Performance of Provenances of *Sesbania macrantha* at Gairo, Morogoro, Tanzania

Mgangamundo*, M.A., A.G. Mugasha and S.A.O Chamshama .

Department of Forest Biology, Faculty of Forestry and Nature Conservation, Sokoine University of Agriculture, P.O.Box 3010, Morogoro, Tanzania

Abstract

Performance evaluation was conducted among 21 provenances of Sesbania macrantha from 9 regions of Tanzania and one region of Rwanda. The trial was established in February, 1996 at Gairo, Morogoro, Tanzania. Assessments were carried out at 6, 12 and 15 months for survival, root-collar diameter and height. Biomass production was assessed during the last assessment occasion. Significant variation among the provenances for survival, root-collar diameter, height and biomass production was observed. The Andago (Arusha) provenance achieved greatest survival (83.3%) followed by the Biharamulo (Kagera) and Kisabya (Kigoma) provenances (80.0%), while Miabeze (Mbeya) provenance had least survival of 20.0%. No significant differences were observed in mean root-collar diameter and height from the 6th to 15th month after planting. Biharamulo(Kagera) provenance was found to be outstanding in respect of total biomass production (12.2 t ha $^{-1}$), followed by Chala (Rukwa) provenance (10.3 t ha $^{-1}$). Kangamo (Mbeya) provenance had the least total biomass production of 2.3 t ha $^{-1}$. Overall, the Andago, Biharamulo, Chala, Kikomakoma, Kisabya and Banda provenances were the best performers while the Lundamoto, Miabeze, Kibondo, Kishoju, Kidiama, Wondo and Kangamo failed to put on promising growth. It is recommended that Sesbania macrantha provenances from Andago, Biharamulo and Chala be used in improved fallow/relay cropping systems in Gairo and other areas with similar environmental conditions in that order of priority.

Key words: Provenances, *Sesbania macrantha,* Survival and Growth.

Introduction

Largely as a consequence of growing human and animal population, there has been a world-wide increase in deforestation (Burley, 1985). Tanzania like many other countries of Sub-Saharan Africa is today confronted with a serious problem of shortages in food, fuelwood, fodder and declining soil fertility. Traditional farming systems escalated the problem further as shifting cultivation led into the regression of tropical forests, desertification and high fuelwood deficit rates.

Agroforestry is frequently invoked as a solution to problems of land and water degradation, shortages of food, fuelwood, cash income, animal fodder and building materials in Sub-Saharan Africa (Rocheleau *et al.*, 1988; Muturi, 1992). Introduction of less land demanding agroforestry technologies has been suggested as one way of reducing deforestation and achieving more sustainable land use practices (Holden, 1993). Among the recently introduced agroforestry technologies for semi-arid areas of Tanzania are the improved fallow and relay cropping systems. In order to fasten the restoration of soil fertility and provide for fodder and fuelwood, fast growing nitrogen-fixing tree/shrub species have been introduced along with such agroforestry systems.

Several thousands species of trees and shrubs could have potential roles to play in both traditional and recently proposed agroforestry technologies the world over (Burley and Carlowitz, 1984; Burley, 1985; Owino, 1992) but vary extremely in the amount and type of information available about their provenances

*Corresponding author

(Burley, 1985). Most species, and particularly those in the tropics show patterns of variation over their natural range which are indicators of vast genetic variation (Namakoong *et al.*, 1980). Since there are genetic differences between seed sources or provenances (Greaves, 1978; Robbins and Hughes, 1983; FAO, 1989), the seed from some locations may give better results than from others when grown in new conditions (Greaves, 1978). Launching successful agroforestry systems in semi-arid areas in Tanzania would therefore need a careful selection of species and provenances which can effectively tolerate drought periods, resist termite attacks, exhibit good growth rate, with a reasonably high biomass production and nitrogen fixing ability.

In broad terms the most suitable provenance is likely to be the one where the environmental conditions of source of seed of provenance and planting site match as nearly as possible (Robbins and Hughes, 1983). However, given the varying tolerance and adaptability of different provenances, and the imprecise methods of quantifying site factors and their interactions, such final selection can only be based on first hand experience of provenances' performance under a given set of site conditions. Such experience can only be gained by the establishment of trials (Webb *et al.*, 1980).

