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Original Research

Benefit and Compatibility of Maize (*Zea mays L.*) Groundnut (*Arachis hypogaea*) Intercropping as Affected by Spacing and Row Arrangements

Melkamu Dugassa[1]*, Hirpa Legesse[2] and Negash Geleta[2]

[1]Center for studies of Environment and Society, Wollega University, P.O. Box: 395, Nekemte Ethiopia

[2]Department of Plant Sciences, Wollega University, P.O. Box: 395, Nekemte Ethiopia

Abstract

A study was conducted during the main cropping season of 2015 /2016 at Wollega University Uke Research and Demonstration station with the objectives of determining the effect of row arrangements and spacing in maize groundnut intercropping on benefit and compatibility of the crops. Maize BH 540 and groundnut (local) were used as a planting material. The treatments consisted of four row arrangements with five intra row spacing for groundnut combined factorially and arranged in randomized complete block design. Groundnut sole was planted at row and plant spacing of (60X10) cm. Row spacing for the intercropped groundnut was 37.5cm when 1:1 and 2:1 row arrangement and 25cm was used in 1X2 and 2X2 row arrangements. Intercropped and maize sole was planted at a spacing of 75 x 25 cm. Data were collected on land equivalent ratio, Competitive ratio, Relative crowding coefficient Agressivity ratio, Area time equivalent ratio and Monetary advantage of the crops. Treatment 1:2X10cm is compatible and beneficial in terms of land equivalent ratio and monetary advantage. The land equivalent ratio, competitive ratio agressivity ratio, area time equivalent ratio and monetary advantage were significantly affected at probability <0.05 due to the interaction effects of row arrangements and spacing and interaction effects. The competitive ratio values were positive for both crops but greater for maize. The additional yield obtained from the crops in the intercropping not only compensated the yield lost but also resulted in more revenue. Hence, intercropping of maize/groundnut is advantageous for the farmers.

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***Corresponding Author:**

Melkamu Dugassa

E-mail:

melkamudugasa@gmail.com

INTRODUCTION

Maize is an annual crop of great importance; it was first domesticated in America. It is the most important cereal crop in the world after wheat and rice (Onwueme and Sinha, 1991). Maize has the highest average yield per hectare and it is grown in most parts of the world over a wide range of environmental conditions. The crop belongings to the Family Poaceae that is used as a source of carbohydrate to both human (in the developing countries) and animal feed worldwide due to its high feeding value (Undie *et al.,* 2012) it is recently used in production of bio fuel. It is equally well accepted for feed ingredient and can contribute up to 30% protein, 60% energy, and 90% starch in animal diet (Dado, 1999). It is a major item in the diet of many tropical countries whereas in the temperate regions, maize is the main grain used for animal feed.

Global production exceeds 600 metric tons (McDonald and Nicol, 2015), with about 60% produced in the developed countries, particularly by the United States of America, China produces 27% of the world's maize and the rest is grown in countries of Africa, Latin America, and southern Asia with a large proportion being produced in the tropics and subtropics. The major producers in Africa are South Africa, Nigeria, Egypt and Ethiopia (USDA, 2007). Maize is one of the most important cereals cultivated in Ethiopia. It ranks second after teff in area coverage and first in total production. Maize is cultivated in a wide range of altitudes, moisture regimes, soil types and terrains, mainly by smallholder crop producers, which comprise 80 percent of the total population, in all regional states. Maize is currently grown across 13 agro-ecological zones, which together cover about 90 percent of the country (Dawit *et al*., 2008). According to CSA 2014, in Ethiopia maize is produced on an area of 2 million hectares and occupies more than 21% of the area allocated to cereals and 30% of the total cereal production which accounted for 6.5 million tones. The crop is grown by the vast majority of the rural households and food staple especially in major growing regions. Current national average grain yield is 3.5 tones ha^{-1} which is very low as compared to developed countries. FAOSTAT, (2010) report showed the yield per hectare of different countries as 10.3 tones ha^{-1} for USA, 9.7 tones ha^{-1} for Germany, 8.4 tones ha^{-1} for Canada 4.96 tones ha^{-1} for South Africa and 5.1 tones ha^{-1} the world average.

In Ethiopia, the crop is an important because of its high productivity per unit area, suitability to major agro ecologies, compatibility with many cropping systems, ease of traditional dish preparation. It is also a food security crop in the country where recurrent drought is a common phenomenon (Tesfaye *et al*., 2001).

