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Role of maize (*Zea mays* L.)- fababean (*Vicia faba* L.) intercropping planting pattern on productivity and nitrogen use efficiency of maize in northwestern Ethiopia highlands

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Field experiments were undertaken for two years at Adet and Motta experimental stations, northwestern Ethiopia with an objective of determining the appropriate planting pattern and optimum rate of N and P fertilizers for maximization of maize/faba bean intercropping system. A factorial combinations of four nitrogen rates (0, 32, 64, and 96 kg N/ha), three phosphorus rates (0, 46 and 69 kg P_2O_5/ha) and two planting patterns (1:1 and 2:1 maize: faba bean alternate row planting) were tested along with two sole crop treatments of maize and faba bean in randomized compete block design with three replications. The results indicated that there was significant difference in maize grain yield at the two locations due to nitrogen and phosphorous fertilizer levels. Significant difference in faba bean yield was observed due to planting pattern. The Land Equivalent Ratio (LER) is more than unity in most of the cases. The highest LERs, 2.0 at Motta and 1.5 at Adet were obtained when a planting pattern of 1:1 maize: faba bean alternate rows was used with the application of 96-46 N- P_2O_5 kg/ha. The specified intercropping pattern exhibited highest System Productivity Index (SPI) and Nitrogen Use Efficiency (NUE). The economic Analysis has also confirmed that the specified 1:1 maize : faba bean intercropping with the application of 96-46 N- P_2O_5 kg/ha treatment gave the best advantage at both locations.

Keywords: Maize (Zea mays), faba bean (Vicia faba), intercropping, planting pattern, LER, SPI, economic profit.

INTRODUCTION

Intercropping is an important practice for the development of sustainable food production systems, particularly in cropping system with limited external inputs (Getachew *et al.,* 2006). This is due to some of the potential benefits of intercropping systems such as high productivity and profitability (Yildirim and Guvence, 2005), improvement of soil fertility through the addition of N by fixation and extraction from the component legume (Hauggaard *et al.,* 2001), reducing damage caused by pests, diseases and weeds (Altieri and Libeman, 1986; Banik et al., 2006), improvement of forage quality (Getachew et al., 2006) and efficient use of environmental resources (Eskandari and Ghanbari, 2010) through the complementary effects of two or more crops grown simultaneously on the same area of land.

It is generally understood that the combinations of a legume and cereal are most common among farmers in the semi-arid tropics and would benefit them in resource limiting condition, compared with corresponding sole crops. Yield advantages have been recorded in many legume-cereal intercropping systems, including soybean-sorghum (Hayder et al., 2003), cowpea-maize (Eskandari and Ghanbari, 2010), fababean-wheat (Ghanbari, 2000) and vetch-oat (Tuna and Orak, 2007). The reason of yield advantage of intercropping are mainly that environmental resources such as water, light and nutrients can be utilized more efficiently in intercropping than in the respective sole cropping systems (Liu et al., 2006).

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Improved agronomic managements are reported to improve nitrogen nutrient use by the crop (Mungai et al., 1998). Various production practices, including plant rotations and intercropping systems, have helped to counteract loss of nitrogen from the agricultural systems (Badaruddin and Meyer, 1994). The underlying principle of better environmental resource use in intercropping is that if crops differ in the way they utilize resources when grown together, they can complement each other and make better combined use of resources than they are grown separately (Willey, 1991).

A survey in the Amhara region of northwestern Ethiopia indicated that in subsistence economy the farmers use a combination of crops grown on a piece of land. The chosen crop combinations normally include cereals, pulses and/or oil seeds primarily to achieve farmer's major objective of food self-sufficiency (UNDP 1996). The most important crop mixtures used by farmers in the area are sorghum (*Sorghum bicolor* (L.) Moench)/chick pea (*Cicer arietinum* L.), sorghum/faba bean (*Vicia faba* L.), sorghum/barley (*Hordeum vulgare* L.), sorghum/finger millet (*Elucine coracana* L.), finger millet/rape seed (*Brassica juncea* L.), bread wheat (*Triricum aestivum* L.) /barley, pea (*Pisum sativum* L.)/faba bean, maize (*Zea mays* L.)/ rape seed, maize/potato (*Solanum tuberosum* L.), and maize/ faba bean (UNDP 1996 and personal observation). Most farmers enumerated the reasons such as scarcity of land, avoidance of risk of crop failure, increased yield, soil conservation and labor economy for practicing the intercropping in the region (UNDP 1996).

Maize-faba bean intercropping is used in many parts of the world, especially in the high lands of east and South Africa, and in Mexico (Mbah et al., 2007). Maize faba bean intercropping has a long history in China (Haigang et al., 2010). It is also practiced in Iran (Esmaeil et al., 2010). Maize/faba bean intercropping is one of the most frequent intercropping systems in north-eastern Ethiopia. In our area no research efforts have been made to improve the productivity of food cereals-legumes intercropping. Productivity of intercropping system may be maximized by efficient use of edaphic and environmental factors by adopting proper crop husbandry such as optimum mixture-ratios of component crops, planting arrangement, fertilizer use and planting schedule (Trenbath 1986; Pal et al., 1988; Willey 1991; Pal et al., 1993; Pal and Shehu, 2001). Currently maize is being grown in mixture with pulses with little consideration to the fertilizer use and planting arrangement. This study was undertaken to fill the information gap about planting patterns and nutrient management especially of fertilizer N and P for maximization of productivity of maize/faba bean intercropping.

