Ethiop. J. Biol. Sci. 12(1): 51-65, 2013
© The Biological Society of Ethiopia, 2013 ISSN: 1819-8678

SHORT COMMUNICATION

PRODUCTION EFFICIENCY OF MAIZE-BASED CROPPING SYSTEM AS AFFECTED BY INTERCROPPING DATE OF COMPANION LEGUME CROPS

Tamiru Hirpa[1,*], Heluf Gebrekidan[2], Kindie Tesfaye[2] and Asfaw Hailemariam[3]

ABSTRACT: Choosing appropriate legume crops and timing of their establishment is believed to be a relevant management option to minimize intercrop competition effects on the main crop. A field study was conducted at the experimental site of the Assosa Research Centre, located in western Ethiopia, to determine the production efficiency of maize-based cropping system under different interseeding dates of companion legume crops. The experiment was laid out in two factors randomized complete block design (RCBD) replicated three times. The factors employed were four legume crops namely, cowpea (*Vigna unguiculata*), soybean (*Glycine max*) and two common bean (*Phaseolus vulgaris*) varieties (Black Dessie and Awash Melka) intercropped with maize (*Zea mays*) at three times [simultaneous, four and eight weeks after maize emergence (WAME)] plus sole stand of the respective species. Significant ($p \leq 0.01$) effect of legume crops was observed on the total grain yield of the maize, where maize association with Black Dessie variety yielded the highest grain harvest (2.813 t ha^{-1}). The effect of intercropping time was, however, non-significant on total grain yield. Computation of the intercrop efficiency revealed that maize and Black Dessie variety complemented each other under intercropping simultaneously and four weeks after maize emergence, indicating that they were not competing for exactly the same ecological niches. Generally, the agronomic measurements and computations of intercrop efficiency affirmed that simultaneous intercropping of maize with Black Dessie variety was remunerative. The economic evaluation, on the other hand, indicated that the net benefit was higher for maize-soybean intercropped simultaneously. This economic performance was not affected under the worst possible input and output price scenarios as shown by the highest marginal rate of return. Hence, farmers stand to gain better when they intercrop maize with soybean or Black Dessie variety than the maize alone.

Key words/phrases: Actual yield loss, Intercrop efficiency, Interseeding, Marginal rate of return, Partial budgeting.

[1] Hawassa University, College of Agriculture, P.O. Box 30, Hawassa, Ethiopia. E-mail: thirpa2002@yahoo.com
[2] Department of Plant Sciences, Haramaya University, P.O. Box 138, Dire Dawa, Ethiopia
[3] National Soil Testing Centre, P.O. Box 141, Addis Ababa, Ethiopia
* Author to whom all correspondence should be addressed

INTRODUCTION

Intercropping system, particularly involving legume crops, is considered as sound means of yield improvement for the fact that it involves integrating crops through efficient use of resources and reductions in costly inputs (Keatings and Carberry, 1993; Morris and Garrity, 1993). The most important reasons to employ intercropping is the increase in productivity per unit of land per unit time via efficient use of radiant energy and space with crops in mixture (Baldy and Stigter, 1997; Sullivan, 2003). Growing mixtures could make an important contribution, especially in risk-prone and variable environments by minimizing crop failure due to biotic and abiotic stresses and secure harvest and nutritional balance in small-scale production systems (Zentner *et al*., 2002). In this regard, intercropping may be helpful for stabilization of household food supply and to solve future food problems in developing countries (Beets, 1982; Tsubo *et al*., 2001).

When a N_2-fixing association (legumes) is used in agriculture, it is presumed that the legumes will satisfy their own N requirements from N fixation, and that fixed N surplus to their needs could subsequently accrue in the soil and benefit other crops (Peoples and Craswall, 1992). In general, intercropping has been shown to be more productive than monocropping, even though combinations of certain crops usually result in increased competition among the components with consequential reduction in yields that may make some crop species unsuitable for such purpose. Hence, in view of intercropping legumes with cereals, the magnitude that legume species interact with the main crop to coexist productively is a major point of consideration (Kleinhenze, 1992).

The extent of competition-induced yield loss of the main crop in intercropping is likely to depend on the competitive ability of the component crops and their date of establishment; choice of compatible legume species and time of their establishment, which are relevant management options in improving the efficiency of this system. Aiming to maximize the yields of intercrop components through minimizing competition effects, selection of compatible genotypes and timing date of seeding are key agronomic issues in intercropping (Muoneke *et al*., 1997; Sarkar *et al*., 1998). Even though these agronomic options seem easily controllable management factors, their effects on intercrop yields need to be well understood and determined experimentally.

