

PARTICIPATORY EVALUATION OF *TEPHROSIA* SPECIES AND PROVENANCES FOR SOIL FERTILITY IMPROVEMENT AND OTHER USES USING FARMER CRITERIA IN EASTERN ZAMBIA

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SUMMARY

In eastern Zambia, farmers prefer direct seeded improved fallow species like *Tephrosia vogelii* to other species because of the reduced labour requirement for establishment. Since relying on two locally available provenances of *T. vogelii* could become ecologically unsustainable, due to pest and disease outbreaks, a wider range of usable direct seeded *Tephrosia* provenance material is desirable. A farmer participatory evaluation of *Tephrosia candida* provenances for their effectiveness as improved fallows and provision of construction materials and fuel wood was conducted. Using an indigenous board game called *bao*, 68 farmers rated the four provenances and five control species/provenances for these benefits. The *T. candida* provenances were rated high for soil fertility improvement. First year *T. candida* post-fallow performance showed that maize yields could be obtained that were comparable with yields following *Tephrosia vogelii* provenances. According to farmers' ratings, *T. candida* provenances could provide better fuel wood and light construction materials than *T. vogelii*, although they were not considered to be as good as *Sesbania sesban* and *Senna siamea*. *Tephrosia candida* provenances have the potential to be tested by many farmers on-farm. Farmers' methods of screening trees can complement scientific predictors, and their early integration into the selection and design of agro-forestry systems can improve relevance and adoption.

INTRODUCTION

Nitrogen deficiency is one of the major factors limiting maize (*Zea mays*) production in Zambia, and elsewhere in southern Africa. Over the years, inorganic fertilizers (major N suppliers) have become unaffordable to most farmers following the removal of agricultural subsidies (Howard and Mungoma, 1996). Short-duration planted fallows (or improved fallows) using a wide range of leguminous tree species such as *Sesbania sesban*, *Gliricidia sepium*, *Tephrosia vogelii* and *Cajanus cajan* have been found to replenish soil fertility and to increase subsequent maize yields (Kwesiga *et al.*, 1999). Consequently, small-scale farmers in eastern Zambia are adopting improved fallows.

Tephrosia vogelii, a direct seeded species, is widely preferred over other species because it does not have to be raised in a nursery. In contrast to species like *S. sesban* and *G. sepium*, it does not need inoculation with specific *Rhizobium* strains as it nodulates with native rhizobial populations in a wide range of soils. *Tephrosia vogelii* is also less affected by pests than the other tree legumes, perhaps due to its pesticidal properties. For example, it is less susceptible to the root-knot nematodes *Meloidogyne javanica* and

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M. incognita than *Sesbania* spp. (Desaeger and Rao, 2000). However, as the land under tree legumes expands rapidly, pest and disease problems are likely to become more common, even for *Tephrosia* spp., thus a wider range of provenances is desirable.

There is little information available on the use of *T. vogelii* or *T. candida* provenances for improved fallows in Zambia, and farmers have been relying on two locally available provenances of *T. vogelii*. There is, therefore, a need to screen a wide range of *Tephrosia* species and provenances for their effectiveness as improved fallows. Identifying a range of promising materials will enhance biodiversity on farms and help farmers to reduce risks. Screening for fallow performance requires predictors such as biomass production and its quality, litterfall and soil inorganic nitrogen by the end of the fallow period (Mafongoya and Dzwela, 1999). These scientific predictors need to be complemented with farmers' own methods of screening trees to develop a participatory approach for identifying suitable germplasm. This will allow early integration of farmers into the process of designing agro-forestry systems, thus improving the systems relevance and adoption.

This paper describes a study aimed at promoting farmer participation in on-station screening trials that were conducted by International Centre for Research in Agro-Forestry (ICRAF) researchers in three districts of eastern Zambia. Farmers identified benefits relevant to testing of *Tephrosia* spp. and other agro-forestry tree species, and rated the trees, using their own criteria, for soil fertility improvement, and production of fuel wood and light construction materials.

