THE PERFORMANCE OF EUCALYPTUS HYBRID CLONES AND LOCAL LANDRACES IN VARIOUS AGROECOLOGICAL ZONES IN KENYA

By

PHANUEL OBALLA
EBBY CHAGALA-ODERA
LYDIA WAMALWA
VINCENT OEBA
ESTON MUTITU
LINUS MWANGI

MARCH 2005

INTRODUCTION

Eucalypts were introduced in Kenya as early as 1902. The aim of the initial introductions was to identify fast growing tree species to supply fuel wood for the Kenya - Uganda railways. To date, over 70 species of eucalypts are grown in Kenya (Oballa, 2002). These species exist in plantations and on farmlands or in trial plots and arboreta. The uses of eucalypts have since increased and they are grown for timber, plywood, power and telephone transmission poles, pulp, building and fencing posts, rails, medicine, honey production, tannin, perfumery and environmental conservation.

Eucalypts are grown widely in most major agro-ecological zones due to their species diversity and ability to grow in a wide range of environments. It is estimated that 15000 ha of eucalypts are grown by Forest Department, 35 000 ha by Private Sector, comprising mostly of major cash crop production estates such as Brooke Bond, James Finlay Ltd, Eastern Produce, Kakuzi and British American Tobacco. An unknown number of hectares are grown by small-scale farmers, urban and county councils in the form of woodlots, ornamentals, boundary planting, avenue plantings and scattered trees on farms and grazing land. Eucalyptus is the third widely planted genus in Kenya after pine and cypress.

Most of the total area under eucalypts is dominated by three species, namely: *E. grandis*, *E. saligna*, and *E. camaldulensis*. A few hectares are under *E. globulus*, *E. paniculata*, *E. tereticornis* and *E. maculata*. *Eucalyptus regnans*, *E. fastigata* and *E. botryoides* though successful, have remained in experimental plots.

In the past, popular practice in establishment of plantations of eucalypts in Kenya have been through seeds except for a few demonstration plots that were planted from clones.

It was not until 1997 when systematic planting of clonal eucalypts was initiated under Tree Biotechnology Project. The project goal was to transfer clonal tree propagation technologies from Mondi Forests, South Africa to Kenya as a means to hasten large-scale improvement of plantations particularly of eucalypts. To date, the project is implemented by Forest Department and KEFRI in collaboration with Mondi Forests and the International Services for the Acquisition of Agrobiotec (ISAAA) and funded by Gatsby Charitable Foundation (United Kingdom). Since 2001, KEFRI has been involved in establishment of trials and monitoring of the growth

performance and resistance to diseases of the introduced clones in various agro-ecological zones in comparison with the locally available landraces of *Eucalyptus* species. Trials were established on several sites namely Karura, Kabage, Naivasha, Kakamega, Laikipia, Muguga, Embu, Gede, Sokoke, Msambweni, Timboroa, Machakos, Marigat, Hombe and Kitui over a period of six years.

Assessment was done in 2004 on nine sites: Karura, Embu, Gede, Sokoke, Msambweni, Timboroa, Machakos, Marigat and Hombe for diameter at breast height (DBH) and height. This report summarizes results of the assessment.

MATERIALS AND METHODS

Twelve clones of hybrids of *Eucalyptus grandis* X *E. camaldulensis* (GCs) hybrids were introduced to Kenya in 1997 from Mondi, S. Africa. Another introduction of 7 clones was done in 2001 comprising one pure *E. grandis* (TAG), three hybrids of *E. grandis x E. camaldulensis*, and three *E. grandis x E. urophyla* (GU) hybrids (Table 1). The materials were thereafter temporarily held in Karura quarantine nursery under observation for six months to confirm the absence of exotic pests and diseases. The materials were then planted in clonal hedges and managed until they were approximately 2 m high. The saplings were cut back to 30 cm and the resulting multiple coppices managed. The coppices with stem sizes of 5 -10 mm were thereafter removed for vegetative propagation as clones and used for establishment of trials.

Seedlings of local landraces of *Eucalyptus* spp were also raised from seeds and used as controls.

