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The effects of spatial arrangement on the yield and yield components of maize in a maize/groundnut intercrop in Nigeria

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ABSTRACT

Objective: To identify a suitable spatial arrangement of a maize/groundnut intercrop for optimal grain yields.

Methodology and results: Eleven treatments involving one maize variety (TZESR – W) and two groundnut varieties (RRB and RMP 12) were evaluated in two years. Four spatial arrangements (1:1, 1:2, 1:3 and 1:4) were used, mixing maize and each of the groundnut varieties, compared to three controls (sole RMP12, sole RRB and sole maize). The highest maize yield of 4867 kg/ha was from 1:3 maize/groundnut (RMP 12) mixture and the best yield of 1086 kg/ha of groundnut was from 1:4 maize/groundnut (RMP 12) mixture. The growth and subsequent yield of maize was not influenced by the spatial arrangement, however, the growth and yield of groundnut was affected by both varietal differences as well as spatial arrangement. Generally, irrespective of maize/groundnut mixture ratio, variety RRB gave wider spread than RMP 12.

Conclusion and application of findings: The values of Land Equivalent Ratio obtained above unity in all the systems indicated complementarity in resource utilization by the component crops. Therefore, spatial arrangement of 1:3 maize/groundnut (RRB) intercrop can be adopted since it gave the highest LER of 2.01.

Key words: Maize intercropping; spatial arrangement; land equivalent ratio.

INTRODUCTION

Maize (*Zea mays* L.) is one of most important cereal crops and ranks as the third most cultivated crop in Africa (Ayeni, 1987). It features prominently in inter–cropping systems involving legume and non–legumes, e.g. soybean, groundnut, cowpea, cassava, and yam among others. Maize is used as human food, livestock feed and as a source of industrial raw material for the production of oil, alcohol and starch.

Grain legume/cereal crop mixtures are highly popular among small-scale farmers in West Africa. Among the reasons for adopting mixed cropping are increased monetary returns, insurance against crop failure and reduction of pest and diseases due to biological diversity within the system (Muoneke & Asiegbu, 1997).

One important characteristic of maize is its high and relatively rapid nutrient requirement. The soils, for example, must supply about 50 – 60kg N/ha (usually nitrate) and 30kg P/ha in plant available forms for each ton of grain produced (Weber, 1996). Most often these requirements are not met by farmers because of limited use of inorganic fertilizers due to high cost and availability. Yet the land is continuously cropped, leading to poor soil fertility, particularly nitrogen (N) supply, which is one of the major constraints to increasing maize yield. In many parts of the Guinea Savannah of West Africa, continuous cropping of cereals and other unsustainable cropping practices have resulted in depletion of key nutrients at rates exceeding 26kg N, 3kg P and 19kg K per hectare, per year (SP–IPM, 2003).

In parts of the Guinea Savannah, livestock manure, human waste and sometimes heap litter from trees have been used to replenish soil fertility. But on the overall such nutrient inputs do not fully compensate for the nutrients removed when crops are harvested. Cereal/legume intercropping has been suggested as one of the ways of restoring soil fertility under continuous cropping (Baker, 1979; Fisher, 1979; Willey, 1979; SP – IPM, 2003). The current trend in global agriculture is to search for highly productive sustainable and environmentally friendly cropping systems (Crew & Peoples, 2004). This has resulted into renewed interest in cropping systems research (Vandermeer, 1989).

It has generally been observed that crop plants spacing and arrangement have considerable influence on the yield of an intercrop. Plant population is the number of plants per unit area while spatial arrangement is the distribution pattern of the plants over the ground, which determines the shape of the area available to individual plants. For cereal/legume intercrop, the arrangement should be such that the cereal will not shade the legume completely and prevent photosynthesis, as this will affect the yield.

Groundnut, when grown in mixture with maize or sorghum, produces lower yields per stand due to shading. However, inspite of the yield reduction, mixtures involving groundnut and cereal still produce a greater total yield per hectare per season than one sole crop. The practice, therefore, is to keep the cereal population low and raise that of groundnut (Kowal & Kassam, 1978).

This study was carried out to identify a suitable spatial arrangement of a maize/groundnut intercrop for optimal grain yield at Makurdi in the Southern Guinea Savannah of Nigeria.