Groundnut is the sixth most important oilseed crop in the world. It is grown on 26.4 million ha worldwide with a total production of 38.2 million metric tons (FAOSTAT, 2010). Developing countries account for 97% of the world's groundnut area and 94% of the total production. Groundnut is an unpredictable crop due to the development of pods underground (Zaman *et al*., 2011).Groundnut is one the five widely cultivated oilseed crops in Ethiopia (Wijnands *et al., 2009).* The crop is grown under rain-fed and used for oil extraction, and for confectionary in Ethiopia. Moreover, it generates considerable cash income for several small scale producers and foreign exchange earnings through export for the country (Geleta *et al*., 2007).

As indicated by FAOSTAT (2010), groundnut yield in Africa is lower (0.98t/ ha) than the average world groundnut yields. Researchers associate these lower yields to abiotic, biotic and socio-economic factors (Pandey *et al*., 2003; Upadhyaya *et al*., 2006; Caliskan *et al*., 2008). In Ethiopia the national average yield of groundnut is 1.123 t/ ha. The survey report (Berhanu, *et al*., 2011) indicated the significant yield gap between the farmers' fields and the research centers, which is due to lack of improved groundnut varieties and as a result of various biotic and abiotic stresses like drought, insect pests, diseases etc.(Abdalla *et al*., 2005).

Andrews and Kassam, (1976) defined intercropping as the agricultural practice of cultivating two or more crops in the same farm and at the same cropping season. In intercropping farming system, usually one main crop and one or more were used as added crops (Saka *et al*., 2007). The two or more crops used in an intercrop may be from different species or different plant families, they can simply be different varieties or cultivars of the same crop species, such as mixing two kinds of barley seed in the same farm. Main purpose of intercropping is to produce a greater yield on a given piece of land by making use of resources in the way of maximum efficiency. According to (Tsigbey *et al*., 2003; Naab *et al*., 2005), to enable the farm family meet its household food needs and cash requirements, many subsistence farmers practice intercropping in which groundnut frequently forms an important part of the system. Groundnut maize intercropping, as a common practice among farmers in dry land areas is well documented in Ghana (Reddy *et al*., 1987 Amankwah *et al*., 1990; Tsigbey *et al*., 2003; Naab *etal*. ,2005) and elsewhere (Molatudi and Mariga, 2012; Siddig *et al*., 2013; Mehdi, 2013). The yields obtained from the intercrops were found to relate directly to their population densities (Langat *et al*., 2006), giving an indication that the overall plant population can be skewed to favor one crop over the other in the intercrop depending on the farmer's priority or individual crop profitability.

Differences in the canopies of crops appear to provide more efficient light use by spatial arrangements than by sole cropping (Dwomon and Quainoo, 2012). In spite of the multi advantages of intercropping, the farmers in the study area plant maize and groundnut crops singly. Moreover, no research has been done in western region of Ethiopia regarding the effects of spacing and row arrangement in maize groundnut intercropping system on benefits and compatibility of the crops. This study was done to fill the information gap regarding the effects of spacing and different row arrangement of maize and Groundnut on benefits and compatibility of the crops in the intercropping system.

MATERIALS AND METHODS

Description of the Study Area

The research was conducted in East Wollega zone, Guto Gida district at Uke Research and Demonstration center of Wollega University during the main rainy season of 2015/2016. Uke is located at about 365km far away from Addis Ababa to the west on Nekemte Bure Bahir Dar Main road. The area is located at altitude between 1500-1700masl; and it is an area with high temperature, and rain fall conditions. Major crops produced in the area include maize, sorghum, soybean, sesame, groundnut etc.

Planting Material

A maize variety BH 540 and groundnut seed locally available were used for the experiment. BH-540 a maize variety released by Bako agricultural research center and ground nut seed used was a local variety produced by farmers locally.

Experimental Design

The treatments consisted of different row arrangements of maize/groundnut alternately (1:1, 1:2, 2:1, 2:2) one row maize and one row groundnut, one row maize and two rows of groundnut, two rows maize and one row groundnut, two rows maize and two rows groundnut with five different intra row spacing (10, 15, 20, 25, and 30) cm for groundnut. The treatments are combined factorially and laid out in Randomized Complete Block Design (RCBD).There were 20 treatment combinations and 2 controls (sole Maize and sole Groundnut.) with three replications. Plot size was 3x4m, ($12m^2$) with spacing of 2m between blocks and 1m between plots.