Table 1: Hybrid clones and local landraces used in the trials

Material	Species/clones
Local landraces	E. saligna, E. grandis, E. tereticornis, E. camaldulensis
Pure E. grandis	TAG5
GCs	GC3, GC10, GC12, GC14, GC15, GC167, GC514, GC522, GC540, GC581, GC584, GC642, GC784, GC785, GC796
GUs	GU7, GU8, GU21

Well established potted plants were used to establish experimental trials on fifteen sites in different years. Of these, trials those at Laikipia, Naivasha, Kakamega, and Muguga were written

off due to poor survival as a result of various factors ranging from game damage, harsh weather conditions and human interference. The trial at Maseno is still under one year.

Details of the various sites where assessments were done are given in Table 2.

Table 2: Details of various sites where trials were established

Number	Site	Geo-reference points	Altitude (m)	Rainfall (mm)
1	Karura	1^{o}15'S, 36^{o}50'E'	1600	900
2	Embu	37^{o}27'E, 0^{o}31'S	1800	1000
3	Gede	3^{0} 12' S, 40^{0} 02' E	13	940
4	Timboroa	35^{o}32'E, 0^{o}05'N	3000	1200
5	Machakos	37^{o}27'E, 1^{o}27'S	2066	1400
6	Hombe	0^{0} 23' S 37^{0} 4'E	2300	1300
7	Sokoke	10^{0}59'E, 96^{0}14'N	325	500-900
8	Msambweni	59E, 95N	10	1000-1350

All trials were planted in complete randomised block design with three or four replicates per site. Not all clones and landraces were established on all the sites (Table 3).

Assessment was done between March and May 2004 on five sites (Karura, Embu, Timboroa, Machakos, and Hombe) for DBH, height branching habit and stem form and four sites (Gede, Sokoke, Msambweni and Marigat) for height only due to the young age. Branching habit was assessed on a scale of 1-4 with 1 being the worst and 4 being the best. Stem form was also assessed on a scale of 1-4 with 1 being the worst and 4 being the best. Mean annual increment (MAI) was also calculated.

RESULTS AND DISCUSSION

Embu trial

Height

The trial was established in May 1999 and it consisted of four local landraces and four GC hybrid clones (Table 3). Analysis done for the results of year one ANOVA at five years of age showed significant differences among treatments for height at $p < 0.001$. Therefore, the clones and species performance in height from the best to the worst were GC14, GC15, GC581, GC642, EG,

ES, EC and ET. All the clones performed equally well at this site as compared to the local landraces GC14 had a height of 17.15m while the local landraces E. camaldulensis and E. tereticornis had the lowest height of 11.99m and 11.58m respectively.

DBH

There were significant differences in DBH in year three at $p < 0.001$(Table 4). The best performing clones and species at this site are GC15, GC581, GC14 and GC642. *E. camaldulensis* and *E. tereticornis* not perform well at this site, as they are more adapted to low and warmer sites.

Branching

The ANOVA showed that there were no significant differences in branching between the clones and species at this site.

Table 5: MAI (ht) of eucalypts in Embu at five years of age

TMT	EC	ET	EG	ES	GC14	GC15	GC581	GC642
MAI	4.11	4.24	5.79	4.94	7.22	6.85	7.63	6.89

Mean Annual Increment (MAI)

GC581 had the MAI at this site of 7.63 followed by GC14 (Table 5) showing that these clones are better adapted to this site than the rest.

Graph 1 shows a steady performance in height of all the clones and species at this site at age 3, 4 and 5 years, while Table 4 also shows consistent performance in DBH for clones and local landraces over the same period. The results indicate that performance of clones at age 3 years is more likely to be retained with age. The difference in growth among treatments is also more pronounced with age.

Graph 1: The performance of eucalypts in Embu

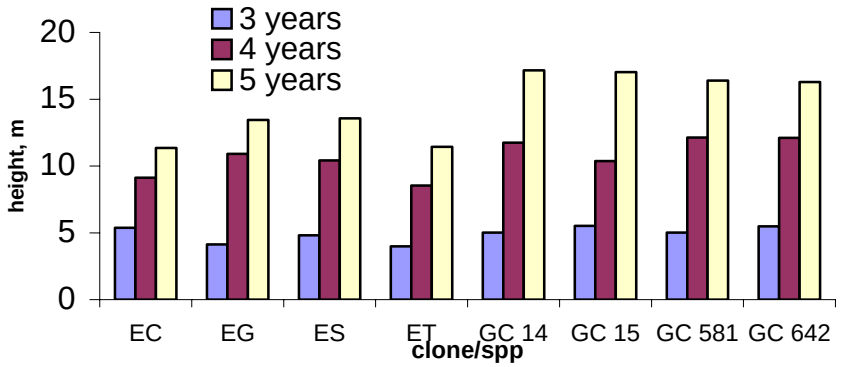


Table 3: Mean height (m) and standard error of means (s.e.) of eucalypts at various ages in different sites in Kenya

