Original Research Article

EFFECTS OF SPATIAL ARRANGEMENTS AND FERTILIZERS ON PRODUCTIVITY IN MAIZE (*Zea mays*) and CELOSIA (*Celosia argentea*) INTERCROP

Abstract

Maize production falls short of demands in the world because of continuous cropping of a land area, which results in loss of natural soil fertility decline in yield. This study was carried out to know the responses of maize to organic and inorganic fertilizer in term of increase in yield and to ascertain a deviate spacing for maize/spinach intercrop. The experiment was conducted at the National Horticultural Research Institute, Ibadan. The nutrient sources were farmyard organic manure (derived from household waste materials), and inorganic fertilizer (N:P:K= 5:15:15). These soil nutrient sources were applied at the rate of 100Kg N/ha. The plant spacing used for the maize/spinach intercrop include; 75 x 50 cm, 75 x 75 cm, 75 x 25cm-sole maize and 25 x 10 cm-sole spinach. Data collected were; plant height, number of leaves, stem girth, leaf area, and yield per cob and fresh weight of spinach. All data were analyzed using the analysis of variance (ANOVA) and means separated by the least significant difference at five percent probability level (LSD, 0.05). F_1T_1 and F_2T_4 gave the highest values for growth and yield parameters other treatments. The highest value for the fresh weight of spinach was obtained atF_2T_2 (9.30a kg). The results suggested that the application of N:P:K fertilizer was the best nutrient source for maize production and maize/spinach intercrop should be planted at either 75 x 50 cm or 75 x 75 cm spacing, although organic fertilizer can still be preferred. It's environmentally friendly, cheaper and its nutrients contents are slowly released and can store longer in the soil, thus subsequent planting can still benefit already from the previous application.

Keywords: Farmyard manure, maize-spinach intercrops, yield, *Celosia argentea*

1. INTRODUCTION

Maize (*Zea mays*) is one of the oldest crops in the world, mainly used as a food source and has become the most important raw material for animal feed (Pimentel and Patzek, 2005). World production of maize is around 790 million tones, providing more than one-third of the calories and proteins in some countries (Chulze, 2010) and maize is predicted to become the crop with the greatest production globally, in the developing world by 2025 (Rosegrant *et al.,* 2008). It is generally believed to have originated from Mexico but reported for the first time in West Africa in 1498 (Van Eijattan, 1965). Among cereal crops, maize has the highest average yield per ha and remains third after rice in total area and production in the world.

Spinach (*Celosia* species) is a fast-growing annual leafy vegetable, cultivated in southwestern Nigeria (Schipper, 2000). The most commonly cultivated species is *Celosia argentea*, which has its origin in West Africa. Its leaves and young shoots are used in soups and the seed contains a significant amount of edible oil (Schipper, 2000). *C. argentea* is used in the treatment of diarrhoea, piles, bleeding nose, disinfectant, inflammation, haematological and gynaecologic disorders in folk medicine (Wiart, 2000).

Despite the importance of maize and spinach, their production still fall short of demands because of cultivation of poor-yield varieties, unpredictable weather conditions, pests and diseases, and continuous cropping of a land area and poor soil fertility, which result into decline in yield. Thus, different fertilizers, organic and inorganic are used to improve soil fertility to boost plant production out puts.

Nitrogen (N) is the most important nutrient required for the production of both maize and spinach. Continuous use of inorganic fertilizer often results into a number of problems such as leaching, surface water and groundwater contamination, soil acidification, reduction in useful microbial communities and increased sensitivity to harmful insects (Chen, 2006). Thus, there is a need for alternative, organic sources of Nitrogen (Akanbi *et al.,* 2006). Use of organic manures have been known to farmers in early agriculture for their favourable effects on soil and could be a potential substitute to inorganic fertilizers. The use of organic manure serves as a means of increasing and maintaining soil fertility (Alasiri and Ogunkeye, 1999). Organic manures are sourced from cheap and abundant household wastes, (Ondo State Government, 2012). Animal manures, when properly and efficiently applied, ensures sustainable crop productivity by immobilizing nutrients that are susceptible to leaching, because the nutrients contained in manures are slowly released and can be stored for a longer period in the soil. The need to reduce the cost of crop fertilization and improved environmental conditions necessitate the utilization of organic manure. Studies have also shown that crops fertilized with organic manure are more naturally nourished, stored longer and do not show susceptibility to rapid mould and rotting (Makinde *et al*., 2011).