There appears inconsistency in reported works so far about effect of relative sowing time of intercrop components on yield and related attributes. Competitive advantage to the main crop in staggered sowing of the intercrops have been reported by different workers, in which earlier sown component showed better growth and yield than simultaneously sown ones (Akanvou *et al*., 2002; Singh and Rathi, 2003; Gbaraneh *et al*., 2004; Mousa *et al*., 2007). In contrast to the above, others have reported that the yields of main crops did not vary significantly with staggered sowing of the intercrop (Reddy and Vissur, 1997; Terao *et al*., 1997; Tarawali *et al*., 1999; Carruthers *et al*., 2000; Adipala *et al*., 2002; Silva *et al*., 2008). The present study was, therefore, initiated with the objective of determining the production efficiency of maize-based cropping system intercropped with legume crops at different dates under the soil and climatic conditions of Assosa areas.

MATERIALS AND METHODS

Description of the study area

This study was carried out in the cropping season of 2008 at the experimental site of the Assosa Research Centre, located in western Ethiopia. According to the classification of EARO (1999), the agro-climate of the area falls under sub-humid lowland (SH1) with a mono-modal rainfall pattern. The area receives an annual rainfall of 1,275 mm. The annual mean maximum temperature reaches 29°C while the mean minimum temperature is 15°C (Fig. 1). The dominant soil at and around the Research Centre is reddish brown, Nitosols.

Experimental treatments and field procedures

The experiment was laid out in two factors randomized complete block design (RCBD) replicated three times. The factors employed were four land race legume crops, namely, cowpea (*Vigna unguiculata*), soybean (*Glycine max*) and two common bean (*Phaseolus vulgaris*) varieties (Black Dessie and Awash Melka) intercropped with maize (*Zea mays*) at three times [simultaneous, four and eight weeks after maize emergence (WAME)] and sole stand of respective species was used as a control treatment plus sole crop of respective legume crops applied on 48 plots of 27 m^2 (4.5 by 6 m) size each.

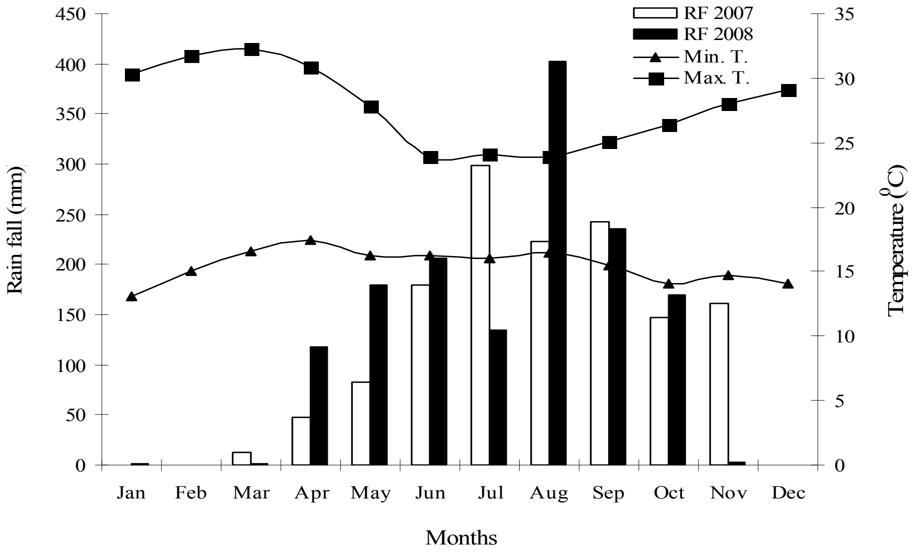

Fig. 1. Monthly mean minimum and maximum temperature (°C) and rain fall (mm) data of 2007 and 2008 in Assosa area. RF = Rain fall; T = Temperature. Source: Assosa Meteorological Service Branch Office.

Constant between and within row spacing of 75 cm by 30 cm for maize was used that gave a population of 44,444 plants ha^{-1}, both in sole and intercrop. Legumes in sole crop were seeded at a spacing of 37.5 cm by 15 cm that gave 177,776 plants ha^{-1}. In mixed plots, however, legume seeds were drilled in single row between two rows of maize crops at intra-row spacing of 15 cm resulting in legume population of 88,888 plants ha^{-1}. The sole crops of the respective components were established as control treatment to be used for the computation of agronomic efficiencies. Maize and legume seeds, obtained from the Assosa Research Centre, were sown at the rate of two seeds per hill, which were later thinned to obtain the required plant populations.

Data collection

To determine the response of main crop (maize) to legume intercropping, data were recorded on yield and yield components. Thousand seeds weight and total stover and grain yields were also recorded to determine treatment effects on maize crop.

