Journal of Agricultural and Crop Research
Vol. 2(1), pp. 11-21, January 2014
ISSN: 2384-731X
Research Paper

Legume-based cropping for sustainable production, economic benefit and reducing climate change impacts in southern Ethiopia

Tenaw Workayehu

Hawassa Agricultural Research Center, Southern Ethiopia, P.O.Box 366, Awassa, Ethiopia.

E-mail: ttenaw@yahoo.com. Tel: +251-911904776.

Accepted 26h November, 2013

Abstract. Bean-maize (*Phaseolus vulgaris* L-*Zea mays*) intercrop is a common practice in southern Ethiopia. However, its effect on weed, productivity, and economic benefit has not been assessed. Climate change has significantly affected crop production in southern Ethiopia. Intercropping is used as a means to reduce the risk of climate change and sustain productivity and production. Agronomic and economic advantages of intercrops were evaluated over five years (2008-2012) at Awassa. Three weeding practices (0, 1, and 2 weeding), and single (MB) and double (MBB) rows of bean alternated with one row of maize were used in complete factorial experiment using randomized complete block design. Sole crop bean (SB) and maize (SM) were included. Variability in rainfall influenced the effect of weeding and intercropping. Seasons with better rainfall had less weed but more pods plant^{-1}, plant density, dry matter, bean and maize yield, energy value and economic benefit. Weeds in intercrop were 30% less compared with sole crop bean. Weed biomass was 16 and 30% less in MBB than SM and MB, respectively. Weeding increased plant height (16%), pods plant^{-1} (19%), grain (60%) and dry matter (38%) yields of bean, energy yield (56%), and monetary benefit (59%). Bean yield was 52 to 68% greater with weeding compared to the unweeded. In the dry year of 2011, weeding increased grain yields of bean and maize by 44 to 124% and 33 to 121% more than the unweeded, respectively. Maize yield varied between 43 and 66% with weeding compared with weed control. Bean yield and total land equivalent ratio (LER) in MB was 35 and 22% more than in MBB, respectively. Maize yield in MB was 15% lower than sole maize but 19% more than MBB. Energy yield and monetary benefit were 19 and 29% higher in MB than MBB, respectively. Intercropping resulted in LER of 20 to 67% yield benefit over sole crop and saved 38% more farm land. Overall, intercropping suppressed weeds and was more productive and economical than sole crop, which reduced risk of climate change and sustained crop production. This would benefit farmers in reducing the risk of climate change and alleviating food shortage.

Keywords: Cropping system, maize, monetary benefit, *Phaseolus vulgaris*, productivity, weed management.

INTRODUCTION

Common bean is grown in an area of more than 244,000 ha by more than 2 million smallholder farmers in Ethiopia (CSA, 2010). The wide range of growth habits of bean varieties enables the crop to grow well under different agro-ecological conditions. South, Oromiya and Amhara regions of Ethiopia are the major producing areas of common bean. Common bean occupies 7.6% of the total grain crop area and covers 5.51% of the regional total grain production (CSA, 2010).

At the national level, bean plays a significant role as a commodity crop earning a considerable amount of foreign exchange for the country and cash for farmers (CACC, 2003). Maize (*Zea mays* L.) and common bean (*Phaseolus vulgaris* L.) constitute vital components of the food consumed in many parts of Ethiopia. About 69, 9.3 and 12.4% of the total production of bean is used for home consumption, seed and sale, respectively. Bean is consumed in traditional dishes, and dry beans are commonly prepared in the form of *nifro* (local name for boiled grain), mixed with sorghum or maize or with *wasa* (local name made from falls banana and common bean mixture) and *wat* (local names for sauce) and with *Koch (*local name made from falls banana*)*. Fresh beans (mature and green beans) are a vegetable for local consumption and export, and are an important source of protein (22%). A more diverse diet that includes intercrops such as beans and vegetables should improve the nutrition of farmers and their families (Setegn and Legesse, 2010).

Farm land holding is small and varies between 0.10 and 0.50 ha (46.5% of the farmers in the region) followed by 25.4% of the total holders having 0.51 to 1 ha (CACC, 2003). This led farmers to use multiple cropping mainly intercropping to increase yield per unit area and reduce the risk from crop failure due to climate change. Intercropping becomes a common practice in the southern region of Ethiopia (Getahun and Tenaw, 1990). Thus, farmers get additional income and alleviate food shortage period that occurs between May and July. Cereals mainly maize and sorghum are intercropped with pulse bean (*Phaseolus vulgaris* L.), faba bean (*Vicia faba*), and field pea (*Pisum sativum* L.) (Getahun et al., 1991). About 57 to 100% of maize production area is intercropped in early and late *belg* (small rains) seasons and intercropped mainly with bean (54 to 71%). Another report also indicated that 85% of all sorghum in the eastern highlands of Ethiopia is intercropped with beans (Setegn and Legesse, 2010).

Maize-bean intercropping is an integral part of the cropping system in small-holder farmers expecting better yield and weed suppression (Getahun and Tenaw, 1990), and provides balanced diet compared to the predominant cereal monoculture and gives high total productivity compared to sole crops of bean and maize. However, this results in crop competition in particular when moisture shortage prevails. About 55% of the farmers in the region reported shortage or unavailability of fertilizer, late supply and high price of fertilizers, and weeds as major production problems. Intercropping of non-cereals with legumes may be an alternative to reduce low soil fertility and weed infestation, and increase grain yield. Legumes in association with non-legumes help utilization of N fixed by legumes with substantial residual buildup in the soil.

Weed management is commonly very labor intensive in smallholder agriculture and often constrains the land area that can be farmed and inadequate weed control is often a major constraint to yield (Wortmann et al., 2009). Crop suppression of weeds is an important component of weed management. Weeds are commonly more suppressed by crop competition with intercropping compared with sole cropping (Getachew et al., 2007; Odhiambo and Ariga, 2001; Moynihan et al., 1996).

