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Performances of maize and soybean as influenced by intercropping and fertilizer sources in the Northern Guinea Savanna agro-ecology of Nigeria

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ABSTRACT

Inorganic fertilizer recommendation for ameliorating soil fertility decline is facing many challenges. Information on the alternative (organomineral fertilizer) for use in the intercrop is scarce in Tarabe, Nigeria. Hence, inorganic and organomineral fertilizer (OF) effects were evaluated on growth, N uptake and yield of maize and soybean. Using a 2 × 9 factorial field experiment in 2016 and 2017, cropping systems (sole and intercrop) were evaluated under nine fertilizer levels (control, 50, 100, 150, 200 kg N/ha OF and 50, 100, 150, 200 kg N/ha NPK 20-10-10 fertilizers) in a randomized complete block design with three replicates. Maize (ACR-95DT) and soybean seeds (TGX 144 8-2E) were sown at 40,000 and 74,000 plants per ha, respectively. The results indicated that intercropping improved maize and soybean leaf area, but resulted in a significant reduction in N uptake and yields in the two growing seasons. Maize yield varied significantly among treatments and ranged from 0.78 (control) - 2.32 t/ha (150 kg N/ha OF) and 1.04 (control) - 2.13 t/ha (150 kg N/ha NPK) in 2016 and 2017, respectively. Also, soybean yield was significantly increased at 100 kg N/ha OF (1.14 t/ha) compared to 150 kg N/ha OF (0.83 t/ha) in 2016, while 150 kg N/ha OF and NPK had significantly higher yields than the other treatments in 2017. The cropping system and fertilizer interaction had no significant influence on maize and soybean grain yields in both years. Organomineral fertilizer at 150 kg N/ha was suggested for improving maize and soybean intercrop.

Keywords: Cropping system, growth, yield, nitrogen uptake, organomineral fertilizer

INTRODUCTION

Maize is a cereal crop that is grown widely throughout the world in a range of agroecological environments and is ranked next to wheat and rice in terms of the area being used for its cultivation (FAO, 2020a). All parts of the crop can be used for food and non-food products. Maize accounts for a high percentage of low-income household expenditures in Sub-Saharan Africa (Ekpa et al., 2018). Despite the important role in income generation, the average yield obtained on farmers field in Nigeria is very low (about 1,590 kg/ha) compared with the world average of 5,500 kg/ha (FAO, 2020b). In Taraba State, grain yield is 2,570.43 kg/ha on farmers' fields (Coster et al., 2020), which is actually lower than the actual yield of 2,300 kg/ha (open pollinated) and 3,500 kg/ha (hybrid) expected in the Savanna (Afolabi et al., 2020). The low yield obtained by farmers was attributed to low soil fertility, pest infestation, weed and disease infection beyond the threshold level and poor varietal potential (Ekpa et al., 2018). Soils in Taraba State are generally low in fertility status resulting from high soil weathering, deficiency in the inherent nutrient status of the soil parent material and continuous cropping that further depleted the low inherent soil fertility status. Thus, attempts to improve maize yield through soil fertility improvement resulted in the use of different fertilizer application and farming system approach.

However, the age-long method of using a combination of different crops through intercropping still forms the major approach for crop yield improvement by most farmers. The advantages of intercropping legumes and cereals for soil fertility enhancement have been well documented. The inclusion of legumes such as soybeans and groundnut in cereals-based cropping system has been reported to improve soil fertility and helps to control the parasitic weed (*Striga hermonthica*) which culminates in increased economic returns to farmers (Bassey et al., 2021).

Soybean is among the major industrial and food crops grown successfully in many states in Nigeria with low input. It is a source of prime or high-priced vegetable oil in the international market. The seed has an average protein content of 40% and is considered richer in protein compared to the common vegetable or animal food sources found in Nigeria (Dugje et al., 2009). The inclusion of soybean in the cropping system was a result of the crop's ability in meeting its own N requirement by fixing atmospheric nitrogen (N), thus a viable and low-cost means for soil fertility improvement. In Nigeria, the integration of various soybean varieties into the traditional cropping systems for sustainable yield increase in maize has been promoted. However, recent trends in research have shown that maintaining high crop yields under intensive cultivation is only possible through the use of organic and inorganic fertilizers or their combination. Other causes of decline in productivity in these systems are low plant populations, high incidences of diseases and pests and stunted crops which are correlated to a number of soil-related biophysical limitations. However, soil fertility decline is still considered a major limiting factor in sub-Saharan Africa to achieving sustainable household food sufficiency in the majority of smallholder farming systems (Stewart et al., 2020).