	Sokoke (2 yrs) (Se 1.22)	Msamb (2 yrs) Se 0.513	Gede (2 yrs) Se 1.809	Macha (5 yrs) Se 1.974	Kar(6 yrs) (s.e. 0.872)	Embu (5 yrs) s.e. 0.872	Hombe (5 yrs) se 0.827	Timb (5 yrs) Se 1.558	Marigat (2yrs) Se 0.736
EC	7.34a	3.34a	7.31a	9.36b		11.99b	10.61b	6.75b	4.45a
ET	5.32a	4.20a	10.04a	11.99b	8.71c	11.58b	10.46b	7.21b	4.02a
EG				22.56a	17.26a	14.75b	16.32a	10.17a	
ES				19.28a	14.53b	13.57b	14.56a	10.80a	
EU	7.04a	4.36a	8.07a						
GC 3								11.69a	
GC 14	7.93a	5.45a	6.73a	21.26a	18.53a	17.15a	13.42a	10.88a	
GC 15				22.46a	16.89a	17.04a	14.84a	11.07a	
GC 10				21.24a	18.78a		14.69a		
GC 12					17.70a				
GC17					20.30a				
GC167	8.28a	5.10a	8.69a						
GC584	9.34a	4.44a	7.73a						
GC514	11.64a	5.08a	6.96a						4.88a
GC522				20.75a	18.51a		15.20a		
GC540	9.23a	4.83a	7.19a						5.83a
GC796	7.97a		7.56a						
GC581	8.98a	5.19a	7.59a	19.58a	18.49a	16.39a	16.02a	12.02a	
GC784	9.22a	5.01a	7.70a						5.37a
GC785	10.5a	5.04a	6.63a						
GC642				20.17a	16.80a	16.28a	14.95a	10.89a	
GU21	9.37a	4.59a	9.16a						
GU8	8.43a	3.13a	9.71a						
GU7	8.31a	3.32a	9.08a						

Note;

1. a, b, c = order of performance in height
2. Macha = Machakos, Timb = Timboroa, Msamb = Msambweni, Kar = Karura

Table 4: Mean DBH (cm) and standard error (s.e.) for eucalyptus clones and landraces at various ages in different sites in Kenya.

	Embu 5yrs (s.e. 1.055)	Karura 6yrs (s.e. 0.737)	Hombe 5yrs (s.e. 1.045)	Machakos 5yrs (s.e. 1.552)	Timboroa 5yrs (s.e. 1.201)
EC	8.93c		11.70b	5.87b	7.07b
ET	8.45c	6.15c	9.65b	9.35b	9.72b
EG	11.86b	14.02a	18.19a	17.25a	11.83b
ES	10.90b	10.72b	14.83a	16.90a	14.84a
EU					
GC 3					13.12a
GC 14	14.87a	12.99a	14.60a	13.66a	12.91a
GC 15	15.65a	11.83a	14.41a	14.07a	12.68b
GC 10		13.18a	16.27a	13.94a	
GC 12		12.76a			
GC17		15.65a			
GC167					
GC584					
GC514					
GC522		13.92a	15.51a	14.84a	
GC540					
GC796					
GC581	15.63a	13.64a	16.20a	14.98a	13.99a
GC784					
GC785					
GC642	14.76a	12.54a	16.64a	14.92a	12.81b
GU21					
GU8					
GU7					

Note: s.e. = Standard error of means

Karura trial

Height

The experiment consisted of three local landraces and seven clones (Table 3) established in April 1998. The ANOVA showed significant differences among clones and local landraces in year five at $p < 0.001$. The performance of the clones and species at this site from the highest are GC17, GC10, GC14, GC522, GC581, GC12, EG, GC15, GC642, ES and ET. GC17 had the highest height of 20.30 m while the local landrace ET had the lowest with 8.71 m, which was less than half that of GC17. EG had a height of 17.26 m. All the clones and EG performed equally well at this site but ES and ET performed the worst at Karura.