In view of the above facts, provenance trials of *Sesbania macrantha, Sesbania sesban, Gliricidia sepium, Cajanus cajan* and *Calliandra calothyrsus* were established in 1996 under the Sokoine University of Agriculture improved fallow and relay cropping research project. The paper evaluates the performance of 21 provenances of *Sesbania macrantha* in terms of survival, root-collar diameter, height and biomass production. In order to provide the basis for selection of the best provenance(s) for concentration on further research and inclusion in improved fallow/relay cropping systems in semi arid areas of Gairo and other areas with similar environmental conditions.

Materials and Methods

Study site

The trial was established at Gairo (36° 45'E, 6° 30'S; 1200 m a.s.l) located on the main road between Morogoro and Dodoma, about 130 km from Morogoro. Rainfall is unevenly distributed, and varies from year to year, with the rainy season starting from November and ending in May. For the period 1982 to 1987, the mean annual rainfall was 499 mm with a range of 388-656 mm. The topography of the area consists of several small hills. The experimental area has a slope of approximately 5-10%. The soil properties for the study site are as described by Mugasha *et al.* (In press).The soil texture is sandy clay loam with a pH in the upper 40 cm varying from 6.1 - 6.3. Other soil properties are as follows: organic carbon content 0.39 - 0.91%, total nitrogen 0.11 - 0.16%, Bray I available P 1.88 - 3.38 μg P g^{-1}, cation exchange capacity 7.01 - 8.66 cmol(+)kg^{-1}. The vegetation cover of Gairo is scarce, and consists mostly of shrubs and a few scattered trees (Chamshama *et al.*, 1994).

Source of provenances

Seed sources of the provenances are as shown in Table 1. Potted seedlings of the provenances were raised at Sokoine University of Agriculture nursery using standard cultural technique (Forest Division, 1982).

Experimental design

A randomised complete block design was used in this provenance trial. The experiment consisted of two replications of 21. Each provenance was represented once in each block. For each provenance (each plot), 5 x 7 trees (spacing 2 x 2 m) were planted. For each plot the outer rows saved as buffer rows. The inner 3 x 5 trees formed a sample (net) plot. The distance between plots was 3 m and that between blocks was 4 m.

Field procedures

The site was prepared by complete clearing of all vegetation followed by ploughing, stacking and pitting. Pit size was 20 cm x 20 cm. Planting was done in February 1996. Weeding was done twice during the rainy season (November-May) and once in the dry season (June-October).

Data collection

Assessments

Assessments were carried out at 6, 12 and 15 months of age. These involved assessments for survival, root-collar diameter (10 cm from the ground) and height. Branch number and biomass production were assessed during the last assessment occasion. For each plot surviving trees in the inner plot were counted at each time of assessment to get tree survival. Root-collar diameter of all the surviving trees in the sample plot was measured using a micro calliper to the nearest 0.01 cm. Height was measured using the digital measring pole to the nearest 0.01 m.

Determination of tree biomass production

Tree sampling for development of allometric equations

A total of 42 *Sesbania macrantha* trees including nearly all root-collar diameter classes were randomly selected from all the provenances. Each tree was measured for height using digital measuring pole to the nearest 0.01 m and root-collar diameter and basal diameter at 10 and 30 cm respectively, above ground using a micro calliper to the nearest 0.01 cm. These trees were felled and partitioned into tree components (i.e. foliar, branches and stems). The tree components were then oven dried (70^{0}C) to constant weight and weighed. Tree components' oven-dry weights were used to develop allometric equations for foliar, branch and stem components.