The maintenance of high crop yields under intensive cultivation is possible only through the use of fertilizers. Large-scale farming practised in developed countries to provide large quantities of food at reduced cost would not have been attained without fertilizers (Doran et al., 1996). Crop yield responses to fertilizer application have been positive but its prohibitive costs and logistics have reduced its use in smallholder cropping systems (Odendo et al., 2007). Fertilizer use in Nigeria came into prominence in the early 1960s when farmers were taught the techniques of its application. Since then, it has been difficult to satisfy the fertilizer demand of Nigerian farmers. The problems of scarcity, decrease in soil organic matter, increase in soil erosion and high cost of inorganic fertilizer beyond the reach of the low-income farmers are major constraints for the application of inorganic fertilizer. Consequently, organomineral fertilizer using composted municipal waste as raw material for crop production is gaining ascendancy (Fadrgrone et al., 2008). In this system, organic materials (farm waste and animal manure) are made into compost and fortified with some deficient nutrients using chemical sources, thereby offering an economical source of soil fertility improvement. Thus, organic-based fertilizer has an advantage in improving the physical, chemical and microbiological properties of the soil. It also supplies micro-nutrients that reduce hazards from the use of lime materials (Fadrgrone et al., 2008). However, the diversity of crop species in the intercrop presents farmers with the challenge of practical management, Also, the difficulty of applying optimum levels that will serve the entire mixture arises. In a bid to support the plan for the maize-soybean transformation in Nigeria, information on the use of commercially available organomineral fertilizer is necessary, particularly in Taraba State, Nigeria. Furthermore, the optimum rates for the use of these inputs in intercrop situations have not been based on sound research findings but on the requirements of each component crop. Hence, the objectives of this study were to evaluate the effects of organomineral and inorganic fertilizers on nutrient uptake, growth and yield for sole maize and in intercrop with soybean.

MATERIALS AND METHODS

Experimental Location

The study was carried out in the year 2016 and 2017, at the College of Agriculture, Jalingo in Taraba State.

Jalingo is located on coordinates 08.9° N and 011.3° E in a Southern Guinea Savanna with a land area of 191 km^2 on an Alfisol. Jalingo has a wet and dry season tropical climate with approximately six months of rainy season. The average rainfall is between 700 mm and 1000 mm and the temperature of about 27 °C (NiMet, 2019). The rainy season begins in May and ends in October, while the dry season commences in November and sometime in April (Figure 1). The site was under continuous cultivation with arable crops such as yam, cassava, maize, cowpea, groundnut, guinea corn and bambara nut for over six years prior to the establishment of the experiment.

Soil sampling and analysis

The experimental site was manually slashed to ensure good land preparation. Soil samples were taken from the experimental site prior to planting maize and soybean to assess the nutrient status of the soil. Soil samples were collected on the field at a depth of 0-15 cm for some physical and chemical analyses following FAO (2020b) sampling procedure. The samples taken were bulked to form a composite sample from where a representative sample was taken which was air-dried and crushed. The composite sample was sieved through 0.2 mm mesh for the determination of soil properties, while the sample for percent total N and organic carbon determination was further passed through a 0.5 mm sieve. The particle size analysis was determined using the method of Bouyoucous (1951). Total nitrogen was determined by the Kjeldahl method (Bremner, 1965), while available P was by the method of Olsen et al. (1954). Organic carbon was determined using Walkley and Black method (Bremner, 1965), exchangeable bases were determined using a flame photometer for K and Na, while Ca and Mg were determined using Atomic Absorption Spectrophotometer (AAS) (model 210, Buck Scientific, made in the USA) after extraction with 1 N ammonium acetate. Using a soil-to-water ratio of 1:1, soil pH was measured. Exchangeable acidity was determined by the KCl extraction method (Mclean, 1965). Effective cation exchange capacity (ECEC) was determined by the summation of Exchangeable bases (Ca, Mg, K and Na) and Exchangeable acidity. The physical and chemical properties of the soil used in this study are shown in Table 1.

Analysis of organomineral fertilizer for nutrient composition

Organomineral fertilizer material of 0.2 g was weighed and subjected to digestion at 360 °C using a Tecator digestion block and tubes for four hours using 10 ml concentrated H_2SO_4, and one tablet of selenium and sodium sulphate was added. Total N was determined from the digest by steam distillation method. P concentration was determined by the Vanadate-molybdate yellow colorimetric method using a spectrophotometer (Olsen et al., 1954). The K was determined with the flame photometer (model FP-640, Ningbo Hinotek Technology, made in China) (Olsen et al., 1954), while Ca, Mg, Mn, Fe, and Cu were determined with AAS. The nutrient content of the organomineral fertilizer is shown in Table 2.