Intercropping is a crop management system involving two or more economic species grown together in a production cycle and planted sufficiently close to each other. Intercropping enhance efficient use of available land nutrients, yield stability, soil and water conservation, reduced leaching of nutrients, balanced distribution of labour and higher economic returns (Hailu, 2015).

Much work has been done on the sole cropping of maize (Babatunde, *et al.,* 2016), spinach (Abdulmaliq, *et al*., 2016) and intercropping of either maize or spinach with other crops such as cowpea and cassava (Akinyemi and Tijani-Eniola, 1997). There are limited reports on maize-spinach intercrop, especially in relation to the spatial arrangement and relative plant population densities. Therefore, the objectives of this study were to determine the optimum planting density of maize-spinach intercrop and to evaluate the effects of farmyard organic manure and N:P:K= 15:15:15 fertilizer on the production of maize and spinach in intercrop.

2. MATERIALS AND METHOD

2.1. Soil Analysis

Top soil (0-15 cm) samples were randomly collected from the experimental site, bulked to form a composite sample; air dried and sieved using a 2mm mesh size. Routine analyses as described in Udo *et al.*; (2009) for physical and chemical properties were carried out on the soil sample to ascertain the soil is spend and in need of fertilizer.

2.2. Description of experimental site, plot design and seed rates.

The experiment was carried out at the National Horticultural Research Institute (NIHORT) between May and July, 2010 at the Farming Systems Experimental Field, Ibadan (latitude 7°22’N longitude 3°58’E). The experimental design was a split-plot fixed into Randomized Complete Block Design (RCBD) with three replicates, 2 nutrient sources(farmyard organic manure and NPK, 15-15-15 fertilizer) being the main plot factor and 4 planting densities as the subplot(75 x 50 cm, 75 x 75 cm, 75 x 25cm, sole maize and 25 x 10 cm, sole spinach)to give 8 treatments as shown in Table 1.Theorganic manure was applied one week before planting while the chemical fertilizer (NPK 15-15-15) was applied two weeks after planting. The amount of fertilizer applied was calculated based on 100KgN/ha. The maize seeds were planted at the rate of 2 seeds per hole and 4plants per plot. Spinach seeds (SokoTLV8) were sown at the rate of 2 seeds per hole. Weeding was done manually and insecticide containing lambda-cyhalothrinas as active ingredient (Trade name:Karate®) was applied to control insect pests.

2.2 Soil Sampling, Physical and Chemical Analysis

Top soil (0-15 cm) samples were randomly collected from the experimental site, bulked to form a composite sample; air dried and sieved using a 2mm mesh size. Routine analyses as described in Udo *et al.*; (2009) for physical and chemical properties were carried out on the soil sample to ascertain the soil is spend and in need of fertilizer.

Table1. Experimental layout of nutrient sources and spatial arrangement/spacing options using split-plot

Designation of treatments	Crop combinations	Spacing (cm)
Organic manure		
*F_1T_1	Sole maize	75 x 25
*F_1T_2	Sole spinach	25 x 10
F_1T_3	Maize/spinach	75 x 50
F_1T_4	Maize/spinach	75 x 75
(NPK 15-15-15)		
*F_2T_1	Sole maize	75 x 25
*F_2T_2	Sole spinach	25 x 10
F_2T_3	Maize /spinach	75 x 50
F_2F_4	Maize /spinach	75 x 75

Asterisk* : sole planting

2.3 Agronomic analysis of maize and celosia

Data collection started at 4 weeks after planting. Leaf area was taken at weekly intervals. Destructive sampling was carried out at two weeks interval on maize, in which one plant was uprooted, separated into leaves, stem and roots. The plant parts were later oven-dried to a constant weight and the value of dry weight was recorded. The fresh weights of spinach were determined at 6 weeks after planting.

