

Hybrid vigour in controlled interspecific crosses of *Eucalyptus tereticornis* x *E. camaldulensis*

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Introduction

In the course of the past decade, interspecific F₁ hybrids of several *Eucalyptus tereticornis* and *E. camaldulensis* parents have been made and studied at this Institute. The present article reports heterotic growth of F₁ hybrids of three such crosses namely FRI-2, FRI-3 and FRI-4.

Materials and Methods

Ten to twelve year old flowering trees of the two species growing on the New Forest estate of this Institute were used in the crossing work. The techniques employed for the emasculation, isolation and pollination of the flowers were the same as those described earlier (VENKATESH and KEDHARNATH, 1965). The crosses were made during the months of September and October, after the monsoon rains when *E. tereticornis* (Et) and the northern (but not the southern) form of *E. camaldulensis* (Ec) flower together at New Forest (VENKATESH and SHARMA, 1975).

Details of the crosses made and the single-site field trials planted of each of the three full-sib hybrid families are given in Table 1.

trials. In the case of trial No. 3 of the cross FRI-4 however, unlike the two others, diameter measurements were also made first at 30.5 cm. height, then at half height and finally at breast height. Volume was computed using SMALIAN'S formula for sectional stem lengths up to half height.

Analyses of variance were done using the appropriate model (SNEDECOR and COCHRAN, 1967) for the data recorded on height (Trials 1, 2 and 3) and diameter (Trial 3 only). Least significant differences (LSD) were also calculated where necessary.

Results

Trial no. 1: In this trial of the cross FRI-2 (Et 20 X Ec), open pollinated seeds of the parental trees were not available for use as controls. Therefore other individual tree progenies and bulk samples were used instead for comparison. These belonged either to pure *E. tereticornis* or to Mysore Gum (MG) a complex and variable hybrid mixture (VENKATESH and KEDHARNATH, 1965) much planted in India and involving among others *E. tereticornis* and *E. camaldulensis*. The first height measurements made some time

Table 1.

| Trial no. | Cross no. and year | Year of sowing | Year of field planting | Location of field trial | Experimental design and espacement |
|-----------|--|----------------|------------------------|---------------------------------------|---|
| I | FRI-2; 1966 Et 20 X Ec (unknown) | 1967 | 1968 | Bhaniawala (25 km. east of Dehra Dun) | RBD; 12 plant rectangular plots; 3 replications; 1.33 X 5.66 m. |
| II | FRI-3; 1968 Et 19 X Ec 2 | 1969 | 1970 | Pathri (80 km. east of Dehra Dun) | RBD; 16 plant square plots; 4 replications; 4.62 X 4.62 m. |
| III | FRI-4; 1970 Et 14 X Ec 2 | 1971 | 1972 | Kaulagarh, Dehra Dun | 14 tree row plots; 3 replications; 2 X 2 m. |

No reciprocal crosses could be carried out because the Ec. parent trees were too tall for safe control-pollination work.

The ripe fruit capsules were harvested in April—May and the seeds extracted. Sowing was done in clay pots in the nursery during September of the same year of harvest. The resulting seedling progenies and corresponding open pollinated parental or other control progenies were pricked out into polyethylene bags and subsequently planted out in the field areas during the monsoon rains in July—August of the second year from the year of crossing.

Height measurements only had been recorded in the nursery and during earlier stages in the field in all three

after transplanting in the field in 1968, are summarised in Table 2.

Table 2. — Trial no. 1: Mean height at 9 months from seed of hybrids of the cross FRI-2, compared with other progenies.

| No. | Seedlot | Total no. of seedlings | Mean ht. (cm.) |
|-----|------------------------------|------------------------|----------------|
| 1 | FRI-2 (Et 20 X Ec) | 34 | 96 |
| 2 | MG tree 11 (Open pollinated) | 36 | 66 |
| 3 | MG tree 55 (Open pollinated) | 36 | 61 |
| 4 | MG tree 11 (control selfed) | 36 | 60 |
| 5 | Et 20 (control selfed) | 36 | 52 |
| 6 | MG bulked seedlot I | 36 | 41 |
| 7 | MG bulked seedlot II | 36 | 32 |

LSD 13.10

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Analysis of variance of Trial no. 1. Height at 9 months from seed:

not statistically significant. A forest fire destroyed this trial before further measurements could be made.

| Source of variation | DF | SS | MS | Variance ratio |
|----------------------|----|---------|---------|----------------|
| Between replications | 2 | 312.15 | 156.07 | 2.87n.s. |
| Between seedlots | 6 | 7519.20 | 1253.20 | 20.89*** |
| Error | 12 | 652.40 | 54.37 | |

n.s. Not significant.
 *** Significant at 0.1% level.