MATERIALS AND METHODS

The study was conducted at three Farmer Training Centres (FTCs) in Chipata South, Chipata North and Katete districts of the Eastern Province of Zambia. These districts were purposely selected because they serve as focal areas for International Center for Research in Agroforestry (ICRAF) research. Eastern Province lies between latitude 10 to 15° S and longitude 30 to 33° E. It borders Malawi to the east and Mozambique to the south, and is at an altitude of 900 to 1200 m asl. The mean annual rainfall in the province is about 1000 mm (range 887–1020 mm), falling between November and April. The province has three distinct seasons: warm and wet from November to April (the main agricultural season), cool and dry from May to August, and a hot, dry season in September and October. The mean daily air temperatures range from 15 to 18 °C during June/July to 21 to 26 °C in September/October. Soils in the province are a combination of medium-textured alluvial soils in the valley and sandvelt soils on the plateau. The most common soil types in Chipata South and Katete are loamy sand or sands (Acrisols or Alfisols). The Alfisols are well drained and relatively fertile but have low water and nutrient-holding capacities (Rausen *et al.*, 1995). In Chipata North, the most common soil types are Luvisols, which are generally heavy loamy clay soils, with the main limitation being the difficulty in tilling the heavy-textured topsoil, especially for farmers using hand hoes.

Population density in the province varies between 25 and 40 persons km⁻². About half of the farmers practice ox cultivation, the others cultivate by hand hoe. Land

tenure is mostly traditional with farmers acquiring land through inheritance. Average cropped land per household of around six members ranges between 1.1 and 1.6 ha for hoe cultivators, and 2.3 to 4.3 ha for ox cultivators. Maize is the most important crop in the area accounting for about 60 to 80 % of total cultivated area (Franzel *et al.*, 2002). Nitrogen is the most important nutrient limiting maize productivity. The steady decline in maize production in the province, partly due to removal of fertilizer subsidies, prompted ICRAF to develop improved fallows of *S. sesban*, *T. vogelii*, *C. cajan* and *G. sepium* that fix N within 2–3 years. Maize yields following two years of improved fallows approach those of fully fertilized plots. The improved fallow system was introduced to farmers in the Eastern Province in 1992. The principal product is the main crop, but others include firewood and building materials and tree seeds. The main crop is maize, or occasionally cotton, sunflower or groundnuts; these are the major crops grown in the province. Cattle, goats and chickens are the most common livestock kept by small-scale farmers.

In July 2002, farmers from four districts (Chipata South, Chipata North, Katete and Chadiza) were invited to evaluate on-station *T. candida* screening trials planted at FTCs in the Eastern Province of Zambia. All the farmers except those from Chadiza evaluated the trial at FTCs in their own districts. Farmers from Chadiza evaluated the Chipata south district trial because the one in Chadiza had a lot of tree dieback. The researchers established the trial with the objective of screening four *T. candida* provenances (*T. candida*, not coded, *T. candida* labelled 02970, *T. candida* 02971 and *T. candida* 02972) for soil fertility improvement. There were five control species in the trial namely: *T. vogelii* (ex Misamfu), *T. vogelii* (ex Chambeshi), *Sesbania sesban*, *Crotalaria pancilla* and *Senna siamea*. The trial was a randomized complete block design with three replications of each treatment although farmers rated only one replicate.

A total of 68 farmers (37 female), invited through informal meetings with farmer extension officers, participated in rating these agro-forestry species for major benefits. This way of selecting participants ensured that only those farmers interested in agro-forestry took part in the evaluation. The average age of the farmers was 41 (*s.d.* = 13.1) with a range of 17–75 years. About 30 % of the farmers had attended primary school without completing it. A similar proportion (37 %) completed this level of education, whilst about 24 % had attended secondary school. The rest would not reveal the education level they had attained, but 59 % of farmers had attended informal training in agro-forestry, and 80 % of the farmers had planted an improved fallow before. About 72 % had a fallow during the period of the evaluation exercise. Most members of the sample were, therefore, knowledgeable about agro-forestry, especially improved fallows.

