Journal of Cereals and Oilseeds Vol. 1(1), pp. 1 – 10, June 2010
Available online at http://www.academicjournals.org/jco
© 2010 Academic Journals

Full Length Research Paper

Effects of plant density of intercropped soybean with tall sorghum on competitive ability of soybean and economic yield at Otobi, Benue State, Nigeria

O. M. Egbe

Department of Plant Breeding and Seed Science, University of Agriculture, P. M. B. 2373, Makurdi, Benue State, Nigeria. E-mail: onyiloegbe@yahoo.co.uk.

Accepted 11 March, 2010

Field experiment was conducted for three years to evaluate the influence of plant population density of intercropped soybean with sorghum on its competitive ability and economic yield at Otobi, Benue State, Nigeria. The experiment was laid out in split-split plot with three replications. The main plot treatment comprised of cropping systems with two levels (sole cropping, intercropping), while the sub-plot treatment was soybean variety at three levels (TGX 536-O2D, Samsoy 2, TGX 923-2E) and the sub-sub-plot treatment was plant population density of soybean at three levels (200,000 plants/ha; 333,000 plants/ha and 400,000 plants/ha). Planting intercropped soybean at 333,000 plants/ha gave significantly higher seed yield than planting at 400,000 plants/ha, which in turn had greater seed yield than planting at 200,000 plants/ha during the three years of experimentation. Increased density of soybean beyond 333,000 plants/ha in the intercrop reduced sorghum yield. The results showed that all the intercrop combinations had land equivalent ratio (LER) and area- time equivalency ratio(ATER) above unity (1.63 - 1.97) and (1.41 - 1.47),respectively, under all the densities of soybean tested, suggesting a considerable benefit for intercropping soybean with sorghum. LER figures decreased with increase in soybean density. ATER was highest at 333.000 plants/ha, suggesting higher productivity at this density. Aggressivity values were consistently negative at 200,000 plants/ha with a mean value of -0.25 and it was inconsistent at 333,000plants/ha and 400,000 plants/ha. The competitive ratio of soybean increased (0.76 - 1.15) with increasing density of the soybean in the intercrop combinations, indicating higher competitiveness at higher densities than the sorghum component. The competitive ratio of sorghum had the opposite response (1.23 - 0.76). Relative crowding coefficient (K) was inconsistent at all densities, while land equivalent coefficient (LEC) was above 0.25 indicating intercrop advantages for all combinations. 'Soybean yield equivalent' was also highest at 333,000 plants/ha (1.70) implying general suitability of soybean to intercropping at this density. Dominance analysis revealed that sole crop treatments were dominated. Intercropped soybean planted at 333,000 plants/ha and 400,000 plants/ha gave significantly higher net benefits than those planted at 200,000 plants/ha. Marginal analysis showed that planting soybean at 333,000 plants/ha gave the highest marginal rate of return and this was 2825%.These results suggest that growing soybean under intercropping at Otobi is biologically efficient at 333,000 plants/ha and more profitable.

Key words: Intercropped soybean, density, competition, Otobi.

INTRODUCTION

Intercropping might positively impact on the future food problems in developing countries (Egbe, 2005).This may be through efficient use of solar energy and other growth resources. Also, optimization of land resource use could be achieved when crops are grown under intercropping and plant population density increased. Growing legumes and cereals together for food is not only popular among subsistence farmers in the tropics, who produce the bulk of food in developing countries, but it is also expanding to the warmer regions in the tropics (Fujita and Ofosu-Budu, 1996). Intercropping is receiving attention because it offers potential advantages for resource utilization, decreased inputs and increased sustainability in crop production, but our understanding of interactions among intercropped species is still very limited. The basic physiological and morphological differences between non-legume and legume benefit their mutual association (Akunda, 2001).The differences in the depth of rooting, lateral root spread and root densities are some of the factors of competition between the component crops in an intercropping system for water and nutrients, and hence input use efficiency. Soybean is considered a crop of enormous potential for improving human diet as well as animal feed and features prominently as raw material base for agro-industries. In Benue State, located in Southern Guinea Savanna of Nigeria, soybean is the most important oilseed crop grown during the wet season and it is currently grown on over 88,000 ha of land with an annual production of over 173,000 tons of grain and a mean yield of 1.95 t/ha (BNARDA, 2007). It is traditionally grown under crop mixtures with varying densities of maize, sorghum, cassava and citrus (Egbe, 1995; BNARDA, 2003).Yield advantages accruing from such crop mixtures had been reported (Egbe, 1995, Muoneke et al., 2007). But several studies on plant population densities in cereal/legume intercropping had reported more yield depression of the legumes than the cereal component (Muoneke et al., 2007; Fujita et al., 1992). Such studies had often used sub-optimal densities of the legume and optimal densities of the cereal, often attributed to farmers' preference for the cereal component.

Akunda (2001) demonstrated that higher soybean populations provided a way to optimizing growth and yields in soybean/millet intercropping systems. Thus, plant population can be used as a tool to manage crop growth, maximize biomass, the time required for canopy closure and yield (Akunda, 2001). In Otobi, located in the Southern Guinea Savanna of Nigeria, growing soybean by peasant farmers for home consumption and the market began in the mid 1980s, and intercropping soybean with the tall traditional sorghum is very popular (BNARDA, 2003). Information on the effects of component densities of maize and sorghum on the yield of soybean are available (Pal et al., 1992; Muoneke et al., 2007), but documented information on the optimum plant population density of the various recommended soybean varieties for intercropping with tall traditional sorghum is scanty. Also information on the profitability of soybean/ sorghum intercropping cropping systems in this region is lacking. It was hypothesized that increased density of soybean intercropped with sorghum could increase its yield, competitive ability and profitability. The present study was undertaken to provide documented information on the effects of densities of intercropped soybean on its economic yield with a view to improve the productivity of soybean/sorghum intercropping system and enhance food security in Southern Guinea Savanna.

