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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 11 (17): 2159-2162, 2008
ISSN 1028-8880

Effective Number of Clones in Seed Orchards of *Cedrus libani* A. Rich.

M.D. Ulusan and N. Bilir
Faculty of Forestry, Suleyman Demirel University, 32260-Isparta, Turkey

Abstract: Numbers of clone and ramet/clone were studied and discussed based on effective number of clones and relative effective number of clones in seed orchards of Taurus cedar (*Cedrus libani* A. Rich.). While, seed orchards had similar number of clones (15, 30 and 33), there were large differences for number of graft/clone within and among orchards. Number of ramets per clone varied between 4 and 43 in an orchard and between 4 and 106 in all orchards considered. Effective number of clones ranged from 24.6-31.4 and relative effective number from 0.82 to 0.99. The results of the study showed that ramet number had moderate variation among clones. It was important that establishment and thinning of seed orchards and estimation of gene diversity in seed orchard crop.

Key words: Taurus cedar, clone, ramet, seed orchard

INTRODUCTION

Taurus cedar or also, called Lebanon cedar (*Cedrus libani* A. Rich.) occupies on the Taurus Mountains in southern Turkey, where the most productive populations are found. It also occupies in Syria and Lebanon as small populations remain today (Boydak, 2003). Taurus cedar forests cover about 183,000 ha, which is 73,000 ha unproductive forest according to 1997' forest inventory (Genc, 2004). But, Boydak (2003) reported that the suitable forest area for the species was 600,000 ha. Taurus cedar has about 400,000 ha forest by annual afforestation which is 30,000-50,000 ha with established 50 million seedlings.

Seed orchards are one of the important seed sources to produced improved seeds both genetically and physiologically for forest plantation and conversion of unproductive forests to productive. Improved seed sources play important role economical and biological success of plantation. For the purpose, eleven clonal seed orchards of Taurus cedar (*Cedrus libani* A. Rich.) were established at 64 hectares by from The Research Directorate of Forest Tree Seeds and Tree Breeding of Turkey. Taurus cedar is classified as one of the economically important species for Turkish forestry and the National Tree Breeding and Seed Production Programme (Koski and Antola, 1993). Establishment of seed orchards and selection of seed stands are one of the important stage of breeding and seed production programs. So, new seed orchards has been established based on the program to cover improved seed demand which is annually about 14 obtained from current seed stands. Number of clones is one of the most important factors both economically and genetically in establishment of seed orchards. But, there are large differences among species and countries used on clone numbers in seed orchards. It is also, valid for seed orchards of the same species. For instance, it was reported as 5-10 clones for *Pinus sylvestris* by Bilir *et al.* (2006), less than 30 clones for *Pinus brutia* by Bilir *et al.* (2004) based on strobili production and it could be reduced to 20 or fewer clones after genetic rouging (Lindgren and Prescher, 2005). When used many clones in establishment of seed orchard, fertility variation among and within clone will be high (e.g., CV) and then balance of fertility by seed orchard manager will be hard. Besides, effective number of clone can be low (Bilir *et al.*, 2006). 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 the equal number of ramet among clones (Kang *et al.*, 2001). But, differences in gamete contribution among clones could be genetic, environmental (Varghese *et al.*, 2006) and management of orchard (Zobel and Talbert, 1984). Besides, years could be impact on flowering differences among clones (Bilir *et al.*, 2005, 2006). Many works were carried out on clone numbers (Kang *et al.*, 2001; Bilir *et al.*, 2004; Lindgren and Prescher, 2005; Prescher *et al.*, 2008) recently.

The objectives of this study were to examine effective number of clones based on clone and ramet numbers in seed orchards of Taurus cedar and to discuss the influence of clonal ramet variation on gene diversity of seed orchard crop. The results of the study were also, discussed with respect to the management of present and future seed orchards.