Farmers first visited the agro-forestry tree plots to discuss the trees and their various functions with researchers. Before embarking on the rating exercise, the benefits associated with the trees were discussed in groups and the common major benefits listed. During the group discussions the criteria or indicators, used to evaluate the trees were identified and agreed (Table 1).

A traditional board game, *baob*, was then introduced to the farmers and its use to rate the trees was discussed. The benefits were written beside curved-out pockets on the *baob*

Table 1. Farmers' criteria used to rate agro-forestry trees for different benefits in eastern Zambia in 2002.

Soil fertility	Fuel wood	Light construction material
Litter fall in plots.	Size of trunks/stems.	Size, length and hardness of trunks/stems.
Leafy biomass.	Hardness of trunks/stems.	Straightness of trunks/stems.
Ability to suppress weeds.	Length of trunks/stems.	Number of straight stems.
Looseness/softness of soil.	Trunk/stem moisture content.	Size of hole in the middle of the stem.
	Bark thickness.	

board, which was placed in each of the nine tree plots. Each farmer, now considered a *baob* player, visited the tree plots, rating each species for each benefit by putting one to four seeds in the pocket next to each benefit. A rating of one seed indicated the tree being a poor source or provider of the benefit described; two seeds indicated a good source/provider, three seeds indicated a very good source/provider while four seeds indicated excellence. Farmers were asked to explain why they were giving certain rates to certain trees for certain benefits. Farmers were allowed to rearrange the rates where necessary after reviewing the whole exercise. This is one of the major advantages of using the board game compared with a formal questionnaire. The final ratings, together with farmer characteristics (age, sex, formal education, informal education in agro-forestry, involvement in improved fallow technologies), which might be associated with the rating of the trees for various benefits, were recorded on structured forms.

In October 2002, the trees were cut and their biomass measured. Fallow litter and foliage were incorporated in the respective plots at land preparation at the end of November 2002. In December, post-fallow plots were hand-sown with hybrid maize (variety Panar 67), which has a grain yield potential of 7–9 t ha⁻¹, at a spacing of 0.25 m within the rows and 1.0 m between the rows (40 000 plants ha⁻¹) in the 10 m by 10 m tree plots. In Katete, land preparation and replanting of the maize had to be done a month later because pigs destroyed the earlier planted crop. Weeding in all the trials was done three times. Maize was harvested at physiological maturity, 140 days after sowing. Maize grain yield was determined on an oven dry weight basis from subplots measuring 6 m × 6 m (net).

During data analysis, the farmer ratings were treated as quantities measured on a continuous scale and were subjected to analysis of variance (ANOVA) using Genstat for Windows (6th edition). A critical assumption was that the variance between observations of the same benefit was constant across the nine tree types. Standard errors of the difference (*s.e.d.*) were used to separate tree ratings and maize yields in the case of a significant *F*-test at $p \leq 0.05$. Cross tabulations and frequencies were calculated using SPSS 11.0 (2001) for Windows. Logistic regression analysis was performed using SAS (SAS Institute, 1996) to analyse the association of farmer age, sex, formal education, informal education in agro-forestry and whether a farmer had planted an improved fallow before with the rating of trees for various benefits.

RESULTS

Farmers in the Eastern Province of Zambia have been involved in agro-forestry activities especially improved fallows since 1992. According to farmers, the primary

Table 2. Rating agro-forestry trees for soil fertility by farmers from four districts of eastern Zambia in 2002: Scale 1 (poor) – 4 (excellent).