DBH

In year six, there was high significance between the mean DBH (Table 4) for the clones and species ($p < 0.001$). The descending performance of the clones and species at this site in DBH are GC17, EG, GC522, GC581, GC10, GC14, GC12, GC642, GC15, ES and ET. GC17 also performed well at this site with DBH of 15.65 cm followed by EG with DBH of 14.02 cm while ET had the worst DBH of 6.15 cm.

Branching habits

The performance of the clones and species in branching habits showed no significant differences at five years of age. The table below shows the performance of the species and clones in branching habits.

Table 6: Branching habits of eucalyptus clones and species in Karura at six years of age

TMT	EG	ES	ET	GC10	GC12	GC14	GC15	GC17	GC522	GC581	GC642
MBH	3.6	3.6	3.7	3.2	3.3	3.7	3.7	3.6	3.7	3.1	3.5

NOTE:

1. Standard error of means (s.e.) = 0.2387
2. TMT = Treatment
3. MBH = Mean Branching Habit

Stem form

The stem form of the species and clones at this site showed no significant differences in performance.

Mean Annual Increment (MAI)

Table 7: MAI (ht) in Karura at six years of age

TMT	ET	EG	ES	GC14	GC15	GC10	GC12	GC17	GC522	GC581	GC642
MAI	1.16	2.31	1.83	2.60	2.24	2.70	1.59	1.09	2.70	2.77	2.23

GC581 and GC14 had the highest mean annual increment (Table 7)at this site showing that they are better adapted to this environment over the others.

Hombe trial

Height

The trial was established in May 1999 and it consisted of four local landraces: EC, EG, ES and EU and six GC clones. At the age five years, the ANOVA showed significant differences in the mean heights at $p < 0.001$ (Table 3). The performance of the species and clones ranking from the highest are as follows EG, GC581, GC522, GC642, GC15, GC10, ES, GC14, EC and ET.

E. grandis had the best average height and DBH of 16.32 m and 18.19 cm (Tables 3 and 4). The height performance for this species was as good as GC 581 and GC 522, which had average heights of 16.0m and 15.2m respectively while ET which was the worst had the average height of 10.46 m.

DBH

The ANOVA showed high significant differences in the fifth year ($p < 0.001$) (Table 4).

Branching habits

The ANOVA showed significant differences in branching between the species and clones at this site ($p < 0.05$). All the clones and landraces performed equally well at this site excluding GC14 as compared to the rest.

Table 8: MAI (ht) of eucalypts at the age of 5 years in Hombe

TMT	EC	EG	ES	ET	GC14	GC15	GC10	GC522	GC581	GC642
MAI	0.62	1.90	1.09	0.09	1.27	0.19	1.43	1.60	1.47	1.55

EG and GC522 had the highest MAI of 1.90 m and 1.60 m (Table 8) respectively.

Marigat trial

Height

Marigat site had two local landraces (EC and ET) and three clones (GC514, GC540 and GC784) planted in May 2002. In year 2, there were no significant differences between the clones and species in the ANOVA at this site (Table 3). GC514 had the highest average height growth of 4.88 m while *E. tereticornis* had the lowest of 4.02 m.

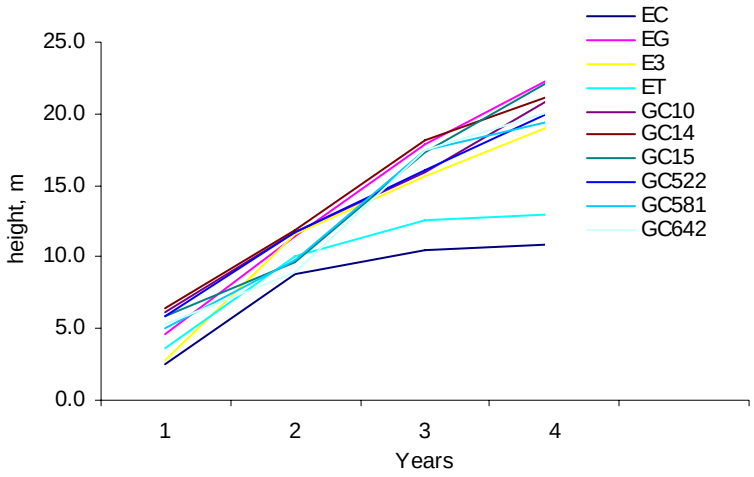
Machakos trial

Height

Four local landraces were used as the controls in this experiment: *E. camaldulensis, E. grandis, E. saligna* and *E. tereticonis,* in comparison with six clones: GC10, GC14, GC15, GC522, GC581 and GC642. The experiment was established May 1999. At five years of age, the ANOVA

