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DETERMINATION OF OPTIMUM SPATIAL ARRANGEMENT AND PLANT POPULATION IN SESAME SORGHUM INTERCROPPING

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ABSTRACT

Information regarding sesame in sorghum intercropping is very little. The present study was undertaken to determine optimum proportion of component crops and to compare the land use efficiency and economic returns of the component crops of sorghum/sesame intercropping system and enhance food security in Mieso area of oromiya region. The experiment was laid out in factorial Randomized Block Design with three replications. The treatment consists of three spatial arrangements (1:1, 2:1 and 2:2 of sorghum: sesame), three intra-row spacing of sesame (5 cm,10 cm and 15 cm) and sole crop of component crops. Intercropping significantly (P<0.05) decreased yield of sesame compared to pure stand. The grain yield of sesame in intercropping (91.0 kg ha^{-1}) was very low compared to sole sesame (430.kg ha^{-1}) which was nearly five times high. Spatial arrangement had statistically (P<0.05) a noticeable influence on the grain yield of sesame. The highest grain yield 110 kg ha^{-1} and 100 kg ha^{-1} were found in 1:1 and 2:1 sorghum: sesame arrangements respectively whereas, the lowest (70 kg ha^{-1}) grain yield was found in 2:2 sorghum: sesame arrangement. The main effect of spatial arrangement and intra row spacing were significantly affected the partial LER of sesame despite their interaction were non-significant. Maximum partial LER of sesame (0.22) was observed at 10 cm intra row spacing while the lower partial LER (0.19) was calculated at 15 cm intra row spacing. Maximum LER value (1.33) was observed at 1:1 sorghum: sesame arrangement whereas the minimum LER value (1.26) was recorded under 2:1 sorghum: sesame arrangement. Closer intra row spacing (5 cm) showed LER of 1.32 while the other wider intra row spacing showed 1.27 total LER each, in fact, the difference was statistically insignificant (P>0.05). This study concluded that intercropping sorghum and sesame in one to one ratio (1 row sorghum: 1 row sesame) found to be appropriate at Mieso agro ecology. Moreover, all arrangements resulted above the yield of sole cropping. Sowing of sesame in 5 and 10 cm intra row spacing under sorghum/sesame intercropping was preferable.

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INTRODUCTION

Intercropping is growing two or more crops in a piece of land together to increase productivity per unit of land. Intercropping is receiving attention because it offers potential advantages for resource utilization, decreased inputs and increased sustainability in crop production, but our understanding of interactions among intercropped species is still very limited. The basic physiological and morphological differences between non-legume and legume benefit their mutual association (Akunda, 2001).

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The differences in the depth of rooting lateral root spread and root densities are some of the factors of competition between the component crops in an intercropping system for water and nutrients and hence input use efficiency. Subsistent farmers in tropics and subtropics practiced intercropping from time immemorial. Moreover, recently it realized that intercropping have several advantage and remains wide spread practice (Hirpa, 2006). It received attention because it offers potential advantages for resource utilization, decreased inputs and increased sustainability in crop production (Egbe, 2010). But several studies on plant population densities in cereal/legume intercropping had reported more yield depression of the legumes than the cereal component (Muonekeet *al*., 2007;

Fujita *et al*., 1992). Such studies had often used sub-optimal densities of the legume and optimal densities of the cereal, often attributed to farmers' preference for the cereal component. In Ethiopia, intercropping is a common practice particularly in semi arid eastern part, subsistent farmers intercrop sorghum/chat, sorghum/groundnut, sorghum/sesame, maize/haricot bean and in humid south and south western part, farmers famously intercrop coffee/enset, coffee/chat etc.Sesame (*Sesamumindicum* L.) is an ancient annual oil crop cultivated in warm climate of the world. In Ethiopia, sesame is widely grown in Amhara, Tigray, Benishangule, Oromiya and Gambella regions mainly for export purpose. Ethiopia is known to be the center of origin and diversity for cultivated sesame and ranked 4th in export of sesame in the world market that brings foreign currency to the country and more than three million smallholders are involved in sesame production. Next to cereals and pulses, oil crops are the third major crops both in area and production of which sesame takes greatest share (Tadele, 2005). Sorghum (*Sorghum bicolor* L.) is the fifth most important cereal crop in the world after wheat, rice, maize and barley. It is adapted to tropical and subtropical climates but the greater part of the area of the crop falls in drought-prone, semi-arid tropical regions of the world (Singh, F., *et al.*1997). Sorghum is one of the staple food grains of the world's poorest people, particularly in semiarid tropics. It covers some 14% of the cultivated area and the third major crop in production and area coverage after 'teff' and maize in Ethiopia (CSA, 2011). The grains used for human consumption including 'injera' making and local beverages while the leaves and stalks are utilized as animal feed, construction and soil management. At Mieso area of Oromiya region intercropping sorghum and sesame is common, mainly to avert failure caused by drought; more than 85% of sesame production is intercropped with sorghum or maize (Bayisa, 2010). The population density and spacing for sole sorghum (Hirpa, 2006) and sole sesame (Tadele, 2005) at the area is well documented. However, information regarding sesame in sorghum intercropping is very little. Hence, this experiment was carried out to provide basic information on spatial arrangement and intra row spacing of sesame in sesame sorghum intercropping. The present study was undertaken to determine optimum proportion of component crops and to compare the land use efficiency and economic returns of the component crops of sorghum/sesame intercropping system and enhance food security in Mieso area of oromiya region.