MATERIALS AND METHODS

A field experiment were conducted for three years (2001, 2004 and 2005) at the National Root Crops Research Institute Sub-station, Otobi {07°10′ N, 08°39′ E, elevation 105.1 m} in Benue State, located in Southern Guinea Savanna of Nigeria (Kowal and Knabe, 1972). The experiments were carried out to determine the effects of increased population densities of intercropped soybean on its competitive ability and economic yield at Otobi. The precipitations at the experimental site within the period of June - November were: 1605.1, 1712.0 and 1570.2 mm for 2001, 2004 and 2005, respectively. The texture of the top soil (0 - 30 cm) of the experimental site was sandy loam. The soil at the experimental site was classified as Typic Paleustalf (USDA). Eight core samples of soil were collected from different parts of the experimental field and bulked into a composite sample and used for the determination of the chemical and physical properties of the soil before planting. The level of total nitrogen (N) was 520 mg kg^{-1} soil, phosphorus and potassium averaged 68.20 and 43.50 mg kg^{-1} soil, respectively. The experiment was laid out in split-split plot with three replications. The main plot treatment comprised of cropping systems with two levels (sole cropping, intercropping), while the sub-plot treatment was soybean variety at three levels (TGX 536-O2D, Samsoy 2, TGX 923-2E) and the sub-sub-plot treatment was plant population density of soybean at three levels (200,000; 300,000 and 400,000 plants/ha designated as P1-0.5 × 0.1, P2-0.5 × 0.06 and P3-0.5 × 0.05, respectively). Gross plot size was 6 × 4 m. Soybean varieties (sole as well as intercrop) were sown on the same day with sorghum (traditional, photoperiodic-sensitive, red-colored grain) during the last week of June of each experimental year. In both sole- and inter-cropped plots, sorghum population density was maintained at 40,000 plants per hectare (0.5 × 0.5 m × 1 plant/hill). Intercropping had a 1:1 (soybean: sorghum) row proportion. All plots received a basal application of 100 kg of NPK: 15:15:15 at the rate of 15 kg N, 6.55 kg P and 12.45 kg K per hectare by broadcasting. The sole- and inter –cropped sorghum were top-dressed four weeks after planting (w.a.p) with 46 kg N per hectare by opening the soil around each plant and banding at 5 - 8 cm depth and covering with the dug-out soil. Two manual weeding were done at 3 w.a.p and 6 w.a.p., respectively. Harvesting of both crops was done from the inner 4 × 3 m at physiological maturity and this represented yield per plot.

Intercrop advantage was calculated by the determination of land equivalent ratio (LER) (Ofori and Stern, 1987). The LER, an accurate assessment of the biological efficiency of the intercropping situation, was calculated as:

$$LER = (Yab/Yaa) + (Yba/Ybb)$$

Where *Yaa* and *Ybb* are yields as sole crops of *a* and *b* and *Yab* and *Yba* are yields as intercrops of *a* and *b*. Values of LER greater than 1 are considered advantageous.

The relative dominance of one species over the other in this intercropping study was estimated by the use of relative crowding coefficient (K) (Banik et al., 2006). K was calculated as:

$$K = (K_{soybean} \times K_{sorghum})$$

Where, $K_{soybean} = Yab \times Zba / (Yaa - Yab) \times Zab$

$K_{sorghyum} = Yba \times Zab / (Ybb - Yba) \times Zba$,

where, Y*ab* and Y*ba* were the yields of soybean and sorghum in the intercrop, respectively, Y*aa* and Y*bb* ,were the yields of soybean and sorghum in sole crop, respectively and Z*ab* and Z*ba* were the respective proportions of soybean and sorghum in the in the intercropping systems. When the value of K is greater than 1.00,

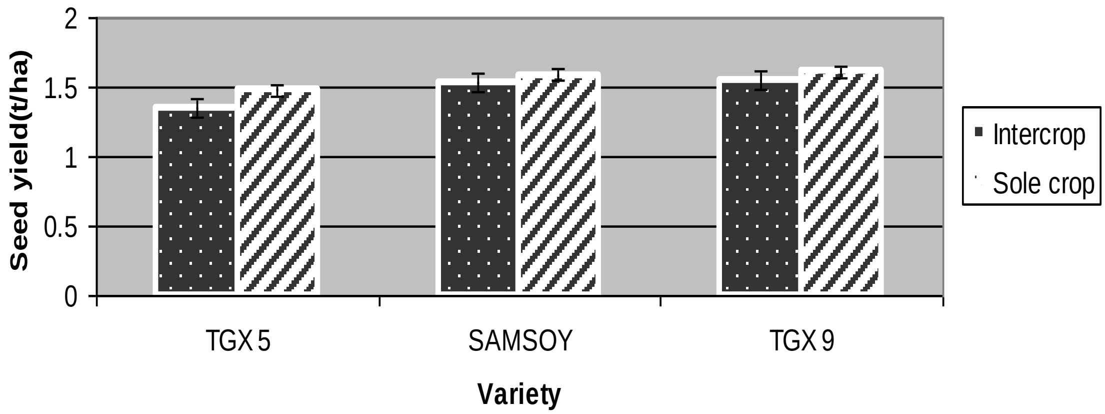

Figure 1. Effect of cropping system with variety on the seed yield of soybean intercropped with sorghum at Otobi. TGX 5=TGX 536-02D, TGX 9=TGX 923-2E, SAMSOY=SAMSOY 2.

there is intercrop advantage; when K is equal to 1.00, there is no yield advantage; and when K is less than 1.00, there is a disadvantage. Land equivalent coefficient (LEC), a measure of interaction concerned with the strength of relationship was calculated thus,

$$LEC = La \times Lb$$

Where, L*a* = LER of main crop and *Lb* = LER of intercrop (Adetiloye et al., 1983). For a two-crop mixture the minimum expected productivity coefficient (PC) is 25%, that is, a yield advantage is obtained if LEC value exceeds 0.25. Area-time equivalency ratio (ATER), the ratio of number of hectare-days required in monoculture to the number of hectare-days used in the intercrop to produce identical quantities of each of the components, was computed as:

$$ATER = \frac{(Rya \times ta) + (Ryb \times tb)}{T}$$

Where, Ry = Relative yield of species '*a*' or 'b' i.e., yield of intercrop/yield of main crop, t= duration (days) for species 'a' or 'b' and T = duration (days) of the intercropping system (Hiebisch and Mc Collum, 1987).

