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Influence of planting densities on the performance of intercropped bambara groundnut with cowpea in Makurdi, Benue state, Nigeria

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Abstract

A field experiment was undertaken during the rainy seasons (August – December) of 2010 and 2011 at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi in Benue State, located in the Southern Guinea Savanna of Nigeria. The objective was to investigate the suitability of some landraces of bambara groundnut for intercropping at varying planting densities with cowpea. The experiment was a 2 x 3 x 3 split-split plot set out in a randomized complete block design with three replications. Intercropping decreased canopy width, number of pods per plant and grain yields of bambara groundnut component. Number of pods plant^{-1} and grain yields of bambara groundnuts increased with increased planting density. Landrace x planting density interaction effects was significant signifying that landraces have to be selected for specific densities. The landraces of bambara groundnuts used for this study are better suited for planting at high densities (>100,000 plants ha^{-1}). Sole cowpea proved superior to intercropped cowpea with bambara groundnut in dry grain yield, total plant biomass and harvest index. Productivity indices indicated that bambara groundnut/cowpea intercropping was productive, but cowpea was the dominant component of this intercropping system.

Keywords: Bambara groundnuts, Cowpea, Intercropping, Planting density

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1. Introduction

Bambara groundnuts (*Vigna subterranea* (L.) Verdc.) is an indigenous African crop that has been cultivated for ages. It is the third most important grain legume after groundnut and cowpea in Sub-Sahara Africa (Ocran, 1998). It is resistant to high temperature and is suitable for marginal soils where other leguminous crops cannot be grown (Yamaguchi, 1983). It makes very little demand on the soil and has a high nutritive value with 63% carbohydrate, 19% protein content and 6.5% oil (Goli, 1997). Karikari et al. (1997) reported that bambara groundnut also contains minerals like calcium (95.5 – 99.0 mg/100mg), iron (5.1 – 9.0/100mg), potassium (11447 – 14355mg/100mg) and sodium (2.9 – 10.6mg/100mg). Bambara groundnut is cultivated primarily for its subterranean pods, which can be boiled, roasted, pounded into flour and boiled to a stiff porridge (Swanevelder, 1998). Rich in protein, it helps to alleviate nutritional disorders in human and livestock (Massawe et al., 2002). Bambara groundnut fixes atmospheric nitrogen through symbiosis with *Rhizobium* bacteria and therefore beneficial in rotation and intercropping (Karikari et al., 1999; Egbe et al., 2009). The annual world production is 330,000 metric tonnes, 45 – 50% of which are produced in West Africa (Nigeria, Niger, Burkina Faso, Chad, Cote d'Ivoire, Ghana and Mali) (PROTA, 2006). In 2008, it was estimated that Nigeria produced between 100,000 and 168,700 metric tonnes from an area 15350 hectares (NFRA, 2008).

"Although it produces a nutritious food and is cultivated throughout Africa the bambara remains one of the crops most neglected by science. Yet empirical evidence and fragmentary research results suggest that it is a crop with great potential" (Swanevelder, 1998, p. 5). Several landraces of bambara groundnuts exist and in Botswana, twenty-six have been collected and characterized using IPGRI Descriptor (IPGRI, IITA, BAMNET, 2000). Nigeria is believed to be one of the centres of origin of this crop, and possesses extensive bambara groundnut genetic resources (Tanimu and Aliyu, 1997). Institute of Agricultural Reseach, Ahmadu Bello University, Zaria, identified about 80 accessions in the country, with varying seed coat colour, seed size, pigmentation around the eye, pod shape, growth habit and other characters (Tanimu and Aliyu, 1997). In Southern Guinea Savanna region of Nigeria, some of the popular landraces include, "Karo", "Okirikiri", "Adikpo", "Kparuru", "Ikpeyiole" and "Carol". In Nigeria, these landraces of bambara groundnut and some others are grown by subsistence farmers in small patches of land. It is regarded as women's crop in most cultures and frequently intercropped or mixed with cowpea, maize and sorghum (Mkandiwire and Sibuga, 2002; DFID, 2002). One major constraint in bambara groundnut production is inadequate information on the type and intensity of mixture/intercropping with other crop types in the farming systems practiced by farmers. Also, planting density of bambara groundnut is often low (< 100,000 plants ha^{-1}) in farmers' fields (Egbe et al., 2009) and especially when the crop is not grown in rows (Ngugi, 1998), resulting in low yields. Planting density of bambara groundnut varies from one location to another in both Eastern and Western Africa. Mkandiwire and Sibuga (2002) had reported a spacing of 30 cm x 30 cm in Tanzania and 60 cm x 30 cm in West Africa. The practice of legume/legume intercropping is common among smallholder farmers, but scientific studies are rare despite potential advantages for soil fertility restoration and increased options for plant protein sources for poor households. Similarly, research information on the optimal plant population of bambara groundnut when being intercropped with cowpea in Southern Guinea Savanna is lacking. The yield advantages and competitive abilities of the bambara groundnut/cowpea intercropping systems have not been documented in Southern Guinea Savanna of Nigeria. The study reported here sought to bridge this knowledge gaps.