MATERIAL AND METHODS

Miesso is located in the Eastern escarpment of the Central Rift valley of Ethiopia that forms the heart and corridor of the Ethiopian Rift Valley. The geographical location of MiessoWoreda is between 8°48''12'-9°19''52'Naltitide and 40°9''30'-40°56''44'Elongitudes and found at an altitude ranging from 1107 to 3106 masl. The trial was conducted for three consecutive years (2010, 2011 and 2012) at Mieso in western Hararghe zone of Oromiya region in eastern Ethiopia. The site is characterized by semiarid climate, where mixed cropping is dominant farming system. The experiment was laid out in factorial Randomized Block Design (RCBD) with three replications. The treatment consists of three spatial arrangements (1:1, 2:1 and 2:2 of sorghum: sesame), three intra-row spacing of sesame (5 cm,10 cm and 15 cm) and sole crop of component crops. The gross plot size was 5 m x 5.6 m (28 m^2) accommodating seven rows of sorghum and different rows of sesame as per the treatment. Spacing of 80 cm x 20 cm was used for sole sorghum while 40 cm x 10 cm spacing was used for sole sesame. The sorghum variety used for this experiment was Teshale, which has 169-271 cm average height, 123 days maturity period and 2.7 t/ha grain yield under farmer field condition. Sesame variety used as a test crop was Tate released by Werer Agricultural Research Center which has 80-100 cm average height,130 days maturity period and 650 kg/ha grain yield under rain fed condition.For base and component crops, phenology and growth data likeemergence date, days to flowering, and days to heading (pod setting for sesame) were recorded by counting number of days from emergence to the time when 50% of the plants in each plot reached at phonological stage. Days to maturity were recorded by counting number of days from emergence to the time when 75% of the plant population reached physiological maturity. Plant height and number of branches/plant were recorded from five randomly sampled plants when the plant reached 75% flowering. Yield and yield components like number of pods/ears per plant were recorded from five randomly selected plants at maturity. Grain yield was recorded after threshing sun dried heads of sorghum and shelling the sun dried pods of component crop from each plot and converted to kg/ha. Thousand seed weight (g) was measured from 1000 seeds using sensitive electronic balance. For sorghum, Panicle weight (gm/plant) at harvest was recorded from measurements made on five randomly selected plants. Biological efficiency of intercropping system was evaluated using land equivalent ratio (LER) based on the method of Mead and Willy (1980). The LER was calculated based on the maximum sole crop yield by using the following formula:

$$PLERsorghum = \frac{Yield of intercrop sorghum}{Yield of sole sorghum}$$

$$PLERsesame = \frac{Yield of intercrop sesame}{Yield of sole Sesame}$$

$$LER = PLERsorghum + PLERSesame$$

Where: PLER =partial land equivalent ratio
LER = land equivalent ratio

Monetary Returns

Monetary advantage (MA) values were calculated based on gross returns as suggested by Willey (1979).

$$MA = (value\ of\ combined\ intercroping)xLER - \frac{1}{LER}$$

Where: MA = Monetary Advantage

Finally, analysis of variance (ANOVA) for the experimental data was performed using SAS software (SAS Institute, 2004). Mean values were achieved by using least significant difference (LSD) test. The probability level less than 0.05 were designated as significant. When there was a statistically significant interaction between the factors, the interaction was considered, rather than the main effects, otherwise, only the main effects of treatments were presented.

