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MAIZE AND SOYA BEAN RESPONSE TO THE RESIDUAL INFLUENCE OF EARLY-SEASON CROPPING SYSTEM AND FERTILISER APPLICATIONS

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ABSTRACT

Continuous land cultivation has led to the application of fertilisers to maintain high crop yields. Favourable effects of different fertiliser sources for improved crop performance have been reported. However, there is scarce information on crop response to the residual effect of organomineral fertilisers (OMFs) applied to early sole and maize-soya bean intercropping. Consequently, the objective of this study was to evaluate the residual effect of N levels of organomineral and inorganic fertilisers applied to maize and soya bean in sole cropping and intercropping. The study was conducted in the years 2017 and 2018 in the Southern Guinea Savannah, Jalingo, Taraba State, Nigeria. Responses to the residual influence of early season cropping systems and applications of OMF and NPK 20-10-10 were evaluated in repeated field trials. The residual effects of a previously assessed 2 ^{x} 9 factorial arrangement, cropping system (sole and intercrop) and fertiliser applications (0, 50, 100, 150, 200 kg N/ha of OMF and 50, 100, 150, 200 kg N/ha of NPK fertiliser) were evaluated in a randomised complete block design with three replicates. Maize (ACR-95DT) and soya bean (TGX 1488-2E) were planted at densities of 40,000 and 74,000 plants/ha, respectively. Data were analysed using ANOVA at $p<0.05$. Maize and soya bean plant heights and N uptake significantly increased under the residual influence of sole cropping compared to intercropping in both years. Furthermore, maize-soya bean intercropping produced significantly lower grain yields than their sole crops in both years. The land equivalent ratio of the system was greater than one in both years. The residual effect of early season intercropping reduced subsequent yields of maize and soya bean, while OMF residual effects favoured sole maize, sole bean, and maize-bean intercrop performances at 100 kg N/ha.

Keywords: residual effect, organomineral fertiliser, cereal-legume intercrop, N uptake, grain yields, cropping system.

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INTRODUCTION

Soil fertility depletion through continuous cropping has necessitated measures to maintain or improve soil nutrient status for consistent high crop yield. Most of the approaches to consistency in high crop yields focus on the use of fertilisers, improved cropping systems and the development of genetically improved crop varieties (Díaz-Chuquizuta et al., 2022; Rodríguez-Pérez et al., 2023). In the Southern Guinea Savannah of Nigeria, fertiliser application for crop performance enhancement is necessary in order to improve the living conditions of farmers. In this region, the soils are highly weathered, sandy in texture, with low soil organic matter and low soil nutrient status because of torrential rainfall leading to soil erosion (Aliyu et al., 2020). These soils have been reported to support crop yield increase through judicious fertiliser application and the adoption of a cropping system that involves the combination of cereal and legume.

Fertilisers are either applied in the form of biofertilisers, inorganic and organic fertilizers or the combination of inorganic and organic forms (organomineral fertilisers (OMFs)) (Ohyama et al., 2017; Díaz-Chuquizuta et al., 2022). The application of inorganic fertilisers provides nutrients instantaneously to the crops (Ohyama et al., 2017; Díaz-Chuquizuta et al., 2022). Despite the high cost of inorganic fertilisers, they have minimal effects on the subsequent crops (Porte et al., 2022), while their frequent application leads to soil acidification and soil organic matter reduction, thus threatening soil health (Mumbach et al., 2019). The favourable response of crops to organic fertiliser in this region has been documented (Imoloame and Ahmed, 2018). Likewise, a study conducted by Porte et al. (2022) has reported the favourable response of subsequent crops to the residual effects of the organic fertiliser applied to a previous crop. However, the sole use of organic fertilisers is not viable due to the large quantities required to satisfy crop nutrient demand. In this sense, the use of OMFs with minimal disadvantage compared to inorganic or organic fertilisers appears more likely to be adopted by farmers (Mumbach et al., 2019). In fact, the positive effects of OMFs on crop yield increase have already been reported (Mumbach et al., 2019). Similarly, previous studies have described favourable responses of crops to organomineral fertilization applied to a previous crop (Salvagiotti et al., 2009; Benites et al., 2022). However, most recommendations refer to sole crops with limited understanding of the response of legume-maize intercropping to the application of OMFs.

