Effect of *Lablab purpureus* and *Vicia atropurpuria* as an intercrop, or in a crop rotation, on grain and forage yields of maize in Ethiopia

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Abstract

The study investigated the effects of maize-annual forage legume associations on maize and fodder production for 4 years in the subhumid zone of western Ethiopia. *Lablab purpureus* (lablab) and *Vicia atropurpuria* (vicia) were grown as pure crops or as intercrops in maize at 2 planting dates (simultaneous *vs* delayed 6 weeks) for 3 consecutive years (1994–1996) and pure maize was planted in all plots in the fourth year (1997). Intercropping significantly ($P < 0.05$) reduced grain yield in the 3rd year, but its effect on stover yield was not significant ($P > 0.05$). Among the intercrops, simultaneous planting of lablab significantly ($P < 0.05$) reduced grain and stover yield but increased forage dry matter (DM) yield. Lablab resulted in lower ($P < 0.05$) grain yield and higher total fodder (maize stover + forage DM) yield than vicia intercropped simultaneously with maize. Delayed planting, however, did not affect ($P > 0.05$) grain, stover, forage DM or total fodder yields. Forage yield of lablab was significantly ($P < 0.05$) higher than that of vicia, as both a monoculture and an intercrop planted simultaneously with maize. Plots under lablab and vicia monocultures for the previous 3 years produced maize yields comparable with those on fertilised plots. Among intercrops, the residual effects of simultaneously planted lablab were ($P < 0.05$) greater than for delayed planting. Grain yields following lablab were greater ($P < 0.05$) than following vicia both as a monoculture and as a simultaneously planted intercrop. When planted as a monoculture or simultaneously planted intercrop with maize, lablab appeared superior to vicia in terms of its ability to improve both feed supply and soil fertility.

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Introduction

The increase in human population and the resultant pressure on arable land have accelerated the transformation of pasturelands into croplands, with either shortened fallows or abandonment of the traditional fallow. This increases the risk of both chemical and physical soil degradation, resulting in poor fertility, which limits pasture production plus crop yield and quality (Jones and Wild 1975; Ruthenberg 1983).

A survey, conducted in the mixed farming system of the Bako district of Ethiopia, has identified low soil fertility and shortage of livestock feed as major constraints in crop and livestock production systems (Legesse *et al*. 1987). Increased production under a system where there is a high demand for short-term food for humans and feed for livestock must come from an intensification of land already under cultivation, while maintaining or enhancing long-term productivity of such land. Inclusion of perennial forage species in a maize/fallow rotation, by under-sowing, can not only alleviate livestock feed shortages but also effectively maintain fertility in subhumid western Ethiopia (G. Lemma and H. Abubeker, unpublished data). In more intensively cultivated areas, however, farmers could not afford to leave land fallow, even for a year. It is thus important to identify productive forage legumes that fit into cropping practices such as intercropping, sequential cropping, crop rotations *etc.* (Tarawali and Mohamed-Saleem 1995). The integration of promising annual forage legumes, as an intercrop into a maize-based production system, has increased soil fertility, boosted subsequent crop yields and provided high quality feed for livestock

(Mohamed-Saleem 1986; Tothill 1986; Otsyina *et al*. 1987; MacColl 1990; Tarawali 1991), but decreased the yield of companion cereal crops as a result of cereal-legume competition for both moisture and nutrients (Rout *et al*. 1990). However, Fussel *et al*. (1992) found that it may be possible to reduce the extent of cereal-legume competition and increase the production of intercrop combinations by modifying sowing dates and the spatial arrangement of crops. Little is known about the suitability of annual forage legumes to incorporate into the traditional maize–legume intercrop, or maize/fallow rotation, in the subhumid zone of western Ethiopia. This paper reports on the effect on grain and forage yields of maize of integrating *Lablab purpureus* (lablab) and *Vicia atropurpuria* (vicia) (both well adapted to the area), as intercrops or in rotation with maize, when planted on different dates, in the subhumid zone of western Ethiopia.

Materials and methods

The study was conducted at the Bako Research Centre (37°09′ E, 09°6′ N; 1650m asl) in the subhumid region of western Ethiopia, over a period of 4 years (1994–1997). The rainfall pattern is bimodal, with a short rainy season, which begins in March and continues intermittently until the main rainy season commences in June. Rainfall during the study period (Figure 1) ranged from 936–1564 mm. Analysis of samples of surface soil (0–30 cm) at the beginning of the experiment indicated that the soil was a sandy clay with OM 3.14%, CEC 13.8 meq/100 g, pH 5.62, total N 0.14% and available P (Bray II) 1.8 ppm.

