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Fertility Variation and Status Number Between a Base Population and a Seed Orchard of *Pinus brutia*

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Abstract

Female, male and total fertility variations were estimated in a base population and a seed orchard derived from the base population in *Pinus brutia*. Relative status number for gametes (female and male contribution) and zygotes (average of female and male contribution) were estimated based on the fertility variation. Average female and male strobilus production were 229.1 and 1003.3 in the base population, and 98.9 and 244.9 in the seed orchard for combined years, respectively. Positive and significant correlations were found between female and male strobilus production in both base population and seed orchard. The male fertility variation was higher than female fertility variation in the seed orchard, while female fertility variation was higher than male fertility variation in the base population. Coefficients of variations in female and male strobilus production were 0.721 and 0.696 in the base population, and 0.403 and 1.110 in the seed orchard for combined years, respectively. Total fertility variation was 1.41 in the base population and 1.40 in the seed orchard for combined years. The relative status numbers estimated based on the total fertility were 70% of census number in the base population, and 71% in the seed orchard for combined years.

Key words: Pinus brutia, seed orchard, base population, sibling coefficient, status number.

Introduction

Seed orchards are important seed sources for forest plantations. They have been established with clones or seedlings, collected from plus trees selected phenotypically from natural stands or plantations. The numbers of clones in seed orchards is important for transmitting gene diversity represented in the natural stands. Variation in fertility is one of the major factors in evolution and management of genetic resources (Bila, 2000) and also in comparison between seed orchards and their base populations. In this study, the base population means the area where clones (plus trees) were selected for establishment of seed orchards.

New seed orchards in Turkey will be established vegetatively with grafts selected based on progeny tests according to the "National Tree Breeding and Seed Production Programme" (Koski and Antola, 1993). Thirty clones have been generally used when first generation seed orchards were established in Turkey (Anonymous, 2001). How many clones should be used to maintain reasonable genetic diversity in seed orchards? There have not been clear answers and interpretations about clone numbers in seed orchards. If there were many clones, genetic diversity 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. For gene diversity of orchard crops, the number of clones may be more important than to use equal number of ramet among clones (Kang *et al.,* 2001).

Seed orchard clones are taken from base populations or breeding populations. This population generally comprises many genotypes and represents high gene diversity. The clones selected from base populations should catch almost all gene diversity in the base population, and transmit it to the next generation (i.e., seed crops).

The purposes of this study are: 1) to evaluate fertility variation among individuals in a base population and a seed orchard of Brutian pine (*Pinus brutia* Ten.); and 2) to determine if clones selected are able to transmit gene diversity represented in the base population to the seed orchard.

Material and Methods

Base population, seed orchard and data collection

The numbers of female and male strobili were assessed from 60 plus trees chosen randomly in a base population of *P. brutia* at the end of April 2002 and at the beginning of May 2003, respectively. The distance between sampled trees is 30 meters or more. The base population at Bucak is located at latitude 37°26' N, longitude 35°25' E, and average elevation 650 m. The tree age in the base population varied from 60 to 80 years, and the population density is approximately 500 trees per hectare.

The studied seed orchard of *P. brutia* originated from plus trees selected from the base population at Bucak and was established at Antalya (latitude 37°20' N, longitude 30°35' E, altitude 310 m), southern part of Turkey in 1985. Grafts were planted at spacing 8 m x 8 m, and the seed orchard is composed of 30 clones (1620 ramets) (Anonymous, 2001). The data of female and male strobilus production were collected from six ramets chosen randomly from each clone at the beginning of April 2001 and at the beginning of May 2003, respectively.

Fertility variation and relative status number

In this study, fertility variation is estimated as a concept of sibling coefficient based on the variation in strobilus production among individuals in the populations (Kang and Lindgren, 1999). The sibling coefficients for female (ψ_f) and male (ψ_m) were estimated as:

$$\psi_f = N\sum_{i=1}^{N}\left(\frac{f_i}{\sum f_i}\right)^2 = CV_f^2 + 1 \qquad [1\text{-a}]$$

$$\psi_m = N\sum_{i=1}^{N}\left(\frac{m_i}{\sum m_i}\right)^2 = CV_m^2 + 1 \qquad [1\text{-b}]$$

where N is the census number, f_i is the number of female strobili of the i^{th} individual, m_i is the number of male strobili of the i^{th} individual and CV_f and CV_m are the coefficients of variation in female and male strobilus production among individuals.

