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Agroforestry: Preliminary Results of Intercropping *Acacia, Eucalyptus,* and *Leucaena* with Maize and Beans

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There is no widespread land shortage in most savanna areas of Tanzania, but a crisis is developing where fuelwood and building poles are in critically short supply. The government has begun an ambitious village afforestation program (Mnzava 1980) but it alone cannot plant and tend trees on the scale needed to avert the impending fuel crisis nor rehabilitate the lands eroded and devastated by misuse and overgrazing that King and Chandler (1978) referred to as "wasted lands."

The government-supported village afforestation programs are not receiving much genuine cooperation from villagers and little can be achieved without this cooperation. The villagers plant the trees, often only because they do not like to refuse, but the failure rate is very high because the trees are planted carelessly and late in the rainy season. The areas are weeded poorly, become invaded by grass, and most of the planted areas are swept with fire within the first 2 years, resulting in the destruction of up to three-quarters of the young trees.

Villagers feel that trees are something they have always cut in the "bush," not planted like a food crop. They do not want to wait up to 10 years to harvest a tree. Poor farmers want tangible (or edible) rewards for their labours during the current season; they are not used to looking very far ahead into the future.

Is "agroforestry" a means of solving the problem of securing the farmer's interest? If the farmer could intercrop food crops among the trees planted, and if the farmer or the community owned the trees planted, would this be conducive to increased cooperation? Before such a system is introduced to the village, it is necessary to ascertain whether or not trees and food crops can grow together, which species are most compatible, and what spacing should be used.

Information on intercropping forest trees with food crops in the semi-arid parts of Tanzania is generally lacking. It is assumed, however, that arable crops would compete for limited available water in tree plantations.

A trial was established in 1978 to study the interaction of trees with food crops. *Eucalyptus melliodora* was planted with maize, beans, and sorghum, separately, on clean-weeded and unweeded plots. The results were so encouraging that further trials, intercropping trees with maize and beans, have been established: *Eucalyptus camaldulensis*, for fuel and poles; *Leucaena leucocephala*, for fuel and fodder; and *Acacia albida*, for fuel and fodder.

This paper presents the results from the 1978 trial and the initial results from the new trials established this year.

Agroforestry in Africa

The basic idea of agroforestry is by no means new, farmers on the slopes of Kilimanjaro have long since developed land-use methods that combine tree crops with annual or perennial crops, and/or with rearing domestic animals. The timber trees *Grevillea robusta* and *Cordia abyssinica* are grown as shade trees over coffee and bananas intermixed with a wide range of annual food crops such as maize, beans, and melons. This system allows permanent sustained agriculture and protects the site from erosion.

In another common system of agroforestry, farmers work in partnership with the government. The farmer clears the land; grows annual or short-term food crops, such as bananas and cassava; and plants tree seedlings among the food crops. As the trees grow, the space for food crops becomes restricted, so the farmer is given a new piece of land to repeat the cycle. This system has been used to create most of the industrial tree plantations in Kenya and northern Tanzania. In West Africa, the system has been popular for nearly 40 years. Recently, it is estimated that in Nigeria alone over 25 000 farmers cultivate nearly 20 000 ha annually in partnership with the Forest Department (Ball 1977).

These examples are all found under conditions of high rainfall. In the dry savanna areas there are two well-known examples in Africa. The first is from Sudan, where the planting of arable crops is followed by *Acacia senegal*, for the production of gum arabic, fuel, and timber (El Houri Ahmed 1979). The second example is from West Africa, where *Acacia albida* is grown on permanently cultivated farmland for the production of fodder and fuel, and as a soil improver (FAO 1974). Both of these species are legumes, in the family Mimosaceae, and both contribute to biological nitrogen fixation.