Various studies showed that intercropping is beneficial in increasing land productivity (Weil and McFadden, 1991), light interception (Ennin et al., 2002), income (Niringiye et al., 2005; Mandal et al., 1990), suppressing weeds (Baldev et al., 2004; Musambasi et al., 2002; Moynihan et al., 1996), and reducing erosion hazard (Setegn and Legesse, 2010; Tenaw et al., 2006; Reynolds et al., 1994). Kariaga (2004) reported better protection of the soil against erosion from intercropping of maize and cowpea. Other studies show that intercropping reduces the hazard coming from climate change through increasing production and productivity (Inns, 1997), thus sustaining food production since Ethiopian agriculture is rainfed-dependent.

Despite the practice of intercropping, information is not available on the yield potential of intercropped crops with different row arrangements; moreover, their effect on weed and economic benefit was not assessed. In addition, effect of seasonal variation on treatment factors and its interaction on growth and grain yield of intercropped crops was not studied. The objective of this study was, therefore, to assess the effects of season and bean-maize intercrop on weed, bean and maize grain yields, land use efficiency, energy yield and economic benefit.

MATERIALS AND METHODS

Site description

The experiment was conducted at Awassa located 38.5 E, 7.1 N, and at an altitude of 1700 masl from 2008 to 2012. The *belg* growing season (local name for dry season) is from February to May and the more important *meher* growing season (local name for summer season) is from June to September. The bimodal rainfall has an annual mean of 1021 mm with 36.4 and 51.3% receiving in *belg* and *meher* seasons, respectively. The mean monthly maximum and minimum temperatures, May (planting time) to September (crop maturity), vary from 24 to 27°C and 12.8 to 13.8°C, respectively. The soil of the experimental site was loam Eutric fluvisol or Fluvent with pH 7.0 (1:2.5 soil/water by weight/volume), 1.9 g kg^{-1} total N (low), 57 mg kg^{-1} available P (high), 23.4 cmol kg^{-1} CEC (medium); 3.25 cmol kg^{-1} exchangeable K (high), 2.39 cmol kg^{-1} exchangeable Mg (low); 10.53 cmol kg^{-1} exchangeable Ca (high), and organic carbon content 2.34% (medium) (Landon, 1984).Soil water holding at field capacity was 0.245 m^3 m^{-3}. Farmers' livelihood are based on rainfed agriculture, mixed agriculture, raising both crop and livestock, and use multiple cropping system.

Treatments and experimental design

Maize (cv. BH140) and bean (cv. Roba) were intercropped with one row of maize alternated with single (MB) or double rows of bean (MBB) and three weeding frequencies. The weeding treatments were no weeding (W0), hand-weeding once at 30 days after emergence (DAE) (W1), and hand-weeding twice at 30 and 60 DAE (W2). Sole crop maize (SM) and bean (SB) treatments weeded twice were included for the determination of production efficiency. Plant population of sole and intercropped maize was 5.0 plants m^{-2} with 0.8 m row spacing. Plant population of sole and intercropped bean in MBB was 25 plants m^{-2} with 0.40 m rows while row spacing of intercropped bean in MB was 0.8 m with 12.5 plants m^{-2}. The complete factorial experiment was in a randomized complete block design with four replications.

Crop management

The experimental plot was plowed and disk tilled using tractor. The planting dates were May 18, 6, 7, 12, and 9 of 2008, 2009, 2010, 2011, and 2012, respectively, and the respective harvesting dates were October 6, 2, 3, 5, and 4. Bean was harvested in the first week of August. There was no serious problem of diseases or insects across years. Urea N was top dressed at the rate of 46 kg N ha^{-1} to both sole crop and intercrop maize at the 6 to 8 leaf growth stage.

Data collection

Plant population at harvest, pods $plant^{-1}$, seeds pod^{-1}, 1000 seed weight, total dry matter of bean and grain yields of maize and bean were determined. Of the six intercropped bean rows, the center four rows were used to estimate plants m^{-2}, grain and dry matter yields of bean. Ten plants per plot were sampled to determine pods $plant^{-1}$ and seeds pod^{-1}. Moisture content of the grain of bean was adjusted to 10% using seed moisture tester. The productivity of intercropping was assessed using land equivalent ratio (LER): LER = Ym/Ysm + Yb/Ysb) (Adu-Gyamfi et al., 1997) where, Ym and Yb are grain yields of intercropped maize and bean; Ysm and Ysb are the grain yields of sole cropped maize and bean and LERm and LERb are partial land equivalent ratios of maize and bean, respectively. When LER < 1 there is a disadvantage to intercropping and the resources are used more efficiently by sole crop than by intercrop; when LER = 1 there is no intercropping advantage or disadvantage, in respect to sole crop; when LEr > 1 there is an intercropping advantage in terms of improved use of environment resources for plant growth (Kitonyo et al., 2013; Mariotti et al., 2006). Energy yield (EY) using caloric measurement was also used to evaluate how much energy was produced from intercropping system relative to sole crops, and coefficient values of 17.8 and 16.8 KJ g^{-1} were used to convert crop yield into energy yield for maize and bean, respectively (Tsubo et al., 2004) since it is important in most diets. Competitive ratios (CR), which represents the ratio of individual LERs of the two component crops and takes into account the proportion of the crops on which they are initially sown (if the value of CR is greater than 1, the competitive ability of the crop is more). Competitive ratio was calculated using: CR = (LERm/LERb) × (Zbm/Zmb), where Zbm and Zmb are proportion area of intercropped maize (0.50 and 0.33 for MB and MBB, respectively) and bean (0.50 and 0.67 for MB and MBB, respectively), respectively (Mahapatra, 2011). It gives an assessment whether the association of the two component crops is advantageous or not. In other words, it gives a clear idea about which crop is more competitive in association. Weed biomass was taken during the first and second weeding from the net harvestable area of the plot, air dried, and weighed for three seasons. Daily rainfall records were kept.