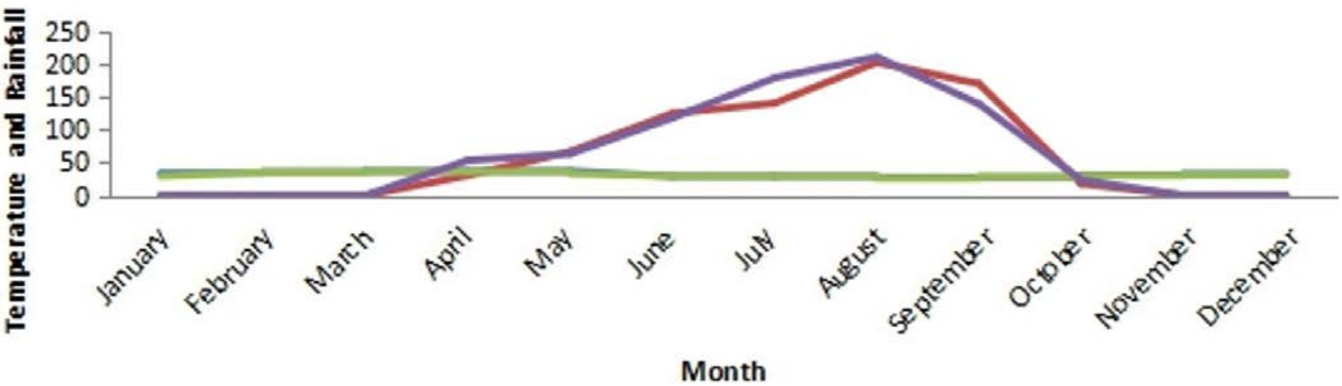

Figure 1. Monthly mean temperature and rainfall of the experimental site for 2016 and 2017 (Source: Taraba State Agricultural Development Programme, Jalingo)

Table 1. Soil physical and chemical properties at the experimental site before the commencement of the study

Parameters	Value
Sand (g/kg)	712
Silt (g/kg)	135.6
Clay (g/kg)	152.4
Textural class	Sandy loam
pH (H_2O)	6.5
Total N (g/kg)	0.09
Organic C (g/kg)	0.73
Available P (mg/kg)	4.59
K (cmol/kg)	0.2
Ca (cmol/kg)	2.2
Mg (cmol/kg)	0.5
Na (cmol/kg)	0.2
Exchangeable acidity (cmol/kg)	0.39
Base saturation (g/kg)	888
ECEC (cmol/kg)	3.49

Table 2. Nutrient composition of organomineral fertilizer

Parameters	Concentration
Total N (g/kg)	44.2
Total P (g/kg)	11
Total K (g/kg)	7
Ca (g/kg)	7
Mg (g/kg)	0.57
Mn (mg/kg)	543
Fe (mg/kg)	605.3
Cu (mg/kg)	237

Treatment and experimental design

The trial was a 2 * 9 factorial experiment involving three cropping systems (sole and intercrop), and nine levels of fertilizer applications (0, 50, 100, 150, 200 kg N/ha organomineral and 50, 100, 150, 200 kg N/ha of NPK 20-10-10 fertilizer), using maize and soybean as test crop. The experiment was laid out in a randomized complete block design with three replicates as described by Gomez and Gomez (1984). Each plot measured 16.5 m^2.

Experimental Materials

The different fertilizers used in the study were organomineral fertilizer (a commercial fertilizer of organic materials fortified with inorganic nitrogen and bone meal for phosphorus) and inorganic fertilizer (NPK 20-10-10). Maize (*Zea mays* L.) variety ACR-95DT and soybean (*Glycine max* L. (Merril)) variety TG_X 1488-2E were used as test crops. The two plants were early maturing (60 days) and obtained from the Germplasm unit of the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria.

Field operations and crop management

Organomineral fertilizer was applied by broadcast on the plots and worked into the soil manually after seedbed preparation two weeks before planting, while inorganic fertilizer was applied using row application at planting maize and soybean seeds. Maize seeds (ACR-95DT) and soybean seeds (TGX 144 8-2E) obtained from IITA, Ibadan were used as planting materials. Maize and soybean were planted at 1.0 m x 0.25 m and 0.15 m x 0.9 m to have a population density of 40,000 and 74,000 plants per ha, respectively. To achieve this for maize and soybean, 3 seeds were sown per hole and later thinned to 2 plants per stand, two weeks after planting. In the intercrop, maize and soybean seeds were sown on alternate rows in a strip. Manual weeding was done at three, six and eight weeks after planting.

Data Collection

Growth parameters determined on maize and soybean included plant height (using the meter rule), leaf area, stem girth (using Vernier caliper), and the number of leaves per plant. The maize leaf area was determined using the linear equation method of Lucas (1981), while the soybean leaf area was determined using the graph method. Data collection was done bi-weekly. Plant tissue analysis was carried out at the point of tasseling/flowering to determine the nutrient concentration and uptake. The total weight of maize and soybean grain yields was determined per plot taken at harvest.

Plant sample preparation for determination of nitrogen uptake

Maize and soybean plants were sampled per plot at silking and flowering, respectively, for the determination of nutrient concentration. The plant samples were air-dried for 72 hours. The samples were oven-dried to a constant weight at 70 °C and then milled with a steel grinder before passing through a 0.5 mm sieve. Plant nutrient concentrations were determined using the procedure described by IITA (1982) manual for plant tissue analysis.

Land equivalent ratio (LER)

LER for assessment of land use advantage. LER is the sum of ratio of intercrop to sole crop for maize and soybean yield.

$$LER = \frac{Y_{im}}{Y_m} + \frac{Y_{is}}{Y_s}$$

Where: Y_{im} = intercropped maize yield; Y_m= monoculture maize yield; Y_{is}= intercropped soybean yield; Y_s = monoculture soybean yield.

