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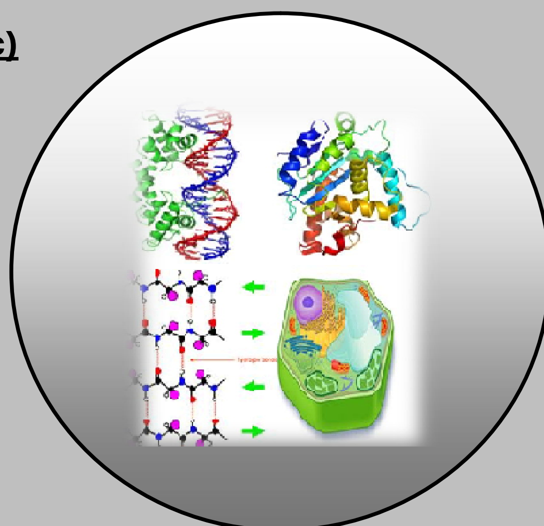

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RESEARCH PAPER

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Effect of Interceding Date on Growth and Yield of Three Legume Crops Intercropped With Maize (*Zea mays*)

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ABSTRACT

A study was conducted at the experimental site of the Assosa Research Center, located in Western Ethiopia, with the objective to determine growth and yield of three legume crops intercropped with maize at different dates. Accordingly, factorial combination of three legume crops, namely; soybean (Glycine max) and two common bean varieties [Back Dessie and Awash Melka (Phaseolus vulgaris)], and three intercropping date [simultaneously with maize, four and eight weeks after maize emergence (WAME)] plus sole crops of the respective species laid in randomized complete block design were used. Highly significant species × intercropping time interaction effects were observed on legume growth and biomass accumulation, whereby simultaneously seeded legume plants grew taller and appeared vigorous than the sole stand and delayed sowing. A highly significant effect of intercropping time was observed on the number of branches, total and percent effective nodules per plant, in which the highest mean numbers were, recorded when legumes were simultaneously planted with maize compared to pure stand. Highly significant species × cropping system interaction effects were also observed on legume yield related parameters (pods/plant and 100 seeds weight), total biomass and grain yields, where drastic reductions of yield attributes, total biomass and grain yields were observed due to delayed interceding. Values of partial and total land equivalent ratio (LER),and actual yield loss (AYL) of legume association with maize, generally fall as interceding of the legume crops was delayed, which indicated that bio-economic efficiency of legume crops in resource utilizations reduced when under seeded in already established maize. This was corroborated by the positive partial and total intercrop advantage (IA) values of simultaneous intercropping, where Black Dessie and maize association proved to be the most remunerative one. Generally, the results of this study revealed that the agronomic and economic advantages of intercropping got lesser and lesser when interceding of legumes was delayed

Key words: Actual Yield Loss; Biomass; Effective Nodule; Grain Yield; Interceding and Pod.

INTRODUCTION

Over the years, food requirements have increased while land availability has become less. Thus, the only way to increase agricultural production is to increase yield per unit area. Being the under storey crop in most intercropping systems, growth and yield of legumes are usually suppressed by the dominant crop. Complementarities in an intercropping situation can occur when the growth patterns of the component crops differ in time or when they make better use of resources in space. Being the under storey crop in most intercropping systems, growth and yield of legumes are usually suppressed by the dominant crop. Planting legumes simultaneously or soon after cereals, according to Olufajo1 and Singh (2002), could reduce the depressive effect of cereals on the legume, particularly if there is no severe competition for water. To determine legume interceding date in cereals, an important consideration could be the choice of the farmer, whether to have a full cereal yield with some additional legume grain and fodder or balanced yield of both. Farmers with the first objective would be reluctant to adopt any practice that may reduce cereal grain yield. Therefore, research objectives need to address both agronomic options so that research out puts can play pivotal role in farmer decision making process. The extent of competition-induced yield loss in intercropping is likely to depend on the competitive ability of the component crops and the date of seeding. Choice of compatible species and time of their establishment, therefore, seems 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 of intercropping, based on growth characteristics and requirements of the component species in question, are key agronomic issues in intercropping (Muoneke *et al*., 1997; Sarkar *et al*., 1998; Banik *et al*., 2000). Even though, such agronomic options seem easily controllable management factors, their effects on intercrop yields need to be well understood and determined experimentally. Mburu *et al*. (2003) opined that intercropping in general and delayed planting of legume in maize in particular, significantly and drastically depressed legume biomass yields compared to sole legume yields. Gbaraneh *et al*. (2004) have also reported highest lablab fodder yield obtained when maize and lablab were simultaneously planted, and declined progressively with delayed under sowing of lablab. Carruthers *et al*. (2000) on the other hand, reported that significant difference in HI, number of pods per plant, and number of seeds per pod was not observed due to planting time of soybean in maize. Most of the reported works on maize-legume mixtures indicated reductions in legume yields while maize yields were unaffected (Cardoso *et al*., 1993; Adipala *et al*., 2002). There appears inconsistency in reported works 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 (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 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*., 1998; Carruthers *et al*., 2000; Adipala *et al*., 2002; Silva *et al*., 2008).

The present study was, therefore initiated with the objective to determine the effect of relative sowing date of legumes as intercrop with maize crop on the performance of three legume crops, under the soil and climatic conditions of Assosa areas.

MATERIAL AND METHODS

Description of the Study Area

The study was carried out in the cropping season of the 2008 at the experimental site of the Assosa Research Center, 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 1275 mm. The annual mean maximum temperature reaches 28 ^{0}C while the mean minimum temperature is 15 ^{0}C. The dominant soil at and around the Research Center 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. Factors employed were three grain legume crops namely; soybean (*Glycine max*) and two common bean varieties [Back Dessie and Awash Melka (*Phaseolus vulgaris*)], intercropped with composite Gibbe-1 maize (*Zea mays* L.) at three times (simultaneous, four and eight weeks after maize emergence (WAME) plus sole crop of respective species applied on 39 plots of 27 m^2 (4.5 by 6 m) size.

