ranked families were 4.37 and 4.48 respectively, implying a possible reduction in juvenile wood phase among progeny of a cross between these two groups of trees of 4.42 years.

The selection intensities implied by the above estimates are improbably high, but it serves to demonstrate that considerable gains could be made. It is important to realize that the reported heritability estimates are based on the assumption that all of the open pollinated progeny are half-sibs. Further, the assumptions that there are no correlations among pollen parents and no correlations between pollen and seed parents, are implicit in the genetic models. Any or all of these assumptions may be violated when open pollinated progeny are used to estimate half-sib covariances, with the probable result that heritabilities will be slightly over-estimated (SQUILLACE 1974, NAMKOONG 1966).

Conclusion

The age of transition from juvenile wood to mature wood in loblolly pine can be estimated only with reference to a particular wood property, such as specific gravity or tracheid length. When each character is considered independently, there is evidence of additive genetic variance influencing the time of transition among loblolly pine of east Texas. Estimated family mean heritabilities of transition age for specific gravity (.36) and tracheid length (.34—.51) are sufficiently high to suggest moderate gains can be achieved by selection on a family mean basis or by combined selection based on family mean and individual tree information.

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Experimentally Synthesized Allotetraploids in Eucalyptus

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Summary

Colchicine induced allotetraploidy in the genus *Eucalyptus* has been reported, which perhaps seems to be the first report of its kind in this genus. Allotetraploids (*E. tereticornis* $\times$ *E. grandis*, 4n = 44) were compared with diploids (F_1 *E. tereticornis* $\times$ *E. grandis* 2n = 22) for various morphological traits. The allotetraploids have quite distinct leaves, flowers, fruits, seeds etc. as compared to diploids and have exhibited vigour in certain traits. Allotriploids were also synthesized by crossing allotetraploids with diploids using *E. tereticornis* and *E. grandis* as pollen parents. Allotriploids have registered faster rate of growth as compared to diploids and tetraploids at nursery stage and are under study for their future growth behaviour and other traits of economic value. This biotechnique could be utilized for the production of fast growing allopolyploids and genetically improved prototypes for different uses.

Key words: Induced Allotetraploids, Induced Allotriploids, Interspecific F_1 hybrid - *Eucalyptus grandis.* HILL ex MAIDEN, *E. tereticornis* SM.

Zusammenfassung

In der Gattung *Eucalyptus* wird über eine durch Cholchizyn induzierte Allotetraploidie berichtet, die vielleicht die erste dieser Art in dieser Gattung ist, über die berichtet wird. Allotetraploide (*E. tereticornis* $\times$ *E. grandis* mit

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4n = 44) werden mit diploiden Nachkommen (F_1 *E. tereticornis* × *E. grandis* mit 2n = 22) in verschiedenen morphologischen Merkmalen verglichen. Im Vergleich zu den diploiden Individuen haben die allotetraploiden ganz andere Blätter, Blüten, Früchte, Samen usw. und in gewissen Merkmalen eine ausgesprochen starke Wuchskraft. Ebenfalls konnten allotriploide Individuen durch Kreuzung von allotetraploiden mit diploiden Individuen erzielt werden, wenn *E. tereticornis* und *E. grandis* als Polleneltern verwendet wurden. Bei den allotriploiden konnten im Vergleich zu den diploiden und tetraploiden im Baumschulalter stärkere Wachstumsraten festgestellt werden, wobei diese in Zukunft auf ihr Wuchsverhalten und andere wirtschaftlich interessante Eigenschaften hin beobachtet werden sollen. Diese Biotechnik kann benutzt werden, um schnellwüchsige, allopolyploide und genetisch verbesserte Prototypen für verschiedene Anwendungsmöglichkeiten zu produzieren.

Table 1. — Schedule of activities.

Sl.No.	Year	Activity
1.	1974	Crosses were made
2.	1975	Crosses harvested
3.	1975	Colchicine treatment Allotetraploids
4.	1976	Transplanted into pots
5.	1977	Transplanted into the field
6.	1980	Flowered but poor setting
7.	1981	Seed collected
8.	1983	Sowing and raising of C_1 seedlings

Table 2. — Measurements of different characters of F_1 hybrids (diploid) and Allotetraploids (*E. tereticornis* × *E. grandis*).