Determination of intercrop efficiency

The relative productive capacity of intercropping maize with legume *vis-à-vis* the respective monocultures were computed for employed management strategies to determine efficiency of the cropping systems. For intercropping system where the primary objective is to produce fixed yield of one component (staple, maize in our case) and some yield of other crop, the concept of staple land equivalent ratio (SLER) has been proposed by Reddy and Chetty (1984) that employs the following formula:

$$SLER = \sum_{i=1}^{n} \frac{Y_i^i}{Y_i^m} \times Z_i \qquad (1)$$

where Y_i^i and Y_i^m are yields of 'i^{th}' component in intercrop and monocrop, respectively, whereas Z_i is its sown proportions in intercrop.

In contrast to SLER, area time equivalent ratio (ATER), which takes growth periods of individual intercrop into consideration, is more suitable to compare sole and intercrops in this experiment, as the growth period (life cycle) of the main crop and intercrops varied. Area time equivalent ratio was calculated by the formula given by Hiebsch and McCollum (1987):

$$ATER = \frac{\sum_{i=1}^{n} Ry_i \times t_i}{T} \qquad (2)$$

where Ry_i and t_i are relative yield and duration (days), respectively, for i^{th} species whereas T is duration (days) of the whole system.

Calculations of aggressivity (A) were used to evaluate the inter-specific competition among intercrops that relate the extent to which the proportion of yield of intercrops to area occupied by crops in the intercrop vary using the formula given by Willey and Rao (1980):

$$A = \frac{Y_i^i}{Y_i^m \times Z_i} - \frac{Y_j^i}{Y_j^m \times Z_j} \qquad (3)$$

where $Y^i{}_i$, Y_i^m and Z_i are as indicated in equation 1, and Y_j^i, Y_j^m and Z_j are similar indicators for the j^{th} component . Competitive ratio (CR) represents simply the ratio of individual LERs of the two component crops, taking into account the proportion of the crops in which they were initially sown. It was calculated using the following formula:

$$CR = \frac{LER_i}{LER_j} \times \frac{Z_j}{Z_i} \qquad (4)$$

where LER_i and LER_j are partial LERs of i^{th} and j^{th} component and Z_i and Z_j are as indicated in equation 3.

Evaluation of economic efficiency

The economic evaluation comprising a partial budget with dominance and marginal analysis was carried out as described by CIMMYT (1988). The minimum acceptable rate of return was set at 100%. To estimate economic parameters, products were valued based on market price collected from local markets during November 2008 where maize was 3.5 Ethiopian Birr (ETB) per kg of grain. Seed price of Black Dessie and Awash Melka varieties, cowpea and soybean were 4.7, 5.0, 6.0 and 6.5 ETB/kg, respectively. A wage rate of 10.0 ETB per work-day and oxen plow rate of 25.0 ETB per work-day were used.

Some of the concepts used in the partial budget analysis are mean grain yield ha^{-1}, gross field benefit (GFB), total variable cost (TVC) and the net benefit (NB). Yield (t ha^{-1}) refers to average grain yield of each treatment harvested from maize plus companion legume crop converted into maize equivalent. The GFB ha^{-1} is obtained as the products of real price and the mean yield for each treatment. The TVC in the partial budget analysis refers to the sum of costs of all variable inputs (seeds in our case) and management practices, whereas the NB ha^{-1} is the difference between the GFB and the TVC.

The dominance analysis procedure, which was used to select potentially profitable treatments, comprised ranking of treatments in order of ascending TVC from the lowest to the highest cost to eliminate those treatments costing more but producing a lower NB than the next lowest cost treatment. The selected and rejected treatments by using this technique are referred to as undominated and dominated treatments, respectively. For each pair of ranked undominated treatments, a percentage marginal rate of return (% MRR) was calculated. The percent MRR between any pair of undominated treatments denotes the return per unit of investment in crop management practices expressed as percentage. The MRR (%) is given by the equation:

$$MRR\ (\%) = \frac{\Delta NB}{\Delta TVC} \times 100 \qquad (5)$$

Thus, a MRR of 100% implies a return of one Birr on every Birr of expenditure in the given variable inputs.

Data analysis

The data collected were subjected to analysis of variance using MSTATC computer software. Treatments that showed significant effects on parameters measured were further separated using least significant difference (LSD) test at 95 and 99% confidence intervals.

RESULTS AND DISCUSSION

Effect on yield attributes of maize crop

Thousand seeds weight of maize crop was found significantly ($p \leq 0.05$) affected by the legume crops intercropped with maize as averaged across the interseeding time. In this regard, maize-Black Dessie association produced the heaviest kernels, 23.78 g heavier than that of maize intercropped with cowpea (Table 1). Maize-cowpea intercrop, on the other hand, gave the lightest maize grains (278.89 g). Thousand grain weight of maize crop, however, was found to be unaffected by interseeding time of legume crops ($p > 0.05$).

