EFFECT OF SOYBEAN POPULATION AND SPATIAL ARRANGEMENT ON NUTRIENT UPTAKE AND PRODUCTIVITY OF GINGER/SOYBEAN INTERCROP IN SOUTH-EASTERN NIGERIA

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ABSTRACT
A field study was conducted in 2007 and 2008 cropping seasons at the research farm of the National Root Crops Research Institute, Umudike, Abia State, to determine the effect of soybean population and spatial arrangement on the productivity of ginger/soybean intercrop in South Eastern Nigeria. Treatments comprised four soybean populations(50,000, 100,000 200,000 and 400,000 plants/ha) factorially combined with three spatial arrangements(one row of soybean to one row of ginger, two rows of soybean to one row of ginger and three rows of soybean to one row of ginger. Intercropping ginger with soybean significantly reduced fresh rhizome and grain yields of ginger and soybean respectively. Highest rhizome yield was obtained by planting soybean at a population of 100,000 plants/ha. One row of soybean to one row of ginger gave not only the highest intercrop productivity expressed by land equivalent ratio, but also the highest N,P,K nutrient uptake by ginger.

Keywords*:* Productivity, nutrient uptake, spatial arrangement, intercrop.

INTRODUCTION
Growing one annual crop in sole stand is a restricted utilization of available land and growth resources. Intercropping crops that differ in growth habit and phenological characteristics offers a more efficient use of land and growth resources (Kumar *et al*., 1987). Many authors (Elemo *et al*.1990; Katung *et a*l.2000) have reported the advantages of intercropping over sole cropping to include efficient utilization of growth resources, risk reduction in production against crop failures, yield stability and soil protection.

In Nigeria and particularly in Southern part of Kaduna State where ginger is highly grown, the most common practice among resource poor farmers is to intercrop ginger with an array of other field crops such as maize, pepper, soybean and okra (Menon, 1967). In most cases, no definite crop arrangement or population is adopted in this zone. In Northwest zone of Nigeria, most farmers intercrop ginger with other field crops at a very high population resulting in soil impoverishment and low yield due to acute crop competition (Dugje, 2004). Others intercrop ginger with other field crops at very low populations leading to inadequate utilization of growth resources (Delgado and Yermanos 1975).

In any cropping system, 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 the resource availability (Gopal;1989). Although intercropping soybean with ginger has been reported to result in higher yield advantage over their sole crop components in South east Nigeria (Nwaogu and Echendu, 2006), there is little or no information on the optimum population and spatial arrangement of soybean that will make for sustainable ginger production in South East Nigeria. The objectives of this study therefore, are:

(i) To determine the effects of different populations of soybean on the productivity of ginger/soybean intercrop.
(ii) To determine the best crop geometry for growth and yield in ginger/soybean intercrop in the rainforest zone of South Eastern Nigeria.

MATERIALS AND METHODS
The study was carried out at the research farm of the National Root Crops Research Institute, Umudike, Abia State, Nigeria (Latitude 05^0 29' N; Longitude 07^0 33'E) during the 2007 and 2008 cropping seasons. The site used for the study was fallowed for two years after being planted to cassava/maize intercrop before commencement of the study. The land used for the experiment was slashed, ploughed and harrowed using a tractor. The soils of the experimental site were sampled and analyzed for their physico-chemical characteristics using standard methods. Treatments comprised four soybean population levels [50,000 (40cm x 50cm), 100,000 (20cm x 50cm), 200,000 (10cm x 50cm) and 400,000 (10cm x 25cm) plants/ha] in factorial combinations with three spatial arrangements (one row of

soybean to one row of ginger, Two rows of soybean to one row of ginger and three rows of soybean to one row of ginger). Sole ginger and sole soybeans were also included for the computation of land equivalent ratios.

The treatments were arranged in a randomized complete block design with three replications. The ginger variety used was Himachal Pradesh (HPL) and soybean variety was TGX 1440-IE (early maturing variety). Ginger rhizome setts ("seed" materials) weighing about 20g were cut from large, healthy and disease-free mother rhizomes. The ginger rhizomes were planted at a depth of 5cm on seed beds measuring 3m x 2m. The rhizome seeds were sown at an intra-row spacing of 0.20m and inter row spacing of 0.20m.

