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The effect of undersowing Eucalyptus(*Eucalyptus camaldulensis L.*) with maize (*Zea mays L*) and cowpeas (*Vigna unguiculata L.*) on tree growth and crop performance

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Maize (*Zea mays L.*) hybrid R201 and cowpea (*Vigna unguiculata L.*) variety IT82D-875 were separately inter-row interplanted with gum-tree (*Eucalyptus camaldulensis L.*) during the 1995–96 cropping season at Domboshava Training Centre. Planting *E. camaldulensis* with cowpeas and maize had no marked effect on the yields of the two annual crops. Sole clean-weeded *E. camaldulensis* had significantly thicker circumference than the *Eucalyptus* in the other treatments, but was comparable to *Eucalyptus* interplanted with the annual crops in terms of branching habit. However, E. *camaldulensis* interplanted with maize showed a slightly higher performance (branching and circumference) than that interplanted with cowpeas. This was probably related to the fertilizer added to the maize/*E. camaldulensis* intercrop since no fertilizer was added to the cowpea/*E. camaldulensis* intercrop. Management factors such as clean weeding in sole *Eucalyptus* markedly increased tree performance as observed through parameters of stem circumference and branching compared to those of the unweeded sole *Eucalyptus* situation. Neither tree branching pattern, height growth nor soil moisture were significantly affected by intercropping with annual crops. Undersowing annual crops to *E. camaldulensis* will facilitate maximum utilization of land and light in the early years of *E. camaldulensis* woodlot establishment. This approach will also allow better tree growth when compared to the unweeded situation which is common in small-holder farming.

Key words: Undersowing, maize, eucalyptus, cowpeas.

Introduction

Several rural afforestation programmes have been initiated in post-independent Zimbabwe (Whitsun Foundation, 1981; Kerkhof, 1990; McGregor, 1991). The programmes have been adopted in response to the worsening deficit of woodland resources in the smallholder communal areas. Communal lands of Zimbabwe comprise 41.9% of the land area but carry about 70% of the population. Increased human population has resulted in widespread clearance of indigenous woodland for fuelwood, timber and land for agricultural cropping (Whitsun Foundation, 1981; Kerkhof, 1990). The resultant degradation of the environment has threatened the sustainability of production in arable farming systems.

Due to the perceived need to come up with a speedy solution, particularly to the fuelwood shortage, planting of *Eucalyptus* was recommended (Whitsun Foundation, 1981). Several reasons underlie the choice of *Eucalyptus* species for rural afforestation. Chief among these is their high productivity and adaptability to a wide range of environmental conditions (Furness, 1979). Furthermore, the exotic genus *E. camaldulensis* meets both fuel and pole requirements (Maghembe and Redhead, 1982). In contrast most savanna woodland species are claimed to take a long time to coppice after cutting (Banks, 1981).

Productivity of woodlots seems to be determined by management, ownership and nearness of the stand to the homestead (Mandondo, 1993; 1995). Community woodlots planted completely or partially die in the first year. Problems mentioned include lack of proper management, poor seedling quality, drought and attack by goats and termites (McGregor, 1991; Clarke and Crockford, 1995). However, even after being given adequate protection from goats and termites, the general evidence is that productivity of *Eucalyptus* is low in Zimbabwe (Lowe, 1986). The rationale of the woodlot programmes of the 1970's and 1980's was based on productivity figures in the region of 6–8 m^3 /ha/yr in Natural Region IV (Lowe, 1986). The actual productivity of *Eucalyptus* woodlots in Zimbabwe has been found to be around 2 m^3 /ha/yr or less (Mandondo, 1993; Clarke and Crockford, 1995).

Despite the management constraints, *Eucalyptus* species continues to be extensively promoted in rural forestry programmes to alleviate the woodland deficit. Considering that farmers manage their annual crops closely; timeously planting them, weeding as well as fertilizing them, annual crops/ *Eucalyptus* mixtures could benefit the tree component by providing a weed-free environment for tree establishment. *Eucalyptus* species would also benefit from the fertilization of the associated annual crop. Furthermore, farmers could benefit from harvests of the annual crops long before they harvest the *Eucalyptus* trees. Elsewhere, growing food crops among trees while they are young is a widespread and established practice. It is usually carried out for the first 1 to 3 years in the life of the tree crop before canopy closure and the ground becomes densely shaded (Evans, 1992).