Data Analyses

Data collected were analyzed using analysis of variance (ANOVA) following the procedure of Gomez and Gomez (1984) and by using the SAS 9.0 software package (SAS 2000). Mean separation (P<0.05) was done using Duncan's Multiple Range Test. The levels of statistical significance are indicated for the cropping system and fertilizer interaction.

RESULTS AND DISCUSSION

Soil properties

The textural classification of the soil was sandy loam and the pH was 6.5 (Table 1). Other chemical properties of the soil were as indicated in the Table. Generally, the textural classification of the soils indicated it to be low in water holding capacity and a high level of soil porosity due to the low clay and silt content (Osujieke et al., 2018). Crop production under these soil type and environmental condition are likely to experience intermittent drought due to irregular rainfall. Consequently, the addition of organic matter is likely to improve crop performance in such a situation. Lal (2016) reported the importance of organic-based materials in the improvement of soil physical condition to enhance crop performance. The soil pH of 6.5 was within the range appropriate for good maize and soybean development. According to N2Africa and ASHC (2014) reports, maize and soybean require soil with a pH range of 4.5 and 8.5 for optimum performance. The soil nutrient composition from the study area reflects highly depleted soils with low nutrient status resulting from high rainfall (Aliyu et al., 2020).

Composition of the organomineral fertilizer

The constituents of the commercially manufactured organomineral fertilizer used in the study were as indicated in Table 2. The OF was high in macronutrients and micronutrients as shown in the Table. The organomineral fertilizer (OF) nutrient composition indicated that it was adequately fortified with N to be able to complement the inadequacy of the soil in supporting crop performance. Aside from nutrient deficiency, savanna soils are low in soil organic matter content. A modest application of organic-based fertilizer, such as the commercially formulated OF will serve as a good complement for enhanced crop performance (Aliyu et al., 2020). Also, the Ca and Mg content could serve as a support for better crop growth.

Effect of cropping system on growth and nitrogen uptake in maize

The heights of maize between the two cropping systems were not significantly different in the sixth week after planting in the two growing years (Table 3). Maize heights were not significantly higher in the sole crop compared to the intercrop for both years. The lack of significant difference in height is attributed to the absence of appreciable competition for light resulting from intercropping with soybean. The finding is in support of Telkar et al. (2017) report that the intercropping of maize with soybean did not have a significant impact on maize height. Maize leaf area was significantly higher under intercropping system compared to the sole crop in 2016. However, intercropping improved maize leaf area by 13.07% compared to sole cropping in 2017, which was not significant. The soil in the study site is sandy with limited tendency to retain soil moisture. The improvement in maize leaf area under intercropping system over the sole crop is likely to be attributed to the impact of the soybean with lower canopy acts as cover, thus reducing soil moisture loss and improving crop performance. The contribution of soybean to improved soil water storage for increased maize performance in the intercrop was reported by Wang et al. (2020). Their finding demonstrated that the achieved improvement in soil water storage helps to promote maize photosynthetic rate and spontaneous growth rate during the co-growth period.

Table 3. Effects of cropping system and fertilizers on the growth and nitrogen uptake of maize at six weeks after planting in years 2016 and 2017

Treatments	2016			2017		
	Plant height (cm)	Leaf area (cm^2)	N uptake (kg/ha)	Plant height (cm)	Leaf area (cm^2)	N uptake (kg/ha)
Cropping system						
Sole	91.03	88.47^{b}	83.73^{a}	90.29	132.72	88.38^{a}
Intercropped	85.59	150.15^{a}	66.77^{b}	85.59	150.07	66.99^{b}
SE ±	3.7	8.65	0.63	3.53	6.19	1.46
Fertilizers						
0 (Control)	88.48^{bc}	163.40^{ab}	60.8^{de}	87.35^{bc}	88.40^{c}	86.26^{b}
50 kg N/ha of OF	84.70^{bc}	134.73^{ab}	76.07^{cd}	74.47^{c}	135.78^{b}	82.66^{bc}
100 kg N/ha of OF	115.97^{a}	178.71^{a}	96.20^{ab}	84.70^{b}	134.73^{b}	111.76^{a}
150 kg N/ha of OF	79.78^{c}	144.99^{ab}	88.00^{abc}	76.45^{c}	144.99^{ab}	102.90^{a}
200 kg N/ha of OF	101.82^{ab}	179.31^{a}	48.07^{e}	88.45^{b}	113.41^{b}	72.04^{c}
50 kg N/ha of NPK	88.45^{bc}	113.41^{b}	62.33^{de}	73.73^{c}	134.19^{b}	84.05^{bc}
100 kg N/ha of NPK	73.73^{c}	134.19^{ab}	79.90^{bcd}	88.48^{bc}	163.02^{ab}	60.80^{cd}
150 kg N/ha of NPK	74.47^{c}	135.76^{ab}	105.03^{a}	115.97^{a}	178.71^{ab}	63.95^{c}
200 kg N/ha of NPK	87.35^{bc}	83.40^{b}	64.75^{de}	101.82^{ab}	179.31^{a}	48.27^{d}
SE ±	5.84	27.12	6.49	5.77	14.4	3.14
SE ± Interaction	8.62^{ns}	37.17*	8.84^{ns}	8.47^{ns}	26.34*	4.44*

OF = Organomineral fertilizer.