Table 1: Seed sources for Sesbania macrantha provenances planted at Gairo, Morogoro, Tanzania

Provenances Batch number	Locality	Latitude	Longitude	Altitude (m.a.s.l)	Mean annual Rainfall (mm)
1167	Wondo (Iringa_	-		1600	630
1168	Lundamoto (Iringa)	-		1500	630
1199	Kangamo (Mbeya)		-	1550	
1210	Chala (Rukwa)	07°37,S	031°17,E	1650	-
1213	Mishamo (Rukwa)	-	-	1260	
1223	Kibondo (Kigoma)	-	-	1250	
1225	Kazarwe (Kagera)	-	-	1310	
1227	Kisabya (Kagera)	-		1360	972
1230	Rubare (Kagera)	-	-	1110	2040
1234	Kishoju (Kagera)	-	-	1150	2040
1235	Karagwe (Kagera)	-	-	1470	972
1240	Biharamulo (Kagera)	-		1160	
1245	Banda (Mwanza)	-	-	1130	-
1239	Kikomakoma (Kagera)	-	-	1297	972
1217	Kwaga (Kigoma)	-	-	1060	977
1220	Kidiama (Kigoma)	-	-	1190	-
1257	Muski (Singida)	04°44,S -	35°00,E	1660	
1258	Andago (Arusha)	04°35,S	25°45,E	1500	-
1158	Mtopesi (Ruvuma)	-	-	910	1227
1196	Miabeze (Mbeya)	-	-	1490	-
15030	Rwanda*	-			

All provenances are from Tanzania except* Rwanda; (-) not available

Allometric equations

Two allometric equations (models) were fitted for the determination of stem, branch and foliar biomass components as follows.

$X = b_1 + b_1(Y_1) + b_2(Y_2)$.(1)

$\ln(X) = b_0 + b_1\ln(Y_1) + b_2\ln(Y_2)$.(2)

Where:

ln = base of natural logarithm

X = dependent variables (number of branches per tree or stem or branch or foliar biomass)

Y_1 = root-collar diameter (cm) or diameter at 30 cm above ground

Y_2 = total tree height (m)

Table 2 shows coefficients of selected allometric equations and their goodness of fit as indicated by R^2 and standard error of estimate.

These allometric equations (models) were selected because of being superior in terms of the goodness of fit (R^2) and SE. These models are also simple to use. The equations were used to derive each component biomass per tree basis. All intercepts were corrected for bias that occurs when converting from logarithmic units (Baskerville, 1972). Plot totals were then established and expanded to a hectare basis as described by Maghembe and Prins (1994).

Data analysis

Statistical analyses were carried out using SAS (Statistical Analysis Systems Institute Inc., 1987). Each tree variable, percent survival, root-collar diameter (cm), height (m), branch number and biomass production (kg ha^{-1}) were subjected to analysis of variance (ANOVA) using plot means. Arcsine transformation was applied to percentage survival data to remove bias. For significant means, the Duncan's Multiple Range Test was used for grouping of means.

To identify the best and the worst overall performing provenances at 15 months, ordinal ranking was developed as follows: for each plot and each growth parameter evaluated, provenances were assigned ranks from the best (assigned 1 point) to the worst (assigned 21 points) performing provenance. Thereafter, ranks were added, then averaged and the overall score was taken as a basis of the overall provenance ranking.

Results and Discussion

Survival

Survival of *S. macrantha* at ages 6, 12, and 15 months is shown in Table 3. Variations in survival between provenances and growth stages existed. With the exception of Chala (Rukwa) and Mishamo (Rukwa) provenances which maintained a constant survival of 54.9% (arcsine transformed), a general decrease in survival percent can be noted in successive assessment dates. Increase in mortality with age has also been reported in *S. macrantha* at Chalimbana (Kamara and Maghembe, 1994)

Table 2: Coefficients of allometric equations and their goodness of fit for *Sesbania macrantha* provenances grown at Gairo, Morogoro, Tanzania.

