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Original Research Article

Response of Maize/Soyabean Mixture to Number of Plants/Stand, Nitrogen Fertility Levels and Green Manure from the Soyabean Companion Crop

Ehiabhi Cyril Odion, Idris Salihu Ahmadu

Department of Agronomy, Institute for Agricultural Research, Ahmadu Bello University, Samaru – Zaria, Nigeria

Abstract

Soil mining is a major problem of low technology farming and replenishing such loses is one of the problems farmers face. Trials conducted in 2004 and 2005 at Samaru, ($11^0 11$'N, $07^0 38$'E and 686m a.s.l) in the northern Guinea savanna ecology of Nigeria, estimated the response of maize (*Zea mays* L.) and soyabean (*Glycine max* (L.) Merr.) intercrops to green manure from the soyabean companion crop at various nitrogen fertility levels. Treatments were a factorial combination of four maize/soyabean mixtures in replacement and additive mixtures as well as their sole crops and four nitrogen rates arranged in randomized complete block (RCBD) in three replicates. Treatments improved the soil's physical and chemical (soil **C**: 2 – 10%; total **N**: over 100%; **CEC**: 20-80%) properties in 2005. Maize in replacement mixture had heavier cobs and 100-seed weight than in additive mixtures; while two plants excelled three plants per stand in these yield components and grain yield per hectare. Soyabean in additive mixture had heavier pods and 100-seed weight and seed yield per hectare than in replacement mixture. Crops in three row plots had significantly heavier pods, 100-seed weight, and seed yield than those in two row plots. Yield and yield parameters of maize increased significantly with increase in the rate of N applied while for soyabeans the 60 and 90 kg N ha^{-1} were similar in yield and yield parameters. Mixtures gave higher than expected LER values of mixed crops. Maize LER values at 60 and 90 kg N ha^{-1} were higher than 1.00, making soyabean a bonus crop. Total LER for the crops showed that crops in mixtures performed better than combined sole crops at 90 kg N ha^{-1}. Agronomic efficiency was highest at 1^2:2(A) cropping pattern and 30 kg N ha^{-1}, while replacement mixtures had higher efficiency values at low N application and the 1^2:2(A) had higher efficiency value at higher N rates.

Keywords: reduced nitrogen rate; maize intensification; agronomic efficiency; green manure; low technology farmer.

INTRODUCTION

Substantial proportion of the world's population relies on agriculture for sustenance and livelihoods, therefore reducing variability in agricultural productivity, enhancing and sustaining productivity are key parameters of a successful farm business. The General Assembly of the United Nations in 2010 (report - A/HRC/16/49), opined that while increasing food production to meet future needs is necessary, preservation of the ecosystem should be central to this improved production, else short-term gains will be offset by long-term losses if it leads to further degradation of ecosystems, threatening future ability to maintain current levels of production. The FAO in 2014 reported that some 33 percent of soil is moderately to highly degraded due to erosion, nutrient depletion, acidification, salinization, compaction and chemical pollution, and opined that soils are both affected by, and may contribute to climate change. Degradation is closely linked to farming practices (Mulvaney et al., 2009; Khan et al., 2007), and it is often assumed that small scale farmers are culprits as they lack facilities to undertake soil fertility improvement and are largely involved in soil mining however, chemical pollution is also a problem. It has been recognized that good soil management can contribute to economic growth biodiversity, sustainable agriculture and food security, eradicating poverty, women's empowerment addressing climate change and improving water availability (General Assembly of the United Nations, 2013; report A/C.2/68/L.52). However reports – (IITA, 1992 and Odion et al., 2007) adaptable to local cultural practices that can be adapted to low technology farming to slow or reverse degradation and improve productivity. In both practices soil fertility can be improved over a short period of time compared to long time taken in fallow systems and the shifting cultivation. Legumes commonly cultivated by these farmers include - cowpea and soyabeans that have been used in the clipping/thinning management practices to improve soil fertility; while others include pigeon pea and lablab (with rooting systems that penetrate hardpans) that have varieties which can grow for more than one season and are thus good for improved fallow system.

