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Research Paper

EFFECT OF SPATIAL ARRANGEMENT ON THE YIELD OF MAIZE AND GROUNDNUT INTERCROP IN THE NORTHERN GUINEA SAVANNA AGRO-ECOLOGICAL ZONE OF GHANA

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The effect of spatial arrangement on the yield of maize and groundnut intercrop in the Northern Guinea Savannah agro-ecological zone of Ghana was investigated. Three component ratios of 3 rows of maize alternated with 1 row of groundnut (3:1), 3 rows of maize alternated with 2 rows of groundnut (3:2), 3 rows of maize alternated with 3 rows of groundnut (3:3), sole maize and sole groundnut were used. Grain yields of the sole crops maize and groundnut were higher than the spatial arrangement crop yields. The Land Equivalent Ratio (LER) and the Relative Crowding Co-efficient (RCC) for the sole crops were higher than the spatial arrangements of the maize and groundnut intercropped arrangements. The estimated Monetary Advantages (MA) of the various spatial arrangements produced a definite gain for all the spatial arrangements. This indicated that the MA of the spatial arrangements benefited from the intercropped arrangements used. The Actual Yield Loss (AYL) in all the spatial arrangements gave positive values, indicating yield gain and response to the spatial arrangements used. The Intercropping Advantage (IA) indicated that the spatial arrangement at 3 rows of maize alternated with 1 row of groundnuts proved to be the most remunerative. Based on the actual yield loss and the intercropping advantage, 3 rows of maize alternated with 1 row of groundnut seemed to be appropriate for the Northern Guinea Savannah Agro-ecological zone of Ghana.

Keywords: Maize, Groundnut, Land Equivalent Ratio, Actual Yield Loss, Intercropping Advantage

INTRODUCTION

In Ghana, the main cropping systems in Northern Guinea Savannah agro-ecological zone are still based on traditional mixed cropping (Diehl, 1984). The main cropping systems are cereals/legumes, root and tuber crops/cereals and legumes/ legumes. The cropping systems are used to maximize production and diversify crops from a parcel of land either in time or space than would be obtained by one crop. Intercropping is the

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growing of two or more crop species simultaneously on the same piece of land during the growing season (Palaniappan, 2000). The main types of intercropping systems include strip, row, relay and mixed.

However, spatial arrangements of crops is another form of intercropping when two or more crops are grown in separate rows or alternating rows on the same piece of land. In spatial arrangements, the crops involved compete for growth resources such as light, water, carbon dioxide and nutrients. Differences in the canopies of crops appear to provide more efficient light use by spatial arrangements than by sole cropping.

Competition is one of the factors that can have a significant impact on yield of mixtures compared with pure stands (Caballero et al., 1995). Higher yields have been reported when competition between two species of the mixtures have lower competition than within the same species (Vandermer, 1990). Competition can also have a significant impact on the growth rate of the different species used in spatial arrangements.

A number of advantages have been advanced for the use of spatial arrangements in place of sole cropping. According to Steiner (1982), spatial arrangements bridge the gap between planting and new harvest "the hungry season" where early maturity crops are planted at the beginning of the rainy season. According to Andrews and Kassam (1976), intercropping reduces the damage caused by pest and diseases and ensures greater yield stability by producing from the same field even if some of the crop fails.

Of the numerous advantages attributed to intercropping, perhaps the most important is the total yield advantage. Petersen (1994) and Olasantan (1986) reported that shading by heavier leaf canopy of an intercropping also reduces soil temperature and moisture loss, which favours multiplication and growth of some soil microorganisms. In spite of the numerous advantages in favour of intercropping, there are some disadvantages associated with it. Addo-Quaye et al., (1993) reported that intercropping systems in mechanization is difficult, management requirements are higher and overall cost per unit production may be higher due to reduced efficiency in planting, weeding and harvesting.

In Ghana, maize yields in intercrop on farm fields have shown a reduction of 20-35% (Ghana Grain Development Project, 1987-90). Such yield decrease has been attributed to differences in spatial arrangements of crops. The objectives of this study were to determine the appropriate spatial arrangement for maize and groundnut intercrop in the northern Guinea Savannah agroecological zone of Ghana and to assess which system is better for resources management with respect to productivity, competition and economic parameters.

MATERIALS AND METHODS

The experiment was carried out during the wet season of 2009 cropping season (June-November) at the University for Development Studies experimental field in Nyankpala in the Northern Guinea Savannah agro-ecological zone of Ghana. The experimental sites receive between 900 mm and 1,300 mm of rainfall per annum (Table 1). The soil on which the experiment was conducted is classified under Nyankpala series. These soils are brown, moderately drained sandy loams, which are free from concretions and developed from the voltains sandstones.

The physical and chemical properties of the soil analyses of the top soil (0-20cm) revealed the following constituents: pH 0.001M (CaCl2) 5.11mg/kg, Organic Carbon 0.76%, Nitrogen 0.6%, available P 8.57mg/kg, Exchangeable K 42.00mg/kg, Calcium 12.590mg/kg, Magnesium 48.84mg/kg, and CEC 3.14cmol(+)kg.