Means in a column followed by the same letters are not significantly different (P < 0.05) according to Duncan's Multiple Range Test; ^{ns} = not significant; * = significant at 5%.

The enhanced photosynthetic rate and spontaneous growth rate were possible through leaf area increase as observed in this study. Similarly, Zaeem et al. (2019) reported a significant increase in the chlorophyll contents of maize due to intercropping with soybean compared to sole maize cropping. Nitrogen uptake in maize was significantly increased under sole crop compared to the intercropping system in both years. This implied that the interaction between maize and soybean resulted in competition for N at the time of nutrient uptake determination. Studies have shown that despite the ability of soybean to fix atmospheric N, it depends on the available soil N to boost early growth before N fixation. Thus, it requires a starter dose of N fertilizer under limited fertility conditions. The initial competition for N at the early co-growth period could cause a significant reduction in N uptake by maize plants at this stage of development. In order to avert the possible competition for N at the early stage in the maize soybean co-growth period, a 2 weeks' delay before introducing maize into the intercrop was suggested (Abdel-Wahab et al., 2016).

Growth and nitrogen uptake in maize as affected by fertilizer application

Fertilizer application significantly increased maize height in the two years of cropping (Table 3). The 100 kg N/ha of OF treatment had significantly taller plants, while least height was observed at 100 and 150 kg N/ha of NPK applications in 2016. However, in 2017, 150 kg N/ha of NPK had significantly taller plants compared to the other treatments, except 200 kg N/ha of OF. The variation in the 2-year results could be attributed to the short drought experienced at the middle reproductive stages of soybean establishment in 2016. The organic matter contained in the OF might have been able to conserve moisture, thereby aiding crop development than the inorganic fertilizer source under moisture-limited conditions. The significant effect of soil organic matter improvement under the water-limiting condition on crop performance has been reported (Menšík et al., 2019; Lal, 2020). Applying 100 and 200 kg N/ha of OF significantly improved the leaf area in maize compared to the application of 50 and 200 kg N/ha of NPK fertilizer in the year 2016. In 2017, the control a had a significantly lower leaf area compared to the other treatments, while 200 kg N/ha of NPK treatment had a significantly higher leaf area than the other treatments involving OF, except 150 kg N/ha of OF. The result was similar to the response observed for maize height, with better performances observed in the OF in 2016 and NPK in the following season. The observed result could be attributed to the role played by soil organic matter improvement under moisture-limited conditions (Lal, 2020). Applying 100 kg N/ha of OF tended to improve maize growth compared to 150 or 200 kg N/ha of OF in the two-year cropping, while 200 kg N/ha was optimum for NPK fertilizer. The result agrees with El-Shamy et al. (2015) report that maize growth was better with integrated nutrient supply and inorganic fertilizer application. The increase in the growth of maize with OF application is attributed to the improvement in soil's physical condition of the soil aside from nutrient supply compared to the inorganic source. Uptake of N in maize showed significant variation among the fertilizer treatments and increased with an increase in the level of applications, except at 200 kg N/ha of OF and NPK fertilizers. Significantly higher N uptake in the 2016 season was observed in the 150 kg N/ha of NPK fertilizer treatment compared to the other treatments. However, 100 and 150 kg N/ha OF-treated plants had significantly higher N uptake compared to the other treatments in 2017. The finding was in support of Abou Seeda et al. (2021) that water and fertilizer supplies were the main factors for improved crop performance under low fertility conditions. These could explain the variation in N uptake observed between the two growing years of cropping.

Interaction of cropping system × fertilizer on maize growth and nitrogen uptake

The interaction of the cropping system and fertilizer application in 2016 and 2017 indicated that there was no significant difference in maize height. The non-significant variation in maize height between the cropping systems suggested that amending the soil through fertilizer application was able to suppress the negative effect imposed by competition for available resources. The application of fertilizer was able to complement the soil nutrient deficiency of the crop and improved the competitive ability of maize in the intercrop. Leaf area was significantly improved by the interaction of the cropping system and fertilizer in both cropping years. A similar result was reported by Abdel-Wahab et al. (2016) and Zaeem et al. (2019). For N uptake, the influence of the cropping system and fertilizer interaction was not significant in 2016, while the interaction was significant in 2017. The variation in responses observed could be associated with the ability of the soybean to use all the N they are able fix plus N from the pool of available N in the soil (Ohyama et al., 2017), hence, the addition of N fertilizer will boost maize N uptake.