Rural farmers contribute a lot to alleviate food insecurity worldwide, and proponents of ecological farming believe that small percentage increases among these farmers will have far greater impacts on the right to food and food sovereignty than even larger percentage increases from the high technology farmers (Rosset, 1999), that make up less than ten percent of the working populace. Increases in output among low technology farmers could lead to breaking the cycle of poverty that is prevalent among rural dwellers and could perhaps facilitate the industrialization of such regions. For example, Irz et al., (2001) discussing the relationship between increasing yields and return on labour with poverty, estimated that for every 10 percent increase in farm yields, there was a 7 percent reduction in poverty in Africa and more than a 5 percent poverty reduction effect for Asia. The World Bank (2010) reported also that increases in overall GDP derived from agricultural labour productivity was, on average, 2.9 times more effective in raising the incomes of the poorest quintile in developing countries than an equivalent increase in GDP derived from non-agricultural labour productivity. It follows therefore that any innovation to improve farm yields will have a positive effect in not only improving the lot of the farmer but could have a multiplier effect (Delgado et al., 1994).

MATERIALS AND METHODS

Field trials were conducted in the wet season of 2004 and 2005 on the Research Farm of the Institute for Agricultural Research, Ahmadu Bello University, Zaria ($11^0$11'N, 07^0 38'E; and 686m above sea level) in the northern Guinea savanna agro-ecology of Nigeria. The soil in the experimental area is sandy loam; low in organic carbon and total N, and acidic in nature.

Crops from the net plots were weighed for total dry matter before the removal of cobs and pods. Produce were then sun dried for five days before the final dry weights were taken. Ten cobs from the net plot were randomly selected for the determination of cob and grain weight per plant as well as 100-seed weight. Grain weight per hectare was determined from the net plot yield. For the soyabean crop, pods were detached from five randomly selected plants for pod weight per plant, and threshed for grain weight per plant and 100-seed weight, while grain weight per hectare was computed from net plot yields. Data collected were subjected to analysis of variance, to test the significance of treatment effects as described by Snedecor and Cochran (1967), and the means were separated using Duncan's multiple range test (DMTR) (Duncan, 1955). Mixed crop efficiency was estimated using the land equivalent ratio (LER), Willey (1979). The agronomic efficiency (AE) for N-rates on maize was estimated from formulae by Dobermann (2007) – $\mathbf{AE = (Y - Y_0)/F}$; while that for cropping pattern was estimated using the formula *AE = [(actual yield – expected yield)/expected yield]* × *100* (Odion et al., 2015).

RESULTS

Soil fertility: Soil sample from the plots at land preparation every season showed that the clay content increased while the silt content decreased in the 2005 season (Table 1). Also the soil's pH, organic C, available P and total N content were improved, while exchangeable bases like Ca, Mg increased as Na and H+Al content decreased markedly (Table 1).

Maize

Cob weight per plant: The replacement mixtures gave significantly heavier cobs than the additive mixtures in both seasons and the combined analysis (Fig. 1). Cob weight at

Table 1. The physico-chemical properties of the experimental site at the Institute for Agricultural research Farm Samaru during 2004 and 2005 wet seasons

Physical composition (g kg^{-1})	0-30 cm depth	
	2004	2005
Clay	140	160
Silt	420	400
Sand	440	440
Textural class	Loam	Loam
Chemical composition		
pH (water)	5.70	6.20
pH (0.01m $CaCl_2$)2:2.50	4.50	5.40
Organic carbon (g kg^{-1})	0.47	0.60
Available P (mg kg^{-1})	15.75	19.25
Total N (g kg^{-1})	0.18	0.42
Exchangeable bases (cmol kg^{-1}		
Ca	4.00	4.60
Mg	0.64	0.76
K	0.20	0.21
Na	0.15	0.13
H +Al	0.40	0.04
CEC	6.40	7.80

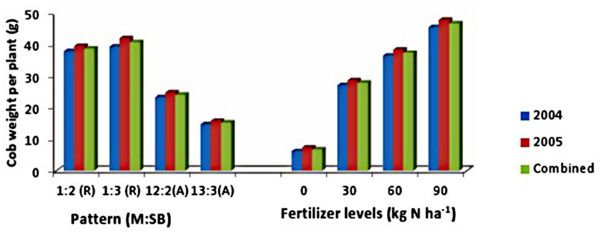

Fig. 1. Effects of cropping patterns and fertility levels on maize cob weight per plant (g) during 2004 and 2005 raining seasons at Samaru.

the 3:3(R) was significantly higher than at the 2:2(R) among the replacement mixtures in both seasons and the combined analysis, while that at the 1^2:2(A) was significantly higher than at the 1^3:3(A) among the additive mixtures.