Constant between and within row spacing's of 75 cm by 30 cm for maize was used that gave population of 44,444 plants ha^{-1}, both in sole and intercrop. Legumes in sole crop were seeded at spacing of 37.5 cm by 15 cm that gave 177,776 plants ha^{-1}, while in the intercropped plots legume seeds were drilled in single row between two rows of maize crop 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 intercrop efficiency. Maize and legume seeds were sown at the rate of two seeds per hill, which were later thinned to obtain the required plant populations.

Data Collection

The responses of legume crops to intercropping and time of seeding compared to the respective sole crop were determined from data recorded on growth, biomass and yield and yield components. The above ground height of legume crops was measured at three sampling dates viz., 30, 60 and 90 days after planting (DAP). To determine nodulation pattern of the legume crops, count of total and effective nodules, nodules that developed pink-brown internal color after slice opening of the nodules (Gwata *et al*., 2003), were recorded after careful uprooting of plants from the middle rows of each plot. Number of branches per plant, biomass yield, number of pods and seeds per plant, and seeds per pod, 100 seeds weight, and grain yield on per plant basis were recorded to determine the intra- and inter-specific competition effects on the performance of legume crops. Data of the above-mentioned parameters were collected from five plants of the respective species randomly taken from the net plot.

Total grain yields of the legume crops were also recorded after final harvest to determine the intercrop productivity and efficiency.

Determination of Intercrop Efficiency

The relative productive capacity of the intercrop vis-à-vis the respective monocultures was computed in terms of land equivalent ratio (LER) using the formula outlined by Mead and Willy (1980):

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

Where Y_i^i and Y_i^m are yields of i^{th} component in intercrop and monocrop, respectively, Z_i is its sown proportions in intercrop. Land equivalent ratio can describe intensity of land use if land use is regarded as total sum of combined yields or sum of yield advantages/disadvantages of each crop, which can adopt values ranging from <1.0 to >1.0 that indicate different levels of biological efficiency

Calculations of aggressively (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):

$$A = \frac{Y_i^i}{Y_i^m \times Z_i} - \frac{Y_j^i}{Y_j^m \times Z_j} \qquad (2)$$

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:

$$CRi = \frac{LER_i}{LER_j} \times \frac{Z_j}{Z_i} \qquad (3)$$

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 2.

Actual yield loss index (AYL), the proportionate yield loss or gain that basis on yield per plant of intercrops in comparison to the respective sole crop gave more precise information about the competition behaviors between and within the component in the intercropping system (Banik *et al*.,2000). The AYL was calculated according to the following formula (Banik, 1996):

$$AYL = \sum_{i=1}^{n} AYL_i \qquad (4)$$

$$AYL_i = \frac{Y_i^i / Z_i}{Y_i^m / Z_i} - 1$$

Where Y_i^i, Y_i^m and Z_i are as indicated in equation 1.

The sign (positive or negative) of the AYL score gives a quantitative assessment of the advantage or disadvantage accrued under intercrop situation when the main objective is to compare yield on a per plant basis.

None of the above competition indices, however, provides any information on the economic advantage of the intercropping system. For this reason, intercropping advantage (IA) was calculated in this study, based on partial actual yield losses and respective unit price of the intercrops based on the prevailing market prices using the following formula (Banik *et al*., 2000):

$$IA = \sum_{i=1}^{n} P_i \times AYL_i \qquad (5)$$

where P_i is unit price of crop *i* (the current price of maize is 350 Ethiopian Birr (EB), Black Dessie 470 EB, Awash Melka 500 EB and soybean 650 EB per 100 kg), and AYL_i is actual yield loss of crop *i*.

Data Analysis

Statistical reliability of agronomic performances and intercrop efficiencies were determined by computation of analysis of variance using MSTATC computer software (MSTAT-C, 1991). Mean separation was done using least significant difference (LSD) tests at 0.05 and 0.01 probability levels.

RESULTS AND DISCUSSION

Effect of Intercropping Time on Growth of Legumes

Highly significant species by intercropping time interaction effects were observed on the height of the legume recoded at 30, 60 and 90 days after planting (DAP). In this regard, simultaneously seeding recorded the highest height at early sampling (30 DAP) of Black Dessie variety; however, plants in sole stand followed by simultaneous planting were the tallest during the later samplings (Figure 1).

In case of Awash Melka variety, highest plant height was recorded in simultaneously seeded treatment, at early and last growth samplings (30 and 90 DAP), and during all growth sampling phases the shortest plants were observed in treatment interceded 4 weeks after maize emergence (WAME). Growth of this crop nearly stabilized after 60 DAP (Figure 2). Simultaneous planting of soybean, on the other hand, produced the tallest plants compared to later introduction and sole crop at samplings of 30 and 90 DAP (Figure 3). Similarly, Carruthers *et al*. (2000) observed that height of intercropped soybean was greater than monocrop. Yadav and Yadav (2000) also reported that clusterbean cultivars intercropped with pearl millet attained significantly higher plant height in mixed stands than in pure stands.

Generally, later introduction of legume crops in maize gave a better establishment of maize ahead of the later introduced intercrop, thereby suppressing growth and lowers down the canopy of legume (Bidinger *et al*., 1996).

If a component crop in association absorbs or intercepts less than its share of a factor of production, it is likely to acquire a correspondingly small share of all other factors of production, which will eventually affect dry matter accumulation and subsequently poor yield (Bidinger *et al.,* 1996; Blade *et al.,* 1997; Mutsaers *et al*., 1997).

