AMERICAN JOURNAL OF AGRICULTURAL SCIENCE, ENGINEERING, AND TECHNOLOGY (AJASET)

ISSN: 2158-8104 (ONLINE), 2164-0920 (PRINT)

VOLUME 7 ISSUE 2 (2023)

PUBLISHED BY: E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Agricultural Science, Engineering, and Technology (AJASET)
Volume 7 Issue 2, Year 2023
ISSN: 2158-8104 (Online), 2164-0920 (Print)
DOI: https://doi.org/10.54536/ajaset.v7i2.131
https://journals.e-palli.com/home/index.php/ajaset

Influence of Different Intercropping Patterns and Crop Nutrient Sources on Yields of Soybean (Glycine Max)/Maize (Zea Mays) Intercrops in Karara (Lokoja Lga), Kogi State, Nigeria

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Article Information

Received: December 25, 2021

Accepted: February 30, 2022

Published: May 17, 2023

Keywords

Aggressivity, Competitive Ratio, Land Equivalent Ratio, Relative Crowding Coefficient, Soybean-Maize Intercropping

ABSTRACT

Field experiments were conducted during 2017 and 2018 rainy seasons at the Kogi State Agricultural Development farm at Karara (Lat. 8.230N, Long. 6.560E Alt. 343.00m) in Kogi State, Nigeria to investigates the influence of different cropping patterns and crop nutrient sources on yields of Soybean-Maize intercrops. Treatment consisted of two crops (Maize and Soybean), two fertilizer sources [Organic source (Poultry Manure) and Mineral Fertilizer (Urea)] and Intercropping patterns (2:2, 2:3, 2:4, 2:5), sole maize and soybean as control. All the treatments were given factorial combination and laid in a Randomized Complete Block Design (RCBD) and replicated three times. The experiment was carried out for two years, the averages obtained indicates the superiority of 2:2 intercropping system over all other systems as exemplified by higher Land Equivalent Ratio (LER) of 1.13, Aggressivity (A) of 0.458, and Competitive Ratio (CR) of 1.63. The 2:2 intercropping system however showed the lowest Relative Crowding Coefficient (RCC) of 0.088 which is an indication for high productivity. Application of mineral fertilizer in the form of Urea was found to be more effective than the use of Poultry manure in both years of the experiment soybean had higher Relative Crowding Coefficient (RCC), Competitive Ratio (CR), and Aggressivity (A) values than maize. Use of mineral fertilizer in the form of urea was more effective than poultry manure in both years. Soybean was more superior in competition than maize, and its productivity dominated the total biomass yields. It was therefore concluded that intercropping soybean with maize at a 2:2 ratio has the potential to improve not only the seed yield but other associated biological yields and high land use efficiently.

INTRODUCTION

Intercropping is the growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage (Gomez & Gomez, 1983). A major benefit of intercropping is increase in production per unit area compared to sole cropping through the effective use of resources, including water, nutrients and solar energy (Nasri *et al.*, 2014). Intercropping is preferred to sole cropping as a result of superior yield due to better absorption of resources, and this is especially realized when legumes are planted with other crops (Sachan & Uttam 1992), that improves soil fertility due to increased nitrogen fixation (Manna *et al.*, 2003). Inter cropping of Poaceae and Leguminosae may result in mutual benefits as both families have different rooting depth and nitrogen requirement. Interspecific interaction between species in the rhizosphere can also affect the nutrient availability and uptake in intercropping (Li *et al.*, 2010). Light, water and nutrients may be more completely absorbed and converted to crop biomass by intercropping, which is the simultaneous growing of two or more crop species in the same field. This is the result of differences in competitive ability for growth factors between intercrop components (Amini *et al.*, 2013). As already mentioned, intercropping has some benefits in terms of a better use of the available resources (Land, light, water and nutrients), and a reduction in crop disorders. It is assumed that the same mechanisms favoring increased water uptake are involved: greater root concentrations or complementary exploration of soil profile. Intercropping of plants with different rooting patterns permits greater exploitation of a larger volume of soil and improves access to relatively immobile nutrients. As a result, intercropped plants tend to absorb more nutrients than those in monoclines (Horwith, 1985). In the case of tomatoes/maize intercropping, tomatoes may absorb nutrients and water from deeper soil profiles than maize as it has deeper rooting system, whereas maize could be satisfied from the shallower soil zones as its root system is fibrous type. Lorenz and Maynard (1988) grouped cauliflower, corn, lettuce, potato, radish and spinach in shallow rooted (45-60cm), Eggplant, Pea and Turnip in moderately deep (90-120cm) and only tomato into deep rotted (>120cm). Despite the numerous benefit associated with intercropping, the practice is being abandoned for sole cropping, the practice is being abandoned for sole cropping since the current extension services and technology generation packages in Nigeria promote sole cropping. This has led most farmers in Nigeria to the practice of harvesting one crop within one season. This practice has led to insufficient food supply for the households and does not make efficient use of the limited resources such as rainfall and land. There are few published reports on the effect of intercropping patterns of maize and soybean under sufficient fertilization types. Therefore, the main objective of this study was

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to investigate the influence of intercropping of maize soybean on the general yields of the crops under two different fertilizers types; Organic and Inorganic.