Due to numerous advantages, cereal-legume intercropping has been a long-standing cultivation system in the Southern Guinea Savannah of Nigeria (Kureh et al., 2006), where productivity with respect to sole cropping is encouraging. It has been determined that the use of maize-bean intercropping improves soil fertility through atmospheric nitrogen fixation by soya bean, thus improving the amount of available N nutrient taken from the soil by the component or subsequent maize (Zheng et al., 2022). Soya bean increases soil N content fixation, which can be acquired by the subsequent crop for yield improvement (Ciampitti et al., 2021). The increase in crop yields in response to the residual effect of soya bean was reported by Uzoh et al. (2019). However, there is scarce information on the yield response of maize and soya bean to the residual effect of supplemental N in organomineral fertilization applied to the previous crop. Therefore, the objective of this study was to evaluate the effect of N levels of organomineral and inorganic fertilisers applied to maize and soya bean in sole cropping and intercropping. Responses to the residual influence of early season cropping systems and applications of OMF and NPK 20-10-10 were evaluated in repeated field trials.

MATERIALS AND METHODS

The study was carried out at the College of Agriculture, Jalingo, Taraba State, Nigeria, between 2017 and 2018. The coordinates of the location are 08.9°N and 011.3°E. The location is within the Southern Guinea Savanna agro-ecological zone of Nigeria and has a land area of 191 km^2. The location is Tropical, Savannah (Aw) according to koppen-Geiger climate classification (Beck, 2018). Jalingo has a wet and dry season tropical climate with approximately six months of rainy season. The rainfall ranges between 700 mm and 1000 mm and the temperature is between 16.11 and 37.22°C (NiMet, 2019). The rainy season begins in May and ends in October, while the dry season starts in November and ends sometimes in April (Fig. 1). The site was earlier cropped with maize and soya bean prior to the establishment of the experiment.

Soil sampling and analysis

Soil samples were collected in the field at a depth of 0-15 cm (topsoil) prior to the establishment of the experiment and physical and chemical analyses were performed. The particle size analysis of the soil from the experimental site was determined using the sedimentation method described by Juo (1978). Total nitrogen and soil organic matter

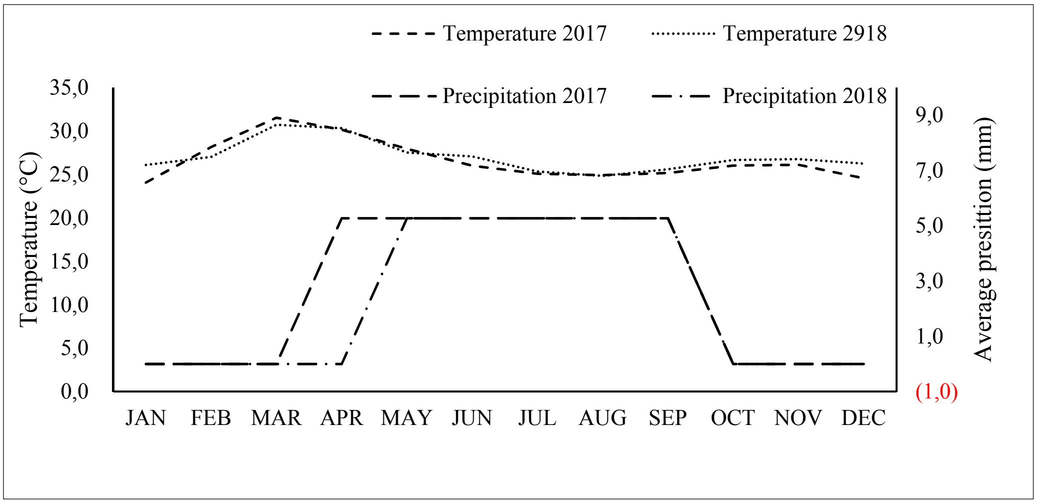

Fig. 1. Precipitation recorded in 2017 and 2018 for the experimental site in Jalingo, Taraba State, Nigeria. Source: NASA power, 2023.