Data analysis

Economic analysis of maize bean intercropping was conducted using yield and the market price of maize and bean (5 Ethiopian Birr (EtB) kg^{-1} for each with an exchange rate of 1 USD = 9.60 EtB) were used to calculate gross income (GI). Treatment variable costs (VC) were determined with: seed rate of 35 and 70 kg ha^{-1} for MB and MBB intercrops, respectively, with EtB 11.43 kg^{-1} seed; labor required for planting the MB and MBB of 50 and 70 person-days ha^{-1}, respectively, at EtB 10 $person^{-1}$ day^{-1}; and labor required for W1 and W2 of 20 and 40 person-days ha^{-1}, respectively, at EtB 10 $person^{-1}$ day^{-1}. Other costs were considered constant across treatments. Net return (NR) was determined as the difference of gross income and variable costs (Babatunde, 2003).

Analysis of variance (ANOVA) was conducted using SAS (SAS, 2000) to determine weed and crop response to weeding frequency and row arrangement (spatial). Data for plant population, seeds pod^{-1} and pods $plant^{-1}$ were log transformed, and LER and competitive ratio were arcsine transformed. Because of the interaction effect of year with weeding frequency and row arrangement, combined analysis over years was conducted after test of homogeneity (Gomez and Gomez, 1984). Tukey's test of significance was used to differentiate treatment means. Stepwise multiple regression analysis was conducted to see the relationship between grain yield of maize and bean as well as weeding frequency and row arrangement. Best fit regression equations were calculated (n = 240).

RESULTS

Rainfall pattern

Distribution of rainfall during the reproductive stages was

Table 1. Rainfall distribution (mm) during the growing seasons of 2008-2012 in comparison with the long-term (1972-1996).

Month	Rainfall during the experimental seasons					Long-term rain (1972-1996)
	2008	2009	2010	2011	2012	
May	231.5	88.0	99.2	67.3	142.1	130.2
June	294.7	114.3	41.1	143.5	29.5	109.7
July	147.1	93.3	189.3	151.2	76.5	134.7
August	117.6	84.0	147.4	79.3	185.8	140.0
September	161.2	150.0	169.3	157.5	139.8	132.6
Total (May - Sep)	952.1	529.6	646.3	598.8	573.7	647.2

Table 2. Effect of weeding frequency (WF) and cropping system (CS) on weed, bean and maize in southern Ethiopia.

Source of variation	Wb	Ht	Swt	PP	SP	PD	Bgy	Bby	Mgy	LER_b	LER_m	LER_t	EY	NI
Y	**	*	**	**	**	**	**	**	**	**	**	**	**	**
WF	**	*	ns	**	ns	ns	**	**	**	ns	*	ns	**	**
CS	**	ns	ns	**	ns	*	**	**	**	*	*	**	**	**
Y*WF	**	ns	ns	*	ns	*	**	**	**	*	**	**	**	**
Y*CS	**	ns	**	ns	ns	ns	**	ns	**	ns	ns	ns	**	**
WF*CS	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Y/S, year/season; WF, weeding frequency; Ht, bean plant height; CS, cropping system; Wb, weed biomass, Swt, bean seed weight; pp, pods plant^{-1}; SP, seeds pod^{-1}; PD, plant density at harvest; Bgy, bean grain yield; Bby, bean biomass yield; Mgy, maize grain yield; LER_b and LER_m, partial LER of maize and bean; LER_t, total land equivalent ratio; EY, energy yield; NI, net income; *, **, and ns indicate significant difference at 5 and 1% probability and not significant, respectively.

good in 2009, 2010 and 2012 seasons with 18, 0 and 11% less than the long term mean, respectively. The rainfall in 2008 was 47% above average. Precipitation in 2011 was 7.5% less and 61% of the growing period without rain and much fell in heavy rainfall events. The heavy rainfall in each season caused transient water logging, which is likely to have reduced crop growth, performance and yields (Table 1).

Weed biomass

The weeding frequency and row arrangement effects varied by year and treatment by year interactions and were significant (Table 2). Weed biomass was 49% less with weeding in 2009 compared with W0 while weeding frequency was not significant in the other years. Weed biomass was much greater in 2011, a year with relatively poor crop performance, compared with 2009 and 2012 (Table 3). The cropping system by year interaction affected weed biomass with more biomass in sole bean compared with other cropping systems in 2009 but with no cropping system effect in 2011 despite high weed biomass; but significantly lower weed biomass in SM and MBB in 2012. Weed biomass was less with MBB compared with other maize cropping systems across the three seasons. The weeding frequency by cropping system interaction was not significant for weed biomass.

Plant height

Frequency of weeding and variation in year significantly affected plant height of bean (Table 2). Bean plants were 12% taller in 2010 (r = 0.25*) compared with 2012, and 15.6% taller with weeding compared with no weeding (Table 4). Weeding once and twice increased plant height by 15 and 16%, respectively, over the weedy check (unweeded control) although variation between W1 and W2 was not significant. An increase in weeding was accompanied by an increase in plant height (r = 0.27*), and 7% of the total variations were attributed to weeding as indicated by the regression equation: Plant height = 34.37 + 2.96W (R^2 = 0.07*) (n = 72), where W-weeding frequency.

Bean yield components

Pods plant^{-1} were 31.3 and 12.4% more with MBB compared with SB and MB (Table 4). Pods plant^{-1} ranged from 5.7 to 17.1 in 2011 and 2008, respectively, with an overall mean of 9.6 (Table 6). Pods plant^{-1} were 56 and 102% more in 2010, and 12 and 25% more overall years, with one and two weeding, respectively, compared to no weeding.

Seed weight was affected by years and the year by cropping system interaction (Table 2). The interaction

Table 3. Weeding frequency (WF) and cropping system (CS) effects on weed biomass in bean-maize intercrop in southern Ethiopia.

Treatment	2008	2009	2010	2011	2012
Weed biomass yield: WF effect					
W0		1.64[b†]		3.56[a]	1.56[bc]
W1		0.75[c]		3.63[a]	0.77[c]
W2		0.91[c]		0.65[ab]	0.81[c]
S.E.(D.F.) 0.22 (16)					
Weed biomass yield: CS effect					
SM		0.66[c]		3.21[a]	0.95[c]
MB		0.83[c]		3.74[a]	1.21[bc]
MBB		0.83[c]		2.34[ab]	0.90[c]
SB		2.07[ab]		3.82[a]	1.12[bc]
S.E.(D.F.) 0.25 (6)					

†The same letter within a trait indicate no significant differences at α = 5%; S.E is standard error of the mean; SE (df)- standard error of the mean and degree freedom, respectively.