An open-pollinated composite maize variety, Beletech, and 2 annual forage legumes, lablab and vicia, were used in this study. Prior to planting in Year 1 (1994), the experimental site was disc-ploughed and harrowed, and then hand-raked to provide a fine seedbed. The trial was laid out as a completely randomised block design with 4 replicates. Plot size was 4.5 m × 8 m.

The maize was sown in rows 75 cm apart at a rate of 25 kg/ha in late April each year following adequate rain to ensure germination and seedling growth. Lablab and vicia were planted as pure stands or as intercrops with the maize either simultaneously in April or 6 weeks after the maize planting. In pure stands, lablab and vicia were sown at 30 and 25 kg/ha, respectively, while seeding rates for the intercropped plots were half those used for the pure stands because of the area taken up by the maize. The maize-forage legume associations consisted of single rows of lablab drilled midway between the maize rows or 2 rows of vicia spaced 25 cm from each other as well as from the maize. Pure stands of forage

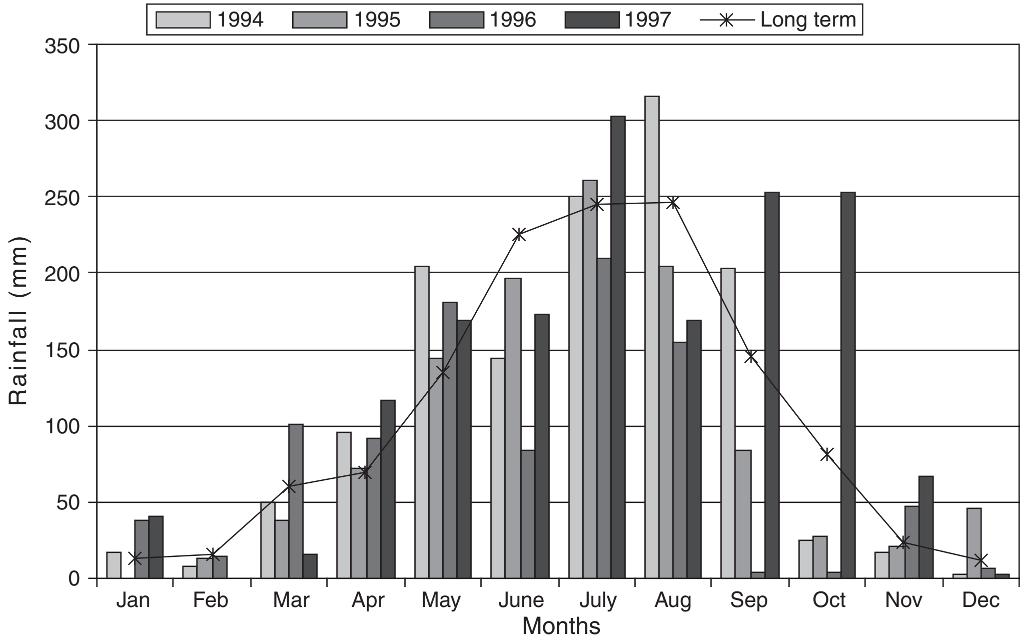

Figure 1. Rainfall records for long-term average (18 years) and the experimental period.

legumes were sown at the same time as the late intercropped forage legumes. Maize monoculture was used as the baseline for comparison.

In the first 3 years (1994–1996), 30 kg/ha P in the form of triple superphosphate (TSP) was applied to the pure legume plots while pure maize and the maize-forage legume intercrops were fertilised at the recommended rates for maize (75:75 N:P kg/ha). In the fourth year (1997), all plots were planted to maize and the recommended fertiliser rate for maize was applied to plots that had not been under pure legumes for the preceding 3 years. Plots planted to pure legumes during the previous 3 years received no fertiliser in the fourth year in order to assess the buildup in N fertility on these plots as a result of the legume growth.

The maize was harvested at physiological maturity (26 weeks after planting) by cutting at 10 cm above ground level, while the legumes were harvested at the 50 % flowering stage (physiological stage of maturity for hay production) at a similar cutting height. As the species have different maturity rates, the simultaneously planted lablab was harvested 64–72 days before maize, while in the delayed planting treatment lablab was harvested 24–30 days before the maize. Similarly, vicia was harvested about 87–90 days before the maize in the case of simultaneous planting and 40–45 days before the maize for the delayed planting treatment. This meant that vicia was harvested about 95–100 days after planting, while lablab was harvested about 110–118 days after planting. Fresh weights of all harvested materials were determined *in situ*. Subsamples of maize residue (including cob) and forage legumes were dried in an oven at 65°C for 48 h for dry matter (DM) determinations. Grain yields were determined following shelling, with moisture level adjusted to 12.5%.