Experimental Procedure

The total area used for the experiment was 1392 m^2 (87*16). The area was cleared of grasses and crop debris and then ploughed with mounted tractor and be harrowed. Planting of seeds was carried out by putting seeds of maize with in ridges by (75*25) cm. using 25 kg $^{-1}$ seed of maize and 100 kg of DAP were used at Sowing and 200kg of urea was used (100 kg during planting and the remining100 kg at knee stage for maize at 40 days after planting). Groundnut sole was planted at row and plant spacing of (60*10), and seed rate is 100kg $^{-1}$.

The intercropped groundnut was planted in between the normal rows of maize. Spacing for the intercropped groundnut crop was 37.5x 10cm, 37.5x15cm, 37.5x20cm, and 37.5x25cm and 37.5x30cm inter and intra row respectively when 1:1 and 2:1row arrangements were used. In 1:2 and 2:2row arrangements, 25x10cm, 25x15cm, 25x20cm, 25x25cm and 25 x30cm inter row and intra row spacing were used respectively. Weeding was carried out manually at 4th and 6th weeks after planting. Harvesting of maize was done by cutting the whole plant after fully matured and dried from the middle three rows and the cobs were collected together while the

Stover was collected separately. The grain of maize was shelled from the cob by hand. Groundnut was harvested by digging out the whole plant including the pods with a hoe and turned over with the roots facing up to dry the pods in the sun to maintain a constant weight before weighing to separate the pods and then shelled by hand to get grain.

Data Collected and Analysis

The land equivalent ratio, competitive ratio relative crowding coefficient agresivity area time equivalent ratio and monetary advantage were collected and computed as follows.

LER= LER= $\frac{\text{Yab}}{Yaa} + \frac{\text{Yba}}{\text{Ybb}}$……. …. (Willey 1979)

CR=$\frac{\text{Yab}}{\text{Yaa x Zab}} \div \frac{\text{Yba}}{\text{Ybb x Zba}}$… (Willey *et al*., 1980)

RCC= $\frac{\text{Yab}}{\text{Yaa}-\text{Yab}} - \frac{\text{Zba}}{\text{Zab}} \ldots\ldots\ldots\ldots (\text{Dawit}, 1960)$

Ag= $\frac{\text{Yab}}{\text{Yaa x zab}} - \frac{\text{Yba}}{\text{Ybb x Zba}}$ ... (Mc Gillchnst 1965)

$$\text{ATER} = \frac{[(\text{Rya} * \text{ta}) + (\text{Ryb} * \text{tb})]}{\text{T}} (\text{Hiebson 1980})$$

MA = (monetary value of combined intercrops)* (LER – 1) / LER. (Gosh, 2004)

Data Analysis

The various agronomic data collected were subjected to analysis of variance using the SAS system September 20, 2004 the GLM procedure for two factorial combinations. The Significance differences between and among means were separated using least significance difference (LSD) at appropriate level of probability.

RESULTS

This study has shown that the land equivalent ratio (LER) was significantly affected at (*P*<0.01) due to the effects of row arrangements and spacing but their interaction was significantly affected (*P*<0.05) (Table 1). The highest LER was obtained from treatment 1:1x10cm while the lowest was from treatment 2:2*30cm (Table 2). All the Land equivalent ratio values of the different row arrangements and spacing of this intercropping study were greater than one indicating that the intercropping was advantageous. The result was in agreement with the findings of Ofori and Stern (1987) who reported that the LER greater than 1, intercropping has an advantage over sole cropping. The LER value of this study was also in agreement with the work of Karikari (2003) who reported LER >1 in Barbara groundnut intercropping with sorghum in Botswana. Several researchers have also reported LER greater than 1 in maize-soybean intercropping. Allen and Obura (1983) observed LER of 1.22 and 1.10 for maize-soybean intercrop in two consecutive years. As stated in Li *et al*. (2003) the higher productivity of the intercrop system compared to the sole crop may have resulted from complementary and efficient use of growth resource by the component crops.