The hybrid progeny Ex X Ec was significantly taller than any other seedlot in the experiment and the three MG progenies and that of Et 20 were significantly taller than the two MG bulked lots. The overall inferiority of the latter is due probably to only inferior genotypes contributing to their constitution. Between-replication differences were

Trial no. 2: When still in clay pots used for seed germination, the hybrid seedlings of cross FRI-3 (Et 19 X Ec 2) exceeded in height and leaf size the open pollinated progenies of both parents by more than two-fold (see Fig. 1 and Table 3). These progenies and seedlings of several other individual families of *E. tereticornis*, *E. camaldulen-*



Figure 1. — Seedlings of FRI-3 (F₁), Et. (T) and Ec. (C) parents in the nursery.

Table 3. — Trial no. 2: Height in nursery and 9 months after planting.

| Progeny | Nursery | | Age 9 months from planting | |
|----------------------|------------------|--------------|----------------------------|--------------|
| | No. of seedlings | Height (cm.) | No. of survivors | Height (cm.) |
| FRI-3 (Et 19 X Ec 2) | 20 | 12.5 | 20 | 98.0 |
| Et 19 (o.p. progeny) | 20 | 5.1 | 18 | 83.0 |
| Ec 2 (o.p. progeny) | 20 | 5.5 | 17 | 107.0 |
| LSD 1.28 | | | | |

Analysis of variance of Trial no. 2. Nursery height and 9 monthly height:

| Trial 2 | Source of variation | DF | SS | MS | Variance ratio |
|------------------|---------------------|----|--------|--------|----------------|
| Nursery height | Between progenies | 2 | 702.20 | 351.10 | 82.42*** |
| | Within progenies | 57 | 242.89 | 4.26 | |
| 9 months' height | Between progenies | 2 | 4234 | 2117 | 1.64n.s. |
| | Within progenies | 52 | 67033 | 1289 | |

n.s. Not significant.
 *** Significant at 0.1% level.

Table 4. — Trial no. 3: Progeny means. Age 4 years.

| Progeny | Height (cm.) | Diameter (cm.) |
|-------------------------|--------------|----------------|
| FRI-4 (Et 14 × Ec 2) | 777 | 5.93 |
| Ec 2 (open pollinated) | 682 | 4.84 |
| Et 14 (open pollinated) | 559 | 3.26 |
| LSD | 131 | 1.23 |

Analysis of variance of Trial no. 3. Height and diameter at age 4.

| Character | Source of variation | DF | SS | MS | Variance ratio |
|-----------|----------------------|----|----------|----------|----------------|
| Height | Between replications | 2 | 5187.03 | 2593.51 | 0.77n.s. |
| | Between treatments | 2 | 72200.30 | 36100.15 | 10.83* |
| | Error | 4 | 13331.27 | 3332.82 | |
| Diameter | Between replications | 2 | 0.7361 | 0.3680 | 1.25n.s. |
| | Between treatments | 2 | 10.8134 | 5.4067 | 18.41** |
| | Error | 4 | 1.1743 | 0.2936 | |

n.s. Not significant.
 * Significant at 5% level.
 ** Significant at 1% level.

Table 5. — Percent superiority of the hybrid FRI-4 (Et 14 × Ec 2) over parental progenies at 4 years in field trial 3.

| Parental progenies (open pollinated) | % superiority of hybrid over parental progenies | | |
|--------------------------------------|---|----------|--------|
| | Height | Diameter | Volume |
| Et 14 (seed parent) | 37.1 | 80.3 | 145.8 |
| Ec 2 (pollen parent) | 11.3 | 25.6 | 42.3 |
| Mid-parent | 24.2 | 52.9 | 94.0 |

sis and Mysore Gum were transplanted as field trial no. 2. Due to periodic inundations of this low lying area mortalities were very high. Heights of surviving stems were recorded in May 1971 for all seedlots but only those of three, namely the hybrid and its parental progenies are given in Table 3.

In this trial mean height increment during the 9 months following outplanting was highest (101.5 cm.) in the Ec parent and least (77.9 cm.) in the Etparent. The hybrids showed intermediate (85.5 cm.) mean height increment and had lost the very marked height superiority which they had initially shown in the nursery. The difference between progenies at this stage was however not statistically significant.

No further useful data were obtainable from this trial because of further mortalities caused by floods and biotic factors.