Village Requirements Related to the Selection of Suitable Tree Species for Village Afforestation

Wood is used within villages primarily as a source of cooking fuel and poles for house building. A fuel species should burn evenly and slowly and give off a steady heat. Most slow-growing savanna species meet this requirement but take a long time to regenerate after cutting. Building poles should be long, straight, and smooth; most indigenous species are short stemmed, crooked, and thorny. The exotic genus *Eucalyptus* meets both fuel and pole requirements: the wood is dense and burns well, the stump coppices rapidly after cutting, and the poles are excellent for building.

Another village requirement in many parts of Tanzania is fodder for goats and cattle. Indigenous savanna species, especially *Acacia*, are browsed but are not normally cultivated for this purpose. In some species, especially *Acacia albida*, the fruits are harvested and stored as an off-season food for livestock; similarly, fodder leaves could also be dried and stored.

1978 Trial of *Eucalyptus melliodora*

Container-grown seedlings of *Eucalyptus melliodora* were planted in February 1978 in farmland that had been plowed and harrowed. The seedlings were planted with a spacing of 2.5 m × 2.5 m and intercropped with the following crops: maize, a tall variety reaching 3 m in height, spacing 90 cm × 30 cm; sorghum, a medium-tall variety reaching 1.7 m in height, spacing 60 cm × 15 cm; and beans, Canadian Wonder variety, 30-40 cm in height, spacing 40 cm × 20 cm. A fourth treatment was clean weeded and a fifth treatment received no weeding. No fertilizer was applied in this experiment.

The experiment was arranged in a Latin square, each plot containing 5 trees × 5 trees. The central core of 3 trees × 3 trees in each plot was periodically measured.

Tree-height measurements were made to the nearest centimetre until 24 months of age, after which measurements were made to the nearest 0.25 m; root collar circumference measurements were made to the nearest millimetre and after 30 months of growth diameter at breast height (DBH) was also measured to the nearest millimetre.

Maize, sorghum, and beans were planted again in 1979 and 1980 and the yields of maize and beans recorded. Sorghum was not harvested because the crop was eaten by birds: the small area did not justify the employment of bird scarers and the object was chiefly to observe the effect of crop competition on the trees.

Results

At the time of the first harvest, the mean height of the unweeded *Eucalyptus* was significantly lower than in the other treatments in which heights did not differ significantly. The trees in the bean and clean-weeded plots were noticeably more robust and more heavily branched than the trees among maize and sorghum, which were spindly due to competition for light. By the end of the 1st year, the trees grown among beans and in clean-weeded plots were significantly taller than and had three times the cross-sectional area at the root collar of the trees grown among maize and sorghum. The unweeded trees were inferior.

The trends in height growth and volume (mean plot height × mean total plot root collar area × an estimated form factor of 30%) are shown in Fig. 1 and 2 respectively.

The survival rate of the trees was excellent, except in the unweeded plots where over half of