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Table 1. – Averages, coefficients of variation (*CV*), correlation coefficient (*r*) of female and male strobilus production in the base population and the seed orchard.

	Base population						Seed orchard					
Year	2002		2003		Combined		2001		2003		Combined	
	female	male	female	male	female	male	female	male	female	male	female	male
Average	265.8	1322.3	192.4	684.4	229.1	1003.3	89.0	289.8	108.1	200.1	98.9	244.9
CV	0.807	0.625	0.458	0.387	0.721	0.696	0.491	1.277	0.318	0.417	0.403	1.110
r [a)]	0.605		0.821		0.646		0.278		0.677		0.296	

[a)] phenotypic correlation coefficient between female and male strobilus production, statistically significant at 0.01 probability level.

Sibling coefficient of clones (i.e., total fertility variation, Ψ) was calculated by KANG and LINDGREN (1999) as:

$$\Psi = N\sum_{i=1}^{N}\left(\frac{0.5f_i}{\sum f_i}+\frac{0.5m_i}{\sum m_i}\right)^2 = 0.25\left[N\sum_{i=1}^{N}\frac{f_i^2}{\sum f_i}+N\sum_{i=1}^{N}\frac{m_i^2}{\sum m_i}+N\sum_{i=1}^{N}\frac{2m_if_i}{\sum m_i\sum f_i}\right] \quad [2]$$

where N is the census number, f_i and m_i are the numbers of female and male strobili of the i^{th} individual, respectively.

Relative status number (N_r) on total fertility (i.e., clone fertility) was calculated as:

$$N_r = \frac{4}{\psi_f+\psi_m+2+2r\sqrt{(\psi_f-1)(\psi_m-1)}} \quad [3]$$

where ψ_f and ψ_m are the fertility variation of female and male parents, and r is the correlation coefficient between female and male fertility.

Results and Discussion

Female and male strobilus production

Averages, coefficients of variation and phenotypic correlation coefficients between female and male strobilus production in the base population and the seed orchard for the studied years are given in *Table 1*.

The averages of female and male strobilus production were higher in the base population than the seed orchard (*Table 1*). Those results might be due to bigger size of trees in the base population than that in the seed orchard. Individuals in the base population produced female strobili 1.4 times and male strobili 1.9 times more in 2002 than 2003, respectively (*Table 1*). ATA (1995) and GENC (2004) reported that good seed year was once in two years or every year in natural stands of the species. Elevation, age, crown closure of the stand (ELER, 1990), and environmental conditions mainly in soil property (BILA and LINDGREN, 1998) might be important factors in the seed yield.

There were variations in strobilus production among individuals both in the base and the seed orchard populations. The variations were however smaller than commonly observed in many other studies (KANG *et al.,* 2003), in particular in 2003. The variation was larger in the base population than in the seed orchard, a contributing reason for that may be that the orchard data were based on the average of several ramets. The variations among trees were remarkably low in 2003, and the production of strobili was also high. This is in agreement with a general trend that when there are many flowers, they are also more equally distributed (KANG *et al.,* 2001). Coefficients of variation of females were higher than those of males in the base population, but it was opposite in the seed orchard (*Table 1*). Large differences in the production of female and male strobili among clones were found in seed orchards by KANG (2001) and also among years by KESKIN (1999).

There were positive significant ($p \leq 0.05$) correlations between female and male strobilus production in both base population and the seed orchard (*Table 1*). This result is well in accordance with the results from seed orchards of *P. brutia* (BILIR *et. al.,* 2002; KESKIN, 1999) and *P. taeda* (SCHMIDTLING, 1983). However, negative genetic correlations between female and male flowering were reported in *P. elliottii* (SCHULTZ, 1971), *P. sylvestris* (SAVOLAINEN *et al.,* 1993) and *P. contorta* (HANNERZ *et. al.,* 2001). On the other hand, positive correlations were found between the number of seed cones and the proportion of filled seed in *Picea sitchensis* (CHAISURISRI and EL-KASSABY, 1993), *P. abies* (KJÆR and WELLENDORF, 1997) and *Pseudotsuga menziesii* (EL-KASSABY and COOK, 1994; REYNOLDS and EL-KASSABY, 1990). The correlation coefficient between female and male fertility should be considered when the total fertility is estimated based on separate estimates of male and female fertility (KANG and EL-KASSABY, 2002), as done in this study.