Cob weight per plant increased significantly with the rate of N applied in both seasons and the combined analysis with the 90 kg N ha^{-1} giving the highest cob weight per plant (Fig.1).

The interaction of cropping patterns by nitrogen levels significantly affected cob weight (Fig. 2). Cob weight increased significantly with increase in the N level at all the cropping patterns, while the replacement mixtures gave significantly heavier cobs than the additive mixture at all N levels. At the N rates however, cob weights at the control (0 kg N ha^{-1}) were similar in additive mixture but not in the replacement mixture, while at 30 kg and 90 kg Nha^{-1} cob weights were similar in the replacement mixtures, but not in the additive mixture (Fig. 2); and at 60 kg N ha^{-1}, cob weight differed significantly between the cropping patterns.

Soyabeans

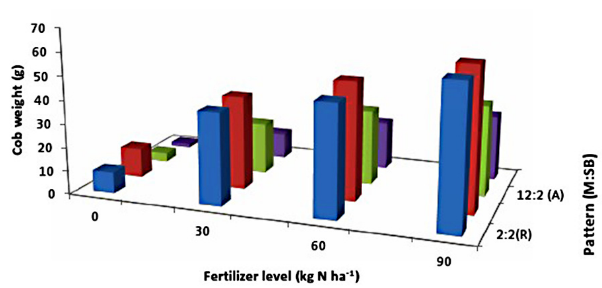

Fig. 2. Effects of cropping patterns and nitrogen levels interaction on cob weight (g) perplant of maize in mixture with soyabean in 2005 raining season

Pod weight per plant: In 2004, pod weight at the 1:2(R) was similar to that at the 1^2:2(A) but significantly lower than at 1:3 and 1^3:3 cropping patterns, while these were also similar in weight to the 1^2:2 cropping pattern (Fig. 3). In 2005, pod weight at the 2:2(R) and 1^2:2(A) were similar and significantly lighter than at the 3:3(R) and 1^3:3(A) cropping patterns that were also similar, while at the combined analysis, pod weight differed significantly between cropping patterns except the 3:3(R) and 1^3:3(A) that were similar.

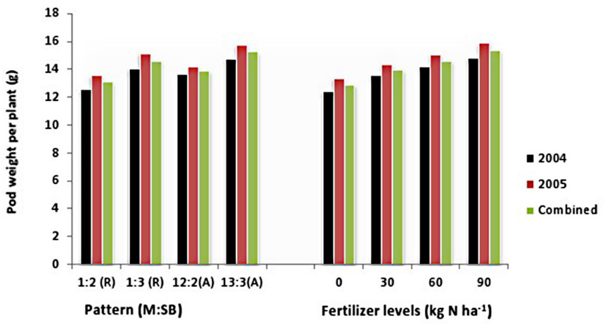

Fig. 3. Effects of cropping patterns and fertility levels on soyabean pod weight (g) per plant during 2004 and 2005 raining seasons at Samaru.

In 2004 and the combined analysis, pod weight increased significantly with increases in the rate of N applied except between 60 kg and 90 kg N ha^{-1} that were statistically at par (Fig. 3), while in 2005, both the control and the 30 kg N ha^{-1} were similar in pod weight but gave significantly lighter pods per plant than the application of 60 and 90 kg N ha-1 that also had similar pod weight.

100 seed weight

Maize: In 2004, 2005 and the combined analysis, the 1^3:3 gave significantly lighter seeds than all other cropping patterns, while in 2004 and the combined analysis, the 2:2(R) and the 1^2:2(A) had similar seed weight but were significantly lighter than those of 3:3(R) (Fig. 4). In 2005, the 2:2(R) and 3:3(R) had similar seed weights that were significantly heavier than those of 1^2:2(A).