Corresponding Author: Nebi Bilir, Faculty of Forestry, Suleyman Demirel University, 32260-Isparta, Turkey

Table 1: Details of the orchards

Orchard No.	Location	No. of clones	No. of ramets	Area (ha)	Establishment year	Spacing (m)
113	Adana-Kadirli	15	907	2.2	1988	6×6
114	Mersin_Mut	30	2232	8.1	1990	6×6
115	Isparta-Dinar	30	1995	7.2	1995	6×6
116	Mugla-Kemer	30	1503	5.4	1990	6×6
117	Eskisehir-Inonu	33	2252	5.6	1990	5×5
118	Antalya-Akseki	33	2781	10.0	1990	6×6
119	Elazig-Mardin	30	3072	7.7	1991	5×5
149	Denizli-Cal	30	1020	2.5	1995	5×5
150	K.maras-Elmalar	30	756	2.7	1995	6×6
184	Eskisehir-Kirka	33	1187	4.3	2005	6×6

MATERIALS AND METHODS

Seed orchards: Details of the studied seed orchards were presented in Table 1 based on 2005's inventory, which was obtained from The Research Directorate of Forest Tree Seeds and Tree Breeding of Turkey.

Effective number of clones: The effective number of clones (N_c) was estimated based on ramet numbers of clones (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 ith clone, n is the number of ramets in the seed orchard; N is the census number of clones and r_i is the proportion of the ith 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).

RESULTS AND DISCUSSION

Numbers of clone and ramet: Although similar numbers of clones were used in establishment of seed orchards, there were large differences for total living number of ramets among orchards and number of ramets per clone within orchard (Table 2). For instance, there were 11 times differences between the lowest and highest number of ramets per clone in orchard 150 (Table 2). The difference could stem from incompatibility between epibiot and hipobiot, environmental factors or establishment cost.

Effective number of clones: Large differences were found among orchards for effective number of clone (N_c), relative effective number of clones (N_r) and coefficient of variation (Table 3). The result showed that number of ramet/clone

Table 2: Numbers of clones and ramets in the orchards

Orchard No.	No. of clones	Average No. of ramet/clone	Range of ramets/clone
113	15	61	42-63
114	30	74	29-91
115	30	67	24-88
116	30	50	13-71
117	33	68	18-89
118	33	84	37-106
119	30	102	35-93
149	30	34	25-35
150	30	25	4-43
Total	261	58	4-106

Table 3: Effective number of clones (N_c), the relative effective number of clones (N_r), coefficient of variation (CV) among clones

Orchard No.	N_c	N_r*	CV (%)
113	14.8	0.98	11.6
114	28.3	0.94	24.5
115	27.9	0.93	27.4
116	27.5	0.92	30.1
117	30.6	0.93	27.9
118	31.4	0.95	22.6
119	29.2	0.97	16.4
149	29.9	0.99	5.7
150	24.6	0.82	46.9
Total	222.6 (N = 261)	0.85	41.5

*; $N_r = N_c/N$

was also, important for effective number of clones and to obtain high gene diversity in seed orchard crop. Similar findings were also reported by Kang *et al*. (2001) and Bilir and Ayan (2005). Effective number of clone (N_c) was related based on coefficient of variation of ramet numbers (CV) and clone numbers (N) by Kang *et al*. (2001) as: $(N_c) = N/(CV^2+1)$. When used similar/equal number of ramets/clone, census number of clone could be close or equal to effective number of clone. All clones contribute equally to gene pool census number is equal to effective number (Kang and Lindgren, 1998; Kang *et al*., 2001).

Effective number of clone (N_c) is related to gene diversity (GD) by Kang (Kang *et al*., 2001) as: $GD = 1\text{-}0.5N_c$.