Species	Chipata North (n = 26)	Chipata South (n = 15)	Katete (n = 12)	Chadiza (n = 15)	Combined (n = 68)
<i>T. candida</i>	3.9	4.0	4.0	4.0	3.9
<i>T. candida</i> (02970)	3.8	3.8	3.9	3.9	3.8
<i>T. candida</i> (02971)	3.7	3.6	3.8	4.0	3.8
<i>T. candida</i> (02972)	3.7	3.7	3.8	3.9	3.7
<i>T. vogelii</i> (Misamfu)	3.2	2.9	3.3	3.1	3.1
<i>T. vogelii</i> (Chambeshi)	3.0	2.7	2.6	3.1	2.9
<i>Sesbania sesban</i>	3.5	3.4	3.1	3.2	3.3
<i>C. pancila</i>	2.3	2.2	2.4	2.5	2.3
<i>Senna siamea</i>	2.1	1.9	2.3	2.1	2.1
<i>s.e.d.</i>	0.20	0.26	0.32	0.25	0.12

Table 3. Rating agro-forestry trees for biomass production by farmers from four districts of eastern Zambia in 2002: Scale 1 (poor) – 4 (excellent).

Species	Chipata North (n = 26)	Chipata South (n = 15)	Katete (n = 12)	Chadiza (n = 15)	Combined (n = 68)
<i>T. candida</i>	3.6	3.7	4.0	3.9	3.8
<i>T. candida</i> (02970)	3.9	3.7	3.9	3.9	3.8
<i>T. candida</i> (02971)	3.7	3.5	3.7	3.9	3.7
<i>T. candida</i> (02972)	3.5	3.4	3.8	3.8	3.6
<i>T. vogelii</i> (Misamfu)	3.1	3.2	2.9	3.1	3.1
<i>T. vogelii</i> (Chambeshi)	2.8	2.8	2.3	2.9	2.7
<i>Sesbania sesban</i>	3.0	3.1	3.2	3.0	3.1
<i>C. pancila</i>	2.8	2.6	3.3	2.9	2.9
<i>Senna siamea</i>	2.9	3.0	3.0	3.3	3.0
<i>s.e.d.</i>	0.20	0.31	0.25	0.29	0.13

objective of planting *Tephrosia* and other agro-forestry species is the restoration of soil fertility. The common major by-products from the nine tree types evaluated were fuel wood production and light construction materials. Although farmers revealed that *Tephrosia* species were also used as pesticides, they did not attempt to rate trees because the ability of the reference species for provision of this attribute was not known.

Soil fertility replenishment

According to farmers' ratings, the potential of the trees to replenish soils differed significantly ($F_{8,573} = 66.4$, $p < 0.001$). The ratings were similar between districts. Farmers rated $T. candida = T. candida$ 02970 = $T. candida$ 02971 = $T. candida$ 02972 > *Sesbania sesban* = $T. vogelii$ (Misamfu) > $T. vogelii$ (Chambeshi) > *C. pancila* > *Senna siamea* for soil fertility improvement (Table 2). Biomass production and weed suppression were two of the major criteria used in the ratings. *Tephrosia candida* provenances produced more biomass than the others and farmers rated them highly ($F_{8,575} = 23.1$, $p < 0.001$) for the attributes (Table 3). They also suppressed weeds and farmers rated them highly ($F_{8,573} = 3.17$, $p < 0.002$) for this criterion too (Table 4).

Table 4. Rating agro-forestry trees for weed suppression by farmers from four districts of eastern Zambia in 2002: Scale 1 (poor) – 4 (excellent).

Species	Chipata North (n = 26)	Chipata South (n = 15)	Katete (n = 12)	Chadiza (n = 15)	Combined (n = 68)
<i>T. candida</i>	3.7	3.7	3.8	3.9	3.8
<i>T. candida</i> (02970)	3.7	3.7	3.6	3.8	3.7
<i>T. candida</i> (02971)	3.7	3.7	3.8	4.0	3.8
<i>T. candida</i> (02972)	3.4	2.9	3.8	3.6	3.4
<i>T. vogelii</i> (Misamfu)	2.6	1.9	2.4	2.5	2.4
<i>T. vogelii</i> (Chambeshi)	1.9	1.5	1.8	1.9	1.8
<i>Sesbania sesban</i>	2.5	1.7	2.1	1.8	2.1
<i>C. pancila</i>	1.9	1.9	1.7	1.9	1.9
<i>Senna siamea</i>	2.4	1.7	2.1	2.3	2.2
<i>s.e.d.</i>	0.22	0.33	0.29	0.30	0.14

Table 5. Logistic regression results of factors affecting scoring trees for soil fertility improvement in eastern Zambia in 2002.