Table 4. Effect of season and weeding frequency on plant height of bean (cm) and row arrangement on pods plant^{-1}.

Year	Plant height (cm)	Weeding frequency (WF)	Plant height (cm)	Cropping systems (CS)	Pods plant^{-1}	Plant density at harvest (plants m^{-2})
2010	42.5[a†]	W0	36.5[b]	SB	9.7[b]	22[a]
2012	38.1[b]	W1	42.0[a]	MB	8.3[b]	18[b]
		W2	42.4[a]	MBB	10.9[a]	21[a]

†The same letter in a column of each trait showed no significant difference at 5% probability level.

Table 5. Effect of cropping system on total dry matter of bean, and row arrangement on partial LER_m and LER_b.

Cropping system	Total dry matter (Mg ha^{-1})	Row arrangement	Partial LER	
			LERm	LERb
SB	3.50[a†]			
MB	2.80[b]	MB	0.90[a]	0.88[a]
MBB	2.23[c]	MBB	0.70[b]	0.76[b]

†The same letter in a column of each trait showed no significant difference at 5% probability level.

effect was due to an 11.7% increase in seed weight with MB compared to SB in 2008 (Table 6). Seed weight varied from 163 to 208 mg seed^{-1} in 2008 and 2012, respectively, with an overall mean of 177 mg seed^{-1}.

Bean plant density was 17 and 14.2% less with MB compared with SB and MBB, respectively (Table 4). Mean bean plant density differed by year and ranged from 15 to 29 plants m^{-2} in 2008 and 2010, respectively. Plant density was not affected by weeding frequency except in 2011 when plant density was 59% greater with weeding compared with no weeding (Table 6).

Bean grain and biomass yields

Grain yield was more with weeding compared with no weeding in 2010, 2011, and 2012 with an overall increase of 60% (Table 6). Weeding once did not affect the yield except that the yield was increased by 56% and decreased by 18% with two compared with one weeding in 2011 and 2012, respectively. Grain yield was less for MBB compared with SB in 2009, 2010, and 2012 with an overall reduction of 40%. Grain yield was less for MB compared with SB in 2012 only with an overall reduction of 19%. Biomass yield was 38.9% greater with SB compared with intercropping, and it was 25.6% more dry matter in MB compared with that in MBB (Table 5). The average biomass yield of bean was 25 and 33.7% less with no weeding compared with weeding once or twice, respectively (Table 6). Weeding increased the biomass by 42.3% compared with no weeding. Even weeding increased the mean dry matter yield of bean by 86.4%

Table 6. Effect of weeding frequency (WF) and cropping system (CS) on pods plant^{-1}, thousand seed weight, plant density at harvest, grain and total dry matter yields and harvest index of bean, and maize grain yield in maize-bean intercrop.

Treatment	2008	2009	2010	2011	2012
Pods plant^{-1} (no.): WF effect					
W0‡	17.1^{a}	7.0^{d-f}	$6.3^{ef†}$	4.6^{f}	7.9^{c-e}
W1	16.3^{a}	6.3^{ef}	9.8^{c}	6.2^{ef}	9.4^{cd}
W2	17.8^{a}	7.2^{d-f}	12.7^{b}	6.2^{ef}	9.9^{c}
		S.E.(D.F.) 0.91 (8)			
Thousand seed weight (g): CS effect					
SB	155.0^{e}	169.8^{b-e}	180.7^{bc}	170.0^{b-e}	208.3^{a}
MB	173.1^{b-d}	173.7^{b-d}	154.7^{c}	180.0^{bc}	205.8^{a}
MBB	162.5^{de}	173.0^{b-d}	165.3^{c-e}	183.3^{b}	206.0^{a}
		S.E.(D.F.) 4.50 (8)			
Bean population at harvest (plants m^{-2}): WF effect					
W0	14^{hg}	29^{a}	19^{de}	11^{i}	22^{bc}
W1	17^{fg}	30^{a}	20^{b-d}	17^{e-g}	22^{bc}
W2	13^{h}	28^{a}	20^{cd}	18^{d-f}	21^{b-d}
S.E.(D.F.) 1.73 (8)					
Bean grain yield, Mg ha^{-1}: WF effect					
W0	0.99^{d-g}	0.56^{i}	0.48^{i}	0.62h^{i}	1.20^{c-e}
W1	1.02^{d-f}	0.66^{g-i}	1.24^{cd}	0.89^{e-h}	2.03^{a}
W2	1.31^{cd}	0.85^{f-h}	1.24^{cd}	1.39^{bc}	1.66^{b}
S.E.(D.F.) 135.9 (8)					
Bean grain yield Mg ha^{-1}: CS effect					
SB	1.07^{b-e}	0.89^{c-f}	1.48^{c-f}	1.09^{b-f}	2.16^{a}
MB	1.38^{b-d}	0.70^{fg}	0.90^{ef}	1.00^{d-f}	1.46^{b}
MBB	0.87^{d-f}	0.48^{g}	0.58^{g}	0.82^{ef}	1.28^{bc}
S.E.(D.F.) 135.0 (8)					
Bean dry matter Mg ha^{-1}: WF effect					
W0	4.31^{ab}	1.48^{ef}	1.13^{f}	1.54^{ef}	2.66^{cdef}
W1	4.18^{abc}	2.02^{def}	2.22^{cde}	2.26^{def}	4.10^{abc}
W2	4.55^{a}	2.94^{bcde}	2.37^{bcde}	3.48^{abcd}	3.39^{abcd}
S.E.(D.F.) 335.3 (8)					
Maize grain yield, Mg ha^{-1}: WF					
W0	3.43^{cd}	2.77^{de}	2.85^{de}	1.32^{f}	3.32^{cd}
W1	3.24^{cd}	2.96^{cd}	7.22^{a}	1.75^{f}	4.48^{bc}
W2	3.32^{cd}	3.79^{c}	7.48^{a}	2.92^{de}	5.19^{b}
S.E.(D.F.) 349.1(8)					
Maize grain yield, Mg ha^{-1}: CS					
SM	3.81^{c}	3.36^{cde}	6.85^{a}	2.43^{fg}	5.40^{b}
MB	3.44^{cde}	3.55^{cd}	5.79^{b}	1.81^{g}	4.01^{c}
MBB	2.74^{def}	2.63^{ef}	4.90^{b}	1.75^{g}	3.59^{c}
S.E.(D.F.) 410.3 (8)					

