OPTIMIZATION OF GAINS AND VARIABILITY DURING SELECTION OF CANDIDATE PLUS TREES IN *EUCALYPTUS TERETICORNIS* SMITH

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Introduction

Tree improvement involves testing of provenances, progenies down to family level and preserving the variation which arises during that process. It was reported that such variation in growth components are generally heritable and phenotypically superior trees can be selected for further improvement (Elridge, 1972; Sindhu *et al.*, 2002). However, there is little consensus about increasing gains through selection due to opinion given to either create and preserve variation in the breeding programmes or to enhance the immediate gains (Falconer, 1981). An ideal strategy would be one that combines gains and create variation with in a population with sufficient representation from different families (Lindgren *et al.*, 1996). *Eucalyptus tereticornis* is an important plantation species and is extensively planted throughout the country. A tree improvement programme was initiated for improvement of yield and a F_2 generation breeding population was evaluated for their performance and superior genotypes with high breeding values were selected for raising F_3 generation progeny trial. To synthesize population for above trial, it was assumed that there is a need to infuse fresh gene pools for widening the genetic base of the base population. Hence, an attempt has been made to select superior genotypes in growth for further improvement from a provenance trial of *Eucalyptus tereticornis*.

Material and Methods

A *Eucalyptus tereticornis* plantation was established during 1982 in an area of 3.00 ha at Midnapore, West Bengal. The initial seed source was five provenances from Australia *viz.* Kennedy River, East of M.T. Frazer, Mitchell River, N.W Black Mountain and N. Mountain Molloy provenances. The trees were planted at an spacement of 2 x 2 m. The soil is alluvial, grainy and acidic in nature. The weather was extreme with a minimum of 6° C during winter to a maximum of 45° C in summer. Six sample plots of 12 x 12 m were laid out randomly within the plantation which has 49 trees in each sample plot. Sample plots were laid out excluding the under grown and areas with wide spaces due to death of trees and we evaluated the entire trial as a single population. Growth components such as total height, clear bole height, GBH, and number of branches were recorded.

The data was analyzed statistically. Population variability was estimated through Co-efficient of Variation (CV) using whole plot data. Phenotypically superior trees were selected through index selection method where double weightage has been assigned to volumetric traits such as total height, clear bole height and GBH to give importance to volumetric traits since much emphasis was given to improve volume traits in Eucalyptus. Single weightage was given to number of branches. The points allotted to each character were provided in (Table 1). The maximum values were used as 100 % for all variables and accordingly total height has got 0.625 points for each meter the tree attained. Clear bole height has got 0.714 points for each meter of clear bole. Likewise, 0.22 points for each one cm of GBH and for each branch 0.333 points were allotted. A computer program has been made to allot points to each unit of each growth variable and a final tally of points for each individual has been carried out and accordingly, the trees with highest scores were selected from the whole plantation. A total of 294 trees were enumerated covering 23 per cent of the population and entered into computer. Several runs are performed to select superior trees based on ranking of trees. After several runs with n=113, n=80, n= 66 and n=30, the run with 66 phenotypically superior trees was selected. To quantify the gains achieved through selection, selection differential and selection pressure has been estimated for individual growth components with the following formula:

$$Sd = X_{st} - X_{sp} \quad \text{----------} \ [1]$$

Where Sd = selection differential,

X_{st} = mean of selected population and
X_{sp} = mean of total population.

$$SLP = (Sd / X_{sp}) \times 100 \ \text{------} \ [2]$$

Where SLP = Selection Pressure

Results

a) Improvement in growth parameters

The inventory of data is presented in Table 2. In the first run, 113 trees were selected and lowest selection differential and high variability for all traits was observed. In the second run, 80 trees were selected and selection indices were increased slightly but the variation reduced to that extent. Hence, third run was conducted with a selection of 66 CPTs and the variability has been maintained. To test the variability level in the population further, one more run was conducted with a selection of 30 trees. In this run, the selection differential reached the peak for all growth traits but the population variability also reached its lowest level. Total height exhibited a selection differential of 8.42 with a selection pressure of 45.59. Clearbole height exhibited a selection differential of 4.99 with a selection pressure of 34.25. GBH has a selection differential of 31.07 with a selection pressure of 76.38 while the number of branches reached a selection differential of 6.16 with a selection pressure of 81.81. Accordingly, the CV is found to be 9.26, 18.97, 12.48 and 36.74 per cent respectively. As an ideal strategy, the run with n= 66 has been short listed and used to select CPTs.