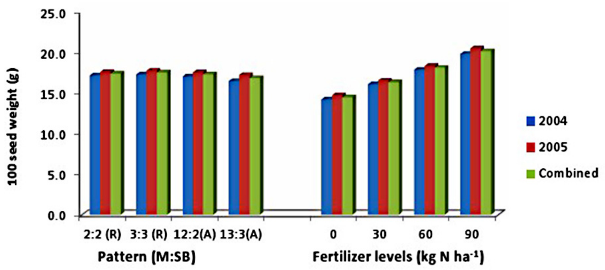

Fig 4. Effect of cropping pattern and fertility levels on hundred seed weight (g) of maize during 2004 and 2005 raining season at Samaru.

In both seasons and the combined analysis, seed weight increased significantly with the rate of N applied (Fig. 4).

Soyabeans: The 100 seed weight of soyabean in additive mixtures was significantly heavier in 2004, 2005 and the combine analysis than those of the replacement mixture; among the replacement mixtures in the combined analysis, the 3:3 (R) had heavier seeds than the 2:2 (R) (Fig. 5).

Among the N-rates, seed weight increased significantly with increases in N-rates in 2004, 2005 and the combined analysis, except between 60 kg and 90 kg N ha^{-1} that were similar in seed weight (Fig. 5).

Grain yield

Maize: The 1^2:2(A) arrangement had the highest grain yield among the cropping pattern in all the years though in 2004 and

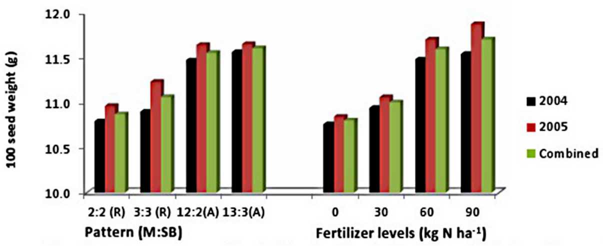

Fig 5. Effect of cropping pattern and fertility levels on hundred seed weight (g) of soyabean and during 2004 and 2005 raining season at Samaru.

the combined analysis it was statistically at par with the 3:3(R) arrangement (Fig. 6). The 1^3:3(A) arrangement had the least grain yield in both seasons and the combined analysis that was significantly lower than all other cropping patterns (Fig. 6).

Grain yield increased significantly with the N rates in both seasons and the combined analysis (Fig. 6).

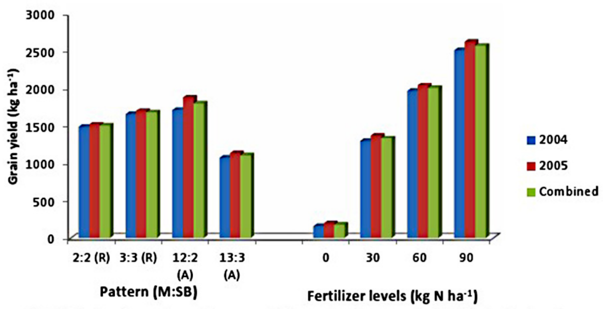

Fig. 6. Effects of cropping patterns and nitrogen levels on grain yield (kg ha^{-1}) of maize 2004 and 2005 raining season at Samaru.

The interaction of nitrogen levels by cropping patterns was significant in 2005 (Fig. 7). At all the cropping patterns, grain yield increased significantly with increases in the N rate applied (Fig. 7). However at the N rates, the replacement mixtures – 2:2(R) and 3:3(R), had statistically similar grain yields at 0 kg, 30 kg and 60 kg N ha^{-1}, while at 90 kg N ha^{-1}, grain yield at the 3:3(R) was significantly higher than at 2:2(R). Grain yield in the additive mixtures were similar at 0 kg N ha^{-1} and were significantly different at 30 kg, 60 kg and 90 kg N ha^{-1}. The two plants per stand - 1^2:2(A) had the highest grain yield at 60 kg and 90 kg Nha^{-1}, while one plant per stand in the 3:3(R) had the highest grain yield at 0 kg and 30 kg Nha^{-1}. The three plants per stand -1^3:3(R) consistently had the lowest grain yield per hectare.

