orchard	Year(s) established (planted)	Latitude, °N	Number of clones (main clones)	Intended (planted) grafts per ha	Description of the orchard, reference
Åkerud	1988-89	60	43	400	Almqvist et al. 1996; Eriksson et al. 1998
Klocke	1988-72	62	60	318	Eriksson et al. 1998
Lustrjaet	1988-72	60	59 (40)	278	Almqvist et al. 1998
Lengtora	1982-84	60	36	400	Jonsson et al. 1976
Skärholma	1958-1960 (+70-88)	64	42	(277-)625	Yazdani et al. 1985
Sävar, experimental seed orchard	1988 (-77)	64	51	156-625	Rosvall et al. 1983

Results

Observations of seed production

In Table 2, rather recent observations of actual biological seed production from mature seed orchards are presented. None of the observations has been used for estimation of per area seed production earlier, although some other aspects of the basic data utilized, have been published for Askerud, Klocke and Lustnaset.

Table 2. Observations of biological seed set (filled seeds)

Seed orchard (seed maturation year)	Seeds per m^2	Seeds per m^2, adjusted A)	Seeds per graft	Remaining grafts/ha; B)	Clones observed	Graft age Oldest, (likely) C)	Grafts observed	Reference
Askerud 2000-02	71		2130	335	40	36 (34)	240	D)
Askerud 1991	70		2000	350	6	26(24)	6	Eriksson et al. 1998
Klocke 1990	129		4781	270	12	22 (20)	≈ 30	Eriksson et al. 1998
Lustnдset 1993-94	179		6470	278	47	25(23)	96	Almqvist et al. 1996
Lengtora 2004	349	349	22340	156	12	42(41)	34	D)
Skaholma 2004	231	153	17761	130	14	46(40)	42	D)
Sдvar 156 – 1999	255	152		125	51	30(29)		
Sдvar 331 – 1999	321	191		269	51	30(29)		D)
Sдvar 625 – 1999	323	192		525	51	30(29)		

A) Adjustment made for cone set in pine forests in the region according to the Swedish Forest Survey (In the region around Savar 1999 it was 1.4 more than normal; 1.5 around Skaholma 2004; and 1.0 around Langtora 2004).
B) Could be arithmetic average of 2 or 3 years, refers to untreated grafts. Skaholma and Langtora are based on inventories of graft density 2004 to 2005 by the authors.
C) Refers to age at seed set.
D) Data not published before.

In seed orchard Askerud the same per hectare seed production is observed at age 24 and 34 (70 and 71 seeds/m^2 respectively). A considerably higher production is observed in Klocke (129 seeds/m^2) and Lustnaset (179 seeds/m^2) even though these orchards are younger than Askerud.

Skaholma and Langtora are mature seed orchards at the end of their service period (actually trees at Langtora were cut in connection with the cone harvest). The seed orchards have not been pruned or managed for the previous five years (Skaholma) or decade (Langtora). The cones may be typically growing 5 meters (Skaholma) or 7 meters (Langtora) from the ground. The seed production in Langtora is outstanding the highest in this study, 349 seeds/m^2, whereas Skaholma has about the same production (153 seeds/m^2) as the experimental orchard Savar at the same spacing.

An interesting result is, that at age 30, different spacings (269 and 525 grafts/hectare) in the experimental seed orchard Savar resulted in the same number of seeds/m^2 (191 and 192 respectively).

In Skaholma and Langtora the clonal variation in seed set was studied. All cones were collected 2004, and the seeds extracted, from 3 grafts per clone for 12-14 clones. The results are summarized in Table 3.

Table 3. Cones, seeds and seed weight per graft at Skaholma and Langtora 2004 and their variation among grafts. CV is coefficient of variation, thus the standard deviation divided by the mean

Seed orchard character	Lengtora		Skaholma	
	Mean	CV	Mean	CV
Filled seeds	22340	0.682	17761	0.845
Weight of filled seeds (g)	125.48	0.753	94.68	0.800
Volume of cones (dm^3)	21.14	0.707	14.13	0.852
Number of cones	1122	0.686	886	0.877
Cones observed from ground	83.5	0.577	80.1	0.721
Seed weight (mg)	5.47	0.153	5.56	0.120

Visual estimation of cone set

An effort to estimate the cone set of individual grafts by a fast visual inspection was done for grafts at Langtora and Skaholma, where also an exact count was done. A spot was chosen with a good view of the graft. Preferable spots to the south were chosen to get better illumination. Only unaided eye was used. Visible cones without moving were counted. Less than 10 per cent of the harvested cones were observed (Figure 1 and 2), which was a surprise for the observer.