Harvest index (HI), the proportion of the mass of economic yield to total aboveground biomass of maize crop was found in this study, unaffected by companion legumes. In a similar observation, Carruthers *et al*. (2000) found no effect on maize HI due to intercropping of soybean and lupine. The effect of intercropping time of the legume crops was, however, found to be significantly affected ($p \leq 0.05$) by the HI of maize crop (Table 1). Early (simultaneous) association gave economic yield equal to half of the total mass, while delaying of legume intercropping that favoured the non-grain growth, resulted in the overall reduction of the harvestable proportion.

Table 1. Effects of legume species and intercropping time (WAME) on 1000 seeds weight (g) and harvest index of maize crop.

Companion legume species (LS)	Intercropping time (IT)†			Mean*
	Simultaneous	4 WAME	8 WAME	
		1000 seeds weight (g)		
Sole maize	NA	NA	NA	290.00^{ab}
Cowpea	273.3	281.7	282.7	278.89^{b}
Black Dessie	308.0	295.0	305.0	302.67^{a}
Awash Melka	273.3	294.7	290.0	286.00^{ab}
Soybean	279.7	273.7	298.7	284.00^{ab}
Mean	283.70	286.25	294.08	
	LS	IT	LS × IT	
LSD (0.01)	NS	NS	NS	
(0.05)	20.85	NS	NS	
		Harvest index (HI)		
Sole maize	NA	NA	NA	0.41
Cowpea	0.54	0.47	0.42	0.48
Black Dessie	0.49	0.42	0.44	0.45
Awash Melka	0.48	0.44	0.43	0.45
Soybean	0.47	0.39	0.44	0.43
Mean*	0.50^{a}	0.43^{b}	0.43^{b}	
	LS	IT	LS × IT	
LSD (0.01)	NS	NS	NS	
(0.05)	NS	0.06	NS	

*Means within a row or a column followed by the same letter are not significantly different at $p \leq 0.05$ probability level.
†WAME =Weeks after maize emergence; LS = Legume species; IT = Intercropping time; HI = Harvest index;
NA = Not applicable; NS = Non-significant

Effects on stover and grain yields of maize crop

The effect of intercropped legume crops on total maize stover production was found to be non-significant. Significant effect ($p \leq 0.05$) of intercropping time of legume crops was observed on biomass accumulation of maize crop, under which intercropping of legume crops on the same date with maize reduced the biomass accumulation. Increased biomass accumulation was observed with delaying interseeding of the associates (Table 2). Mburu *et al.* (2003) made similar observation in his test of intercropping dates of velvet bean (*Mucuna prurien*) with maize crop, where planting of the legume four weeks after maize emergence recorded the highest aboveground biomass. Maluleke *et al.* (2004), on the other hand, found reduced maize dry matter accumulation at the later stage of growth when planted simultaneously with lablab.

Table 2. Effects of intercropping time (WAME) of legume crops on total stover and grain yields (t ha^{-1}) of maize crops.

Companion legume species (LS)	Intercropping time (IT)†			Mean*
	Simultaneous	4 WAME	8 WAME	
Total stover yield (t ha^{-1})				
Sole maize	NA	NA	NA	7.09
Cowpea	3.17	5.15	6.44	4.92
Black Dessie	5.63	6.52	7.65	6.60
Awash Melka	3.51	6.07	5.93	5.17
Soybean	5.11	6.72	6.30	6.04
Mean*	4.35^{b}	6.12^{a}	6.58^{a}	
	LS	IT	LS × IT	
LSD (0.01)	NS	NS	NS	
(0.05)	1.51	NS	NS	
Grain yield (t ha^{-1})				
Sole maize	NA	NA	NA	2.812^{a}
Cowpea	1.51	1.88	2.0	1.795^{b}
Black Dessie	2.83	2.64	2.96	2.813^{a}
Awash Melka	1.37	2.57	2.11	2.018^{ab}
Soybean	1.96	1.77	2.12	2.147^{ab}
Mean	2.015	2.341	2.657	
	LS	IT	LS × IT	
LSD (0.01)	NS	NS	NS	
(0.05)	0.81	NS	NS	

*Means within a row followed by the same letter are not significantly different at p≤0.05 probability level.
†WAME =Weeks after maize emergence; LS = Legume species; IT = Intercropping time; NA = Not applicable; NS = Non-significant

Significant effect of cropping system (intercrops and sole maize) was observed on the overall grain yield of the main crop (maize). In this regard, association of maize with Black Dessie variety gave the highest grain output (2.813 t ha^{-1}), almost same with the sole maize. Cowpea as a companion crop, however, reduced maize grain yield by about 36.2% as compared to Black Dessie variety and the sole crop (Table 2). Even though a trend of increased means of maize grain yield was observed with delaying the time of legume intercropping, the effect was statistically non-significant (p> 0.05). The stability of maize grain yield over intercropping time could be attributable to a possible comparative advantage of maize over legumes in light interception and water and nutrient uptake. In agreement with this observation, others have also reported that the yield of main crops did not vary significantly with staggered sowing of the intercrop (Reddy and Vissur, 1997; Terao *et al*., 1997; Tarawali *et al*., 1999; Carruthers *et al*., 2000; Adipala *et al*., 2002; Mburu *et al*., 2003; Silva *et al*., 2008).