Table 1: ANOVA for Intercropping evaluation

Sources of variation	Degree of freedom	Mean square values								
		CRM	CRG	RCCM	RCCG	Ag.M	AgG	LER	ATER	MA
Replication	2	5.215**	0.0035**	289.176*	0.008**	0.0022**	0.0022**	0.0027*	0.0027*	3155435*
Arrangement(A)	3	67.202**	0.0505**	300.090*	7.67**	0.835**	0.835**	0.0418**	0.0418**	148119008.7**
Spacing (B)	4	44.931**	0.0384**	109.004^{Ns}	0.074**	0.017**	0.017**	0.0988**	0.0988**	59638019.7**
AXB	12	1.971**	0.0026**	228.83*	0.002*	0.001**	0.001**	0.0031*	0.0031*	1115383.9*
Error	38	0.215	0.0001	191.522	0.0006	0.0001	0.0001	0.0271	0.0271	423064.3
CV		7.007	7.308	27.631	2.74	1.925	1.925	2.301	2.301	9.897

*= means significantly different at probability of 0.05, ** highly significant at 0.01 and CRG=Competitive ratio of groundnut RCCM=relative crowding co-efficient of maize, RCCG=relative crowding co-efficient of groundnut, Ag.M=agressivity of maize, AgG=agressivity of groundnut, LER=land equivalent ratio ATER= area time equivalent ratio MA=monitory advantage

Table 2: Land equivalent ratio (LER) due to the interaction effects of spacing and row arrangement

Factors	Spacing				
	10 cm	15 cm	20 cm	25 cm	30 cm
Row arrangement					
1:1	1.37	1.26	1.21	1.16	1.16
1:2	1.36	1.24	1.18	1.18	1.16
2:1	1.11	1.08	1.07	1.05	1.04
2:2	1.17	1.12	1.09	1.09	1.07

Mean =1.16, LSD=0.05 and CV=2.30

Agressivity

There was a significant difference (*P*<0.01) in agressivity values due to the effect of row arrangement and spacing and their interactions (Table 1). Agressivity value of maize was positive while agressivity value of groundnut was negative (Table 3 and 4) respectively. The positive agressivity values of maize may shows that maize was the dominant crop of the intercropping while groundnut was dominated. In this study both crops had the same numerical value but the sign of the dominant crop was positive and that of the dominated one was negative. The greater the numerical value might be due to higher competitive abilities. The result was in agreement with the work of Gosh *et al.* (2006) who stated that a positive agressivity value meant dominance of a component crop in an intercrop arrangement.

Table 3: Agressivity of Maize due to the interaction the effects of row arrangement and spacing

Factors	Spacing				
	10 cm	15 cm	20 cm	25 cm	30 cm
Row Arrangement					
1:1	0.69	0.7	0.77	0.81	0.81
1:2	0.83	0.83	0.86	0.87	0.88
2:1	0.31	0.36	0.39	0.41	0.42
2:2	0.39	0.41	0.43	0.44	0.45

Mean=0.60, LSD=0.017 and CV=1.93

Table 4: Agressivity of groundnut due to the interaction effects of row arrangement and spacing

Factors	Spacing				
	10 cm	15 cm	20 cm	25 cm	30 cm
Row arrangement					
1:1	-0.69	-0.7	-0.77	-0.81	-0.81
1:2	-0.83	-0.83	-0.86	-0.87	-0.88
2:1	-0.31	-0.36	-0.39	-0.41	-0.42
2:2	-0.39	-0.41	-0.43	-0.44	-0.45

Mean=0.60, LSD=0.017 and CV=1.93

Competitive Ratio

The ANOVA of this study has shown that there was a significant difference ($P<0.01$) in competitive ratios due to the effect of row arrangement, spacing and their interaction (Table 1). All the competitive ratios in this study were greater than one for maize while it was less than one in all row arrangements and spacing for groundnut. This might be due to intercropping advantage of maize because of its dominant nature over groundnut. This might indicate the intercropping disadvantage for groundnut (Table 5 and 6). The result was in agreement with the works of (Willey, 1981) who reported that the competitive ratio is less than 1 is an advantage in intercropping. The result was also in agreement with the works of Ofori and Stern (1987) who reported that in cereal-legume intercropping, the cereal components usually tend to have greater competitive ability because of their relatively higher growth rate, height advantage, and more excessive root system.