MATERIALS AND METHODS

Field experiments were carried out at Adet ($11^0$17'N; $37^0$31'E, elevation 2240 m) and Motta ($11^0$12'N, $37^0$88'E elevation 2470 m) experiment Stations located in northwestern Ethiopia for two consecutive cropping seasons. The average annual rainfall of Adet and Motta is 1293 and 1296 mm, respectively, of which about 70 % are received during the months from June to September. The mean maximum and minimum temperatures are 24^0C and 9^0C at Adet and 24.3^0C and 9.6^0C at Motta. Experimental soil of Adet was nitosol containing 11% sand, 21% silt, 69% clay, 0.189% total N, 2.7 g/kg available P (Olsen), 0.450 cmol/kg K^+, 25.32 cmol/kg CEC, with soil pH 5.4. Whereas Motta soil is nitosol containing 5% sand, 34% silt, 61% clay, 0.26% total N, 2.34 g/kg available P (Olsen), 0.714cmol/ kg K^+, 28.59 cmol/kg CEC, with soil pH 4.97

Factorial combinations of 4 rates of nitrogen (0, 32, 64, and 96 kg N/ha), 3 rates of phosphorous (0, 46 and 69 kg P_2O_5/ha) and two planting patterns of maize/faba bean intercropping (1 maize: 1 faba bean and 2 maize:1 faba bean) were laid out in a randomized complete block design with three replications. Planting pattern 1 maize: 1 faba bean was maintained by planting maize rows spaced 75 cm apart and planting one row of bean between the two maize rows. In planting pattern of 2 maize:1faba bean, maize rows were also planted at a row spacing of 75 cm and after every two maize rows one row of faba bean was planted. Intra-row spacing in maize and faba bean were 30cm and 8cm, respectively, irrespective of planting patterns. In addition, sole maize and sole faba bean were also included as experimental treatments. The sole maize was planted at 75 x 30 cm spacing supplied with 64 kg N/ha and 46 kg P_2O_5 /ha. Sole faba bean was planted at 40 x 8 cm with the application of 18 kg N/ha and 46 kg P_2O_5/ha. The *CS-20 DK* variety of faba bean and the *BH-540* variety of maize were used. Both crops were planted at the same time in the last week of May at both locations. Full dose of P_2O_5 and half dose of N, per treatments, were applied at planting and the remaining dose of N was side-dressed along the rows at knee-high stage to the maize, both in sole and mix-culture. In case of sole faba bean, full dose of N and P_2O_5 were applied at planting. Gross plot of 4.5 x 5.1 m were used. Central 4 rows of 4.5 m length constituted the net plot for yield determinations at harvest. All recommended cultural practices were followed to raise a successful crop.

At maturity, both crops were harvested and data were collected on grain yield, 1000-seed weight, number of cobs/maize plant and number of pods/faba bean plant. The data were subjected to analysis of variance