Dependent variable	Eq. No.	Regression estimator (bo)	b_1	b_2	R^2	SE
Branch biomas (kg per tree)	1	-0.7559 (0.1075)	0.6334 (0.0548)		0.83	0.06
Stem biomass (kg per tree)	2	-4.0707 (0.4604)	1.3481 (0.157)	1.2335 (0.35)	0.89	0.04
Foliar biomass(kg per tree)	3	3-4.6938 (0.4295)	2.9263 (0.2191)		0.87	0.05
Total biomass (kg per tree)	4	-6.7643 (0.8801)	3.664 (0.4489)		0.71	0.08

Equation 1 through 4 follow the general form; ln(x) = bo + ln(d30) = ln(ht). Where, X=number of branches per tree, or tree component mass in kg per tree, d30 = tree diameter (cm) at 30cm above ground, ht = total tree height (m). All intercepts were corrected for bias that occur when converting logarithmic units (Baskarville, 1972). Numbers in parantheses are standard errors of the regression coefficients.

and *S. sesban* at Chipata, Zambia (Kwesiga and Coe, 1994). This can be attributed to failure to withstand intense competition for growth resources, as there was no notable sign of diseases or insect attacks.

Statistical analysis showed that, there were significant ($P<0.05$) differences in survival between provenances at all ages. This was expected since *S. macrantha* with a wide natural distribution is expected to have a considerable genetic variation which enables it to adopt to a great diversity of ecological conditions. At 15 months, highest survival (before angular transformation) was achieved by the Andago (Arusha) provenance (83.3%). This was followed by the Biharamulo (Kagera) and Kisabya (Kigoma) provenances (80.0%), while the Miabeze (Mbeya) provenance had least survival of 20.0%. The survival percent achieved by the Andago provenance at age 15 months in this trial is higher than the 71% reported by Kamara and Maghembe (1994) in a 12 month old *S. macrantha* trial at Chalimbana, Zambia. Considering survival, provenances such as Andago, Biharamulo and Kisabya which sustained a high level of survival indicate the potential of some *S. macrantha* provenances as long-term sources of fuelwood, green manure and fodder.

Table 3: Mean survival (%) trends in Sesbania macrantha provenances at Gairo, Morogoro, Tanzania. 1996 - 1997

Provenance	Transformed survival (%) Age (months)			Untransformed survival (%)
	6	12	15	15
Wondo	39.2	53.2	28.9	23.3
Lundamoto	43.1	32.9	30.3	26.7
Kangamo	54.9	9.2	30.9	26.7
Chala	54.9	54.9	54.9	66.7
Mishamo	54.9	54.9	54.9	66.7
Kibondo	43.1	30.3	30.3	26.7
Kazarwe	39.2	-	-	-
Kisabya	74.5	67.0	64.9	80.0
Rubare	71.8	55.9	53.9	63.0
Kishoju	61.2	56.9	56.9	70.0
Karagwe	66.0	54.9	52.8	63.3
Biharamulo	63.8	63.8	63.8	80.0
Banda	63.4	61.2	61.2	76.7
Kikomakoma	61.2	59.1	59.1	73.3
Kwaga	52.9	45.0	43.0	46.7
Kidiama	61.2	48.9	47.0	53.3
Muski	59.1	57.1	57.1	70.0
Andogo	69.2	67.0	67.0	83.3
Mtopesi	54.9	48.9	47 0	53.3
Miabeze	47.0	36.8	26.3	20.0
Rwanda	52.8	50.8	50.8	60.0
P > F-ratio	0.006	0.012	0.003	0.002
RMSE	8.095	9.637	9.733	14.9
CV%	14.4	19.20	20.20	27.0

RMSE = Redidual Mean Square Error

Growth and biomass production

Table 4 shows trends in height. Statistical analysis showed that, there were significant differences ($P<0.05$) between provenances in mean height at ages 6 and 12 months. At the age of 12 months the Rwanda provenance attained the highest mean height of 4.23 m, followed by Andago (Arusha) 4.15 m, Banda (Mwanza) and Kikomakoma (Kagera) provenances 3.98 m, while the Kangamo (Mbeya) provenance had least mean height of 2.54 m. The provenances showed no significant ($P>0.05$) differences in mean height at age 15. However, the Rwanda provenance had the greatest height of 4.59m at this age.The maximum height and lifespan attained by these provenances are higher than the 12 months lifespan and 3.98m mean height reported by Kamara and Maghembe (1994) in *S. macrantha* grown at Chalimbana, Zambia.