Numbers of clone and ramets could change during or after establishment with progeny test, thinning (Bondesson and Lindgren, 1993; Prescher *et al*., 2004) or survival. There were many factors for contribution of clones to gene pool of seed crop such as strobili, cone and seed production of ramets. But, the number of clone win an orchard is used commonly to discussions at establishment of orchards and to monitoring operations. Maximum gene diversity in seed orchard crops can only be attained when all parents contribute equally to the gamete pool (Kang *et al*., 2001). If there is a large variation for ramet number and fertility among clones, the census number alone could not be meaningful in terms of genetic diversity and regulatory policy. Bilir *et al*. (2004) reported that 30 clones were enough for establishment of seed orchards on strobili production and fertility variation in

Prinus brutia. When used many clones in establishment of seed orchard, fertility variation among and within clone will be high (e.g., CV) and then balance of fertility by seed orchard manager will be hard. Genetically advanced seed orchards can have fewer clones because the advantages of few clones become higher if they are tested. Lindgren and Prescher (2005) suggested around 20 clones for Scots pine and 10 for *P. taeda* in southern United States for clonal seed orchards with tested clones. When applying genetic thining more ramets can be thinned away the lower the breeding value of the clone, thus, both the effective number and the relative effective number can be reduced following genetic thinning (Bondesson and Lindgren, 1993). When the relative effective number is low it can be optimal to increase it (Prescher *et al.*, 2008). Besides, effective number of clone can be low. So, fewer clones (e.g., 5-10 clones) should be used at establishment of seed orchard.

For instance, distribution of ramet numbers to clones of seed orchards of 149 and 150 which were established with the same clone numbers (N = 30) was presented in Fig. 1a and b.

Effective number of clones were estimated 29.9 (N_r = 0.99) in seed orchard 149 and 24.6 (N_r = 0.82) in seed orchard 150 (Table 3). The result showed that coefficient of variation of ramet numbers was more important than total number of ramet or average number of ramet/clone on effective number of clone. Similar result was also reported by Bilir and Ayan (2005) in oriental spruce seed orchards. Beside, the top of 6 clones had 20% of total number of ramets in seed orchard 150, while, it was 6.7% in seed orchard 149. If we remove these clones after genetic thinning, relative effective number of clone will increase from 0.82 (N_c = 24.6, N = 30) to 0.93 (N_c = 22.2, N = 24) in orchard 150. Relative effective numbers were mostly higher than 0.7 in Finnish, Swedish and Korean coniferous seed orchards (Kang *et al.*, 2001).

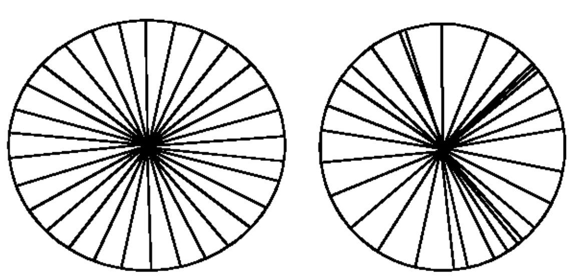

Fig. 1: Distribution of amets to clones in orchards (a)149 and (b) 150

CONCLUSIONS

There were large differences for ramet numbers among and within orchard. But, it could be balanced by traditional or genetic forest tending.

Large differences among orchards for effective number of clone showed that number of ramet/clone was also important for effective number of clones together with number of clones using establishment of seed orchards. Maximum gene diversity in seed orchard crops can only be attained when all parents contribute equally. So, similar number of ramet per clone should be used to obtain high gene diversity in seed orchard crop. Gene diversity in seed orchard crop also could be obtained by mixing seeds from different seed orchard.

Many factors could be considered (e.g., clone and seed production of ramets) for contribution of clones to gene pool of seed crop. But, the number of clone in an orchard should be used to discussions at establishment of orchards and to monitoring operations.

Results of the study should be used in management of current seed orchards (e.g., balancing of clone and ramet numbers) and establishment of seed orchards (e.g., determination of clone and ramet numbers).

ACKNOWLEDGMENTS

Authors acknowledge administrative support from The Research Directorate of Forest Tree Seeds and Tree Breeding of Turkey (040817/44039).

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