2. Materials and methods

A field experiment was undertaken during the rainy seasons (August – December) of 2010 and 2011 at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi [latitude 07^{o} 45'-07^{o}50'N, longtitude 08^{o}45'-08^{o}50'E, elevation 98 meters above sea level, masl] in Benue State, located in the Southern Guinea Savanna of Nigeria. The study aimed at investigating the suitability of some landraces of bambara groundnut for intercropping at varying planting densities with cowpea in Nigeria. The experimental site received a total rainfall of 1115.3mm and 1211.4 mm in 2010 and 2011, respectively. The soil was classified as Dystric Ustropept (USDA). The same site was used for the experiment in each year. Ten core samples of soil were collected from different parts of the experimental field from a depth of 0-30 cm and bulked into a composite sample and used for the determination of the physical and chemical properties of the soil (see Table 1) before planting. The soil samples were air-dried at room temperature for one week, ground (using mortar and pestle) to pass through a 0.3 mm screen for chemical analysis. Mechanical analysis was carried out by the hydrometer method described by Bouyoucos (1962). Soil pH was obtained using a 1:2.5 soil-water ratio. Total organic carbon was determined by the use of an improved chromic acid digestion and spectrophotometric method (Heanes, 1984) and organic matter was estimated by multiplying the organic carbon figure by 1.724. Available phosphorus was determined by using Bray1 procedure (Bray and Kurtz, 1945). Nitrogen in soil was estimated by phenols colour formation method (Chaykin, 1969) after micro-Kjeldahl digestion; exchangeable potassium and calcium were determined using the methods described by Juo (1983). Magnesium was assessed using the methodology developed by Tel and Rao (1982). Effective cation exchangeable capacity (ECEC) was obtained by the summation method.

The plot was manually cleared with machetes and ridged with hand hoes before laying the experiment as a 2 x 3 x 3 split-split plot set out in a randomized complete block design with three replications. The main plot treatments comprised of two cropping systems [sole cropping (bambara groundnut, cowpea *var.* IT97K-499-35) and intercropping (bambara groundnut + cowpea)], while the sub-plot treatment was made up of three bambara groundnut landraces ("Adikpo", "Okirikiri" and "Karo"). The sub-sub-plot treatments comprised of three planting densities of bambara groundnut (200,000 plantsha-1, designated as P1 and set out as 1 m x 0.05 m x 1 plant/stand; 100,000 plantsha-1, designated as P2 and set out as 1 m x 0.1 m x 1 plant/stand; 50,000 plantsha-1, designated as P3 and set out as 1 m x 0.2 m x I plant/stand). The bambara groundnut landraces were obtained from the local markets in Ankpa ("Karo"), Otukpo ("Okirikri") and Makurdi ("Adikpo"). The cowpea variety used was IT97K-499-35 obtained from International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. It was planted in both sole and intercropping at 50,000 plants per ha, set out as 1 m x 0.2 m x 1 plant/stand. Intercropping was formed by planting bambara groundnut at the top of the ridge, while cowpea occupied the side of the same ridge in a 1:1 row arrangement at the respective planting densities mentioned above. Both sole bambara groundnut and sole cowpea occupied the top of the ridge. The gross plot was made up of four ridges, spaced 1 m apart and 3 m long (12 m^2), while the bordered area had two ridges 2 m long (4 m^2). Planting was done on the 5th day of August in both 2010 and 2011. No fertilizer was applied, as often practiced by farmers who intercrop bambara groundnut with cowpea (Mulila-Mitti, 1997). The plots were weeded manually using hand hoes at 3 weeks after planting (WAP) and at 6WAP as recommended by BNARDA (2003). At first flower opening, plots with cowpea were sprayed with 30 milliliters of Decis®EC (25 g/l (2.8% w/w) deltamethrin) in 20 liters of water. This was done three times at fortnightly intervals as recommended by BNARDA (2003). The data collected included the following:

(i) Bambara groundnut component: canopy width (cm), plant height (cm), number of pods per plant, number of seeds per pod, seed yield (tha-1).
(ii) Cowpea component: number of branches and pods per plant, pod length (cm), dry pod weight (t ha^{-1}), dry grain yield (t ha^{-1}), total plant biomass (tha-1) and harvest index.

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:

$$\text{LER} = (Yab/Yaa) + (Yba/\text{Y}bb)$$

where *Yaa* and *Ybb* are yields as sole crops of bambara groundnuts and cowpea and *Yab* and *Yba* are yields as intercrops of bambara groundnuts and cowpea. Values of LER greater than 1 are considered advantageous.

Land equivalent coefficient (LEC), a measure of interaction concerned with the strength of relationship was calculated thus,

$$\text{LEC} = \text{L}a \times \text{L}b$$

where, L*a* = LER of bambara groundnuts and *Lb* = LER of cowpea (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.

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:

$\text{R}a = \text{L}a/\text{L}b \text{ x } \text{z}ba/zab$

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.*

Crop *a* = bambara; crop *b* = cowpea.

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).

Year x treatment interactions were not significant, so data for both years were pooled together and analyzed. Data collected were analyzed using GENSTAT Release 11.1 (PC/Windows) (2008.VSN International Ltd., London) and the least significant difference (LSD) test at 5% probability level was used to compare the treatment means.