The rapid early growth exhibited by some provenances tested in this trial shows that *S. macrantha* has an advantage over other fodder trees. For instance studies in *G. sepium* at Msekera, Zambia (Kwesiga, 1994) showed that, at age 27 months mean height ranged from 2.8 to 4.5 m which is lower than what was observed in this *S. macrantha* provenance trial. Because of its fast growth *S. macrantha* will therefore be suitable for planting, besides restoring soil fertility, also provides fuelwood and fodder. This is so because for effective nutrient recycling and enhancement of soil organic matter fast growth and high biomass productivity are essential (Duguma and Mollet, 1997).

The root-collar diameters of the provenances tested were significantly different ($P<0.05$) at the age of 6 months (Table 5), but showed no significant ($P>0.05$) differences at ages 12 and 15 months. At age 15 months the Chala (Rukwa) provenance attained the greatest mean root-collar diameter of 6.90 cm, while the least mean height was attained by the Kishoju (Kagera) provenance (5.22 cm). This is considerably greater than the 4.48 cm reported by Burleigh and Yamoah (1997) in a 19 months old *S. sesban* grown in the northern highlands of Rwanda.

Table 4: Mean height (m) in relation to age of *Sesbania macrantha* provenance at Gairo,Morogoro, Tanzania. 1996-1997.

Provenance	Age (months)		
	6	12	15
Wondo	2.39	3.03	3.54
Lundamoto	3.09	3.38	3.46
Kangamo	2.09	2.54	2.87
Chala	3.45	3.97	4.08
Mishamo	3.41	3.75	3.92
Kibondo	3.01	3.96	4.19
Kazarwe	2.11	-	-
Kisabya	3.30	3.65	3.98
Rubare	3.68	3.89	4.43
Kishoju	2.73	3.00	3.28
Karagwe	3.54	3.82	4.20
Biharamulo	3.44	3.88	3.98
Banda	3.30	3.98	4.16
Kikomakoma	3.71	3.98	4.14
Kwaga	3.21	3.73	4.09
Kidiama	3.11	3.55	3.65
Muski	3.53	3.80	3.95
Andago	3.77	4.15	4.32
Mtopesi	3.55	3.81	4.08
Miabeze	2.08	3.12	3.46
Rwanda	2.53	4.23	4.59
P>F-ratio	0.032	0.002	0.072
RMSE	0.528	0.288	0.749
CV%	17.2	7.90	12.5

RMSE= Residual Mean Square Error

Statistical analysis revealed significant ($P<0.05$) differences in oven dry biomass production between provenances at the age of 15 months, with the yield range of 12.2 to 2.3 t ha $^{-1}$ (Table 6). The Biharamulo (Kagera) provenance was outstanding in respect of biomass production 12.2 t ha $^{-1}$ (15 months after planting). The Kangamo (Mbeya) provenance attained the least biomass production of 2.3 t ha $^{-1}$. Variations between provenances in biomass production were also reported in *S. sesban* at Zwai, Ethiopia (Heering, 1995) and *G. sepium* at Msekera, Zambia (Kwesiga, 1994). The Biharamulo provenance had the greatest branch biomass of 5.3 t ha^{-1}, while Kangamo had the least branch biomass of 0.9 t ha^{-1}. The Biharamulo provenance was also observed to have the greatest leaf biomass production of 3.8 t ha^{-1} and the least leaf biomass was produced by the Wondo and Kibondo provenances (0.9 t ha^{-1} each). The leaf biomass produced by most of the tested *S. macrantha* provenances is significantly higher than the 0.6-2.9 t ha^{-1} range of fodder yield from *S. macrantha* reported by Karachi *et al.*, (1994) at Tumbi, Tanzania. It is also higher than the 1.1 t ha^{-1} from *Sesbania formosa* and 0.44 t ha^{-1} from *Sesbania grandiflora* grown in Yaonde, Cameroon (Duguma and Tonye, 1994). The woody biomass produced by *S. macrantha* may provide the much needed fuelwood and so reduce the pressure exerted on natural forests.