It is therefore, worthwhile to explore the potential of introducing annual crops into *Eucalyptus* woodlots particularly in the early years in trying to enhance productivity of *Eucalyptus* species. The objectives of this experiment was to investigate the effect of undersowing *Eucalyptus camaldulensis* with maize (*Zea mays L*) and cowpeas(*Vigna unguiculata L.)* in the early years of tree establishment, on yields of maize and cowpeas, on growth of the *Eucalyptus*, and on the competition for moisture between the crop and tree components.

Materials and methods

A trial of maize (*Zea mays L.*) and cowpea (*Vigna unguiculata L.)* underplanted in *Eucalyptus camaldulensis* was conducted at Domboshava Training Centre, 30 km northeast of Harare city, during the 1995–96 rainy season. The site has a long-term mean rainfall of 850 mm with the 1995–96 season having received above average rainfall totalling 874 mm. The soil is typical of many communal areas, being a slightly acid sandy loam of low fertility. A chemical analysis of the soil at planting showed pH (CaCl2) of 5, available phosphorus (P_2O_5) of 14 parts per million (ppm), 0.14 meq/100 grams potassium, 1.04 meq/100 grams calcium and 0.37 meq/100 grams magnesium.

The maize cultivar R201, a three-way cross drought-hardy hybrid grown extensively in the communal areas and a cowpea cultivar: IT82D–875, were used in the experiment. *E. camaldulensis* seedlings of a mean height of 30 cm and a stem circumference of about 0.5 cm was transplanted at the same time as maize and cowpeas which were planted on 6 December 1995. The gross plot size was 58.32 m^2 (10.8 m * 5.4 m) and the net plot size was 18.23 m^2 (2.7 m * 6.75 m). Three hundred kg/ ha of compound D (N 8%: P 14%: K 7%) was applied i.e. at the rate of 16 g/ planting station. Carbofuran was applied on *E. camaldulensis* planting stations at 10 g/ planting hole to control termites (Mazodze, 1992). When maize had reached a height growth of 60 cm, at approximately six weeks after planting, 150 kg/ha ammonium nitrate (34.5%N) was applied i.e. at the rate of 8 g/ planting station. Plant spacing for maize was 0.9*0.6 m, but with two plants being grown per planting station to open the canopy for the intercropped *E. camaldulensis*. This resulted in a maize plant population of 37 037 plants/ha. *E. camaldulensis* was spaced at 2.7 m * 2.7 m resulting in a plant population of 1 372 plants/ha. Cowpea was spaced at 0.45 m * 0.2 m giving a population of 111 111 plants/ha. These populations and spacings were maintained regardless of whether the crops were grown as sole or mixed stands.

The treatments were:

(1) Eucalyptus camaldulensis undersown with cowpeas, clean weeded.
(2) *Eucalyptus camaldulensis* undersown with maize, clean weeded.
(3) Sole *Eucalyptus camaldulensis*, unweeded.
(4) Sole *Eucalyptus camaldulensis*, clean weeded.
(5) Sole cowpeas, clean weeded.
(6) Sole maize, clean weeded.

Weeding was done three times before maize and cowpea harvesting, at 3, 7 and 11 weeks from planting. The frequency of weeding depended on weed pressure. The treatments were arranged in a Randomised Complete Block Design layout with four replicates.

Maize was harvested from the net plot after maturity. The cobs were further dried and shelled after the samples had recorded an average moisture of 15%. Adjusted grain weight was obtained by the formula:(100-%moisture at harvest/100–12.5)*grain weight at harvest. E. *camaldulensis* height was measured at 8–week intervals, taking height from the most robust apical shoot. Three readings were taken from January to the end of June when the maize was harvested. The circumference of the *E. camaldulensis* stems was also measured at 8-week intervals from planting at a height of 10 cm from the rootcollar. Measurements were taken from the same 3 *E. camaldulensis* trees in the net plot. Circumference was determined on the four treatments involving *E. camaldulensis* per every replicate.