showed significant differences between the clones and species ($p < 0.001$). The performance of the clones and species in height from the highest at this site were EG, GC15, GC10, GC14, GC522, GC642, GC581, ES, ET and EC. The local landraces showed the worst performance except *E. grandis*, which was the best in height in Karura.

Graph 2: The performance in height (m) of eucalypts in Machakos from year one to year five



From the graph above, the general trend of the performance of the eucalypts is almost steady apart form a few species and clones. For example, ET started out well but terminal growth stopped after the second year of sowing leading to lateral growth of the branches; clone GC14 also started out steadily but reduced in annual increment in the fifth year. The difference in performance appears to be greater with age.

DBH

The DBH analysis taken at five years of age showed that were significant differences between the clones and species ($p < 0.005$). The performance of the clones and species ranking from the highest in DBH are EG, ES, GC581, GC642, GC522, GC15, GC10, GC14, ES and EC. DBH for EG and ES were the highest having 17.25 cm and 16.90 cm respectively while that for EC was the lowest with 5.8 cm.

Graph 3: Height of GC clones and local eucalyptus landraces in Machakos at five years of age.

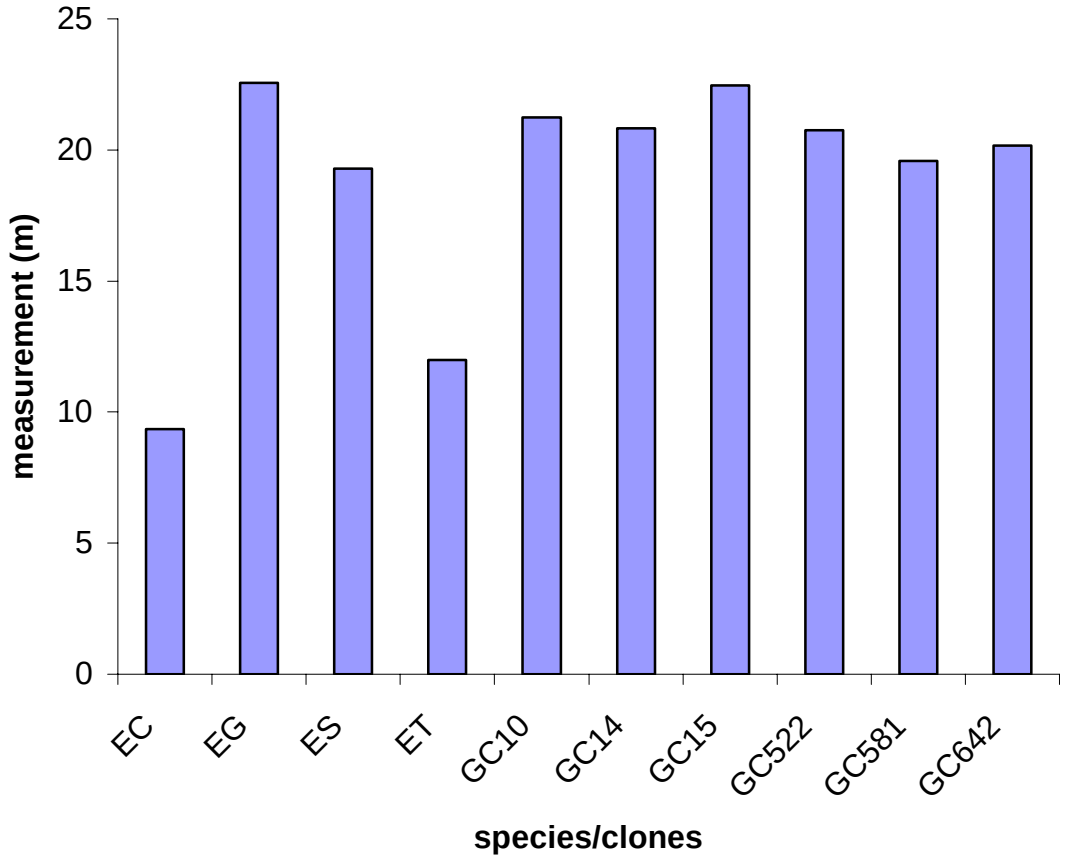


Table 9 MAI (ht) of eucalypts in Machakos at five years of age

TMT	EC	ET	EG	ES	GC14	GC15	GC10	GC522	GC581	GC642
MAI	1.37	1.69	3.62	3.3	1.58	3.33	3.02	2.99	2.75	2.97

EG, GC15 and GC10 had the highest MAI at this site (Table 9).

Timboroa trial

Height

This trial was established in July 1999 with GC14, GC15, GC3, GC581 and GC 642 and also four local landraces *E. camaldulensis*, *E. grandis*, *E. saligna* and *E. tereticornis.* At five years of age the ANOVA showed significant differences in mean height of the species and clones at $p < 0.05$ (Table 3). Ranking from the highest in height at this site is as follows GC581, GC3, GC15, GC642, GC14, ES, EG, ET and EC.

DBH

At two years of age, the ANOVA showed that there were no significant differences between the clones and species at this site but this scenario changed in year five where there were significant differences ($p < 0.01$).

Branching habits

There was no significant difference in the branching habits between the clones and species at this site at the age of five.

Stem form

There was no significant difference in the stem form at the age of five years in Timboroa.

Table 10: MAI (ht) of eucalypts in Timboroa at four years

TMT	EC	EG	ES	ET	GC3	GC14	GC15	GC581	GC642
MAI	0.42	1.75	1.61	0.18	1.84	1.89	1.51	2.11	2.11