MATERIALS AND METHODS

Two field experiments were conducted at the Kogi Agricultural Development Farm (On-station Research Farm) located at Karara (Lat. 8.23^{0}N, Long. 6.56^{0}E Alt. 343.00m) in Lokoja Local Government Area of Kogi State, Nigeria, during 2017 and 2018 rainy seasons. Karara, which is located within the Southern Guinea Savanna Ecological zone of Nigeria is characterized by an average rainfall of about 180mm mostly distributed between the months of April and October. Mean monthly minimum and maximum temperature of about 17^{0}c and 36.2^{0}c respectively. The soil is generally sandy to sandy-loam. Climatological data collected during the period of the experiment are presented in table 1. The physical/ chemical properties of the soils of the two sites used for the experiments are presented in table 2.

Treatment and Experimental Design.

The treatment consisted of two crops (Maize and Soybean), two fertilizer types (organic and mineral) and four (4) intercropping patterns (2:2, 2:3, 2:4, 2:5 sole maize and sole soybean as controls). These treatments were given factorial combination and laid in a Randomized Complete Block Design, with three replications.

Planting and Planting Materials

The land was cleared of vegetation materials, ploughed and harrowed twice to a fine tilt. The field was then marked out into 72 plots of 4m x 5m. Each plot was separated from one another using a distance of 0.3m. An inter block spacing of 0.75m was used, to allow for precision sampling and recording. Planting was carried out on the 14th April and 18th April during 2017 and 2018 wet seasons respectively. The maize and soybean used were all improved and relatively high yielding. An Open-pollinated maize (TZESR) and Soybean (Samsoy II) were sown simultaneously. The soybean was drilled using an inter row spacing of 75cm, while maize was sown 25cm x 75cm apart. The inter cropped plots were sown as follows:

Treatment 1: 2 rows (50cm apart) to 2 rows (100cm -wide) as maize (33%) and soybean (67%) respectively.

Treatment 2: 3 rows (75cm-wide) to 2 rows (100cm -wide) as maize (43%) and soybean (57%) respectively.

Treatment 3: 4 rows (100cm wide) to 2 rows (100cm -wide) as maize (50%) and soybean (50%) respectively.

Treatment 4: 5 rows (125cm wide) to 2 rows (100cm -wide) as maize (55%) and soybean (45%) respectively.

Treatment 5: Sole maize (4 rows apart at 25cm intra -row spacing).

Treatment 6: Sole Soybean (4 drilled rows by 75cm apart).

The crop nutrient sources used were Poultry manure (1.5%N) as organic and Urea (46%N) as inorganic or mineral nutrient source. Urea was used at the rate of 60kg N/ha (2.6bags) while poultry manure was applied at the rate of 4.0 tons/ha. Poultry manure was supplied basically (before sowing) while urea was applied in two-split doses – 1st at 3 weeks after planting of both crops and the second applied during tasseling for maize and at pod formulation for soybean.

Observations and Data Collection.

All observations on growth and yield components were made on three (3) randomly tagged plants from the two out rows (Discards) only. Data collected on the maize crop are – Cob/plant, Seeds/cobs, 100-Seed wt, Seed Yield, Biomass Yield, Harvest Index, and Number of Cob/plant. In the case of Soybean, 100-Seed wt, Seed Yield, Biomass and Harvest Index were measured.

Analysis of Data.

The MSTAT Statistical package was used to analyze the data, however this package was to provide whether or not we accept the null hypothesis of equal mean treatment effect between sole and intercropped plots only. Where ever the null hypothesis was rejected, the treatments were further separated using Duncan Multiple Range Test (DMRT). For the Analysis of the Competition effect, indices such as: LER, (Land Equivalent Ratio), Agressivity (A), Competitive Ratio (CR) and Relative Crowding Coefficient (RCC) were used using the appropriate formulae.