All the growth components were improved significantly and the variability has been considerably reduced in selected trees *i. e.* with n= 66 over the overall population parameters (Table 2). The mean total height of 18.47 m for total population has been increased to 25.27 m in selected population. The range of total height has been increased from a minimum of 8 m in the total population to 21 m. Likewise, clearbole height showed an increased mean value of 17.8 m over the mean of 14.57 m in the total population. The minimum range also increased from 4 m in the total population to 10 m in the CPTs. Similarly, GBH was increased from a mean of 40.68 cm in total population to a mean of 68.41 cm in the selected population. The minimum range of GBH has been shot up to 53 cm from 17 cm in the total population. The mean number of branches, however, showed an increase to 12.47 in the selected population.

b) Selection intensity and realized gain

As all the characters showed an overall improvement of yield in the form of increased growth parameters in the selected population, selection differential and selection pressure has been estimated for each growth component to quantify the exact amount of yield (Table 2). The total height, clearbole height, GBH, and number of branches exhibited a fairly good amount of selection differential and equally significant selection pressure has been exerted on the population. Thus, there was an overall increase in the yield in all those volumetric traits. However, improvement of clearbole height has been decreased when the selected population increased. In case of run with n=113 CPTs, the selection differential is just 0.72 with a selection pressure of 4.94 whereas the same has reached negative zones in the run with n=80 CPTs thus, making the selection irrational. It reached 3.23 of selection differential and 22.12 selection pressure in the run with n=66 and continued to increase in subsequent runs.

Table 1

Index scheme for selecting Candidate Plus Trees in E. tereticornis.

Sl.No	Selection traits	Points awarded
1	Total height	20
2	Clearbole height	20
3	GBH	20
4	No. of branches	10
	Grand Total	70

It can be seen from the table that significant reduction in the overall variability of the selected population was achieved which was indicated through the CV in the growth components which in turn create uniformity in the plantation. In case of clearbole height, the gains reached negative, while the unbiased variability in the population remained significant suggesting that variation is fairly associated with the trait.

Discussion

Strong relationships are observed between gains and variability as reported by many evolutionary computer programmers (Bedau and Packard, 1992; Goldberg *et al.*, 1993 and Hancock, 1994) suggesting that higher gains with less variation may dilute the capacity of genotypes to create variation in further generations. In the first instance, 113 CPTs were selected which gave a lowest selection differential for all traits but this run is associated with higher variability. In the second run, 80 trees were selected and the selection indices were increased slightly along with the decrease in variability. Hence, third run was conducted with the selection of 66 CPTs and the selection indices were increased highly while the good amount of variability has been maintained. To test the variability level in the population further, fourth run was conducted with a selection of 30 trees. In this run, the selection differential reached the peak in all growth traits along with the proportionate decrease in population variability. As an ideal strategy, the run with n = 66 (CPTs) is short-listed and selected.

Differences in plant size within an even aged plantation may be due to intrinsic differences in factors such as seed size, germination time and relative growth rate, in addition to biotic and abiotic environmental components (Weiner and Solbrig, 1984). It was assumed that such variation in populations remained significantly large and has a tendency to increase as a function of average

Table 2

Descriptive statistics with selection differential (sel. Dif.) and selection pressure (sel pre.) for growth parameters.