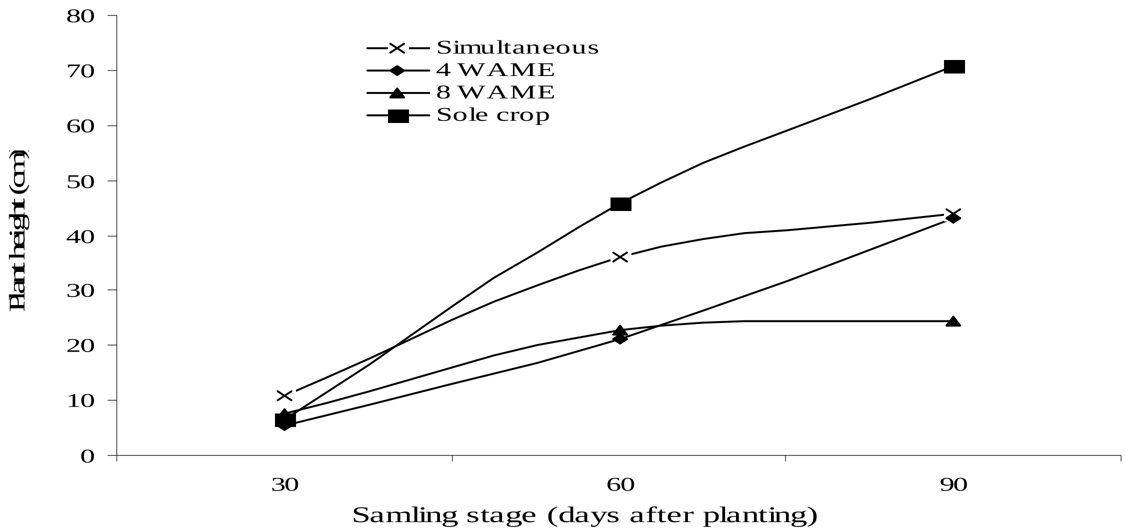

Figure 1. Effects of intercropping time [weeks after maize emergence (WAME)] on the height (cm) of Black Dessie variety at different growth stages.

LSD (P < 0.01) values 30 DAP = 2.631; 60 DAP = 18.25; 90 DAP = 40.85.

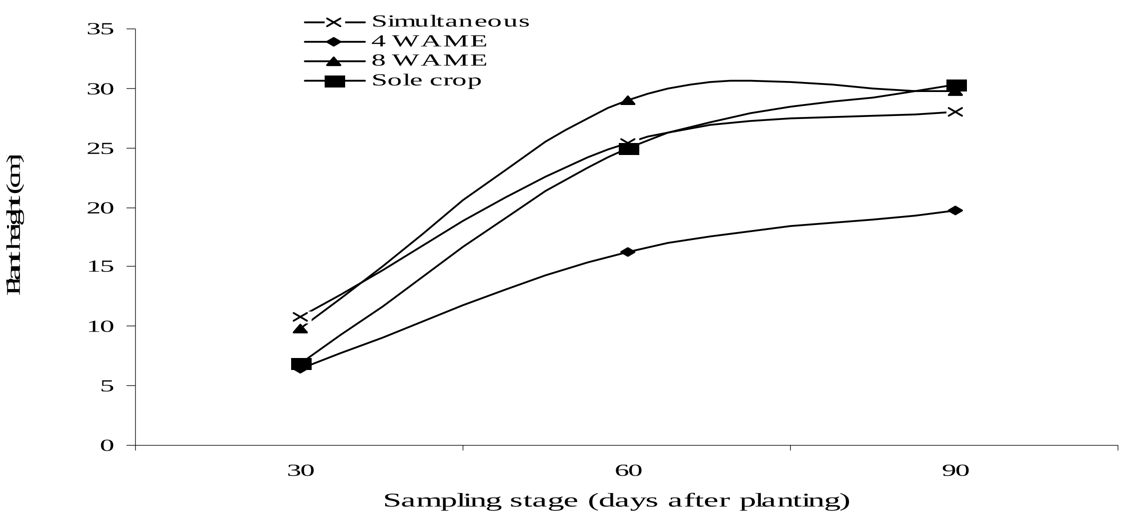

Figure 2.Effect of intercropping time (WAME)] on the height (cm) of Awash Melka variety at different growth stages.

LSD (P ≤ 0.01) values 30 DAP = 2.631; 60 DAP = 18.25; 90 DAP = 40.85.