Competitive ratio (CR) indicates the number of times by which one component crop is more competitive than the other. Relative species competition is often evaluated using competitive ratios (Putnam et al., 1984).This was calculated as:

$$Ra = La/Lb \times zba/zab$$

Where R*a* is the competitive ratio of crop *a* and L*a* and L*b* are the LERs of crops *a* and *b* respectively, z*ba* is the proportion of crop *a* in the *ab* intercrop and z*ab* is the proportion of crop *b* in the *ab* intercrop. If R*a* < 1, there is a positive benefit and the crop can be grown in association; if R*a* > 1, there a negative benefit. The reverse is true for R*b.*

Aggressivity is another index that represents a simple measure of how much the relative yield increase in crop *a* is greater than that of crop *b* in an intercropping system. It was calculated as:

$$Aab = (Yab/YaaZab) - (Yba/YbbZba)$$

Where Y*aa* and Y*bb* are yields as sole crops of *a* and *b* and Y*ab* and Y*ba* are yields as intercrops of *a* and *b.* Z*ab* and Z*ba* are the sown proportions of *a* and *b*, respectively.

If A*ab* =0, both crops are equally competitive; if *Aab* is positive, *a* is dominant; if *Aab* is negative, *a* is the dominated crop (Ghosh et al., 2006).

Soybean yield equivalent was calculated as described by Prasad and Srivastava (1991).

$$\text{Soybean equivalent (t/ha)} = \frac{\text{Yield of intercrop} \times \text{Market price of intercrop}}{\text{Market price of soybean}}$$

The economic performance of the intercropping were evaluated to decide if soybean yield at intercropped with sorghum in 2001,2004 and 2005 at Otobi at different densities and additional sorghum yield justified adoption of this intercropping system by farmers in Southern Guinea Savanna of Nigeria. Therefore, returns per naira invested (RI) was computed as RI = gross margin (GM) ⁄ total variable cost (TVC) The higher the value of RI the more profitable is the cropping system. Furthermore, the economic analysis was carried out as described by CIMMYT (1998) to estimate the benefit-cost ratio. A dominance analysis was done and the nondominated treatments were further subjected to marginal rate analysis.

Standard procedures were followed to collect data and analyzed using GENSTAT Release 7.23 (2007), following standard analysis of variance procedures (Gomez and Gomez, 1984) and least significant difference (LSD) test at 5% probability level was used to compare the treatment means. It must be noted that data for each trait measured for the three years were pooled and analyzed to determine the year effect before being analyzed for the respective years of 2001, 2004 and 2005.

RESULTS

The rainfalls during each of the three years of experimentation were adequate for crop growth and development.

Intercropping significantly depressed yield of TGX 536-02D, but the yield reductions in the other two varieties were not significant (Figure 1). Intercropped soybean produced lower seed yield than their sole crop counterparts at the various densities tested. Samsoy 2 and TGX

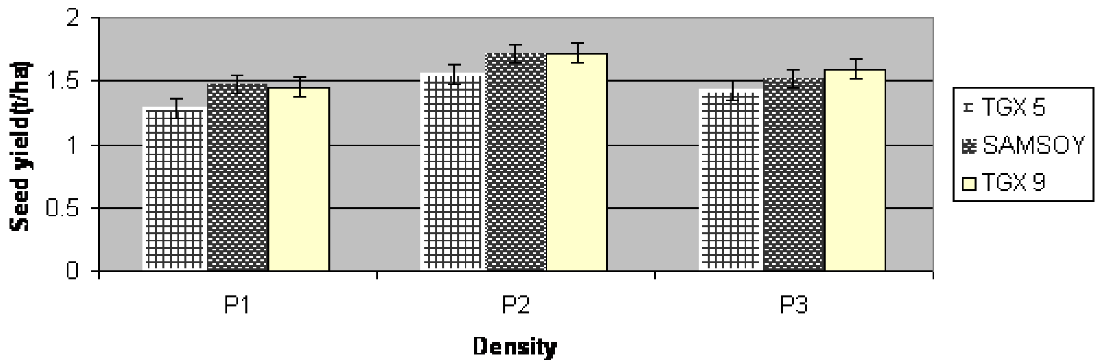

Figure 2. Influence of variety with density on the seed yield of soybean intercropped with sorghum at Otobi.