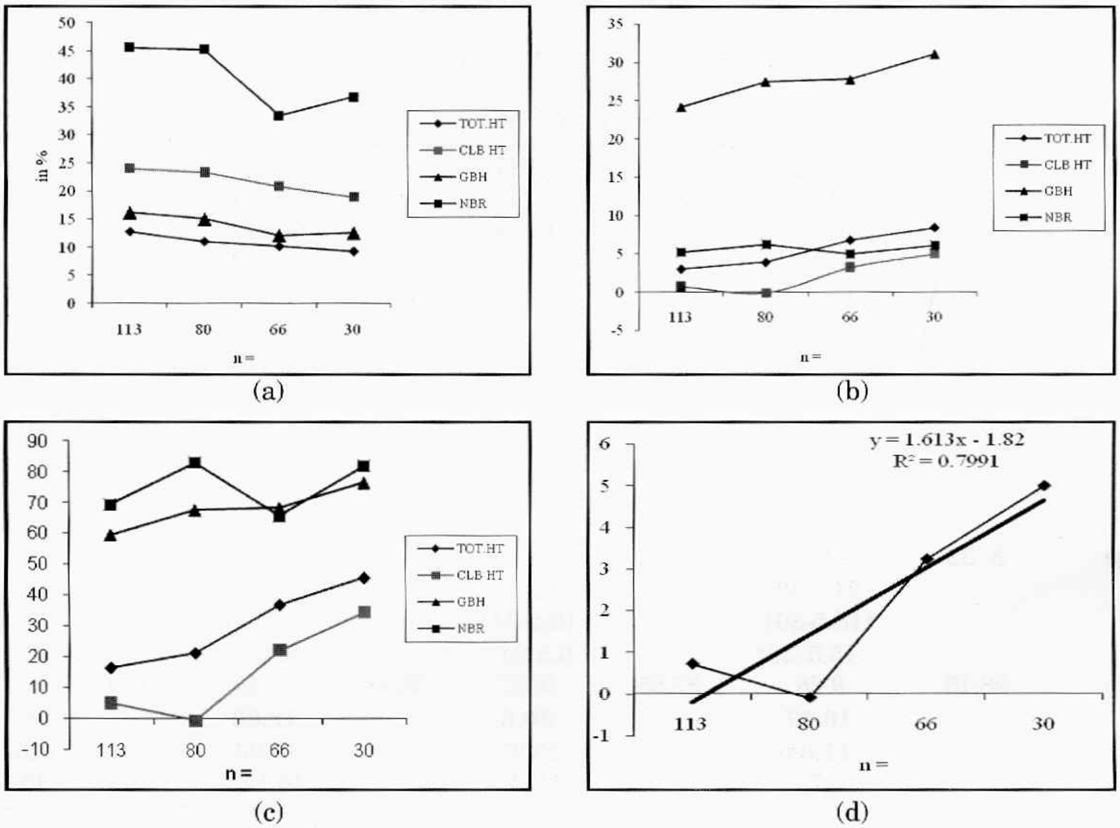
	Total height (m)		Clearbole height (m)		GBH (cm)		No.of branches	
	Tot. pop	Sel. pop	Tot. pop	Sel. pop	Tot. pop	Sel. pop	Tot. pop	Sel. pop
Mean	18.47	*26.89* **25.27** **(22.37)** 21.49*	14.57	*19.56* **17.8** **(14.48)** 13.85*	40.68	*71.75* **68.41** **(68.13)** 64.82*	7.53	*13.69* **12.47** **(13.77)** 12.75*
SD	5.2	*2.49* **2.57** **(2.47)** 2.74*	5.51	*3.71* **3.7** **(3.37)** 3.32*	13.6	*8.95* **8.22** **(10.19)** 10.46*	3.76	*5.03* **4.17** **(6.23)** 5.81*
SE +	0.3	*0.45* **0.32** **(0.28)** 0.26*	0.32	*0.68* **0.46** **(0.38)** 0.31*	0.79	*1.63* **1.01** **(1.12)** 0.98*	0.22	*0.92* **0.51** **(0.74)** 0.55*
Range	8- 32	*22-32* **21 – 32** **(18.5-30)** 15.5-30*	4 - 28	*10 – 28* **10-28** **(6.5-24)** 6.5-24*	17- 93	*59-93* **53-93** **(48-104)** 48-104*	1- 30	*8 -30* **8-30** **(5-30)** 5-30*
CV (%)	28.15	*9.26* **10.17** **(11.04)** 12.75*	37.85	*18.97* **20.8** (23.27) 23.97*	33.43	*12.48* **12.02** (14.96) 16.14*	50.14	*36.74* **33.4** **(45.24)** 45.57*
Sel.dif.	*8.42* **6.8** **(3.9)** 3.02*		*4.99* **3.23** **(-0.09)** 0.72*		*31.07* **27.73** **(27.45)** 24.14*		*6.16* **4.94** **(6.24)** 5.22*	
Sel.pre.	*45.59* **36.82** **(21.12)** 16.36*		*34.25* **22.12** **(-0.62)** 4.94*		*76.38* **68.17** **(67.48)** 59.34*		*81.81* **65.6** **(82.87)** 69.32*	