Variable	Parameter estimate	<i>s.e.</i>	<i>p</i>
Age	0.0099	0.00511	0.053
Gender	0.328	0.1691	0.052
Formal education	0.072	0.0904	0.424
Informal education in agro-forestry	0.243	0.1907	0.203
Planting improved fallow before	0.449	0.3677	0.0278

Explanatory variables in the model:

Age = farmer.

Gender = farmer (1 = male, 2 = female).

Formal education = level of school farmer attained (1 = attended primary, 2 = completed primary, 3 = attended secondary, 4 = completed secondary).

Planting improved fallow before = farmer experience in planting improved fallows (1 = yes, 2 = No).

Differences were observed between men and women in the ratings of trees for soil fertility ($F_{1,591} = 5.3$, $p = 0.02$). Out of the nine tree types evaluated ratings by males were higher than by females in seven cases. Females' ratings of trees were only higher than those by males for *Sesbania sesban* and *Senna siamea*. Logistic regression results showed that gender, age and earlier experience in planting improved fallows were associated with rating of trees for soil fertility improvement (Table 5).

Post-fallow maize yields

In Chipata North and South districts, post-fallow maize yields were in the following order: *Sesbania sesban* > *T. candida* = *T. candida* 02970 = *T. candida* 02971 = *T. candida* 02972 = *T. vogelii* (Misamfu) = *T. vogelii* (Chambeshi) = *C. pancila* > *Senna siamea* (Table 6). Maize yields in Katete were drastically reduced in all the treatments because of delayed planting.

Table 6. First maize yields (t ha^{-1}) following different agro-forestry tree species in three districts of eastern Zambia in 2003.

Species	Chipata North	Chipata South†	Katete‡
<i>T. candida</i>	3.2	3.3	0.9
<i>T. candida</i> (02970)	3.6	3.4	0.6
<i>T. candida</i> (02971)	3.6	2.9	0.6
<i>T. candida</i> (02972)	3.4	2.8	0.5
<i>T. vogelii</i> (Misamfu)	3.5	3.2	1.7
<i>T. vogelii</i> (Chambeshi)	3.5	2.3	0.7
<i>Sesbania sesban</i>	4.7	4.4	0.4
<i>C. panicola</i>	2.8	2.9	0.7
<i>Senna siamea</i>	1.0	1.2	0.4
<i>s.e.d.</i>	0.71	0.52	0.38
<i>p</i>	0.05	< 0.001	< 0.001

† Farmers from Chadiza rated the trial at Chipata South Farmer Training Centre (FTC).

‡ Maize crop had to be replanted after four weeks as it had been browsed by animals.

Table 7. Rating agro-forestry trees for fuel wood production by farmers from four districts of eastern Zambia in 2002: Scale 1 (poor) – 4 (excellent).