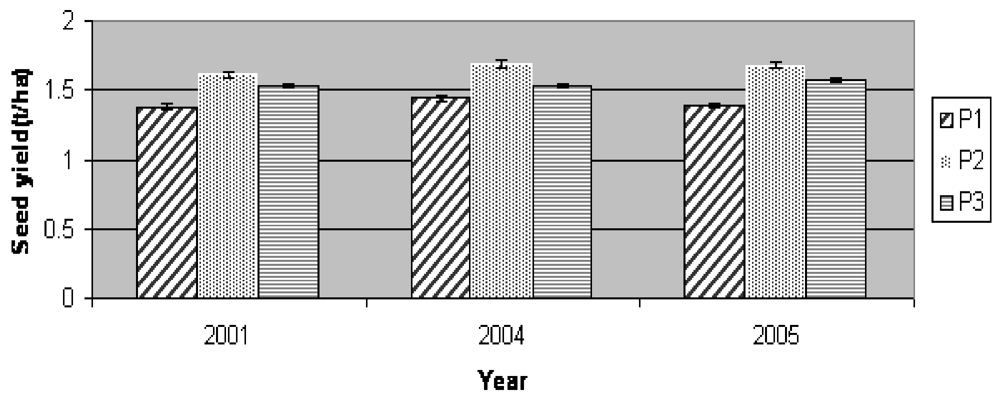

Figure 3. Effects of density on the seed yield of soybean intercropped with sorghum at Otobi.

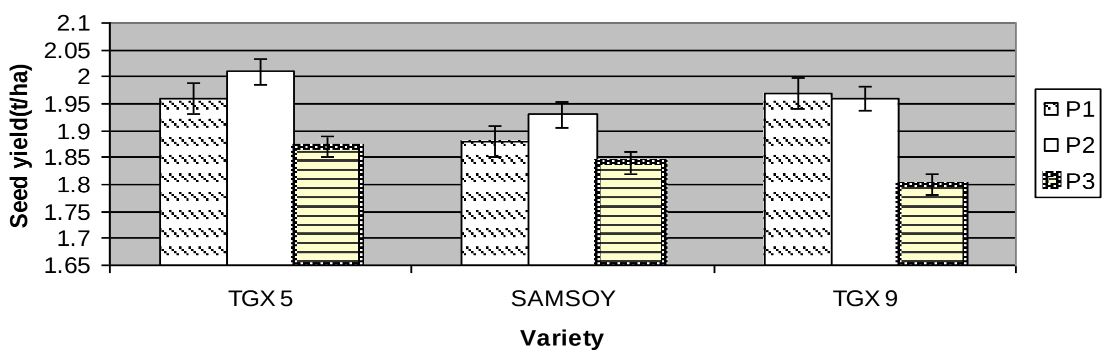

Figure 4. Influence of variety and density on the seed yield of sorghum intercropped with soybean at Otobi.

923-2E gave significantly higher seed yield than TGX 536-O2D at P1, P2 and P3 (Figure 2). The main effect of density on the seed yield of soybean intercropped with sorghum was consistently significant ($p \leq 0.05$) in 2001, 2004 and 2005. Planting soybean at P2 gave significantly higher seed yield than planting at P3, which in turn had greater seed yield than planting at P1 during the three years of experimentation (Figure 3). Sorghum seed yield was significantly higher in P1 and P2 than in P3 under the three soybean varieties tried (Figure 4). Sorghum seed yield exceeded 2.0 t/ha only when grown with TGX 536-02D at P2. The results showed that all intercrop combinations had LER above unity at the densities of soybean tested in this study (Figure 5). The LER figures

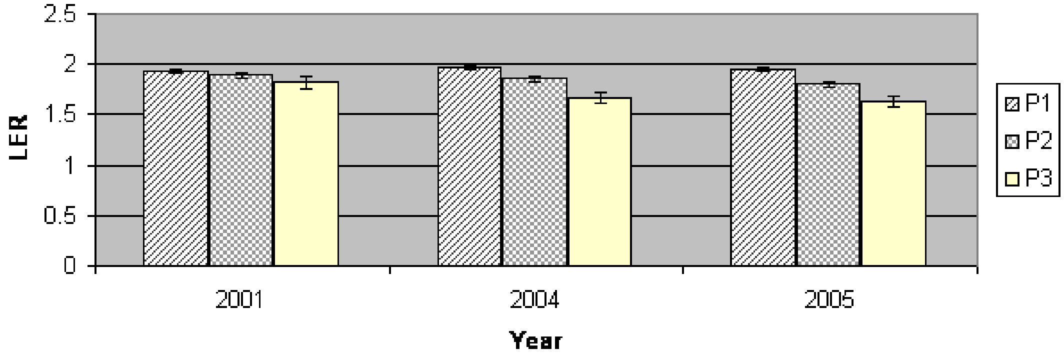

Figure 5. Influence of density on LER of soybean intercropped with sorghum at Otobi.

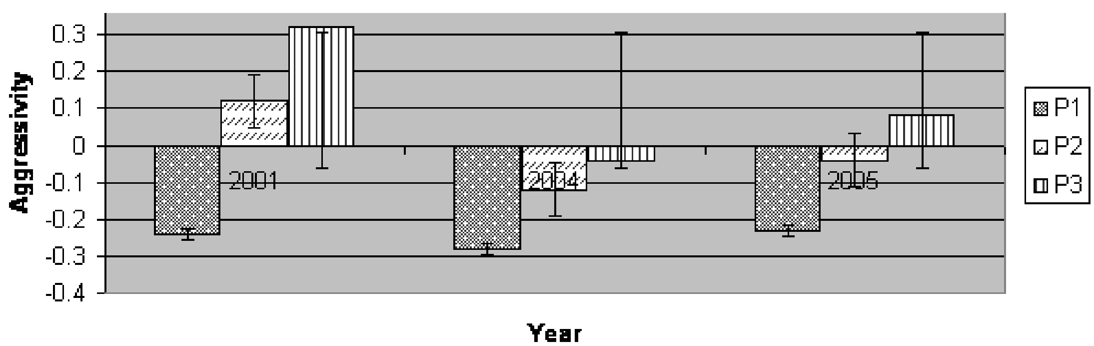

Figure 6. Influence of density on aggressivity of soybean intercropped with sorghum at Otobi.