Parental trees are selected initially according to their phenotypes for traits such as vigour, form, wood quality or other desired characteristics, which include general adaptability (ZOBEL and TALBERT, 1984). However, when we know genetic information (e.g., genetic value, fertility), such information could also be used as a criterion of selection for seed production in seed orchards (LINDGREN *et al.,* 2004). Fertility of parent trees/clones might be important for seed orchard layout (BILIR, 2002).

Fertility variation and relative status number

Female, male and total fertility variation, and relative status number are presented in *Table 2*. Female fertility variation was higher than male fertility variation in the base population,

Table 2. – Female and male fertility variation (ψ_f & ψ_m), total fertility variation (Ψ) and relative status number (N_r) for the base population and the seed orchard.

	Base population			Seed orchard		
Year	2002 (60)[a)]	2003 (60)	Combined (120)	2001 (30)	2003 (30)	Combined (60)
ψ_f	1.64	1.21	1.52	1.24	1.10	1.16
ψ_m	1.39	1.15	1.48	2.63	1.17	2.23
Ψ	1.40	1.16	1.41	1.55	1.11	1.40
N_r	0.71	0.86	0.70	0.64	0.90	0.71

[a)] census number (*N*) in parentheses.

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but male fertility was higher than female fertility in the seed orchard (*Table 2*). These results were in accordance with the reports from seed orchards of *Pinus brutia* by BILIR *et al.* (2002) and a seed stand of *P. radiata* by BILIR *et al.* (2003). KANG *et al.* (2003) reported that large differences in fertility among trees were found in natural stands, plantations and seed orchards.

KANG *et al.* (2003) found that fertility was higher in natural stands than seed orchards. In this investigation, the variation in seed orchards may be reduced as the clonal values were based on an average of six ramets. Female, male and total fertility variations were higher in 2002 than in 2003 in the base population (*Table 2*). Total fertility of the base population (1.41) was close to that of the seed orchard (1.40) in combined years (*Table 2*). The relative status numbers estimated based on the total fertility were also similar in the base population (0.70) and the seed orchard (0.71) for combined years (*Table 2*).

Probably some rare alleles could be missing when the base population transmits gene pool to the seed orchard. In this study, fertility variation among genotypes was used to estimate relative effective number and gene diversity between base and orchard populations. Other factors such as genetic relatedness and gene flow could also be important.

While 6.6 tons of seeds are produced from current seed sources (2.2 tones of them from seed orchards and 4.4 from seed stands) of the species, Turkey needs 9.8 tons seed for the plantation in the species (CENGIZ, 2003). To meet seed demand of *P. brutia* in Turkey, new seed orchards will be established vegetatively with grafts after progeny tests according to the "National Tree Breeding and Seed Production Programme of the species" in Turkey (KOSKI and ANTOLA, 1993). Only a single base population has been used in the establishment of each first-generation seed orchard in Turkey (ANONYMOUS, 2001). Thus, more base populations and plus trees should be selected and used in the establishment of seed orchard for producing genetically improved enough seeds. High gene diversity, in turn, could be maintained in seed crops produced from seed orchard populations.

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References

ANONYMOUS (2001): 2000 yili calisma raporu, 2001 yili calisma programi (Working report of 2000 and working plan of 2001). The Research Directorate of Forest Tree Seeds and Tree Breeding, No: **3** (132/7), Ankara, Turkey, 149 pp.

ATA, C. (1995): Technique of Silviculture. Karaelmas University, Bartin Forestry Faculty publishers, Bartin, Zonguldak, No: 4/3, 453 pp.

BILA, A.D. (2000): Fertility variation and its effects on gene diversity in forest tree populations. Ph. D. Thesis. Swedish University of Agricultural Science, Umeå, Sweden. Acta Universitatis Agriculturae Sueciae, Silvestria **166** 31 pp.

BILA, A. D. and LINDGREN, D. (1998): Fertility variation in *Milletia sthuhlmannii*, *Brachystegia spiciformis*, *Brachystegia bohemii* and *Leucaena leucocephala* and its effects on relatedness in seeds. For. Genet. 5: 119-129.

BILIR, N. (2002): Clonal repeatabilities for female and male flowering in seed orchards of pines in Turkey. IUFRO Symposium on Evolutionary Genetics of Forest Trees. Slovakia, August 25–29.