3. Results

3.1. Bambara groundnut component

3.1.1. Canopy width of bambara groundnut

The interaction effects of cropping systems x landraces x planting densities on the canopy width of bambara groundnut intercropped with cowpea in Makurdi was significant ($P \leq 0.05$), the other interaction effects were not. The main effects of cropping systems and planting density were also significant, but the effect of landraces was not.

Table 2 presents the results of the effects of cropping systems x variety x planting densities on the canopy width of bambara groundnuts in Makurdi. Canopy width of bambar groundnuts varied from 24.67 cm to 32.67 cm. At P1, sole crop 'Karo' produced significantly higher canopy width (32.67 cm) than all the intercropped treatments and sole crop 'Okirikiri'. Canopy width of sole crop 'Adikpo' (30.33 cm) at P1 was not significantly different from that of sole crop 'Karo', although it was less. At P2 and P3, no significant difference was observed among the treatments in canopy width produced.

Under intercropping, canopy width of bambara groundnuts increased with decreased planting density, while in sole systems it was erratic (Table 2).

3.1.2. Plant height of bambara groundnut

Plant height of bambara groundnut landraces varied with the planting density used (Table 3). The values of plant height of the landraces of bambara groundnut were lowest at P3. While the plant height of 'Adikpo' decreased with decrease in planting density, the plant height of 'Karo' and 'Okirikiri' increased significantly from P1 to P2 and decreased thereafter. The decreases were also significant. Karo produced the tallest plants of bambara groundnut, but there was no significant difference between the plant height of 'Okirikiri' and 'Adikpo' in Makurdi. Generally, plants were tallest at P2 (21.78 cm) and shortest at P3 (17.11 cm) (Table 3).

3.1.3. Number of pods per plant of bambar groundnut

The main effects of cropping systems, landraces and planting density and the interaction effects of cropping systems x landraces, cropping systems x planting density and landraces x planting density on the number of pods per plant of bambara groundnuts intercropped with cowpea were significant (P≤ 0.05). Cropping systems x landraces x planting density interaction effects on the number of pods per plant of bambara groundnuts intercropped with cowpea were not significant (P≥ 0.05). Intercropping significantly decreased the number of pods of bambara groundnut landraces in Makurdi (Table 4). Percentage reduction of number of pods by intercropping varied from 17.78 to 42.87 depending on the landrace. 'Karo' (42.87%) had the highest level of reduction in number of pods of intercropped bambara groundnuts, while 'Adikpo' (17.78%) had the lowest (Table 6). In both sole and intercropping, Adikpo had the highest number of pods per plant, while 'Karo' had the lowest. Under intercropping, 'Adikpo' produced significantly higher number of pods (11.33) than 'Okirikiri' (9.56), which in turn gave significantly higher number of pods than 'Karo' (4.89). In sole systems, 'Adikpo' only had significantly higher number of pods than 'Karo'. Intercropping reduced the number of pods per plant of bambara groundnuts at all planting densities (Table 5). Percentage reduction of number of pods per plant increased with decrease in planting from P1 to P3. P1 had the lowest level of reduction (14.33%), followed by P2 (31.35%) and P3 (33.27%).

Number of pods per plant of 'Karo' and 'Okirikiri' increased significantly from P1 to P2 and thereafter declined at P3 (Table 8). Number of pods per plant of 'Adikpo' decreased with declining planting density, but the decrease was significant only from P2 to P3 (Table 6).

3.1.4. Number of seeds per pod of bambara groundnut

Treatment effects on the number of seeds per pod of bambara groundnut landraces intercropped with cowpea were not significant.

3.1.5. Grain yield of bambara groundnut

The main effects of cropping systems, landraces and planting density and the interaction effects of cropping systems x landraces, cropping systems x planting density and landraces x planting density on the grain yield of bambara groundnuts intercropped with cowpea were significant (P≤ 0.05). Cropping systems x landraces x planting density interaction effects on the grain yield of bambara groundnut intercropped with cowpea were not significant (P≥ 0.05).

Table 7 presents the grain yield of bambara groundnut landraces intercropped with cowpea in Makurdi. Intercropping significantly reduced the grain yield of all the tested bambara groundnut landraces as compared to sole cropping. Percentage reduction varied from 11.43 to 40.00 with a mean of 27.29. 'Karo' had the lowest percentage reduction (11.43), while 'Adikpo' had the highest (40.00). Under intercropping, 'Adikpo'(0.33 tha-1) produced significantly higher grain yield than only 'Karo' (0.31 tha-1),but in sole cropping, 'Adikpo' (0.55 tha-1) gave significantly higher grain yield than 'Okirikiri' (0.46 tha-1), which in turn had significantly higher grain yield than 'Karo' (0.35 tha-1).

Grain yield of bambara groundnut decreased with reduced planting density when intercropped with cowpea (Table 8). Under intercropping, bambara groundnut at P1 gave significantly higher grain yield than P2, which in turn gave higher yield than P3. In sole cropping, grain yields of bambar groundnuts in P1 and P2 were at par and these were significantly higher than the yields at P3 (Table10). Grain yields of Karo and Adikpo decreased continually from P1 to P3, but increased from P1 to P2 and decreased at P3 in Okirikiri (Table 9). In Karo, grain yields were significantly higher in P1 than P2, which in turn was higher than in P3. In Adikpo, grain yields were statistically at par at P1 and P2, but both planting densities had significantly higher grain yields than P3.Generally, the grain yields of bambara groundnuts decreased with decreased density, but the decrease was only significant at P3.