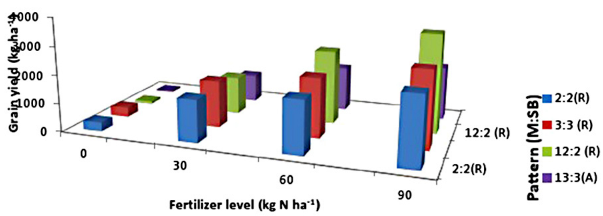

Fig. 7. Effects of the interaction of cropping patterns and nitrogen levels on grain yield (kg ha^{-1}) of maize in mixture with soyabean in 2005 raining season.

Soyabeans: The three rows of soyabean were similar in grain yield in both the replacement and the additive mixtures but were significantly higher than those of the two rows in the mixtures in 2005 and the combined analysis (Fig. 8). In 2004 however, grain yield in 3:3(R) was statistically at par with that of the 1^2:2(A) arrangement (Fig. 8). In both seasons and the combined analysis, grain yield was higher in the 1^2:2(A) arrangement than the 2:2(R) (Fig. 8).

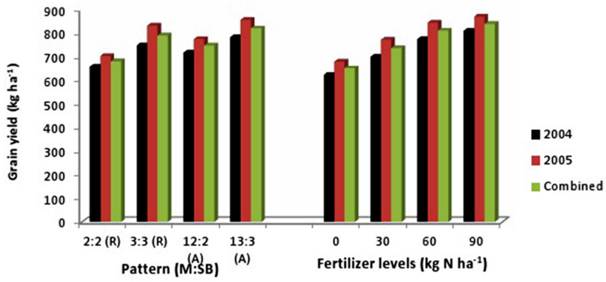

Fig. 8: Effects of cropping patterns and nitrogen levels on grain yield (kg ha^{-1}) of soyabean 2004 and 2005 raining season at Samaru.

Grain yield in soyabeans also increased with N rates in 2004, 2005 and the combined analysis and the differences were significant except between the 60 kg and 90 kg N ha^{-1} (Fig. 8).

Land equivalent ratio

Maize: The maize crop gave higher than expected LER values at all the cropping patterns in both seasons (Fig. 9). In the replacement mixtures, the mixtures with three rows of soyabean had higher relative LER values than those with two rows; while in the additive mixture the converse was the case. The two plants per stand in the additive mixture (1^2:2(A)) had the highest relative LER value among the cropping patterns while the three plants per stand (1^3:3(A)) had the least relative LER value (Fig. 9).

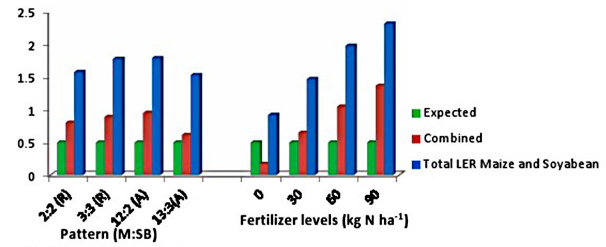

Fig 9. Grain LER for maize mixtures in the combined seasons, and total LER for the average of both seasons at Samaru

The relative LER values increased with the application of nitrogen and further increases also resulted in further increases that were higher than the expected values (Fig. 9). Thus while the relative LER was lower than expected at the control (0 kg N ha^{-1}), at 60 kg and 90 kg N ha^{-1} the relative LER values were greater than 1.00 (the value for the maize sole crop) in both seasons.

Soyabeans: The soyabean crop also gave LER values that were higher than expected LER values in both years (Fig. 10). LER values were higher in the three rows of soyabean compared with the two rows in both seasons, while LER values were higher for soyabean in the additive mixture than for replacement mixture.

LER values were higher than expected in both seasons and the values increased with increases in the rate of nitrogen applied except at 90 kg N ha^{-1} in 2005 (Fig. 10).

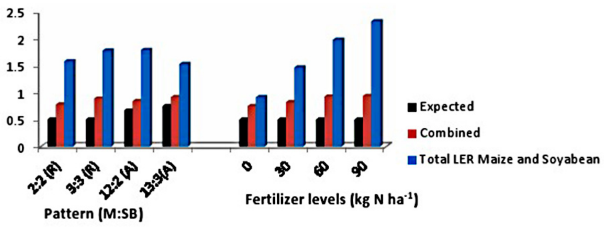

Fig. 10. Seed LER for soyabean mixtures in the combined seasons, and total LER for the average of both seasons at Samaru.