Plantings were done on 26th May 2007 and 9th June 2008 (for ginger) and on 28th June 2007 and 16th July, 2008 (for soybean). All the plots were mulched 2 days after planting using 20t/ha wilted *Panicum maximum* grass. Data on percentage establishment at six weeks after planting (WAP), plant height at 20 WAP, number of leaves per plant at 20 WAP, fresh rhizome yield at 32 WAP and N, P, K uptake at 20 WAP were collected. The data on plant height, number of leaves per plant and N, P, K uptake were collected on five plants from the inner- most row of each plot.

The two year data on N, P,K uptake were pooled after a non-significant test for heterogeneity of variances was established (Gomez and Gomez, 1984). The harvesting of the fresh rhizomes at 8 months after planting (MAP) was done with digging fork.

Laboratory Analyses
Determinations of the relevant physico-chemical properties of the soil of the experimental fields were undertaken before the trial using standard methods as reported by Soil Science Society of America (1996). The determined soil characteristics included total nitrogen (N); available phosphorus (P); exchangeable potassium (K), calcium (Ca) and magnessium (Mg); pH; soil organic matter (OM); and texture.

Data analysis
The data were analyzed statistically using analysis of variance (ANOVA) and treatment means were compared using the Least Significant Difference at 5% level of probability according to the method reported by Gomez and Gomez, (1984).

RESULTS AND DISCUSSION

Physico-chemical Properties of Soil Used
General nutrient status of the soil used for the study was low as expressed through low levels of organic matter, total nitrogen and exchangeable calcium, magnesium and potassium (Table 1). The soil was therefore, of low fertility according to soil fertility classification for ginger production in South East Nigeria (Njoku et al, 1995).

Table 1: Selected physico-chemical properties of soils of the study area before commencement of trials.

	N (%)	P (mg/k)	K ....(cmol/kg)..........	Ca	Mg	pH	OM (%)	Texture
2007	0.11	11.20	0.14	1.80	1.40	5.8	1.50	Sandy loam
2008	0.16	8.10	0.22	1.20	0.20	5.5	1.20	Sandy loam

Effect on Ginger Plant Height, Tillering Capacity and Number of Leaves
The number of tillers per plant was greater in ginger intercropped with soybean than in sole-cropped ginger. Tiller formation increased significantly with increasing soybean population and the highest number of tillers was recorded at a soybean population level of 100,000 plants/ha.

Inclusion of soybean in ginger production system resulted in a progressive reduction in ginger plant height relative to sole-cropped ginger (Table 2). The reduction in ginger height may be attributed to increased inter and intra specific competition for space, soil moisture, nutrients and light. At a high soybean population density of 400,000 plants/ha, ginger plant height reduced by 39 % in 2007 and 33 % in 2008 contrary to expectation and the reports of other scientists (Azraf-Ul-Haq et al., 2007). It is generally known that intercropping of field crops particularly at high population density increases plant height due to etiolation resulting from competition for light among the intercropped species (Egbe and adeyemo, 2006).

In general, ginger plant height response to soybean intercrop was better in 2007 than in 2008. Taller ginger plants were produced in 2007 across all soybean population levels tested compared to 2008. Across the four soybean population levels evaluated, best performance in terms of tiller development, plant height and number of leaves per ginger plant was recorded at 100,000 soybean plants per hectare which also produced statistically similar number of tillers compared to 200,000 and 400,000 plants/ha.

Soybean spatial arrangement also significantly affected tiller development in ginger. Tiller formation increased as the number of soybean rows to one row of ginger increased. An opposite trend was however, recorded with plant height and number of leaves (Table 3).

Effect on Soybean Pod, Seed and Number of Leaves

Intercropping ginger with soybean resulted in a significant reduction in weight of soybean pod per plant relative to sole soybean (Table 2). At a high soybean population level of 400,000plants/ha, the reduction was as high as 49% (in 2007) and 48 %(in 2008). The reduction in pod weight may be attributed to increased intra-specific competition for light and nutrients between the two intercropped species. Similarly, soybean spatial arrangement also had a significant effect on the weight of soybean pods produced per plant. Heavier pods were produced in the one row of ginger: one row of soybean arrangement than in the other spatial arrangements studied (Table 2).

As soybean population increased, the number of soybean seeds produced per pod decreased. The highest number of seeds per pod was recorded with three rows of soybean to one row of ginger. Both soybean population and spatial arrangement significantly affected the number of soybean leaves per plant. Number of soybean leaves per plant was significantly higher under intercrop than in sole- cropped situations. Highest mean number of soybean leaves of 33.4 (in 2007) and 48.6 (in 2008) was recorded at 100,000 soybean plants /ha. Three rows of soybean to one row of ginger arrangement gave the highest mean number of soybean leaves per plant with 29.4 and 38.5 in 2007 and 2008 respectively (Table 3).