3.2. Cowpea component

The treatment effects on the number of branches per plant, number of pods per plant, dry grain yield, total plant biomass and harvest index of cowpea intercropped with bambara groundnut landraces in Makurdi were significant ($P \leq 0.05$), but days to 50% flowering, number of seeds per pod and 100 – seed weight were not significant. Table 10 presents the results of the number of branches and pods per plant, dry grain yield, total plant biomass and harvest index of cowpea intercropped with bambara groundnut landraces in Makurdi. The intercropped treatments had higher number of branches per plant than the sole. However only such intercrop treatments as cowpea combined with 'Adikpo' at P1,'Karo' at P3 and 'Okirikiri' at P1 had significantly higher number of branches/plant than the sole crop treatment. Cowpea intercropped with 'Okirikiri' at P1 had the highest number of branches per plant (9.67), while the sole crop cowpea had the lowest (4.00). Pods/plant varied from 10.00 to 17.33 with a mean of 14.27. Intercropped plots gave lower number of pods per plant than the sole crop treatments, but only cowpea intercropped with 'Karo' at P1 and P3 and 'Okirikiri' at P3 had significantly had lower number of pods per plant than the sole crop. Pod length varied between 13.67 and 16.67 cm. Pod length of sole cowpea were at par with all intercrop treatments. Intercropped cowpea with Adikpo at P3 produced the longest pods (16.67 cm), and this was significantly greater than only 'Karo' at P3,'Okirikiri' at P1 and P2,'Adikpo' at P1 and P2. Grain yield of cowpea varied between 0.60 tha-1 and 1.23 tha-1 with a mean of 0.89 tha-1. Sole cowpea produced significantly higher dry grain yield than all intercropped treatments, except when combined with 'Adikpo' at P1. The trend observed in total plant biomass was similar to that in dry grain yield. Harvest index (HI) varied from 0.23 to 0.45. Sole cowpea gave the highest harvest index (0.45), and this was significantly higher than HI of all intercropped plots. The HI of all intercropped plots was statistically at par.

3.2.1. Productivity of bambara groundnut landraces intercropped with cowpea

The land equivalent ratio (LER) values of bambara groundnut landraces intercropped with cowpea at three different planting densities are presented in Figure 1. All intercrop combinations had LER greater than unity. Though not significant, the LER of Karo increased with decreased planting density, while the LER of the other two landraces decreased with declined planting density. Land equivalent coefficient (LEC) figures of bambara groundnut landraces intercropped with cowpea at three different densities are shown in Figure 2. Intercrop combinations gave LEC values above 0.25 in all instances. While LEC values declined with declining planting densities in Okirikiri and Adikpo, the trend was inconsistent with Karo. Competitive ratio (CR) of bambara groundnut decreased with decreased density (Figure 3). The CR of Karo at P1 was significantly higher than all the other treatments. CR values of bambara groundnut intercropped with Karo at P1 was above unity; all the others were less than unity. The CR of cowpea varied with the bambara groundnut landraces used (Figure 4). The CR values of cowpea intercropped with landraces of bambara groundnut were above unity in most cases, except when combined with Karo at P1 (0.52) and P3 (0.58) and Okirikiri at P3 (0.98). Figures 5 and 6 present the aggressivity values of bambara groundnut landraces and cowpea components, respectively. While all aggressivity values were negative for the bambara groundnut component (Figure 5), it was positive for all the cowpea components, irrespective of the planting density used. In all of the cases, aggressivity values increased with declining planting density. Karo, however, exhibited erratic aggressivity, especially between P1 and P2 (Figure 5).