The experimental design was a randomized complete block. There were 20 experimental plots each measuring 8.0 m X 7.0 m .The spaces between blocks and experimental units were 1.0 m and 1.5 m, respectively. Five planting arrangements were used, each replicated four times. The spatial arrangements were:

(i) sole maize

(ii) 3 rows of maize alternating with 1 row of groundnut

(iii) 3 rows of maize alternating with 2 rows of groundnut

(iv) 3 rows of maize alternating with 3 rows of groundnut and

(v) sole groundnut

"Dodzi" improved maize variety and "Chinese groundnut" was sown at spacings of 80 cm X 40 cm and 50 cm X 40 cm, respectively. The plots were manually weeded at 14 and 40 days after planting. At maturity, all the plants were harvested per plot for grain yield determination. Harvesting was done at 130 and 100 days after emergence for maize and groundnut, respectively. The maize was shelled by hand and the maize grains dried to 14 % moisture content before weighing. Groundnuts were harvested by manual lifting of pods using bare hands. The soil was shaken off the pods and the plants turned over with the roots facing up to dry the nuts in the sun to about 10% moisture content before weighing.

The productivity of the sole crops and the spatial arrangements were compared by calculating land equivalent ratio (LER), relative crowding coefficient (RCC), monetary advantage (MA), actual yield loss (AYL) and intercropping advantage (IA). The biological index of LER used followed the procedure of Mead and Willey (1980).

$$LER = \frac{\text{Intercrop yield of maize}}{\text{Sole yield of maize}} + \frac{\text{Intercrop yield of groundnut}}{\text{Sole yield of groundnut}} \quad ...(1)$$

When the value of LER is greater than 1, the intercropping favours the growth and yield of the species where as when LER is lower than 1, the intercropping negatively affects the growth and yield of crops grown in mixtures (Caballero et al., 1995). Thus LER gives a better picture of the competitive abilities of the component crops. It also gives actual yield advantage of intercropping.

The relative crowding coefficient (RCC) is used in replacement series of intercropping. It indicates whether a species or a crop when grown in mixed population has produced more or less yield than expected in a pure stand. It is determined using the equation:

$$RCC = \frac{Yab \times Zba}{(Yaa - Yab) \times Zab} \quad ...(2)$$

where Yab = mixture yield of maize

Yaa = Sole yield of maize

Zba = Sown proportion of groundnut in the spatial arrangement

Zab = sown proportion of maize

The monetary advantage (MA) is based on land equivalence ratio of the economic

performance of the spatial arrangements and was calculated using the procedure of Willey (1979):

$$MA = \frac{(\text{Value of combined intercrops}) \ X \ (LER-1)}{LER}$$

where MA= Monetary advantage

LER = Land equivalent ratio

The actual yield loss (AYL) is the proportionate yield loss or gain of intercropped in comparison to the respective sole crop, i.e. it takes into account the actual sown proportion of the component crops with its pure stand. In addition, partial actual yield loss (AYL legume and AYL cereal) represents the proportionate yield loss or gain of each species when grown as an intercrop relative to their yield in pure stand .The AYL is calculated according to the formula (Banik et al., 1996):

$$AYL = AYL_{legume} + AYL_{cereal} \quad ...(4)$$

$$AYL\ legume = \left\{\frac{(Yvc \ / \ Xvc) - 1}{Yv \ / \ Xv}\right\} \quad ...(5)$$

$$AYL\ cereal = \left\{\frac{(Ycv \ / \ Zcv) - 1}{Yc \ / \ Zc}\right\} \quad ...(6)$$

where AYL=Actual yield loss

YVC=Yield of groundnut intercrop

XVC=Yield of intercropped cereal

YV=Sole groundnut

XV=Sole maize

YCV=Intercrop yield of maize

ZCV=Intercrop yield of groundnut

YC=Sole proportion of maize

ZC=Sole yield of groundnut

The AYL can have positive or negative values, indicating advantages or disadvantages occurred in intercrops when the main objective is to compare yield on a per plant bases.

The intercropping advantage (IA) of the intercrop components was calculated using the following formulas (Banik et al., 2001):

$$IA_{cereal} = AYL_{cereal} \ X \ P_{cereal} \quad ...(7)$$

$$IA_{legume} = AYL_{legume} \ X \ P_{legume} \quad ...(8)$$

where P cereal is the commercial value of cereal (the current price of maize is GH¢ 38. and groundnut current price is GH¢ 42).

The data collected was analyzed using Genstat (version?)

RESULTS AND DISCUSSION

Grain yields

Table 2 shows grain yields of the sole crops and the intercrops. Generally, the sole crops of maize and groundnut recorded higher grain yields, while the spatial arrangement, 3 rows of maize alternating with 3 rows of groundnut, recorded the least yield. This low grain yield in the spatial arrangement was due to shading and interspecific competition. This observation is in agreement with the findings of Fukai and Trenbath (1993), which attributed the low grain yield to competition during the grain production stage. The poor yield of the groundnut was attributed to the shading effect of the maize plants on the groundnut in the spatial arrangement. This agrees with the findings of Chui and Shible (1984), which attributed poor performance of groundnut in intercropping by the taller component crop (maize).