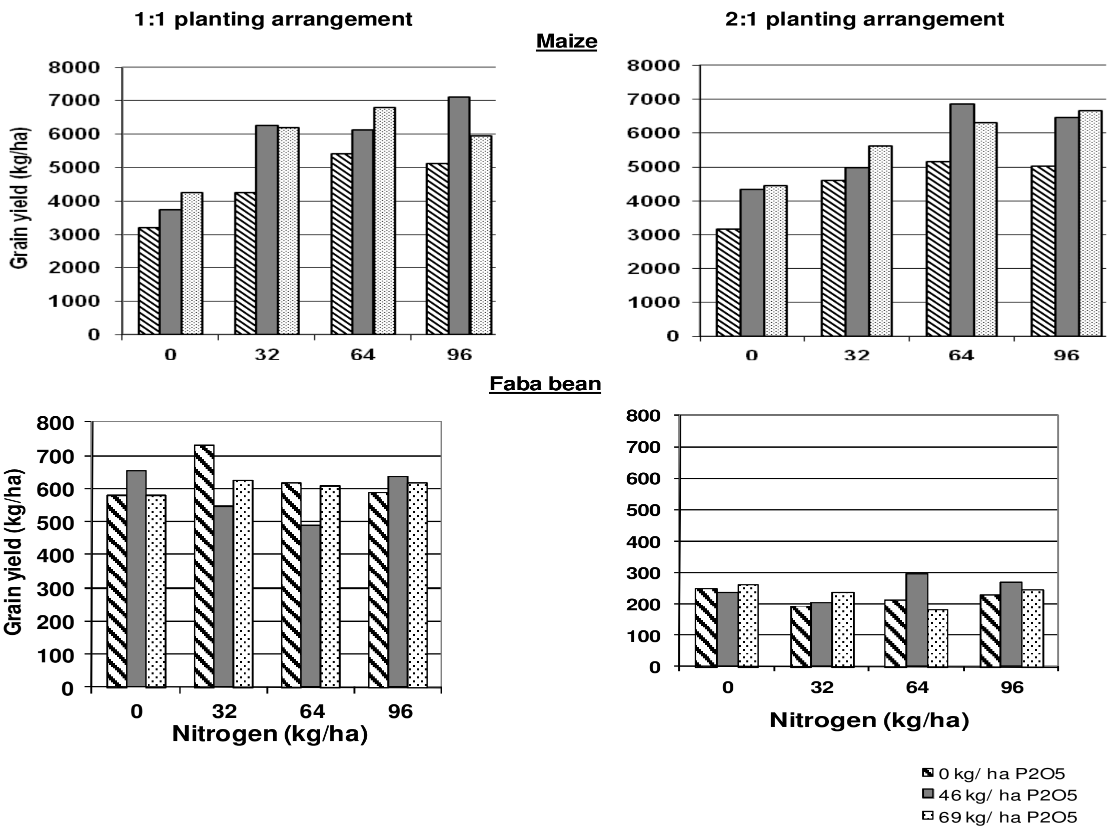

Figure 1. N rate X P2O5 rate X planting pattern interaction effect on maize and faba bean grain yield at Adet.

(ANOVA) using Statistical Analysis System (SAS) Version 9.2 (SAS Inc., 2002).

Land Equivalent Ratio (LER) had been calculated to assess the productivity of the intercropping systems (Willey, 1991; Pal *et al*., 1988). It was calculated as:

LER = $Yij/Yii + Yji/Yjj$;

where Yii and Yjj denote yields of crops i and j in sole culture and Yij and Yji are the corresponding yields in mixed crops.

System productivity index (SPI), is another index for assessing intercrops as stated by Odo (1991), which standardizes the yield of the secondary crop, b, in terms of the primary crop, a. It was computed as:

SPI = $Sa/Sb*Yb + Ya$;

where Sa and Sb are the mean yield of maize and faba bean in sole culture and Ya and Yb are the mean yield of maize and faba bean, respectively in mixed culture.

Agronomic Nitrogen Use Efficiency (NUE) was calculated as extra kilogram of grain per extra kilogram of N applied (Mushayi et al., 1999; Hatfield and Prueger, 2004).

Grain yields were also subjected to economic analysis using CIMMYT partial budget methodology (CIMMYT, 1988). Average price of maize Ethiopian Birr (ETB) 4/kg and faba bean grains ETB 9/kg and cost of fertilizer was ETB 12 and ETB 10 per kg of diammonium phosphate (DAP) and urea, respectively were taken for the economic analysis. 1 USD is currently exchanged for 17.2 ETB. The labour cost was estimated to be Birr 15 per man day. Following the CIMMYT partial budget methodology, first total variable costs (TVC), gross benefits (GB) and net benefits (NB) were calculated. There after treatments were arranged in the order on increasing TVC. In the next step dominance analysis were performed to exclude dominated treatments from the marginal rate of return (MRR) analysis. A treatment is said to be dominated if it has a higher TVC than the treatment which has lower TVC next to it but having a lower NB. A treatment which is non-dominated and having a MRR greater than one and having the highest NB is said to be economically profitable.

RESULTS

Data over two years for each location were averaged in order to have concise presentation because of the similarities in responses to N, P and planting pattern on productivity of component crops and of the system (Figure 1 and 2). The N x P_2O_5 x planting pattern interaction was

