Seed orchards and seed collection stands of Scots pine in Turkey

Nebi Bilir & M. Denizhan Ulusan

Faculty of Forestry, Suleyman Demirel University, 32260 - Isparta/Turkey

(nebilir@orman.sdu.edu.tr or nebilir@hotmail.com)

Abstract

Scots pine (*Pinus sylvestris L.*) has 22 seed orchards covering 116 ha and 36 seed collection stands (seed stands) covering 4813 ha. The seed orchards had on average 5.6 ha and 21 years, 41 clones and 36 ramets per clone. The effective number of clones was on average 37.3, which is 91% of census number indicating that the clones are represented by similar number of ramets. The stands had 134 ha, 1660 m. altitude, 105 years, 26 m. height, 35 cm diameter on average, were briefly documented in this study. Seed orchards in Turkey usually draw their clones from a single seed collection stand. Although it was changed for years based on annual plantation program, at beginning of the century more than 90 % of seed demand for forest plantation in Turkey was covered from the seed stands for some years, and the impact of seed orchard crop is raising.

There were large differences for number of clone and ramets per clone and total number of ramets among the orchards. Large differences for the documented characters were also found among the seed stands. Results of the study were discussed based on seed source management and breeding programs.

Key words: *Pinus sylvestris*, seed sources, effective number of clone, breeding program.

Introduction

Scots pine

Scots pine ***(Pinus sylvestris* L.)** is one of the economically and ecologically most important forest tree species for both Europe and Asia. It has also an interesting growing as an introduced exotic species such as Korea, China, Mexico and New Zealand, where provenance and cultivation trials have been established (Boratyński, 1991). Scots pine occupies between 37°-70° N latitude and 7°-137° E longitude in the world (Anonymous, 2001).

Scots pine is one of the five native pines (*Pinus brutia*, *P. nigra*, *P. sylvestris*, *P. pinea*, *P. halepensis*) in Turkey. It is classified as one of the economically important species for Turkish forestry and the "National Tree Breeding and Seed Production Programme" which is a part of the Turkish–Finnish project, implemented in cooperation between the Turkish Ministry of Forestry and Enso Forest Development Oy Ltd (Koski and Antola, 1993). While Scots pine grows between 0-2700 meters (mainly 1000-2500 m.) above sea level in Turkey, it also grows up to 3125 meters. Within its natural area it grows in different ecological conditions. Such a wide range of ecological conditions could favor the formation of a variety of ecotypes. For instance, Turkey has *Pinus sylvestris* ssp. *hamata* var. *hamata* and *P. sylvestris* ssp. *hamata* var. *compacta* (Anonymous, 2001; Genc, 2004). Pure stands of the species occupy roughly 750 000 ha in mostly Black sea coastal mountains at northern part of Turkey (38°41'-41°48' N latitude, 28°00'-43°05' E longitude) where the climate is humid, of which roughly 475 000 ha (65%) are considered to be productive forests. Scots pine had only 3 % of the artificial and 1 % of the natural regeneration area during the last 20 years (Koski and Antola, 1993). Annual yield is 1 976 688 m^3 in the species. Annual increment is 10.43 m^3 varied between 1.33 and 26.81 in Turkey (Anonymous, 2001).

Afforestation is one of the important ways to turn into productive forest of unproductive forest and to increase its current distribution area. For instance, its distribution was increased from 738 192 ha (Anonymous, 2001) to 757 426 (Caliskan, 1997) between 1980 and 1997. But, suitable area for afforestation of the species is about 500 000 ha (Anonymous, 2001). Seed collection stand and orchards are more important seed sources for the plantation. The natural range of the species was divided geographically into four main and seven sub breeding zones based on climatically and ecological conditions in the "National Tree Breeding and Seed Production Programme" (Koski and Antola, 1993) (*Figure 1*). Collected seed both seed orchard and seed stands are mostly tested such as germination percentage by Forest Tree Seeds and Tree Breeding Directorate. And some of the collected seed are exported or sold to local private companies. For instance, 15 kg Scots pine seeds were exported during last five years (Anonymous, 2004).