content were determined by the Kjeldahl and the H_2SO_4–$K_2Cr_2O_7$ methods, respectively (Juo, 1978). Soil available P was determined using the Olsen method according to Juo (1978). Exchangeable bases were determined using a flame photometer for K and Na, while Ca and Mg were determined using an atomic absorption spectrophotometer (AAS) (Buck Scientific Model) after extraction with 1 N ammonium acetate. Exchangeable acidity was determined by the KCl extraction method (Juo, 1978). Effective cation exchange capacity (ECEC) was determined by the sum of exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity (Anderson and Ingram, 1993). The physical and chemical properties of the soil before the establishment of the experiment are shown in Table 1.

Analysis of the previously applied organomineral fertiliser for nutrient composition

An amount of 0.2 g of commercial OMF was used. The material was subjected to digestion at 360°C for four hours using 10 mL concentrated H_2SO_4 in a Tecator digestion block and tubes as described by Juo (1978). The total N content was determined from the digest by the steam distillation method, while P concentration was determined by the vanadomolybdate yellow colorimetric method using a spectrophotometer (Juo, 1978). The K was determined with a flame photometer (model FP-640, China) (Juo, 1978), while Ca, Mg, Mn, Fe, and Cu were determined using an AAS. The nutrients contained in the OMF are 44.2, 11, 7, 7 and 0.57 g/kg for total N, total P, total K Ca and Mg.

Treatment and experimental design

The trial was a 2 ^{x} 9 factorial arrangement involving the residual influence of two cropping systems (sole and intercrop), and nine levels of fertiliser applications (0, 50, 100, 150, 200 kg N/ha OMF and 50, 100, 150, 200 kg N/ha of NPK 20-10-10 fertiliser), using maize and soya bean as test crop. The experiment was laid out in a randomized complete block design with three replicates. Each plot measured 16.5 m^2. To evaluate the residual effects of previously established cropping and fertiliser application, maize and soya bean in sole cropping and intercropping were re-established in the same plots to maintain the initial cropping in all plots, with no addition of fertiliser.

Experimental materials

The different fertilisers used in the previous cropping systems were Pacesetter OMF (a commercially formulated fertiliser of municipal organic waste materials fortified with inorganic nitrogen and bone meal for phosphorus) and inorganic fertiliser (NPK 20-10-10). Maize (*Zea mays* L.) variety ACR-95DT. Soya bean (*Glycine max* L. (Merril)) variety TGX 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

In the previous field establishment, OMF was applied by broadcast on the plots and worked into the soil manually after seedbed preparation two weeks before planting, while inorganic

Table 1. Physical and chemical properties of the soil used prior to the establishment of the experiment.

Parameters	Values
Physical properties	
Sand (g/kg)	712.0
Silt (g/kg)	135.6
Clay (g/kg)	152.4
Textural classification	Sandy loam
Chemical properties	
pH (H_2O)	6.5
Organic C (g/kg)	0.73
Total N (g/kg)	0.09
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

fertiliser was applied using row application at planting of maize and soya bean seeds. Maize seeds (ACR-95DT) and soya bean seeds (TGX 144 8-2E) obtained from the IITA (Ibadan) were used as planting materials. Maize and soya bean 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, three seeds sown per hole were later thinned to 2 plants/stand at two weeks after planting. In the intercrop, maize and soya bean seeds were sown in alternate rows in a strip. The field was weeded manually at three, six and eight weeks after planting. These operations began immediately after the harvest of the previous crops to catch-on the rains within the season in 2017 and 2018.