Indices of Competition

Land Equivalent Ratio (LER)

LER is an index of intercropping advantage that indicated the amount of interspecific competition or facilitation in an intercropping system (Fetene 2003):

$LER = Y_{is}/Y_{ss} + Y_{im}/Y_{sm}$ ---------------- (1)

Where Y_{is} and Y_{ss} are the yields of intercrop and sole cropping of soybean, and Yim and Ysm are the yields of intercrop and sole cropping of maize respectively. LER of 1.0 indicates that the two intercropped species make alike demands on the same limiting resources. LER more than 1.0 reveals an intercropping advantage or a demonstration that interspecific facilitation is higher than interspecific competition so that intercropping results in greater land use efficiency. LER under 1.0 reveals mutual antagonism in the intercropping system. As a result, a LER less than 1.0 has no intercropping advantage and indicates that interspecific competition is more than interspecific facilitation in the intercropping system (Fetene 2003; Wahla *et al.* 2009).

Aggressivity

In order to measure yield changes of two component crops affected by interspecies competition in intercropping, McGilchrist (1965), introduced the Aggressivity. This index compares the yields between intercropping and sole cropping, as well as their respective land occupancy (Wahla *et al.* 2009). Thus, we used the aggressivity concept to estimate the interspecies competitiveness of Maize relative to soybean in the intercropping system:

$Ams = Y_{im}/(Y_{sm} \times F_m) - Y_{is}/(Y_{ss} \times F_s)$---------- (2)

Where Ams is the aggressivity of maize relative to soybean in the intercropping system, Yim and Yis are yields of maize and soybean in intercropping, Ysm and Yss are yields of maize and soybean in sole cropping and Fm and Fs are the proportions of the area occupied by maize and soybean. If Ams is over 0.0, the competitive ability of maize exceeds that of soybean in intercropping; in any other case, the soybean offers greater competitiveness.

The Relative Crowding Coefficient (RCC)

The RCC introduced by De Wit (1960) was used as an indicator to consider and compare the competitive ability of one species to the other in the intercropping system. Based on this, Wahla *et al.* (2009) gave the following detailed definition:

$K_m = (Y_{im} \times F_s)/((Y_{sm} - F_{im}) \times F_m)$; $K_s = (Y_{is} \times F_m)/((Y_{ss} - F_{is}) \times F_s)$, ------------------ (3)

Where K_m and K_s are the relative crowding coefficients of maize and soybean, and Y_{im}, Y_{sm}, Y_{is} and Y_{ss} are the yields of intercropped and sole cropping of maize, and soybean, respectively; F_{im} and F_{is} are the proportional land occupancy of maize and soybean in the intercropping system. F_m and F_s are the proportional land occupancy of sole maize and sole soybean respectively. Each component crop has its own K value in an intercropping system (Bhatti *et al.* 2006). The higher the K value of one species is, the more competitive and dominant that species is in the intercropping system (Wahla *et al.*, 2009).

Competitive Ratio

The CR was used to evaluate which one crop competes with the other in an intercropping system (Willey & Rao, 1980; Wahla *et al.*, 2009), and can be calculated by following the formula (Bhatti *et al.* 2006):

$CR_{ms} = (Y_{im}/(Y_{sm} \times F_m))/(Y_{is}/(Y_{ss} \times F_s))$, ----- (4)

Where CRms is the competitive ratio of maize relative to soybean, Y_{im} and Y_{is} are the yields per unit area of maize and soybean in intercropping, Y_{sm} and Y_{ss} are the yields per unit area of maize and soybean in sole cropping and F_m and F_s are the proportions of the area occupied by maize and soybean in the intercropping system. When CRms is greater than 1.0, the competitive ability of maize is higher than soybean in the intercropping system (Zhang *et al.* 2011).

RESULT AND DISCUSSION

The weather results of the study area presented in table 1, indicates normal rainfall distribution for the period where the experiment was conducted. The result of physical and chemical properties of the soil is equally presented in table 2. The soil sandy-clay loam which allows for free percolation of rainfall. The chemical properties of the soil as presented in table 2 shows that the soil is extremely low in Nitrogen and to a lesser extent, phosphorus and potassium.

Yield and Yield Components

In the second year, the mean monthly rainfall was above normal, but in the first year, it was below normal. The mean monthly temperature was slightly above normal (long-term temperature) in both years (table 1 & 2). During the growing season, the temperature in the second year was higher than in the first year; this could be a reason for the differences between years (table 5).