Outstanding growth and biomass production for *S. macrantha* has also been reported by Kamara and Maghembe (1994) from studies done in Zambia. The greater production of branch and leaf biomass indicates that *S. macrantha* can be a suitable species for use in improved fallows and relay cropping systems. The high leaf biomass production can also be advantageous in supply of fodder and therefore, this species can be used as fodder bank to improve the quality of dry season fodder. Earlier studies have indicated that leaves of *S. macrantha* are good source of fodder and they contain high nutrient concentration especially

Table 5: Mean root-collar diameter (cm) in relation to age of *Sesbania macrantha* provenance at Gairo, Morogoro, Tanzania. 1996-1997.

Provenance	Age (months)		
	6	12	15
Wondo	2.76	4.60	5.98
Lundamoto	3.18	5.81	6.82
Kangamo	2.95	5.03	5.62
Chala	3.95	5.92	6.90
Mishamo	4.23	5.50	6.06
Kibondo	3.09	5.52	5.72
Kazarwe	1.52	-	-
Kisabya	3.42	5.00	5.95
Rubare	3.34	4.75	5.73
Kishoju	2.51	3.76	5.22
Karagwe	3.65	4.86	5.74
Biharamulo	4.14	5.46	6.52
Banda	4.00	5.25	5.59
Kikomakoma	4.00	5.35	6.13
Kwaga	2.96	5.26	6.34
Kidiama	2.89	3.81	5.32
Muski	3.98	4.89	5.76
Andago	3.97	5.01	5.77
Mtopesi	4.17	5.66	6.33
Miabeze	3.61	5.30	6.68
Rwanda	2.31	4.57	5.77
P>F-ratio	0.023	0.056	0.722
RMSE	0.656	0.568	0.749
CV%	19.7	11.2	12.15

RMSE= Residual Mean Square Error

nitrogen (Ghai *et al.*, 1985: Onim *et al.*, 1990) which indicates the potential of the species for improved fallows and green manure production for soil improvement.

Overall provenance performance - ordinal ranking

The ordinal ranking showing of overall provenance performance is shown in Table 7. The overall performance of Andago, Biharamulo, Chala, Kikomakoma, Kisabya and Banda provenances has been highly encouraging. These provenances have shown consistent promising growth throughout the study period under the prevailing site and climatic conditions at Gairo. While the Mishamo, Rwanda, Mtopesi, Rubare, Karagwe, Muski and Kwaga showed average performance, the Lundamoto, Miabeze, Kibondo, Kishoju, Kidiama, Wondo and Kangamo provenances failed to put on promising growth at Gairo site.

The growth variables described in this paper are among the most important in the selection of the best provenances for use in agroforestry. The wider natural distribution of *S. macrantha*, and the corresponding diversity of environments where the species occurs predicted the great degree of variability in growth and morphological characteristics to be exhibited by its

Table 6: Biomass production in Sesbani macrantha provenances at 15 months at Gairo, Morogorogo, Tanzania.

Provenance	Biomass component (t ha^{-1})			
	Foliar	Branch	Stem	Total
Wondo	0.9	1.1	0.7	2.7
Lundamoto	1.2	1.5	0.9	3.6
Kangamo	0.8	0.9	0.6	2.3
Chala	3.2	4.6	2.5	10.3
Mishamo	2.7	3.6	2.3	8.6
Kibondo	0.9	1.4	0.9	3.2
Kazarwe	-	-	-	-
Kisabya	3.0	4.1	2.7	9.8
Rubare	2.1	3.1	2.1	7.3
Kishoju	2.0	2.3	1.7	6.0
Karagwe	2.2	3.3	2.2	7.7
Biharamulo	3.8	5.3	3.1	12.2
Banda	2.7	3.8	2.5	9.0
Kikomakoma	3.0	4.3	2.7	10.0
Kwaga	2.0	2.9	1.8	6.7
Kidiama	1.5	2.0	1.4	4.9
Muski	2.5	3.4	2.3	8.2
Andogo	2.9	4.3	2.9	10.1
Mtopes	2.4	3.3	2.0	7.7
Miabeze	1.1	1.4	0.8	3.3
Rwanda	2.1	3.3	2.2	7.6
P>F-ratio	0.003	0.003	0.001	0.002
RMSE	0.473	0.722	0.398	1.554
CV%	29.0	31.9	27.8	29.2

RMSE = Residual Mean Square Error

Table 7: Ordinal ranking of 15 months old *Sesbania macrantha* provenances at Gairo, Morogoro, Tanzania.