E. camaldulensis branching was also determined at 8-week intervals. A branch was defined as having at least three fully expanded leaves on it.

Soils were systematically sampled for gravimetric moisture determination from every plot at depths of 15 cm and 90 cm. The soil samples from different depth were placed in sealed 300 ml glass jars. Samples were weighed before oven-drying, oven-dried at 1050C for 48 hours and re-weighed. Percentage moisture content was determined using the formula below:

100*((Wet soil sample weight — dry soil sample weight)/dry soil sample weight). Moisture content was expressed in g/kg of soil.

Whilst analysis of variance (ANOVA) was used for most of the parameters, a two-Sample t-test was done to compare the yields of sole maize and maize grown with E. *camaldulensis* and between sole cowpea and cowpea grown with *E. camaldulensis*.

Results

E. camaldulensis circumference at all stages measurement showed significant differences due to treatments (P<0.05). Sole clean weeded *E. camaldulensis* (treatment 4) gave the highest circumference and sole unweeded *E. camaldulensis* attained the lowest (Table 1). There was significant (P<0.05) difference between the circumference in sole weeded *E. camaldulensis* and that of the *E. camaldulensis* intercropped with maize and cowpeas, respectively. However trees intercropped with maize and cowpeas had similar circumference. Furthermore, *E. camaldulensis* intercropped with maize attained a circumference significantly different from sole *E. camaldulensis* unweeded (P<0.05). Significant differences were also obtained between the circumference of sole *E. camaldulensis* weeded and that of unweeded in treatment 3 .

E. camaldulensis branching at all measurement stages revealed significant differences due to treatments (P<0.05). Sole clean-weeded *E. camaldulensis* (treatment 4) attained the highest number of branches and sole unweeded (treatment 3) had the lowest (Table 2). There was a significant (P<0.05) difference between the branching in treatment 4 and treatment 3 . Treatment 4 (sole *Eucalyptus*) and treatment 1 (*E. camaldulensis*/cowpeas weeded) also showed difference at 24 weeks from planting but after 32 weeks there was no significant difference (P<0.05) in branching. *E. camaldulenssis* branching in treatment 2 (*E. camaldulensis*/maize weeded) and treatment 1 (*Eucalyptus*/ cowpeas weeded) showed no significant differences (P<0.05) at all stages and these two treatments were not

Table 1: Circumference of *E. camaldulensis intercropped with maize and cowpeas after* 16, 24 and 32 weeks of growth.

Treatment	Circumference (cm) at 16 wks	at 24 wks	at 32wks
1 (E. camaldulensis/cowpeas-weeded)	4.0 bc	4.4 bc*	5.6 bc
2 (E. camaldulensis/maize-weeded)	4.6 b	5.3 b	7.0 b
3 (Sole E. camaldulensis, unweeded)	3.1 c	3.1 c	3.9 c
4 (Sole E. camaldulensis, weeded)	6.5 a	7.9 a	9.6 a
S.E.D	0.38	0.63	0.58
LSD (P<0.05)	1.22	2.02	1.86
CV (%)	17	25	18

*Where figures followed by the same letter in the column are not significantly different (P< 0.05)

Table 2: Branching of E. camaldulensis intercropped with maize and cowpeas after 16, 24 and 32 weeks of growth.

Treatment	Branching (Numbers) at 16 wks	at 24 wks	at 32wks
1 (E. camaldulensis/cowpeas-weeded)	10 b*	12 bc	16 ab
2 (E. camaldulensis/maize-weeded)	13 ab	17 ab	17 ab
3 (Sole E. camaldulensis, unweeded)	6 b	7 c	7 c
4 (Sole E. camaldulensis, weeded)	18 a	21 a	25 a
S.E.D	2.32	2.83	3.57
LSD (P<0.05)	7.41	9.06	11.44
CV (%)	39	40	43

*Where figures followed by the same letter in the column are not significantly different (P< 0.05)

Table 3: Height of E. camaldulensis intercropped with maize and cowpeas after 16, 24 and 32 of growth.