Table 2. Effects of Soybean Population and Spatial Arrangement on Yield Parameters of Ginger in a Ginger/Soybean Intercrop at Umudike

	No. of tillers/plant		**Ginger plant height (cm)**		**No. of leaves/plant**	
Treatment	2007	2008	2007	2008	2007	2008
Soybean Population						
Ginger sole	9.2	8.6	53.3	47.2	12.0	12.4
50,000plts/ha	11.3	9.4	44.8	41.8	14.1	17.4
100,000plts/ha	16.4	13.9	47.9	40.4	16.8	18.9
200,000plts/ha	15.7	12.7	38.9	36.3	13.3	17.6
400,000plts/ha	13.6	12.8	38.6	31.6	14.7	16.6
Mean	13.2	11.5	44.7	39.5	14.2	16.6
LSD(0.05)	3.71	3.99	9.48	5.04	4.49	2.57
Soybean Arrangement						
1:1	11.4	9.2	46.3	44.6	18.4	16.7
2:1	13.5	11.2	33.1	38.7	10.9	12.4
3:1	14.9	13.4	30.6	36.4	12.3	12.1
Mean	13.27	11.27	36.67	39.90	13.87	13.73
LSD (0.05)	1.50	1.80	6.73	3.51	NS	NS
Pop x Arrangement:	NS	NS	7.8	6.4	2.6	2.7

Table 3. Effects of Soybean Population and Spatial Arrangement on Yield Parameters of Soybean in a Ginger/Soybean Intercrop at Umudike

	Wt.of pod/plant (gm/plant)		No. of seeds/pod		No of leaves/ plant	
Treatment	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
Soybean Population						
Soybean sole	14.1	13.9	22.1	19.4	28.1	32.1
50,000plts/ha	8.5	10.2	23.2	21.4	28.1	31.7
100,000plts/ha	12.3	12.7	20.9	18.8	33.4	48.6
200,000plts/ha	7.8	8.9	19.1	15.9	30.1	33.9
400,000plts/ha	7.2	7.3	16.7	14.0	30.0	36.0
Mean	9.98	10.6	20.4	17.9	29.94	36.46
LSD(0.05)	2.08	2.20	2.65	3.02	2.16	6.89
Soybean Arrang ement						
1:1	10.6	11.8	18.1	15.6	21.7	18.4
2:1	8.1	9.5	18.5	16.6	28.6	31.7
3:1	8.2	8.1	23.4	20.4	29.4	38.5
Mean	8.97	9.8	20.0	17.53	26.57	29.53
LSD (0.05)	1.07	1.59	2.27	2.06	3.3	8.61

Effect on Fresh Ginger Rhizome Yield

Ginger rhizome yield was not significantly (P= 0.05) affected by soybean population in both years. Rhizome yield significantly decreased as the number of soybean row to one row of ginger was increased by one in both 2007 and 2008 (Table 4). Averaged across the four soybean population levels evaluated the highest mean rhizome yield of 12t/ha was recorded with 100,000 soybean stands/ha for the two years of study and this figure was not statistically different from the yield figures obtained from the sole ginger crop yield within the period. The highest intercrop rhizome yields of 11.6t/ha and 11.8t/ha were obtained with 1:1 ginger: soybean row arrangement in 2007 and 2008 respectively.

Table 4. Effect of Soybean Population and Spatial Arrangement on the Fresh Rhizome Yield of Ginger in a Ginger/Soybean Intercrop at Umudike

Soybean Population (Plants/ha)	**2007 Fresh Rhizome Yield (t/ha) Soybean Arrangement 1:1**	**2:1**	**3:1**	**Mean**	**2008 Fresh Rhizome Yield (t/ha) Soybean Arrangement 1:1**	**2:1**	**3:1**	**Mean**
50,000	11.1	9.3	8.9	9.8	12.2	8.8	8.1	9.7
100,000	13.3	12.4	10.4	12.0	12.7	11.3	12.2	12.1
	11.7	10.2	9.6	10.5	10.6	10.6	9.4	10.2
200,000	10.1	8.9	9.7	9.6	11.7	9.3	8.9	10.0
400,000	11.6	10.2	9.7	10.5	11.8	10.0	9.7	10.5
Mean	-	-	-	15.6	-	-	-	13.3
Ginger Sole								
LSD (0.05):	= NS				= NS			
Population	= 0.71				= 0.74			
Arrangement								
Population	X							
Arrangement	= NS				= NS			