2.4 STATISTICAL ANALYSIS

The recorded data on growth performance of the crops were subjected to analysis of variance (ANOVA) using g. Statistics Analysis System 8.0 (SAS) GLM procedure (SAS, 1999) and the means were separated using Duncan Multiple Range Test (DMRT). Land equivalent ratio (LER): the indicator of the efficiency of intercropping for using the resources of the environment compared with monocropping. The LER was calculated as: LER=$\frac{YAB}{YAA}+\frac{YBA}{YBB}$

Where:
YAB= yield of crop A (maize) when intercropped with crop B (spinach)
YBA=yield of crop B (spinach) when intercropped with crop A (maize)
YAA= yield from sole planted crop A
YBB=yield from sole planted crop B

3. RESULTS

3.1 Soil Analysis

Table2 shows the values of the physical and chemical properties of the soil sample collected from the experimental site of National Horticultural Research Institute, Ibadan. The soil belongs to the textural class of sandy loam with 812g/kg sand, 94g/kg silt and 94g/kg clay contents. The Nitrogen status of the soil (0.49g/kg) was lower than the critical value (10-15g/kg), hence nitrogen fertilization was needed.

3.2 Growth performance and yield of maize

Table3 shows that the height of maize was affected by the treatments at different weeks of sampling. It was observed that the plant height increased progressively as the sampling week increases and became steady from 8weeks after planting. There were no significant differences on plant height in relation to the nutrient sources and spacing. The plant height obtained from F_2T_4 at 8weeks after planting (192.60cm) was significantly higher compared to other treatments. The number of leaves increased up till 8 weeks after planting. At 4-5 weeks after planting, there was no significant difference in the number of leaves observed among the plots (Table4). Table5 Shows the yield components of maize plant. There were significant differences in the weight of cobs produced per plots based on the spacing and nutrient sources applied and treatment F_2T_4 produced the highest value of cob weight than other treatments.

3.3. Growth performance and fresh weight of spinach

Treatment F_2T_2gave the highest fresh weight of 9.30Kg in (Table 6), which was significantly higher than other treatments in the experiment, followed by F_1T_2 (7.0Kg), which was significantly different from F_2T_3 (4.54Kg), while F_2T_4 gave the lowest fresh weight of (2.10Kg). This result shows that the organic manure used in this experiment performed above average.

Table 2: Physical and chemical properties of experimental soil

Physical Parameters	**Value(g/kg)**
Sand	812
Silt	94
Clay	94
Textural class	Sandy loam
Chemical properties	**Value(g/kg)**
pH	1.20
Organic carbon	4.80
Total Nitrogen	0.49
Available P (mg/kg)	18.80
Total acidity	1.50
Exchangeable bases	**(cmol/kg)**
K	0.42
Ca	13.50
Mg	2.50
Na	1.24

Table 3. Effect of fertilizers and spacing on plant height (cm) of maize (*Zea mays*)

Treatments	Weeks after planting				
	4	**5**	**6**	**7**	**8**
*F_1T_1	47.60	51.40	87.40	121.30	170.00
*F_1T_2	-	-	-	-	-
F_1T_3	37.60	42.30	76.00	102.90	150.50
F_1T_4	45.90	45.50	86.90	121.90	167.60
*F_2T_1	49.00	56.30	90.00	121.00	156.60
*F_2T_2	-	-	-	-	-
F_2T_3	43.70	53.20	74.70	115.20	169.50
F_2T_4	41.90	59.40	107.90	156.00	192.60
	ns	ns	ns	ns	ns

Asterisk *: sole planting, ns: no significant difference, F: Fertilizer, (F_1=farmyard organic manure, F_2=NPK 15:15:15 Fertilizer); T: plant spacing, (T_1=75 x 25 cm, T_2= 25 x 10 cm, T_3=75 x 50 cm, T_4=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability. ns= Non significant