Growth and nitrogen uptake in soybean as influenced by cropping system

Soybean height did not vary significantly for the cropping system in the two years of cultivation (Table 4). The non-significant variation in height indicated that the height of the maize did not cast significant shade over the soybean. Nevertheless, the above-ground competition for light with maize in the intercrop causes a reduction in soybean height in both years. The result was in line with Zaeem et al. (2019) result that intercropping maize with soybean resulted in significant soybean height reduction. The non-significant reduction observed in the study could be attributed to the height of the maize used, in that it was not as tall as the maize variety used in their study. The introduction of short component crops in the intercrop improves light interception by the lower canopy crop to improve photosynthetic ability. The soybean leaf area was not significantly improved by the cropping system in both seasons. However, the intercrop improved soybean leaf area by 16.92 and 19.55% relative to the sole crop in 2016 and 2017, respectively. Sole-cropped soybean had significantly higher N uptake compared to the intercrop in both years of cultivation. The result is in support of Ren et al. (2021) that reported a 22% N uptake reduction of intercropped soybean compared to sole crop. The variation in the N uptake could be related to the competition for N in the intercrop relative to the sole cropping system. The co-growth of the component crops did not improve soybean N uptake. The significant reduction in N uptake for the intercropped soybean relative to the sole soybean could also be due to the impairment caused by early competition for N from the soil N reservoir. Consequently, the soil N pool nor the N fixing ability of the soybean was not capable of supporting the soybean or associated crop demand for N. The increased leaf area and lower N uptake in the intercropped compared to the sole soybean suggest that the ability of the leaf to function will be hampered by low chlorophyll content, thus poor photosynthate assimilation.

Nitrogen uptake of soybean as influenced by fertilizer application

Soybean height was significantly enhanced by fertilizer application in the year the two growing years. Soybean height was significantly increased at 200 kg N/ha of NPK compared to the other treatments in the two years of planting. However, applying OF at 100 kg N/ha significantly improved soybean height compared to 150 kg N/ha of OF. Leaf area improved with an increase in OF application. Applying OF at 200 kg N/ha significantly increased soybean leaf area compared to other treatments involving NPK fertilizer application in 2016. Similarly, applying 200 kg N/ha of OF treatment had the highest leaf area in 2017, but this was not significantly different from the other treatments. The benefit of applying fertilizer to soybean growth have been reported (El-Shamy et al., 2015; Ohyama et al., 2017). Soybean requires large amounts of N to sustain high photosynthesis rates to fully achieve its yield potential (Ohyama et al., 2017). Nitrogen uptake in soybean varied significantly among the fertilizer treatments in the two growing years. Applying NPK at 100 kg N/ha had the highest N uptake, while the lowest was observed at 50 kg N/ha of NPK fertilizer in 2016. However, in 2017, the highest N uptake was observed at 100 kg N/ha of OF, while the treatment involving NPK at 200 kg N/ha had the least uptake. The increase achieved in N uptake for soybean must have resulted

Table 4. Effects of cropping system and fertilizer on the growth parameters of soybean at six weeks after planting in years 2016 and 2017

Treatments	2016			2017		
	Plant height (cm)	Leaf area (cm^2)	N uptake (kg/ha)	Plant height (cm)	Leaf area (cm^2)	N uptake (kg/ha)
Cropping system						
Sole	20.74	27.66	65.79^{a}	21.62	24.55	67.89^{a}
Intercropped	20.68	32.34	53.51^{b}	19.31	29.35	55.28^{b}
SE ±	0.178	2.2	1.85	0.178	1.26	1.37
Fertilizers						
0 (Control)	29.64^{bc}	24.99^{b}	59.15^{bc}	26.32^{b}	37.68	61.17^{c}
50 kg N/ha of OF	29.98^{bc}	26.06^{b}	68.73^{ab}	26.74^{b}	34.89	71.39^{ab}
100 kg N/ha of OF	29.17^{b}	30.76^{ab}	67.62^{ab}	27.34^{b}	37.74	75.22^{a}
150 kg N/ha of OF	27.96^{c}	34.95^{ab}	52.88^{c}	25.63^{b}	34.96	67.45^{bc}
200 kg N/ha of OF	29.01^{bc}	40.07^{a}	39.40^{d}	27.01^{b}	38.40	69.95^{ab}
50 kg N/ha of NPK	32.44^{b}	29.60^{b}	50.92^{c}	29.15^{ab}	37.65	51.75^{d}
100 kg N/ha of NPK	26.91^{c}	25.51^{b}	72.43^{a}	24.72^{b}	26.55	55.61^{cd}
150 kg N/ha of NPK	27.77^{c}	29.42^{b}	60.37^{bc}	25.36^{b}	21.18	60.95^{c}
200 kg N/ha of NPK	41.54^{a}	26.62^{b}	65.37^{ab}	32.13^{a}	36.25	40.72^{e}
SE ±	1.25	4.14	3.47	1.27	5.61	2.35
SE ± Interaction	1.673^{ns}	12.57^{ns}	4.59*	1.68^{ns}	12.58^{ns}	3.42*

OF = Organomineral fertilizer.

Means in a column followed by the same letters are not significantly different ($P < 0.05$) according to Duncan's Multiple Range Test; ^{ns} = not significant; * = significant at 5%.

from the nutrient applied to the soil for improving crop performance. Under soil N limitation, the application of fertilizer N is necessary before the crop starts to nodulate. According to a study, soybean depends on the soil for N supply before active nodulation and obtained 25 - 73% of plant N from the soil (Ohyama et al., 2017). However, excessive N supply at early growth stages may result in lodging-induced yield reduction.