Table 1: Mean Temperature (°C) and Rainfall (mm) at Experimental Site (Nyankpala)

Month 2009	Mean temperature (°C)	Rainfall (mm/month)
January	27.50	0
February	32.05	6.70
March	33.30	28.40
April	32.35	108.48
May	30.80	70.10
June	30.00	1004
July	27.05	323.70
August	25.80	271.50
September	27.80	345.80
October	28.05	130.90
November	28.30	0
December	28.25	3.20
Average monthly	29.27	191.84

Source: SARI Meteological Station 2009

Table 2: Average grain yield for maize/groundnut intercrop of different spatial arrangements

Spatial Arrangements	Average Grain Yield/ha (Maize)	Average Grain Yield/ha (Groundnut)
Sole maize	1531	–
Maize + groundnut (3:1)	839	156
Maize + groundnut (3:2)	776	142
Maize + groundnut (3:3)	732	124
Sole groundnut	–	347
LSD (0.05)	832	224

LAND EQUIVALENT RATIO (LER)

In general, the sole crops recorded higher LERs while the spatial arrangements (3:1, 3:2, 3:3) recorded LER values of 0.91, 0.92 and 0.84, respectively (Table 3). This implied that the sole crops were more productive than the intercrops. This agrees with the findings of Willey (1980), who asserted that when LER value in an intercrop is less than one, the result does not favour the intercrop arrangement but when the sole crop LER is greater than one, the result favours the sole crop.

Table 3: The Economic Indices For The Various Spatial Arrangements

Spatial arrangements	LER	RCC	MA(¢)	AYLa	AYLb	AYL	Iaa	Iab	IA
Sole maize	1	–	–	–	–	–	–	–	–
Maize + groundnut(3:1)	0.91	0.23	963	0.33	-0.25	0.08	12.5	-11.25	1.29
Maize + groundnut(3:2)	0.92	0.2	918	0.24	-0.19	0.05	9.1	-8.55	0.57
maize + groundnut(3:3)	0.84	0.16	855	0.22	-0.18	0.04	8.1	-8.10	0.26
Sole groundnut	1	–	–	–	–	–	–	–	–
mean	0.95	0.19	922.98	0.26	-0.20	0.05	10.00	-9.30	0.70

Note: current price of maize =GH¢38.00; Current price of groundnut = GH¢42.00; $1.00 = GH¢1.53

RELATIVE CROWING COEFFICIENT (RCC OR K)

The spatial arrangements (3:1, 3:2, 3:3) recorded Rcc values of 0.23, 0.20 and 0.16, respectively (Table 3). This finding is in agreement with de Wit (1960), who reported that when the coefficient < 1 = 1 and 1 > 1 are used to imply that component crops produced less yield, equal yield, and greater yield respectively.

Monetary Advantage (MA): The spatial arrangement with 3 rows of maize alternating with 1 row of groundnut produced the highest MA values of GH¢ 9631, while 3 rows of maize alternating with 3 rows of groundnut produced the least MA values of GH¢ 855. This confirms the findings of Ghost (2004), who asserted that the higher the MA value the more profitable the cropping system.

ACTUAL YIELD LOSS (AYL)

This actual yield loss of maize gave values of 0.33, 0.24 and 0.22 respectively (Table 3). This indicated yield gain by maize. The AYL values of groundnut (intercrops, 3:1, 3:2, 3:3) gave negative values of -0.25, -0.19 and -0.18, respectively (Table 3) indicating yield loss. Also Banik *et al*., (2000), reported that the actual yield loss (AYL) gave precise information about the competition than the other indices between and within the component crops and the behaviour of each species in the intercropping system, as it is based on yield per plant. The result (Table 2) revealed that in the maize and groundnut spatial arrangement the maize plant was the dominant one because of the partial AYL of the cereal was greater than the partial AYL of groundnut. These findings are in agreements with Ghost (2004), who reported that cereals (maize, sorghum, and pear millet) were also the dominant species in the groundnut- cereal intercropping systems.

INTERCROPPING ADVANTAGE (IA)

The IAs (3:1, 3:2, 3:3) recorded values of 1.29, 0.57 and 0.26 respectively (Table 3). According to Banik *et al.,* (2000), intercropping advantage is an indicator of economic feasibility of the intercropping system used. This indicates whether the system is advantageous or disadvantageous. 3 rows of maize alternating with 1 row of groundnut proved to be the most remunerative one (IA=+1.29).

CONCLUSION

The spatial arrangement with 3 rows of maize alternating with 1 row of groundnut (IA = +1.29) the northern Guinea Savannah agro- ecological zone of Ghana. Thus on the basis of the result of this experiment, 3 rows of maize alternating with 1 row of groundnut is suitable for the northern Guinea Savannah agro-ecological zone of Ghana. The spatial arrangement 3:1 seems promising in the development of sustainable maize-groundnut production with a limited use of external input. They can be used by farmers in Northern Guinea savanna area as it is the most profitable system with good economic returns. It is not prudent to make a recommendation from results of one season.

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