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Full Length Research Paper

Effect of ginger- grain legume cropping system and spatial arrangement on soil fertility management and yield of intercropped ginger in the guinea savanna of Nigeria

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Abstract

Effect of grain legume inclusion and spatial arrangement in a ginger-based system on critical indices of soil fertility and on the intercrop fresh rhizome yield of ginger was assessed in a two year (2012/2013) study conducted at the research farm of the National Root Crops Research Institute, Nyanya Out-Station, Abuja. Treatments comprised four crop mixtures (Ginger + Cowpea, Ginger + Soybean, Ginger + Mung bean, and Ginger + Lablab) in factorial combinations with four spatial cropping arrangements [one row of ginger: one row of legume (1G: 1L), one row of ginger: two rows of legume (1G: 2L), one row of ginger: three rows of legume (1G: 3L) and ginger and legume planted in no definite crop arrangement (control)]. Sole components of each of the crops used in the mixture (i.e. Ginger, Cowpea, Soybean, Mung-bean and lablab) were also included as checks. The treatments were arranged in a randomized complete block design with three replications. Results showed that inclusion of grain legume crops such as cowpea, soybean, mung-bean and lablab into the farming system of the Guinea Savanna of Nigeria either as a sole crop or as an intercrop provided the system with improved mineral nutrition. These grain legume crops when planted in mixture with ginger, resulted not only in increased nutrient status of the Guinea Savanna soil but also in enhanced growth, rhizome yield and yield variables of ginger relative to when ginger was sole-cropped. Intercropping ginger with Mung-bean gave the highest responses in terms of ginger leafiness, tiller formation and fresh rhizome yield than when ginger was intercropped with cowpea, soybean or lablab. Highest improvement in ginger yield and soil chemical attributes was achieved when one row of ginger was planted with two rows of legume crops. Growing ginger in mixture with the legumes at ginger: legume ratio less or more than 1:2 decreased rhizome yield of ginger in the Guinea Savanna of Nigeria.

Keywords: Grain legume, Cropping System, Ginger rhizome Yield, Soil fertility.

INTRODUCTION

Nigeria is located in the tropical zone (between latitude 4^o and 14^oN, and longitude 2^oE), with a vast area having savanna vegetation (Salako, 2003). The major soils found in the Savanna zone of Nigeria have coarse-textured surface soil, and are low in organic matter and chemical fertility and therefore, low in crop productivity. Low soil fertility, which is due to interplay of many factors, is a major constraint to increased food production in the Savanna and is a large contributor to poverty and food insecurity in the whole of the Sub-Saharan Africa (Gruhn et al., 2000). Many reasons have been given as being responsible for the low soil resource base in the Savanna among which are inherent or induced deficiencies of major nutrients such as N, P, and K or low nutrient holding capacities, high soil acidity and low soil organic matter (Salako, 2003).

Among the many approaches recommended for improvement of soil fertility and by extension, crop productivity in Sub-Saharan Africa including the Guinea Savanna of Nigeria, use of inorganic chemical fertilizers appears to be the most popular among smallholder ginger farmers (Moses et al., 2003). However, chemical fertilizers are expensive and generally out of reach for many poor resource farmers. Moreover, in some areas in the Savanna, there is evidence to show that non-judicious, long-term use of chemical fertilizers, especially on light-textured soils, can lead to the contamination of surface and groundwater (Bumb and Baanante, 1996).

Improved crop productivity can also be achieved through the use of organic fertilizers such as compost or farmyard manure and recycling of crop and organic residues in production systems can also improve crop productivity. However, lack of availability of organic fertilizers in sufficient quantities in the region and the high cost of transporting the bulky materials are major constraints. In the face of this agricultural scenario, scientists have therefore, advocated the introduction of legumes into the existing cropping systems of farmers in Nigeria as a sustainable low input option for improving crop productivity and a logical approach for soil fertility maintenance.

Legumes play a wide role in contributing to food security, income generation, and maintenance of environment for millions of small-scale farmers in sub-Saharan Africa (Tarawali et al., 2002).