Intercrop efficiency

Staple land equivalent ratio and area time equivalent ratio

Among the four legume crops used for this study, only three of them, two common bean varieties (Black Dessie and Awash Melka) and soybean produced perfect pods and seeds; therefore, for the purpose of computations of intercrop efficiency, cowpea was excluded. In this respect, staple land equivalent ratio (SLER) and area time equivalent ratio (ATER) were used in the present study to determine the effect of intercropping on the land use efficiency. Significant treatment combination (associated legume species by intercropping time) effect was observed on partial SLER of maize, where values greater than one ($SLER_m$>1) were recorded in all associations of maize with Black Dessie variety and soybean interseeding 8 WAME (Table 3). The highest partial SLER value for maize was recorded when maize and Black Dessie were simultaneously intercropped, which showed that 16% more grain yield than sole maize was obtained in maize alone due to the association ($SLER_m$=1.16).

Table 3. Values of staple land equivalent ratio (SLER) and area time equivalent ratio (ATER) of maize (m) intercropped with legume crops (l) on three dates [simultaneously (I), 4 WAME (II) and 8 WAME (III).

Treatment combination		SLER			ATER		
		$SLER_m$	$SLER_l$	$SLER_{total}$	$ATER_m$	$ATER_l$	$ATER_{total}$
Black Dessie	I	1.04^{ab}	1.10^{ab}	2.14	1.04^{ab}	0.66^{ab}	1.70
	II	1.04^{ab}	0.42^{b-d}	1.46	1.04^{ab}	0.24^{bc}	1.28
	III	1.16^{a}	0.10^{d}	1.26	1.16^{a}	0.05^{c}	1.21
Awash Melka	I	0.56^{b}	1.15^{a}	1.71	0.56^{b}	0.67^{ab}	1.24
	II	0.97^{ab}	0.20^{d}	1.17	0.97^{ab}	0.11^{c}	1.08
	III	0.86^{ab}	0.28^{d}	1.14	0.86^{ab}	0.15^{c}	1.00
Soybean	I	0.77^{ab}	0.99^{a-c}	1.76	0.77^{ab}	0.79^{a}	1.56
	II	0.75^{ab}	0.61^{a-d}	1.36	0.73^{ab}	0.52^{a-c}	1.24
	III	1.09^{a}	0.39^{cd}	1.48	0.98^{ab}	0.28^{bc}	1.26
LSD (0.01)		NS	NS	NS	NS	NS	NS
(0.05)		0.5	0.68	NS	0.48	0.47	NS

Means within a column followed by the same letter are not significantly different at $p \leq 0.05$ probability level.
SLER = Staple land equivalent ratio; ATER = Area time equivalent ratio; NS = Non-significant;
Cowpea: No grain yield

While considering total SLER, all the treatment combinations valued $SLER_{total}$>1, ranging between 2.14 and 1.14, the highest being recorded by simultaneous intercropping of maize and Black Dessie variety. Similar to this finding, Chemeda Fininsa (1997) observed LER>1 in all combinations of bean/maize intercrop, while evaluating the effects of planting pattern, relative planting date and intra-row spacing of haricot bean/maize intercrop. Accordingly, intercrop combinations of this study could be considered more efficient than the respective monocrop from a land use perspective (Willey and Rao, 1980). Even though, values of $SLER_{total}$ in this study were statistically identical, declining trends were recorded with delayed interseeding of legumes, where simultaneous association of maize-Black Dessie variety gave the best ratio (Table 3).

The ATER provides a more realistic comparison of the yield advantage of intercropping over that of sole cropping than land equivalent ratio (LER), as it considers variation in time taken by the component crops of different intercropping systems (Khan and Khaliq, 2004). In all treatment combinations, the ATER values were smaller than SLER values (Table 5), indicating the over estimation of resource utilization in the latter. The values of $ATER_m$ in this study, ranged between 1.16 and 0.56, which followed a trend similar to that of $SLER_m$. In this regard, delaying underseeding of Black Dessie variety recorded the highest value ($ATER_m$=1.16), while simultaneous seeding of Awash Melka variety being the least ($ATER_m$= 0.56).