MATERIALS AND METHODS

Study location: The trials were conducted at the teaching and research farm of the University of Agriculture, Makurdi (7° 41'N; 8° 37'E) in the Southern Guinea Savanna zone of Nigeria during 2001 and 2002 wet seasons Mid June to Early November. The two sites lying side by side were used in succession and were cropped to cotton prior to the trial each year.

Trial layout: A total of eleven treatments involving one maize variety (TZERS –W) and two groundnut varieties (RRB and RMP 12) were used. The maize and groundnut varieties were all obtained from IITA, Ibadan. Four spatial arrangements (1:1, 1:2, 1:3 and 1:4) were used in mixing maize and each of the groundnut varieties. Three controls (sole RMP 12, sole RRB and sole maize) were included. The trial was laid out in a randomized complete block design with three replications on a $30m^2$ net plot size.

In both years, the trial sites were cleared and ridges prepared 75cm apart. Two or three seeds were planted per hill at intra row spacing of 20cm for groundnut and 20cm for maize. The seedlings were thinned to two stands per hill 10 days after planting (DAP). Both crops were planted on the 10^{th} and 12^{th} June in 2001 and 2002, respectively. A single dose of fertilizer was applied to groundnut (50kg P_205/ha), while a split dose was applied to maize (50kg N/ha, 50kg P_205/ha and 50kg K_20/ha at 3 WAP and top dressed with 40kg N/ha at 6 WAP). Weeding using hoe was done twice at 3 and 6 WAP. Harvesting was done at 90, 100 and 136 DAP for maize, cv. RRB and cv. RMP 12, respectively.

Data recording and analysis: Observations made included crop stand, plant and spread of groundnut, groundnut pod weight, 1000-grain weight and grain yields of both crops. The Land Equivalent Ratio (LER) was calculated from the yield obtained as follows:

L.E.R = (Yield of A in Mixture/ Yield of A in sole) + (Yield of B in Mixture/ Yield of B in sole).

Data was analyzed using PROC. MIXED procedure in SAS (SAS 1995). The model was composed of maize and groundnut varieties as fixed effects and replicates as random effects, means were separated using Duncan Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

The highest maize yield of 4866.50kg/ha was obtained from 1:3 maize/groundnut (RMP 12) mixture while the highest groundnut yield was 1086.0kg/ha from 1:4 maize/groundnut (RMP 12) mixture (Table 1 & 2). The growth and subsequent yield of maize in the trials was not influenced by the spatial arrangement, however, the growth and yield of groundnut was affected by both varietal differences as well as spatial arrangement. (Table 2 & 3). These data agree with earlier findings by Kowal and Kassam (1970) that groundnut, when in mixture with sorghum, millet or maize produces lower yields per stand because of shading. However, despite this decrease in groundnut yield, mixtures involving groundnut and cereal still produce a greater total yield per hectare/season than one sole crop.

Table 1: Effect of spatial arrangement on groundnut pod weight, seed weight and 1000 seed weight in a maize – groundnut intercrop at Makurdi, Nigeria. Data are for year 2001and 2002 cropping seasons combined.

Treatments	Pod Weight (kg/ha)	Grain Yield (kg/ha)	1000 seed weight (g)
1 Maize: 1Groundnut (RMP 12)	1449.6[c]	1021.0[ab]	418.6[a]
1 Maize: 2 Groundnut (RMP 12)	1492.6[b]	1048.0[ab]	408.6[a]
1 Maize: 3 Groundnut (RMP 12)	1478.2[b]	1042.0[ab]	420.6[a]
1 Maize: 4 Groundnut (RMP 12)	1535.9[a]	1086.0[a]	414.6[a]
Sole Groundnut (RMP 12)	1533.8[a]	1094.0[a]	413.1[a]
1 Maize: 1 Groundnut (RRB)	520.2[g]	366.0[c]	288.0[d]
1 Maize: 2 Groundnut (RRB)	588.4[f]	417.0[c]	305.2[bc]
1 Maize: 3 Groundnut (RRB)	693.5[d]	479.0[bc]	320.2[b]
1 Maize: 4 Groundnut (RRB)	616.7[e]	446.3[ab]	307.5[bc]
Sole Groundnut (RRB)	693.6[d]	499.0[abc]	300.2[b]
Sole Maize	-	-	-
C. V %	0.3	13.0	1.0s

Means followed by the same litter(s) are not significantly different (P ≤ 0.05) DNMRT.