Data on yields of grain, stover, forage DM and total fodder (stover + forage) were subjected to ANOVA testing for each year separately using proc ANOVA (SAS 1987). Within the analysis of variance, single degree-of-freedom orthogonal contrasts were performed to compare: 1) the overall effect of cropping systems (monocropping *vs* intercropping); 2) among the monocultures: maize *vs* average of the 2 legumes, and lablab *vs* vicia (rotation) monoculture; 3) within the intercrops: overall effect of lablab *vs* vicia intercrops, simultaneous *vs* delayed legume planting, and the interaction between legume species and date of planting. Some of the orthogonal comparisons were, however, found to be susceptible to the confounding effect of other factors due to the desire to simulate farmers' situations and formulate appropriate packages. In such cases, this has been deliberately ignored in the discussion and subsequent conclusions in the paper.

Simple economic analyses were performed for each year separately to demonstrate the additional profits or losses associated with the integration of legumes under the various options.

Results

Rainfall was well distributed in Year 1, while the distribution in Year 3 was relatively poor with limited rain after the end of May. Rainfall in Year 4 was well above the average for the preceding 3 years (Figure 1).

Yields of maize grain, stover and total fodder DM were significantly greater ($P < 0.01$) in Year 1 than in Years 2 and 3. Average grain yields of 6990, 5530 and 5380 kg/ha, stover DM yields of 9435, 6664 and 7343 kg/ha, and total fodder DM yields of 7946, 6072 and 6757 kg/ha were recorded across all treatments in Years 1, 2 and 3, respectively.

Intercropping of maize with forage legumes resulted in a significant ($P < 0.05$) reduction in maize grain yield in Year 3, but not in Years 1 and 2 (Table 1). For intercrops, grain yield was affected by an interaction between legume species and date of planting in both Years 2 and 3. Intercropped lablab depressed ($P < 0.05$) grain yields when planted simultaneously with maize, but not ($P > 0.05$) when planting was delayed. Planting date had no significant ($P > 0.05$) effect on the grain yield of maize intercropped with vicia.

The overall effect on stover yield of intercropping maize with forage legumes was not significant ($P > 0.05$) (Table 1). However, in Years 2 and 3, stover yields were lower with simultaneous planting than with delayed planting ($P < 0.05$).

Forage yields of legume intercrops were significantly ($P < 0.05$) affected by an interaction between legume type and planting date. Lablab produced significantly more ($P < 0.05$) forage DM than vicia, both as a pure crop and as a simultaneously planted intercrop (Table 2). Simultaneous planting gave significantly ($P < 0.05$) higher forage DM yields of lablab than delayed planting, but planting date had no significant ($P > 0.05$) effect on forage yield of vicia.

Intercropping of maize with forage legumes consistently produced more total fodder (stover

+ forage) than the average yields of maize and legumes in pure stands. On intercropped treatments, main effects of species and date of planting plus the interaction between them were non-significant in Years 1 and 3. However, in Year 2, total fodder yield showed a significant (P < 0.05) interaction between legume species and planting date (Table 2). Intercropping with lablab produced significantly (P < 0.05) higher total fodder biomass yield than with vicia for simultaneous planting, but not with delayed planting. Simultaneous planting significantly (P < 0.05) reduced total fodder yield when maize was intercropped with vicia, but not when planted with lablab.

The residual effect of lablab and vicia intercropped with maize, or in a crop rotation, on succeeding maize (grain and stover) yields is presented in Table 3. Although maize crops sown on the legume monoculture plots were grown without fertiliser in the fourth year, grain yields did not differ from those receiving supplemental fertiliser (P > 0.05). However, grain yields on previously intercropped areas showed a significant (P < 0.05) interaction between legume species and date of planting. Simultaneously planted plots produced higher (P < 0.05) maize yields than delayed planting plots for lablab intercropped maize (Table 3). For vicia, however, delayed planting plots produced significantly (P < 0.05) higher grain yields than simultaneously planted plots (Table 3). Lablab plots produced higher (P < 0.05) grain yields than vicia plots both as a monoculture and as an intercrop simultaneously planted with maize, but the effect of legume species was not significant (P > 0.05) when planting was delayed.