4. Discussion

Canopy structure is important for the display of leaves for light interception for photosynthesis in crop plants. Canopy width of bambara groundnuts varied from 24.67 cm to 32.67 cm in this study, indicating that these landraces could be grouped under the bunched type. Karikari et al. (1997) reported that the spreading types could attain canopy spread of 120 cm or more, but at average spacing of 30 cm x 30 cm, the bunch types did not form close canopies. The non-significant difference in canopy width of both sole and intercropped bambara groundnut with cowpea at P2 (100,000 plantsha-1) and P3 (50,000 plantsha-1) might be an indication that competition at these densities was not sufficient to induce a response. This observation was in contrast to that obtained at P1 (200,000 plantsha-1) where sole crop 'Karo' had superior canopy width to intercropped treatments, implying better display of leaves for light interception for photosynthesis in sole systems when compared to intercropped environments. Plant height of bambara groundnut landraces were shortest at P3, probably indicating reduced competition at this density, unlike the situations at P2 and P3. Increased plant height of bambara groundnut at P2 and P3 might be due to competition for light with increased densities; such responses are usually termed morphological plasticity. Redfearn et al. (1999) had stated that soybean exhibited a high degree of morphological plasticity, presumably in response to increased competition for solar radiation when intercropped with sorghum. Egbe and Bar-Nyam (2010) made a similar observation in pigeonpea/sorghum density studies in Makurdi and Otobi. Both number of pods/plant (mean=10.13) and grain yields (mean=0.39 tha-1) of bambara groundnut landraces used in this study were low. Yields of over 3.0 tha-1 have been reported in Potchefstroom in South Africa (Swanevelder, 1998). Begemann (1987) reported that the yield potential of bambara groundnut ranged between 500-2,600 kgha-1 depending on variety, cropping system and management. The low yields might have resulted from non-application of fertiliser to the crops; they had to depend solely on the native fertility of the soil, which was low in nitrogen, phosphorus and potassium, among others. The inclusion of fertiliser treatments might be an open window for further research to improve the productivity of this crop. The significant cropping systems x landraces on the yield of bambara groundnuts has implications for selection of landraces for intercropping. Wein and Smithson (1981) had demonstrated significant interaction of genotype x cropping systems in their study on cowpea. The decline in the number of pods per plant and grain yield of intercropped bambara groundnut landraces as compared to sole cropping might also have resulted from reduced canopy width due to inter- and intra- specific competition for plant growth resources. The cowpea component of the intercropping was more dominant in competition for growth resources than the bambara groundnut. This is evident by the positive aggressivity indices of cowpea and the negative aggressivity indices of bambara groundnut landraces reported in this work at all densities. Though not a cereal, cowpea was taller (data not shown) and had spreading growth habit that gave it the advantage to compete more favorably for above-ground growth resources than bambara groundnuts. Reduced performance of low canopy legumes under intercropping is common. Ikorgu (1998) had reported that pod yield of bambara groundnut was reduced when intercropped with cassava in eastern Nigeria and attributed the reductions to interspecific competition as well as shading of the legume by the taller intercrop component. For better performance of the bambara groundnut intercrop, the density of the cowpea component may have to be reduced to < 50,000 plantsha-1. The increased yield of bambara groundnuts in both sole and intercrop environments with increased planting density was in agreement with the findings of Akpalu (2010) and Kouassi and Zorobi (2011).These workers reported that increasing plant population density resulted in high pod and grain yield. Kouassi and Zorobi (2011) indicated that the highest values of yield characters were obtained with the highest plant density (250,000 plantsha-1) in their experiment in Cote d'Ivoire. The significant landraces x planting density implies that landraces have to be selected for specific densities (e.g' Karo' and 'Adikpo' have to be planted at P1 and Okirikiri could be planted at P2). Also, the differential responses of the landraces to planting density could be attributed to genotypic effects. Makanda et al. (2009) reported differences in performance between varieties of bambara groundnut during off-season evaluation in Zimbabwe. These results indicate that the landraces of bambara groundnuts used for this study are better suited for planting at high densities (>100,000 plantsha-1). The superior performance of sole cowpea as compared to intercrop treatments in dry grain yields, total plant biomass and harvest index is a further confirmation of previous findings of Moriri et al. (2010) and Egbe et al. (2010). These researchers had reported negative influence of intercropping on cowpea yields and attributed this to depressive effects of inter- and intra- plant competition for both above- and below- ground growth factors (light, air, water, nutrients, etc.). The results of the productivity indices used in this study indicated yield advantages (LER figures were all above 1.0 and LEC values were beyond 0.25). Ofori and Stern (1987) had stated that values of LER greater than 1 are considered advantageous, while Adetiloye et al. (1983) indicated that 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. The declined LER and LEC values with declining planting density might be a further evidence for higher productivity of these bambrara groundnut landraces at higher densities (>100,000 plantsha-1). Karikari (2003) had reported intercrop advantages in Bambara groundnut/sorghum intercrop in Botswana. Competitive ability of bambara landraces intercropped with cowpea evaluated by use of competitive ratio (CR) indicated that only 'Karo' at P1 had CR value of over 1.0.This suggested that only Karo at P1 could compete favourably with cowpea; all others could not. This was further buttressed by the negative aggressivity values of all bambara groundnut landraces at all densities. On the contrary, cowpea combined with bambara groundnut had CR values above unity, indicating positive benefit of intercropping. Aggressivity values of the cowpea component were positive at all densities, further indicating that cowpea was the dominant component of the bambara groundnut/cowpea intercrop in Makurdi. The results of productivity indices indicated that bambara groundnut/cowpea intercropping was productive, but competitive indices showed that cowpea was the dominant component of this intercropping system.

5. Conclusion

Intercropping depressed canopy width, number of pods per plant and grain yields of bambara groundnut component of bambaranut/cowpea intercrop in Makurdi. The significant landraces x planting density interaction effects signified that landraces have to be selected for specific densities ('Karo' and 'Adikpo' have to be planted at P1 and Okirikiri could be planted at P2). The landraces of bambara groundnuts used for this study are better suited for planting at high densities (>100,000 plantsha-1). Sole cowpea also proved superior to intercropped cowpea with bambara groundnut in dry grain yield, total plant biomass and harvest index. Yield advantages measured by land equivalent ratio and land equivalent coefficient indicated intercrop advantage, but competitive abilities of the bambara groundnut landraces were inferior to that of the cowpea component.