Provenance	Parameter and ordinal ranking score					
	Mean survival	Mean height	Mean RCD	Biomass production	Mean	Overall rank
Andago	1	3	11	3	4.50	1
Biharamulo	3	10	4	1	4.50	1
Chala	8	9	1	2	5.00	2
Kikomakoma	5	7	7	4	5.75	3
Kisabya	2	10	10	5	6.75	4
Banda	4	6	15	6	7.75	5
Rwanda	11	1	11	10	8.25	6
Mishamo	8	11	8	7	8.50	7
Mtopesi	12	9	6	9	9.00	8
Rubare	9	2	14	11	9.00	8
Karagwe	10	4	13	9	9.00	8
Muski	6	11	12	8	9.25	9
Kwaga	13	8	5	12	9.50	10
Lundamoto	15	14	2	15	11.50	11
Miabeze	17	14	3	16	12.50	12
Kibondo	15	5	15	17	13.00	13
Kishoju	7	15	17	13	13.00	13
Kidiama	12	13	16	14	13.75	14
Wondo	16	13	9	18	14.00	15
Kangamo	14	16	15	19	16.00	16

provenances when grown under different environmental conditions. This is because of the different genetic adaptation of the provenances to the local conditions.

Conclusions and Recommendations

Observed phenotypic variation is generally assumed to reflect the inherent genotypic variation among the provenances. The significant variation in plant traits within some Tanzanian provenances could be due to genetic differentiation resulting from environmental differences among the habitats occupied by these provenances. The differences in growth rates and biomass production exhibited by the *S. macrantha* provenances tested in this trial emphasize the high genetic variation and the importance of identifying the right seed source. Basing on the results from this trial, the Andago, Biharamulo, Chala, Kikomakoma, Kisabya and Banda provenances which were outstanding are suggested to be used in the ongoing improved fallows and relay cropping systems research in Gairo and other areas with similar environmental conditions.

More provenance evaluations could also be important to further extend the genetic base of usable genotypes. The high variation between the provenances in desirable traits allows the selection of the best seed sources for further evaluation of fallow effect and fodder value. Further work is thus needed on these provenances to quantify their differences in soil fertility improvement and subsequent crop yield as well as the nutritional values, fodder quality and digestibility. Results from this work will then give suggestions to farmers on which seed source to use in the proposed agroforestry systems in order to maximise crop yield on a sustainable basis.

Acknowledgements

We thank S. Mnyonga, Ms. M. Mackihiyo and N. Swalehe for experimental establishment and assessment. We are grateful to the International Livestock Research Institute (ILRI) formerly the International Livestock Centre for Africa (ILCA) for availing accessions used in this study. We also thank the Norwegian

Agency for Development Cooperation (NORAD) for financial support.

References

Baskerville, G.L. 1972. Use of logarithmic regression in the estimation of plant biomass. Can. J. For., 2: 49 - 53.

Burleigh, J.R. and Yamoah, C.F. 1997. Site factors associatedwith the performance of *Leucaena leococephala* (Lam) de Wit and *Sesbania sesban* (L) Merill in pure and mixed stands in the northern highlands of Rwanda. Agroforestry Systems 37: 121-131.

Burley, J. and Carlowitz, P., (eds.) 1984. Multipurpose tree germplasm. Proc. Workshop held at Washington D.C. ICRAF, Nairobi, Kenya. 285 pp.

Burley, J. 1985. Global needs and problems of the collection, storage and distribution of multipurpose tree germplasm. Science and Practice of Agroforestry 2. ICRAF, Nairobi, Kenya. 220 pp

Chamshama, S.A.O, Maliondo, S.M.S and Mackengo, S.J. 1994. Early performance of *Faidherbia albida* intercropped with maize at Gairo, Morogoro, Tanzania. J. Trop. For. Sci. 7: 220-229.