Apart from being a major source of dietary protein and oil for the people of Guinea Savanna, legumes are known to biologically fix atmospheric nitrogen (N) in symbiosis with *Rhizobium* bacteria. The fixed N can at least partly reduce the N fertilizer requirement of the main field crop in rotation. Thus it becomes an affordable source of N for resource-poor farmers in Nigeria (Nwaogu and Echendu, 2006). In most farming systems in Nigeria, legumes are usually intercropped with cereals and other field crops to improve land productivity **(**Gbaraneh et al, 2004**).** This practice is believed to provide the farmer with several options for returns from land and labor, and often increases efficiency with which scarce resources are used. It also reduces dependence upon a single crop that is susceptible to environmental and economic fluctuations (Elemo et al., 1990; Katung et al., 2000).

In most ginger/ grain legumes intercrop in the Guinea Savanna, smallholder farmers do not adopt any definite crop spatial arrangement or even definite crop population. The result is that while most farmers intercrop ginger with very high population of grain legumes resulting in acute crop competition for available growth resources, low crop yield and quick soil nutrient impoverishment (Dugje, 2004), others intercrop ginger at very low grain legume populations leading to inadequate utilization of growth resources (Delgado and Yermanos 1975).

In any cropping system however, the geometry and population of individual plants have an important role on the growth and yield of the crops as they have a regulatory or compensation capacity over resource availability (Gopal 1989). The objectives of this study are: (i) To determine the effect of grain legume inclusion and spatial arrangement in ginger-based system on the growth, yield and yield variables of ginger in the Guinea Savanna; (ii) To assess the effect of ginger/grain legume intercrop and spatial arrangement on critical elements of soil fertility under rain-fed agriculture in the Guinea Savanna ecology of Nigeria.

MATERIALS AND METHODS

The study was carried out in 2012 and 2013 cropping seasons at the research farm of the National Root Crops Research Institute, Nyanya, Abuja (Latitude 09^{o} 04’ N; Longitude 07^{o} 37$'$). The soil of the study site was sandy loam in texture and low in fertility according to soil fertility classification for ginger by Njoku et al., (1984) with total N, available P and soil organic matter contents of 0.18 %, 10.6 mg/kg and 2.14 % respectively. Exchangeable K, Ca and Mg values were 2.14, 3.72 and 1.77 cmol/kg respectively. Treatments consisted of four crop mixtures (Ginger + Cowpea, Ginger + Soybean, Ginger + Mung bean, and Ginger + Lablab) in factorial combinations with four spatial cropping arrangements [one row of ginger: one row of legume, one row of ginger: two rows of legume, one row of ginger: three rows of legume and ginger and legume planted in no definite crop arrangement (control). Sole components of the various crops used in the mixture (i.e. Ginger, Cowpea, Soybean, Mung-bean and lablab) were also included as checks. Both the ginger and the legume component were planted on 24th and 14th May for 2012 and 2013 cropping seasons respectively. Treatments were laid on tractor-slashed, ploughed and harrowed plots measuring 3m x 5m in a randomized complete block design with three replications. Twenty gram seed rhizome setts cut from disease-free mother rhizome were planted at inter and intra plant distances of 30 cm x 50 cm. Inter plot distance was kept at 1 m while inter-replicate distance was maintained at 2 m. Erect-growing Cowpea (*Vigna unguiculata (L.) Walp),* Soybean *(Glycine max (L.) Merr),* Mung bean *(Vigna radiate (L.) Wilczek) and* Lablab (*Lablab purpureus)* used for the study were obtained from the National Seed Council of Nigeria Umudike branch, Abia State. The grain legumes were planted at an equal population density of 20, 000 plants/ha (50 cm x 100 cm). The plots were mulched two days after planting (DAP) to a thickness of 5 cm with mature, wilted *Panicum maximum* grass. The plots were fertilized by broadcasting during planting using 300 kg/ha of NPK fertilizer. The plots were kept weed-free throughout the period of study by rouging. The effect of application of treatment on soil fertility was evaluated by examining the changes in nutrient status in the topsoil (0 – 20 cm) at two growth intervals of 3 and 6 months after planting of ginger (MAP) in each season. Data were also collected on fresh rhizome yield, ginger plant height, number of leaves per ginger plant and ginger tillering capacity. The data were subjected to statistical analysis using Analysis of Variance procedure for randomized complete block design. Treatment means with significant differences were detected using the Least Significant Difference at 5 % probability level.