The decrease in rhizome yields at soybean population level greater than 100,000 plants/ha is attributed to possible reduction in light interception due to shading effect by the soybean crops. The better intercrop yield performance recorded with 100,000 soybean plants/ha is believed to be as a result of microclimate modification by the soybean crops in terms of provision of minimal amount of shading and possible nutrient fixation especially N which Njoku et al, (1995) identified as the most critical element for better field performance of the crop in the tropics. Application of soybean at population greater than 100,000 plants /ha may have caused excessive shading resulting in etiolation and yield depression. Ginger is known to do well in an environment having not more than 21 % shading (Merabai et al., 2001).

Effect on Soybean Grain Yield

Soybean grain yield was not significantly influenced by soybean population (Table 5). Grain yield of soybean increased with increase in the number of rows of soybean to one row of ginger. There is bound to be an increased nodulation with increase in soybean population and this may have accounted for the increase in grain yield when more number of soybean rows was used (Table 5).

Table 4. Effects of Soybean Population and Spatial Arrangement on the Grain Yield of Soybean in a Ginger/Soybean intercrop at Umudike

	2007				**2008**			
Soybean	**Soybean Grain Yield (t/ha)**				**Soybean Grain Yield (t/ha**			
Population	**Soybean Arrangement**				**Soybean Arrangement**			
(Plants/ha)	**1:1**	**2:1**	**3 :1**	**Mean**	**1:1**	**2:1**	**3:1**	**mean**
50,000	1.2	1.0	1.4	1.2	0.9	1.0	1.1	1.0
100,000	1.3	1.7	1.7	1.6	1.1	1.2	1.6	1.3
200,000	1.2	1.4	1.8	1.5	0.8	0.9	1.2	1.0
400,000	1.3	1.5	1.8	1.5	1.2	0.8	0.9	1.0
Mean	1.3	1.4	1.7	-	1.0	0.9	1.2	-
Soybean Sole	-	-	-	2.3	-	-	-	2.1
LSD (0.05)								
Population		= NS				= NS		
Arrangement								
Population X		= 0.22				= 0.26		
Arrangement		= NS				= NS		

Effect on Crop Productivity

The land equivalent ratio (LER) (used as an index of productivity) showed that all the intercrop mixtures were better than growing each of the component crops sole (Table 6). This indicates that the component crops were compatible and mixtures more productive than sole crops.

Soybean population significantly affected the productivity of the intercrop mixtures. Intercropping ginger with soybean planted at 100,000 plants/ha was the most productive with LER of 1.45 in 2007 and 1.51 in 2008.

The higher productivity obtained when ginger was intercropped with soybean relative to sole cropping is attributed to increased nitrogen use efficiency by ginger from the atmospheric N fixed by the soybean crop (Nwaogu and Echendu, 2006). Njoku and Ohiri (1988) identified nitrogen as the most critical element for ginger field performance. Another reason may be due to shading effect. Because ginger is a relatively shade-loving plant (Meerabai et al., 2001), the inclusion of soybean in the system provided some measure of shade that helped the plant to perform better under intercrop situations.

Table 6. Land Equivalent Ratio of Ginger/Soybean Intercrop as Affected by Soybean Population and Spatial Arrangement at Umudike

Soybean Population (plant/ha)	2007 Land Equivalent Ratio Soybean Arrangement 1:1	2:1	3:1	Mean	2008 Land Equivalent Ratio Soybean Arrangement 1:1	2:1	3:1	Mean
50,000	1.23	1.21	1.40	1.28	1.35	1.34	1.33	1.34
100,000	1.42	1.53	1.39	1.45	1.48	1.42	1.68	1.51
200,000	1.27	1.08	1.22	1.19	1.18	1.23	1.28	1.23
400,000	1.21	1.35	1.40	1.32	1.45	1.08	1.10	1.21
Mean	1.28	1.29	1.35		1.37	1.27	1.35	
Ginger	-	-	-	1.00	-	-	-	1.00
LSD(0.05):								
Population		= 0.11				= 0.12		
Arrangement						= NS		
Population X		= NS				= NS		
Arrangement								
		= NS						

Effect on NPK Nutrient Uptake

Soybean population and spatial arrangement significantly affected soil N and P uptake of the ginger /soybean mixture .Inclusion of soybean in the system stimulated a significant increase in the uptake of soil N and P by ginger crop (Table 7). At each of the incremental levels of soybean population evaluated, there was a remarkable increase in the amount of soil N and P taken up by the intercropped ginger relative to the sole-cropped ginger. Averaged over the two years of experimentation, the increase in N uptake of the intercropped ginger over the sole-cropped ginger ranged from 73.0 to as high as 193.0 %. Soybean intercrops population of 200,000 plants /ha resulted in more N and P uptake of 193 and 88.5% respectively over the sole ginger (Table 7).