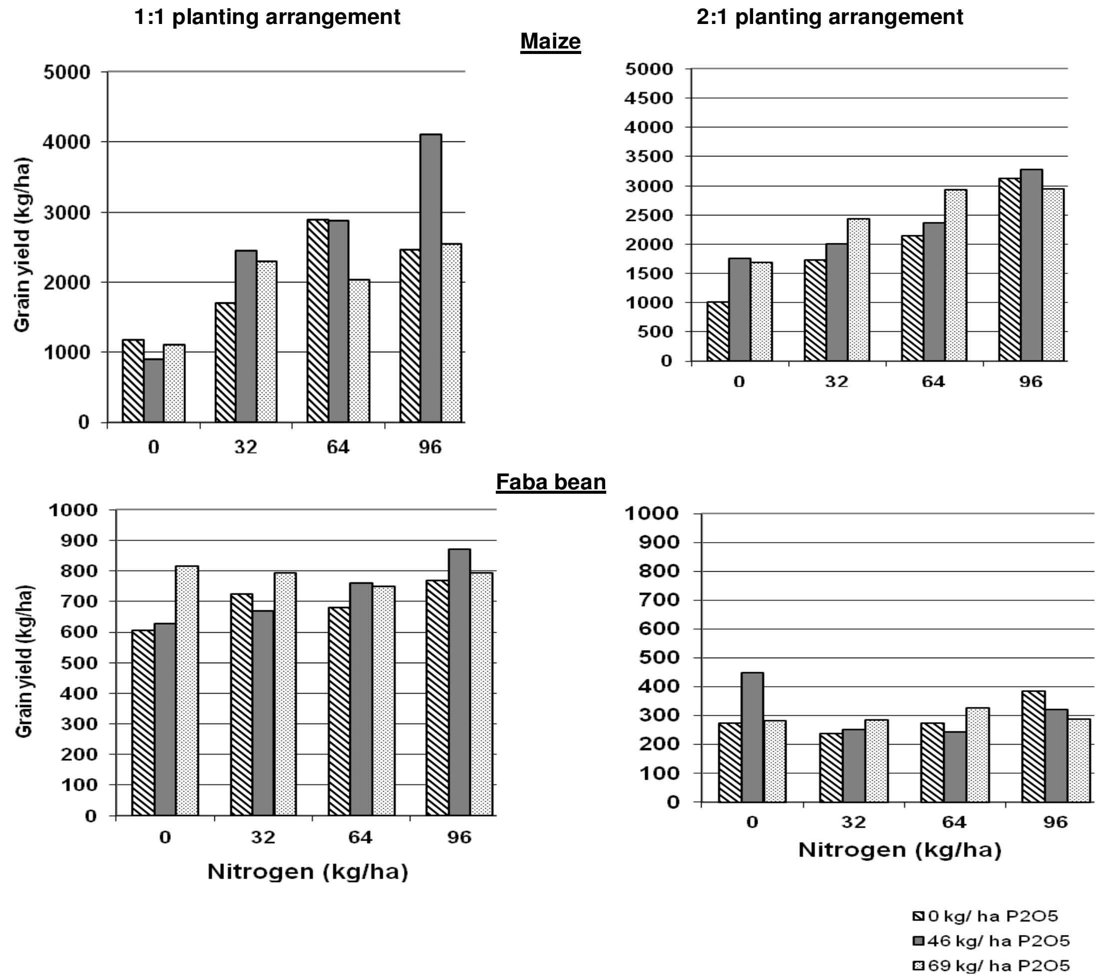

Figure 2. N rate X P2O5 rate X planting pattern interaction effect on maize and faba bean grain yield at Motta.

significant in affecting the yields of both component crops in both years at both locations (Table 1 and Table 2). At Adet, increasing levels of N rates from 0 to 96 kg/ha increased the grain yield in quadratic fashion in combination with 0 or 69 kg P_2O_5/ha as against almost linear increase when applied with 46 kg P_2O_5/ha under 1: 1 maize/faba bean planting arrangement (Figure 1). For the same rate of 64-46 N-P_2O_5 application, 1: 1 maize/faba bean planting arrangement resulted in 19% and 4 % yield increment over the sole maize planting at Adet and Motta, respectively (Table 1). Similarly using the same rate of 64-46 N-P_2O_5 application, 2: 1 maize/faba bean planting arrangement resulted in 6 % and 1 % yield increment over the sole maize planting at Adet and Motta, respectively(Table 1).

Application of 46 or 69 kg P_2O_5/ha increased the maize yield significantly in absence of N in 1:1 planting arrangement in contrast to that observed in 2:1 planting arrangement (Figure 1). While at Motta, interactions of planting pattern and phosphorous fertilizers, nitrogen and phosphorus fertilizers and also interaction of all the factors (planting pattern, nitrogen and phosphorus fertilizers) showed significant difference on maize grain yield (Table 1). Significant difference in faba bean grain yield due to planting pattern was observed at the two locations (Table 2). Application of different levels of N and P_2O_5 fertilizers to the maize rows did not bring significant difference in faba bean yield at both locations.

The statistical analysis for the parameters other than grain yield indicated that nitrogen fertilizer application significantly influence maize plant height at Motta and Adet (Table 3). Difference in P_2O_5 fertilizer levels influence maize plant height only at Adet. The highest maize plant height at Adet was obtained with the application of 64-46 N- P_2O_5. While at the other location, Motta, maize showed heist highest when 96-69 N- P_2O_5 was applied. Statistical difference in maize thousand-kernel weight was observed

Table 1. Effect of fertilizer, planting pattern and their interactions on the grain yield of maize

N/P_2O_5 (kg ha^{-1})	Adet			Motta		
	Intercropping Pattern		Mean	Intercropping Pattern		Mean
	1M:1Fb*	2M:1Fb**		1M:1Fb	2M:1Fb	
0/0	3194	3144	3169.0	1173	1010	1091.5
0/46	3747	4342	4044.5	906	1756	1331.0
0/69	4254	4437	4345.5	1101	1677	1389.0
32/0	4295	4598	4446.5	1701	1719	1710.0
32/46	6262	4974	5618.0	2443	2000	2221.5
32/69	6193	5609	5901.0	2286	2427	2356.5
64/0	5412	5150	5281.0	2486	2141	2313.5
64/46	6870	6134	6502.0	2983	2899	2921.0
64/69	6787	6302	6544.5	2870	2929	2899.5
96/0	5126	5012	5069.0	2454	3126	2790.0
96/46	7108	6469	6788.5	4110	3273	3691.5
96/69	5943	6647	6295.0	4540	4942	4741.0
Mean	5371	5296		2208	2280	
Sole Maize	5765			2873		
CV %		21.40			22.60	
	PP			PP	N x P_2O_5	Pp x P_2O_5	NxPpxP_2O_5
LSD						
1%	NS			NS	411	291	582
5%	NS			NS	545	385	770

*1M: 1Fb= 1Maize: 1 Faba bean alternate row planting
**2M: 1Fb= 2Maize: 1 Faba bean alternate row planting.