BILIR, N., KANG, K. S. and OZTURK, H. (2002): Fertility variation and gene diversity in clonal seed orchards of *Pinus brutia*, *Pinus nigra* and *Pinus sylvestris* in Turkey. Silvae Genet. **51**: 112–115.

BILIR, N., KANG, K. S. and LINDGREN, D. (2003): Fertility variation and effective number in the seed production areas of *Pinus radiata* and *Pinus pinaster.* Silvae Genet. **52**: 75–77.

CENGIZ, N. (2003): Inventory of supply and demand of seed for Turkey. B.18.0.AGM.0.04.02.781/81/443, Ankara, 1 pp.

CHAISURISRI, K. and EL-KASSABY, Y. A. (1993): Estimation of clonal contribution to cone and seed crops in a Sitka spruce seed orchard. Ann. Sci. For. **50**: 461–467.

ELER, U. (1990): Seed yield in Calabrian cluster pine (*Pinus brutia* Ten.) by age. Forest Research Institute, Technical Bulletin No: **225**, Antalya, 78 pp.

EL-KASSABY, Y. A. and COOK, C. (1994): Female reproductive energy and reproductive success in a Douglas-fir seed orchard and its impact on gene diversity. Silvae Genet. **43**: 243–246.

GENC, M. (2004): Principles of Silviculture. Suleyman Demirel University, Forestry Faculty publishers No: **44**, Isparta, 341 pp.

HANNERZ, M., AITKEN, S. N., ERICSSON, T. and YING, C. C. (2001): Inheritance of strobili production and genetic correlation with growth in lodgepole pine. For. Genet. **8**: 323–329.

KANG, K. S. (2001): Genetic gain and gene diversity of seed orchard crops. Ph. D Thesis. Swedish University of Agricultural Science, Umeå, Sweden. Acta Universitatis Agriculturae Sueciae, Silvestria **187**, 75 pp.

KANG, K. S. and EL-KASSABY, Y. A. (2002): Considerations of correlated fertility between genders on genetic diversity: P*inus densiflora* seed orchard as a model. Theor. Appl. Genet. **105**: 1183–1189.

KANG, K. S. and LINDGREN, D. (1999): Fertility variation among clones of Korean Pine (*Pinus koraiensis* S. et Z.) and its implications on seed orchard management. For. Genet. **6**: 191–200.

KANG, K. S., BILA, A. D., HARJU, A. M. and LINDGREN, D. (2003): Fertility variation in forest tree populations. Forestry **76**: 329–344.

KANG, K. S., HARJU, A. M., LINDGREN, D., NIKKANEN, T., ALMQVIST, C. and SUH, G. U. (2001): Variation in effective number of clones in seed orchards. New For. **21**: 17–33.

KESKIN, S. (1999): Clonal variation in flowering and cone characteristics in a *Pinus brutia* seed orchard. SAFRI Technical Bulletin No. **9**, Antalya, 96 pp.

KJÆR, E. D. and WELLENDORF, H. (1997): Variation in flowering and reproductive success in a Danish *Picea abies* (Karst.) seed orchard. For. Genet. **4**: 181–188.

KOSKI, V. and ANTOLA, J. (1993): National tree breeding and seed production programme for Turkey 1994–2003. The Research Directorate of Forest Tree Seeds and Tree Breeding, Ankara, Turkey, 52 pp.

LINDGREN, D., CUI, J., SON, S. G. and SONESSON, J. (2004): Balancing seed yield and breeding value in clonal seed orchards. New For. **28**: 11–22.

REYNOLDS, S. and EL-KASSABY, Y. A. (1990): Parental balance in Douglas-fir seed orchards-cone crop vs. seed crop. Silvae Genet. **39**: 40–42.

SAVOLAINEN, O., KARKKAINEN, K., HARJU, A., NIKKANEN, T. and RUSANEN, M. (1993): Fertility variation in *Pinus sylvestris:* a test of sexual allocation theory. Amer. J. Bot. **80**: 1016–1020.

SCHMIDTLING, R. C. (1983): Genetic variation in fruitfulness in a loblolly pine (*Pinus taeda* L.) seed orchard. Silvae Genet. **32**: 76–80.

SCHULTZ, R. P. (1971): Stimulation of flower and seed production in a young slash pine orchard. U.S. Southeastern For. Exp. Station. USDA Forest Service, SE-91, 10 pp.

ZOBEL, B. and TALBERT, J. (1984): Applied forest tree improvement. John Wiley & Sons, New York, USA. 505 pp.

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