(Tot. pop- total population; Sel. Pop.- selected population). Figures are indicated as below: Italics- n= 30; Bold- n = 66; Bold in parenthesis- n = 80 and * - n= 113.

response to environment and increases as selection intensity increased. Hence, selection for short term gains (Falconer, 1981) and long term gains (Robertson, 1960) can be achieved within the available genetic potential for further breeding. However, due to non- linear nature of multiple alleles, the directions of change in gene frequencies may occur. During the course of selection, the alleles may change from positive to negative while phenotypic gains improve (Namkoong *et al.*, 1984). Hence, it is required to maintain a balance between gains in phenotypic values and diversity within a breeding population. Keeping the above view, it was assumed that 66 CPTs which were selected may represent adequate genetic base.

However, it may be noted that the number of branches has significantly increased in the selected population. One reason which may be ascribed to such behavioural attitude was the final volume production is the end result of photosynthetic activity of the foliage mass thus suggesting that the yield will also increase along with net photosynthesis activity (Ellison and Niklas, 1988; Dong and de Kroon, 1994). Further, significant lower variability in the selected population increases the total yield per unit area of the plantation as occurrence of higher variability indicates the environmental influences that alter the canalization of growth factors in the genotypes (Sakai and Shimamoto, 1965). Thus the selection pressure exerted on these growth components created a good amount of selection differential resulting in significant improvement in yield in selected population. In our earlier studies, the CPTs exhibited significant amount of intra specific variation and developmental stability in the leaves suggesting the dominance of deterministic factors in the

Fig.1



Graphs showing statistical parameters in growth components after runs with different number of superior trees: a) CV (%); b) selection differential; c) selection pressure and d) linear regression on selection differential of clearbole height (Clearbole height showed negative values in N= 80 run).

development of leaves and assumed that those genotypes have better buffering mechanisms to overcome environmental perturbations thus assuring stability over time and space (Sumita and Sindhu, 2005). Since the stability was assured and the selected population represents sufficient broad genetic base, these 66 CPTs may be selected for inclusion into F_3 generation breeding programme in addition to parents already selected through recurrent selection from F_2 generation base population.

Variations play important role in designing the genotypes to various end uses. Several workers attempted various methodologies for superiority selection and Simpson (1953) in his exegesis on phenotypic selection opined that high positive phenotypic correlation can be obtained through directing the variation toward some particular outcome rather than random. Though randomness of variations is a central principle of modern evolutionary theory, such variations can be directed by acquired phenotypic traits. In support of this view, it was assumed that due to laws of probability, correlation between phenotypic adaptations and random genetic variations may happen, especially if the phenotypic adaptations keep the lineage alive long enough for these variations to occur.

Waddington (1942) proposed similar mechanism where if organisms are subjected to sweeping environmental changes, they can sometimes adapt during their lifetimes because of their inherent plasticity, there by acquiring new physical traits. If these traits are already exists in the population although not expressed in normal environments, they can quickly expressed in the changed environments. If the trait is related to fitness of the individual, thus the traits can become genetically expressed and these genes will spread in the population. However, a trade-off existed between these two, so that the organisms retain its fitness (Hinton and Nowlan, 1987). Bedau and Packard (1992) called these measures of change as sustained change and generation of innovative functional structures. These structures are functionally designed and continually modified by the evolutionary forces.

The negative values exhibited by clearbole height are due to messy genetic algorithms which improve the program's function. It indicates optimization performance by explicitly building up longer highly fit populations from well-tested small populations (Goldberg, *et al.,* 1993). After initial population has formed and fitness evaluated, the trait proceeds in two phases- primordial phase which enrich the population with small, promising candidates followed by juxtapositional phase where the population is put to use. The primordial phase initiates selection by culling the population at regular intervals. At some number, that phase ends and juxtapositional phase is invoked. The population size stays fixed; selection continues which are perfect and legal populations. Such messy genetic algorithms were first reported by Goldberg *et al.* (1993) when they are using such genetic algorithms to trace the evolution of traits in different generations. To test the worthiness of the trait, linear regression was performed with the formula Y= mx + b using the least square method and straight line were obtained (R^2= 0.7991) suggesting the above point of view (Fig.1 (d)).