Species	Chipata North (n = 26)	Chipata South (n = 15)	Katete (n = 12)	Chadiza (n = 15)	Combined (n = 68)
<i>T. candida</i>	2.7	2.9	2.7	2.6	2.7
<i>T. candida</i> (02970)	2.3	3.1	2.7	2.9	2.7
<i>T. candida</i> (02971)	2.5	3.1	2.5	2.7	2.7
<i>T. candida</i> (02972)	2.6	2.7	2.2	2.3	2.4
<i>T. vogelii</i> (Misamfu)	2.2	2.7	1.9	2.1	2.3
<i>T. vogelii</i> (Chambeshi)	2.0	2.3	1.7	2.0	2.0
<i>Sesbania sesban</i>	3.5	3.2	3.5	3.3	3.4
<i>C. panicola</i>	1.4	1.4	1.4	1.5	1.4
<i>Senna siamea</i>	3.4	3.1	3.1	3.6	3.3
<i>s.e.d.</i>	0.26	0.39	0.37	0.36	0.17

Fuel wood production

Significant differences ($F_{8,573} = 28.9$, $p < 0.001$) were observed in the manner that farmers rated the tree species for fuel wood production. Overall, the ratings for fuel wood production were: *Sesbania sesban* = *Senna siamea* > *T. candida* = *T. candida* 02970 = *T. candida* 02971 = *T. candida* 02972 > *T. vogelii* (Misamfu) = *T. vogelii* (Chambeshi) > *C. panicola* (Table 7). There were also differences in the way farmers from different districts rated the trees ($F_{3,573} = 4.7$, $p = 0.003$). *Sesbania* was consistently rated high for fuel wood production in Chipata North, Chipata South and Katete districts. By contrast, farmers from Chadiza district rated *Senna siamea* highest for fuel wood production. Differences were observed in the way male and female farmers rated trees for fuel wood production ($F_{1,591} = 5.5$, $p = 0.02$). Male farmers rated all trees except *Sesbania sesban* higher than females. Gender was the only significant variable among the factors considered (Table 8).

Table 8. Logistic regression results of factors affecting scoring trees for fuel wood production improvement in eastern Zambia in 2002.

Variable	Parameter estimate	<i>s.e.</i>	<i>p</i>
Age	0.0074	0.00474	0.118
Gender	0.361	0.1570	0.022
Formal education	-0.069	0.0839	0.410
Informal education in agro-forestry	0.138	0.1783	0.438
Planting improved fallow before	-0.471	0.3283	0.151

Explanatory variables in the model (see Table 5).

Table 9. Rating agro-forestry trees for light construction materials by farmers from four districts of eastern Zambia in 2002: Scale 1 (poor) – 4(excellent).

Species	Chipata North (n = 26)	Chipata South (n = 15)	Katete (n = 12)	Chadiza (n = 15)	Combined (n = 68)
<i>T. candida</i>	2.3	2.3	2.4	2.3	2.3
<i>T. candida</i> (02970)	2.5	2.7	2.6	2.1	2.5
<i>T. candida</i> (02971)	2.4	2.5	2.7	2.5	2.5
<i>T. candida</i> (02972)	2.2	2.5	1.9	2.1	2.2
<i>T. vogelii</i> (Misamfu)	1.6	2.0	1.3	1.5	1.6
<i>T. vogelii</i> (Chambeshi)	1.2	1.9	1.3	1.5	1.4
<i>Sesbania sesban</i>	3.0	2.9	3.7	3.0	3.1
<i>C. panicula</i>	1.2	1.1	1.1	1.1	1.1
<i>Senna siamea</i>	3.1	3.1	2.4	2.9	2.9
<i>s.e.d.</i>	0.26	0.39	0.34	0.36	0.17

Light construction material

Farmers rated trees differently for light construction material ($F_{8,572} = 32.0$, $p < 0.001$). The ratings were similar across districts. The ratings were in the order: *Sesbania sesban* = *Senna siamea* > *T. candida* = *T. candida* 02970 = *T. candida* 02971 = *T. candida* 02972 > *T. vogelii* (Misamfu) = *T. vogelii* (Chambeshi) > *C. panicula* (Table 9). Gender of farmers did not influence the way trees were rated. Among the factors considered in the logistic regression analysis, education, informal education in agro-forestry and whether farmers had planted improved fallows before were significantly associated with this assessment (Table 10).