Duguma, B. and Tonye, J. 1994. Screening of multipurpose tree and shrub species for agroforestry in the humid lowlands of Cameroon. For. Ecol. Manage. 64: 135-143.

Duguma,B and Mollet, M. 1997. Provenance evaluation of Calliandra calothyrsus meissner in the humid lowlands of Cameroon. Agroforestry Systems 37:45-57.

FAO, 1989. Forestry and food security. FAO For. Pap. No. 90. 58 pp.

Forest Division, 1982. Management practices in coniferous plantations in Tanzania. Notes on Forestry Operations, Forest Division, Dar es salaam, 68 pp.

Ghai, S.K., Rao, D.L.N. and Batra, L. 1985. Comparative study of the potential of *Sesbanias* for green manuring. Trop. Agric. (Trinidad) 62: 52-56.

Greaves, A. 1978. Description of seed sources and collections for provenances of *Pinus caribaea*. Trop. For. Pap. No.12 Commonwealth Forestry Institute, Oxford. 98pp.

Heering, J.H. 1995. The effect of cutting height and frequency on the forage, wood and seed production of six *Sesbania sesban* accessions. Agroforestry Systems 30: 341-350.

Holden, S.T. 1993. The potential of agroforestry in the high rainfall areas of Zambia: a peasant programming model approach. Agroforestry Systems 24: 39 - 55

Kamara, C.S. and Maghembe, J.A. 1994. Performance of multipurpose tree and shrub species 28 months after planting at Chalimbana, Zambia. For. Ecol, Manage. 64: 145-151.

Karachi, M., Lema, N., Sabas, E. and Shirima, D. 1994. Growth, biomass production and plant mortality of seven *Sesbania sesban* Var. *nubica* and three *Sesbania macrantha* accessions at Tumbi, Tanzania. For. Ecol. Manage., 64: 153-159.

Kwesiga, F. 1994. Performance of fifteen provenances of *Gliricidia sepium* in eastern Zambia. For. Ecol. Manage., 64: 161-170.

Kwesiga, F. and Coe, R. 1994. The effect of short rotation planted fallows on maize yield. For. Ecol. Manage., 64: 199-208.

Maghembe, J.A. and Prins, H. 1994. Performance of multipurpose trees for agroforestry two years after planting at Makoka, Malawi. For. Ecol. Manage., 64: 171 - 182.

Muturi, N.S., 1992. Curriculum for in-servce training in agroforestry and related subject in Kenya. Technical handbook. RSCU, Nairobi, Kenya. 81pp.

Namakoong, G., Barnes, R.D. and Burley, J. 1980. A philosophy of breeding strategy for tropical forestry trees. Trop. For. Pap. No. 16, Commonwealth Forestry Institute, Oxford. 67p.

Onim, J.E.M., Mathuva, M., Otieno, K. and Fitzhugh, H.H. 1990. Soil fertility changes of *Leucaena, Sesbania* and *Pigeon pea*. Agroforestry Systems 12: 197-215.

Owino, F. 1992. Improving multipurpoe tree and shrub species for agroforestry systems. Agroforestry Systems 19: 131 - 137

Robbins, A.M.J. and Hughes, C.E. 1983. Provenance region for *Pinus caribaea* and *Pinus oocarpa* within the Republic of Hondurus. Trop. For. Pap. No. 18, Commonwealth Forestry Institute, Oxford. 77pp.

Rocheleau, D., Webber, F., and Juma, F.A. 1988. Agroforestry in dry-land Africa. ICRAF, Nairobi, Kenya. 311 pp.

Statistical Analysis Systems Institute Inc., 1987. Stat. Guide to personal computers, 6th edn. SAS Institute Inc., Cary, NC. USA. 846pp.

Webb, B.D., Wood, J.P. and Smith, J. 1980. A guide to species selection for Tropical and Sub-tropical plantations. Trop. For. Pap. No. 15, Commonwealth Forestry Institute, Oxford.