Aggressivity and competitive ratio

Calculations of aggressivity (A) pointed out that maize was dominated when legume crops were simultaneously seeded with maize, as indicated by negative A_{ml} values in Table 4.

Table 4. Aggressivity (A) and competitive ratio (CR) of maize (m) intercropped with legume crops (l) on three dates [simultaneously (I), 4 WAME (II) and 8 WAME (III)].

Treatment combination		A_{ml}	CR	
			CR_m	CR_l
Black Dessie	I	-0.06^{b-d}	2.39^{c}	0.55^{a-d}
	II	+0.62^{a-c}	6.09^{bc}	0.25^{b-d}
	III	+1.06^{a}	23.31^{a}	0.04^{d}
Awash Melka	I	-0.59^{d}	1.03^{c}	1.23^{a}
	II	+0.78^{ab}	9.71^{b}	0.11^{cd}
	III	+0.57^{a-c}	6.19^{bc}	0.22^{b-d}
Soybean	I	-0.22^{cd}	2.18^{c}	0.84^{ab}
	II	+0.14^{b-d}	4.17^{c}	0.79^{a-c}
	III	+0.70^{ab}	10.0^{b}	0.22^{b-d}
LSD (0.01)		0.86	5.27	NS
(0.05)		-	-	0.68

Means within a column followed by the same letter are not significantly different at the specified probability levels.
A = Aggressivity; CR = Competitive ratio; NS = Non-significant.
Cowpea: No grain yield

Under delayed seeding of legumes, however, the upper hand was taken by maize. The change in dominancy behaviour of maize across the intercropping time of legume crops in the present study is substantiated by the rising values of competitive ratio (CR) of maize crop with delay in seeding of legume crops (Table 4). Generally, maize was found in this study to be more competitive than the legume crops as indicated by higher CR_m values throughout the seeding dates (Table 4).

Economic efficiency of intercropping legume crops with maize

The partial budget presented in Table 5 showed that the least total variable cost (TVC) was recorded by sole cropping of maize, while the highest net benefit (NB) was obtained from maize-soybean (10162.90) followed by maize-Black Dessie variety (8041.90 ETB ha^{-1}) interseeded simultaneously, which gave 42.16 and 12.49% higher NB, respectively, than sole maize.

Table 5. Partial budget with dominance and marginal rate of return (MRR) analysis to establish the profitability of maize interseeding with legume crops at different time†.

Partial budget with dominance					
Treatment	**Yield (t ha^{-1})**	**GFB (EB ha^{-1})**	**TVC (EB ha^{-1})**	**NB (EB ha^{-1})**	**Dominance**
Sole maize	2.81	9842.00	2693.10	7148.90	Undominated
M-BD simultaneous	3.21	11235.00	3193.10	8041.90	Undominated
M-CP simultaneous	1.51	5285.00	3221.95	2063.05	Dominated
M-SB simultaneous	3.86	13510.00	3347.10	10162.90	Undominated
M-AM simultaneous	1.72	6020.00	3386.95	2633.05	Dominated
M-BD 4 WAME.	2.79	9765.00	3458.55	6306.45	Dominated
M-CP 4 WAME.	1.88	6580.00	3569.70	3010.30	Dominated
M-SB 4 WAME.	2.86	10010.00	3713.70	6296.30	Dominated
M-AM 4 WAME.	2.64	9240.00	3903.55	5336.45	Dominated
M-BD 8 WAME	3.00	10500.00	4018.55	6481.45	Dominated
M-AM 8 WAME	2.20	7700.00	4199.75	3500.25	Dominated
M-CP 8 WAME	2.00	7000.00	4260.00	2740.00	Dominated
M-SB 8 WAME	2.78	9730.00	4283.70	5446.30	Dominated

Marginal rate of return (MRR %)					
Treatment	TVC (EB ha^{-1})	NB (EB ha^{-1})	Incremental cost	Incremental benefit	MRR (%)
Sole maize	2693.10	7148.90			
M-BD simultaneous	3193.10	8041.90	500.00	893.00	178.60
M-SB simultaneous	3347.10	10162.90	154.00	2121.00	1377.27

†EB = Ethiopian Birr; GFB = Gross field benefit; TVC = Total variable cost; NB = Net benefit; MRR = Marginal rate of return; M = Maize; CP = cowpea; BD = Black Dessie; AM = Awash Melka; SB = Soybean; WAME = Weeks after maize emergence

This showed that intercropping of maize with soybean or Black Dessie variety is profitable than monocrop maize. Yilmaz *et al*. (2008) similarly reported 65-34% increase in monetary profit per unit area in intercropping legumes with maize compared to sole legume or sole maize planting. Santalla *et al*. (2001) also recorded more net income when bush beans was intercropped with sweet maize compared to sole maize cropping. Treatments of maize-soybean and maize-Black Dessie interseeded simultaneously were also found undominated by preceding treatments with lower TVC (Table 5). According to the marginal rate of return (MRR) analysis, intercropping of maize either with soybean or Black Dessie variety on the same date reduced the production costs and gave return of 13.77 and 1.78 Birr per one Birr investment (Table 5), which indicated that maize-soybean association simultaneously was marginally profitable.