Analysis of variance showed that there was a significant effect of treatments interaction on seed and biomass yield of maize, and 1000-seed weight, seed yield, biomass yield and harvest index of soybean in both years (table 4). The main effects of crop nutrient source and intercropping patterns on pod number, 1000-seed weight and harvest index of maize were significant in the two-year studied (table 4). In the maize, the number of seeds per pod only at the first year was significantly influenced by the interaction of treatments (table 4). For soybean, seeds per pod were also influenced by interaction of treatments in 2018, but in 2017, the main effects of treatments had a significant impact on these traits (table 4). In both years, the number of cobs/plant, 1000-seed weight, harvest index and the number of seeds/cob of maize subjected to mineral fertilizer (urea) were improved in comparison with poultry manure (table 5). Also, in soybean, the highest number of pods/plant and the number of seeds/pod were obtained from mineral fertilizer (urea) application (table 5). In mineral fertilizer (urea), more nutrient accessibility (N) (table 2) led to improvement in the yield and yield component (Uhart & Andrade 1995). Compared with the intercropping patterns, sole cropping of maize had the highest pod numbers, 1000-seed weight and harvest index in the first year, but in 2018, the highest mentioned traits were obtained in sole cropping and 5:2 intercropping pattern (table 6). More light absorption and access to other inputs in sole cropping of maize may cause high performance of photosynthesis and ultimately increase some yield components (tables 6 and 7). In soybean, 2:2 intercropping pattern was most effective on number of pods/plant and the number of seeds/pod in comparison with other intercropping patterns in 2017 (table 6).

According to the mean comparison, sole cropping of maize in 2017, application of mineral fertilizer (urea) resulted in maximum number of seeds/cob (table 8). Soybean at the first year in 2:2 intercropping pattern under mineral fertilizer had higher 1000-seed weight and harvest index (table 8). Also in 2018, soybean planted at 2:2 intercropping pattern in mineral fertilizer had the highest influence on number of pod per plant and harvest index in comparison with other treatments (tables 7 and 8). Due to lack of competition between maize plants with soybean for light and other resources, as well as utilization of chemical fertilizers and pest and disease management, sole cropping of maize had the highest seed number per cob with application of mineral fertilizer. As compared with sole cropping, some component yield reduction at intercropping can be attributed to competition for moisture, nutrients and solar radiation associated with intercropping mixtures (Belel *et al.*, 2014).

The total seed yield of soybean grown in sole cropping and all intercropping patterns increased in 2018 relative to 2017. But the biomass yield decreased in 2018 in some intercropping patterns. The total biomass of soybean at sole cropping in mineral fertilizer in 2017 was more than that of other intercropping patterns and poultry manure in both years (table 8). Compared to the use of poultry manure, the mineral fertilizer increased the total yield of both plants, because of more input usage (tables 2 and 8). The sole cropping of soybean for both systems in 2017 yielded higher than all the maize: soybean combinations. But in 2018, the 2:2 pattern without any significant difference with 3:2 pattern had the most total biomass yield (table 8). The total seed and biomass yield of maize was always lower than that of soybean grown in sole cropping and all intercropping patterns during the two experimental years (table 8). The facilitative effect of maize can uptake part of its nitrogen requirements through symbiotic biological nitrogen fixation which, in turn, reduces the over burden pressure on soil nitrogen supply. Through this process, soybean will have more available soil nitrogen to utilize. In the first year of experiment, the total biomass yield of soybean subjected to mineral fertilizer (urea) treatment was markedly higher than that of mono-cultured maize and all intercropping patterns. In 2018, the biomass yield of 2:2 and 3:2 intercropping pattern in Urea was higher than other patterns and Poultry manure (table 8). However, the performance of legume and other crops intercropping varied by intercropping pattern, and many previous studies have reported that intercropping with legumes can achieve an enhance biomass and yield over corresponding monoculture (Zhang *et al.*,2011; Huňady & Hochman, 2014; Zafaranieh, 2015).

Sole cropping of maize in both years had the least biomass yield. Therefore, in our study, the 2:2 pattern was the optimal intercropping pattern. Some recent studies also demonstrated the potential for increased biomass yields through intercropping of annual legumes with soybean (Kazemini & Sadeghi, 2012; Sadeghi & Sasanfar, 2012; Zafaranieh, 2015), and our findings are consistent with those results.

The biomass yield of an intercropping system is positively associated with the competitiveness of the component crops (Piano & Annicchiarico, 1995; Li *et al.*, 2001). The interspecific competition, including above and below ground competition, is defined as the interaction between the two species that reduces the fitness of one or both of them (Li *et al.*, 2001) and obviously plays an important role in determining the species yields in an intercropping system (Li *et al.*, 2001; Zhang *et al.*, 2007). The species with the stronger competitiveness is generally termed the dominant species or superior competitor, and has a greater capacity to acquire resources and to occupy the superior ecological niche (Grace, 1990).

Table 1: Metrological data showing mean monthly rainfall (mm), temperature (^{0}C) and relative humidity (%) of the study area, Karara.