Table 4.Effect of nutrient sources and spacing on the number of leaves of maize

Treatments	**Weeks after planting**					
	4	**5**	**6**	**7**	**8**	**9**
*F_1T_1	9	10	12^{ab}	13^{abc}	15^{ab}	15^{ab}
*F_1T_2	-	-	-	-	-	-
F_1T_3	8	12	13^{abc}	12^{abc}	14^{ab}	14^{ab}
F_1T_4	9	11	13^{ab}	13^{abc}	14^{ab}	15^{a}
*F_2T_1	10	11	13^{ab}	13^{abc}	14^{ab}	14^{ab}
*F_2T_2	-	-	-	-	-	-
F_2T_3	10	10	13^{ab}	13^{ab}	15^{a}	15^{a}
F_2T_4	8	9	11^{ab}	13^{abc}	14^{ab}	15^{a}
	ns	ns				

Asterisk *: sole planting, ns: no significant difference, F: Fertilizer, (F_1=farmyardorganic manure, F_2=NPK 15:15:15 Fertilizer); T: plant spacing, (T_1=75 x 25 cm, T_2= 25 x 10 cm, T_3=75 x 50 cm, T_4=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability.
ns= Non significant

Table5: Effect of different fertilizers and spacing on cob weight and total yield of maize (*Zea mays)*

Treatment	Cob weight per plant (g)	Total yield per plot (g)
*F_1T_1	159.15[cd]	222.55[c]
*F_1T_2	-	-
F_1T_3	171.23[bcd]	225.96[c]
F_1T_4	99.02[d]	280.00[bc]
*F_2T_1	106.99[d]	208.07[c]
*F_2T_2	-	-
F_2T_3	280.70[a]	296.25[bc]
F_2T_4	260.54[a]	400.43[a]

Asterisk *: sole planting, ns: no significant difference, F: Fertilizer, (F_1=farmyard organic manure, F_2=NPK 15:15:15 Fertilizer); T: plant spacing, (T_1=75 x 25 cm, T_2= 25 x 10 cm, T_3=75 x 50 cm, T_4=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability.

Table 6: Fresh weight of Spinach in maize/spinach intercrop

Treatment	Fresh weight of Spinach (g)
*F_1T_1	-
*F_1T_2	7.0^{ab}
F_1T_3	2.13^{cd}
F_1T_4	4.90^{bc}
*F_2T_1	-
*F_2T_2	9.30^{a}
F_2T_3	4.54^{bcd}
F_2T_4	2.10^{cd}

Asterisk *: sole planting, ns: no significant difference, F: Fertilizer, (F_1=farmyard organic manure, F_2=NPK 15:15:15 Fertilizer); T: plant spacing, (T_1=75 x 25 cm, T_2= 25 x 10 cm, T_3=75 x 50 cm, T_4=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability.

3.4 Land Equivalent Ratio

Table 7 indicates the land equivalent ratio of maize/spinach intercrop. The LER was more than one (>1) in almost all the treatment (F_1T_3, F_2T_3 and F_2T_4) thus indicating yield advantage in almost all the different spacing used in the experiment, also it means that land utilization efficiency for maize/ spinach intercropping pattern was more advantageous than sole cropping. The highest value (1.51) was recorded at F_2T_3 while the lowest value (0.86) was recorded by F_1T_4. The LER greater than one (LER>1.0) have been reported with various maize intercropping (Saban *et al.,* 2007; Carr *et al*., 1995).

Table 7: Land Equivalent Ratio of maize/spinach intercrop

Treatment	Total yield per plot (Kg)		Land equivalent ratio
	Maize	Spinach	
*F_1T_1	3.10	-	-
*F_1T_2	-	7.00	-
F_1T_3	2.18	2.13	1.09
F_1T_4	0.76	4.30	0.86
*F_2T_1	2.98	-	-
*F_2T_2	-	8.50	-
F_2T_3	2.90	4.54	1.51
F_2T_4	3.13	1.33	1.21

Asterisk *: sole planting, ns: no significant difference, F: Fertilizer, (F_1=farmyard organic manure, F_2=NPK 15:15:15 Fertilizer); T: plant spacing, (T_1=75 x 25 cm, T_2= 25 x 10 cm, T_3=75 x 50 cm, T_4=75 x 75 cm). Mean with different letter in the same column are significantly different at 5% probability.