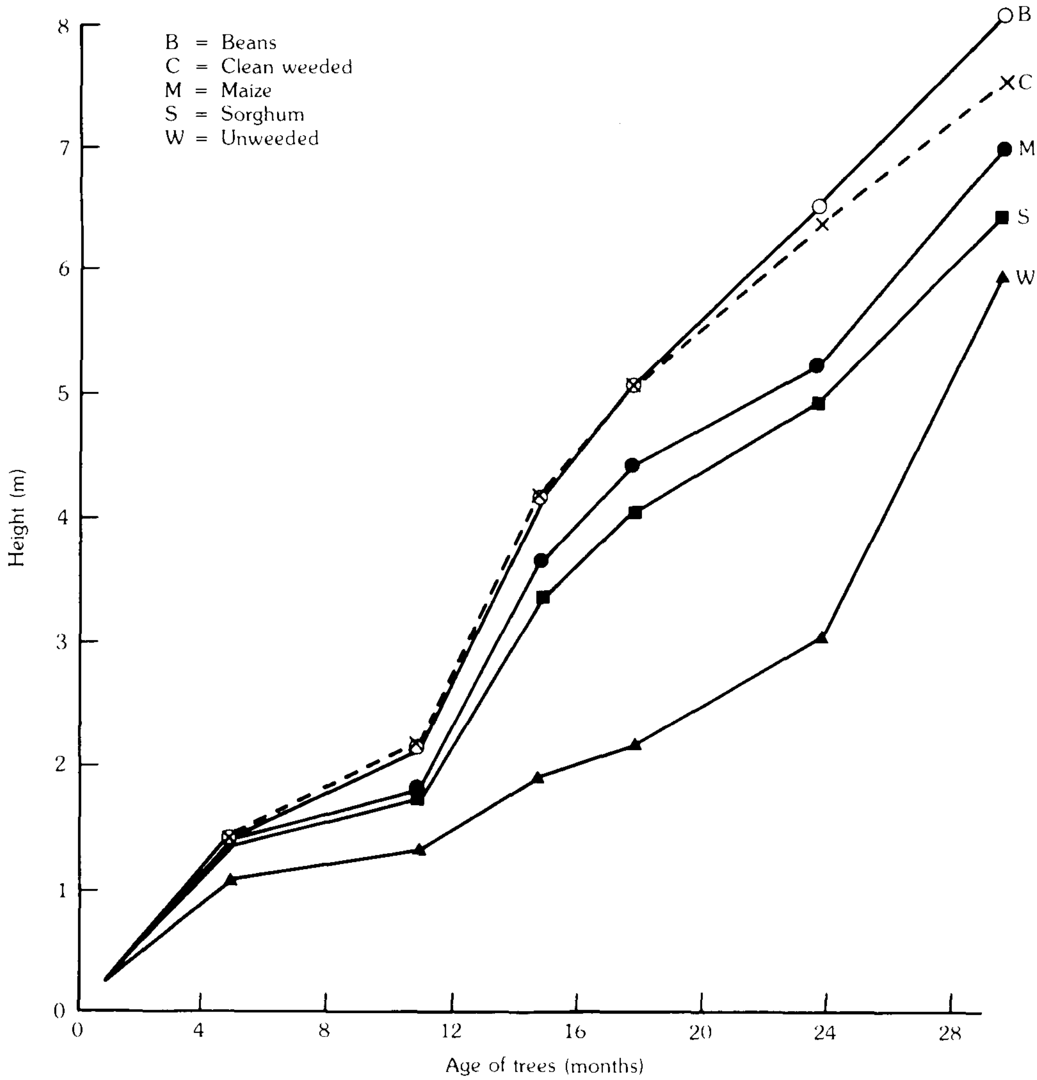

Fig. 1. Mean height of Eucalyptus melliodora *intercropped with maize, beans, and sorghum compared with clean-weeded and unweeded trees at Morogoro.*

the trees died during the first 2 years. Table 1 shows the means per treatment for survival, height, DBH, and volume 30 months after planting.

The yield of maize was 1280 kg/ha in the 1st year and 100 kg/ha in the 2nd year. In the 3rd year it did not flower. Sorghum followed a similar pattern, although yields were not recorded. At a spacing of 2.5 m × 2.5 m, the trees were too close to permit sufficient light for maize and sorghum to grow after the 1st year.

The yield of beans was only 100 kg/ha in the 1st year when the crop was badly attacked by an unidentified fungus. In the 2nd year, the yield was better but was only 150 kg/ha. In the 3rd year, the beans were etiolated, resulting in an insignificant yield.

It was apparent that normal yields could be expected in the 1st year with little effect on the tree crop in the case of *Eucalyptus melliodora*, but for cropping in subsequent years wider spacing of the trees may be necessary. To answer the question of how far apart trees could be grown and still yield poles of adequate form and size requires further investigation.