GC581 and GC642 had the highest MAI at this site showing that of the clones and species here, they are best suited to this environment.

Gede trial

Height

Three local landraces: EC, ET and EU were used as the controls for clones GC14, GC167, GC514, GC540, GC581, GC584, GC784, GC785, GC796, GU21, GU7 and GU8. This experiment was established in 2002. At age two years, ANOVA showed no significant difference in performance in the species and clones grown at this site (Table 3) although clonal hybrid GC796 were either dead or dying probably from drought. This shows clearly that this clone is not adapted to this site.

Sokoke trials

Height

The local landraces used as controls for this experiment were EC, ET and EU and were compared with performance of nine GC and three GU clones. This experiment was planted in 2002 and ANOVA at age 2 years showed no significant differences among treatments. The performance was the same for all the clones and species at this site (Table 3) although GU7 and GU8 were showing signs of water stress.

Msambweni trial

Height

The two-year-old trial that was established in June 2002 had landraces as controls and eleven clones. ANOVA in the second year showed no significant differences in performance among clones and species (Table 3). There was an equal performance in all the clones and species grown at this site although GC796 died and so no assessment was done after the first year showing clearly that it was not adapted to that environment.

CONCLUSION

Performance of clones and local landraces was not consistent over all sites. However, there appears to be consistency in performance of clones with age at the same site. The assessment suggests that on sites above 2000m, the pure species of EG and ES seem to outdo the clones. Clone GC581 seems to be the best as it excels at all the sites from this study. Table 11 gives tentative recommendation of the various clones and local landraces that may be grown in different sites. Caution should be taken particularly for Gede, Msambweni, Marigat and Sokoke, as the trials are still too young to make concrete recommendations.

Table 11: Recommendations on best performing eucalyptus clones and local landraces in various agro-ecological zones in Kenya

Site	Recommended species or clones
Sokoke	GC 514, GC 785
Msambweni	All clones and species grown at this site except GC796
Gede	All clones and species grown at this site except GC796
Machakos	EG, ES, GC 14, GC 15, GC 10, GC 522, GC 581, GC 642
Karura	GC 15, GC 10, GC 522, GC 581
Embu	GC 15, GC 14, GC 581, GC 642
Hombe	EG, GC 522, GC 581
Timboroa	ES, GC 3, GC 14, GC 15, GC 581 and GC 642.
Marigat	GC 514, GC 540 and GC 784