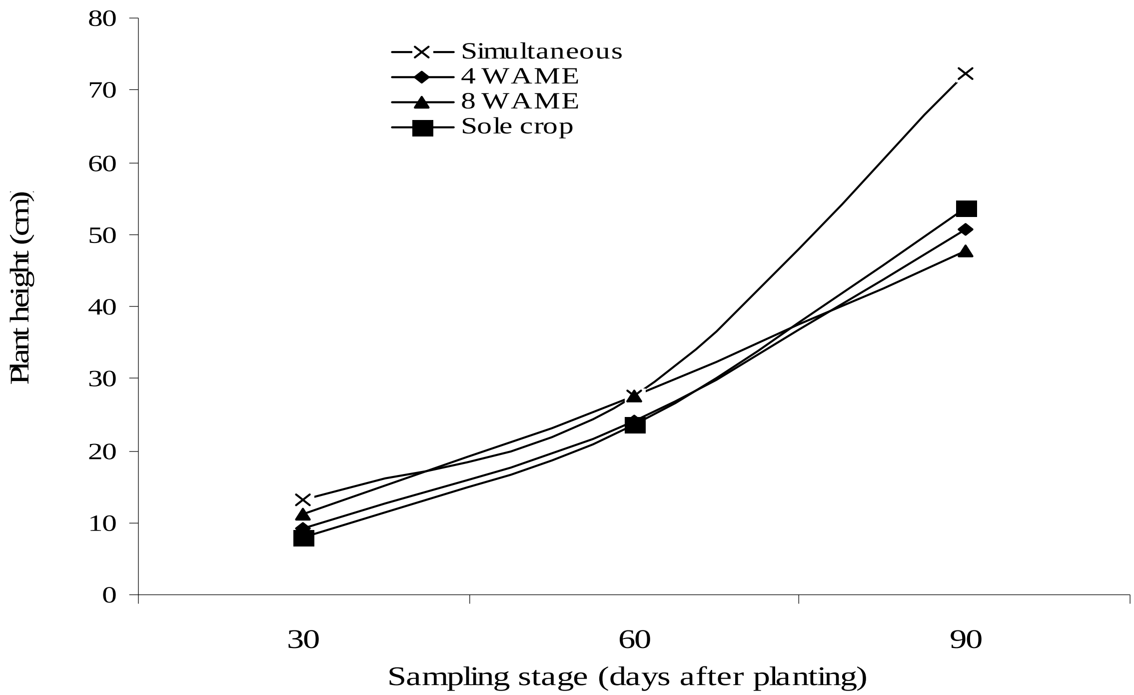

Figure 3. Effects of intercropping time (WAME) on the height (cm) of soybean plant at different growth stages.

LSD (P ≤ 0.01) values 30 DAP = 2.631; 60 DAP = 18.25; 90 DAP = 40.85.

With regard to branching pattern, species variability was observed among the legume crops of present study, whereby soybean recorded the highest number of branches per plant (Table 1), mainly due to the inherent characteristics of branching potential (Ano, 2005). A highly significant effect of intercropping time was observed on the number of branches, in which highest mean number being recorded when legumes were simultaneously planted with maize, even superior to sole stand (Table 1). The performance of simultaneous interseeding in branching with respect to sole stand signifies that intra-specific competitions were higher than inter-specific competitions in the legume crops. This observation disagrees with that of Yadav and Yadav (2000) who reported a significant reduction in number of branches of cluster bean cultivars mix-cropped with pearl millet compared to their pure stand. Generally, trends of drastic decline in number of branches in legumes was observed with delay in intercropping and the overall poorest growth was recorded when they were introduced 8 WAME. Similar results were observed by Adipala *et al*. (2002) who reported that cowpea simultaneously planted with maize had on average more branches per plant than those planted two and four weeks after planting maize.

Table 1. Effects of species and intercropping time [weeks after maize emergence (WAME)] on branching (number) of legume crops.

Legume species (LS)	Sole crop	Intercropping time (IT)†			Mean*
		Simultaneous	4 WAME	8 WAME	
Black Dessie	1.3	5.0	0.3	0.3	1.75b
Awash Melka	2.0	4.7	0.7	0.3	1.92b
Soybean	4.8	8.0	3.1	0.0	3.98a
Mean*	2.7b	5.83a	1.53bc	0.33c	
	LS	IT	LS × IT		
LSD (0.01)	1.32	1.32	NS		
(0.05)	-	-	NS		

*Means within a column or a row followed by the same letter are not significantly different at $P \leq 0.01$ probability level.

†WAME = Weeks after maize emergence; LS = Legume species; IT = Intercropping time; NS = Non-significant.

The growth pattern of the intercropped legume crops could, therefore, be summarized as that simultaneous seeding of legume crops with maize resulted in taller plant with better canopy than the monocrop; whereas delayed intercropping of legumes in established maize stand were observed to result in inferior plants with poor canopy. Accordingly, simultaneously intercropped legumes exhibited a high degree of morphological plasticity compared to sole crop, presumably in response to increased competition for light (Redfearn *et al*., 1999; Carruthers *et al*., 2000).

Nodulation pattern of legume crops, in this study, showed a highly significant difference among the species where Black Dessie variety produced the highest mean number (9.67 $plant^{-1}$) as averaged across the cropping system (intercropping times + sole crop) (Table 2). The difference in total nodule number per plant due to cropping system, however, was non-significant ($P > 0.05$). Legume crops also exhibited significant variation ($P \leq 0.01$) in the percentage count of effective nodules, whereby soybean that produced least total count of nodules recorded the highest percentage effective nodules. Regardless of the total nodules, cropping system was observed to affect the percentage effective nodules (Table 2). In this case, delayed interceding resulted in reduced proportion of effective nodules; whereas simultaneous sowing of legume crops with maize produced the highest, even more than the respective sole stand. The higher proportion of effective nodules in simultaneously intercropped legume crops than their respective sole crop could be attributable to the presence of non-N_2 fixing associate that can reduce the inorganic N concentration in the soil, hence, N_2 fixation might have been increased in simultaneous intercropping compared to the monocrop situation (Danso *et al*., 1987; Rerkasam *et al*. 1988).

This is in line with a report of Ayisi *et al*. (2004) on cereal-cowpea intercrops, indicating that cowpea cultivars produced more number of effective nodules in the intercrop system than when grown as sole crops, and they found higher amount of N fixed by the legumes in the intercropped cowpea than the sole crops. This result, however, disagrees with that of Tamado and Eshetu (2000) and Tamado *et al*. (2007) who reported that significantly lower number of nodules for common bean varieties grown in intercropping with maize and sorghum compared to sole.

Table 2.Effects of species and intercropping time (WAME) on number of total and percentage effective nodules/plant of legume crops.

Legume species (LS)	Sole crop	Intercropping time (IT)†			Mean*
		Simultaneous	4 WAME	8 WAME	
Number of total nodules					
Black Dessie	9.7	12.3	10.3	6.3	9.67a
Awash Melka	2.7	10.3	5.0	10.7	7.12ab
Soybean	5.7	7.3	3.0	1.0	4.25b
Mean	6.03	9.93	6.65	5.75	
	LS	IT	LS × IT		
LSD (0.01)	5.21	NS	NS		
(0.05)	-	NS	NS		
%effective nodules					
Black Dessie	37.5	45.2	49.8	35.4	41.97ab
Awash Melka	24.4	27.9	35.5	15.3	25.78b
Soybean	61.7	78.3	58.3	31.0	57.33a
Mean*	41.2b	56.36a	36.33b	33.28b	
	LS	IT	LS × IT		
LSD (0.01)	20.9	NS	NS		
(0.05)	-	12.9	NS		

Means within a column or a row followed by the same letter are not significantly different at the specified probability levels.