Financial return from the maize monoculture was higher than from the legume monoculture. However, intercropping the maize and legumes gave an increase in profitability in 1994 and 1995, but not in 1996 (Tables 4, 5 and 6). Except for lablab monoculture or simultaneously intercropped lablab, profits in the residual year were greater on maize monoculture than on the remaining treatments (Table 7).

Table 1. Effect of intercropping maize with lablab and vicia at different planting dates, on maize grain and stover yields.

Parameters	Mono-crop	Intercropped maize[1]					Contrast[2]			
	Maize	Lablab, S	Vicia, S	Lablab, L	Vicia, L	se	A	B	C	D
Grain yield (kg/ha)										
Year 1	6955	6437	6815	7672	7085	668.0	NS	NS	NS	NS
Year 2	5405	3680	5942	6435	6212	536.7	NS	NS	*	*
Year 3	6273	3662	5207	6230	5535	418.3	*	NS	**	*
Stover yield (kg/ha)										
Year 1	9577	9315	7935	10 415	9933	1044.9	NS	NS	NS	NS
Year 2	6975	4985	5817	7477	8065	596.2	NS	NS	**	NS
Year 3	6365	5277	6840	9165	9068	1120.4	NS	NS	*	NS

[1] Legume planting date: S = Simultaneous with maize; L = 6-week delayed planting.
[2] Single-degree-of-freedom orthogonal contrasts between: A = maize monoculture *vs* average of intercrops; B = lablab *vs* vicia intercrops; C = simultaneous *vs* delayed planting; D = legume species × date of planting interaction.

Table 2. Effect of intercropping maize with lablab and vicia at different planting dates on fodder and total fodder DM yields in comparison with pure stands.

Parameters	Monoculture			Intercropped maize[1]					Contrast[2]					
	Maize	Lablab	Vicia	Lablab, S	Vicia, S	Lablab, L	Vicia, L	se	A	B	C	D	E	F
Forage DM yield (kg/ha)														
Year 1	–	5595	475	1660	540	117	0	139.6	***	–	***	***	***	***
Year 2	–	5595	475	2875	125	115	0	130.4	***	–	***	***	***	***
Year 3	–	5615	2052	2275	413	413	35	350.0	***	–	***	*	**	*
Total fodder (forage + stover) yield (kg/ha)														
Year 1	9577	5595	475	10980	8475	10 592	9933	879.4	***	***	***	NS	NS	NS
Year 2	6975	5595	475	7860	5942	7592	8065	498.5	**	***	***	NS	NS	*
Year 3	6365	5615	2052	7552	7252	9358	9103	1007.0	***	***	*	NS	NS	NS

[1] Legume planting date: S = Simultaneous with maize; L = 6-week delayed planting.
[2] Single-degree-of-freedom orthogonal contrasts between: A = Overall averages of monocultures and intercrops; B = maize *vs* average of legume monocultures; C = lablab *vs* vicia monoculture; D = lablab *vs* vicia intercrops; E = simultaneous *vs* delayed planting; F = legume species × date of planting interaction.

Table 3. Residual effect of lablab and vicia as intercrops or in a crop rotation on succeeding maize (grain and stover) yield.

Parameters	Monoculture			Intercropped maize[1]					Contrast[2]					
	Maize	Lablab	Vicia	Lablab, S	Vicia, S	Lablab, L	Vicia, L	se	A	B	C	D	E	F
Succeeding maize yield (kg/ha)														
Grain	6627	7333	5113	6677	5130	5347	6253	499.1	NS	NS	*	NS	NS	*
Stover	8035	8465	6867	9118	7657	7205	8530	691.5	NS	NS	NS	NS	NS	NS

[1] Legume planting date: S = Simultaneous with maize; L = 6-week delayed planting.
[2] Single-degree-of-freedom orthogonal contrasts between: A = Averages of monocultures and intercrops; B = maize monoculture *vs* average of legume (rotation) monocultures; C = lablab *vs* vicia monoculture; D = lablab *vs* vicia intercrops; E = simultaneous *vs* delayed planting; F = legume species × date of planting interaction.

Table 4. Economics of integrating lablab and vicia as an intercrop or in a crop rotation with maize (1994).