Variables	Month (s)															
	2017							2018								
	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp. (^{0}C) Min	21.61	21.17	20.71	20.26	20.50	20.00	18.00	15.31	20.3	22.7	22.4	22.1	22.40	21.8	19.3	15.10
Max	29.52	28.67	27.35	26.61	27.43	27.00	25.31	21.30	31.3	30.7	31.3	27.40	28.41	28.33	23.11	7.61
Rainfall	135.13	161.82	170.43	126.73	201.92	180.62	33.52	4.57	128.40	171.30	173.20	134.30	218.71	123.42	7.61	__
Relative Humidity (%)	74.77	75.67	74.90	76.13	77.00	72.00	63.00	57.00	75.00	73.00	75.00	54.00	76.00	86.00	53.00	49.00

Source: Metrological Station, Department, Geography, and Physical Planning, Kogi State University, Anyigba.

Table 2: Physical and Chemical Characteristics of Soil sample taken from Experimental site before the establishment of the experiment.

Soil properties	Year	
	2017	2018
Physical properties	0-30cm depth	0-30cm depth
Sand (%)	86.24	85.29
Silt (%)	2.61	03.44
Clay (%)	11.15	11.27
Textural class	Sand-clay loam	Sand-clay loam
Chemical properties		
pH in H2O (1:2.5)	6.13	6.27
Organic Carbon (%)	0.51	0.43
Organic Matter (%)	0.88	0.78
Total Nitrogen (%)	0.03	0.01

Available Phosp. (mg/kg)	9.00	11.40
Exchangeable Cation (Cmol/kg)		
K+	2.75	3.65
Mg2+	1.97	2.62
Ca2+	4.16	5.11
Na+	0.95	0.87
CEC (Meq/100g)	9.83	12.23

Table 3: Proximate Analysis of the crop nutrient sources (Urea and Poultry Manure) used in the experiment

Nutrient	**Urea**	**Poultry manure**
Nitrogen	46%	1.5%
Phosphorus	0%	9.2%
Potassium	0%	15.3%
Carbon	3%	21.0%

Ler of the Intercropping System

Data on LER of different intercropping patterns are presented in table 9. In first year, only the 2:2 sowing pattern had yield advantages, values greater than 1.00. In contrast, LER values of other intercropping patterns were all less than 1.0 In the second year, LER values of all intercropping pattern were more than 1.00. Only the two years mean of 5:2 pattern was less than one. Likewise, of the corresponding soybean LER values, only that of 2018 was above 1.0 and in 2017, only the 2:2 pattern had a LER value of more than one. In 2018, the 2:2 pattern had the highest LER value, indicating that the 2:2 pattern had the most yield advantage compared to other patterns and thus stable productivity (table 9).

Aggressivity

The component crops did not exhibit equal competitive intensity based on aggressivity. In both sowing years, the aggressivity index of soybean relative to maize A(sm) was positive in all intercropping patterns. Furthermore, the average A(sm) values of two years were significantly greater than zero ($P \leq .05$), indicating that soybean was the dominant species and had much greater competitiveness in the intercropping system of soybean with maize (table 10). The reduction in maize yield under intercropping with soybean could be attributed to the interspecific competition between the intercrop components for water, light, air and nutrients and also the aggressive effects of soybean on maize (Matusso *et al.*, 2014). The shading of the maize by the taller soybean plants may also have contributed to the reduction in the yields of the intercropped maize (Belel *et al.*, 2014; Karanja *et al.*, 2014). The productivity of the dominant species directly influences the apparent performance of the intercropping communities (Connell, 1990; Li *et al.*, 2001). Thus, the interspecific competitive behavior is essential for the structural stability of the intercropping agro ecosystem. Furthermore, knowledge of competitiveness can predict yields in an intercropping system. The competitive abilities of component crops can be defined in terms of aggressivity, relative crowding coefficient (K) and competitive ratio (Bhatti *et al.*, 2006; Wahla *et al.*, 2009).

Table 4: Two-Year Analysis of Variance (Mean Square) for Yield and Yield Components of Maize and Soybean Intercropping as affected by different farming systems and intercropping patterns.

		Maize						**Soybean**					
Source of Variation	**Df**	**Number of Cob/ plant**	**Number of Seed/ Cob**	**1000-Seed wt.**	**Seed Yield**	**Biomass Yield**	**Harvest Index**	**Number of Cob/ plant**	**Number of Seed/ Cob**	**1000-Seed wt.**	**Seed Yield**	**Biomass Yield**	**Harvest Index**
2017													
Replications	2	0.15	0.0002	0.06	0.0003	0.0002	0.16	1.24	0.31	0.08	0.03	0.023	3.43
Farming systems (FS)	1	115.2**	0.81**	97.9**	0.6**	1.51**	156.54**	101.8**	160.7**	49.92**	5.15**	9.39**	296.2**
Intercropping pattern (IP)	4	14.14**	0.38**	9.52**	1.56**	6.52**	40.76**	11.25**	17.13**	5**	3.53**	27.97**	47.85**
FS X IP	4	0.25ns	0.06**	0.9ns	0.07**	0.17**	2.4ns	0.12ns	0.23ns	0.36**	0.09**	0.22**	1.16*
Error	18	0.44	0.012	0.32	0.0007	0.0007	1.98	0.09	0.11	0.03	0.002	0.002	0.33
Coefficient of Variation	2.06	3.97	1.33	3.53	1.53	3.38	1.49	0.81	0.48	2.12	0.81	1.56	2.06
2018													
Replications	2	0.01	0.004	0.13	0.0005	0.09	25.25	0.54	3.97	0.41	0.039	0.09	1.14
Farming systems (FS)	1	133.9**	0.46**	56.8**	0.69**	7.46**	274.2**	175.2**	79.38**	16.72**	6.93**	10.47**	394.3**