RESULT AND DISCUSSION

Phenology and growth: The result of this experiment indicated that arrangement and intra-row spacing had no marked influence on 50% flowering, 75 % physiological maturity and plant height of either base crop or component crop (Table 1). Moreover, both sorghum and sesame did not show any significant difference on growth and phenology in pure stand or intercropping, except sorghum matured a day earlier when intercropped. On average, sesame reach 50% flowering in 44-45 days and 75% physiological maturity in 108-109 days while sorghum reach 50% flowering in 69-71 days and 75% physiological maturity in 101-102 days. Influence of spatial arrangement was not statistically significant (P>0.05) on plant height of the component crops. However, 1:1 arrangement of sorghum/sesame was found to be relatively taller (202 cm) as compared to pure stands of sorghum (190.1 cm) and other arrangements (187.5 cm) each.

planted sesame. Sole sesame had 284.3 plants per plot at harvest opposed to 138 in intercrop , sole sesame had 38 pods per plant while only 21 with intercropped sesame. In addition, number of fruiting branches per plant and thousand seed weight (TSW) were lower in intercropped sesame. Badran (2009) reported the same trend in maize/sesame intercropping in Alexandria. In the other hand, intercropping of sorghum with sesame did not affect the yield component of sorghum. There was no any significant difference in yield components between intercropped sorghum and solid planted, except for stand count per plot at harvest. This observation was similar to the finding of Hirpa (2006) under sorghum/pigeon pea intercropping at Mieso area. Spatial arrangement had no any impact on yield components of component crops, except plant

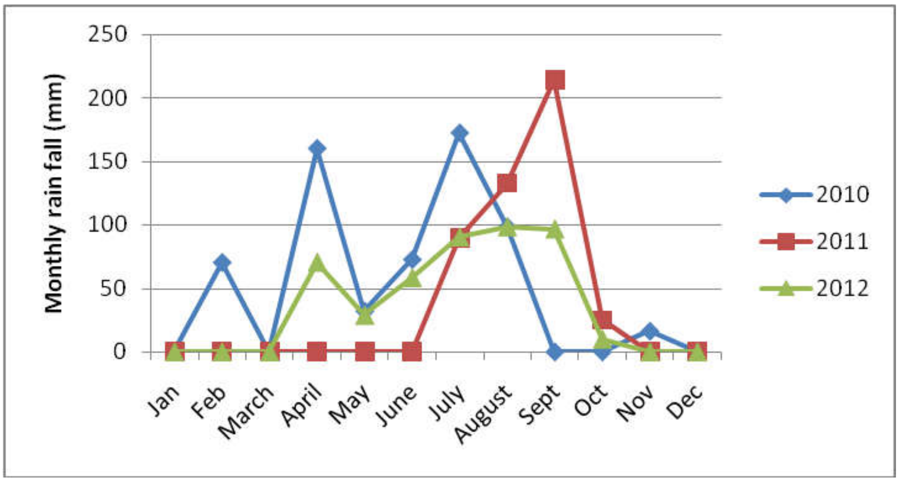

Figure 1.Mieso monthly rain fall for 2010-2012 cropping season

Table 1.Effect of intercropping on phenology and growth of sesame and sorghum (average of three years: 2010, 2011, 2012) at Mieso

	Sesame			Sorghum		
Treatment	Days to 50 % flowering	Days to 70 % Maturity	Plant height (cm)	Days to 50 % flowering	Days to70 % maturity	Plant height (cm)
Sole	44.1	108.7	95.9	69.8	102.1a	190.1
Intercropped	44.7	108.4	98.3	69.7	101.2b	192.6
$LSD_{0.05}$	Ns	ns	Ns	Ns	0.6	Ns
Arrangement (A)						
1:1	44.6	108.3	97.6	69.5	101.3	202.9
2:1	44.9	108.5	98.6	69.7	101.3	187.5
2:2	44.5	108.4	98.7	69.7	101.1	187.5
$LSD_{0.05}$	Ns	Ns	Ns	Ns	Ns	Ns
Intra spacing (I)						
5	44.5	108.1	99.8	69.5	101.0	199.6
10	45.0	108.2	96.5	70.3	101.5	186.5
15	44.5	109.0	98.7	69.3	101.1	191.8
$LSD_{0.05}$	Ns	Ns	Ns	Ns	Ns	Ns
Year	**	**	*	Ns	Ns	*
A*I	Ns	Ns	Ns	Ns	Ns	Ns
Mean	44.7	108.4	98.3	69.7	101.2	192.6
CV%	3.6	1.7	8.8	2.7	1.0	18.4

/*ns= non-significant

This result is in line with the findings of Yusuf (2003), who pointed out intercropping of sorghum/haricot did not show statistically significant difference on 50% Phenological stages of sorghum development. Samia*et al*. (1994) also reported intercropping sweet sorghum with sesame had no significant effect on sweet sorghum height. There was no significant interaction of spatial arrangement and intra row spacing (Table 1) on growth and phenological stage of component crops.