CONCLUSION

According to the results of the present study, stover yield of maize crop increased with delay in intercropping of legume crops, probably due to the aggressively competitive ability of the legume crops when seeded on the same date with maize. The grain yield of maize, on the other hand, was statistically stable over intercropping times, which could be attributable to the partitioning of the greater proportion of assimilates to the reproductive growth than vegetative under simultaneous intercropping situation. This is indicated in the present study by significantly lower stover yield and corresponding higher HI values for simultaneous intercropping treatments. Significant companion species effect was observed on the grain yield of maize crop, where association of maize with Black Dessie variety gave the highest grain yield of maize (2.813 t ha^{-1}). Compared to maize-cowpea intercrop, association of maize with Black Dessie variety gave 56.71% more grain yield. Generally, maize and Black Dessie in intercrop complemented each other (weaker inter-crop competition than intra-crop competition) under simultaneous and 4 WAME interseedings, which means that they were not competing for exactly the same ecological niche. Competitiveness of the intercrops was, on the other hand, signified in the other combinations. In summary, intercropping of maize with legume crops has enormous potential in terms of improving yields and consequently returns to management, in which computations of agronomic performance and intercrop efficiencies on the perspective of land use, affirmed the highest productive efficiency of simultaneous intercropping of maize with Black Dessie variety. The economic analysis also revealed the marginal profitability of simultaneous maize-soybean intercropping.

ACKNOWLEDGEMENTS

The authors would like to take this opportunity to thank the Benishangul Gumuz Regional Bureau of Agriculture and Haramaya University for providing the finance and logistics to pursue this study. The authors would like to acknowledge Prof. Belay Kassa and Mr. Habtamu Hika who supported the authors earnestly throughout the study period.

REFERENCES

Adipala, E., Ocaya, C.P. and Osiru, D.S.O. (2002). Effect of time of planting cowpea (*Vigna unguiculata* (L.) walp.) relative to maize (*Zea mays* L.) on growth and yield of cowpea. *Tropicultura* **20**(2): 49-57.

Akanvou, R., Kropff, M.J., Bustiaams, L. and Becker, M. (2002). Evaluating the use of two contrasting legume species as relay intercrop in upland rice cropping system. *Field Crop Res*. **74**: 23-36.

Baldy, C. and Stigter, C.J. (1997). **Agrometeorology of Multiple Cropping in Warm Climates**. INRA, Paris.

Beets, W.C. (1982). **Multiple Cropping and Tropical Farming Systems**. Westview Press, Boulder.

Carruthers, K., Prithiviraj, B., Cloutier, Q.D., Martin, R.C. and Smith, D.L. (2000). Intercropping of corn with soybean, lupin and forages: Silage yield and quality. *Eur. J. Agron*. **12**: 103-115.

Chemeda Fininsa (1997). Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean/maize intercrop. *Afr. Crop Sci. J.* **5**(1): 15-22.

CIMMYT (1988). **From Agronomic Data to Farmer Recommendations: An Economics Training Manual**. Completely revised edition, Mexico.

EARO (Ethiopian Agricultural Research Organization) (1999). Distribution of existing research centres by agro-ecological zones. Addis Ababa, Ethiopia.

Gbaraneh, L.D., Ikpe, F.N., Larbi, A., Wahua, T.A.T. and Torunana, J.M.A. (2004). The influence of lablab (*Lablab purpureus*) on grain and fodder yield of maize (*Zea mays*) in a humid forest region of Nigeria. *J. App. Sci. Env. Manag.* **8**(2): 45-50.

Hiebsch, C.K. and McCollum, R.E. (1987). Area x time equivalency ratio: A method of evaluating the productivity of intercrops. *Agron. J.* **79**: 15-22.

Keatings, B.A. and Carberry, P.S. (1993). Resource capture and use in intercropping: Solar radiation. *Field Crop Res*. **34**: 273-301.

Khan, M.B. and Khaliq, A. (2004). Study of mung bean intercropping in cotton planted with different techniques. *J. Res. Sci.* **15**(1): 23-31.

Kleinhenze, V. (1992). **Intercropping with Legumes in the Tropics.** AVRDC–The World Vegetable Center, Taiwan, 62 pp.