†The same letter in a column of each trait showed no significant difference at 5% probability level.
‡W0, W1 and W2, SM, SB, MB, and MBB are no weeding, and weeding once and twice, sole crops of maize and bean, alternate row intercrop planting of maize and bean, and intercrop maize alternated with two rows of bean, respectively; S.E is standard error of the mean; SE (df)- standard error of the mean and degree freedom, respectively.

compared with no weeding during the dry season of 2011.

Maize grain yield

Effects of weeding and cropping system were variable depending on seasonal rainfall (Table 2). Seasons with better rainfall produced more yields that ranged from 59 to 192.5% over the drier year (2011). Weeding showed significant yield difference in all years except 2008, and increased maize yield by 6.9 to 162.5% compared with weed control (Table 6). In the drier year of 2011, weeding increased maize yield by 32.6 to 121.2%, relative to the weedy check (unweeded control), even weeding twice increased the yield by 66.9% more than weeding once. However, variation between one and two times weeding was not significantly different in most of the years except in 2011. The yield from MB intercrop was not significantly different from sole maize in three years. In addition, yield variation between MB and MBB intercrops was not significant in four years although the yield in MB varied between 3.4 and 35% over MBB.

Competitive ratio (CR)

Effect of weeding on competitive ability of bean was dependent on year variation. Under weedy condition, bean competed significantly more in 2008 (1.16 in W0, and 1.50 in W2) in which a value with more than one shows the crop was more competitive (Table 7). In the drier year of 2011, CR value of bean in W0 was high (2.41) compared with maize (0.40). Competitive ability of maize was improved by 90 and 110% when weeded once and twice, respectively, over W0 in 2011 when moisture shortage prevailed.

Land equivalent ratio

Partial land equivalent ratio of maize (LERm) and bean (LERb) in MB intercrop was 28.6 and 15.8%, respectively, more productive than MBB intercrop, and both bean and maize had higher total land equivalent ratio (LER) in the single than double alternate row intercrop (Table 5). Land equivalent ratio was more than one in all years; even weeding increased LER in the dry season (2011), which varied between 1.68 (W2) and 2.41 (W1) compared to the weedy check (Table 7). On average, weeding increased crop productivity by 58 to 73% more than the sole crops. Reduction in bean yield associated with maize varied between 13 and 53% in most of the years while the yield of intercropped maize was reduced by 10 to 61%. The overall contribution of bean to the total LER in the intercrop was 49.4 (MB) and 52.1% (MBB) while that of maize was 50.6 (MB) and 47.9% (MBB). More seed weight, grain, total dry matter and energy yields were obtained from MB compared with MBB and sole bean, but not significantly different from sole maize indicating better crop performance in MB. The average LER in all years, averaged across weeding frequencies, varied between 1.28 and 1.98. Single row arrangement had more LERm and LERb compared with double alternate row. The finding also showed that 37 to 42% more land was saved from weeding once and twice, which could be used for other farm activities.

Energy yield (EY)

Mean energy yield (GJk^{-1}) ranged from 45.5 in 2009 to 82.8 in 2010 with an overall mean of 55.0 (Table 7). Energy yield was greater with weeding twice compared with no weeding in all years except 2008 and 2009 with an overall mean increase of 66.3%. Weeding once and twice resulted in increased energy yield compared to no weeding in 2010. Energy yield was least with sole crop bean and only 38.4% of the energy yield of sole crop maize. Yield with sole crop maize was 38.3 and 39.8% more compared with MBB in 2011 and 2012, respectively, with an overall benefit of 28.4%.

Economic benefit

Net returns to variable costs were affected by the main effects of weeding and row arrangement and year by treatment interactions (Table 2). Net returns were greater with W1 compared with W0 in 2010 and 2012 by 165.5 and 48.8%, respectively, but not affected much by weeding in the other years (Table 7). Net return was similar for W1 and W2 except in 2011 when net return was 132.6 and 66.6% more with W2 compared with W0 and W1, respectively. Even the net income from W1 was 39.6% more than the control (W0). Net return was greatest with MB and least with sole crop bean, and greater with MB compared with sole crop maize in two of the five years. Using stepwise multiple regression analysis, weeding frequency and row arrangement were determined to contribute 17.7 and 11.1% of the total variations in intercrop net return: Net return = 20848 + 4791Wf - 4432Ra, where Wf is weeding frequency and Ra is maize-bean row arrangement.

DISCUSSION

The current study showed that weeding once (24%) and twice (35%) significantly reduced weed biomass compared with the unweeded control, indicating weeding once would suffice to control weeds, which saves time and labor of the farmers which can be distributed to other farm activities. Better plant growth (16% more) and

Table 7. Weeding frequency and cropping system effects on partial LERb and LERm, competitive ratio, energy value of bean, and net income of maize-bean intercrop.