DISCUSSION

Since the participation of many farmers may prove to be expensive and time-consuming, and may limit the number of species that can be screened, the involvement of farmers in screening of agro-forestry trees for the various uses has traditionally been limited to a few farmers hosting on-farm trials in the Eastern Province of Zambia. Farmers' indigenous knowledge has rarely been used to screen trees for various uses. For example, the predictors developed, without farmer involvement, by Mafongoya

Table 10. Logistic regression results of factors affecting scoring trees for light construction materials in eastern Zambia in 2002.

Variable	Parameter estimate	s.e.	p
Age	0.0059	0.00481	0.219
Gender	-0.133	0.1588	0.402
Formal education	-0.181	0.0852	0.034
Informal education in agro-forestry	-0.457	0.1801	0.011
Planting improved fallow before	1.012	0.3337	0.002

See Table 5 for explanatory variables in the model.

and Dzowela (1999) for improved fallows performance, were mainly based on the agronomic traits of the fallow species.

In this study, 68 farmers were involved in a participatory screening study in rating agro-forestry trees for soil fertility, fuel wood production and light construction materials. Among the nine tree types evaluated, *Sesbania sesban*, *T. vogelii* (Misamfu) and *T. vogelii* (Chambeshi) were well known to farmers since they have been using them as improved fallows since 1992. The four *T. candida* provenances were introduced for testing as improved fallows on only 13 farms in 2000, and although most farmers had witnessed their growth, they had not yet seen their effect on subsequent crops. *Senna siamea* is an indigenous tree in eastern Zambia and is known for the provision of construction materials and fuel wood. Farmers had not had experience with *C. panicola* either as an improved fallow or as a provider of construction materials or fuel wood.

For soil fertility replenishment potential, farmers rated the four *T. candida* the most highly. Post-fallow first maize yields at Chipata North and South districts sites, where planting was on time, were higher in the *Sesbania sesban* plots than in the other species. These had statistically similar yields except in the case of *Senna siamea*. Since the *T. candida* provenances were highly rated, and they produced similar yields of maize to the two *T. vogelii* provenances already being used by the farmers, the chances of the candidas being adopted are high. Although farmers had not yet seen the crop yield effect from the candidas, they were able to rate these new types by using the common attributes (biomass production and litterfall, weed suppression, texture and colour of soil) associated with improved fallows that they already knew. The candidas produced more biomass, suppressed weeds, and because they had grown bigger than the other trees, the roots had loosened the soil. Agronomic screening of fallow species by Mafongoya and Dzowela (1999) also showed that post-fallow maize yields were highly correlated with above-ground biomass and litterfall. These traits in turn were highly correlated with soil inorganic nitrogen. In this study, large biomass and litterfall did not appear to be highly correlated with maize yields because the range of total biomass and litterfall production was too small. Also, the narrow range of provenances tested (i.e. four *T. candida* and two *T. vogelii* provenances) contributed to making the correlation very weak. Results previously reported (Mafongoya *et al.*, 2003) for 14 provenances with a wide range of values showed significant correlations between biomass and litterfall, and maize yields. Results from farmers, therefore, suggest that

their selection criteria have some ecological principles, which are related to soil fertility improvement.

Planted fallows help to suppress weed growth. Reduction of light and the thick layer formed by leaf fall reduces weed seed germination (Sileshi and Mafongoya, 2003). Hence, the dense tree canopy and the large litterfall, produced by the *T. candida* provenances, smother the weeds. This reduces the labour required during land preparation and weeding. *Tephrosia vogelii* provenances have an open canopy, which results in more weed biomass production.

Softening of soil is a measure of changes in soil physical properties caused by root penetration. Agro-forestry tree systems improve soil physical properties (Lal, 1989). It is expected that trees will improve soil physical properties differently depending on the rooting systems. The *T. candida* provenances had grown very large and it is thought that their rooting systems were proportionally large compared to other species/provenances.