Trial no. 3: This trial comprised offspring of the inter-specific cross FRI-4 (Et 14 X Ec 2) and open pollinated progenies of its parents. Of the three trials this one located near the Institute at Dehra Dun, has given the most detailed information on the relative growth performance of the hybrid and its parental progenies at different ages.

The first height measurements in this trial were made in July, 1972 when the seedlings were still in container bags. Subsequent height and all diameter measurements were recorded after transplanting in the experimental area at Kaulagarh. The periodic mean heights of the hybrids and the two parental controls are shown in Fig. 2. Similar diameter measurements, first at a height of 30.5 cm. then at half height and finally at breast height, are plotted in Fig. 3. Results of analysis of the fourth year data are shown in Table 4.

From the height curves in Fig. 2, it will be seen that, to start with, mean height of the hybrids 9 months from seed

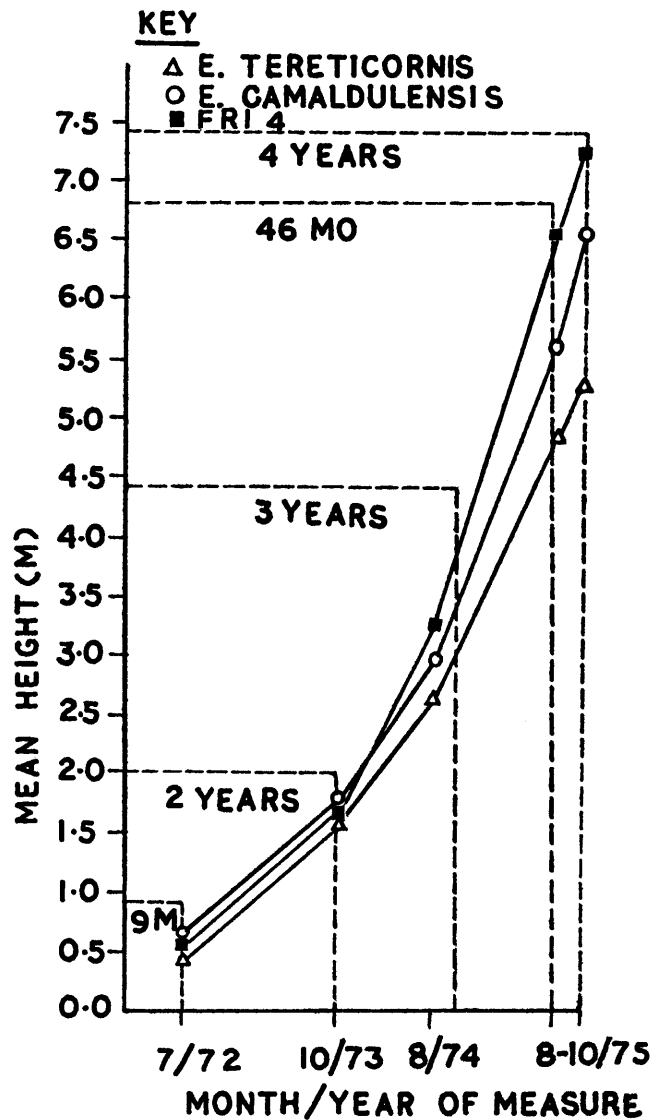


Figure 2. — Height growth curves.

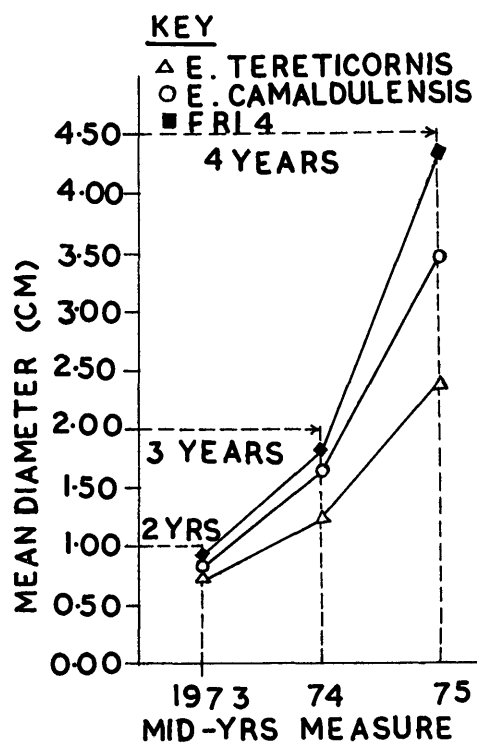


Figure 3. — Diameter growth curves.

germination, was intermediate between that of the parental progenies. At 2 years the position was much the same but during the third year of growth the hybrid eventually outgrew the better Ec parent. Thereafter, height growth superiority of the hybrid increased with age (see Fig. 2) deviating from those of both parents, at first gradually then increasingly between 1974 and 1975.