Treatment	2008	2009	2010	2011	2012
Competitive ratio of bean: WF effect					
W0‡	1.16[ab] (0.74)*	0.51[b] (1.34)	0.76[b] (1.64)	2.41[a] (0.40)	0.81[b] (0.76)
W1	0.82[b] (1.03)	0.97[b] (1.11)	0.49[b] (1.30)	0.80 (0.76)	0.67[b] (0.89)
W2	1.50[ab] (0.49)	0.53[b] (1.39)	0.50[b] (1.52)	0.80[b] (0.84)	0.68[b] (0.86)
S.E.(D.F.) 0.23 (8)					
Partial LER_b: WF effect					
W0	1.31[ab] (0.88)	0.83[b-d] (1.16)	0.63[d] (0.67)	0.65[d] (0.39)	0.60[d] (0.63)
W1	0.77[cd] (0.90)	0.87[a-d] (1.12)	0.47[d] (0.75)	1.28[a-c] (1.13)	0.64[d] (0.73)
W2	1.37[a] (0.71)	0.52[d] (0.79)	0.48[d] (0.84)	0.87[a-d] (0.81)	0.71[d] (0.79)
S.E.(D.F.) 0.14 (8)					
Land Equivalent Ratio: WF effect					
W0	2.19[ab†]	1.99[abc]	1.30[d]	1.04[d]	1.23[d]
W1	1.67[bcd]	1.99[abc]	1.22[d]	2.41[a]	1.37[cd]
W2	2.08[ab]	1.31[d]	1.32[d]	1.68[bcd]	1.50[cd]
S.E.(D.F.) 0.19 (8)					
Energy yield GJk^{-1}: WF effect					
W0	48.69[d]	39.06[d-f]	39.63[d-f]	21.83[f]	51.53[cd]
W1	47.94[d]	41.90[d-f]	102.84 [a]	26.19[ef]	72.21[bc]
W2	48.66[d]	55.37[cd]	106.10 [a]	45.89[e]	77.66[b]
S.E.(D.F.) 8.71 (8)					
Energy yield GJk^{-1}: CS effect					
SM	65.07[d-f]	57.26[ef]	117.04[a]	41.52[f-h]	92.12[a-c]
SB	23.03[gh]	19.05[h]	31.92[gh]	22.72[gh]	46.48[e-g]
MB	58.74[d-f]	60.67[d-f]	98.94[ab]	31.00[gh]	68.53[c-e]
MBB	46.87[e-g]	44.80[e-g]	83.66[b-d]	29.96[gh]	61.41[d-f]
S.E.(D.F.) 7.45 (12)					
Net income, Ethiopia birr ha^{-1}: WF effect					
W0	17793[def]	12769[efg]	12561[fgh]	7749[h]	18720[bcd]
W1	17165[def]	13952[defg]	33349[a]	10818[gh]	27861[abc]
W2	19037[cde]	18041[de]	34247[a]	18023[cde]	28153[ab]
S.E.(D.F.) 3103.6 (8)					
Net income, Ethiopia birr ha^{-1}: CS effect					
Maize	19041[abcd]	16754[bcd]	34246[a]	12149[de]	26954[ab]
MB	27130[ab]	22278[abc]	35038[a]	15993[cde]	30620[a]
MBB	18943[abcd]	15262[bcde]	27416[ab]	13631[de]	26478[ab]
Bean	6869[f]	5389[f]	10176[ef]	7 014[f]	15593[bcd]
S.E.(D.F.) 2544.2 (12)					

*Numbers in parenthesis are competitive ratio and partial LER of maize (LERm)
†The same letter within a trait and across years indicate no significant differences at α = 5%.
‡LER_b, partial land equivalent ratio of bean; W0, W1 and W2, SM, SB, MB, and MBB are no weeding, and weeding once and twice, sole crops of maize and bean, alternate row intercrop planting of maize and bean, and intercrop maize alternated with two rows of bean, respectively; S.E is standard error of the mean; SE (df)- standard error of the mean and degree freedom, respectively.

increased pods plant^{-1} of bean (19% more) was obtained from weeding compared to the unweeded control because of better crop performance from better distribution of rainfall and crop ground cover which inhibited weed seed germination that reduced weed competition. In addition, weed removal significantly increased the average grain (84%) and dry matter (42%) yields of bean particularly in the dry year of 2011 (86% more dry matter) and maize yield (55% higher) compared to the weedy check and this was attributed to reduced weed-growth that minimized weed competition. According to Baumann et al. (2000) and Getachew et al. (2006), intercropping helps to increase weed suppression relative to monocropping. Similarly, Hussain et al. (2013) reported that maize-French bean intercropping reduced weed population by 35 to 56%. The work of Weil and McFadden (1991) also indicated reduced weed growth and for optimum yield only one weeding instead of two or three weeding in maize-groundnut, maize-mung-bean or maize- sweet potato intercropping is needed.

Single alternate row arrangement in year 2008 significantly produced more seed weight over sole crop bean because of less bean population relative to double alternate row arrangement, and better availability of soil moisture, which is in line with the finding of Hirpa (2013). In the drier year of 2011, seed weight and total dry matter and grain yields of bean and maize in MB were not different from their sole crops due to better soil cover by the component crops which reduced moisture loss. Probably intercropping could conserve soil moisture through its canopy cover (Tenaw et al., 2006), which reduces evaporation by hindering direct sun-heat from reaching the ground, and resulted in higher grain yield of maize and bean. Tenaw et al. (2006) noted an increase of 2.75% more soil moisture under intercrop compared with sole crop maize. According to Sani et al. (2011) intercropping resulted in more efficient utilization of moisture by the intercrops compared with sole crops due to better soil moisture conservation. The companion crops with various root systems in the soil might reduce water loss, increase water uptake and increase transpiration. The increase in transpiration may make the microclimate cooler, which, along with increased leaf cover, helps to cool the soil and reduce evaporation (Innis, 1997).

Common bean, on average, experienced 19 to 21% yield reductions in maize-bean intercrop due to within and between crop species competition while partial LERb greater than one in treatments with no weed control and weeding twice in 2008 showed that bean yield within an intercrop surpassed that of sole bean pointing the benefit of intercropping. The reduced bean yield was due to high maize competition, which was taller and had vigorous growth and root system that hindered light interception and competed more for soil moisture, nutrients and light interception, which is also indicated by Rezaei-Chianeh et al. (2011). Low grain (29%) and dry matter (57%) of bean and maize grain (22%) yields compared to their sole crops in MB and MBB was due to inter and intra-species competition The findings of other researchers (Tenaw et al., 2006; Thorne et al., 2002; Banik, 1996) also show reduced grain yields of intercropped crops compared with their sole crops. Undie et al. (2012) reported a reduce grain yield of soybean in late maize-soybean intercropping and found the relative yield totals more productive than sole crops. The work of Yilmaz et al. *(*2008) showed the dominancy of maize in maize-bean and maize-cowpea intercropping resulting in increased grain yield of maize. Spatial arrangement of single row of maize alternating with single row of bean gave the best yields as also reported by Addo-Quaye et al. (2011). Other report (Thorne et al., 2002) also shows that grain yields of maize and cowpea in maize-cowpea intercrop were 51 and 12% less, respectively, than their respective sole crops. Dolijanović1 et al. (2009) reported a 49% yield increase in alternate rows in relation to monocrops of maize and soybean In contrary, Odhiambo and Ariga (2001) reported higher bean yield from MBB than MB due to the long rains at Emabwi.