Intercropping patter (IP)	4	22.17**	0.3**	19.46**	2.93**	7.64**	595.4**	24.52**	11.32**	1.14**	3.92**	10.3**	133.7**
FS X IP	4	0.1ns	0.005ns	0.28ns	0.05**	0.28**	38.09ns	2.67**	2.79**	7.56**	0.13**	0.23**	12.17**
Error	18	0.22	0.003	0.13	0.001	0.05	14.5	0.13	0.28	0.13	0.003	0.004	0.37
Coefficient of variant	1.41	1.87	0.82	2.8	8.94	8.81	2.13	1.11	1 2.1	1 1.15	1.33	1.41	1.87

*Note: ns; not significant. *Significant at 0.05 probability level. **Significant at 0.01 probability level.*

In general, non-legume crop is considered a suppressing crop in annual legume/non-legume intercrop system (Haynes, 1980; Wahla *et al*., 2009), for example, Soybean-Wheat (Li *et al*., 2001), peanut/maize (Inal *et al*., 2007) and Faba-bean/barley (Strydhorst *et al*., 2008).

Table 5: Two-Year Mean Comparison for Some Yield Components of Maize and Soybean Affected by Fertilizer Type.

		Maize				**Soybean**	
Year	**Fertilizer type**	**Number of Cobs/Plant**	**Number of seeds/cob**	**1000-seed weight (g)**	**Harvest Index (%)**	**Number of Pods/per plant**	**Number of seeds/Pod**
2017	Urea	34.11a	ns	448.2a	43.85a	22.36a	2.3a
	Poultry Manure	30.19b	ns	412.b	39.28b	18.67b	3.1b
2018	Urea	35.64a	3.37a	458.3a	46.33a	ns	Ns
	Poultry Manure	31.42b	3.13b	430.8b	40.28b	ns	Ns

Note: Means followed by the same letter(s) in each column within each year is statistically not significant (P ≤ .05) at 5% level of probability using N-Duncan multiple range test. based on variance analysis (Table 4).

Relative Crowding Coefficient (RCC)

The interspecific competitive abilities were determined by the Relative Crowding Coefficient (K). Referring to the k values of all intercropping patterns, in 2017, 2:2, 2:3 and 2:4 intercropping patterns, K_s was always greater than K_m. But in the 5:2 sowing pattern, K_m was greater than K_s, thus maize was more competitive than soybean in the intercropping community (table 11).

However, similar results were observed in our study, as indicated by the competitive indicators of Aggressivity (Asm), the crowding coefficient (K_s and K_m) and the competitive ratio (CR_{sm}). The average Asm value over two years for each sowing pattern was positive, suggesting that soybean was the dominant species and had much great competitiveness in Soybean-Maize intercropping. Thus, soybean was able to acquire more resource than maize, and its yield influenced the total biomass of the intercropping system. Soybean with its superior ability to uptake nitrogen and with a more vigorous rooting system was able to make a more efficient use of the available resources which caused it to become the dominant crop in intercropping treatments. Regardless of the first year and intercropping patterns, the RCC of Soybean (K_s) was always higher than the corresponding Km value of maize, except in the 5:2 pattern in both years that Km was more than Ks. Thus, soybean had stronger competitive ability and acquired the growth resources more competitively than maize in the intercropping system.

Soybean dominated and occupied a superior ecological niche in the intercropping system. The competitive ratio (CR) is considered a better measure of competitive ability of the crops compared with the RCC and Aggressivity (Willey & Rao, 1980; Wahla *et al*., 2009). Higher maize CR values in our study indicated that in different intercropping patterns, soybean was more competitive than maize.

Table 6: Two-year Mean Comparison for some yield components of Maize and Soybean affected by Intercropping Patterns.