4. DISCUSSION

Maize production throughout Africa depends solely on fertilizer application, especially for the production of the vegetative part and nitrogen is an important nutrient for the production of maize. Hence this study was carried out to compare the responses of maize to organic and inorganic fertilizer and to ascertain a definite spacing to be used in maize/celosia intercrop.

As regards morphological parameters, the highest value for plant height of maize was obtained at treatmentF_2T_4 (192.60m) over the weeks of sampling. This could be attributed to the fact that NPK, being a chemical fertilizer readily released its constituent nutrients especially nitrogen, for plant growth and development. The NPK- treated plots with larger spacing (75x50cm and 75x75cm) plots produced plants with the highest value of leaf area which is the capacity of the plant to produce assimilate per unit land area in which dry matter accumulation depends. Considering the number of leaves produced a continuous increase was observed until 8 weeks after planting when the plant attained the reproductive stage and senescence set in to cause a slight reduction in number of leaves. As the planting spacing increases and the number of leaf increases, the assimilatory capacity of such plant also increases. Since the stem determines the stoutness of the plant and tends to carry a significant proportion of total dry matter of the plant; this deposited dry matter is withdrawn at a later stage of growth to support reproductive development.

In the case of maize yield per plant, it was observed that in most of the samples collected, NPK-treated plots with larger spacing gave the highest yield. All these reports indicated the superiority of in inorganic fertilizers over organic sources for increasing the grain yield of crops (Read *et al.,* 1985). According to Akintoye (1999), the application of N-fertilizer to maize often influences dry matter production by increasing leaf area development and photo-efficiency of the leaf area. Thus, the lowest grain yield of maize resulting from low leaf area was obtained in organic-treated plot (F_1T_4) with 0.76Kg, while the highest was obtained from NPK- treated plot (F_1T_1) which was 3.10Kg and there were significant differences among the treatments at 5% level of probability.

The land equivalent ratio (LER) can be used to standardize intercrop yields against the sole crop. In this study, the LER values were greater than one in almost all the treatments, these implies that those treatments were highly efficient and therefore exhibited higher degree of mutual compensation (Odo, 1991), although individual yield of component crops in an intercropping combination is reduced, total yield of the intercrop is significantly greater than that of each crop grown in sole cropping (Pal *et al*., 1993). This still agrees with the report of Okigbo and Greenland (1976) on the advantage of an intercropping system in giving high yields through beneficial interaction from nearby intercrops. Andrews (1972) had consistently obtained a yield increase from crops grown in mixture compared with crops grown sole.

It could be explained that while the application of inorganic fertilizer has an obvious advantage of immediate release of its nutrient to the soil for plant growth and development, the application of organic fertilizer has its own advantage of enriching the soil organic matter and thereby constituting longer-term benefit to the soil and the plant, thus further research can be done by first applying the organic manure on the soil as a basal application before applying the inorganic fertilizer at different rate.

5. CONCLUSIONS

Tropical soils are inherently low in fertility hence the need to supply external nutrient input which may either be from either organic or inorganic sources that are essential to improve and sustain crop production on our soil. Inorganic fertilizers are costly and beyond the reach of poor farmers, on the other hand, organic fertilizer is easily available and cheap and the results obtained from organic fertilizer treated plots in some plots are not significantly different from the results obtained from the inorganic treated plot. Also, the organic fertilizer will be more economical at the long run for increasing crop production by the poor farmers, and takes longer time to release nutrient hence other crop planted after maize/spinach can still benefit from the organic fertilizer already applied.

The results obtained in this experiment also showed that maize under intercropping with spinach did best at a wider spacing of 75 x 75 cm and spinach being a C_3 plant can best be intercropped with maize which is a C_4 plant. The result in treatment F_2T_2 can be attributed to the quick response of inorganic fertilizer used in the experiment, compare to the organic fertilizer which usually takes longer time to decompose but in the longer run gives better support to soil and plant and since the LER is greater than one, the intercropping favours the growth and yield of both maize and spinach.

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