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Table 1. Physical and chemical properties of the surface soil (0-30 cm) at the experimental site in Makurdi in 2010 and 2011

	Makurdi	
Parameter	2010	2011
Sand (%)	74	71
Silt (%)	18	18
Clay (%)	8	11
Textural class	Sandy loam	Sandy loam
pH (H_2O)	6.30	6.50
Organic carbon (g kg^{-1})	8.82	6.62
Total N (g kg^{-1})	0.70	1.40
Available P (cmol kg^{-1} soil)	17.50	8.75
Ca^{2+} (cmol kg^{-1} soil)	4.60	4.00
Mg^{2+} (cmol kg^{-1} soil)	2.40	1.30
K^+ (cmol kg^{-1} soil)	0.14	0.12
Na^+ (cmol kg^{-1} soil)	0.65	0.78
ECEC (cmol kg^{-1} soil)	7.79	6.20

Table 2. Influence of cropping systems (CRS) x variety (VAR) x density (pop) on canopy width (cm) of bambara groundnut varieties intercropped at varying densities with cowpea in Makurdi

Cropping systems	Canopy width				
	Planting density				
	Variety	P1	P2	P3	Mean (CS X VAR)
Intercropping	Karo	27.00	28.33	30.00	28.44
	Okirikiri	27.00	28.33	24.00	26.44
	Adikpo	29.33	27.33	31.67	29.44
Mean		27.78	27.99	28.56	28.11
Sole cropping	Karo	32.67	27.33	24.33	28.11
	Okirikiri	24.67	27.00	25.67	25.78
	Adikpo	30.33	31.33	26.67	29.44
Mean (CS X POP)		29.22	28.55	25.56	27.78
FLSD(0.05)					
CRS		3.73			
VAR		2.36			
POP		1.67			
CRS X VAR		3.33			
CRS X POP		2.92			
VAR X POP		3.16			
CRS X VAR X POP		4.48			

Table 3. Effect of landraces x planting density on the plant height of bambara groundnut intercropped with cowpea in Makurdi

Landraces	Plant height			
	Planting density			
	P1	P2	P3	Mean
'Karo'	20.00	23.67	17.17	20.28
'Okirikiri'	19.00	22.67	15.67	19.11
'Adikpo'	21.33	19.00	18.50	19.61
Mean	20.11	21.78	17.11	19.67
FLSD (0.05)				
VAR	1.08			
POP	1.28			
VAR X POP	2.03			

Table 4. Effects of cropping systems (CS) x landraces (VAR) on the number of pods per plant of bambara groundnuts intercropped with cowpea in Makurdi

Landraces	Number of pods per plant			
	Intercropping	Sole cropping	Mean	Percentage reduction by intercropping
Karo	4.89	8.56	6.72	42.87
Okirikiri	9.56	12.67	11.11	24.55
Adikpo	11.33	13.78	12.56	17.78
Mean	8.59	11.67	10.13	28.40
FLSD (0.05)				
CS	1.39			
VAR	0.49			
CS X VAR	1.07			

Table 5. Effect of cropping systems x planting density on the number of pods per plant of bambara groundnuts intercropped with cowpea in Makurdi

Cropping systems	Number of pods per plant			
	Planting density			
	P1	P2	P3	Mean
Intercropping	9.33	9.00	7.44	8.59
Sole cropping	10.89	13.11	11.00	11.67
Mean	10.11	11.06	9.22	10.13
FLSD (0.05)				
CS	1.39			
POP	0.49			
CS X POP	1.07			

Table 6. Effect of landraces x planting density on the number of pods per plant of bambara groundnuts intercropped with cowpea in Makurdi.

Landraces	Number of pods per plant			
	Planting density			
	P1	P2	P3	Mean
‘Karo’	6.67	7.17	6.33	6.72
‘Okirikiri’	10.50	13.00	9.83	11.11
‘Adikpo’	13.17	13.00	11.50	12.56
Mean	10.11	11.06	9.22	10.13
FLSD (0.05)				
VAR	0.49			
POP	0.59			
VAR X POP	0.93			

Table 7. Effects of cropping systems (CS) x landraces (VAR) on the grain yield (tha-1) of bambara groundnut intercropped with cowpea in Makurdi

Landraces	Grain yield			
	Intercropping	Sole cropping	Mean	Percentage reduction by intercropping
Karo	0.31	0.35	0.33	11.43
Okirikiri	0.32	0.46	0.39	30.44
Adikpo	0.33	0.55	0.44	40.00
Mean	0.32	0.46	0.39	27.29
FLSD (0.05)				
CS	0.04			
VAR	0.02			
CS X VAR	0.03			

Table 8. Effect of cropping systems x planting density on the grain yield (tha-1) of bambara groundnuts intercropped with cowpea in Makurdi

Cropping systems	Grain yield			
	Planting density			
	P1	P2	P3	Mean
Intercropping	0.39	0.33	0.23	0.32
Sole cropping	0.50	0.52	0.35	0.46
Mean	0.44	0.43	0.29	0.39
FLSD (0.05)				
CS	0.04			
POP	0.02			
CS X POP	0.03			

Table 9. Effect of landraces x planting density on the grain yield (tha-1) of bambara groundnuts intercropped with cowpea in Makurdi

Landraces	Grain yield			
	Planting density			
	P1	P2	P3	Mean
'Karo'	0.39	0.36	0.24	0.33
'Okirikiri'	0.40	0.48	0.30	0.39
'Adikpo'	0.54	0.44	0.34	0.44
Mean	0.44	0.43	0.29	0.39
FLSD (0.05)				
VAR	0.02			
POP	0.02			
VAR X POP	0.03			