Parameters	Monoculture			Intercropped maize[1]			
	Maize	Lablab	Vicia	Lablab, S	Vicia, S	Lablab, L	Vicia, L
Gross income from sale of grain (ETB/ha)[1]	5564.00	0	0	5149.60	5452.00	6137.60	5668.00
Cost of fertiliser allocated to grain production (ETB/ha)[2]	606.09	0	0	606.09	606.09	606.09	606.09
Net return from grain production (ETB/ha)	4957.91	0	0	4543.51	4845.91	5531.51	5061.91
Additional profit/loss from grain production due to legume integration (ETB/ha)	–	***–4957.91***	***–4957.91***	***–414.40***	***–112.00***	***573.60***	***104.00***
Estimated value of maize stover (ETB/ha)[1]	1713.66	0	0	1725.14	1469.56	1928.86	1839.59
Estimated value of available forage (ETB/ha)[1]	0	4489.99	381.19	1332.15	433.35	93.89	0
Cost of fertiliser allocated to forage production(ETB/ha)[2]	0	163.00	163.00	0	0	0	0
Net return from fodder (stover + forage) production (ETB/ha)	1713.66	4326.99	218.19	3057.29	1902.91	2022.75	1839.59
Additional profit/loss from fodder production due to legume integration (ETB/ha)	–	***2613.33***	***–1495.47***	***1343.63***	***189.25***	***309.09***	***125.93***
Overall additional profit/loss from grain and fodder production due to legume integration (ETB/ha)	–	**–2344.58**	**–6453.38**	**929.23**	**77.25**	**882.69**	**229.93**

[1] Return from sale of maize grain is calculated using 0.80 ETB/kg; for maize stover and forage, it is estimated using 0.158 ETB/kg DM and 0.802 ETB/kg DM, respectively. (1 USD = 8.5–8.6 ETB)
[2] Cost of fertiliser is calculated using 200 ETB/100 kg for urea, 250 ETB/100 kg for DAP and 250 ETB/100 kg for TSP.

Table 5. Economics of integrating lablab and vicia as an intercrop or in a crop rotation with maize (1995).

Parameters	Monoculture			Intercropped maize[1]			
	Maize	Lablab	Vicia	Lablab, S	Vicia, S	Lablab, L	Vicia, L
Gross income from sale of grain (ETB/ha)[1]	4324.00	0	0	2944.00	4753.60	5148.00	4969.60
Cost of fertiliser allocated to grain production (ETB/ha)[2]	606.09	0	0	606.09	606.09	606.09	606.09
Net return from grain production (ETB/ha)	3717.91	0	0	2337.91	4147.51	4541.91	4363.51
Additional profit/loss from grain production due to legume integration (ETB/ha)	–	***–3717.91***	***–3717.91***	***–1380.00***	***429.60***	***824.00***	***645.60***
Estimated value of maize stover (ETB/ha)[1]	1291.77	0	0	923.22	1077.31	1384.74	1493.64
Estimated value of available forage (ETB/ha)[1]	0	4489.99	381.19	2307.19	100.31	92.29	0
Cost of fertiliser allocated to forage production(ETB/ha)[2]	0	163.04	163.04	0	0	0	0
Net return from fodder (stover + forage) production (ETB/ha)	1291.77	4326.95	218.15	3230.41	1177.62	1477.03	1493.64
Additional profit/loss from fodder production due to legume integration (ETB/ha)	–	***3035.18***	***–1073.62***	***1938.64***	***–114.15***	***185.26***	***201.87***
Overall additional profit/loss from grain and fodder production due to legume integration (ETB/ha)	–	**–682.73**	**–4791.53**	**558.64**	**315.45**	**1009.26**	**847.47**

[1] Return from sale of maize grain is calculated using 0.80 ETB/kg; for maize stover and forage, it is estimated using 0.158 ETB/kg DM and 0.802 ETB/kg DM, respectively. (1 USD = 8.5–8.6 ETB)
[2] Cost of fertiliser is calculated using 200 ETB/100 kg for urea, 250 ETB/100 kg for DAP and 250 ETB/100 kg for TSP.

Table 6. Economics of integrating lablab and vicia as an intercrop or in a crop rotation with maize (1996).