Character	Mean Value (diploid) (5 plants)	Mean Value (allotetraploid) (5 plants)
Leaf :		
Length of Petiole (cm)	1.93 ± 0.00	3.04 ± 0.18
Length of Lamina (cm)	19.08 ± 0.32	21.09 ± 1.34
Width of Lamina (cm)	3.90 ± 0.12	6.44 ± 0.42
Length of Leaf (cm)	21.00 ± 0.34	25.67 ± 0.84
Leaf index (L/W)	4.99 ± 0.48	3.22 ± 0.25
Stomata :		
Upper epidermis		
Length (mμ)	32.13 ± 0.93	32.44 ± 0.39
Width (mμ)	23.51 ± 0.36	23.51 ± 0.58
Frequency	4.40 ± 0.29	3.08 ± 0.35
Lower epidermis		
Length (mμ)	27.59 ± 0.57	30.38 ± 0.54
Width (mμ)	19.33 ± 0.44	22.66 ± 0.39
Frequency	27.50 ± 0.66	15.30 ± 1.12
Flower :		
No. of flowers/ inflorescence and range	6.9 (7-9)	7.6 (6-7)
Pedicel length (mm)	1.8 ± 0.13	3.6 ± 0.22
Receptacle length (mm)	4.2 ± 0.13	3.6 ± 0.00
Receptacle width (mm)	5.0 ± 0.00	6.7 ± 0.26
Operculum length (mm)	5.5 ± 0.17	5.8 ± 0.13
Operculum width (mm)	5.1 ± 0.00	7.5 ± 0.10
Length of Style (mm)	4.3 ± 0.15	4.1 ± 0.10
Pollen grain size (mμ)	21.96 ± 0.09	32.10 ± 0.08
Pollen fertility	96%	90.3%
Fruit :		
Capsule length (mm)	5.51 ± 0.02	10.26 ± 0.08
Capsule width (mm)	4.74 ± 0.07	6.03 ± 0.08
No. of Values	4-5	5-6
Seed :		
Seed size	Small	Large
100 seed weight (mg)	24.1	89.1
Germination	96%	70%

Introduction

In the genus Eucalyptus allotetraploids have not been produced earlier by colchicine treatment though induced autoteraploids have been reported (Janaki Ammal and Khosla, 1969; Kapoor and Kedharnath, 1974). Allopolyploidy as a technique could be used to make F_1 hybrids true breeding (Wright, 1964) and also it could be utilized in breaking the crossing barriers in between certain species. In vegetable crops the pioneer and classical work on induction of Allopolyploids is that of *Raphanobrassica*. The Russian cytologist G. D. Karpechenko (1926) synthesized a polyploid from intergeneric cross between *Raphanus sativus* (Radish) and *Brassica oleracea* (Cabbage) cited by (Dawson, 1962) after treating F_1 with colchicine having 18 radish and 18 cabbage chromosomes. Allopolyploidy in general helps in production of new species and genera. In this context, interspecific F_1 hybrids of *Eucalyptus tereticornis* Sm. (female) and *E. grandis* Hill ex Maiden. (male) were produced and allotetraploidy was induced by colchicine treatment in order to produce uniformity in the future populations and to synthesize experimentally new plant types and to examine them for multifarious uses. This work also demonstrates the possibility of incorporating desirable traits from two different species into a new polyploid species and a technique to produce triploids experimentally. The results of these experiments are reported in this communication.

Materials and Methods

A cross was made between *Eucalyptus tereticornis* (female) and *E. grandis* (male) during 1974 and F_1 hybrid seed was produced. Eighteen F_1 seeds were kept at 25° C