The purpose of selection in tree breeding is to how to choose the individuals in the population. Selection has to be balanced with variation. Too-strong selection means that suboptimal, highly fit individuals will take over the population, reducing the diversity needed for further change and progress; too-weak selection will result in too-low gains as reported by Hancock (1994).

In case of run with n=30, the pressure on population is very high and a small number of individuals are much fitter than the others. Under this high gains selection, though they produce seeds, less variation prevents their off-springs for further exploration, thus putting much emphasis on exploitation of highly fit individuals at the expense of explorations in further generation's search space. In subsequent generations, when all individuals in the population are similar, there are no fitness differences for selection to exploit and the population may grinds to a near halt, suggesting that the rate of gains depends on the variance of the fitness in the population (Baker, 1987).

Rank selection avoids giving the largest share to small group of highly fit individuals and thus reduces the selection pressure when the fitness variance is high. It keeps up selection pressure when the population variance is low. This method has a possible disadvantage of slowing down selection pressure *i.e.* highly fit individuals may be omitted. However, the increased preservation of diversity that results from ranking leads to more efficient selection than that of quick convergence that can result from fitness-proportionate selection.

SUMMARY

A computerized index scheme was developed for selection of candidate plus trees in *Eucalyptus tereticornis* provenances and an overall increase in the yield in the volumetric traits was achieved in the selected population. To quantify the realized gains and thereby to test association of variability within each of selected population, several runs were conducted with different number of trees. Realized gains and level of variation exhibited strong associate ships. Selection of large number of trees decreases the gains but overall population variability was increased. As gains increased, level of variation was decreased. However, a trade-off existed between the two. Hence, the genotypes retain their superiority. As an ideal strategy, a run with 66 candidate plus trees were selected which gives sufficient selection pressure allowing sufficient variation to float within the selected population. Total height exhibited a selection differential of 6.8 m with a selection pressure of 36.82%. Clear bole height has a selection differential of 3.23 m and selection pressure of 22.12%. Similarly, GBH has selection differential of 27.73 cm and 68.17% selection pressure was exerted followed by number of branches with 4.94 and 65.6% selection differential and selection pressure respectively. The yield improvement is associated with lower co-efficient of variation indicating lower amount of population variability which facilitates formation of uniform plantations.

***Key words*:** Tree improvement, Variation, Yield, Growth, Index selection.

यूकेलिप्टस टेरेटिकार्निस स्मिथ के अभ्यर्थी श्रेष्ठ वृक्षों के चयन में लाभ और विभिन्नीयता को इष्टतम बनाना

सुमित सरकार व एच.सी. सिन्धु वीरेन्द्र

सारांश

युकेलिप्टस टेरेटिकार्निस स्थल भेदों में अभ्यर्थी श्रेष्ठ वृक्ष चुनने के लिए एक संगणित्र वाली निर्देशांक योजना तैयार की गई है जिससे चुने गए वृक्षों में आयतनात्मक लक्षणों की प्राप्ति में समग्र वृद्धि प्राप्त कर ली गई। प्राप्त हुए लाभ मात्रांकित करने और उससे चुने गए वृक्षों के प्रत्येक समूह में विभिन्नता साहचर्य परीक्षित करने को वृक्षों की भिन्न-भिन्न संख्या लेकर कई प्रयत्न करके देखे गए। प्राप्त हुए लाभ और विचरण स्तरों में गहरा सम्बन्ध रहता पाया गया। अधिक संख्या में वृक्ष चुनने से लाभ घट जाते हैं। किन्तु समग्र वृक्ष संख्या की विचरण बढ़ जाती है। जैसे-जैसे लाभ बढ़े विचरण का स्तर घटता गया। किन्तु इन दोनों के बीच एक संतुलन स्तर भी रहता है। अत: समपित्रैक अपनी श्रेष्ठता बनाए रखते हैं। आदर्श रणनीति यह रही कि 66 अभ्यर्थी श्रेष्ठ वृक्ष चुने जाएं जिससे पर्याप्त चयन दबाव प्राप्त हो जाता है और चुनी गई वृक्ष संख्या के अन्दर पर्याप्त विचरण भी रखी जा सकती है। कुल ऊंचाई ने चुनाव प्रभेदक 6.8 मी रखना प्रदर्शित किया जिसमें चयन दबाव 36.82% रखा गया था। स्वच्छ तने की ऊंचाई में चयन प्रमेदक 3.23 मी और चयन दबाव 22.12% रखा गया। इसी तरह वृक्षोच्चता पर परिधि का चयन प्रभेदक 27.73 सेमी और चयन दबाव 68.17% रखा गया जिसके उपरान्त शाखाओं की संख्या के चयन प्रभेदक तथा चयन दबाव क्रमश: 4.94 और 65.6% रखे गए। प्राप्ति में सुधार विचरणों के निम्न गुणांक से जुड़ा हुआ है जो वृक्ष संख्या के विचरण की कम मात्रा का सूचक है जिससे एक समान रोपवन तैयार करना सुविधाप्रद हो जाता है।