Yield components: The data shown in Table 2 revealed intercropping sesame with sorghum significantly reduced all recorded traits of yield components as compared with sole

density at harvest for sesame (Table 2). Compared to other spatial arrangements sesame had the lowest plant population under the 2:1 spatial arrangement. Plant density and pod number per plant of sesame were significantly influenced by intra row spacing while number of fruiting branch and TSW were not affected. The highest plant density per plant at harvest (174.1) recorded with 5 cm intra spacing and the lowest (109.5) plant density at harvest was recorded with 15 cm intra row spacing. The highest pod numbers per plant (24.4) were observed with 15 cm intra spacing while the lowest pods (19.9) was recorded from 5 cm spacing. This indicates plant density and pod number per plant had inverse

Table 2. Effect of intercropping on grain yield and yield components of sesame and sorghum (average of three years: 2010, 2011, 2012) at Mieso

	Sesame					Sorghum			
Treatment	Stand count at harvest	Number of pods/plant	Number of branch/plant	Grain yield kg ha^{-1}	TSW	Stand count at harvest	Panicle weight (g)	Grain yield kg ha^{-1}	TSW
Sole	284.3a	38.9a	7.8a	430.0a	2.9a	86.2a	48.6	1580.0	18.4
Intercropped	138.03b	21.88b	5.3b	91.0b	2.58b	73.8b	54.0	1490.0	18.3
LSD $_{0.05}$	33.9	5.5	1.2	23.0	0.2	7.0	ns	Ns	ns
Arrangement (A)									
1:1	153.8a	20.1	5.3	110.0a	2.6	75.2	54.4	1520.0	18.4
2:1	102.4b	23.4	5.7	100.0a	2.6	74.0	54.7	1520.0	18.3
2:2	157.9a	22.1	5.0	70.0b	2.6	72.3	52.9	1440.0	18.2
LSD$_{0.05}$	15.2	ns	Ns	14.0	Ns	Ns	ns	Ns	ns
Intra spacing (I) (cm)									
5	174.1a	19.9b	4.8	94.0	2.6	73.5	55.1	1480.0	18.4
10	130.4b	21.3ab	5.7	96.0	2.6	72.5	52.4	1420.0	18.0
15	109.5c	24.4a	5.5	83.0	2.5	75.6	54.5	1570.0	18.3
LSD$_{0.05}$	15.2	4.3	Ns	Ns	Ns	Ns	ns	Ns	ns
Year	*	*	*	*	*	*	*	*	*
A*I	ns	ns	Ns	Ns	Ns	Ns	ns	Ns	ns
Mean	138.03	21.88	5.3	91.0	2.58	73.8	54.0	1490.0	18.3
CV%	20.2	35.9	33.5	28.5	10.5	12.6	25.2	37.3	13.9

/*ns= non significant, TSW=thousand seed weight

Table 3. Land Equivalent Ratio and Monetary advantage of intercropping (average of three years: 2010, 2011, 2012) at Mieso

Treatment	Partial LER		Total LER	Monetary advantage (Birr ha^{-1})
	Sesame	Sorghum		
Arrangement				
1:1	0.24a	1.08	1.33	5889
2:1	0.22a	1.09	1.26	4347
2:2	0.16b	1.06	1.28	4647
LSD$_{0.05}$	0.03	Ns	Ns	Ns
Intra spacing (I) (cm)				
5	0.21ab	1.1	1.32	5252
10	0.22a	1.06	1.27	4481
15	0.19b	1.08	1.27	5151
LSD$_{0.05}$	0.03	Ns	Ns	Ns
Year	*	*	*	Ns
A*I	ns	Ns	Ns	Ns
Mean	0.21	1.08	1.29	4961.1
CV%	26.9	25.99	23.2	116.3

/* ns= non significant, LER=land equivalent ratio

relationship. Yield components of sorghum did not respond to intra row spacing of sesame at all.