Data collection

Growth parameters determined in maize and soya bean included plant height, leaf area, stem girth, and number of leaves per plant. Plant height and stem girth measurements were taken using a meter ruler and a Vanier calliper, respectively. Maize leaf area was determined using the linear equation method of Musa and Usman (2016), while soya bean leaf area was determined using the graph method. All measurements were taken on a bi-weekly basis. Plant tissue analysis was carried out at the point of tasselling/flowering to determine nutrient concentration and uptake. Total weight of maize and soya bean grains were determined per plot at harvest.

Plant sample preparation for the determination of nitrogen uptake

Maize and soya bean plants were sampled per plot at flowering 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 concentration was determined using the procedure described by Juo (1978) for plant tissue analysis.

Land equivalent ratio (LER): LER for assessment of land use advantage. LER is sum of ratio of intercrop to sole crop for maize and soya bean yield (Karunarathna and Maduwanthi, 2022).

$$LER = (Yim \div Ym) + (Yis \div Ys)$$

Where: Yim = intercropped maize yield; Ym = monoculture maize yield; Yis = intercropped soya bean yield; Ys = monoculture soya bean yield.

Data analyses

Data were analysed using an analysis of variance and 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 fertiliser interaction.

RESULTS AND DISCUSSION

Residual effects of cropping system on the growth parameters of maize

The residual effects of the previous cropping system on the growth parameters observed at the sixth week after planting are presented in Table 2. The residual effects of sole cropping significantly increased maize height and N uptake compared to the intercrop in 2017 and 2018. Significant increase in leaf area was observed in the sole crop resulting from the residual effect of cropping system in 2017. In 2018, the residual effect of cropping system on leaf area was not significant. However, sole cropping improved maize leaf area by 46.94% compared to maize-soya bean intercropping. There was a significant increase in N uptake by sole cropping compared to the intercropping in both years. The need for land-use intensification to increase crop production and cope with an increasing population has led to intercropping with compatible crops in order to reduce detrimental effects on soil fertility for a sustainable system (Xiang et al., 2021). The increase in maize height, leaf area and N uptake in sole cropping compared to intercropping indicates that there was serious nutrient depletion from the preceding cropping, limiting maize growth. The benefits of soil N fixation through soya bean in the previous cropping was inadequate and not commensurable to what was removed by maize and soya bean. This agrees with Taliman et al. (2019), who reported that low soil nutrient supply does not promote growth of N-fixing bacteria at legume roots to the level required to allow that the maize adjacent to soya bean to benefit, thus resulting in yield reduction for both crops. The reduction in yield of the succeeding crop could be the consequence of poor soil conditions from the previous cropping.

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Residual effects of fertilisers on the growth parameters of maize

The evaluation of the residual effect of fertilisers in 2017 and 2018 revealed that NPK at 200 kg N/ha significantly increased maize plant height compared to the other treatments (Table 2). Leaf area in maize was not significantly increased by the residual effect of fertiliser application in 2017. However, the highest leaf area value was observed in the 150 kg N/ha OMF treatment, being 37.58% higher than the highest value observed for NPK fertiliser (150 kg N/ha). The residual effect of previous fertiliser application at 150 kg N/ha OMF significantly increased maize leaf area compared to treatments involving NPK fertiliser at 50 and 100 kg N/ha. In addition, the residual effect of 150 kg N/ha OMF treatment significantly increased

Table 2. Residual effects of cropping system and fertilisers on growth parameters and N uptake in maize at six weeks after planting in 2017 and 2018.