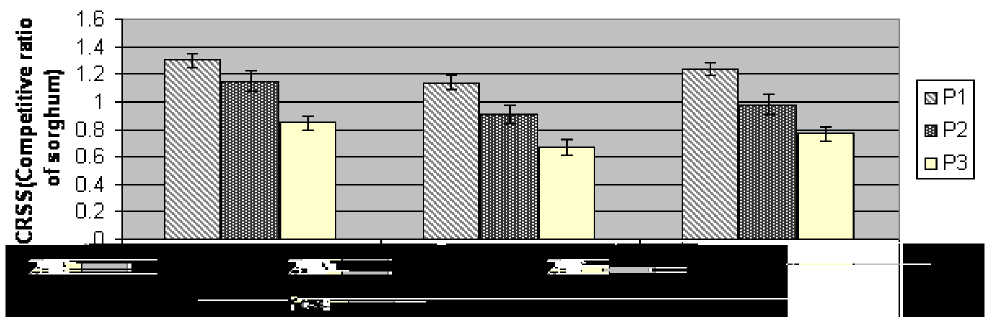

Figure 7. Effects of density on competitive ratio (CRSS) of sorghum intercropped with soybean at Otobi.

decreased with increase in soybean density from P1 to P3 during the three years of the work. LER figures were highest at P1 and lowest at P3 (Figure5). Aggressivity values of soybean were consistently negative at P1 with a mean value of -0.25 and it was inconsistent at P2 and P3 during the course of the work for three years (Figure 6). Figure 7 presents the influence of density on the competitive ratio of sorghum (CRSS) at Otobi in 2001, 2004 and 2005. The competitive ratio of sorghum decreased with increasing density of soybean in the intercrop combinations used in this study. P1 consistently gave higher values of CRSS than P2, which in turn had higher values than P3.The competitive ratio of soybean (CRSSO) increased with increasing density of the soybean in the intercrop combinations (Figure 8). CRSSO was highest at P3 an d least at P1. The main effect of density significantly influenced the total relative crowding coefficient (K) of soybean varieties intercropped with sorghum. The effect of density on the total relative crowding coefficient of soybean intercropped with sorghum at Otobi was inconsistent during the three years of the study (Figure 9). The interaction effects of variety with density,

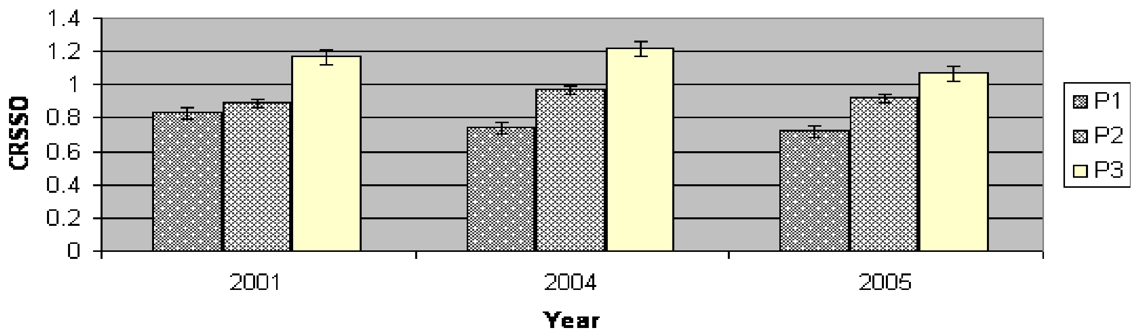

Figure 8. Influence of density on the competitive ratio (CRSS) of soybean intercropped with sorghum at Otobi.

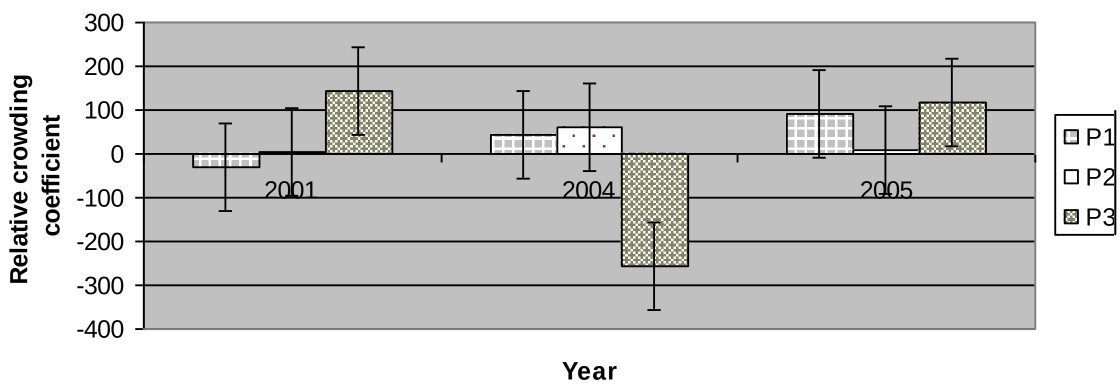

Figure 9. Effect of density on the relative crowding coefficient of soybean intercropped with sorghum at Otobi

Table 1. Effect of density on the land equivalent ratio (LEC), area-time equivalency ratio (ATER) and the soybean equivalent yield (SOYEQUIV.) on soybean intercropped with sorghum at Otobi.