Treatment	Height (m) at 16 wks	at 24 wks	at 32wks
1 (E. camaldulensis/cowpeas-weeded)	1.2	1.3	1.4
2 (E. camaldulensis/maize-weeded)	1.6	1.8	1.8
3 (Sole E. camaldulensis, unweeded)	1.1	1.5	1.3
4 (Sole E. camaldulensis, weeded)	1.7	1.5	1.6
S.E.D	0.27	0.28	0.20
F test	NS*	NS	NS
CV (%)	28	27	19

*not significant

significantly different from sole clean weeded *E. camaldulensis* (treatment 4) after 32 weeks from planting.

No significant height growth differences due to treatments were obtained (P< 0.05; Table 3).

A two-sample t-test for the grain yield of maize in the *E. camaldulensis* / maize intercrop (treatment 2) against maize yield in sole maize (treatment 6) showed no significant difference (P<0.05). Treatment 2 (maize/*E. camaldulensis* weeded) had a slightly higher yield of 3.6 t/ha than treatment 6 (sole maize weeded) which attained a yield of 3.4 t/ha (Table 4).

There were no significant differences between the yields obtained in the *E. camaldulensis*/cowpeas intercrop weeded (treatment 1) and treatment 5 (sole cowpeas weeded) after subjecting the data to a two-sample t-test. However treatment 5 gave a slightly higher yield of 2.9 t/ha than that of treatment 1 of 2.7 t/ha (Table 4). Hence, there was a slight decrease in grain yield due to undersowing of cowpeas into *E. camaldulensis*.

Table 4: Grain yields of maize and cowpeas in sole stands compared with the yield from the intercrop system.

Treatment	Maize (t/ha) (t/ha)	Cowpea (t/ha)
1 (intercropped cowpeas)	—	2.7
2 (intercropped maize)	3.6	—
3	—	—
4	—	—
5 (sole cowpeas)	—	2.9
6 (sole maize)	3.4	—

Soil sampled from a depth of 15 cm and 90 cm on all plots showed no significant difference in moisture between all treatments (P<0.05; Table 5). Soil sampled 16 weeks after planting and that sampled 32 weeks after planting (at harvest time) showed revealed no significant differences either.

Discussion

E. camaldulensis trees in clean weeded sole stands gave the highest stem circumference and branching but there was no significant difference in height growth across treatments (Table 1, 2 and 3). This is because sole trees experienced less competition than when combined with an annual crop or when competing with weeds in unweeded plots(Ofori and Stern, 1987). *E. camaldulensis* in the sole clean-weeded plots were noticeably more robust and more branched than trees in sole unweeded stands but slightly different from *E. camaldulensis* among maize and cowpeas. This shows that the maximisation of management aspects such as weeding and termite control could result

Table 5: Gravimetric moisture content in g/kg of soil at 16 and 32 weeks from planting, measured at 15cm and 90cm soil depth.

	Moisture 16 wks		Moisture at 32 wks	
Treatment	at 15 cm	at 90 cm	at 15cm	at 90 cm
1	60	130	50	150
2	40	150	40	150
3	50	130	40	150
4	60	150	40	120
5	50	130	40	130
6	60	150	40	140
S.E.D	3.4	5.2	3.5	6.5
F test	NS*	NS	NS	NS
CV (%)	20	12	28	16

*not significant

in an increase in the mean annual growth increment of *E. camaldulensis* relative to the communal woodlot management system were the trees are neglected (McGregor, 1991; Mandondo, 1993; Clarke and Crockford, 1995). Branching is a trait favoured in a fuelwood species as high branching means more volume of wood to burn. Intercropping of *E. camaldulensis* with annual crop did not seem to depress the *E. camaldulensis* capacity to branch.