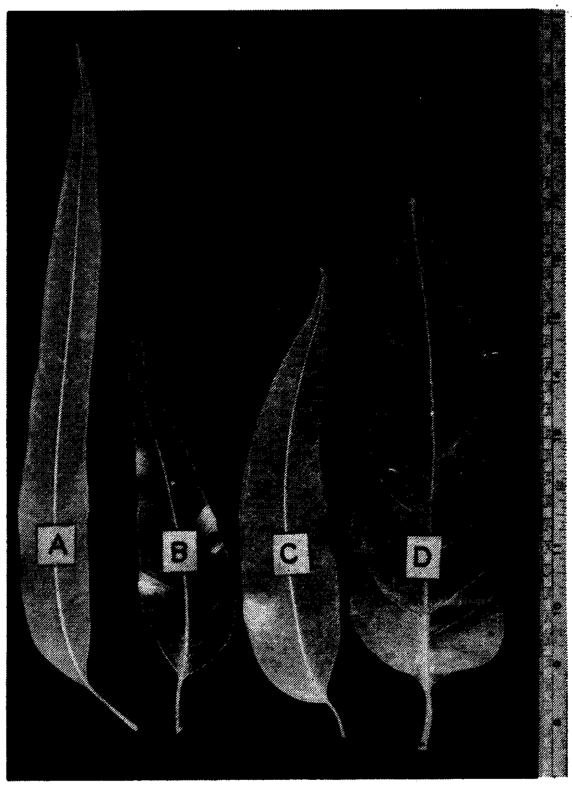

Figure 1. — Typical mature leaves of; A) *E. tereticornis* B) *E. grandis;* C) Diploid F_1 *E. tereticornis* × *E. grandis;* D) Allotetraploid (*E. tereticornis* × *E. grandis*).

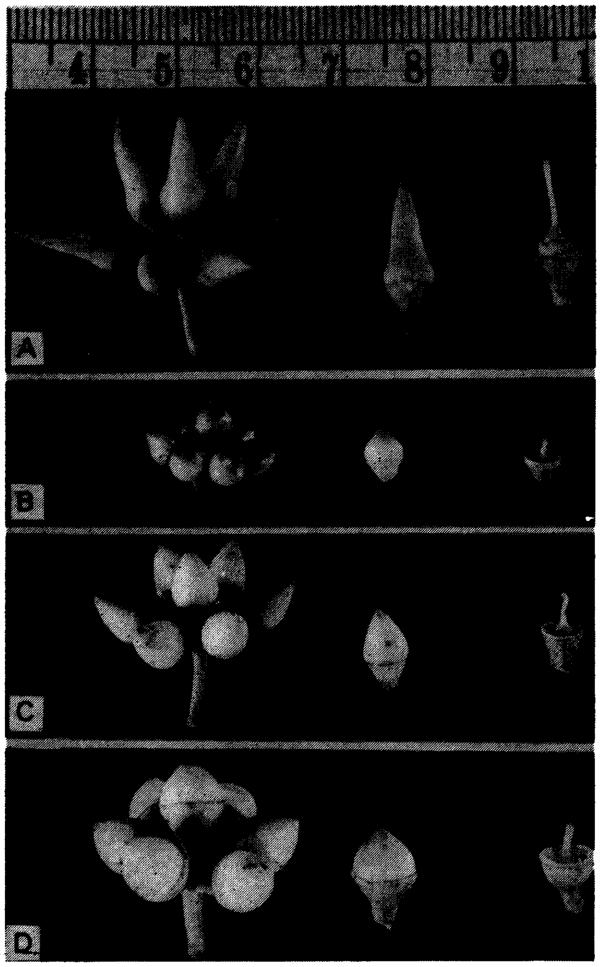

Figure 2. — Inflorescence, flower bud and pistil of: A) *E. tereticornis;* B) *E. grandis;* C) Diploid F_1 *E. tereticornis* × *E. grandis;* D) Allotetraploid *(E. tereticornis* × *E. grandis).*

and 100% humidity in a seed germinator, where 15 seeds germinated which were transplanted into pots. When the hybrids produced a fourth pair of leaves, they were cut back leaving one pair of leaves at the base. Later on, when axillary buds started sprouting 10 hybrids were treated with 0.6 per cent solution of colchicine in 10 per cent glycerol and 5 with 10 per cent glycerol only to serve as control as suggested by Kapoor and Kedharnath (1974). Leaf buds were fixed in 1:3 acetic-alcohol for chromosome count and 5 hybrid seedlings were confirmed as allotetraploids. The schedule of activities followed is summarised in *Table 1.*