Density	LEC				ATER				SOYEQUIV.			
	2001	2004	2005	Mean	2001	2004	2005	Mean	2001	2004	2005	Mean
P1	0.98	0.79	0.84	0.87	1.45	1.42	1.41	1.43	1.87	1.60	1.42	1.63
P2	0.91	0.86	0.83	0.87	1.48	1.47	1.46	1.47	1.89	1.60	1.60	1.70
P3	0.98	0.80	0.78	0.85	1.43	1.41	1.40	1.41	1.72	1.47	1.54	1.58
Mean	0.96	0.82	0.82	0.86	1.45	1.43	1.42	1.44	1.83	1.53	1.52	1.63
LSD(0.05)	0.13	0.09	0.18		0.13	0.03	0.05		0.05	0.03	0.07	

main effects of variety and density on the LEC of soybean intercropped with sorghum at Otobi were not significant in any of the years of the study. Mean LEC values varied from 0.85 at P1 to 0.87 at P2 and P3. The main effect of density significantly influenced ATER and 'soybean yield equivalent' (SOYEQUIV.) (Table1). ATER values were above 1.00 in all treatment combinations, and varied from 1.41 - 1.47 with a mean of 1.44. Although, ATER values did not vary significantly in 2001, soybean intercropped at P2 produced the highest significant ATER figures in 2004 and 2005. 'Soybean equivalent yield' (SOYEQUIV) figures were significantly higher at P1 and P2 than at P3 in 2001 and 2004. However, in 2005, P2 and P3 gave significantly higher 'soybean yield equivalent' than P1 (Table 1).The highest mean value of 'soybean equivalent yield' was obtained at P2. TVC (total variable cost) indicated that sole cropping produced higher values (₦52,480.00) than intercropping (₦46,730.00) (Table 2). Table 3 showed that inter-cropping consistently gave higher values of gross margin (GM) and RI. The values of GM ranged from ₦16, 310.00/ha to ₦17, 230.00/ha under sole cropping, and from ₦33,960.00/ha to ₦43,080.00/ha under inter-cropping. RI values varied from ₦ 0.31 to ₦ 0.91 under

Table 2. TVC (₦'000/ha) of soybean intercropped with sorghum at Otobi in 2001, 2004 and 2005.

Cropping system	TVC			
	2001	2004	2005	Mean
Sole cropping	50.89	52.90	53.66	52.48
Intercropping	45.59	47.61	46.98	46.73
Mean	48.24	50.26	50.32	49.61
FLSD(0.05)	0.16	0.17	0.16	

Table 3. Effect of cropping system on the GM (₦'000/ha) and RI of soybean intercropped with sorghum at Otobi in 2001, 2004 and 2005.

Cropping system	GM				RI			
	2001	2004	2005	Mean	2001	2004	2005	Mean
Sole cropping	17.23	16.31	17.15	16.90	0.34	0.31	0.91	0.52
Intercropping	33.96	42.07	43.08	39.70	0.75	0.89	1.37	1.00
Mean	25.60	29.19	30.12	28.30	0.55	0.60	1.14	0.76
LSD(0.05)	0.74	0.81	0.86		0.02	0.02	0.12	

GM: gross margin.
RI: returns per investment.

Table 4. Effect of variety on the GM (₦'000/ ha) and RI of soybean intercropped with sorghum at Otobi in 2001, 2004 and 2005.

Variety	GM				RI			
	2001	2004	2005	Mean	2001	2004	2005	Mean
TGX536-O2D	25.11	28.56	29.51	27.73	0.53	0.58	0.48	0.53
SAMSOY2	26.24	31.93	32.37	30.18	0.56	0.64	0.66	0.62
TGX923-2E	25.43	27.66	28.47	27.19	0.54	0.57	0.58	0.56
Mean	25.59	29.38	30.12	28.37	0.54	0.59	0.57	0.57
LSD (0.05)	0.90	0.99	1.06		0.02	0.01	0.02	

Table 5. Effect of density on the GM (₦'000/ ha) and RI of soybean intercropped with sorghum at Otobi in 2001, 2004 and 2005.

Variety	GM				RI			
	2001	2004	2005	Mean	2001	2004	2005	Mean
P1	22.80	25.89	27.51	25.40	0.48	0.53	0.49	0.50
P2	26.64	30.93	31.56	29.71	0.57	0.63	0.65	0.62
P3	27.35	30.75	31.29	27.09	0.58	0.63	0.58	0.60
Mean	25.97	29.19	30.12	27.40	0.54	0.59	0.57	0.57
LSD (0.05)	0.90	0.99	1.06		0.02	0.02	0.02	

sole system and ₦0.75 to ₦1.37 under intercropping. GM and RI also differed with the varieties of soybean (Table 4). SAMSOY 2 gave higher GM and RI than TGX 923-2E and TGX 536-O2D. Soybean intercropped with sorghum at P1 gave consistently lower values of GM and RI than those planted at P2 and P3 (Table 5). Table 6 presents the results of dominance analysis of soybean varieties intercropped with sorghum at Otobi. The results showed that the sole crop systems were dominated and there were no significant differences between the intercropped soybean varieties in both TVC and the net benefits that accrued. Table 7 indicates the dominance analysis of soybean intercropped at different densities with sorghum. Intercropped soybean planted at P2 and P3 gave

Table 6. Dominance analysis, soybean varieties intercropped with sorghum at Otobi.

Treatment	TVC(₦'000/ha)	Net benefits(₦'000/ha)
Intercropped TGX923-2E	46.73	37.92
Intercropped TGX 536-02D	46.73	38.85
Intercropped Samsoy 2	46.73	42.34
Sole TGX 536-02D	52.48	16.60 D
Sole TGX 923-2E	52.49	16.46 D
Sole crop Samsoy2	52.49	17.40 D
LSD(0.05)	0.79	5.63

Table 7. Dominance analysis, soybean intercropped at different densities with sorghum at Otobi.

Treatment	TVC(₦'000/ha)	Net benefits(₦'000/ha)
Intercropped soybean planted at P1	46.71	35.83
Intercropped soybean planted at P2	46.73	41.48
Intercropped soybean planted at P3	46.75	41.80
Sole crop soybean planted at P1	52.48	14.96 D
Sole crop soybean planted at P3	52.50	17.79 D
Sole crop soybean planted at P2	52.50	17.94 D
LSD (0.05)	0.79	5.32

Table 8. Marginal analysis, soybean intercropped at different densities with sorghum at Otobi.