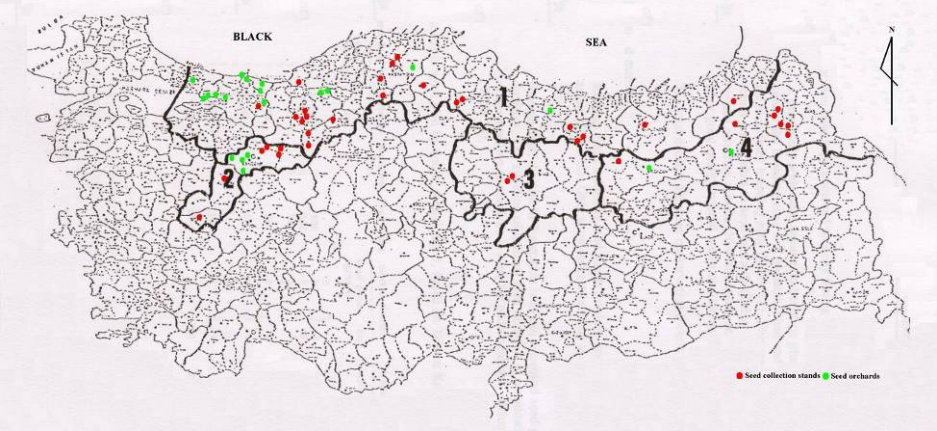

Figure 1. Breeding zones, present seed orchards and seed collection stands of Scots pine.

Seed orchards

The first trial seed orchard with Scots pine (10 clones and 96 ramets) was established in Turkey in April of 1964. Turkey has currently 171 seed orchards in 1165.4 ha of eight forest tree species (*Pinus brutia*, *P. nigra*, *P. sylvestris*, *P. halepensis*, *P. pinea*, *Cedrus libani*, *Picea orientalis*, *Liquidambar orientalis*). Tree breeding in Turkey on an operational scale was initiated with plus tree selection and establishment of seed orchards in 1972, Establishment of seed orchards have been continued with 6952 plus trees selected phenotypically (e.g. growth rate, stem and branch forms) mostly in seed collection stands of 11 species (www.ortohum.gov.tr, 2007). It was characteristics of the present Turkish seed orchards that they have been established with about 30 plus tree clones each, selected from a single seed stand at the same breeding zone. While phenotypic selection was used in establishment of early seed orchards, phenotypic selection and progeny test will be combined in establishment of new seed orchards based on National Tree Breeding and Seed Production Programme. Both establishment of seed orchards and selection of seed collection stands are administered by "Forest Tree Seeds and Tree Breeding Directorate" of Ministry of Environment and Forestry.

Seed collection stands

There are 338 seed collection stands (seed stands) in 46 086 ha of 27 forest tree species in Turkey. They are selected phenotypically based on geography (natural distribution area) and target characters of the species in breeding program. For instance, the most important characters of Scots pine which should be improved by means of breeding are height growth. In addition the quality character that effect the usefulness of stem should be

improved. Besides, forest resistance is essential for high elevation areas near the forest tree line such as Kars-Sarikamis (more than 2200 m elevation) (Koski and Antola, 1993). The seed collection stands are also used as source of vegetative materials/ancestor of long-term breeding populations to establish seed orchards.

Seed orchards and seed collection stands of Scots pine in Turkey were documented based on establishment (number of clone and ramets, effective number of clones) and selection characters (altitude, area, age, height and diameter). Results of the study were discussed for National Tree Breeding and Seed Production Programme.

Material and Methods

Seed orchards

General information of seed orchards was taken from Forest Tree Seeds and Tree Breeding Research Directorate. In this study following criterions of the orchards were used based on Turkish forestry.

Number of clones and ramets per clone

Number of clones and ramets per clone have important roles on gene diversity in seed orchard crops and economy of the seed orchard (i.e., selection of clones, growth of graft, establishment, thinning). If many clones were used, genetic diversity would be high; establishment cost also would be high. When a small number of clones are used, some rare allele in a base population may be lost in a seed orchard due to sampling effect (Bilir *et al*., 2004). For gene diversity of orchard crops, the number of clone may be more important than to use equal number of ramet among clones (Kang *et al*., 2001). Classes of number of clones were determined according to the minimum clone numbers (30) (Bilir *et al.*, 2004).