Table 2. Effect of fertilizer, planting pattern and their interactions on the grain yield of faba bean

N/P_2O_5 (kg ha^{-1})	Adet			Mota		
	Intercropping Pattern		Mean	Intercropping Pattern		*Mean*
	1M:1Fb	**2M:1Fb**		**1M:1Fb**	**2M:1Fb**	
0/0	579	248	413.5	604	275	439.5
0/46	652	238	445.0	627	449	538.0
0/69	578	259	418.5	815	283	549.0
32/0	730	192	461.0	724	237	480.5
32/46	548	205	376.5	668	252	460.0
32/69	625	235	430.0	792	286	539.0
64/0	617	211	414.0	678	274	476.0
64/46	489	295	392.0	761	243	502.0
64/69	607	181	394.0	749	327	538.0
96/0	587	230	408.5	768	386	577.0
96/46	637	268	452.5	872	322	597.0
96/69	616	245	430.5	794	287	540.5
Mean	605	234		738	302	
Sole faba bean	2198			1631		
CV(%)		34.6			25.3	
LSD	Pp	N X P_2O_5	Pp X NXP_2O_5	Pp	N X P_2O_5	Pp X NXP_2O_5
1%	290.1	NS	NS	314.0	NS	NS
5%	214.9	NS	NS	232.6	NS	NS

Table 3. Effect of fertilizer, planting pattern and their interactions on plant height of maize

N/P_2O_5 (kg ha^{-1})	Adet				Mota				
	Intercropping Pattern				Intercropping Pattern				
	1M:1Fb		2M:1Fb	Mean	1M:1Fb		2M:1Fb		Mean
0/0	165.0		165.7	165.35	158.5		147.3		152.90
0/46	180.7		182.1	181.40	153.5		148.4		150.95
0/69	189.9		182.2	186.05	159.2		160.8		160.00
32/0	195.3		192.8	194.05	159.2		167.5		163.35
32/46	208.4		194.3	201.35	169.9		155.5		162.70
32/69	208.9		199.6	204.25	156.2		178.9		167.55
64/0	199.2		202.7	200.95	178.9		168.8		173.85
64/46	201.5		216.9	209.20	178.0		176.2		177.10
64/69	206.6		211.2	208.90	177.5		187.9		182.70
96/0	202.4		194.8	198.60	187.2		184.6		185.90
96/46	211.6		210.8	211.20	194.2		190.9		192.55
96/69	212.8		209.1	210.95	188.0		197.8		192.90
Mean	198.5		196.9				171.7		172.1
CV(%)			6.2				8.5		
LSD	N	P_2O_5			N	P_2O_5	N X P_2O_5	Pp X P_2O_5	NXPpXP_2O_5
(1%)	55.2	47.8			6.9	NS	NS	8.4	NS
(5%)	73.0	63.3			9.1	NS	NS	11.1	NS

Table 4. Effect of fertilizer, planting pattern and their interactions on thousand kernels weight of maize

N/P_2O_5 (kg ha^{-1})	Adet				Mota				
	Intercropping Pattern				Intercropping Pattern				
	1M:1Fb		2M:1Fb	Mean	1M:1Fb		2M:1Fb		Mean
0/0	328		343	335.5	274		272		273.0
0/46	339		355	347.0	272		280		276.0
0/69	362		351	356.5	262		293		277.5
32/0	356		356	356.0	289		304		296.5
32/46	373		342	357.5	307		293		300.0
32/69	379		372	375.5	304		311		307.5
64/0	367		356	361.5	313		302		307.5
64/46	388		391	389.5	329		322		325.5
64/69	379		369	374.0	282		324		303.0
96/0	386		362	374.0	296		306		301.0
96/46	381		375	378.0	350		329		339.5
96/69	376		371	373.5	321		326		323.5
Mean	367.8		361.9		299.9		305.2		
CV(%)			5.47				10.67		
LSD	N	P_2O_5			N	P_2O_5	N X P_2O_5	Pp X P_2O_5	NXPpXP_2O_5
(1%)	9.3	8.1			15.1	NS	NS	NS	NS
(5%)	12.3	10.7			20.0	NS	NS	NS	NS

due to nitrogen and P_2O_5 fertilizers at the two locations (Table 4). The highest maize thousand seeds weights were observed with the application of 64-46 N- P_2O_5 and 96-46 N- P_2O_5 at Adet and Motta, respectively. Thousand seeds of faba bean showed significant response only to the application of P_2O_5 fertilizers at Adet, while it showed both for nitrogen and P_2O_5 fertilizers at Motta (Table 5). Maximum thousand seeds weights of faba bean were realized with the application of 64-46 N- P_2O_5 at Adet and with 96-46 N- P_2O_5 at Motta locations.Intercropping pattern, nitrogen, and P_2O_5 fertilizers at Adet significantly influenced faba bean plant height. However, only nitrogen fertilizer