Treatment	Total variable cost(₦/ha)	Marginal costs(₦/ha)	Net benefits(₦/ha)	Marginal benefits(₦/ha)	Marginal rate of return (%)
Intercropped soybean at P1	46,710.00	20.00	35,830.00	5,650.00	28250
Intercropped soybean at P2	46,730.00	20.00	41,480.00	320.00	1600
Intercropped soybean at P3	46,750.00		41,800.00		

significantly higher net benefits than those planted at P1. Marginal analysis showed that planting soybean at P2 gave the highest marginal rate of return (Table 8) and this was 2825%.

DISCUSSION

The yield reduction of the intercropped soybean might be associated with interspecific competition between the intercrop components for growth resources (light, water, nutrients, air, etc.) and the depressive effects of sorghum. Pal et al. (1992) and Muoneke et al. (2007) had observed similar yield reductions in soybean intercropped with maize and sorghum in Benue State, Nigeria and associated the yield depression to interspecific competition and the depressive effect of the cereals. Ghosh (2004) further explained that because of the differences in canopy height of soybean and sorghum, the two species not only competed for nutrient water but also for sunlight. Samsoy 2 and TGX 923-2E recorded higher seed yield than TGX 536-O2D at the various densities. Such differential responses might be due to inherent genotypic capabilities of these varieties to withstand shade. Egbe and Kalu (2009) had reported similar observations when different pigeon pea varieties were evaluated under intercropping with sorghum in Benue State, Nigeria. Plant densities of soybean seemed to have had the dominant effect on the seed yield of soybean intercropped with sorghum at Otobi. Pal et al. (1992) had indicated that yields of component crops in the intercrop varied significantly with the components population density. Intercropped soybean planted at P2 (333,000 plants ha^{-1}) produced significantly higher seed yield than those planted at the other two densities. These results contradicted earlier findings (BNARDA, 1993; Egbe, 1995) which had recommended a lower density (200,000 plants ha^{-1}) of soybean for intercropping with sorghum. The better performance of soybean at P2 than P3 might be ascribed to reduced competitiveness for growth resources at P2 as compared to P3. This was further elucidated by the competitive ratio values for soy-bean (CRSSO), which was less than 1.00 at P1 and P2 but greater than 1.00 at P3, suggesting that competition became more severe at P3 (400,000 plants/ha). Ghosh et al. (2006) had indicated that if competitive ratio was less than 1, there is a positive benefit and the crop can be grown in association, but if greater than 1, there was negative benefit. According to Willey and Rao (1980), competitive ratio (CR) gives a better measure of competitive ability of crops and can prove a better index as compared to aggressivity. Seed yield of sorghum was significantly higher at P1 and P2 than at P3, further indicating adverse influence of interspecific competition at P3. Generally, the cereal component is considered a suppressing crop in legume/cereal associations like soybean/maize (Quainoo et al., 2000; Muoneke et al., 2007). This was shown to be completely true only when soybean was intercropped at sub-optimal densities (e.g. P1) as indicated by aggressivity figures in this study. Aggressivity values were inconsistent beyond P1. The consistent negative aggressivity values at P1 suggested that soybean was dominated at that population density. Although LER figures were above unity under all intercrop combinations in this study, it decreased with increasing density of soybean, suggesting decreased efficiency in land resource utilization with increasing density of soybean. The K values were generally inconsistent; however, the negative K figures obtained at P1 in 2001 and at P3 in 2004 suggested potential yield reductions at these densities as compared to P2. For a two-crop mixture the minimum expected productivity coefficient (PC) is 25%s, that is, a yield advantage is obtained if LEC value exceeds 0.25 (Adetiloye et al., 1983). All intercrop combinations in this study had LEC values above 0.25, suggesting yield advantages. Similar to LER, ATER values were above 1.00 indicating intercrop benefits. In particular, soybean intercropped at P2 gave the highest ATER of 1.47, further indicating that intercropping soybean at this density might be more productive. 'Soybean yield equivalent' was also highest at P2, implying general suitability of soybean to intercropping at this density. Intercropped soybean gave higher values of GM and RI and net benefits than the sole systems, probably because of the additional yield and values of the sorghum component. Egbe (2005) had made similar observations in pigeon pea/sorghum and pigeon pea-/maize intercropping studies at Otobi. Farmers are mostly concerned with the profitability of their farm enterprises. Njoroge et al. (1993) estimated the net benefit of intercropping coffee with food crops by subtracting the total variable costs from the gross profits. Similarly, Egbe (2005) had estimated the total profit and the marginal benefit; cost ratio from investment on different farm inputs used in pigeon pea/sorghum intercropping system by computing returns per naira invested (RI). Intercropped samsoy 2 was more profitable than the other soybean varieties probably because it attracted a higher price than the others and it also gave higher seed yield. The greater profit obtained at P2 than at the other densities might probably have arisen from the higher yield of soybean at this population density. These results suggest that growing soybean under intercropping is more profitable and biologically efficient at 333,000 plants/ha. Samsoy 2 is the preferred variety because of its grain yield and higher price in the market.

Conclusions

Planting intercropped soybean at 333,000 plants/ha gave significantly higher seed yield than planting at 400,000 plants/ha, which in turn had greater seed yield than planting at 200,000 plants/ha. The competitive ratio of soybean increased with increasing density of the soybean in the intercrop combinations, but the competitive ratio of sorghum had the opposite response. Land equivalent ratio (LER),area – time equivalency ratio(ATER), land equivalent coefficient(LEC) and 'soybean yield equivalent' indicated yield advantages for all intercrop combinations, especially at P333,000 plants/ha. Relative crowding coefficient (K) was inconsistent at all densities, while aggressivity was inconsistent at 333,000 and 400,000 plants/ha. Soybean intercropped with sorghum at 333,000 plants/ha gave higher net benefits and marginal rate of return than those planted at 200,000 and 400,000 plants/ha. These results suggest that growing soybean under intercropping is biologically efficient at 333,000 plants/ha and more profitable.