	2017			2018		
Treatments	**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	70.63a	60.19a	65.33a	63.51a	55.14	64.01a
Intercrop	50.12b	31.30b	57.67b	44.15b	29.26	58.51b
SE	4.21	15.15	0.634	4.21	11.36	0.23
Fertilisers						
0 (Control)	61.17b	61.92a	42.90f	60.12b	60.64a	65.55c
50 kg N/ha OMF	54.70b	42.53ab	50.39e	53.36b	40.25bc	62.65d
100 kg N/ha OMF	50.21b	59.78a	63.99c	53.04b	58.12ab	74.64b
150 kg N/ha OMF	63.53b	66.81a	81.28a	59.48b	63.14a	82.49a
200 kg N/ha OMF	51.89b	40.33ab	65.35c	60.42b	38.42bc	62.13d
50 kg N/ha NPK	52.56b	29.28c	53.43e	48.44b	27.24bc	62.99d
100 kg N/ha NPK	50.29b	27.63c	66.24c	58.34b	25.51c	50.60e
150 kg N/ha NPK	67.41b	48.56ab	74.24b	64.12b	46.5abc	49.25e
200 kg N/ha NPK	91.62a	34.85bc	55.68de	87.56a	38.75bc	41.02f
SE	6.27	13.66	1.372	6.29	10.66	0.75
SE± Interaction	9.38*	23.7ns	1.94*	9.18ns	23.77ns	1.03*

OMF = Organomineral fertiliser, ns = not significant, means in a column followed by the same letters are not significantly different (P< 0.05) according to Duncan's Multiple Range Test. * = P> 0.05, SE = standard error.

N uptake compared to the other treatments in both years. Cropping intensification requires proper soil management strategies (including soil amendment) to sustain the production system, thus ensuring food security of the increasing population (Mumbach et al., 2019). The residual effect of OMF application at 150 kg N/ha improved soil organic matter content and nutrients, and thus crop yield, by enhancing and sustaining soil quality and soil health (Shahane and Shivay, 2021). In this respect, Mumbach et al. (2019) reported that mineral fertilisers can promote higher crop growth than OMFs due to their higher solubility after application in the early stages of crop development. However, their impact on subsequent cropping is reduced. The residual effect of OMFs with delayed- or slow-release mechanism improves subsequent crop growth through the discharge of some of the nutrients (Mumbach et al., 2019), resulting in the soil physical condition improvement, particularly in sandy soils such as those found in this region (Shahane and Shivay, 2021). Furthermore, other contribution of residual OMF in improving crop performance could be attributed to the supply of Ca, Mg and other micronutrients.

Residual interaction of cropping system and fertilisers on the growth parameters of maize

A significant increase in maize height resulted from the residual effect of early season cropping system and fertiliser interaction in 2017, while this effect was not significant in 2018 (Table 2). Leaf area in maize was not affected by the interaction of cropping system and fertiliser in both years. Land use intensification requires an appropriate cropping system and efficient soil management strategies to ensure sustainable farming practices (Di Bene et al., 2024). This would improve farmers' livelihood with minimal damage to the environment. The interaction of cropping system and fertiliser application resulted in significant N uptake by maize in the two cropping years. Zheng et al. (2022) reported that nodulation of adjacent soya bean roots is enhanced under low mineral N fertiliser of maize, thus increasing cereal growth and yield in the intercropping system.

Residual effects of cropping system on the growth parameters of soya bean

The residual effect of cropping system on maize height was significant in 2017, but not in 2018 (Table 3). Soya bean height under the residual

Table 3. Effects of intercropping and residual fertilisers on the growth parameters of soya bean at six weeks after planting in 2017 and 2018.

	2017			2018		
Treatments	**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	18.74a	27.42	65.79a	18.52	22.81	60.01a
Intercrop	16.68b	34.57	53.51b	15.32	28.42	47.32b
SE	0.152	3.56	1.85	0.18	8.65	0.643
Fertilisers						
0 (Control)	31.42a	36.69	36.55d	31.48a	34.68	34.51f
50 kg N/ha OMF	30.61ab	34.40	56.11bc	28.70ab	31.80	56.50b
100 kg N/ha OMF	28.46ab	37.08	64.02b	27.97ab	35.48	64.50a
150 kg N/ha OMF	25.46ab	36.36	62.11bc	24.78b	34.44	66.02a
200 kg N/ha OMF	24.27b	31.74	50.62c	26.82b	33.47	49.51d
50 kg N/ha NPK	28.67ab	32.42	46.52cd	24.45b	31.61	42.79e
100 kg N/ha NPK	24.35b	26.28	79.98a	26.73b	24.90	62.74a
150 kg N/ha NPK	27.31ab	21.76	52.63bc	27.47ab	23.41	50.66c
200 kg N/ha NPK	30.72a	35.81	56.37bc	31.35a	36.14	55.74bc
SE	1.25	5.61	3.91	1.36	5.74	1.84
SE± Interaction	1.69ns	7.59ns	5.53 ns	8.62ns	37.17ns	2.54*