		Maize				**Soybean**	
Year	**Intercropping Pattern**	**Number of Cobs/Plant**	**Number of seeds/pod**	**1000-seed wt (g)**	**Harvest index (%)**	**Number of Pod/Plant**	**Number of seeds/pod**
2017	Sole	34.35a	ns	44.76a	46a	19.15e	2.1e
	2:2	30.68d	ns	41.45d	32.98bc	22.68a	3.2a
	3:2	30.78d	ns	42.36c	39.62c	20.29c	2.3c
	4:2	32.05c	ns	42.85c	41.75b	20.82b	2.2b
	5:2	32.9b	ns	43.63b	40.49bc	19.63d	2.0d
2018	Sole	35.4a	3.51a	46.35a	51.43a	ns	ns
	2:2	31.13d	2.98e	41.88e	28.72c	ns	ns
	3:2	32.05c	3.07d	43.58d	37.45b	ns	ns
	4:2	33.73b	3.29c	44.6c	47.46a	ns	ns
	5:2	35.35a	3.41b	45.86b	51.46a	ns	ns

Note: The same letters in each column within each year show non-significant difference at P ≤ .05 by Duncan test. ns: not significant based on variance analysis (Table 4). Patterns mean bitter vetch and soybean row ratios (maize: soybean).

Table 7: Pod number per plant and number of seeds per pod of soybean affected by fertilizer type and different intercropping patterns.

Year	Fertilizer type	Intercropping Patterns	Number of Pods/plant	Number of Seeds/Pod
2018	Urea	SS	47.73d	16.71d
		2:2	22.61a	50.33b
		3:2	21.4b	51.5a
		4:2	20.66c	50.33b
		5:2	17.1d	48.2cd
	Organic	SS	13.44f	44.93f
		2:2	16.98d	48.73c
		3:2	15.3e	46.76e
		4:2	15e	45.73f
		5:2	13.6f	45.66f

Note: The same letters in each column within each year show non-significant difference at P ≤ .05 by Duncan test. Pattern means maize and soybean row ratios (Maize: Soybean).

Competitive Ratio (CR) of Soybean and Maize Intercropping.

The Competitive Ratio of Soybean (CR_{sm}) in different Soybean-Maize intercropping patterns always exceeded 1.0 in both years and thus were higher than the competitive ratios of Maize relative to soybean during two years' period (CRms is the reciprocal of CR_{sm}, the value of CR_{ms} were not listed) (table 12). Meanwhile, the average CR_{sm} value over two years was also higher than 1.0 for each intercropping configuration suggesting that soybean had greater competitive intensity relativeto Maize in Soybean-Maize combination (table 1).

Table 8: Yield and some Yield Components of Maize and Soybean Intercropping affected by Fertilizer type and different Intercropping Patterns.

			Maize			Soybean					
Year	Fertilizer type	Intercropping Patterns	Number of seeds/cob	Seed yield (t/ha)	Biomass yield (t/ha)	1000-seed weight (g)	Seed yield (t/ha)	Biomass yield (t/ha)	Harvest index (%)	Total seed yield (t/ha)	Total biomass yield (t/ha)
2017	Urea	SS	-	4.05a	-	37.16d	4.05a	10.87a	37.28d	-	10.87a
		2:2	2.71cd	3.98a	1.01g	38.96a	3.55b	8.17c	43.54a	0.42g	9.18b
		3:2	2.58def	3.11b	1.35e	38b	2.56d	6.44e	39.79b	0.55f	7.79c
		4:2	2.83c	3.09b	1.69d	38.26b	2.35e	5.79f	40.65b	0.74d	7.49e
		5:2	3.1b	2.83d	2.17c	37.66c	1.89f	4.94h	38.13cd	0.94c	7.12f
		MS	3.46a	1.99f	4.09a	–	–	–	–	1.99a	4.09i
	Poultry Manure	SS	–	2.82d	–	34.13h	2.82c	9.22b	30.63g	–	9.22b
		2:2	2.5ef	2.94c	0.82h	37.2d	2.63d	6.78d	38.77c	0.31h	7.6d
		3:2	2.4f	2.22e	1.09f	35.26f	1. 8f	5.5g	32.82f	0.42g	6.59g
		4:2	2.66cde	2.23e	1.38e	35.76e	1.68g	4.9h	34.34e	0.55f	6.28h
		5:2	2.65cde	1.96f	1.7d	34.8g	1.32h	4.22i	31.39g	0.64e	5.92h
		MS	2.83c	1.32g	3.06b	–	-	–	–	1.32b	3.06j
2018	Urea	SS	-	4.22b	-	37.36b	4.22a	8.51a	49.61c	-	8.51b
		2:2	ns	4.39a	2.08e	34.5d	3.79b	7.08b	53.47a	0.59f	9.16a
		3:2	ns	4.28b	2.4de	38.06a	3.44c	6.57d	52.29b	0.84e	8.97a
		4:2	ns	3.92c	2.74cd	37.66ab	2.81f	5.68f	49.47c	1.11d	8.43b
		5:2	ns	3.31d	2.88c	37.36b	1.92h	4.62h	41.61e	1.39c	7.5c
		MS	ns	2.62i	5.4a	–	–	–	–	2.62a	5.4f