RESULTS AND DISCUSSION

Generally, both cropping system and spatial arrangement significantly affected the response of the soil to some soil fertility indices. Inclusion of grain legume crops into ginger-based system resulted in a significant improvement in the mineral N, organic carbon and available P contents of the soil relative to when ginger was planted sole. Among the ginger/grain legume intercrops, soil mineral N in response to crop mixture varied between 4 and 6 MAP. For example, at 4 MAP, intercropping ginger with Mung-bean component gave the highest soil mineral N increases of 175 % relative to sole ginger. This figure was closely followed by ginger/cowpea intercrop with 113 % increase in N relative to sole ginger. However, at 6 MAP, highest soil mineral N improvement of 110 % over sole ginger was obtained with the inclusion of cowpea component into the ginger system. Sole cropping of the grain legumes proved to be superior in terms of improvement in soil mineral N content at both 4 and 6 MAP compared to when the legumes were intercropped with ginger. The ability of legumes to fix atmospheric nitrogen, their nodulated roots and plant residues left after harvesting represent a valuable source of N.

The results of this study tend to indicate that the four grain legume crops had varying liming potentials as evidenced from the slight increases in soil pH observed at both 4 and 6 MAP following their application in plots that received grain legume components either as sole crop or in intercrop relative to when ginger was planted sole. Such soil pH increases were slightly higher when the legumes were sole cropped than when intercropped with ginger. But averaged over the ginger/legume intercrops, increases in soil pH peaked with the inclusion of Mung bean component into the system at both growth periods. Relatively higher values of soil available P, total organic carbon and exchangeable Mg were recorded when the grain legumes were sole cropped than when intercropped with ginger. This could be ascribed to higher nutrient competition between the ginger crop and the legume crop components under intercrop situations. Ginger is a heavy nutrient demanding crop and therefore growing it in association with other crops is bound to exert some measure of pressure on the nutrient pool of the soil. Among the ginger/grain legume intercrops evaluated, ginger/Mung-bean intercrop produced better results in terms of soil chemical improvement irrespective of the growth period of measurement. For all soil fertility parameters assessed, planting one row of ginger to two rows of grain legume crops yielded higher responses. Inclusion of grain legume crops into ginger system without any definite crop arrangement (i.e. control) resulted in lower soil exchangeable cations (K, Ca and Mg) response comparative to when an ordered spatial planting arrangement was followed.

Intercropping had a variable effect on ginger plant height at 4 MAP. For instance, while ginger plant height reduced by 27 and 92 % in ginger/ cowpea intercrop in 2012 and 2013 respectively, there were 24 and 8 % increases in ginger plant height when ginger was intercropped with Mung-bean for the same year (Table 2). Also, no ginger plant height difference was observed when ginger was intercropped with Soybean at 4 MAP for both years. Ginger grown in mixture with either soybean or Mung-bean resulted in the production of taller ginger plants in both years at both 4 and 6 MAP compared to sole-cropped ginger. The reduction in ginger plant height following the inclusion of cowpea in the system relative to sole-cropped ginger is suspected to be as a result of intercrop competition and reduction in photosynthetic active radiation due to shading brought about by the cowpea canopy. For the two years of study, intercropping ginger with Mung-bean proved to be a more viable low-input technological option as it gave higher responses in terms of ginger leafiness, tiller formation and fresh rhizome yield than when ginger was intercropped with cowpea, soybean or lablab. The better ginger growth and yield responses obtained in plots that received Mung-bean component relative to those treated with cowpea, soybean or lablab is attributed to the more pronounced favourable effects of Mung-bean on soil chemical properties especially N, P and pH (Table 1). When a legume plant dies in the field, all of its remaining nitrogen, incorporated into amino acids inside the remaining plant parts, is released back into the soil. In the soil, the amino acids are converted to nitrate (NO_3^-), making the nitrogen available to other plants, thereby serving as fertilizer for future crops (Newton et al., 2011).