Grain Yield: Intercropping significantly (P<0.05) decreased yield of sesame compared to pure stand (Table 2). The grain yield of sesame in intercropping (91.0 kg ha^{-1}) was very low compared to sole sesame (430.kg ha^{-1}) which was nearly five times high. The yield reduction of the intercropped sesame might be caused by inter specific competition between the intercrop components for light, water, nutrients, air, etc. and the depressive effects of sorghum. Nevertheless, intercropping did not influence the yield of sorghum which is the base crop and the staple food at the area. The mean yield of sorghum in intercropping was 1490 kg ha^{-1} compared to 1580kg ha^{-1} in pure stand. This finding was in similar trend with many authors (Hirpa, 2006) in sorghum/pigeon pea, Samia et.al (1994) sorghum/sesame intercropping, Badran (2009) in maize/sesame intercropping.Spatial arrangement had statistically (P<0.05) a marked influence on the grain yield of sesame. The highest grain yield 110 kg ha^{-1} and 100 kg ha^{-1} werefound in 1:1 and 2:1 sorghum: sesame arrangements respectively whereas, the lowest (70 kg ha^{-1}) grain yield was found in 2:2 sorghum: sesame arrangement. The response of sorghum grain yield for spatial arrangement was insignificant (P>0.05) despite a slight yield decrease (1440 kg ha^{-1}) in 2:2 sorghum: sesame arrangement compared to other arrangements thatproduced 1520 kg ha^{-1} grain yield of sorghum each.

The effect of intra row spacing on grain yield of sesame and sorghum in intercropping was not statistically significant (P>0.05). The trend of grain yield for sesame and sorghum were at disparity; grain yield of sesame inconsistently decreased with increased intra row spacing while grain yield of sorghum inconsistently increased with increased intra row spacing of sesame in intercropping. This could be, there was slight completion from denser sesame population on sorghum plants. However, the overall competition effect of sesame on sorghum yield was minimal. The interaction of spatial arrangement and intra row spacing was insignificant (Table 2) on grain yield of both crops.

LER and Monetary advantage: Biological land used efficiency of intercropping system (LERs) above 1.0 show an advantage to intercropping, while numbers below 1.0 show a disadvantage to intercropping. The main effect of spatial arrangement and intra row spacing were significantly affected the partial LER of sesame despite their interaction were non-significant (Table 3). The highest partial LER of sesame (0.24) was recorded at 1:1 sorghum: sesame arrangement while the lowest partial LER of sesame (0.16) was observed at 2:2 sorghum: sesame arrangement. For intra row spacing, the maximum partial LER of sesame (0.22) was observed at 10 cm spacing while the lower partial LER (0.19) was calculated at 15 cm intra row spacing. In other words, compared to the pure stand, yield loss of sesame under intercropping ranged from

76-84%. Partial LER of sorghum was more than one in all cases indicating sorghum was more productive under intercropping than pure stand. Nonetheless, there was no significant difference (P>0.05) between different spatial arrangements or different intra row spacing of sesame on partial LER of sorghum.The total LER was non-significant (P>0.05) for spatial arrangement and intra row spacing (Table 3). The total LER value of this study was greater than one in all cases indicating the yield advantage of intercropping over sole cropping. The maximum LER value (1.33) was observed at 1:1 sorghum: sesame arrangement whereas the minimum LER value (1.26) was recorded under 2:1 sorghum: sesame arrangement. Closer intra row spacing (5 cm) showed LER of 1.32 while the other wider intra row spacing showed 1.27 total LER each, in fact, the difference was statistically insignificant (P>0.05). The overall yield advantage of intercropping ranged from26-33% compared to sole cropping. This is mainly due to compensation from stable sorghum yield that offset the lower yield of sesame under intercropping system throughout the three years.

Monetary advantage: The data (Table 3) revealed spatial arrangement, intra row spacing or their interaction did not affect the gross monetary return from sorghum/sesame intercropping. Despite insignificant (P>0.05), the maximum gross monetary return of 5889 birr ha^{-1} was obtained at 1:1 arrangementof sorghum: sesame whereas the lowest 4347 birr ha^{-1} was obtained at 2:1 sorghum: sesame intercropping. The highest gross monetary return of 5252 birr ha^{-1} was obtained at narrower intra spacing of 5 cm sesame under intercropping while the lowest gross monetary return 4481 birr ha^{-1} was obtained from 10 cm intra row spacing of sesame under inter cropping.

Conclusion

This study concluded that intercropping sorghum and sesame in one to one ratio (1 row sorghum: 1 row sesame) found to be appropriate at Mieso agro ecology. Moreover, all arrangements resulted above the yield of sole cropping. Sowing of sesame in 5 and 10 cm intra row spacing under sorghum/sesame intercropping was preferable. The most appealing, yield, growth and phenology of sorghum were not affected by intercropping; signifying sesame can be grown simultaneously as component crop for additional income. This study was mostly has been focused on crop combinations and intra row ratios only, giving less importance to moisture, sowing time, nutrient dynamics and favorable influence of component crop on base crop. Further investigations on aforementioned practices and effect of varying rainfall pattern be worth due attention. In the time of diminishing size of holding, the net cultivated area and risks of failure due to erratic rain fall, intercropping can increase the total production of sesame in the area as could be seen from the remarkable increases in LER and monetary returns.

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