†WAME = Weeks after maize emergence; LS = Legume species; IT = Intercropping time; NS = Non-significant.

The reduction in percentage effective nodules in delayed intercropping could also be due to its profound effect on the canopy architecture and might have had consequential reduction of nodule number per plant, since shading often reduces nodule number (Ballare *et al*., 1991; Red fearn *et al*., 1999).

Data on biomass accumulation per plant of the legume crops were recorded at two stages (at mid-flowering and final harvest).

According to these records, significant differences ($P \leq 0.01$) were observed among the legume species, where soybean at both stages of growth recorded the highest biomass accumulation (Table 3), attributable to inherent characteristics of the species. During both growth stages, significant ($P \leq 0.05$) species by intercropping time interaction effects were observed on biomass accumulation, where the two common bean varieties recorded their respective highest biomass weights when intercropped simultaneously with maize. In the case of soybean, however, plants in the pure stand recorded the highest biomass. A consistent decline of biomass weights were recorded during both samplings, as intercropping was delayed after maize (Table 3). Gbaraneh *et al*. (2004) and Maluleke *et al*. (2004) similarly accountda consistently reduced biomass accumulation of later-planted lablab in the intercropping system with maize compared to those simultaneously planted.

Table 3. Interaction effects of species and cropping system and/or intercropping time (WAME) on biomass accumulation of legumes (g/plant).

Legume species (LS)	Sole crop	Intercropping time (IT)†			Mean*
		Simultaneous	4 WAME	8 WAME	
Biomass at flowering stage (g/plant)					
Black Dessie	9.3bc	12.5b	6.3bc	3.0bc	7.79b
Awash Melka	8.0bc	9.0bc	2.3bc	1.8c	5.29b
Soybean	37.2a	42.0a	11.0bc	5.7bc	23.92a
Mean*	18.11a	21.17a	6.56b	3.50b	
	LS	IT	LS × IT		
LSD (0.01)	7.33	8.23	NS		
(0.05)	-	-	10.50		
Biomass at harvest (g/plant)					
Black Dessie	10.7cd	14.8c	6.0de	1.7e	8.29b
Awash Melka	7.2de	10.7cd	2.8e	1.7e	5.46b
Soybean	40.2a	25.2b	12.3cd	6.4de	21.01a
Mean*	19.33a	16.72a	7.06b	3.23c	
	LS	IT	LS × IT		
LSD (0.01)	3.61	4.16	7.21		

*Interaction means or main effect means within a column or a row followed by the same letter are not significantly different at the specified probability level.

†WAME = Weeks after maize emergence; LS = Legume species; IT = Intercropping time, NS = Non-significant.

With regard to total biomass yield of the legume crops, soybean produced the highest mean weight (285.56 kg ha^{-1}), while Awash Melka variety recorded the least (48.61 kg ha^{-1}) as averaged across the cropping system (Table 4).

Highly significant species by cropping system interaction effect on total biomass was also observed in the present study, where pure stands of the respective species yielded the highest amount followed by simultaneous intercropping.

A consistent decline of total biomass yield of the legume crops was observed with delay in time of seeding the legume crops. In a similar study, Mburu *et al*. (2003) reported that intercropping in general and delayed planting of mucuna in maize in particular, significantly and drastically depressed mucuna biomass yields compared to sole mucuna. Reddy and Visser (1997) also found that delaying cowpea sowing by seven weeks after millet led to significantly lower growth and dry matter yields of cowpea compared to simultaneous sowing.

Table 4.Interaction effects of species and intercropping time (WAME) on total above ground biomass accumulation of legume crops (kg/ha) at harvest.

		Intercropping time (IT)†			
Legume species (LS)	Sole crop	Simultaneous	4 WAME	8 WAME	Mean*
Black Dessie	205.6bc	113.9cd	38.9d	13.9d	93.05b
Awash Melka	100.0d	63.9d	16.7d	13.9d	48.61b
Soybean	733.3a	244.4b	102.8cd	61.7d	285.56a
Mean*	346.3a	140.74b	52.78c	29.82c	
	LS	IT	LS × IT		
LSD (0.01)	52.25	60.34	104.5		

*Interaction means or main effect means within a column or a row followed by the same letter are not significantly different at $P \leq 0.01$ probability level.

†WAME = Weeks after maize emergence; LS = Legume species; IT = Intercropping time

Effect on Yield Related Parameters of Legume Crops

A highly significant treatment interaction effect was observed on number of pods per plant, where simultaneous planting gave the highest number of pods per plant in both common bean varieties while sole cropping resulted in the highest pod per plant of soybean (Table 5). A consistent reduction in number of pods per plant was recorded with delay in interceding of the legume crops, in which soybean produced highest numbers throughout the cropping system treatments. While considering cropping system effects on number of pods, highly significant differences were observed among the treatments, where sole crop followed by simultaneous intercropping produced the highest amount of pods per plant. Yadav and Yadav (2000) similarly reported that cluster bean cultivars in mixture with pearl millet produced a lower number of pods per plant compared to pure stand. The mean number of pods declined with delay in intercropping times, which could be due to depressive effect of the taller maize in delayed introduction of legumes. In line with this finding, Muoneke *et al*. (2007) reported that delayed interseeding reduced number of soybean pods per plant.

Considering the number of seeds per pod, both the common bean varieties produced more than soybean, attributable to inherent varietals characteristics (Ano, 2005).

Highly significant effect of cropping system was also observed on number of seeds per pod, whereby simultaneous intercropping yielded the highest number of seeds/pod, even higher than the sole crop. Delaying introduction of the legume crops in already established maize stand resulted, generally in a progressive decline in the number of seeds/pod (Table 5). Adipala *et al*. (2002) reported similar finding. Carruthers *et al*. (2000), however, could not observe significant difference in number of pods per plant, and number of seeds per pod due to planting time of soybean with maize.