In mean diameter growth (Fig. 3), from the outset the hybrid was superior to either parent, the margin of superiority increasing with age even more sharply than in the case of height. The heterotic effect is thus more pronounced for diameter than for height.

Discussion

All the three interspecific crosses of *E. tereticornis* × *E. camaldulensis* reported on here showed heterosis in growth rate. The stage when this was shown and its persistence differed however. Whereas hybrids of the first two crosses FRI-2 and FRI-3, gave very early evidence of superior vigour, this was not true of the cross FRI-4 whose average height growth was initially intermediate between that of the two parental controls. However, during the subsequent 2–3 years' growth, hybrids of this cross outgrew and surpassed the better Ec parent in height growth as they had done from the beginning in diameter growth. Subsequently, superiority in diameter and height of the hybrids of this cross steadily increased with age up to the time of the latest assessment.

From the viewpoint of increased wood production, a sustained though somewhat delayed manifestation of hybrid vigour such as that shown by FRI-4 is to be preferred to and is of far greater economic consequence than a very early but ephemeral display of such vigour.

The apparent decline of the early heterotic superiority of the FRI-3 hybrid over the better Ec parent in the field trial was possibly due to an adverse response of the hybrid to the swampy site conditions of this trial and a corresponding favourable response of the *E. camaldulensis* progeny.

The present study of crosses between a few trees of *E. tereticornis* and *E. camaldulensis* furnishes some additional evidence of the occurrence of hybrid vigour in the growth rate of forest trees in general (RIGHTER, 1962) and of eucalypts in particular (PENFOLD and WILLIS, 1961, PRYOR, 1967). The study further indicates that such heterotic vigour may be differentially expressed at different ages and on different sites and in crosses involving different parent trees. It is evident that trees because of their long life spans, are ideal material for the study of possible changes in heterotic vigour with age.

Summary

Hybrid vigour in early growth rate is reported for three controlled interspecific F₁ crosses of *Eucalyptus tereticornis* × *E. camaldulensis*. All the three crosses, tested at single sites, displayed hybrid vigour at some stage of their growth. However, only one hybrid (FRI-4) promised economically important heterosis, as it showed sustained though somewhat delayed hybrid vigour in the field. At 4 years of age (= Ca 1/3 rotation cycle) and under one set of conditions, the F₁ hybrid of this cross exceeded the midparent progeny averages by 24.2% in height, 52.9% in diameter and 94% in standing volume. Heterosis in comparison with the superior parent, *E. camaldulensis* was 11.3% in height, 25.6% in diameter and 42.3% in volume.

Key words: Hybrid vigour, interspecific crosses, *Eucalyptus tereticornis* SM., *E. camaldulensis* DEHN.

Zusammenfassung

Es wurde „Hybrid vigour“ bei Nachkommen aus Kreuzungen der Arten *Eucalyptus tereticornis* × *E. camaldulensis* beobachtet. In einem Falle konnte eine Mehrleistung von 24,2% an Höhenwachstum, von 52,9% an Dickenwachstum, d. h. eine Mehrleistung von 94% an Volumen gegenüber den Ausgangsarten festgestellt werden.

Literature Cited

- PENFOLD, A. R. and WILLIS, J. L.: The Eucalypts. Leonard Hill (Books) Ltd., London (1961). PRYOR, L. D.: *Eucalyptus* in plantations—present and future. FAO-F-MMF-67: 993–1008 (1967). — RIGHTER, F. I.: Evidence of hybrid vigour in forest trees. In *Tree Growth* by T. T. KOZLOWSKI (Ed.). The Ronald Press Co., New York. p. 345–355 (1962). — SNEDCOR, G. W. and COCHRAN, W. G.: *Statistical Methods*. Oxford & IBH Publishing Co. (1967). — VENKATESH, C. S. and KEDHARNATH, S.: Genetic improvement of *Eucalyptus* in India. *Silvae Genet.* 14: 155–159 (1965). — VENKATESH, C. S. and SHARMA, V. K.: The flowering phenology of some eucalypts at New Forest: its significance and implications in hybridization. *J. Indian Acad. Wood Sci.* 6: 119–121 (1975).