Genetic Gain and Diversity of Seed Crops under Alternative Management Options in a Clonal Seed Orchard of *Pinus thunbergii*

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There are various orchard management options to increase genetic gain while conserving genetic diversity, including selective harvesting, genetic thinning, and the combination of both. The practice of selective harvesting improves only the genetic contribution of seed parents, while both seed and pollen parents are improved with genetic thinning. For the production of improved seeds, many factors such as clonal genetic value, selection intensity, fertility variation and pollen contamination should be considered.

The objectives of this study were to evaluate the genetic gain and diversity of seed crops from a *P. thunbergii* clonal seed orchard under different management options, and to determine appropriate selection intensity (i.e., seed collection proportion, thinning rate) in selective harvest and genetic thinning. Additionally, the effects of gene migration from outside the orchard on genetic gain and diversity, and the consequences of alternative management options for seed production are also discussed. This paper reports on different alternatives for seed orchard management to increase genetic gain while maintaining adequate levels of genetic diversity.

METHODS AND MATERIALS

Seed orchard description

The clonal seed orchard of *P. thunbergii* is located on An-myun island, in the western part of Korea (lat. 36° 3'N, long. 126° 2'E and alt. 35m) and established in 1980. The orchard is planted at 5m x 5m spacing, with approximately equal numbers of grafts. Clonal fertility was estimated from assessments of strobilus production over nine consecutive years.

Additive genetic values for each orchard-parent genotype were obtained from open-pollinated progeny tests (represented by general combining ability, *GCA*). Parental *GCA* values for volume growth at age 12 were estimated by the method of best linear unbiased prediction (BLUP), based on height and diameter at breast height measured from field trials.

Genetic gain and diversity

Genetic value (G) and diversity (status number, N_s) of seed crops were estimated under four management alternatives, as follows:

1) Alternative 1: selective seed harvest from the best 50% of clones, without genetic thinning

$$G = 0.5 i_{(N_f, N)} \sigma_A + MC \qquad N_s = \frac{4NN_f}{\Psi[N + (1-2M)(3-2M)N_f]}$$

2) Alternative 2: 50% genetic thinning, removing clones with inferior genetic values

$$G = (1-M) i_{(N_f, N)} \sigma_A + MC \qquad N_s = \frac{N_f}{(1-M)^2 \Psi}$$

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3) Alternative 3: 75% genetic thinning, a more intensive genetic thinning than Alternative 2
4) Alternative 4: 20% selective harvest after 50% genetic thinning

$$G = \frac{\left(i_{(N_f,N)} + (1-2M)i_{(N_m,N)}\right)\sigma_A}{2} + MC \quad N_s = \frac{4N_f N_m}{\Psi[N_m + (3-8M+4M^2)N_f]}$$

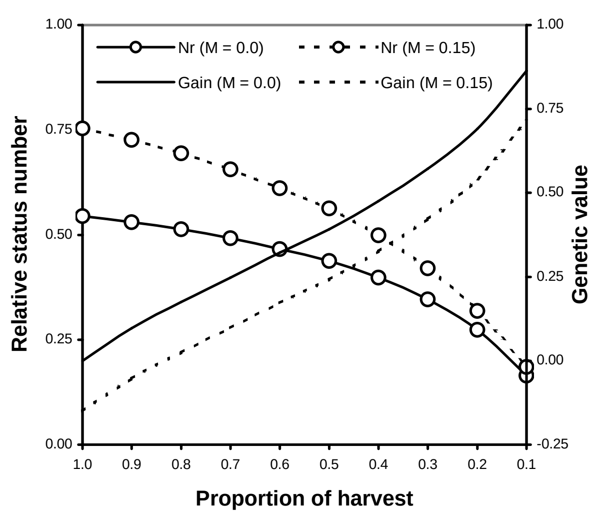
where i is selection intensity; σ_A is additive genetic variance; M is gene migration; C is inferiority of contaminating pollen; N is the census number; N_f is the number of seed parents and N_m is the number of pollen parents. Ψ is the sibling coefficient describing fertility variation among clones.

RESULTS AND DISCUSSION

Selective seed harvest (Alternative 1), genetic thinning (Alternatives 2 and 3) and the combination of both options (Alternative 4) increased genetic gain over the initial orchard condition (i.e., before thinning). The increase was, however, coupled with a decrease in status number. Genetic gain was highest and diversity (status number) lowest in Alternative 3 under both gene migration scenarios.

In Alternative 1, seeds are collected only from clones with higher genetic values, while the entire orchard remained intact. Selection is only for the seed parents, and not for pollen parents. Under genetic thinning options (Alternatives 2 and 3), seeds are harvested from all of the remaining clones after thinning; thus, as opposed to Alternative 1, both pollen and seed parents are improved by the irreversible removal of clones with lower genetic values. The remaining selected clones contribute to the seed crop as both male and female parents. Selection, therefore, occurs for both parents at the same time and with the same intensity.

In Alternative 4, all clones remaining after the 50% genetic thinning serve as the pollen source, while seeds are harvested from a subset of clones consisting of the top 20% with the highest genetic value. Thus, selection occurs twice; the first is simultaneous selection against inferior clones (pollen and seed parents) at the time of thinning, and the second is the selection against the subset of the remaining clones acting as seed parents only.



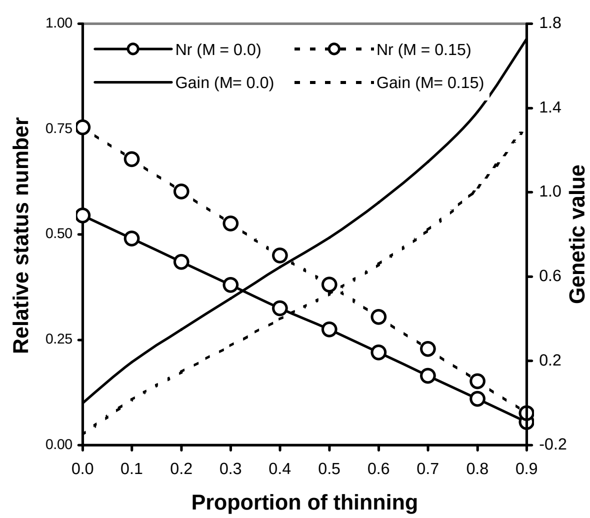


Figure 1. Relation between genetic value and relative status number (N_r) for selective harvest

(left) and genetic thinning (right) with different levels of foreign gene migration (*M*). In these examples, fertility variation (Ψ) was set to 2 and contamination inferiority (*C*) equal to –1.

Relative gain from orchard management varied with the proportion of selected and/or thinned clones (Fig. 1). The increase in genetic value was not linear relative to the proportion of selected and/or thinned clones in selective harvest and genetic thinning options. Genetic thinning gave greater gain than selective harvest at the same intensity, but this was accompanied by a greater loss of status number.

Strong genetic thinning (e.g., Alternative 3) would remove many clones and subsequently result in a substantial loss of diversity and seed production. However, the combination of genetic thinning and selective harvest would be better than selective harvest alone, because the usual purpose of a seed orchard is to obtain maximum gain with some appropriate level of genetic diversity (Lindgren and El-Kassaby, 1989). Seed production will also recover in a few years as tree crowns develop and occupy the openings created by tree removal (Kang et al., 2003).

REFERENCES

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