Table 5. Interaction effects of species and intercropping time (WAME) on pod and seed production of legume crops.

Legume species (LS)	Sole crop	Intercropping time (IT)†			Mean*
		Simultaneous	4 WAME	8 WAME	
Number of pods/plant					
Black Dessie	7.2c-e	9.0cd	3.9d-f	1.1f	5.29b
Awash Melka	6.2d-f	7.7c-f	2.4ef	2.2ef	4.62b
Soybean	29.3a	23.2b	12.8c	9.0cd	18.56a
Mean*	14.22a	13.30a	6.36b	4.08b	
	LS	IT	LS × IT		
LSD (0.01)	2.93	3.39	5.87		
Number of seeds/pod					
Black Dessie	4.0	6.2	4.8	3.7	4.65a
Awash Melka	5.5	5.3	4.5	3.8	4.78a
Soybean	2.3	2.3	2.2	2.0	2.17b
Mean*	3.91ab	4.59a	3.81ab	3.14b	
	LS	IT	LS × IT		
LSD (0.01)	0.83	0.94	NS		
(0.05)	-	-	NS		

*Interaction means or main effect means within a column or a row followed by the same letter are not significantly different at $P \leq 0.01$ probability level.

†WAME = Weeks after maize emergence; LS = Legume species; IT = Intercropping time; NS = Non-significant.

In the present study, significant ($P \leq 0.05$) interaction effect of treatments was observed on total number of seeds per plant, whereby the highest number being recorded by soybean plant in pure stand and the lowest in Black Dessie variety and planting 8 WAME combination (Table 6). Both common bean varieties, however, recorded their highest numbers in plots simultaneously seeded with maize. Number of seeds per plant linearly declined with delayed under seeding of legume crops in maize stand (Table 6). The decline in numbers of pods per plant, seeds per pod and total number of seeds per plant under delayed interceding of legume crops could probably be due to the shading effect of the taller component maize that generally depressed the vigor of the legume crops in the lower canopy.

This, on the other hand, resulted in concomitant reduction of photosynthesis to a level that the legume plants compensated by decreasing the amount of assimilate allocation to reproductive growth or grain production (Legere and Schreiber, 1989; Carruthers *et al*., 2000). The case might have also been that the level of shading during grain filling stage of the later seeded legumes was higher than before as maize attains its maximum growth thereof, resulting in drastic reductions in number of legume pods per plant and seeds per pod for delayed intercrop treatments.

With respect to hundred seeds weight of the legume crops, a highly significant interaction effect was found in the present study, whereby Awash Melka variety recorded the highest seed weight (18 g) under simultaneous intercropping with maize (Table 6). Hundred seeds of intercropped legume crops gained higher weight than the sole crop, where the two common bean varieties recorded their highest weight when simultaneously intercropped with maize. Soybean in intercrop produced heavier seeds than the sole stand, which is in difference with the observation of Carruthers *et al*. (2000), who stated that 100 seeds weight of soybean decreased by intercropping and for delayed intercropping three weeks after maize emergence.

Table 6. Interaction effects of species and intercropping time (WAME) on number of seeds/plant and 100 seed weight (g) of legume crops.

Legume species (LS)	Sole crop	Intercropping time (IT)†			Mean*
		Simultaneous	4 WAME	8 WAME	
Number of seeds/plant					
Black Dessie	29.5cd	56.5ab	18.5d-f	4.1f	27.13b
Awash Melka	34.0cd	40.5bc	11.2ef	8.3f	23.47b
Soybean	66.7a	52.7ab	27.9c-e	17.7d-f	41.23a
Mean*	43.37a	49.39a	19.16b	10.02b	
	LS	IT	LS × IT		
LSD (0.01)	11.58	13.38	NS		
(0.05)	-	-	17.05		
100 seeds weight (g)					
Black Dessie	12.3c	16.0ab	14.0bc	14.7bc	14.25
Awash Melka	12.3c	18.0a	14.0bc	12.7c	14.25
Soybean	13.0c	14.3bc	14.7bc	13.4c	13.85
Mean*	12.56b	16.11a	14.22ab	13.56b	
	LS	IT	LS × IT		
LSD (0.01)	NS	NS	2.425		
(0.05)	NS	1.903	-		

*Interaction means or main effect means within a column or a row followed by the same letter are not significantly different at the specified probability levels.

†WAME = Weeks after maize emergence; LS = Legume species; IT = Intercropping time; NS = Non-significant.

Grain Yield and Harvest Index

Data of grain yield on per plant basis showed a highly significant interaction effect of the treatments used in the study. In this regard, legume crops responded differently to cropping system treatments, where simultaneous intercropping of the common bean varieties yielded the highest grain weight as compared to the subsequent seeding and their respective sole crop; whereas in the case of soybean plants, in sole stand yielded more grain than intercropping treatments (Table 7). Grain weight per plant of the three legume crops in intercropping, generally exhibits a drastic decline as their seeding was delayed after maize.

Table 7.Interaction effects of species and intercropping time on per plant (g) and total grain yield (kg/ha) of legume crops.

Legume species (LS)	Sole crop	Intercropping time (IT)†			Mean*
		Simultaneous	4 WAME	8 WAME	
Grain per plant (g)					
Black Dessie	4.5de	8.0bc	3.7d-f	0.8f	4.25b
Awash Melka	4.2d-f	6.3cd	1.8ef	0.8f	3.29b
Soybean	18.2a	10.5b	6.2cd	2.7ef	9.38a
Mean*	8.94a	8.28a	3.89b	1.44c	
	LS	IT	LS × IT		
LSD (0.01)	1.734	2.002	3.468		
Grain yield (kg/ha)					
Black Dessie	551.7bc	285.8bc	113.1c	28.5c	244.80b
Awash Melka	476.6bc	246.4bc	46.1c	61.9c	207.72b
Soybean	2585.2a	1023.9b	584.3bc	354.3bc	1136.51a
Mean*	1204.51a	518.69b	247.83b	148.23b	
	LS	IT	LS × IT		
LSD (0.01)	448.8	518.2	897.6		

*Interaction means or main effect means within a column or a row followed by the same letter are not significantly different at $P \leq 0.01$ probability level.