Stem circumference seems to have been affected more by intercropping with cowpeas and maize (treatment 1 and 2) than was the pattern of branching (Table 1 and 2). Maghembe and Redhead (1982) observed that undersown annual crops in the first year had little effect on the tree crop in the case of E. *melliodora*, but for cropping in subsequent years wider spacing of the trees may be necessary. These workers planted *E. melliodora* in intercrops with maize, broad bean (*Vicia faba L.*) and sorghum (*Sorghum bicolor L.*), separately on clean weeded and unweeded plots in Tanzania. Growth of *E. melliodora* intercropped with maize showed comparable height growth with clean-weeding and superior growth to spot weeding (Maghembe and Redhead, 1982; Chingaipe, 1985). In Hawaii *E. grandis* grown in intercropping systems with a legume *Paraserianthes falcataria* was 63% taller and 65% larger in diameter than *E. grandis* grown in pure stands and receiving inorganic nitrogen fertilizer at approximately 6-month intervals for the first 36 months of establishment and growth (Schubert, Dean and Craig, 1988).

Although the E. camaldulens*is* trees were of no economic value after the first season of crop production, they seem not to have been excessively affected by the introduction of annual crops (maize and cowpeas). However, neglecting *E. camaldulensis* stands (not weeding) severely retarded growth. *E. camaldulensis* therefore, benefitted from the weeding of associated annual food crops. Whilst clean weeding gave the best growth performance, it is however not realistic to expect clean-weeded sole stands in community afforestation projects. Communal farmers in these projects tend to concentrate more in tending their annual crops which have quicker returns relative to trees which are known to grow on their own in forests and have delayed economic yields. For instance, *E. camaldulensis* is felled as usable timber after 8–10 years (Forestry commision, 1992).

The yields of maize and cowpeas in sole stands were not significantly different from those of the intercropped situation (Table 4). The trees in all treatments were too young to have had a marked effect on maize and cowpeas yields. The results demonstrate that reasonable grain yields can be obtained, at least in the first growing season of intercropping with *E. camaldulensis*. However, in the following seasons when the canopy starts to close, competition may reduce maize and cowpea yields.

Trees intercropped with cowpeas showed reduced growth relative to those intercropped with maize probably because of the absence of fertilizer which was added to the maize stands only. Whilst legumes are capable of fixing nitrogen into organic compounds which can be used by crops grown in association with them, it is likely that the nitrogen from cowpeas will only be available to the Eucalyptus in the following season as the soil organic pool releases it. In Brazil, Compa'nhia Agric'ola e Florestais (a company) cultivates 3–5 rows of soyabeans (*Glycine max L.*) between rows of *Eucalyptus grandis L.* which are 3 m apart. Yields of soyabean of up to 2.4 t/ha have been achieved and there is evidence that the trees benefit from residual nitrogen left in the soil after harvesting the legume. Any fertilizer applied to the food crop will usually benefit the trees. Similarly, the weeding necessary for the food crop may also be of benefit though the food crop itself may compete to some extent with trees for available moisture (Evans, 1992). Trees are commonly planted at spacings appropriate for their size at maturity. This inevitably leads to under-utilization of available light in the early years of planting and intercropping in the open space can maximise light absorption. Modern productive orchards can intercept as little as

30% of available light at five years of growth (Jackson, 1987). It is therefore logical that *E. camaldulensis* did not reduce maize and cowpea yields in the first year. This implies that most Zimbabwean villagers can capitalize on the system and make use of the land area in the first year to tend their annual crops since land is limiting in some communal areas. This approach would contribute to higher productivity in woodlots due to management factors like weeding and fertilization of the annual crops.

There was no significant difference in gravimetric moisture content across treatments on all the soils sampled at different times. *E. camaldulensis* has been documented in India not to impose competition for moisture (Harding, Hall, Swaminath and Murthy, 1991). The genus *Eucalyptus* has over 500 species and some of the species do transpire massive volumes of water. The other explanation for lack of competition for moisture could be the overally good season experienced in the 1995/96 rainy season However, possibilities of competition for moisture may exist under stress conditions.

Whether growing a food crop is detrimental or beneficial to tree growth is bound to vary from site to site, but the widespread belief is that the presence of a food crop affects tree growth, which is not always true as demonstrated in this experiment.

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