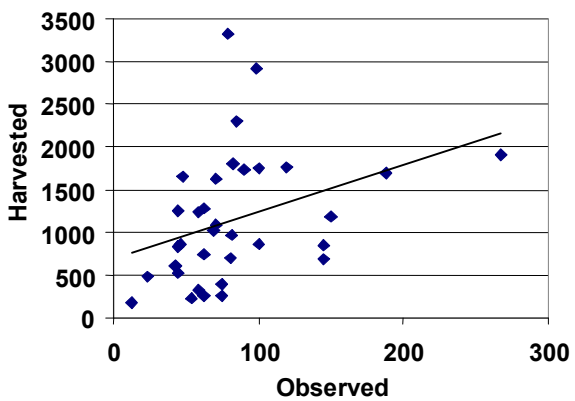

Figure 1. Relationship between visually estimated number of cones and harvested (= true number) cones per ramet in seed orchard Langtora 2004.

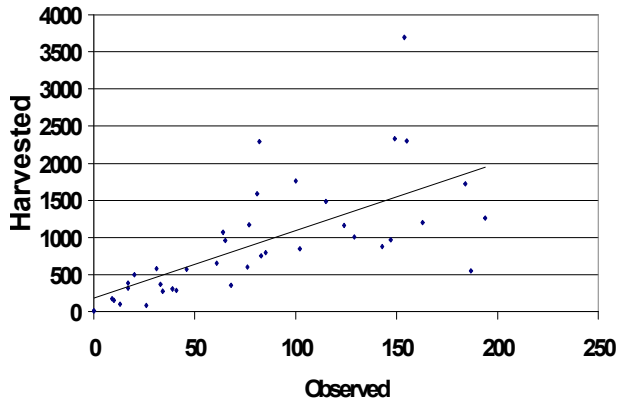

Figure 2. Relationship between visually estimated number of cones and harvested (= true number) cones per ramet in seed orchard Skaholma 2004.

The visual estimates were regressed against the exact counts :

$Y = 695 + 5.50X$; $r = 0.359$ (Langtora)

$Y = 179 + 9.12X$; $r = 0.673$ (Skaholma)

where X is visible cones for a ramet, Y is harvested cones for a ramet, r is the coefficient correlation.

Seed weight

One motivation for seed orchards is the superior technical seed quality. One important factor is the seed weight, which is generally considerable higher than for stand seeds. Recorded values in Swedish Scots pine seed orchards for 16 years, are compiled in Table 4. After 1988 the series was broken for administrative reasons. The table is based on many individual annual reports from former «Institutet for Skogsforbattring» (list of these sources can be found at http://www.skogforsk.se/), which never have been compiled before. Table 4 also compiles some previously not published data with stand seeds analyzed in response to enquiries from practical forestry.

Table 4. Seed weights of Swedish Scots pine seeds (mg/seed or g per 1000 seeds) harvested in seed orchards and stands

Year (seed maturation)	Seed orchard seeds				Stand seeds	
	Northern Sweden	Middle Sweden	Southern Sweden	Average	Middle Sweden	Northern Sweden
1973	6.57	6.39	6.44	6.467	n/a	4.64
1974	6.08	5.55	6.33	5.987	n/a	4.23
1975	5.48	5.83	6.54	5.950	n/a	2.89
1976	6.32	6.53	7.31	6.720	5.36	4.30
1977	5.31	5.43	5.86	5.533	4.11	4.00
1978	5.37	6.09	6.12	5.860	n/a	3.47
1979	5.96	6.12	6.33	6.137	4.13	4.07
1980	6.07	6.47	6.25	6.263	3.77	4.03
1981	5.76	6.14	6.27	6.057	3.85	3.85
1982	5.51	5.76	6.33	5.867	4.03	3.67
1983	5.86	6.14	6.56	6.187	4.02	3.79
1984	5.88	6.07	6.34	6.097	n/a	3.63
1985	6.06	6.70	6.84	6.533	3.82	3.78
1986	6.28	6.16	6.20	6.213	n/a	3.89
1987	5.54	6.20	6.26	6.000	n/a	2.41
1988	6.93	7.15	6.97	7.017	n/a	4.47
Average	5.936	6.171	6.434	6.180		3.82
# Seeds/kg	168 457	162 058	155 415	161 801	-	261 706