†WAME = Weeks after maize emergence; LS = Legume species; IT = Intercropping time.

Highly significant treatment interaction effect was found on total grain yield of the legume crops, which showed that the actual yield records for each legume species were higher in the sole crop than the intercrops, irrespective of land use (relative yield). All of the legume crops in the intercrop treatments revealed a yield fall due to delay in intercropping times, with the exception of slight raise recorded in Awash Melka variety at the last planting date (Table 7). While evaluating the effects of planting pattern and relative planting date of haricot bean-maize intercrop, Chemeda (1997) also reported a reduction in bean seed yield with delayed planting.

Reductions in grain yield of other legume crops due to delaying planting in maize have also been reported by others (Carruthers *et al*., 2000; Lawson *et al*., 2007). The progressive decline of canopy development in later under seeded legume crops manifested, in the present study, by lower main stem height, poor branching and finally less biomass could not provide adequate assimilate for grain filling. Under such circumstances, flowers abort and/or seeds are only partially filled (Adipala *et al*., 2002).

Significant ($P \leq 0.05$) species variability was observed in harvest index, where Awash Melka variety that yielded the least biomass owed the highest index and the reverse is true for soybean (Table 8). The effect of intercropping treatments was also found to significantly affect the proportion of economic harvest of the legume crops, which showed that under seeding four WAME and simultaneously with maize succumb better value compared to the sole stand. This result disagrees with the finding of Carruthers *et al*. (2000), who reported that simultaneously seeding of soybean with maize resulted in decreased HI.

Table 8.Effects of species and intercropping time (WAME) on harvest index (HI) of legume crops.

		Intercropping time (IT)†			
Legume species (LS)	Sole crop	Simultaneous	4 WAME	8 WAME	Mean*
Black Dessie	0.42	0.53	0.61	0.50	0.517ab
Awash Melka	0.58	0.62	0.60	0.50	0.576a
Soybean	0.44	0.42	0.50	0.42	0.443b
Mean*	0.48b	0.52ab	0.57a	0.47b	
	LS	IT	LS × IT		
LSD (0.01)	0.089	NS	NS		
(0.05)	-	0.075	NS		

*Means within a row or a column followed by the same letter are not significantly different at the specified probability levels.

†WAME = Weeks after maize emergence; LS = Legume species; IT = Intercropping time; NS = Non-significant.

Relationships between Growth and Yield Components

In this study, significant positive correlation was observed between percent effective nodules (%EN) and number of pods per plant (PP) (Table 9), indicating the contribution of N-fixation for grain filling in legume crops as indicated by Gwata *et al*. (2003). Similarly, number of branches per plant (NB) was also significantly correlated with pods per plant (PP) ($r = 0.68$) and seed weight per plant (SWP) ($r = 0.71$); signifying that the role of canopy development in assimilation and assimilate allocation to reproductive growth (Adipala *et al*., 2002). Significant ($P \leq 0.05$) negative relation was also recorded between pods/plant and seeds per pod (SPP) proving that number of perfect seeds/pod is determined by the ability of the plant to allocate photosynthate to every pod the plant can carry.

Table 9. Correlation coefficients between growth and yield parameters of legume crops.

	NTN	%EN	NB	BF	BH	PP	SP	SWP	HSW	TGY
NTN	1	-0.04	0.05	-0.04	-0.04	-0.16	0.032*	-0.01	0.32*	-0.09
%EN		1	0.35*	0.42*	0.45*	0.39*	-0.29	0.40*	0.14	0.33*
Nb			1	0.70**	0.77**	0.68**	-0.03	0.71**	0.33*	0.46**
BF				1	0.84**	0.92**	-0.32	0.98**	0.00	0.85**
BH					1	0.88**	-0.39*	0.83**	-0.04	0.79**
PP						1	-0.47**	0.89**	-0.03	0.8**
SP							1	-0.23	0.35*	-0.41*
SWP								1	0.09	0.86**
HSW									1	-0.12
TGY										1

* = Significant at P = 0.05; ** = Significant at P = 0.01; NTN = No. of total nodules; %EN = Percentage effective nodules; NB = No. of branches; BF = Biomass at flowering; BH = Biomass at harvest; PP = Pods/plant; SP = Seeds/pod; SWP = Seed weight/plant; HSW = Hundred seed weight; TGY = Total grain yield.

Intercrop Efficiency

Land equivalent ratio

Significant ($P \leq 0.05$) effect of treatment combination (species and intercropping time) was observed on partial LER of legumes, where values greater than one were recorded in early seeding of the two common bean varieties (Awash Melka and Black Dessie). Partial LER of legume crops generally fall as interceding was delayed (Table 10), which indicated that bio-economic efficiency of legume crops in utilization of natural resources (land and light) declined when under seeded in already established maize. While considering total LER, all the treatment combinations valued $LER_{total} > 1$, ranging between 2.14 and 1.14.Accordingly, intercrop combinations of this study could be considered more efficient than the respective monocrop from a land use perspective (Willey 1980).Similarly to this finding, Chemeda (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.

Agressivity and competitive ratio

Positive aggressivity values, at early seeding of the legume crops, indicated in Table 10 signified that legume crops were dominant over maize when simultaneously seeded with maize. The negative values in the subsequent seedlings, however, proved that legumes were less competitive with maize when seeded under already established maize. Generally, the dominance behavior of maize crop over the legumes is corroborated by lower CR_l values of legume crops (Table 10); with the exception of Awash Melka variety that recorded the highest A_{lm} value (+0.59) became more competitive over maize (CR_l= 1.23).