Across the four spatial arrangements evaluated, best ginger performance in terms of height, number of leaves per plant and tillering capacity was recorded using one row of ginger to two rows of legume crops irrespective of legume source. The same trend was recorded with respect to fresh rhizome yield. The lower ginger growth and rhizome yield performances observed at ginger: legume ratio lower or higher than 1: 2 is attributed to

Table 1. Effect of Ginger/Grain Legume Cropping System and Spatial Arrangement on Soil Chemical Properties in the Guinea Savanna of Nigeria (Average of 2012 and 2013 Croppings).

Parameter	4 MAP							6 MAP						
	N	Org. C	Av.P	K	Ca	Mg	pH	N	Org. C	Av. P	K	Ca	Mg	pH
	………(mg/kg)….		(mg/kg)	……………(cmol/kg)……….				…………(%)………		(mg/kg)	…………(cmol/kg)…………			
Crop Mixture:														
Ginger Sole	0.16	1.66	10.20	0.10	2.11	1.30	5.8	0.20	1.54	9.64	0.11	1.84	1.02	5.5
Cowpea Sole	0.40	3.88	12.70	0.12	2.70	2.20	6.6	0.48	4.21	11.30	0.11	1.68	1.12	6.4
Soybean Sole	0.30	2.66	12.30	0.26	3.10	2.30	6.3	0.38	2.70	13.3	0.22	2.86	2.60	6.3
Mung-bean Sole	0.46	2.84	16.20	0.26	1.80	1.74	6.5	0.56	3.04	15.5	0.24	2.33	1.56	6.2
Lablab Sole	0. 38	3.35	14.4	0.22	2.46	1.80	6.3	0.38	2.86	12.6	0.18	2.80	2.40	6.0
G + CP	0.34	3.84	11.60	0.16	2.64	1.88	6.4	0.42	3.84	10.42	0.22	2.74	1.30	6.2
G + SB	**0.24**	2.48	11.4	0.20	1.66	1.20	6.0	0.32	2.88	11.3	0.18	2.86	1.62	5.8
G + MB	**0.44**	2.67	14.80	0.24	2.74	2.00	6.5	0.28	3.11	13.30	0.26	3.20	1.81	6.3
G + LB	0.32	3.04	13.7	0.11	2.22	1.84	6.0	0.36	3.26	12.70	0.22	2.44	1.80	6.2
Arrangement:														
1:1	0.20	2.31	10.7	0.12	3.40	2.07	6.0	0.16	1.98	8.40	0.11	2.82	1.78	6.1
1:2	0.58	3.88	14.8	0.28	4.66	2.88	6.7	0.44	3.78	12.60	0.20	3.06	2.6	6.5
1:3	0.34	2.40	14.4	0.20	4.41	2.86	6.4	0.28	2.74	10.20	0.18	2.76	2.05	6.0
Scattered	0.22	2.20	11.3	0.11	2.22	1.86	6.2	0.18	2.58	10.50	0.10	1.66	1.76	6.2
LSD (0.05):														
Mixture	0.12	1.24	2.35	NS	NS	NS	NS	0.13	1.11	2.33	NS	NS	1.20	NS
Arrangement	0.14	1.31	2.14	NS	1.38	NS	NS	0.08	1.23	2.37	NS	NS	NS	NS

Table 2. Effect of Ginger/Grain Legume Cropping System and spatial Arrangement on Intercropped Ginger Plant Height (cm) at 4 MAP in the Guinea Savanna