OMF = Organomineral fertiliser, ns = not significant, means in a column followed by the same letters are not significantly different ($P < 0.05$) according to Duncan's Multiple Range Test. * = $P > 0.05$, SE = standard error effect of sole cropping was significantly higher compared to maize-soya bean intercropping. However, in 2018, the increase in maize height resulting from the residual effect of sole crop was not significant. The increase in leaf area due to the residual influence of intercropping was not significantly higher than that observed in the sole crop in both years. Possibly, due to competition or interference among the plants in vertical space for better light interception, solar radiation reaching soya bean plant was limited (Ren et al., 2021: Ginting et al., 2023). Hence, competition for space by the shading effect from maize canopy was not a major limiting factor for soya bean in this experiment. The increase in leaf area resulting from the residual effect of cropping system indicates that sole cropping significantly increased N uptake in soya bean compared to the intercropping in both years. Hence, the accumulation of N assimilated in the sole soya bean cropping system could help to reach a higher yield compared to that in the intercropped soya bean.

Residual effects of fertilisers on the growth parameters of soya bean

The residual effect of previous fertiliser application significantly influenced soya bean plant height in 2017 and 2018 (Table 3). Plants treated with 200 kg N/ha NPK and the control had significantly taller plants compared to those fertilized with 100 kg N/ha NPK and OMF in 2017. Similarly, in 2018, the residual effects of 200 kg N/ha NPK and the control treatments resulted in significantly taller plants compared to the other treatments, except for 50 and 100 kg N/ha OMF, and 150 kg N/ha NPK treatments. Soya bean leaf areas were not significantly influenced by the residual effects of fertiliser application in both years. However, soya bean leaf area ranged from 21.76 cm^2 (150 kg N/ha NPK treatment) to 37.08 cm^2 (100 kg N/ha OMF treatment) in 2017. In 2018, the leaf area ranged from 23.41 cm^2 (150 kg N/ha NPK treatment) to 36.14 cm^2 (200 kg N/ha NPK treatment). A high yield of soya bean requires continues assimilation of N at the vegetative and reproductive stages of growth from the residual nutrient available (Ohyama et al., 2017). In the present study, nitrogen uptake varied significantly for residual fertiliser applications in the two cropping years. Nitrogen uptake was significantly higher at 100 kg N/ha NPK compared to the other treatments in both years, except for 100 and 150 kg N/ha OMF in 2018. A study conducted by Salvagiotti et al. (2009) revealed that soil residual nitrate and N mineralised from soil organic matter present in the OMF was effectively utilized by soya bean for improved growth and grain yield. Furthermore, the N deposited in the rhizosphere of soya bean by N-fixing bacteria after the previous cropping is adsorbed by the soil organic matter and slowly released later by the OMF. The N and other nutrients that are not fully mineralized during the previous cropping and fixed N by soya bean are further released into the plant rhizosphere for crop uptake. The highest soya bean seed yields observed with OMF compared to NPK fertiliser agree with Mumbach et al. (2019), who indicated that OMFs are better used for sustaining crop yield than inorganic fertilisers.

Residual effects of cropping system and fertiliser interactions on the growth parameters of soya bean

The interactions of cropping system and fertiliser indicated no significant variation for the residual contribution of early season OMF and NPK applications on plant height and leaf area of soya bean in 2017 and 2018 (Table 3). Cropping system and fertiliser interaction did not have a significant residual influence on N uptake for soya bean in 2017, while the residual influence of the interaction was significant in 2018.