Table 5. Effect of fertilizer, planting pattern and their interactions on thousand seeds weight (g) of faba bean

N/P_2O_5 (kg ha^{-1})	Adet			Mota				
	Intercropping Pattern		Mean	Intercropping Pattern				Mean
	1M:1Fb	2M:1Fb		1M:1Fb		2M:1Fb		
0/0	434.3	418.5	426.40	451.7		474.0		462.85
0/46	439.8	429.5	434.65	489.0		500.7		494.85
0/69	442.7	438.5	440.60	482.3		482.0		482.15
32/0	420.3	417.5	418.90	489.7		474.3		482.00
32/46	442.3	429.8	436.05	468.0		473.7		470.85
32/69	460.8	440.2	450.50	490.3		510.3		500.30
64/0	432.2	426.7	429.45	468.0		448.3		458.15
64/46	434.8	448.3	441.55	474.3		473.3		473.80
64/69	447.2	458.2	452.70	493.3		519.3		506.30
96/0	435.5	429.0	432.25	471.7		502.3		487.00
96/46	447.7	432.8	440.25	472.0		496.7		484.35
96/69	440.2	442.0	441.10	501.0		515.3		508.15
Mean	439.8	434.3		479.3		489.2		
CV(%)		5.9				4.2		
LSD	N	P_2O_5		N	P_2O_5	N X P_2O_5	Pp X P_2O_5	NXPpXP_2O_5
(1%)	NS	10.6		NS	9.44	23.1	NS	NS
(5%)	NS	14.0		NS	12.5	30.6	NS	NS

causes significant difference on plant height of faba bean at Motta. Number of faba bean seeds/pod and pods per plant were influenced by non-of the factors at the two locations.

Land equivalent ratio (LER) analysis was carried out in order to assess the advantage of intercropping over the sole cropping (Table 6). The LER is more than unity in most of the cases at the two locations which shows that intercropping of maize and faba bean is advantageous in many instances than planting each of the crops in sole. The highest LERs, 2.0 at Motta and 1.5 at Adet, were recorded when a planting pattern of 1 maize: 1 faba bean alternate rows was used with the application of 96-46 N-P_2O_5 kg/ha. The maximum LER values indicate the specific planting pattern and fertilizer level gave a 100% advantage at Motta and a 50% advantage at Adet than planting maize or faba bean independently.

The system productivity index (SPI) analysis which standardized the yield of the secondary crop (faba bean) in terms of the primary crop (maize) also identified the combinations that utilized the growth resources most effectively and maintained a stable yield performance. It showed that the 1M:1FB pattern gave the highest mean SPI value than the 2M:1FB planting pattern almost across the different fertilizer rates at the two locations (Table 7).

The intercropping enabled the maize to utilize nitrogen more efficiently even at the lower N rates (Table 8). For the same N rate, 64 kg/ha applied to sole maize, 1M:1FB and 2M:1FB intercropping patterns, the NUE was found to be higher at the the1M:1FB intercropping pattern followed by the 2M:1FB intercropping pattern (Table 8).

Economic analysis of the results has indicated that intercropping of maize and faba bean is advantageous than sole planting of the crops at the two experimental locations (Table 9 and Table 10). The highest economic advantage with a net return of Ethiopian Birr 31229 at Adet and Birr 21352 at Motta were observed for the treatment which is a combination of a planting pattern of 1 maize: 1 faba bean alternate rows combined with the application of 96-46 N- P_2O_5 kg/ha. The monetary advantage gained from the intercropping treatment is 50 % higher over the sole planting of maize at Adet while it is 128 % higher over the sole planting of maize at Motta.

DISCUSSION

Maize yield was observed to increase by intercropping it with faba bean. For the same fertilizer levels the maize yield is found to be higher than the sole planting when faba bean is intercropped with it. This finding is supported by a number of research results which reported an increase in the cereal yield component because of cereal-legume intercropping. After 4 years systematic field experiments on maize and faba bean intercropping, Li et al. (2007) confidentially reported that the maize yield in the intercropping over yield the sole maize yield by 43%. They found that maize over yielding resulted from

Table 6. Effect of fertilizer, planting pattern and their interactions on Land Equivalent Ratio (LER) at Adet and Motta (1999-2000)