Total land equivalent ratio: The total LER for the crops at the cropping patterns and nitrogen application rates were higher than 1.00 in both seasons except at the 0 kg N ha^{-1} (Figs. 9 and 10). At 60 kg N ha^{-1} in 2005 and at 90 kg N ha^{-1} in both seasons, LER value were either equal to or greater than 2.00 (the value for both sole crops).

Agronomic efficiency: Among the cropping patterns, the 1^2:2(A) had the highest agronomic efficiency (AE) value and the 1^3:3(A) the least value; while among the nitrogen rates the application of 30 kg N ha^{-1} had the highest and the pure stand with application of 120 kg N ha^{-1} had the least agronomic efficiency value (Table 2).

Efficiency from the interaction of cropping pattern by N levels however, showed that the replacement mixtures [2:2(R) and 3:3(R)] had higher values than the additive mixtures at 0 and 30 kg N ha^{-1}, while the 1^2:2(A) additive mixture had higher values than both replacement mixtures and the 1^3:3(A) additive mixture at 60 and 90 kg N ha^{-1}. The 1^3:3(A) had the least efficiency values at all the rates of N applied (Table 3).

DISCUSSION

This experiment was conceived to compare the performance of maize at reduced nitrogen fertilization rates and higher number of plant per stand (in a crop intensification system) with a sole crop of maize using recommended fertilizer rate. Maize in the mixtures, in addition to the applied nitrogen, was also complimented with fodder from the soyabean companion crop, to further enhance soil fertility.

The increase in the clay and the decrease in the silt content of the soil, as well as the improved pH, organic C, available P, total N and cation exchange capacity (CEC) are indications that the conditions for improved production were created by the treatments imposed (Meyer, 1982; Keller, 1982; Haas et al., 2007; CSA, 2013). The high grain yield at the two plants per stand may also have been due to the improved soil condition created by the addition of green manure as the cob weight per plant was lower by about 40% compared to the one plant per stand while 100 seed weight was only lower by 5%. This indicates that grain filling was better at this cropping pattern even though there were two cobs per stand, while the one plant per stand may have had luxury consumption of nutrients during the grain filling period.

Table 2. Effects of cropping patterns and nitrogen levels on grain yield (kg ha^{-1}) and agronomic efficiency of maize and soyabean 2004 and 2005 raining season at Samaru.

Treatment	Grain yield (kg ha^{-1})			
	Maize	AE	Soyabean	AE
Patterns (M:SB)				
2:2 (R)	1502.5^b	***(44.0)***	679.1^c	***(56)***
3:3 (R)	1678.6^a	***(60.0)***	789.1^a	***(81)***
1^2:2 (A)	1797.3^a	***(70.0)***	745.8^b	***(71)***
1^3:3 (A)	1104.8^c	***(6.0)***	818.6^a	***(88)***
SE ±	54.1		10.39	
Fertilizers (kg N ha^{-1})				
0	177.8^d		649.9^c	
30	1334.6^c	***(38.6)***	735.1^b	***(3)***
60	2004.7^b	***(30.5)***	809.1^a	***(3)***
90	2566.0^a	***(26.4)***	838.5^a	***(2)***
SE ±	54.11		10.39	
Sole crop	2091.9	***(16.0)***	872.2	

Means followed by the same letters within the same treatment group are not significantly different at 5% level of probability using DMRT. Agronomic efficiency in parentheses.

Table 3. Effects of the interaction of cropping patterns and nitrogen levels on grain yield (kg ha^{-1}) of maize in mixture with soyabean in 2005 raining season

Treatment	Nitrogen levels (kg N ha^{-1})							
	0		30		60		90	
Patterns M:SB								
2:2(R)	313.6^{h}	***-70***	1496.8^{e}	***41***	1867.2^{d}	***76***	2397.6^{c}	***126***
3:3 (R)	336.4^{h}	***-68***	1654.4^{e}	***56***	2105.2^{d}	***98***	2706.0^{b}	***155***
1^{2}:2 (R)	80.8^{a}	***-92***	1346.8^{f}	***27***	2608.4^{b}	***145***	3482.8^{a}	***228***
1^{3}:3(A)	52.4^{a}	***-95***	987.6^{g}	***-7***	1585.2^{e}	***49***	1908.4^{d}	***80***
SE ± 84.74								

Means followed by the same letters within the same treatment group are not significantly different at 5% level of probability using DMRT. Agronomic efficiency in italics.