Residual effects of cropping system on maize and soya bean yields

The yield responses of maize and soya bean to the residual effect of cropping system differed significantly in 2017 and 2018 (Table 4). Maize yields were significantly lowered by the residual effect of intercropping compared to sole crop residual in both years of cultivation. This implied that the productivity of maize through soya bean combination in the intercrop was not improved or sustained in the two years of evaluation. However, Uzoh et al. (2019) reported that maize yield was not significantly affected by intercropping. Hence, the N fixation through soya bean root nodulation was not adequate to complement the N requirement of maize in intercropping compared to sole cropping. Thus, the N nutrient extracted through intercropping surpasses the ability of soya bean in replacing the lost nutrient from the previous cropping. According to Ohyama et al. (2017), the ability of soya bean in fixing N for accompanying crop use will depend on the soil nutrient status at the initial growth stage of the plant. Under low N status, the potential of soya bean in N fixation is limited. This was evident from the result of N uptake determined at the sixth week after planting since N uptake for maize-soya bean intercropping was significantly lower than in the respective sole crops in both years. This result corroborates the findings of Mwila et al. (2021), who found that simultaneous cultivation of two legumes enhanced legume yields. The yield improvement was attributed to higher crop residue produced by repeated legume cultivation, thus helping to enhance the soil quality compared to the conditions under intercropping. Furthermore, the nutrient depleted from the soil was not only N but also other nutrients (Ohyama et al., 2017), which cannot be replenished by soya bean in the system. The depletion in the other essential nutrients from the soil reserve could contribute to the final decrease in yield observed for the intercrop compared to their sole counterparts in the present study. In addition, the above ground competition could have contributed to the significant decrease in soya bean yield. The shade cast on the soya bean by maize in intercropping could reduce soya bean leaf area by intercepting good quality sunlight, and thus affect the optimum yield potential of the crop (Ren et al., 2021; Ginting et al., 2023).

Residual effects of fertiliser applications on maize and soya bean yields

The appropriate implementation of a cropping system that could ensure the long-term ability of soils to continuously produce food for an increasing population is essential for sustainable development (Kopittke et al., 2019). The influence of the previously applied fertilisers on maize and soya bean are shown in Table 4. The residual benefits of 150 kg N/ha of OMF significantly improved maize yield compared to the other treatments in 2017. Similarly, in 2018, 150 kg N/ha of OMF increased maize yield significantly compared to 50 kg N/ha of NPK and the control. Crop yield increase is related to the availability of nutrients for improved crop growth and yield (Mumbach et al., 2019). The residual influence of fertiliser application under nutrient limiting conditions for yield increase in maize has been reported (Shrestha et al., 2021). In addition to the supply of other essential plant nutrients, the improvement in maize yield under OMF application compared to NPK has been attributed to an increase in soil organic matter content (Mumbach et al., 2019). The contribution of increased organic matter to crop yield improvement has been documented in the literature (Mumbach et al., 2019; Oldfifield et al., 2019). Higher yield in crops through organic matter increase has been attributed to the ability of organic matter to retain soil water and nutrients. In addition, soil organic matter promotes efficient drainage and aeration, thus minimizing topsoil loss via erosion (Oldfifield et al., 2019). However, under residual NPK application, maize grain yield was higher at 150 and 200 kg N/ha in both years of cultivation.