Cropping system × fertilizer on growth and nitrogen uptake in soybean

The cropping system and fertilizer interaction had no significant influence on soybean height and leaf area in the two years of planting. The influence of competition experienced by soybean in the intercrop could have been reduced by the application of fertilizer. The competition for nutrients may have been complemented by the application of fertilizer, thereby reducing the dependence of soybean on the soil nutrient reservoir for growth. The result supports findings that the application of fertilizer improves soybean performance in the intercrop (Ohyama et al., 2017). However, the interaction of the cropping system and fertilizer indicated significant improvement in N uptake by soybean in the two growing years. The implication of the significant variation was that the nutrients supplied through fertilizer application were acquired by the maize crop, thus enhancing soybean root nodules to function adequately and improve soybean

N uptake. Furthermore, a reasonable application of P and K-containing fertilizers is an important approach to improving the growth of soybean (Zhao et al., 2022). The phosphorus contained in the NPK and OF fertilizers helps to increase the low light-utilization efficiency of soybean under maize shading conditions (Zhao et al., 2022). In their report, the application of phosphate fertilizer increased light-saturated net photosynthetic rate, apparent quantum yield, maximum electron transport rate, and maximum Rubisco carboxylation rate under shaded conditions, thereby improving soybean grain yield.

Effects of cropping system on grain yields in maize and soybean

The grain yield observed in maize was significantly higher for the sole crop than the intercrop in 2016 and 2017 (Table 5). Crop yields are determined by the contribution of the growth parameters and nutrient uptake, which are influenced by the above and below competition for available resources in the intercropping system. Studies comparing sole and intercropping vary in the reported yield observed for either crop in the system (Ren et al., 2021). The result was inconsistent with Su et al. (2014) report. Despite the improved leaf area observed in the intercropped, sole maize and sole soybean had significantly higher grain yields. The significant increase in the sole maize yield was probably due to the availability of the limited N at the time of uptake determination and its effective utilization which resulted in the higher sole maize yields relative to the intercrop. A significant increase in the grain yield of soybean was observed in the sole crop compared to the intercrop in the two growing years. The reported yield differences could be explained through the response of the crop to environmental factors affecting crop yields. The soybean is grossly affected by shade from the maize plant, which can cause a reduction in the reception of solar radiation by plants, both intensity and quality, thus affecting plant activities (Su et al., 2014). Also, the competition for available light caused significant downregulated net photosynthetic rate, transpiration rate and stomatal conductance at the early stage of soybean growth (Su et al., 2014). Furthermore, maize requires relatively high amounts of nitrogen from the soil (Pasley et al., 2020), the poor soybean yield implied the soil N reserve and the N supplied through N fixation by soybean was inadequate to support the crops, thus leading to the significant yield reduction in soybean. The result is consistent with Ren et al. (2021) report that under N limiting situation, the symbiotic fixation of N by soybean may be inadequate to support good growth for the component crops in the intercrop. The observed result is consistent with Lv et al. (2014) observations that the below ground competition for water, rooting space and nutrient is more crucial to yield than the above-ground competition for light, radiation and space in the intercropping system. The limited supply of N in the intercrop. The poor grain yield for soybean in 2016 could be attributed to inadequate rainfall during the early period of crop establishment coupled with competition for available resources. According to Lv et al. (2014), Ohyama et al. (2017) and Ren et al. (2021) drought, excessive rain, extreme temperature, and low light can cause significant yield reduction in soybean.

Effects of fertilizers on grain yields for maize and soybean

Applying fertilizers significantly improved maize grain yields in 2016 and 2017. The application of 150 kg N/ha of OF significantly enhanced maize grain yield compared to the other treatments, except for 150 kg N/ha of NPK treatment in 2016. However, in 2017, 150 kg N/ha of NPK treatment had significantly higher maize grain yield compared to 50 and 200 kg N/ha of OF but was not significantly different from the other treatments. Fertilizer application for improved maize performance is essential when there is an insufficiency in soil nutrient reservoirs to meet crop demand. The optimum response was 150 N/ha for the OF and NPK fertilizers and it synchronizes with the rates with the levels of application that had higher N uptake. The result further buttresses the importance of N nutrition in plants for increased grain yield in maize. According to Nasielski et al. (2019), an increase in N availability for root uptake improves maize grain yield.