Intercropping Pattern	N (kg/ha)	P2O5 (kg/ha)	Land Equivalent Ratio (LER)					
			Adet			Mota		
			Maize	Faba bean	Total	Maize	Faba bean	Total
1:1	0	0	0.55	0.26	0.8	0.41	0.37	0.8
1:1	0	46	0.65	0.30	0.9	0.31	0.38	0.7
1:1	0	69	0.74	0.26	1.0	0.38	0.50	0.9
1:1	32	0	0.75	0.24	1.0	0.59	0.44	1.0
1:1	32	46	1.09	0.25	1.3	0.84	0.41	1.3
1:1	32	69	1.07	0.28	1.4	0.79	0.49	1.3
1:1	64	0	0.94	0.28	1.2	1.00	0.42	1.4
1:1	64	46	1.06	0.22	1.3	0.99	0.47	1.5
1:1	64	69	1.18	0.28	1.5	0.70	0.46	1.2
1:1	96	0	0.89	0.27	1.2	0.85	0.47	1.3
1:1	96	46	1.23	0.29	1.5	1.42	0.53	2.0
1:1	96	69	1.03	0.28	1.3	0.88	0.49	1.4
2:1	0	0	0.55	0.11	0.7	0.35	0.17	0.5
2:1	0	46	0.75	0.11	0.9	0.61	0.28	0.9
2:1	0	69	0.77	0.12	0.9	0.58	0.17	0.8
2:1	32	0	0.80	0.09	0.9	0.59	0.15	0.7
2:1	32	46	0.86	0.09	1.0	0.69	0.15	0.8
2:1	32	69	0.97	0.11	1.1	0.84	0.18	1.0
2:1	64	0	0.89	0.10	1.0	0.74	0.17	0.9
2:1	64	46	1.19	0.13	1.3	0.82	0.15	1.0
2:1	64	69	1.09	0.08	1.2	1.01	0.20	1.2
2:1	96	0	0.87	0.10	1.0	1.08	0.24	1.3
2:1	96	46	1.12	0.12	1.2	1.13	0.20	1.3
2:1	96	69	1.15	0.11	1.3	1.02	0.18	1.2

Table 7. System productivity index (SPI) of maize and faba bean intercropping patterns at adet and Motta

	Location			
	Adet		Motta	
$N-P_2O_5$ (kg/ha)	1M:1FB	2M:1FB	1M:1FB	2M:1FB
0/0	4713	3794	2245	1498
0/46	5457	4966	2019	2553
0/69	5770	5116	2548	2179
32/0	6210	5102	2986	2140
32/46	7699	5512	3629	2447
32/69	7832	6225	3692	2935
64/0	7030	5703	4089	2627
64/46	7417	7644	4224	2790
64/69	8379	6777	3357	3509
96/0	6666	5615	3817	3811
96/46	8779	7172	5658	3845
96/69	7559	7290	3949	3451
Mean	6959	5910	3518	2815

its greater uptake of phosphorus mobilized by the acidification of the rhizosphere via faba bean root release of organic acids and protons. This finding is further supported by the result of Haigang et al. (2010) who had also attributed the maize grain yield increment in maize faba bean intercropping to the proton release by faba bean which play an important role in improving P uptake of intercropped maize. Fujita et al. (1992) had also re-

Table 8. Effect of maize faba bean intercropping on nitrogen use efficiency (NUE) of maize

Intercropping Pattern	N (kg/ha)	Adet		Motta	
		Maize grain yield (kg/ha)	NUE	Maize grain yield (kg/ha)	NUE
Sole mz	64	5765	90	2892	45
1M:1FB	32	5583	**174**	2143	**67**
1M:1FB	64	6111	95	3096	48
1M:1FB	96	6059	63	3135	33
2M:1FB	32	5060	**158**	2049	**64**
2M:1FB	64	6107	95	2976	47
2M:1FB	96	6043	63	3114	32

Table 9. Economic analysis of Maize-Faba bean intercropping at Adet

Intercropping Pattern	N (kg/ha)	P (kg/ha)	TVC (Eth. Birr)	NB (Eth. Birr)	MRR
2,1	0	0	20	14788	
1,1	0	0	40	17947	158
2,1	32	0	716	19404	2
1,1	32	0	736	23014	181
1,1	64	0	1431	25770	4
1,1	32	46	1544	28436	24
1,1	32	69	1949	28448	0
1,1	64	69	2644	29967	2
1,1	96	46	2936	31229	4

Table 10. Economic analysis of Maize-Faba bean intercropping at Motta

Intercropping Pattern	N (kg/ha)	P (kg/ha)	TVC (Eth. Birr)	NB (Eth. Birr)	MRR
2M:1FB	0	0	20	6495	
1M:1FB	0	0	40	10088	180
1M:1FB	32	0	734	12584	4
1M:1FB	64	0	1431	16215	5
1M:1FB	96	46	2936	21352	3

ported that there is a possibility of nitrogen nutrient transfer from the legume to the cereal which could improve the yield of the cereal during the intercropping of a cereal with a legume.