	Poultry Manure	SS	-	3.1e	-	35.03d	3.1d	6.87c	45.21d	-	6.87d
		2:2	ns	3.4d	1.56f	37.03b	2.96e	6.09e	48.62c	0.44g	7.65c
		3:2	ns	2.78f	1.62f	35.76c	2.15g	5.11g	42.02e	0.63f	6.74d
		4:2	ns	2.64g	1.62f	35.06d	1.76i	4.5i	39.24f	0.88e	6.12e
		5:2	ns	2.48h	1.98ef	34.6d	1.4j	3.99j	35.12g	1.08d	5.98e
		MS	ns	2j	3.75b	–	–	–	–	2b	3.75g

Note: The same letters in each column show non-significant difference at P ≤ .05 by Duncan test. ns: not significant based on variance analysis (Table 4). SS and MS means soybean and maize sole cropping, respectively. Patterns means maize and soybean row ratios (Maize: Soybean).

Table 9: LER values of different Intercropping Patterns of Maize and Soybean affected by Fertilizer type.

	Intercropping patterns (Maize: Soybean)			
Year	2:2	3:2	4:2	5:2
2017	1.06	0.93	0.97	0.97
2018	1.21	1.14	1.09	1.02
Two years' average	1.13	1.03	1.03	0.99

** Significantly different from at P ≤ 0.05*

Table 10: Aggressivity of Soybean relative to Maize (Asm) for the different Intercropping Patterns for two years.

	Intercropping patterns (Maize: Soybean)			
Year	2:2	3:2	4:2	5:2
2017	0.51*	0.332*	0.295*	0.13*
2018	0.407*	0.425*	0.387*	0.175*
Two years' average	0.458*	0.392*	0.341*	0.152*

** Significantly different from at P ≤ 0.05*

Table 11: RCC of Soybean (Ks) and Maize (Km) based on different Intercropping patterns.

		Intercropping patterns (Maize: Soybean)			
Year	K value	2:2	3:2	4:2	5:2
2017	Ks	1.47	0.39	0.32	0.21
	Km	0.071	0.115	0.18	0.26
2018	Ks	2.45	0.82	0.45	0.24
	Km	0.107	0.15	0.207	0.28
Two years' average	Ks	1.96	0.6	0.38	0.23
	Km	0.088	0.13	0.19	0.27

Ks: K value of soybean, Km: K value of maize.

Table 12: Competitive ratio of soybean (CR) and maize intercropping.

		Intercropping patterns (Maize: Soybean)			
Year	CR value	2:2	3:2	4:2	5:2
2017	CRsm	1.71	1.46	1.36	1.15
2018	CRsm	1.55	1.55	1.43	1.19
Two years' average	CRsm	1.63	1.51	1.4	1.17

CRsm: Competitive ratio of soybean relative to maize.

Our results suggest that soybean is the dominant crop in Soybean - Maize combination, at least under the current experimental settings, as indicated by the higher RCCs, CR and positive Aggressivity. This reveals that soybean intercropped with maize utilized the resources more aggressively, and its production was the major factor that determined the overall yields. Other reports examining forage production also indicated that intercropping improves the stability of agricultural production and provides greater crop security as a whole (Skelton & Barrett 2005). Moreover, intercropping is a desirable Land use system to compensate the deficiency in currently available arable land (Abdel-Magid *et al.*, 1991).

CONCLUSION

In the first year (2017), only the 2:2 intercropping pattern had a biomass yield advantage based on the LER value above 1.0. In the subsequent year (2018), all

Soybean-Maize intercropping patterns displayed yield advantages and higher Land Use Efficiency based on higher LER values. The biomass yields of sole soybean and all intercropping patterns increased in the second year. Soybean was the dominant crop and a superior competitor in the Soybean-Maize combination, and had higher Aggressivity (A), Relative Crowding Coefficient (RCC) and Competitive Ratios (CR) compared to maize. Thus, the higher annual increase in soybean yield resulted in the higher total biomass of Soybean-Maize associations compared to that of soybean and maize sole cropping. The average annual biomass yields of soybean decreased with the increasing land proportion occupied by maize in the intercropping system. Generally, in both years, the 2:2 intercropping pattern presented the most stable yield advantage. Therefore 2:2 system of intercropping is recommended to have a high potential for profit maximization and resource use efficiency with no detrimental effect of one crop relative to the other if farmers can heed. Future research works can look into other crops with high combining abilities for resource use efficiency and profitability.

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