Table 2: Effect of spatial arrangement on maize plant height, grain yield and 1000 seed weight in a maize – groundnut intercrop at Makurdi, Nigeria. Data are for year 2001 and 2002 cropping seasons combined.

	Plant Height (cm)			Grain yield (kg/ha)	1000 seed weight (g)
Treatments	3 WAP	6 WAP	9 WAP		
1 Maize: 1 Groundnut (RMP 12)	4.97[b]	81.33[bc]	249.30[abc]	4071.60[d]	375.0[c]
1 Maize: 2 Groundnut (RMP 12)	4.93[b]	84.65[b]	233.80[cd]	4247.20[c]	477.0[a]
1 Maize: 3 Groundnut (RMP 12)	5.63[a]	87.92[b]	264.00[a]	4866.50[a]	365.2[c]
1 Maize: 4 Groundnut (RMP 12)	5.47[a]	75.53[cd]	225.80[de]	3731.90[g]	397.0[c]
Sole Groundnut (RMP 12)	-	-	-	-	-
1 Maize: 1 Groundnut (RRB)	5.10[b]	74.0[d]	206.80[c]	3826.20[f]	411.8[b]
1 Maize: 2 Groundnut (RRB)	5.56[a]	69.52[d]	226.80[de]	3961.30[c]	376.7[c]
1 Maize: 3 Groundnut (RRB)	5.65[a]	82.32[b]	240.80[bcd]	4487.80[b]	445.2[ab]
1 Maize: 4 Groundnut (RRB)	5.63[a]	85.02[b]	255.90[ab]	4370.50[b]	372.3[c]
Sole Groundnut (RRB)	-	-	-	-	-
Sole Maize	5.63[a]	103.83[a]	262.40[ab]	4560.80[b]	463.0[a]
C. V %	2.60	1.70	0.70	0.10	3.20

Means followed by the same litter(s) are not significantly different (P ≤ 0.05) DNMRT; WAP = Weeks after planting.

Table 3: Effect of spatial arrangement on groundnut plant height and spread in a maize – groundnut intercrop at Makurdi, Nigeria. Data are for year 2001 and 2002 cropping seasons combined.

	GROUNDNUT PLANT HEIGHT (CM)			GROUNDNUT PLANT SPREAD (CM)		
Treatments	3 WAP	6 WAP	9 WAP	3 WAP	6 WAP	9 WAP
1 Maize: 1 Groundnut (RMP 12)	3.79[d]	9.83[f]	16.83[d]	10.23[d]	27.45[d]	41.30[de]
1 Maize: 2 Groundnut (RMP 12)	3.88[cd]	10.27[ef]	18.72[d]	11.57[bcd]	29.63[cd]	36.97[e]
1 Maize: 3 Groundnut (RMP 12)	4.65[a]	11.38[d]	25.60[c]	10.98[cd]	32.55[bc]	48.60[c]
1 Maize: 4 Groundnut (RMP 12)	4.28[abc]	10.90[de]	23.97[c]	11.78[abcd]	33.97[ab]	40.05[cd]
Sole Groundnut (RMP 12)	4.08[bcd]	11.50[d]	25.92[c]	12.45[abc]	31.58[bc]	43.92[cd]
1 Maize: 1 Groundnut (RRB)	4.00[bcd]	10.38[ef]	32.27[b]	13.42[a]	34.42[ab]	59.98[b]
1 Maize: 2 Groundnut (RRB)	4.42[ab]	11.57[d]	33.78[ab]	13.08[ab]	35.07[ab]	56.73[b]
1 Maize: 3 Groundnut (RRB)	4.40[ab]	14.22[b]	36.55[a]	11.88[abc]	37.80[a]	60.55[ab]
1 Maize: 4 Groundnut (RRB)	4.37[ab]	12.30[c]	18.17[d]	13.13[ab]	37.07[a]	61.12[ab]
Sole Groundnut (RRB)	4.37[ab]	16.80[a]	35.92[ab]	13.32[a]	33.78[ab]	65.28[a]
Sloe Maize	-	-	-	-	-	-
C. V %	18.9	2.9	0.9	8.4	2.3	2.9

Means followed by the same litter(s) are not significantly different (P≤ 0.05) DNMRT; WAP = Weeks after planting.