References

Baker, J. E. (1987). Reducing bias and inefficiency in the selection algorithm. In: Genetic algorithms and their applications. *Proceedings of the Second International Conference on Genetic Algorithms*, (J.J. Grefenstette ed),Erlbaum.

Bedau, M. A. and N. H. Packard (1992). Measurement of evolutionary activity, teleology and life. In: *Artificial Life, II*. C. G. Langton, Taylor, C., Farmer, J. D. and Rasmussen, S. (eds). Addison- Wesley.

Dong, M. and H. de Kroon (1994). Plasticity in morphology and biomass allocation in *Cynodon dactylon*, a grass species forming stolons and rhizomes. *Oikos*, **70:** 99-106.

Ellison, A. M. and K. J. Niklas (1988). Branching patterns of *Salicornia europaea* (Chenopodiaceae) at different successional stages: a comparison of theoretical and real plants. *Am. J. Bot.*, **75:** 501-512.

Elridge, K. G. (1972).Genetic variation in growth of *Eucalptyus regnans*. *Bulletin*. **46**. Forestry and Timber Bureau, Canberra.

Falconer, D. S. (1981). *Introduction to quantitative genetics*. Longman, London.

Goldberg, D. E., K. Deb, H. Kargupta and G. Harik (1993). Rapid, accurate optimization of difficult problems using fast messy genetic algorithms. In: *Proceedings of the Fifth International Conference on Genetic Algorithms*. S. Forresst (ed). Morgan Kaufmann.

Hancock, P. J. B. (1994). An empherical comparision of selection methods in evolutionary algorithms. In: Evolutionary computing: (T. C. Fogarty, ed). AISB Workshop, Leeds, UK, April, 1994. Selected papers, Springer- Verlag.

Hinton, G. E. and S. J. Nowland (1987). How learning can guide evolution. *Complex systems*, **1:** 495 -502.

Lindgren, D., L. Gea and P. Jefferson (1996). Loss of genetic diversity monitored by status number. *Silvae. Genet.* **45:** 52-59.

Namkoong, G., H. C Kang and J. S Brouard (1984). *Tree Breeding: principles and strategies*. Springer-Verlag, Newyork. 85 pp.

Robertson, A. (1960). A theory of limits in artificial selection. *Proc. R. Soc. Lon. B. Biol. Sci.*, **153**: 234- 249.

Sakai, K. I. and Y. A. Shimamoto (1965). Developmental genetic studies of panicle characters in rice, *Oryza sativa* L. *Genet. Res.*, **6:** 172.

Simpson, G. G. (1953). The Baldwin effect. *Evolution*, **7**: 110-117.

Sindhu, H. C., P. V. Somashekar, R. N. Lakshmikanth and T. S. Rathore (2002). Variation and performance of *Eucalyptus tereticornis* Clones in Bangalore. *Myforest*, **38** (1): 89-94.

Sumita and H. C. Sindhuveerendra (2005). Variation studies in eucalyptus-V: intra-specific variation in the leaves and developmental stability in high yielding *Eucalyptus camaldulensis*. *My forest*, **41** (3): 413-421.

Waddington, C. H. (1942). Canalization of development and the inheritance of acquired characters. *Nature*, **150**:563-565.

Weiner, J and O. T. Solbrig (1984). The meaning and measurement of sizehierarchies in plant populations. *Oecologia*, **61:** 334-336.