Crop Mixture	2012					2013				
	Crop Spatial Arrangement					Crop Spatial Arrangement				
	1 G: 1L	1G:2L	1G:3L	Control	Mean	1G:1L	1G:2L	1G:3L	Control	Mean
Sole Ginger	-	-	-	-	78.4	-	-	-	-	81.2
Ginger + Cowpea	64.3	60.4	52.4	52.4	57.4	72.6	77.7	66.4	62.2	69.7
Ginger + Soybean	88.2	96.8	92.2	77.4	88.7	84.5	88.9	82.2	70.1	81.4
Ginger + Mung bean	96.4	108.4	104.4	80.2	97.4	88.8	96.7	90.4	74.3	87.6
Ginger + Lablab	60.1	72.3	60.6	66.3	64.8	64.2	70.2	71.2	60.2	66.5
Mean	77.3	84.5	77.4	69.1	-	77.5	83.4	77.6	66.7	-
	LSD (0.05):					LSD (0.05):				
	Crop Mixture = 5.882					Crop Mixture = 3.944				
	Crop Spatial Arrangement = 3.563					Crop Spatial Arrangement = 3.723				
	Crop (Mixture x Spatial Arrangement) = 1.439					Crop (Mixture x Spatial Arrangement) = 1.285				

Table 3. Effect of Ginger/Grain Legume Cropping System and spatial Arrangement on Intercropped Ginger Plant Height (cm) at 6 MAP in the Guinea Savanna

Crop Mixture	2012					2013				
	Crop Spatial Arrangement					Crop Spatial Arrangement				
	1 G: 1L	1G:2L	1G:3L	Control	Mean	1G:1L	1G:2L	1G:3L	Control	Mean
Sole Ginger	-	-	-	-	83.4	-	-	-	-	88.2
Ginger + Cowpea	75.8	77.7	74.3	94.2	80.6	80.1	88.6	72.5	75.6	79.2
Ginger + Soybean	93.2	100.8	96.6	78.9	92.4	92.1	99.4	87.3	77.7	89.1
Ginger + Mung bean	122.4	140.3	132.5	88.7	121.0	97.4	103.8	96.8	86.7	96.2
Ginger + Lablab	70.5	88.6	71.9	75.4	76.6	78.8	89.9	78.5	74.4	80.4
Mean	90.5	101.9	93.8	84.3	-	87.1	95.4	83.8	78.6	-
	LSD (0.05):					LSD (0.05):				
	Crop Mixture = 6.876					Crop Mixture = 3.941				
	Crop Spatial Arrangement = 4.345					Crop Spatial Arrangement = 2.674				
	Crop (Mixture x Spatial Arrangement) = 2.114					Crop (Mixture x Spatial Arrangement) = 1.776				

Table 4. Effect of Ginger/Grain Legume Cropping System and spatial Arrangement on Intercropped Ginger Tillering Capacity (No. of tillers/plant) at 6 MAP in the Guinea Savanna

Crop Mixture	2012					2013				
	Crop Spatial Arrangement					Crop Spatial Arrangement				
	1 G: 1L	1G:2L	1G:3L	Control	Mean	1G:1L	1G:2L	1G:3L	Control	Mean
Sole Ginger	-	-	-	-		-	-	-	-	
Ginger + Cowpea	8.0	18.0	10.0	7.0	10.8	8.0	10.0	7.0	6.0	7.8
Ginger + Soybean	11.0	16.0	12.0	8.0	11.8	10.0	14.0	12.0	10.0	11.5
Ginger + Mung bean	14.0	24.0	18.0	12.0	17.0	13.0	20.0	15.0	15.0	15.8
Ginger + Lablab	13.0	16.0	12.0	10.0	12.8	14.0	22.0	14.0	12.0	15.5
Mean	11.5	18.5	13.0	9.3	-	11.3	16.5	12.0	10.8	-
	LSD (0.05):					LSD (0.05):				
	Crop Mixture = 1.224					Crop Mixture = 1.450				
	Crop Spatial Arrangement = 2.336					Crop Spatial Arrangement = 1.155				
	Crop (Mixture x Spatial Arrangement) = NS					Crop (Mixture x Spatial Arrangement) = NS				