Discussion

Observations of seed production

According to Table 2, there are annual variations in seed production and the observations may have been done unrepresentative years, therefore for some of the values we adjusted as if the seed orchard harvests had varied as observations on cone set made by the Swedish Forest Survey. However these adjustments are likely to be too large, the variations in cone set are likely to be smaller in seed orchards than in stands and the deviations in the seed orchards are likely to reflect real deviations from stands as well as annual fluctuations, but still the adjustments are given to give an idea of how unrepresentative the few observations may be. Another uncertainty is that the observations of the Swedish Forest Survey are done visually, c.f. the discussion below.

The Savar seed orchard was established as an experimental orchard situated physically adjacent to the Swedish Forest Research Institutes station, and this gives probably an advantage (higher per area seed production) compared to an ordinary operative orchard. From the beginning it has a better protection situation (better fencing; problems are noted and acted on faster; etc.). Lost grafts are usually replaced rather fast and the spacing at operation had not declined much compared to the initial.

The study shows that dense spacing does not seem to promote seed production beyond 30 years, however this is very scarce and difficult to interpret data. The experimental orchard has 16 large seed orchard plots, all with different treatments (thus no true replications). It is thus unreliable to separate a single factor like spacing, since many factors are confounded.

The high per area seed production in the more than 40 year old seed orchards, Skaholma and Langtora, with large grafts growing at a density of magnitude 150 grafts/hectare, strongly indicates that biological seed production does not decline when grafted seed orchards get old and large with widely spaced trees. That harvests often decrease in old seed orchards is more likely to be associated with lower accessibility of cones, lower priority in connection with higher costs of harvest and management actions, to get cones more accessible on large grafts. The seed orchards were

not recently pruned, which probably contributed to the high seed production. Therefore the seed production can probably not be considered sustainable, at least if cones should stay within reach.

The estimated variation among grafts (CV) in fertility does not differ much if measured as any of the characters: filled seeds, weight of filled seeds, volume of cones, number of cones, or cone counts from ground. Thus probably all measures results in usable estimates of female fertility variation and the most cumbersome methods need not be generally used for that purpose.

Seed weights can probably be as variable among grafts in a seed orchard as among years. The seed weight 2004 was probably lower than average for Langtora. Probably this is connected to that no fertilization had been done for a long time and that the seed crop was high, but the seed weight is still much higher than in stands. For Skaholma the average seed weight 1973-88 was 5.59 mg, 2004 does not deviate from average.

Visual estimates of cone set

That few cones are visible in a seed orchard could be as the nourishment state is usually good in a seed orchard, the crowns could be rather dense and many cones could be hidden. In our study we saw only about 10% of all cones. The Swedish Forest Survey makes annual inventories of cone set (mentioned in Table 2). Trees are observed by a binocular from a point chosen to see many cones. Hagner (1957 p26-28) made such an inventory of 170 pines on different localities covering Sweden. The trees were felled and all cones collected. It was found that 23.1 % of the cones were seen. In a stand the crown is not so dense, so more of the cones may be visible. Also the use of binocular will increase the number of observed cones somewhat.

The coefficient correlation in this study is rather low, but still visual estimates seem good enough to get an impression about the variation among grafts, and thus probably also among clones. Even if the correlation is moderate, it is still high enough to be used as a guide about which grafts produce many or few cones.

Seed weight

Seed orchard seeds are considerable heavier than stand seeds, even in not well-maintained seed orchards. The reason why orchards produce seeds that is heavier than stand seeds seems to be complex. Seed orchards are generally established on fertile soils on agricultural land, they are located in mild locations with high temperature sum and the capillarity in the soils is normally good, but the difference is not dramatic and is larger among years than among parts of the country. Trees within orchards are widely spaced and commonly pruned, the use of fertilizer, herbicides and moving grass are regular treatments. Clones within northern orchards are often southerly transferred. Perhaps a contributing reason could be that plus tree selection is a selection of trees that produce higher seed weight. Perhaps top pruning, which breaks the apical dominance and forces more nutrition to branches and less to height growth, can be a contributing reason, but heavier seeds are observed also in non pruned seed orchards.

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