To answer this question, as well as test other

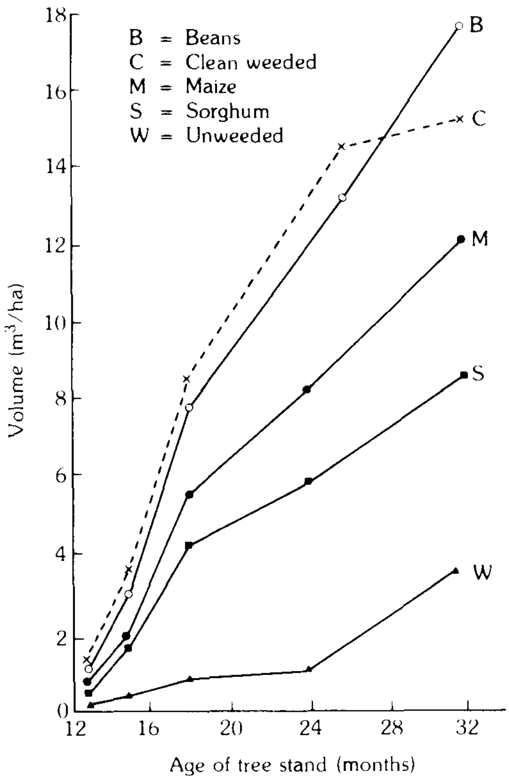

Fig. 2. Volume production of Eucalyptus melliodora *intercropped with maize, beans, and sorghum compared with clean-weeded and unweeded trees at Morogoro.*

Table 1. Mean survival, height, DBH, and volume of 30-month old *Eucalyptus melliodora* intercropped with maize, sorghum, and beans compared with clean-weeded and unweeded trees.

Treatment	Survival (plot mean)	Height (m)	DBH (mm)	Volume[a] (m^3/ha)
Maize	8.4	6.9	61	12.0
Sorghum	8.2	6.4	53	8.2
Beans	7.8	8.0	71	17.6
Clean-weeded	7.8	7.5	67	14.7
Unweeded	4.2	5.9	42	2.4
LSD (P = 0.05)	0.8	0.6	6	3.5
LSD (P = 0.01)	1.0	0.8	8	4.5

NOTE: LSD = least-significant difference.
[a]Volume at 30 months calculated from mean height × cross-sectional area at 1.3 m × form factor of 40%.

multipurpose species of trees that are particularly useful as fuel/fodder and fuel/poles, a series of long-term experiments began in 1980. In these experiments, only maize and beans were intercropped with trees, and recommended fertilizer regimes were followed.

1980 Investigations

(1) Fuel and Pole Production: Intercropping of *Eucalyptus camaldulensis* with Maize and Beans

Container-grown plants were planted on 28 January 1980 in plowed and harrowed land that had been fallow for some years. The experimental design was a split plot, with food crops and weeding treatments forming the main plots and tree spacing forming the subplots. There were four blocks.

Main Plots

Maize was planted 16-20 March 1980 with a spacing of 75 cm × 30 cm, leaving a circle of 50-cm radius around each tree. Fertilizer was applied at a rate of 400 kg/ha ammonium sulphate and 200 kg/ha triple superphosphate in split applications.

Beans were planted 7-13 April 1980 with a spacing of 40 cm × 20 cm, leaving a circle of 20-cm radius around each tree seedling. Fertilizer was applied at a rate of 200 kg/ha ammonium sulphate and 200 kg/ha triple superphosphate. The ammonium sulphate was broadcast when the beans were well established.

Clean weeding was accomplished by harrowing, supplemented by hoeing. No fertilizer was applied.

Spot-weeding, using a hoe, was carried out in a circle of 50-cm radius around each tree, as is the normal Tanzanian forestry practice. No fertilizer was applied.

Subplots

In one of the subplots, no trees were planted; the other subplots had tree spacings of 3 m × 3 m, 4 m × 4 m, or 5 m × 5 m.

Each subplot with trees had a minimum of 25 trees, the central core of 3 trees × 3 trees forming the measurement unit. Two height measurements were made on 5 June 1980 and 16 July 1980. The yields of maize and beans were recorded at harvest. Crops will be planted annually until prevented by tree-canopy closure.