Effective number of clones

The effective number of clones (N_c) was estimated based on ramet numbers of clones (n) (Kang *et al*., 2001) as:

$$N_c = \frac{n^2_{total}}{\sum_{i=1}^{N} n_i^2} = \frac{1}{\sum_{i=1}^{N} \left(\frac{n_i}{n_{total}} \right)^2} = \frac{1}{\sum_{i=1}^{N} r_i^2}$$

where n_i is the number of ramets for i^{th} clone; N is the census number of clones and r_i is the proportion of the i^{th} clone in the seed orchard. If the clones are unrelated and not inbred the effective number of clones can be considered as equivalent to the status number of clones (Kang *et al*, 2001).

Seed collection stands

Seed stands data were taken from website of "Forest Tree Seeds and Tree Breeding Research Directorate (www.ortohum.gov.tr, 2007). Following characters of the stands were documented in the study.

Age

Age is important for reproductive characters such as cone and pollen production of individual/stand. Age classes were determined according to the rotation age (80-100 years) of the species (Genc, 2004).

Altitude

The character is important for both seed production used in plantation and gene conservation. Altitude classes were determined according to the low (≤1200 m), middle (1200-1600) and high (1600≤) zones (Koski and Antola, 1993).

Area

It is important for selection/breeding program cost, thinning, and protection. Its classes were determined according to the minimum area number, which is about 100 ha (Koski and Antola, 1993).

Height and diameter

Height has an important role in seed cost (e.g. seed collection). Height and diameter are important phenotypical characters during selection of seed stand and clone.

Results and Discussion

Seed orchards

Scots pine has 22 seed orchards in 116 ha (*Table 1*, *Figure 1*), two of which is *Pinus sylvestris* var. *compacta* in 4.8 ha. One of the orchards is shown in *Figure 2*. Current seed orchards covered 9 % of seed demand for some years (e.g. 2002) (Cengiz, 2003). But, it was related to annual plantation program. For instance, plantation area was 7542 ha in 2002; 1227 ha in 2003; 3897 ha in 2004; 3149 ha in 2005; 2000 ha in 2006 (Personal communication with M. Alan). So, seed orchard crop was fully covered for 2003, but was not sufficient for 2002. It could be also changed for good/poor seed year or age of the orchards. 30 % of the orchards including 404 clones (49% of total clones) at 39.6 ha (34% of total area) is lower than fifteen years (*Table 1*). Male strobili appear sporadically in the first three years after grafting regardless of origin. Until 12 to 15 years graft produce more female strobili than male. At the age of 15 to 20 years, the production of male strobili was about 5 times higher than female (Chalupka, 1991). Bilir *et al*. (2007) estimated average seed production as 2.3 kg per hectare

in three Turkish seed orchards of the species for one year data. New seed orchards are established as emphasized in National Tree Breeding and Seed Production Programme.

Table 1. Number of clones (N), total number of ramets (∑n), effective number of clone (N_c), the relative effective number of clones (N_r), coefficient of variation (*CV*) among clones in ramet numbers and general knowledge.

Breeding zone	N	∑n	N_c	N_r (= N_c /N)	CV	Area (ha)	Spacing (m)	Age (year)
1	10	94	9.9	0.99	8.5	0.2	5x5	43
3	25	1222	23.2	0.93	27.3	6.0	7x7	25
1	28	1035	25.3	0.91	32.0	5.1	7x7	25
2	29	1100	26.7	0.92	29.2	5.4	7x7	24
1	29	1193	26.8	0.93	28.1	6.2	7x7	21
1	30	1034	22.9	0.76	55.6	5.1	7x7	19
4	30	1050	27.4	0.92	30.2	5.5	7x7	17
1	30	1154	27.4	0.92	31.0	5.8	7x7	30
2	30	1200	27.9	0.93	27.0	7.2	7x7	23
4	30	1274	27.9	0.93	27.1	6.5	7x7	20
2	30	1406	27.0	0.95	33.1	6.9	7x7	15
1	30	1807	28.4	0.95	23.0	6.7	6x6	10
1	30	1987	28.4	0.96	23.6	7.2	6x6	12
1	31	917	28.2	0.91	31.3	5.1	7x7	18
1	31	1258	28.5	0.92	29.2	4.0	5x5	31
4	36	2060	32.5	0.66	32.7	5.7	5x5	3
1	43	728	34	0.79	51.3	3.6	7x7	30
1	43	1220	39.7	0.93	28.5	6.0	7x7	30
2	126	453	107.7	0.90	41.2	3.2	7x7	7
2	152	2021	145.3	0.86	31.3	9,9	7x7	9
average	41	1211	37.3	0.91	31.0	5.6	-	21
range	10-152	94-2060	9.9-145.3	0.76-0.99	8.5-55.6	0.2-9.9	-	3-43