Parameters	Monoculture			Intercropped maize[1]			
	Maize	Lablab	Vicia	Lablab, S	Vicia, S	Lablab, L	Vicia, L
Gross income from sale of grain (ETB/ha)[1]	5018.40	0	0	2929.60	4165.60	4984.00	4428.00
Cost of fertiliser allocated to grain production (ETB/ha)[2]	606.09	0	0	606.09	606.09	606.09	606.09
Net return from grain production (ETB/ha)	4412.31	0	0	2323.51	3559.51	4377.91	3821.91
Additional profit/loss from grain production due to legume integration (ETB/ha)	–	***–4412.31***	***–4412.31***	***–2088.80***	***–852.80***	***–34.40***	***–590.40***
Estimated value of maize stover (ETB/ha)[1]	1178.80	0	0	977.30	1266.77	1697.36	1679.39
Estimated value of available forage (ETB/ha)[1]	0	4506.04	1646.73	1825.69	331.43	154.88	28.09
Cost of fertiliser allocated to forage production(ETB/ha)[2]	0	163.04	163.04	0	0	0	0
Net return from fodder (stover + forage) production (ETB/ha)	1178.80	4343.00	1483.69	2802.99	1598.20	1852.24	1707.48
Additional profit/loss from fodder production due to legume integration (ETB/ha)	–	***3164.20***	***304.89***	***1624.19***	***419.40***	***673.44***	***528.68***
Overall additional profit/loss from grain and fodder production due to legume integration (ETB/ha)	–	**–1248.11**	**–4107.42**	**–464.61**	**–433.40**	**639.04**	**–61.72**

[1] Return from sale of maize grain is calculated using 0.80 ETB/kg; for maize stover and forage, it is estimated using 0.158 ETB/kg DM and 0.802 ETB/kg DM, respectively. (1 USD = 8.5–8.6 ETB)
[2] Cost of fertiliser is calculated using 200 ETB/100 kg for urea, 250 ETB/100 kg for DAP and 250 ETB/100 kg for TSP.

Table 7. Economics of integrating lablab and vicia as an intercrop or in a crop rotation with maize during the succeeding year (1997).

Parameters	Monoculture			Intercropped maize[1]			
	Maize	Lablab	Vicia	Lablab, S	Vicia, S	Lablab, L	Vicia, L
Gross income from sale of grain (ETB/ha)[1]	5301.60	5866.40	4090.40	5341.60	4104.00	4277.60	5002.40
Cost of fertiliser allocated to grain production (ETB/ha)[2]	606.09	0	0	606.09	606.09	606.09	606.09
Net return from grain production (ETB/ha)	4695.51	5866.40	4090.40	4735.51	3497.91	3671.51	4396.31
Additional profit/loss from grain production due to the residual effect of legume integration (ETB/ha)	–	***1170.89***	***–605.11***	***40.00***	***–1197.60***	***–1024.00***	***–299.20***
Estimated value of maize stover (ETB/ha)[1]	1488.08	1567.72	1271.77	1688.65	1418.08	1334.37	1579.76
Cost of fertiliser allocated to forage production(ETB/ha)[2]	0	0	0	0	0	0	0
Net return from maize stover production (ETB/ha)							
Additional profit/loss from fodder production due to the residual effect of legume integration (ETB/ha)	1488.08	1567.72	1271.77	1688.65	1418.08	1334.37	1579.76
Overall additional profit/loss from grain and fodder production due to the residual effect of legume	–	***79.64***	***–216.31***	***200.57***	***–70.00***	***–153.71***	***91.68***
integration (ETB/ha)	–	**1250.53**	**–821.42**	**240.57**	**–1267.60**	**–1177.71**	**–207.52**

[1] Return from sale of maize grain is calculated using 0.80 ETB/kg; for maize stover and forage, it is estimated using 0.158 ETB/kg DM and 0.802 ETB/kg DM, respectively. (1 USD = 8.5–8.6 ETB)
[2] Cost of fertiliser is calculated using 200 ETB/100 kg for urea, 250 ETB/100 kg for DAP and 250 ETB/100 kg for TSP.

Discussion

The present maize-forage legume association study has shed some light on the possible benefits of integrating annual forages into the traditional maize monoculture system. Invariably, smallholder farmers appreciate the improved soil fertility and/or increased fodder production, following the introduction of improved forages into the maize-based cropping system. However, finding the most appropriate maize-forage production technologies is difficult and could vary from one group of farmers to another, depending upon socio-economic circumstances. Some smallholder farmers may, for example, be able to afford modest mineral fertiliser applications to a forage-maize intercrop but could be reluctant to set aside the limited areas of cropland under legume fallow or vice versa.