Table 7. Effect of Soybean Population and Spatial Arrangement on N,P,K Uptake of Ginger in a Ginger/Soybean Intercrop at Umudike (Average of 2007 and 2008 Cropping Seasons).

Soybean population (plants/ha)	Soybean Spatial Arrangement Nutrient uptake (%) N 1:1	N 2:1	N 3:1	N Mean	P 1:1	P 2:1	P 3:1	P Mean	K 1:1	K 2:1	K 3:1	K Mean
50,000	3.6	2.7	2.2	2.8	4.1	3.3	2.4	3.3	1.6	1.3	1.2	1.4
100,000	3.8	2.1	1.8	2.6	4.7	3.6	2.8	3.7	1.8	2.1	1.6	1.8
200,000	5.2	4.3	3.7	4.4	5.6	4.8	4.4	4.9	2.3	2.2	1.3	1.9
400,000	4.2	3.6	2.4	3.6	5.1	3.1	1.7	3.3	1.2	1.6	1.4	1.4
Ginger Sole	-	-	-	1.5	-	-	-	2.6	-	-	-	2.0
Mean	4.2	3.2	2.5	-	4.9	3.7	2.8	-	1.7	1.8	1.4	-
LSD (0.05):		**N**				**P**				**K**		
Population	=	1.31				1.26				NS		
Arrangement	=	0.68				0.34				NS		
Pop. x Arrang.	=	NS				NS				NS		

The higher N and P uptake of ginger in intercrop with soybean relative to sole ginger is suspected to be as a result of atmospheric N-fixation by the soybean which makes more N available in the soil for crop uptake. This result corroborates the higher intercrop productivity obtained in Table 4. Potassium uptake by ginger was not affected by soybean population and arrangement.

A significant decrease in N and P uptake was also recorded with increase in the number of soybean rows to the row of ginger. The highest uptake of N and P was observed with one row of soybean to one row of ginger. A more or less different trend was observed with the N, P and K uptake of soybean. N, P, K which was in general, higher in the sole soybean than in the intercropped soybean (Table 8). Nutrient uptake was higher in the 1:1 row arrangement than 2:1 and 3:1 row arrangements.

Table 8. **Effect of Soybean Population and Spatial Arrangement on N, P, K Uptake of Ginger in a Ginger/Soybean Intercrop at Umudike (Average of 2007 and 2008 Cropping Seasons).**

	SOYBEAN SPATIAL ARRANGEMENT Nutrient Uptake (%)											
Soybean population (plants/ha)	N				P				K			
	1:1	2:1	3:1	Mean	1:1	2:1	3:1	Mean	1:1	2:1	3:1	Mean
50,000	1.8	2.2	1.3	4.4	2.1	3.1	1.8	2.3	2.1	2.6	2.3	2.3
100,000	2.2	2.7	1.6	2.2	1.6	3.3	1.4	2.4	1.8	1.9	1.4	1.7
200,000	1.8	2.6	2.1	2.2	1.4	2.2	1.6	1.7	1.2	2.2	1.2	1.5
400,000	1.3	2.6	1.8	1.9	1.2	2.0	1.6	1.6	1.3	1.8	1.0	1.4
Ginger Sole	-	-	-	3.2	-	-	-	2.5	-	-	-	2.8
Mean	1.8	2.5	1.7		1.8	2.7	1.6		1.6	2.2	1.5	
LSD (0.05):		N				P				K		
Population	=	2.31				NS				NS		
Arrangement	=	NS				NS				NS		
Pop. x Arrang.	=	NS				NS				NS		

CONCLUSION

Intercropping ginger and soybean increases the productivity of the system but decreases weight of pod and number of seeds obtainable per soybean plant relative to sole soybean. One row of soybean to one row of ginger at 100,000 plants/ha gives a better result in terms of rhizome yield and intercrop productivity and should therefore, be recommended.

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