Table 10. Land equivalent ratio (LER), aggressiveness (A) and competitive ratio (CR) of legume crops (l) seeded on three dates [simultaneously (I), 4 WAME (II) and 8 WAME(III)] as intercropped with maize crop (m).

Treatment combination		LER				CR	
		LER_l	LER_m	LER_{tot}	A_{lm}	CR_l	CR_m
Black Dessie	I	1.1ab	1.04ab	2.14	+0.06a-c	0.55a-d	2.39c
	II	0.42b-d	1.04ab	1.46	-0.63b-d	0.25b-d	6.09bc
	III	0.10d	1.16a	1.26	-1.06d	0.04d	23.31a
Awash Melka	I	1.15a	0.56b	1.71	+0.59a	1.23a	1.03c
	II	0.20d	0.97ab	1.17	-0.78cd	0.11cd	9.71b
	III	0.28d	0.86ab	1.14	-0.57b-d	0.22b-d	6.19bc
Soybean	I	0.99a-c	0.77ab	1.76	+0.22ab	0.84ab	2.18c
	II	0.61a-d	0.75ab	1.36	-0.14a-c	0.79a-c	4.17c
	III	0.39cd	1.09a	1.48	-0.7cd	0.22b-d	10.00b
LSD (0.01)		NS	NS	NS	0.86	NS	5.27
(0.05)		0.68	0.5	0.5	-	0.68	-

Means within a column followed by the same letter are not significantly different at specified probability level.
LER = Land equivalent ratio; A = Aggressivity; CR = Competitive ratio; NS = Non-significant.

Actual yield loss and intercrop advantage

Quantification of yield loss or gain due to association of species or the variation of the plant population could not be obtained through partial LERs, whereas partial actual yield loss (AYL) indicates the yield loss or gain by its sign as well as its value (Banik *et al*., 2000). In the present study, values of AYL_l and AYT_{total} were positive under simultaneous intercropping (Table 11), indicating that legume crops compensated for yield loss of maize when interceded on the same date with maize.

Intercropping advantage (IA), which is an indicator of the economic feasibility of the intercropping systems, affirmed that simultaneous intercropping of legumes with maize was advantageous and the value of IA for legumes reduced with delayed interceding. In this regard, the partial and total IA values of simultaneous intercropping of Black Dessie with maize proved to be the most remunerative one (IA_l = +1282.5 and IA_{tital} = +1353.5, respectively). Moreover, delaying the interceding of this crop for 4 WAME recorded exceptionally positive partial and total IA values (Table 11). Generally, the role legumes played in associations in terms of economic advantage got lesser and lesser when their interceding was delayed.

Table 11. Actual yield loss (AYL) and intercropping advantage (IA) of legume crops (l) seeded on three dates [simultaneously(I), 4 WAME (II) and 8 WAME(III)] as intercropped with maize crop (m).

Treatment combination		AYL				IA		
		AYL_l	AYL_m	AYL_{tot}		IA_l	IA_m	IA_{tot}
Black Dessie	I	+2.73a	+0.203a	+2.93a		+1282.5a	+71.02a	+1353.5a
	II	+0.74b	+0.08ab	+0.82c		+347.5b	+29.02ab	+376.5b
	III	-0.62c	+0.153a	-0.47d		-293.2cd	+53.41a	-237.8cd
Awash Melka	I	+2.1a	-0.25b	+1.87b		+1050.0a	-88.61b	+961.4a
	II	-0.16bc	-0.123ab	-0.29d		-82.1b-d	-44.60ab	-126.7cd
	III	-0.59c	-0.07ab	-0.66d		-296.4cd	-23.95ab	-320.4cd
Soybean	I	+0.19bc	-0.083ab	+0.11cd		+112.8bc	-30.00ab	+42.8bc
	II	-0.3c	-0.253b	-0.55d		-195.8cd	-87.85b	-283.7cd
	III	-0. 7c	+0.02ab	-0.68d		-453.9d	+7.83ab	-446.1d
LSD (0.01)		NS	NS	NS		NS	NS	NS
(0.05)		0.92	0.346	0.99		468.9	132.9	490.4

Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ probability level. AYL = Actual yield loss; IA = Intercropping advantage; NS = Non-significant.

CONCLUSION

Our data show that simultaneous seeding of legume crops with maize resulted in taller plants with better canopy than the monocrop, while delaying intercropping of legumes in maize stand was observed to result in shorter, less branched and less nodulated plants. Hence, it could be concluded that simultaneously intercropped legumes exhibited a high degree of morphological plasticity compared to sole crop, presumably in response to increased competition for light. The result of this study also confirmed that yield parameters of legume crops namely, number of pod per plant and seeds per pod were adversely affected with delayed interseeding of legume crops in an already established maize crop, which consequently reduced total grain yield, probably due to the shading effect of the taller component maize. The effect of planting date treatments also significantly affected the HI of the legume crops, which showed that seeding of legumes simultaneously with maize and 4 WAME provided better HI values compared to the sole stand. Significant effect of treatment combinations was observed on partial LER of legumes, where values greater than one were recorded in early seeding of the two common bean varieties. Partial LER of legume crops generally fall as interseeding was delayed, which indicated that bio-economic efficiency of legume crops in resource utilizations declined when underseeded in already established maize. Moreover, values of AYL_l and AYT_{total} were found to be positive under simultaneous intercropping and reduced with delay in interseeding, indicating that legume crops better compensated for yield loss of maize due to intercropping when interseeded on the same date with maize. This was corroborated by the positive partial and total IA values of simultaneous intercropping, where Black Dessie and maize association proved to be the most remunerative one.

Generally, computations of agronomic performances and intercrop efficiencies revealed that the advantages of intercropping exacerbated when seeding of legumes was delayed after maize.

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