Results and Discussion

Measurements were recorded on different features of leaf, stomata, flower, pollen, fruit and seed of 5 F_1 diploids and 5 allotetraploids for comparison *(Table 2).* The chromosome number of F_1 hybrids ($2n = 22$) and allotetraploids ($4n = 44$) was confirmed from leaf bud squashes. The diploid chromosome number of *E. tereticornis* and *E. grandis* is $2n = 22$ (Ruggeri, 1960). Allotetraploids showed vigour in certain characteristics which may be seen from the data *(Table 2)* and their corresponding photographs *(Fig. 1, 2, 3).* There was very poor flowering and seed setting at the age of about 4 years. But during their second flowering period about 800 seeds were collected from 112 fruits (7 seeds per fruit) and C_1 seedlings were raised during October, 1983 which are vigorous in comparison to their control (F_1 hybrids) and parent species. The performance of the C_1 seedlings of allotetraploids is under observation for their future use. These allotetraploids have been synthesized experimentally for the first time in the genus *Eucalyptus* and probably this is also the first example in the case of forest tree species. The seedlings produced from the seed collected from the allotetraploids will be tested for their breeding behaviour and performance in the field and compared with their counterpart diploids. If they maintain their superiority then it seems likely that this technique could be utilized to bring reproductive uniformity, to produce superior growth in eucalypts and to produce allotriploids. Wright (1976) has suggested that chromosome doubling may play a role in the improvement of genus like *Eucalyptus* which does not have natural polyploid series.

It will not be out of place to mention here that in the second flowering period during 1981, pollen from diploid *E. tereticornis* and *E. grandis* trees was applied to the emasculated flowers of an allotetraploid to produce allotriploids. Allotriploid seedlings were raised in pots during October, 1983. These triploid seedlings though very few in number are also vigorous. Nilsson-Ehle (1936) put forward an idea based on his early studies on the reaction and potentialities of the autotriploid giant aspen *(Populus tremula)* that such polyploids are also useful in forest tree breeding, thus, it will be of interest to test the utility of allotriploids produced artificially for the first time in *Eucalyptus.* The results on their production and performance will be published soon.

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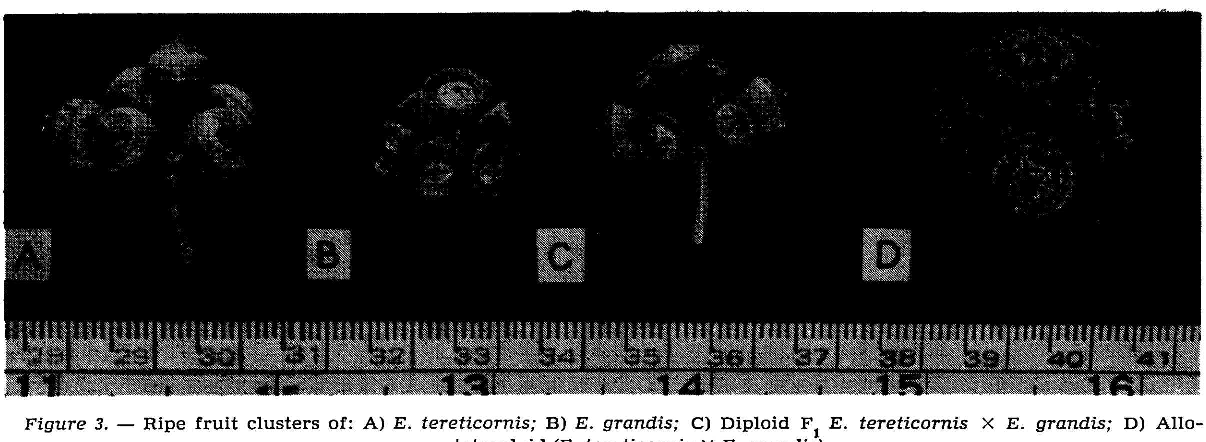

Figure 3. — Ripe fruit clusters of: A) *E. tereticornis;* B) *E. grandis;* C) Diploid F_1 *E. tereticornis* × *E. grandis;* D) Allotetraploid *(E. tereticornis* × *E. grandis).*

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A Flexible Computer Algorithm for Designing Seed Orchards

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Abstract

The seed orchard design problem is shown to be equivalent to the three-dimensional traveling salesman problem found in Operations Research literature. The primary constraints, restricting inbreeding and promoting outcrossing, are used to create a "cost" matrix upon which an implicit enumeration scheme is used to find the solution. The resulting algorithm yields promising results for creation of basic seed orchard layouts. Extensions of the algorithm to design more complex orchard layouts are also discussed.