Table 5. Effect of Ginger/Grain Legume Cropping System and spatial Arrangement on Intercropped Ginger Leafiness (No. of leaves/plant) at 4 MAP in the Guinea Savanna

Crop Mixture	2012					2013				
	Crop Spatial Arrangement					Crop Spatial Arrangement				
	1 G: 1L	1G:2L	1G:3L	Control	Mean	1G:1L	1G:2L	1G:3L	Control	Mean
Sole Ginger	-	-	-	-		-	-	-	-	
Ginger + Cowpea	23.0	27.0	18.0	15.0	20.8	18.0	22.0	17.0	12.0	17.3
Ginger + Soybean	13.0	18.0	14.0	10.0	13.8	11.0	13.0	9.0	8.0	10.3
Ginger + Mung bean	28.0	32.0	26.0	20.0	26.5	21.0	28.0	25.0	18.0	23.0
Ginger + Lablab	17.0	20.0	12.0	10.0	14.8	14.0	15.0	18.0	12.0	14.8
Mean	20.3	24.3	17.5	13.8	-	16.0	19.5	17.3	12.5	-
	LSD (0.05):					LSD (0.05):				
	Crop Mixture = 3.644					Crop Mixture = 3.891				
	Crop Spatial Arrangement = 2.670					Crop Spatial Arrangement = 1.082				
	Crop (Mixture x Spatial Arrangement) = 1.140					Crop (Mixture x Spatial Arrangement) = NS				

Table 6. Effect of Ginger/Grain Legume Cropping System and Spatial Arrangement on Fresh Rhizome Yield of Intercropped Ginger (t/ha) in the Guinea Savanna

Crop Mixture	2012					2013				
	Crop Spatial Arrangement					Crop Spatial Arrangement				
	1 G: 1L	1G:2L	1G:3L	Control	Mean	1G:1L	1G:2L	1G:3L	Control	Mean
Sole Ginger	-	-	-	-		-	-	-	-	
Ginger + Cowpea	14.3	12.6	10.2	10.7	12.0	13.2	14.3	11.0	11.2	12.4
Ginger + Soybean	12.2	18.3	14.4	12.2	14.3	13.8	16.6	12.2	11.8	13.6
Ginger + Mung bean	16.4	28.4	18.9	16.4	20.0	15.7	23.3	14.7	12.2	16.5
Ginger + Lablab	11.3	13.3	13.5	11.7	12.5	12.4	13.4	10.6	13.3	12.4
Mean	13.6	18.2	14.3	12.8	-	13.8	16.9	12.1	12.1	-
	LSD (0.05):					LSD (0.05):				
	Crop Mixture = 2.666					Crop Mixture = 1.061				
	Crop Spatial Arrangement = 1.332					Crop Spatial Arrangement = 1.112				
	Crop (Mixture x Spatial Arrangement) = 1.044					Crop (Mixture x Spatial Arrangement) = 1.122				

under or over utilization of growth resources such as soil nutrients, light and moisture respectively by the component crops in the mixture.

CONCLUSION

Inclusion of grain legume crops such as cowpea, soybean, mung-bean and lablab into the farming system of the Guinea Savanna of Nigeria either as a sole crop or as an intercrop provided the system with improved mineral nutrition. These grain legume crops when planted in mixture with ginger, resulted not only in increased nutrient status of the Guinea Savanna soil but also in enhanced ginger growth, rhizome yield and yield variables relative to when ginger was grown sole. Intercropping ginger with Mung-bean gave the highest responses in terms of ginger leafiness, tiller formation and fresh rhizome yield than when ginger was intercropped with cowpea, soybean or lablab. Highest improvement in ginger yield and soil chemical attributes was achieved when one row of ginger was planted with two rows of legume crops. Growing ginger in mixture with cowpea, soybean, mung-bean or lablab at ginger: legume ratio less or more than 1:2 decreased rhizome yield of ginger in the Guinea Savanna of Nigeria.

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