Table 10. Number of branches and pods per plant, pod length (cm), dry grain yield (tha-1), total plant biomass (tha-1) and harvest index of cowpea intercropped with bambara groundnut landraces in Makurdi

Treatment	Branches /plant	Pods/ plant	Pod length	Dry grain yield	Total plant biomass	Harvest index
Sole cowpea	4.00	17.33	15.33	1.23	4.38	0.45
Cowpea intercropped with Karo at P1	4.33	13.67	15.33	0.60	2.42	0.24
Cowpea intercropped with Karo at P2	4.67	15.33	16.00	0.98	3.97	0.25
Cowpea intercropped with Karo at P3	5.67	10.00	14.67	0.71	3.03	0.23
Cowpea intercropped with Okirikiri at P1	9.67	14.33	14.67	1.00	3.65	0.25
Cowpea intercropped with Okirikiri at P2	4.67	17.00	14.33	0.82	3.27	0.25
Cowpea intercropped with Okirikiri at P3	4.67	11.00	15.67	0.78	3.09	0.25
Cowpea intercropped with Adikpo at P1	5.33	14.00	13.67	1.03	4.05	0.25
Cowpea intercropped with Adikpo at P2	4.33	14.67	13.67	0.88	3.97	0.23
Cowpea intercropped with Adikpo at P3	5.00	15.33	16.67	0.88	3.49	0.25
Mean	5.23	14.27	15.00	0.89	3.53	0.27
FLSD (0.05)	1.03	3.80	1.68	0.21	0.98	0.06

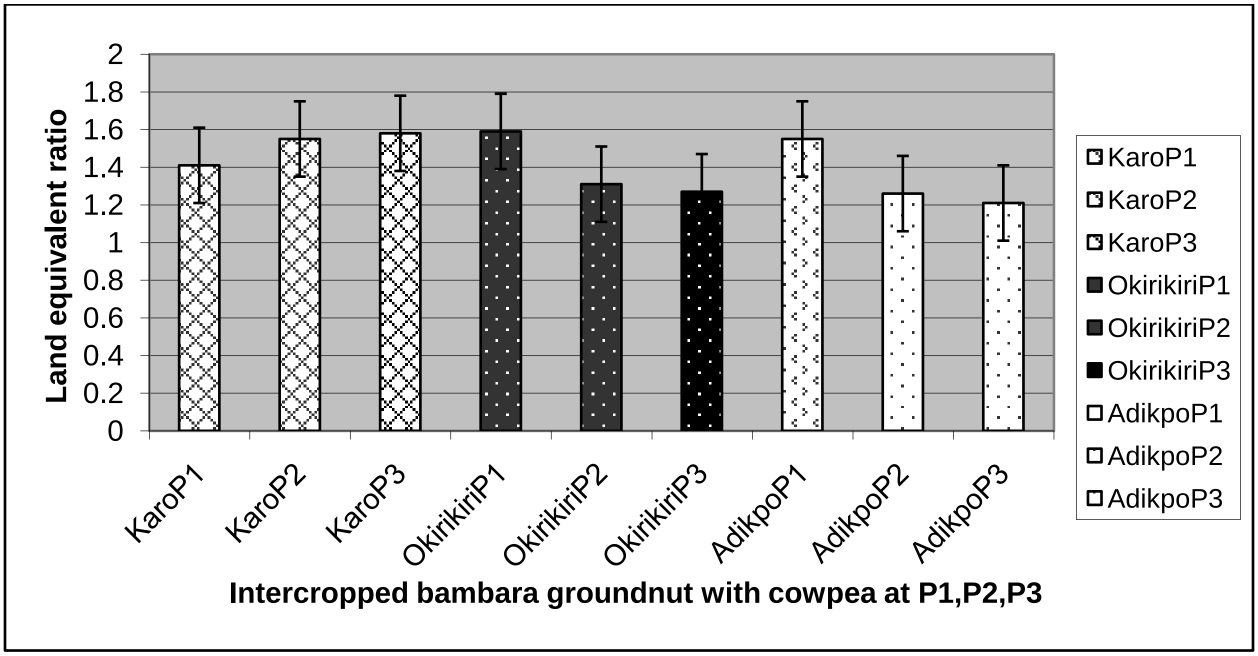

Figure 1. Land equivalent ratio of intercropped bambara groundnut landraces with cowpea at P1 (200,000 plantsha-1), P2 (100,000 plantsha-1) and P3 (50,000 plantsha-1)