Table 5: Competitive ratio of Maize due to the interaction effects of row arrangement and spacing

Factors	Spacing				
	10 cm	15 cm	20 cm	25 cm	30 cm
Row arrangement					
1:1	3.28	3.53	4.51	5.62	5.81
1:2	6.38	6.58	8.41	9.33	10.35
2:1	2.71	3.82	5.16	6.21	7.43
2:2	5.16	6.5	8.49	10.59	12.64

Mean=6.63, LSD=0.81 and CV=7.00

Table 6: Competitive ratio of groundnut due to the interaction effects of row arrangement and spacing

Factors	Spacing				
	10 cm	15 cm	20 cm	25 cm	30 cm
Row arrangement					
1:1	0.3	0.28	0.22	0.18	0.17
1:2	0.16	0.15	0.12	0.11	0.09
2:1	0.37	0.26	0.19	0.16	0.13
2:2	0.19	0.15	0.12	0.09	0.08

Mean=0.18, LSD=0.001 and CV=7.13

Relative Crowding Coefficient (RCC)

The results of study has shown that there was a significant difference ($P<0.05$) in relative crowding coefficient of maize (RCCM) due to the effect of row arrangement while the effect was not significant due to spacing. RCCM was significantly affected by the interaction effects (Table 1). The relative crowding coefficient of maize (RCCM) in this study was positive and greater than one in all the row arrangements and spacing which might indicate that maize produced greater yield (Table 7). In contrary to this, the result of relative crowding coefficient of groundnut (RCCG) in this study was negative in all the row arrangements and spacing that might indicate groundnut produced less yields (Table 8). The result was in agreement with Dewit (1960) who reported that when the coefficient <1 =1 and >1 are used to imply that component crops produced less yield, equal yield and greater yield respectively.

Table 7: Relative crowding coefficient of maize due to the interaction effects of row arrangement and spacing

Factors	Spacing				
	10 cm	**15 cm**	**20 cm**	**25 cm**	**30 cm**
Row arrangement					
1:1	65.89	50.83	61.56	50	49.22
1:2	53.24	39.46	34.53	47.98	48.94
2:1	42.76	52.77	48.23	56.22	56.25
2:2	36.27	54.51	39.12	52.36	61.56

Mean=50.08, LSD=24.62 and CV=27.63

Table 8: Relative crowding coefficient of groundnut due to the effects of row arrangement and spacing

Factors	Spacing				
	10 cm	**15 cm**	**20 cm**	**25 cm**	**30 cm**
Row arrangement					
1:1	-0.57	-0.62	-0.72	-0.79	-0.79
1:2	-0.05	-0.07	-0.19	-0.23	-0.26
2:1	-1.78	-1.85	-1.89	.-1.91	-1.93
2:2	-0.76	-0.82	-0.87	-0.89	-0.92

Mean= -0.89, LSD= -0.04 and CV= -2.74

Area Time Equivalent Ratio (ATER)

The ANOVA of this study has shown that there was a significant difference at (P<0.05) in ATER due to the effects of row arrangement, spacing and their interactions (Table1).

Monitory Advantage (MA)

The ANOVA results of this study has shown that there was a significant difference at (P<0.01) in MA due to the effects row arrangement and spacing but their interaction was significant (P<0.05) (Table 1). The highest MA was attained in treatment 1:2*10cm that might be attributed to the highest plant population of groundnut that resulted in highest grain yield hectare^{-1} (Table 9). Single row arrangement and wider spacing resulted in the lowest MA due to less groundnut yield due to less plant population per hectare.

The estimated Monetary Advantage of the row arrangements and spacing in this intercropping study has produced a definite gain for all the row arrangements and spacing that might be attributed to an additional yield gain from groundnut. This shows that this intercropping is beneficial than sole cropping. The result was in agreement with the work of Dwomon and Quainoo (2012) who reported a definite gain in spatial arr angements in the intercropping system.

Table 9: Monetary Advantage (MA) due to interaction effects of row arrangement and spacing

Factors	Spacing				
	10cm	**15cm**	**20cm**	**25cm**	**30cm**
Row arrangement					
1:1	12415.71	11125.09	8489.05	6385.03	6054.21
1:2	12651.7	11945.28	8642.71	7960.70	7049.78
2:1	6412.74	4352.24	2940.66	2311.85	1865.88
2:2	6868.72	5179.82	3530.49	2866.98	2386.23

Mean=6571.74, LSD=1157.22 and CV=9.89

CONCLUSIONS

From this study, it can be concluded that Maize can be intercropped with groundnut compatibly. The compatibility of the crops in the intercropping was investigated using different intercropping evaluation methods developed by different scholars. The benefit of maize groundnut intercropping was evaluated using monitory advantage and this indicated that maize groundnut intercropping was beneficial than their respective sole cropping.

Conflict of Interest

None declared.

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