Maluleke, H.M., Ayisi, K.K. and Whitbread, A.M. (2004). Lablab density and planting-date effects on growth and grain yield in maize-lablab intercrops. In: **Tropical Legumes for Sustainable Farming Systems in Southern Africa and Australia**, pp. 99-105 (Whitbread, A.M. and Pengelly, B.C., eds). ACIAR Proceedings No. 115, Australian Centre for International Agricultural Research, Canberra.

Mburu, M.W.K., Mureithi, J.G. and Gachene, C.K.K. (2003). Effects of mucuna planting density and time on water and light use in a maize-legume intercrop system. *Legume Res.* **9**: 2-8.

Morris, R.A. and Garrity, D.P. (1993). Resource capture and utilization in intercropping: Non-nitrogen nutrients. *Field Crop Res*. **34**: 319-334.

Mousa, M.A., Mohamed, A., Mohamed, F., Dokashi, M.H. and Elnobi, E.F.E. (2007). Intra-row intercropping of cowpea and cucumber with okra as influenced by planting date of secondary crops. *Ass. Univ. Bull. Environ. Res*. **10**(1): 13-32.

Muoneke, C.O., Asiegbu, J.E. and Udeogalanya, A.C.C. (1997). Effect of relative sowing time on the growth and yield of the component crops in okra⁄maize and okra⁄cowpea intercropping systems. *J. Agron. Crop Sci*. **179**: 179-185.

Peoples, M.B. and Craswall, E.T. (1992). Biological nitrogen fixation: Investments, expectations, and actual contributions to agriculture. *Plant Soil* **141**: 13-39.

Reddy, K.C. and Vissur, P.L. (1997). Cowpea intercrop growth and yield as affected by time of planting relative to millet. *Afr. Crop Sci. J*. **5**: 351-357.

Reddy, M.N. and Chetty, C.K.R. (1984). Staple land equivalent ratio for assessing the yield advantage from intercropping. *Exp. Agri.* **20**: 171-177.

Santalla, M., Rodino, A.P., Casquero, P.A. and de Ron, A.M. (2001). Interactions of bush bean intercropped with field and sweet maize. *Eur. J. Agron.* **15**: 185-196.

Sarkar, R. K., Chakraborty, A. and Bala, B. (1998). Effect of alternative cropping systems on yield and advantage in direct seeded upland rice areas in Indian sub-tropics. *J. Agron. Crop Sci.* **180**: 1-6.

Silva, P.I.B, Silva, P.S.L., de Oliveira, O.F. and de Sousa, R.P. (2008). Planting times of cowpea intercropped with corn in the weed control. Caatinga (Mossoró, Brasil), 21(1): 113-119 (www.ufersa.edu.br/caatinga) (Accessed on 16th May 2008).

Singh, K.K. and Rathi, K.S. (2003). Dry matter production and productivity as influenced by staggered sowing of mustard intercropped at different row ratios with chickpea. *J. Agron. Crop Sci.* **189**: 169-175.

Sullivan, P. (2003). **Intercropping Principles and Production Practices.** National Center for Appropriate Technology (NCAT), ATTRA publication, 135 pp.

Tarawali, G., Dembele, E., N'guessan, B. and Youri, A. (1998). Small holder use of Stylosanthes for sustainable food production in sub humid West Africa. In: **Cover Crops in West Africa: Contributing to Sustainable Agriculture**, pp. 107-170 IDRC, Ottawa, Canada.

Terao, T., Watanabe, I., Matsunaga, R., Hakoyama, S. and Singh, B.B. (1997). Agrophysiological constraints in intercropped cowpea: An analysis. In: **Advances in Cowpea Research**, pp. 129-140 (Singh, B.B., Mohan Raj, D.R., Dashiell, K.E. and Jackai, L.E.N., eds.). International Institute of Tropical Agriculture and Japan International Research Centre for Agricultural Sciences, Ibadan, Nigeria.

Tsubo, M., Walker, S. and Mukhala, E. (2001). Comparisons of radiation use efficiency of mono- and inter cropping systems with different row orientations. *Field Crop Res.* **71**(1): 17-29.

Willey, R.W. and Rao, M.R. (1980). A competitive ratio for quantifying competition between intercrops. *Exp. Agri.* **16**: 117-125.

Yilmaz, S., Atak, M. and Erayman, M. (2008). Identification of advantages of maize-legume intercropping over solitary cropping through competition indices in the East Mediterranean Region. *Turk J. Agric. For.* **32**: 111-119.

Zentner, R.P., Wall, D.D., Nagy, C.N., Smith, E.G., Young, D.L., Miller, P.R., Campbell, C.A., McConkey, B.G., Brandt, S.A., Lafond, G.P., Johnston, A.M. and Derksen, D.A. (2002). Economics of crop diversification and soil tillage opportunities in the Canadian prairie. *Agron. J.* **94**: 216-230.