There were large differences among the orchards based on number of clones (N), total number of ramets (∑n) (*Table 1*). There were fifteen times differences between the lowest (N=10) and the highest (152) seed orchard for the number of clones. Besides, average of number of ramets per clone was 36 and varied between 4 and 67. Most of the orchards (70 %)

had more than 30 clones and more than 30 ramets per clone (*Table 1*). Bilir *et al*. (2006-a) suggested less clones (e.g., 5-10 clones) based on fertility and gene diversity in establishment of seed orchards both economy and balance among clones. Bilir *et al*. (2004) reported that even though the production of strobili is assumed to be proportional to the successful number of gametes, the number of 30 clones could hardly deliver entire gene diversity of the base population into the seed orchard. When used many clones in establishment of seed orchard, fertility variation among and within clone can be high (e.g., CV) and then balance of fertility by seed orchard manager can be hard (Bilir *et al*., 2006-a). Besides, effective number of clone can be low. So, fewer clones (e.g., 5-10 clones) should be used at establishment of seed orchard. It could be reduced to 20 or fewer clones after genetic rouging (Lindgren and Prescher, 2005). While early Turkish seed orchards were established with about 30 plus tree clones selected phenotypically from a single seed stand, new seed orchards have been established with 100-200 clones based on progeny test and the breeding program. Besides, number of seed stands or base populations used establishment of seed orchard should be increased for high gene diversity in seed orchard crop and transmit of gene diversity by afforestation to next generations and resistance of afforestation to biotic and a biotic factors.

Figure 2. Scots pine seed orchard established at Mengen, Bolu, with spacing 7x 7 m., 1034 grafts from 30 clones selected from a seed collection stand in 1988.

Effective number of clones

There were small differences between effective number of clones and number of clones, more than 90% of relative effective number of clones (*Table 1*). Using of equal or similar number of ramets per clone is important for effective number of clone. For instance, effective numbers of clone were 22.9 (N_r = 0.76, CV=55.6) and 28.4 (N_r = 0.96 CV=23.6)

which have the same clone number, respectively. Effective number of clone (N_c) was also estimated based on number of clones (N) and coefficient of variation (*CV*) for the number of ramets among clones as $N_c = N/(CV^2+1)$ (Kang *et al*., 2001).

Effective number of clones (N_c) becomes the status number (N_s) of the orchard crop if parents are unrelated, non-inbred and parental fertility is proportional to the ramet number and all parents are included (Lindgren and Mullin, 1998; Nikkanen and Ruotsalainen, 2000; Kang *et al*., 2001). Gene diversity (*GD*) can be related with the effective number of clones ($GD=1-0.5/N_c$) by Lindgren and Kang (1997) or with status number (N_s) as: $GD = 1- 1/ (2*N_s)$, and also with the relative effective number of clones (N_r) and clone numbers (N) as: ($GD=1-0.5/N*N_r$). Maximum gene diversity of seed orchards crop for a given clone number is attained when all parents contribute equally to the gamete gene pool (Kang, 2001). In this situation coefficient of variation (*CV*) among clones for ramet numbers play important role in gene diversity of seed orchards crop.

Table 2. Number, area (ha), number of clones and number of ramets for seed orchards and number of plus trees selected and proposed for Scots pine and estimated seed demand in the four Turkish breeding zones.

	Breeding zones			
	1	2	3	4
Number & (%)	11 & (55 %)	5 & (25 %)	1 & (5%)	3 & (15 %)
Total area & (%)	55 & (49 %)	32.6 & (29 %)	6.0 & (6%)	17.7 & (16 %)
Number of clones & (%)	335 & (41 %)	367 & (44 %)	25 & (3%)	96 & (12 %)
Number of ramets & (%)	12440 & (51 %)	6180 & (26 %)	1222 & (5 %)	4384 & (18 %)
Current selected plus trees[1]	1124	380	475	440
Proposal number of selected plus trees[1]	1500	500	500	500
Seed demand (kg) & (%)[2]	985 & (68%)	24 & (2%)	164 & (11%)	270 & (19%)

[1)] Koski and Antola, 1993 ; [2)] Anonymous, 1992

There were large differences among seed orchards for the coefficient of variation (*CV*) of ramet numbers among clones (*Table 1*). But, it could be balanced by genetic thinning together with reproductive characters. Bilir et al. (2006-b) reported higher variation within clones than among the clones for strobili production in three Turkish Scots pine seed orchards. Most of the orchards were established in first breeding zone as seen from *Table 2* and *Figure 1*. It is normal that because about 41 % of the natural distribution is in first breeding zone.