Previous work in subSaharan Africa has indicated that forage legume-cereal intercropping can increase the quantity and quality of crop residues, but may depress grain yields of the companion cereal crop (Mohamed-Saleem 1985; Nnadi and Haque 1986; Kouane *et al.* 1993). Our results confirm these findings. The observed reduction in maize grain yield when sown simultaneously with lablab was to be expected since the vigorous lablab would have competed for both light and soil resources. Nambiar *et al*. (1983) and Izaurrald *et al*. (1990) reported that competition for both light and soil resources reduced yield of intercrop components. Shehu *et al.* (1997) also found that fewer leaves were produced per plant resulting in reduced growth of individual maize plants in a maize-*Stylosanthes hamata* intercrop due to competitive effects. Increased yields of lablab forage compensated for the reduction in grain yield, resulting in additional profit in 1994 (Table 4) and 1995 (Table 5), but not in 1996 (Table 6). The favourable residual effects of lablab for simultaneously planted maize-lablab intercrop also indicated an additional gain in terms of soil fertility and thereby increased net return (Table 7).

For simultaneously planted maize-lablab intercrop, smallholder farmers must decide whether a short-term reduction in grain yield would be acceptable in order to acquire the additional high-quality forage for livestock with a slight increase in financial return; in the long term, higher grain yields from succeeding maize crops would be an added benefit, due to the positive residual effect of this practice on soil fertility. Similar advantages of intercropping maize with forage legumes were reported by Ikwuegbu *et al*. (1994) and Tarawali and Mohamed-Saleem (1994). Apart from the above benefits, maize-forage legume intercropping improves net return per unit area further due to reduced labour, land and fertiliser inputs for the establishment and management of forage legumes as a monoculture.

Except in Year 3, vicia grew poorly whether as a monoculture or as an intercrop with maize. This was particularly pronounced when vicia was intercropped with maize as a delayed planting. As a result, maize yields on plots previously under a vicia monoculture were below those on areas previously under either maize or lablab monocultures. Plots previously under lablab monoculture for 3 consecutive years, when planted to maize, produced maize yields similar to those on areas fertilised with 75:75 N:P kg/ha. Thus, by implication, it appears that this legume supplied N comparable with that applied from the mineral fertiliser and probably saved around 606 ETB/ha/annum that would have been spent on the purchase of mineral fertiliser (Table 7). However, due to the confounding effect of variable rates of fertiliser applied to the maize monoculture and the legumes, it was difficult to make a clear distinction between N_2 fixation and variability in the amount of fertiliser applied and that subsequently taken up by the plants. Mohamed-Saleem and Otsyina (1986) reported that about 30–80 kg/ha N could be added to the soil by the legume component when cereals are rotated with legumes in short-term fallows. While these effects were obtained after legume monoculture for 3 years, smallholder farmers may opt for only a single year of legume between maize crops. In addition to the positive impact of legumes on soil fertility, the high quality fodder produced during the fallow years can complement fibrous forages. Thus, both as a monoculture and as a simultaneously planted intercrop with maize, lablab appeared superior to vicia in terms of its contribution to the feed supply and soil fertility, thereby improving net return per unit area in the subhumid zone of western Ethiopia.

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References

Fussel, L.K., Klaij, M.C., Renard, C. and Ntare, B.R. (1992) Millet-based cropping systems for improving food production in the southern Sahelian zone. In: *Proceedings of the workshop on appropriate technologies for developing sustainable food production systems in the semi-arid regions of sub-Saharan Africa*, *Ouagadougou, Burkina Faso, 11–14 April 1989*. pp. 109–127. (Purdue University Press: West Lafayette, Indiana, USA).

Ikwuegbu, O.A., Tarawali, G. and Iji, P. (1994) Sustaining a crop-livestock farming system in the sub-humid zone of Nigeria by matching feed from improved *Stylosanthes*-based pastures and livestock production. In: de Leeuw, P.N., Mohamed-Saleem, M.A. and Nyamu, A.M. (eds) Stylosanthes *as a forage and fallow crop*. *Proceedings of the regional workshop on the use of* Stylosanthes *in West Africa held in Kaduna, Nigeria, 26–31 October 1992*. pp. 167–174. [ILCA (International Livestock Centre for Africa): Ethiopia].

Izaurrald, R.C., Juma, N.G. and McGill, W.B. (1990) Plant and nitrogen yield of barley-field pea inter-crop in cryoboreal sub-humid central Alberta. *Agronomy Journal,* **52**, 291–301.

Jones, M.J. and Wild, A. (1975) Soils of the West African Savanna — The maintenance of their fertility. *Technical communication 55*. *CABI (Commonwealth Agricultural Bureau International), Harpenden, UK.* 87pp.

Kouane, C.N., Pwell, J.M., Renard, C.A. and Quesenberry, K.H. (1993) Plant yields and fodder quality related characteristics of millet-stylo inter-cropping systems in the Sahel. *Agronomy Journal,* **85**, 601–605.