REFERENCES

Adetiloye PO, Ezedinma FOC, Okigbo BN (1983). Aland equivalent coefficient concept for the evaluation of competitive and productive interactions on simple complex mixtures. Ecol. Modelling., 19: 27-39.

Akunda EM (2001). Intercropping and population density effects on yield component, seed quality and photosynthesis of sorghum and soybean. J. Food Tech. (Africa) 6: 170-172

Banik P, Midya BK, Sarkar, Ghose SS (2006). Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. Eur. J. Agron. 24: 325-332.

BNARDA (1993). Benue State Agricultural and Rural Development Authority.Annual Report, 1993, BNARDA, Makurdi, Nigeria, p. 32

BNARDA (2003). Benue State Agricultural and Rural Development Authority. Annual Report, 2003, BNARDA, Makurdi, Nigeria, p. 25.

BNARDA (2007). Benue State Agricultural and Rural Development

Authority. Annual Report, 2007, BNARDA, Makurdi, Nigeria, p.28
CIMMYT (1998). From Agronomic Data to Farmer Recommendations: An Economic Training Manual. Completely revised edition. Mexico. D.F.
Egbe OM (1995). Effects of plant densities of intercropped local sorghum with soybean varieties and productivity of soybean/sorghum intercropping in Southern Guinea Savanna. M.Sc. thesis, University of Agriculture, Makurdi, Nigeria.
Egbe OM (2005). Evaluation of some agronomic potentials of pigeonpea genotypes for intercropping with maize and sorghum in Southern Guinea Savanna. Ph.D. thesis, University of Agriculture, Makurdi, Nigeria.
Egbe OM, Adeyemo MO (2006). Estimation of the effects of intercropped pigeonpea on the yield and yield components of maize in Southern Guinea Savanna of Nigeria. J. Sustain. Dev. Agric. Environ., 2: 107-119.
Egbe OM, Kalu BA (2009).Evaluation of pigeonpea(*Cajanus cajan* (L.) Millsp.) genotypes for intercropping with tall sorghum (*Sorghum bicolor* (L.) Moench.) in Southern Guinea Savanna of Nigeria. ARPN. J. Agric. Biol. Sci., 4: 54-65.
Fujita K, Ofosu-Budu KG, Ogata S (1992). Biological nitrogen fixation in mixed legume-cereal cropping systems. Plant soil, 141: 155-175.
Fujita K, Ofosu-Budu KG (1996). Significance of legumes in intercropping systems. *In*: Ito O, Katayama K, Johansen C, Kumar Rao JVDK, Adu-Gyamfi JJ, Rego TJ (eds). Roots and nitrogen in cropping systems of the semi-arid tropics. JIRCAS Int. Agric. Ser. No.3 Japan., pp. 19-40.
GENSTAT (2007). GENSTAT Release 7.23 (Copyright 2007) Lowes Agricultural Trust Rothamsted Experimental Station.
Ghosh PK (2004). Growth, yield, competition and economics of groundnut/cereal fodder intercropping in the semi-arid tropics of India. Field Crops Res., 88: 227-237.
Ghosh PK, Manna MC, Bandyopadhyay KK, Ajay, Tripathi AK, Wanjari RH, Hati KM, Misra AK, Acharya Subba Rao CL (2006). Interspecific interaction and nutrient use in soybean/sorghum intercropping system. Agron. J., 98: 1097-1108.
Gomez KA, Gome AA (1984). Statistical procedures for agricultural research. 2nd ed. John Willey & Sons, Toronto, ON, Canada.
Hiebisch CK, McCollum RE (1987). Area x time equivalency ratio: a method of evaluating the productivity of intercrops. Aggro. J., 79: 15-22.
Kowal JM, Knabe DT (1972). An agroclimatological atlas of the Northern States of Nigeria with explanatory notes. Ahmadu Bello University Press, Zaria.
Muoneke CO, Ogwuche MAO, Kalu BA (2007). Effect of maize planting density on the performance of maize/soybean intercropping system in a guinea savanna agroecosystem. Afr. J. Agric. Res., 2: 667-677.
Njoroge JM, Waithaka K, Chweya JA (1993).Effects of intercropping young plants of the compact Arabica coffee hybrid cultivar. Ruiru II with potatoes, tomatoes, beans and maize on coffee yields and economic returns in Kenya. Expl. Agric., 29: 373-377.
Ofori F, Stern WR (1987). Cereal –legume intercropping systems. Adv. Agron., 41: 41-90.
Pal UR, Oseni TO, Norman JC (1992).Effect of component densities on productivity of soybean/maize soybean/sorghum intercrop. J. Agron. Crop Sci., 170: 66-70.
Prasad K, Srivastava RC 91991). Pigeonpea (*Cajanus cajan*) and soybean (Glycine max) intercropping system under rainfed situation. Indian J. Agric. Sci.. 61: 243-246.
Putnam DH, Herbert SJ, Vargas A (1984). Intercropped corn soybean density studies. 1. Yield complementarity. Expl. Agric. 21: 41-51.
Quainoo AK, Lawson IYD, Yawson A (2000). Intercrop performance of maize, sorghum and soybean in response to planting pattern. J. Ghana Sci. Ass., 2: 31-35.
Willey RW, Rao MR (1980). A competitive ratio for quantifying competition between intercrops. Expl. Agric., 17: 257-264.