Effect of cropping pattern: The yield and yield parameters were affected by the intensification of maize in the mixtures and the space allotted to the companion crop. In the replacement mixtures, maize grain yield was highest when intercropped with three rows of soyabean. The high yield was supported by higher grain yield and cob weight per plant, shelling percentage, harvest index and 100-seed weight. It would seem that the wider spacing between the maize rows in the arrangements significantly affected the performance of maize in this trial as the plants had higher yield parameters in the widely spaced arrangement. However, in the additive mixtures, maize in the two plants per stand had a higher grain yield than maize in the three plants per stand. The higher yield was also supported by higher grain yield and cob weight per plant, and 100-seed weight. In these mixtures, competition within stands seem to have been very important, as the three plants per stand consistently produced lower than the two plants per stand. When both additive and replacement mixtures were compared, grain yield per hectare was highest at the two plants per stand though yield parameters were not as high as in the one plant per stand of the replacement mixtures. The implication is that the maize crop in the replacement mixtures probably had more nutrients than was required for optimum production and it thus enjoyed luxury consumption of nutrients since it was possible to support a higher plant population, while in the three plants per stand the nutrients were not adequate to support such higher population per stand, resulting in reduced grain yields.

Effect of nitrogen application: Maize productivity improved with the application of nitrogen fertilizer as shown by the increase in yield and yield parameters at the nitrogen rates. However, while the addition of nitrogen resulted in 13-40% increase in 100-grain weight over the control, differences between the low, medium and high nitrogen rates in 100-grain weight were not as high. Aside from N application improving the fertility of the soil, the incorporation of green manure would have further improved the physical, chemical and biological status of the soil predisposing it to better moisture and nutrient retention and thus absorption by the crops (Chirinda et al., 2008; FAO, 2009; Davis et al., 2012).

Productivity of mixtures: The productivity of the mixture as measured by the LER showed that the crops performed higher than expected both at the cropping pattern and with the application of nitrogen. The productivity of the maize crop was particularly spectacular judging from the high LER values that were obtained. Maize performance at the 60 and 90 kg Nha^{-1} were higher than 1.00 (the sole crop value) indicating that productivity at these N-levels were higher than from the sole crop. The implication of the finding includes the possibility of green manure improving nutrient usage by the maize crop, as shown by the improved soil condition, and the improved N supply through the supply of organic-N and ensured its retention for a longer time as observed by Gardner and Drinkwater (2009). In addition, it was observed that agronomic efficiency (AE) decreased with increase in the rate of N applied, was particularly low for the sole crop (where no green manure was applied). This could mean that as N application increased a situation where the concentration of N was out of proportion with other nutrients available was created (Cisse, 2007), leading to the inefficient use of the applied nutrient either through luxury consumption or the leaching of nutrient. This inefficiency in the use of applied nitrogen was confirmed in the estimation of AE from the interaction of nitrogen rates by cropping patterns (Table 3). At the control and 30 kg N ha^{-1}, the one plant/stand produced better than where two plants/stand were used, the situation was however reversed at 60 kg and 90 kg N ha^{-1}, indicating better utilization of nutrients in the 1^{2}:2 cropping pattern. Also the addition of green manure could have improved the soil's physical and chemical composition allowing for a better utilization of applied nutrients and thus improving the performance of the maize crop (Cisse, 2007).

CONCLUSIONS

The improved productivity of maize and soyabean in this trial shows that both crops complemented each other and that the incorporation of the thinned soyabean improved the utilization of N by the maize crop such that companion soyabean crop was a bonus at the 60 and 90 kg N applications. The practice could be recommended for sustainable production, among resource poor farmer as well as in regions where soil organic matter loss is rapid due to high temperatures to maintain and/or improve soil organic matter content.

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Corresponding author:

Ehiabhi Cyril Odion
Department of Agronomy
Institute for Agricultural Research
Ahmadu Bello University
P.M.B. 1044
Samaru – Zaria, Kaduna State
Nigeria
E-mail: ecodion@yahoo.c.uk