The total land productivity was improved in the intercropping systems supported by higher total LERs. The highest LER at Motta, 2.0, indicate that a land size which is double than the one used for the intercrops would have been required to get equivalent yield by planting the crops separately (Willey, 1991). Similarly the maximum LER value at Adet, 1.5, indicate additional 0.5 unit of land would have been needed to get equal yield by planting maize and faba bean in pure stands. LER was less than one at Motta when no nitrogen fertilizer was applied in the first planting pattern, 1 maize: 1 faba bean row. The result observed at Adet showed that the lower LER values were observed when the lowest nitrogen rates were used in the second planting pattern (2maize: 1 faba bean row intercropping). Variation in LER results due to difference in fertilizer levels, planting pattern and locations. The differences in LER showed that nutrient levels, planting pattern, and locations are determinant for an intercropping system to be advantageous or not. Similar results had been reported by different authors (Andrews and Kassam, 1983; Palaniapan, 1985; Trenbath, 1986). The LER analysis for the two locations has also revealed that suitable intercropping pattern for different areas might differ based on factors like the potential of the areas, the adaptability of the varieties, e.t.c., in line with the reports of some writers (Francis, 1986; Trenbath, 1986; Robinson, 1997).

Nitrogen use efficiency (NUE) is the fraction of applied nitrogen that is absorbed and assimilated by the plant. Intercropping, in the current investigation is found to increase the NUE of maize. It is believed by many authors that intercropping increase the nitrogen nutrient use efficiency of cereal crops. Woomer *et al.* (2004) reported that nitrogen fertilizer use efficiency of sorghum increased by 46% through intercropping it with cowpea. Fusuo and Long (2003) stated that root interactions between intercropped faba bean and maize enhances nitrogen and phosphorus uptake by intercropped maize. They elaborated that when the roots of two species intermingled, the N and P uptake were 38.4 g N m^{-2} and 4.2 g P m^{-2}, respectively. However, when the roots of the two species were separated completely using root bariers, they were reduced to 31.8 g N m^{-2} and 3.3 mg Pm^{-2}, respectively. Given to the nitrogen fixing nature of faba bean, the system is more reliable for sustainable and environmentally safe crop production than the sole production of the cereal, maize (Sanchez, 1975; Pal and Shehu, 2001). Improving a plant's ability to utilize nitrogen is a key component in enhancing environmental sustainability. For example, based on fertilizer use in 1996, just a 1% increase in the NUE for cereal production worldwide could save farmers over $234 million in fertilizer costs (Raun and Johnson, 1999), as well as decrease environmental consequences. It was further elaborated by Ahrens *et al.*, (2010) that improvement in Nitrogen use efficiency is a key issue for sustainable and profitable nitrogen use in high-input Agriculture.

In line with the LER, the economic analysis of maize faba bean intercropping in the highlands of northwestern Ethiopia indicated that intercropping of maize and faba bean is advantageous than sole planting of the crops at the two experimental locations. Generally the LER, SPI, NUE and economic analysis have confirmed that the intercropping practice of maize and faba bean is a superior and advantageous than sole cropping at both locations. Similar to the present investigation, Esmaeil *et al.*, (2010) reported maximum land equivalent ratio (1.97) and highest profitability through maize-faba bean intercropping. Several functions or parameters such as monetary advantage, aggressiveness, cash return, land equivalent ratio (LER), standard land equivalent ratio (LERs), relative value total (RVT) and equivalent yield have been used to assess the efficiency of intercrops or mixed crops. No single index is capable of giving a good comparison of intercropping system and so a number of indices are used together to assess the economic viability of the system (Hayder et al., 2003). However, LER is considered as the most appropriate in combination with the absolute yields of the crops (Esmaeil et al., 2010). The land equivalent ratio (LER) of intercrops provides an accurate assessment of the competitive relationship between the component crops, the best use of land as well as the overall productivity of the intercropping system (Hayder et al. 2003). The agronomists decides on the biological efficient, while the economist decides on the economic worthiness of the system using one or more than one of the economic indices. In general quite often a biological efficient system is also economically effective but it may also happen that a biologically efficient system is not economically viable and can not be recommended for wide scale adoptation by farmers (Hayder et al., 2003). Besides the biological and economical advantages, the maize faba bean intercropping system also offers the production of not only carbohydrate but also protein for the balanced nourishment of the farmer's family (Francis, 1986).

CONCLUSION

Intercropping is an important practice in the highlands of northwestern Ethiopia. It is considered as part of the subsistence farming designed to meet increase domestic food requirements. Intercropping is found to increase total grain production, provide diversity of products and reduce economic and environmental risks common in monoculture systems. The results of this experiment have shown that with intercropping, it is possible to produce additional yield of faba bean without any decrease, even with an increase of maize yield at both locations. The system offers a chance of profitable production as the LER and economic analysis had confirmed it. The combinations of 1 maize: 1 faba bean planting pattern with the application of 96-46 kg N-P_2O_5/ha was found to be the highest profitable treatment. It also gave the farmers option of producing both carbohydrate and protein at a time. The intercropping system is more appropriate in terms of sustainability than sole cropping of cereals since the legume component enrich the soil through nitrogen fixation. There was also good ground coverage during intercropping which was important with regard to soil conservation especially at the early stage of the maize crop. In conclusion therefore, for optimum sustainable productivity and profitability of maize–faba bean intercropping, a planting pattern of 1Mz:1FB with a fertilizer application of 96-46 kg N-P_2O_5/ha should be adopted in the highland of northwestern Ethiopia.

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