Long-term soil studies are in progress. The main aim of these studies is to monitor soil nitrogen changes under *Eucalyptus*, *Leucaena*, and *Acacia* monocultures and when intercropped with maize and beans. The studies, to be conducted over a 4-year period, will enable a comparison to be made of soil nitrogen under *Eucalyptus* with that under *Acacia* and *Leucaena*. The roots of *Acacia* and *Leucaena* are nodulated and show signs of active biological nitrogen fixation by rhizobia.

(2) Fodder and Fuel Production: Intercropping of *Acacia albida* with Maize and Beans

Trees were planted on 8 February 1980 under conditions similar to those in experiment 1. The experimental layout was also the same, except that there was no spot-weeding treatment. The subplots had a wider spacing because *Acacia albida* has a wide crown when mature. In this case, the 3 m × 3 m spacing was replaced by 6 m × 6 m spacing. In all other respects, the treatments and records were the same.

(3) Fuel Production: Intercropping of *Leucaena leucocephala* with Maize and Beans

In this investigation, the variety Hawaiian Giant was planted on 25 February 1980. The investigation is a replica of investigation 1.

(4) Fodder Production: Intercropping of *Leucaena leucocephala* with Maize and Beans

The variety Hawaiian Giant was planted on 2 March 1980. The experimental design was a split plot, with the same main plots as in investigation 2. In the subplots, *Leucaena* was planted in rows 18 m long with 1 m between plants. In one set of plots, no trees were planted; the others had rows with spacings of 3 m, 4 m, 5 m, and 6 m. The minimum number of rows in a plot was five. The middle seven trees of the central three rows formed the measurement unit in each subplot.

Results

The trees in all experiments were too young to have a marked effect on the maize and bean yields. An effect was expected to occur from the 2nd year onward, when the canopy starts to close. In contrast, the maize, in particular, had a marked effect on the trees because it is a tall crop casting considerable shade. It was only in investigation 4 that the maize and bean yields were normal. In investigations 1-3, the planting time, and tasseling time of maize, coincided with severe droughts and growth and yields were very poor and uneven. This caused great variation in the interaction between the food and tree crops and masked the significance of the results.

Investigation 1: *Eucalyptus camaldulensis*

The height was assessed on 5 June 1980 and 16 July 1980 approximately 18 and 24 weeks, respectively, after planting. Analysis of variance showed the effect of intercropping to be significant at the $P = 0.05$ level, whereas the replication effect was highly significant ($P = 0.01$) due to variable edaphic factors. Table 2 shows the variation of mean height under the various treatments.

Investigation 2: *Acacia albida*

Acacia intercropped with maize was higher than *Acacia* intercropped with beans. Clean-weeded *Acacia* was the shortest. The differences were not statistically significant, nor were the effects of spacing. *Acacia* grows slowly, initially, as it develops a deep taproot before the stem grows more rapidly. It is expected that significant interactions between the tree and the intercropped maize and beans will be manifested by the 2nd year.

Table 3 gives the mean heights of *Acacia albida* measured on 4 June 1980 and 16 July 1980 after approximately 17 and 23 weeks, respectively, of growth.

Investigation 3: *Leucaena leucocephala* Grown for Fuel

The treatments have had a marked effect on the height of the *Leucaena*. *Leucaena* among maize

Table 2. Height of *Eucalyptus camaldulensis*, after 18 and 24 weeks of growth, intercropped with maize and beans compared with clean-weeded and spot-weeded *Eucalyptus*.

	Mean height at 18 weeks (cm)	Mean height at 24 weeks (cm)	Increase over 6-week period (%)
Intercropped with maize	120	145	21
Intercropped with beans	103	138	34
Clean weeded	87	114	31
Spot weeded	90	110	22
LSD ($P = 0.05$)	9	13	
LSD ($P = 0.01$)	12	19	

NOTE: LSD = least-significant difference.

Table 3. Height of *Acacia albida*, after 17 and 23 weeks of growth, intercropped with maize and beans compared with clean-weeded *Acacia*.