Seed collection stands

Scots pine has 36 seed collection stands, (*Figure 1*) in 4813 ha, selected phenotypically such as stem and crown forms, small branch (*Figure 3*). The general characters of the stands of the species were given in *Table 3*.

Figure 3. Seed collection stand (left) where a plus tree was selected (right) (1300 m).

More than 90% of the seed demand for plantation in the species is covered from these stands for some years as related to annual plantation program. They are also base population of vegetative material to establish seed orchards. Although seed collection stand is a way of cheap breeding such as short-term breeding, seed orchard has also some advantage such as harvesting cost and quality in seed crop. For instance, while average of one thousand seed weight is 4 g, it increases up to 6-7 g in seed orchard crop (Urgenc, 1982). Also, seed harvest is possible on ground in seed orchard. While it was found 9.2 g in natural populations (Boydak, 1977) and 9.9 g in eleven seed collection stands (Turna, 2003) and 9.3 g in three seed collection stands (Ucler, 1991) in Turkey, it was estimated 11 g in three Turkish Scots pine seed orchards (Bilir *et al*., 2007). Besides, seed orchard crop (Bilir, 2007 unpublished data) had bigger size than seed stand seed (Turna, 2003). The differences were also valid for subspecies and variety of the species. For instance, 1000 seed weight was 2-4 g in *Pinus sylvestris* ssp. *lapponica*, 4-7 g in *P. sylvestris* ssp. *sylvestris* (Molotkov and Patlaj, 1991).

Table 3. Averages and ranges of the seed stands.

	area (ha)	altitude (m)	age (year)	Height (m)	diameter (cm)
Average	134	1660	105	26	35
Range	45-303	900-2350	78-164	16-36	17-45

The seed stands are 0.7% of total area of Scots pine. It should be at least 3-5% for gene conservation and seed harvest. Seed stand is also a way of the cheap breeding. So, new seed stands should be selected. 47 % of the current seed stands are over than rotation age of the species (100 years). The species starts seed production at natural stands 30 years (Anonymous, 1986). Urgenc (1982) suggested that seed stand in Scots pine could be selected up to 90 or 135 years. Stands of high quality and of high productivity at an age of 60-80 years are best suited for the selection of plus trees or up to 100 years depending on the felling age (Philgas, 1991). Besides, size and quality of seeds harvested from more than 200 years seed stand could be low (Genc, 2004). While 100 ha were proposed as minimum seed collection stand area (Koski and Antola, 1993), 35 % of the stands had less than 100 ha. Half of the stands were between 1200 and 1600 meters, while 44 % of them were more than 1600 m. The seed stands for altitude are normal. Then, while new seed stands are selected, age and areas should be considered. There were large differences among the stands for the characters such as seven times differences between the lowest and largest area of the stands.

More than 50 % of the seed stands are in first breeding zone based on number and area, it is well accordance with natural distribution area of the species in first zone (*Table 4*).

Table 4. Natural distribution and seed collection stands (ha) based on breeding zones.

	Breeding zones			
	1	2	3	4
Number & (%)	20 & (56%)	7 & (19.5%)	2 & (5.5%)	7 & (19%)
Total area & (%)	2772 & (58%)	600 & (12%)	377 & (8%)	1064.5 & (22%)
Core area & (%)	1890 & (62%)	260 & (9%)	313 & (11%)	582.5 & (19%)
Natural area & (%)*	299 205 & (40.5%)	5170 & (0.7%)	278 038 & (37.6%)	155 191 & (21%)

*; Anonymous, 1980

While natural distribution area of the species is high in third zone, number and area of the selected seed stand is very low (*Table 4*). It can be because of the similarity of distribution of main stands (*Figure 1*) and also seed demand in the zone (*Table 2*). While annual seed demand of Scots pine is reported about 715 kg (Cengiz, 2003), it is reported in another study as 1 440 kg (Anonymous, 1992). The differences can be because of the good seed year or annual plantation program.

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