Age, gender and experience of the farmers in planting improved fallows influenced the rating of trees for soil fertility improvement. Older farmers have vast experience in farming issues, in general, and soil fertility, in particular. It appears that female farmers know more about improved fallow technology than males. Most rural women in the Eastern Province are poor and poor farmers favour improved fallows because they cannot afford mineral fertilizers. It is expected that with more experience in the use of improved fallows the farmers will learn what to look for in a good fallow tree.

Fuel wood is a very important source of energy for many smallholder farms in Africa. Women and children are the ones who traditionally collect fuel wood from the secondary forests. This task can compete for labour with other productive functions in the household. Fuel wood from improved fallows on farm may provide a means to conserve the natural vegetation, which is under threat due to deforestation. In this study farmers rated *Sesbania sesban* and *Senna siamea* most highly. The criteria farmers used to select good species for fuel wood were: wood which does not snap, hard wood, thick and long trunks, with no big hole in the middle, and thin barks. Farmer experience with some of the trees also helped in rating them. *Sesbania* and *Senna* spp. were rated highly because farmers already knew that they provided a lot of good quality fuel wood. Two-year improved fallows using *Sesbania sesban* produced about 15 t ha⁻¹ of fuel wood from on-farm trials (Kwesiga *et al.*, 1999). The two *T. vogelii* provenances were rated low for fuel wood production. These have been used by farmers before and have been found to be of low quality (Govere, 2002). During the rating exercise farmers explained that *Tephrosia* spp. were said to have had a 'big hole' in the middle and were 'too light' although they had big trunks. *Crotalaria* was rated the lowest fuel wood provider because it did not have stems. Trees that produce hard timber are likely to have dense wood. This will mean a high calorific value and good burning qualities. Trees that produce thick trunks (with no 'big holes' in the middle) would have a good wood volume and fires from these would last long enough to cook different dishes. Trees with thin bark have lower moisture content and dry quickly. If trees have thick bark they contain more moisture and produce a lot of smoke, which causes discomfort in the house.

Male farmers rated most trees higher than females for fuel wood production. In the logistic results, only gender came out significant among the factors tested for association with the ratings. Fuel wood collection is mostly a domain of women and children as noted earlier. Therefore women are probably more knowledgeable than men about issues related to fuel wood quality and volume.

Through this exercise farmers seem to have provided indicators with ecological implications about trees suitable for quality fuel wood production. Further research needs to be conducted to determine wood densities, calorific values and quality of different fires and try to correlate these with farmers' rating as has been done with soil fertility.

The farmers rated *Sesbania* and *Siamea* as the best species for the provision of light construction material. Size, length, straightness and hardness of trunks and stems were the overriding criteria for rating trees for this attribute. The ratings were therefore similar to those for fuel wood production. Among the factors considered in the logistic regression analysis, education, informal education in agro-forestry and whether farmers had planted improved fallows before were significantly associated with rating the trees for light construction materials. The negative association of education could imply that less educated farmers are involved in construction activities more than the educated and thus know more about construction materials. As with fuel wood, there is a need to determine objectively the quality of the different tree species for construction materials.

The use of the *bao* game helped farmers to control the rating process. Farmers checked the seeds on the board and rearranged where necessary before the final rates were recorded. This gave the farmers time to reflect on rates they were attaching to trees for provision of different benefits. The game is generally engaging and entertaining to the farmers, in addition to providing useful data (Franzel, 2001).

CONCLUSIONS

The *T. candida* provenances screened in this study have the potential to be tested by many farmers on-farm. Farmers rated them highly for soil fertility replenishment, and agronomic data showed that subsequent maize yields can be comparable to those following the *T. vogelii* provenances that farmers have been using for over a decade. This study has shown that farmers have indigenous knowledge that they can use to develop indicators to select agro-forestry species for various benefits. Such farmer participation in evaluating agro-forestry species needs to be broadened through the involvement of farmers across many regions. If validated, such an approach could improve the relevance of agro-forestry technologies to the beneficiaries and increase the chances of uptake and adoption.

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