	Mean height at 17 weeks (cm)	Mean height at 23 weeks (cm)	Increase over 6-week period (%)
Intercropped with maize	56	81	45
Intercropped with beans	49	75	53
Clean weeded	47	66	40

was the tallest and had straight, unbranched stems. In contrast, the *Leucaena* among beans and in the clean-weeded and spot-weeded plots was shorter and branchy. These trees also flowered and were bearing abundant fruit, whereas the taller *Leucaena* among maize was not flowering. The maize had a profound effect on the height, form, and physiology of *Leucaena*. Table 4 shows the mean height of *Leucaena* measured on 6 June 1980 and 16 July 1980 after approximately 17 and 23 weeks, respectively, of growth.

It was apparent that intercropping with maize would be an advantage if the objective was to produce a large proportion of poles because it precludes *Leucaena's* common habit of heavy branching and multiple leaders from near the base of the tree.

Investigation 4: *Leucaena leucocephala* Grown for Fodder

The growth pattern was similar to that of *Leucaena* in investigation 3, but growth of both the tree and the interplanted food crops was much better than in any of the other investigations because planting coincided with heavy rains. The mean heights of *Leucaena*, measured on 4 June 1980 and 15 July 1980 approximately 13 and 19 weeks, respectively, after planting, are shown in Table 5.

There was a block effect significant at the $P = 0.05$ level, probably due to edaphic factors. The mean yield of maize in investigation 4 was 1645 kg/ha, which compares favourably with high yields obtained on the university farm and was greater than twice the national average yield of maize in Tanzania (i.e., 670 kg/ha) (Acland 1971). The mean yield of beans was 401 kg/ha, an average yield by peasant standards (Acland 1971).

Table 4. Height of *Leucaena leucocephala*, after 17 and 23 weeks of growth, intercropped with maize and beans compared with clean-weeded and spot-weeded *Leucaena*.

	Mean height at 17 weeks (cm)	Mean height at 23 weeks (cm)	Increase over 6-week period (%)
Intercropped with maize	129	161	25
Intercropped with beans	107	139	30
Clean weeded	112	140	25
Spot weeded	91	112	23
LSD ($P = 0.05$)	8	12	
LSD ($P = 0.01$)	11	16	

NOTE: LSD = least-significant difference.

Table 5. Height of *Leucaena leucocephala*, after 13 and 19 weeks of growth, intercropped with maize and beans compared with clean-weeded *Leucaena*.

	Mean height at 13 weeks (cm)	Mean height at 19 weeks (cm)	Increase over 6-week period (%)
Intercropped with maize	160	194	21
Intercropped with beans	104	160	54
Clean weeded	114	153	34
LSD ($P = 0.05$)	11	15	
LSD ($P = 0.01$)	15	22	

NOTE: LSD = least-significant difference.

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Discussion

Liwenga (question): I am pleased to see that foresters have also joined us in the task of increasing food production. However, I question the usage of the term intercropping where crops are grown under trees. Can this be clarified?

Maghembe (answer): The most widely discussed intercrops have been cereals and legumes. The most important point is to manipulate tree crowns, through spacing and other cultural treatments, to allow healthy tree-crop mixtures throughout the tree rotation.

Liwenga (question): *Eucalyptus* is said to have very high water intake. Doesn't Mr Maghembe think that when grown with maize it would absorb all the water and that the crops would suffer?

Maghembe (answer): It is true that some *Eucalyptus* species may have very high water intake. However, the genus has over 500 species. Our experience with *E. melliodora* and *E. camaldulensis* has not shown this problem.

Edje (question): The work done by the Division of Forestry, University of Dar es Salaam is commendable. What recommendations do you make for an agroforestry system in areas of land hunger?

Maghembe (answer): Areas of land hunger would benefit from using multipurpose species. In this connection, tree legumes that contribute to soil fertility through biological nitrogen fixation provide fodder for livestock and good fuelwood and poles.

Mansfield (comment): I want to congratulate the Division of Forestry for pioneering this important task. Good land for agricultural crops is good land for livestock as well as for trees. Their functions are complementary rather than competitive. Therefore, whichever takes prime land at a point in time depends upon the needs of the society.