Table 5. Effects of intercropping and fertilizer application on grain yield (t/ha) of maize and soybean in years 2016 and 2017

Treatments	2016		2017	
	Maize	Soybean	Maize	Soybean
Cropping system				
Sole	1.67[a]	1.30[a]	2.11[a]	1.61[a]
Intercropped	1.05[b]	0.40[b]	1.94[b]	0.61[b]
SE ±	0.09	0.16	0.07	0.079
LER	0.91		1.23	
Fertilizers				
0 (Control)	0.78[c]	0.91[ab]	1.04[b]	0.59[b]
50 kg N/ha of OF	1.13[bc]	0.83[ab]	1.51[b]	0.80[b]
100 kg N/ha of OF	1.35[bc]	1.14[a]	1.79[ab]	1.29[ab]
150 kg N/ha of OF	2.32[a]	0.61[b]	1.83[ab]	1.50[a]
200 kg N/ha of OF	1.13[bc]	0.72[ab]	1.21[b]	0.51[b]
50 kg N/ha of NPK	1.22[bc]	1.02[ab]	1.59[ab]	0.81[b]
100 kg N/ha of NPK	1.26[bc]	0.82[ab]	1.90[ab]	1.16[ab]
150 kg N/ha of NPK	1.75[ab]	0.82[ab]	2.13[a]	1.52[a]
200 kg N/ha of NPK	1.32[bc]	0.81[ab]	1.66[ab]	0.89[b]
SE ±	0.31	0.17	0.291	0.163
SE ± Interaction	0.42[ns]	0.28[ns]	0.394[ns]	0.230[ns]

OF = Organomineral fertilizer.

Means in a column followed by the same letters are not significantly different (*P* < 0.05) according to Duncan's Multiple Range Test; [ns] = not significant; * = significant at 5%.

Soybean grain yield was significantly improved at 100 kg N/ha of OF compared to 150 kg N/ha of OF, but not significantly different from the other treatments in 2016. In 2017, 150 kg N/ha of OF and 150 kg N/ha of NPK had significantly higher soybean grain yield compared to the other treatments, except 100 kg N/ha of OF and 100 kg N/ha of NPK treatments. Field studies have shown that the total assimilated N in soybean shoots has a high correlation with the seed yield. Observations in this study were also similar (Ohyama et al., 2017; Ren et al., 2021). The treatments with higher N uptake had higher grain yield. The yield reduction at the higher rate of NPK fertilizer and OF applications could be attributed to excessive N supply at early growth stages, thus causing lodging-induced yield reduction. These claims were evident above 100 kg N/ha level of application for NPK fertilizer and OF applications. Studies have indicated that applications of organic combined with chemical fertilizers optimized soil quality, stabilized crop yield, and enhanced crop adaptation to climate change (Menšík et al., 2019). The lower yield observed for maize and soybean in the intercrop compared to the sole crop was in consonance with Takim et al. (2019). Applying fertilizer containing Ca at the early flowering stage of soybean helps to enhance days to 50% flowering and sustain pod formation in soybean for better performance.

The interaction of cropping system and fertilizers on grain yields in maize and soybean

The cropping system and fertilizer interaction had no significant influence on maize and soybean grain yields in 2016 and 2017. The improvement is possible in that the competed soil resources that limit the rate of assimilated photosynthates for crop growth in the intercrop are supplied (Su et al., 2014). Also, the ability of the soybean plant to tolerate the negative shading effect of the maize canopy resulted in an increase in soybean grain yield (Liu et al., 2017). The non-significant variation in cropping system × fertilizer application on the observed yields for maize and soybean could the attributed to the effect of fertilizer in suppressing the negative contribution of below-ground competition on yield depression (Sari et al., 2022). The N, P and K nutrients in the inorganic fertilizer, with the additional Ca, Mg and micronutrients in the OF were possibly made available to complement the soil nutrient pool for improved maize and soybean yields

Land Equivalent Ratio (LER)

The LER for the two-year cropping indicated that the yield observed in 2016 was below 1. This implied that the interaction between the two crops resulted in high competition for the available resources that led to yield depression in soybean than in maize. Maize has a higher competitive ability for above and below-ground resources than soybean in the intercrop (Lv et al., 2014; Nweke and Anene, 2019; Ren et al., 2021). Under limiting conditions, maize acquires more of the available resource, thus restraining soybean performance in the intercrop. However, the LER for 2017 was above 1, implying a yield advantage on intercropping over sole crops. The LER showed that 8% more land area would be required to equal the yield of sole cropping by the intercropping system in 2016, while 23% more area would be required by sole cropping in 2017 to equal the yield of the intercropping system. The yield advantage of 1.54 in soybean and maize intercropping systems was reported by Choudhary (2014). The mean value of the two-year cropping indicated that the cropping system had an intercrop advantage of 1.07.

CONCLUSION

In general, the observed responses from OF were similar to NPK fertilizer in maize and soybean development and N uptake, without resulting in a substantial growth difference in the two years of cropping. The heights of sole and intercropped maize and soybean were similar in both cropping periods, However, relative to sole cropping, intercropping with soybean improved maize leaf area, while the response of soybean was opposite. The interaction between maize and soybean resulted in a reduction in maize and soybean N nutrient uptakes and grain yields in both cropping years. The application of 100 kg N/ha of OF treatment enhanced maize height and leaf area in 2016, while in 2017, 100 kg N/ha of OF and 150 kg N/ha of NPK applications favored maize height over the other levels of fertilizer application. The uptake of N in maize and grain yields increased with an increase in the level of applications but reduces above 150 kg N/ha of OF and NPK fertilizers.

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