Alternate row arrangement of bean intercrop (MB) yielded, on average, 35% more than double alternate (MBB) because of reduced interspecies competition in single (3 bean plants per maize plant) compared with double row intercrop (6 bean plants), which is in line with the finding of Liben et al. (2001). Amount and distribution of rainfall were factors responsible for variation in bean yield besides the effect of maize shade and its competitiveness for moisture and nutrient. The finding of Kutu and Asiwe (2010), shows that single alternate row of maize-dry bean intercrop produced highest grain yields of maize and bean, and productivity in both seasons (2006 to 2007).

Weeding increased the energy yield (EV) by an average of 56% compared to the weedy check due to less weed growth and reduced competition while intercropping resulted in 104% more energy yield than sole crop bean (EYb) which was attributed to reduced weed population resulting in less weed crop competition. Because of reduced weed competition that resulted in enhances better crop growth in 2011, energy yield was 65% more than the weedy check indicating how if weeds are not removed can reduce the energy yield to be produced in the dry season. This result is in line with the finding of Tsubo et al. (2004) who reported more energy yield from sole maize and intercrop; in contrary, Zuofa and Tariah (1992) reported low energy yield.

The finding showed that alternate row maize-bean intercropping was more economical relative to sole crops of the companion crops and this was attributed to better crop growth and efficient use of resources. There was a 28 to 98% yield advantage from intercropping, and also saved a land that varied between 36 and 42% in all weeding practices showing that farmers can allocate their extra land to other farming. The report of Liben et al. (2001)

shows higher economic advantage from single alternate row arrangement of maize-faba bean intercropping. Similarly, the finding of Hussain et al. (2013) shows the benefit of intercropping in terms of reduced weed population, increased land utilization and economic benefit. Overall, intercropping was more effective and efficient than sole crops in the use of environmental resources as demonstrated by higher LER and was economical.

CONCLUSIONS

The effect of weeding and row arrangement was dependent on seasonal rainfall, and resulted in significant variations in growth and grain yields of the component crops. There were better crop yields at the time of better rainfall while low yields were obtained when there was moisture shortage. Weeding increased crop yield and net income in the drier year of 2011. Intercrop reduced labor because of less weed infestation and reduced competition between maize and bean. The result showed that single alternate row intercrop (MB) is recommended for increased productivity and profitability while providing bean harvest early enough to partially resolve the experience of food shortage from May to July, and contribute to food security. Such system if practiced can reduce soil erosion, increase soil fertility and crop productivity and can easily be practiced in other areas of the region. In addition, intercropping reduces crop failure and ensures in reducing the effect of climate change. On the other hand, intercropping could be an ecofriendly approach for reducing weed problems through non-chemical methods. Hence, this finding can benefit farmers through increased productivity and diversification of income and food sources.

ACKNOWLEDGEMENT

I would like to forward my appreciation and thanks to those who helped me in the execution of this study and reviewing the manuscript. I also appreciate the financial support by the Ethiopian government to conduct this study.

REFERENCES

Addo-Quaye AA, Darkwa AA, Ocloo GK (2011). Yield and productivity of component crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement. ARPN J. Agric. Biol. Sci. 6 (9):50-57.

Adu-Gyamfi JJ, Ito O, Yoneyama T, Katayama K (1997). Nitrogen management and biological nitrogen fixation in sorghum/pigeon pea intercropping on Alfisols of the semi-arid tropics. Soil Sci. Plant Nutr. 43:1061-1066.

Babatunde FE (2003). Intercrop productivity of roselle in Nigeria. Afr. Crop Sci. J. 11:43-47.

Baldev RA, Chaudhary GR, Jat AS (2004). Nutrient depletion by weeds, weed control efficiency and productivity of pearl millet as influenced by intercropping systems and integrated weed management. Indian J. Agric. Sci. 74:534-538.

Banik P (1996). Evaluation of wheat and legume intercropping under 1:1 and 2:1 row replacement series system. J. Agron. Crop Sci. 176:289-294. doi: 10.1111/j.1439-037X.1996.tb00473.x

Baumann DT, Kropf MJ, Bastiaans L (2000). Intercropping leeks to suppress weeds. Weed Res. 40:361-376.

CSA (Central Statistics Agency) (2010). Agricultural sample survey, 2009/10 (Sep –Dec 2009).. Report on area and production of crops (private peasant holdings, meher season). Stat. bullet. 4:446. Addis Ababa, Ethiopia.

CACC (Central Agricultural Census Commission) (2003). Ethiopian Agricultural Sample enumeration, 2001/02. Results of SNNPR (Southern Nation, Nationalities and Peoples Region) statistical report on area and production of crops, Part II A. Addis Ababa, Ethiopia.

Dolijanović Z, Kovačević D, Oljača S, Simić M. (2009). Types of interactions in intercropping of maize and soybean. J. Agric. Sci. 54(3):179-187.

Ennin SA, Clegg MD, Francis CA (2002). Resource utilization in soybean/maize intercrops. Afric. Crop Sci. J. 10:251-261.

Getachew A, Amare G, Sinebo W (2007). Cereal-faba bean mixed cropping: yield advantage and land use efficiency. Research Report 70. Ethiopian Institute of Agricultural Research.

Getahun D, W Mwangi, Tenaw W, Grisley B (1991). Areka area mixed farming zone, North Omom region: diagnostic survey. Res. Rep. No. 15. Institute of Agricultural Research. Addis Ababa, Ethiopia.