Legesse Dadi, Gemehu Gedano, Tesfaye Kumsa and Getahun Degu (1987) Bako mixed farming zone diagnostic survey report. *Research Report* No. **1**, *IAR (Institute of Agricultural Research), Addis Ababa, Ethiopia.*

MacColl, D. (1990) Studies in maize (*Zea mays*) at Bunda, Malawi. III. Yield in rotation with pasture legumes. *Experimental Agriculture*, **26**, 263–271.

Mohamed-Saleem, M.A. (1985) Effect of sowing time on grain and fodder potential of sorghum under-sown with stylo in the sub-humid zone of Nigeria. *Tropical Agriculture (Trinidad)*, **62**, 151–153.

Mohamed-Saleem, M.A. (1986) The ecology, vegetation and land use of sub-humid Nigeria. In: Von Kaufmann, R., Chater, S. and Blench, R. (eds) *Livestock systems research in Nigeria's sub-humid zone. Proceedings of the second ILCA/NAPRI symposium held in Kaduna, Nigeria, 29 October–2 November 1984*. pp. 59–84. [ILCA (International Livestock Center for Africa): Addis Ababa, Ethiopia].

Mohamed-Saleem, M.A. and Otsyina, R.M. (1986) Grain yields of maize and the nitrogen contribution following *Stylosanthes* pastures in the Nigerian sub-humid zone. *Experimental Agriculture,* **22**, 207–214.

Nambiar, P.T.C., Rao, M.R., Reddy, M.S., Floyd, C.N., Drat, P.J. and Willey, R.W. (1983) Effect of inter-cropping on nodulation and nitrogen fixation by groundnuts. *Experimental Agriculture*, **19**, 79–86.

Nnadi, L.A. and Haque, I. (1986) Forage legumes in African crop-livestock production systems. *ILCA Bulletin*, **30**, 10–19. *ILCA, Addis Ababa, Ethiopia*.

Otsyina, R. M., Von-Kaufmann, R. and Mohamed-Saleem, M.A. (1987) *Manual on fodder bank establishment and management*. [ILCA (International Livestock Center for Africa): Addis Ababa, Ethiopia]. 27 pp.

Rout, D., Pradhan, L., Barik, T. and Misra, S.N. (1990) Studies on pure stand and cereal-legume association of maize, sorghum, cowpea and rice bean in different proportions. *Indian Agriculturalist*, **34**, 41–46.

Ruthenberg, H. (ed.) (1983) *Farming systems in the tropics*. (Clarendon Press: Oxford, UK). 424 pp.

Statistical Analysis System (SAS) (1987) *Procedures guide for personal computers*. Version 6. (SAS Institute Inc.: Cary, NC, USA).

Shehu, Y., Alhassan, W.S. and Phillips, C.J.C. (1997) The effect of inter-cropping maize with *Stylosanthes hamata* at different row spacing on grain and fodder yields and chemical composition. *Tropical Grasslands*, **31**, 227–231.

Tarawali, G. (1991) Residual effect of *Stylosanthes* fodder banks on grain yield of maize. *Tropical Grasslands*, **25**, 26–31.

Tarawali, G. and Mohamed-Saleem, M.A. (1994) Establishment techniques for stylo associated cropping systems. In: de Leeuw, P.N., Mohamed-Saleem, M.A. and Nyamu, A.M. (eds) Stylosanthes *as a forage and a fallow crop. Proceedings of the regional workshop on the use of* Stylosanthes *in West Afria held in Kaduna, Nigeria, 26–31 October 1992*. pp. 183–192. (ILCA: Ethiopia).

Tarawali, G. and Mohamed-Saleem, M.A. (1995) The role of forage legume fallows in supplying improved feed and recycling nitrogen in sub-humid Nigeria. In: *Livestock and Sustainable Nutrient Cycling in Mixed farming systems of sub-Saharan Africa. Volume II. Technical papers. Proceedings of an International Conference held in Addis Ababa, Ethiopia, 22–26 November 1993*. pp. 263–276. (ILCA: Addis Ababa, Ethiopia).

Tothill, J.C. (1986) The role of legumes in farming systems of sub-Saharan Africa. In: Haque, I., Jutzi, S. and Neats, P.J.H. (eds) *Potentials of forage legumes in farming systems of sub-Saharan Africa. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 16–19 September 1985*. pp. 162–185. (ILCA: Addis Ababa, Ethiopia).

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