The varietal difference affected the growth and yield of groundnut. Though both varieties were sown on the same day, they matured and were harvested on different dates. Variety RRB grew faster and was harvested earlier than cv. RMP 12. However, variety RMP 12 gave heavier yields in all different treatments. The differences could be explained by the fact that the late maturing variety had more time for pod filling, better exposure to sunlight and formed additional pods on the spread branches. On the other hand, the early maturing type had less time for pod filling; its erect nature placed it at a disadvantaged position in terms of exposure to light and photosynthetic activity, as well as pod formation.

Spatial arrangement and varietal differences affected the height and spread of the groundnuts at 3, 6 and 9 weeks after planting (Table 3). At 3 WAP, the taller plants were in plots of 1:3 maize/groundnut (RMP 12) mixture, and this was comparable to most mixtures of RRB. However, at 9 WAP, the taller plants were in plots with RRB (1:3) and RRB sole; while the shortest plants were in plots with 1:1 and 1:2 maize/groundnut (RMP 12) mixture. Generally, irrespective of the mixture ratio, variety RRB, gave the wider spread when compared to those mixtures with RMP 12. At 9 WAP, sole groundnut (RRB) gave the widest spread; while the least spread was obtained from 1:2 maize/groundnut (RMP 12) mixtures. Therefore, significant differences occurred among the treatments in the two varieties, each variety not reaching its maximum height and spread due to the shading effect of maize.

Table 4: The effect of spatial arrangement on yield of maize, groundnut and land equivalent ratio in a maize – groundnut intercrop at Makurdi. Data are for year 2001 and 2002 cropping seasons combined.

Treatments	Maize yield (kg/ha)	Groundnut yield (kg/ha)	Land equivalent ratio
1 Maize: 1 Groundnut (RMP 12)	4071.60	1021.0	1.82
1 Maize: 2 Groundnut (RMP 12)	4247.20	1048.0	1.88
1 Maize: 3 Groundnut (RMP 12)	4866.5	1042.0	2.01
1 Maize: 4 Groundnut (RMP 12)	3731.9	1086.0	1.73
Sole Groundnut (RMP 12)	-	-	-
1 Maize: 1 Groundnut (RRB)	3826.2	366.0	1.56
1 Maize: 2 Groundnut (RRB)	3961.3	417.0	1.69
1 Maize: 3 Groundnut (RRB)	4487.8	479.0	1.93
1 Maize: 4 Groundnut (RRB)	4370.5	446.3	1.84
Sole Groundnut (RRB)	-	499.0	-
Sole Maize	4560.8	-	-

There were significant differences among the treatments in terms of 1000 seed weight of groundnuts (Table 2). The shading at different levels by the maize plant reduces the photosynthetic ability of groundnut, which most likely explains the difference. Generally, irrespective of maize/groundnut mixture ratio, higher seed weight was obtained with mixture involving variety (RMP 12) than those with cv. RRB.

It is clear from the results obtained that inter–cropping maize and groundnut is of greater benefit because all the treatments gave a land equivalent ratio (LER) greater than 1 (one) (Table 4). The values of LER above unity in all the system indicated complementarity in resource utilization by the component crops. Efficient utilization of land resource where scarcity of land makes farmers to grow many crops on small pieces of land is one of the rationales of intercropping in traditional farming systems (Willey, 1979; O'Callaghan *et al*., 1994). This study confirms earlier reports by Altieri (1987) that total yield per hectare in mixtures are often higher than sole crop yield even when yields of individual components are reduced.

Generally, mixing allowed better exploitation of available resources by the crops, resulting in greater total yields as reflected in the LER values. LER values are more dependent on the yields of maize which has higher potential due to its height (Remison, 1980). The reduced groundnut (RMP 12 and RRB) yield is however not as much as would be expected because the maize and groundnut were not mixed in the same row, but sown on separate rows.

The highest LER of 2.01 was obtained from plots intermixed at 1:3 maize/groundnut (RRB), and therefore this gives the best spatial arrangement for intercrop–cropping maize and groundnuts. Adopting this system would enable farmers to grow more crops on smaller pieces of land.

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