Getahun D, Tenaw W (1990). Initial results of informal survey. Areka mixed farming zone, Wolayita district, Sidamo region. Working paper no. 11. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural research.2nd edn. An international Rice Research Institute Book. John Wiley and Sons, Singapore p.680.

Hirpa T (2013). Maize productivity as affected by intercropping date of companion legume crops. Peak J. Agric. Sci. 1(5):70-82.

Hussain Z, Marwat KB, Munsif F, Samad A, Hashim S, Bakht T (2013). Influence of intercropping in maize on performance of weeds and the associated crops. Pak. J. Bot. 45(5):1729-1734.

Innis DQ (1997). Intercropping and the Scientific Basis of Traditional Agriculture. London: Intermediate Technology Publications.

Kariaga BM (2004). Intercropping maize with cowpeas and beans for soil and water management in western Kenya. 13th International soil conservation organization conference, Brisbane, July 2004.

Kitonyo OM, Chemining'wa GN, Muthomi JW (2013). Productivity of farmer-preferred maize varieties intercropped with beans in semi-arid Kenya. Int. J. Agron. Agric. Res. 3(1):6-16.

Kutu FR, Asiwe JAN (2010). Assessment of maize and dry bean productivity under different intercrop systems and fertilization regimes**.** Afr. J. Agric. Res. 5(13):1627-1631.

Landon JR (1984). Booker Tropical Soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Booker Agricultural International Ltd., Great Britain..

Liben M, Tadese T, Assefa A (2001). Determination of nitrogen and phosphorus fertilizer levels in different maize-faba bean intercropping patterns in northwestern Ethiopia. Seventh Easterrn and southern Africa Regional Maize conference pp. 513-518

Mahapatra SC (2011). Study of Grass-Legume Intercropping System in terms of competition Indices and Monetary advantage index under acid lateritic soil of India. Am. J. Expt. Agric. 1(1):1-6.

Mandal BK, Rajak S, Mandal BB, Nandy SK (1990). Yield and economics as influenced by intercrops of maize, groundnut and green gram. Indian J. Agric. Sci. 60:209-211.

Mariotti M, Masoni A, Ercoli L, Arduini I (2006). Forage potential of winter cereal/legume intercrops in organic farming. Ital. J.Agron. 3:403-412.

Moynihan JM, Sommons SR, Sheaffer CC (1996). Intercropping annual medic with conventional height and semidwarf barley grown for grain. Agron. J. 88(5):823-828.

Musambasi D, Chivinge OA, Mariga IK (2002). Intercropping maize with grain legumes for striga control in Zimbabwe. Afr. Crop Sci. J. 10:163-17.

Niringiye CS, Sskabembe CS, Kyamonywa S (2005). Effect of plant population on yield of maize and climbing beans grown in an intercropping system. Afr. Crop Sci. J. 13:83-93.

Odhiambo GD, Ariga ES (2001). Effect of intercropping maize and beans on striga incidence and grain yield. Proc. 7th Eastern Southern Africa Reg. Maize Conf. 11-15 Feb 2001.

Reynolds MP, Sayre KD, Vivar HF (1994). Intercropping wheat and barley with N-fixing legume species: a method for improving ground cover, N-use efficiency and productivity in low input systems. J. Agric. Sci. pp. 175-183.

Rezaei-Chianeh E, Nassab ADM, Shakiba MR, Ghassemi-Golezani K, Aharizad S, Shekari F (2011). Intercropping of maize and faba bean at different plant population densities. African J. Agric. Res. 6(7):1786-1793.

Sani BM , Danmowa NM, Sani YA, Jaliya MM. (2011). Growth, Yield and Water Use Efficiency of Maize-Sorghum Intercrop at Samaru, Northern Guinea Savannah, Nigeria. Nigerian J. Basic Appl. Sci. 19(2):253-259.

SAS Institute (2000). SAS User's Guide 8.2 ed. SAS Inst., Cary, NC, USA pp.183-186.

Setegn G, Legesse D (2010). Improved bean technologies: production and post harvest guideline. EIAR (Ethiopian Institute Agricultural Research), CRS (Catholic Relief Service). Addis Ababa, Ethiopia.

Tenaw W, Husni MHA, Anuar AR, Rahman ZA (2006). Effect of coffee residue and intercropping on soil-physico-chemical properties and yield of component crops in southern Ethiopia. Ethiopian J. Nat. Resour. 8(2):199-216.

Thorne RJ, Thornton PK, Kruska RL, Raynolds L, Waddington SR, Rutherford AS, Odero AN (2002). Maize as food, feed and fertilizer in intensifying crop-livestock systems in East and Southern Africa: An exante impact assessment of technology interventions to improve smallholder welfare. ILRI Impact assessment series 11. ILRI, Nairobi, Kenya. p. 123.

Tsubo M, Ogindo HO, Walker S (2004). Yield evaluation of maize-bean intercropping in a semi-arid region of South Africa. Afr. Crop Sci. J. 12:351-358.

Undie, UL, Uwah DF, Attoe EE. (2012). Effect of intercropping and crop arrangement on yield and productivity of late season Maize/soybean mixtures in the humid environment of south southern Nigeria. J. Agric. Sci. 4(4):37-50.

Weil RR, McFadden ME (1991). Fertility and weed stress effects on performance of maize-soybean intercrop. Agron. J. 83:717-721.

Wortmann CS, Mamo M, Mburu C, Letayo E, Abebe G, Kayuki KC, Chisi M, Mativavarira M, Xerinda S, Ndacyayisenga T (2009). Atlas of sorghum (*Sorghum bicolor* (L.) Moench) production in eastern and southern Africa. Available at http://intsormil.org/ smscientificpubs/Sorghum%20Atlas%20web.pdf (verified 21 Apr. 2011). Univ. of Nebraska-Lincoln, Lincoln.

Yilmaz S, Atak M, 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.

Zuofa K, Tariah NM (1992). Effects of weed control methods on maize and intercrop yields and net income of small-holder farmers, Nigeria. Trop. Agric. Trinidad 69(2):167-170.

http://www.sciencewebpublishing.net/jacr