Key words: inbreeding, outcrossing, clonal performance, operation research permutated neighborhood, advanced generation breeding orchards.

Zusammenfassung

Das Problem der Anlage von Samenplantagen wird dem Problem des "Three-dimensional-traveling-Salesman" gleichgesetzt, das in der Operations-Forschungsliteratur zu finden ist.

Die primären Zwänge, Inzucht zu beschränken und Fremdung zu begünstigen, werden benutzt, um eine Kostenmatrix zu erstellen, auf die ein stillschweigend inbegriffenes Nummerierungsschema angewendet wird, um eine Lösung zu finden. Die daraus resultierenden algorithmischen Erträge versprechen Resultate, die zur Entwicklung von grundlegenden Samenplantagen-Anlagen dienen können.

Die Ausmaße des Algorithmus, um mehr komplexe Samenplantagen zu entwerfen, werden ebenfalls diskutiert.

Introduction

Tree improvement programs have become an integral part of plantation management of forest trees. Even though emphasis has recently been given to genetic engineering and vegetative propagation, the genetically improved plant material for most programs will continue to be obtained from seed orchards. While many criteria should be considered before designing an orchard *(Table 1)*, the objective is to randomly assign a set of clones to an area while simultaneously separating related ramets by a minimum distance to inhibitit inbreeding and varying the neighborhoods surrounding the ramets of each clone to promote outcrossing.

Since seed orchards are costly to establish, maintain and evaluate (Jett and Zobel, 1977), care must be taken to design the orchard for optimum seed production. Some of the earliest orchards consisted of row-plots, each involving ramets from a single clone, and completely random designs. These plans often led to inbreeding from inadequate separation among ramets of a clone. Ensuing simple fixed designs such as systematic (Giertych, 1965) or shifting-block layouts (Malac, 1962) were easily implemented but also failed to satisfy many of the design constraints of an orchard. Other designs such as the Fisher balanced lattice (Langner and Stern, 1955), cyclic balanced incomplete block (Freeman, 1969), and directional cyclic balanced incomplete block (Dyson and Freeman, 1968) quickly fell into disfavor because they are difficult to employ.

In 1967, La Bastide devised a computer algorithm which develops a "permutated neighborhood" design that achieves most of the objectives of a seed orchard. In reality, it is a completely random design upon which restrictions are imposed to reduce inbreeding and increase outcrossing. The major drawback of the algorithm was its excessive computer runtime. In recent years, Bell and Fletcher (1978) and Hatcher and Weir (1981) have also employed computers to facilitate the tedious layout of more sophisticated "permutated neighborhood" seed orchard designs, but none of the methods fully meets the requirements of a seed orchard. In particular, the methods usually relax the outcrossing constraint and are adapted to a particular subset of the constraints listed in *Table 1.* The algorithms are inflexible and would require substantial modification time to accomodate a different subset of constraints.

The need exists for a flexible computer algorithm that can be employed regardless of the set of constraints. Computer design of seed orchards consists of two steps: (1) definition of a set of constraints to be adhered to during the design process, and (2) formulation of an efficient and stable algorithm that utilizes the set of constraints and produces a seed orchard layout having the desired qualities. The topic of this treatise is the description of an algorithm that can be used to design an orchard consisting of unrelated clones. Extensions to the algorithm to address more complex orchard designs are presented in the Conclusions.

Mathematical Formulation

The most commonly mentioned constraints for development of a seed orchard design are promoting outcrossing and restricting inbreeding *(Table 1).* Outcrossing should be promoted to capitalize on genetic gain in seed orchards where progeny test information of the clones is lacking (Zobel *et al.*, 1958). The potential genetic gain can be greatly impaired if inbreeding freely occurs (Gansel, 1971). The remaining constraints can be categorized either as exten-

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