The response of soya bean to the residual effect of applied fertilisers resulted in a significant increase in grain yield at 200 kg N/ha of NPK and 100 kg N/ha of OMF compared to the other treatments, except for 200 kg N/ha of OMF and 100 kg N/ha of NPK in 2017 and 2018. The lowest yields were observed in the control treatments in both years of cultivation. This implies that the supplemental application of fertiliser to the previously cultivated crops benefited soya bean grain yield. The previous cultivated crops did not exhaust the available nutrients from the soil. The fact that the responses observed from the residual fertiliser treatments indicate that there were adequate nutrients in the soil to initiate better growth compared to the control treatments for maize and soya bean in both years (Bagale, 2021). Yield increases in soya bean depend on N application time and available soil N at planting (Menza et al., 2017). Additionally, unused nutrients from the previous crop benefit the subsequent soya bean crop. The increase in soya bean yield under NPK application could be attributed to higher P leftover due to the high level of application compared to that of OMF. Phosphorus is very crucial to soya bean grain yield. The nutrient helps to transport and store the energy produced during photosynthesis for growth, development, and reproduction (Bagale, 2021). As phosphorus is relatively immobile in the soil, the crop may have difficulty obtaining enough of the nutrient during earlier cropping. Therefore, the leftover phosphorus is made available for the succeeding crop for improved yield.

Residual effects of cropping system and fertiliser interaction on maize and soya bean yields

Proper integration of crop diversity, complemented with appropriate soil management strategies, would ensure limited soil degradation for continuous crop production (Kopittke et al., 2019; Di Bene et al., 2022), leading to the improvement of farmers' livelihood. The interactions of the residual effects of early season cropping system and fertilisers on maize and soya bean yields are presented in Table 4. The interactions were significant for maize and soya bean grain yields in 2017 and 2018. The LER index of the cropping system was similar in both years, being higher than 1. The LER indicated a positive effect of crop combination with respect to sole cropping. Regarding cropping systems, maize and soya bean intercropping showed advantages over sole maize or sole soyabean cropping. Similar results were obtained in a recent study conducted by Ginting et al. (2023), who have

Table 4. Residual effects of intercropping and fertiliser application on grain yield (kg/ha) and land equivalent ratio (LER) of maize and soya bean in 2017 and 2018.

Treatments	2017		2018	
	Maize	soya bean	Maize	soya bean
Cropping system				
Sole	955.23a	1358.14a	1181.72a	1405.49a
Intercrop	605.35b	606.19b	547.96b	838.26b
SE	61.53	133.46	60.98	130.93
LER	1.08		1.06	
Fertilisers				
0 (Control)	414.07c	736.22b	739.52b	705.44d
50 kg N/ha OMF	564.50c	782.54b	805.54ab	1075.76b-d
100 kg N/ha OMF	600.88c	1282.53a	1004.20ab	1498.94a-c
150 kg N/ha OMF	1569.71a	952.54b	1157.27a	671.87d
200 kg N/ha OMF	540.86c	982.84ab	711.11bab	850.21cd
50 kg N/ha NPK	624.66c	836.76b	755.16b	1072.84b-d
100 kg N/ha NPK	631.09c	1011.02ab	817.97ab	1617.28ab
150 kg N/ha NPK	1055.85b	796.91b	949.51ab	828.32b-d
200 kg N/ha NPK	1020.96b	1358.12a	843.25ab	1776.21a
SE	130.52	283.11	129.36	237.75
SE± Interaction	197.27*	421.98*	200.01*	426.03*

OMF = Organomineral fertiliser, ns = not significant, means in a column followed by the same letters are not significantly different ($P < 0.05$) according to Duncan's Multiple Range Test. * = $P > 0.05$, SE = standard error.

reported that maize and soya bean combination promotes higher maize and soya bean yields compared to sole cropping.

CONCLUSION

OMF and NPK fertiliser exhibited similar responses in maize and soya bean development and N uptake, without resulting in a substantial growth difference in the two years of cultivation. However, the residual effect of OMF was similar to that of NPK fertiliser in enhancing the performances of maize and soya bean in the subsequent planting. Furthermore, the effect of the residual applications of 100, 150 and 200 kg N/ha OMF were similar for OMF and NPK fertilisers on maize and soya bean. Consequently, the application of OMF at 100 kg N/ha is recommended in the Northern Guinea Savannah of Nigeria.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors contribution

The three authors of the article had an active participation in: bibliographic review, in the development of the methodology, in the discussion of the results, and review and approval of the final version of the article.

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