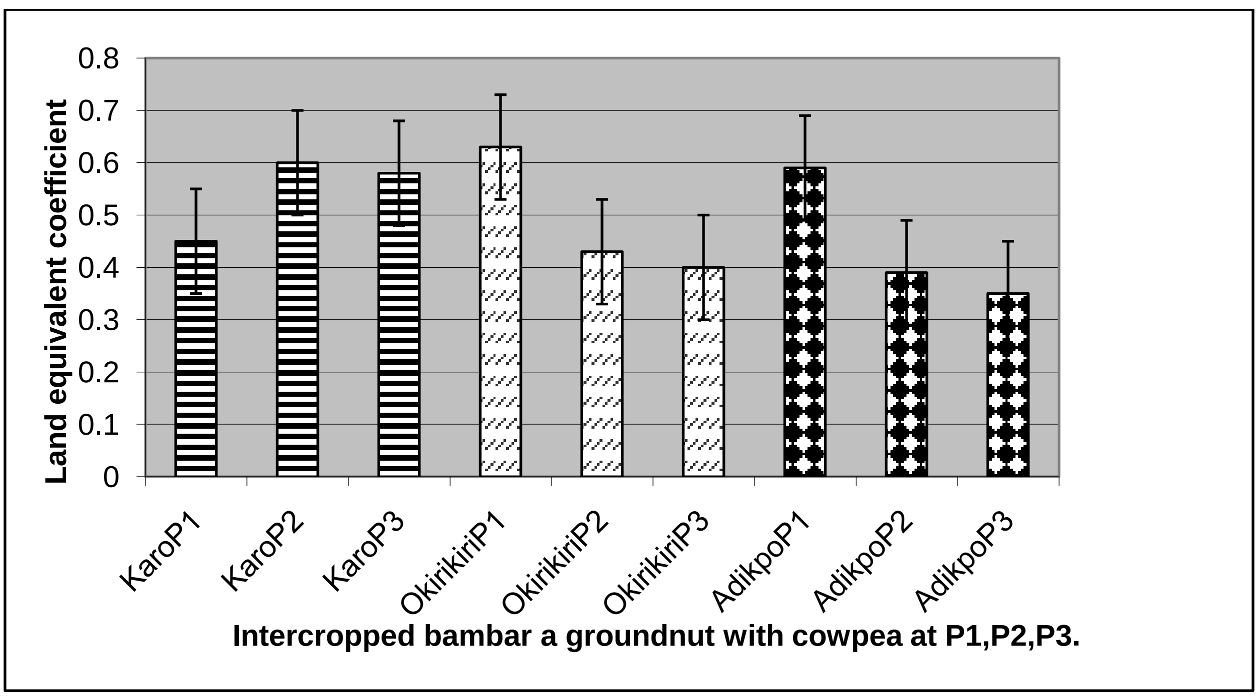

Figure 2. Land equivalent coefficient of intercropped bambara groundnut landraces with cowpea at P1 (200,000 plantsha-1), P2 (100,000 plantsha-1) and P3 (50,000 plantsha-1)

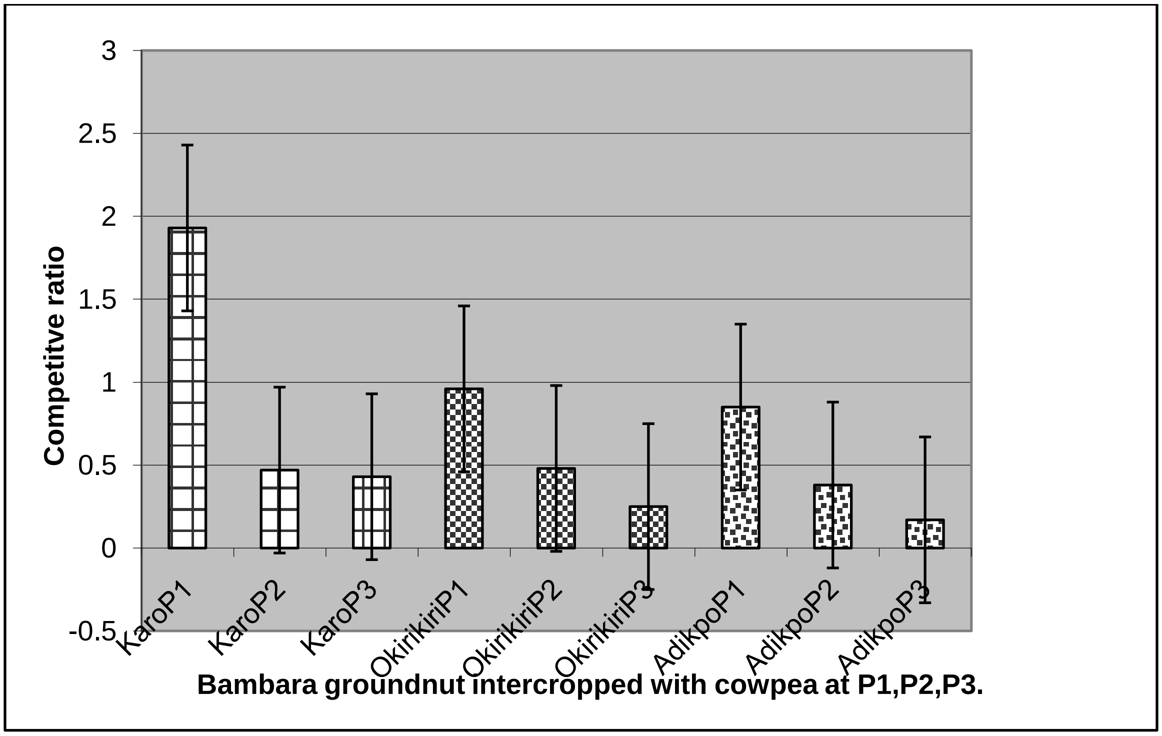

Figure 3. Competitive ratio of intercropped bambara groundnut landraces with cowpea at P1 (200,000 plantsha-1), P2 (100,000 plantsha-1) and P3 (50,000 plantsha-1)

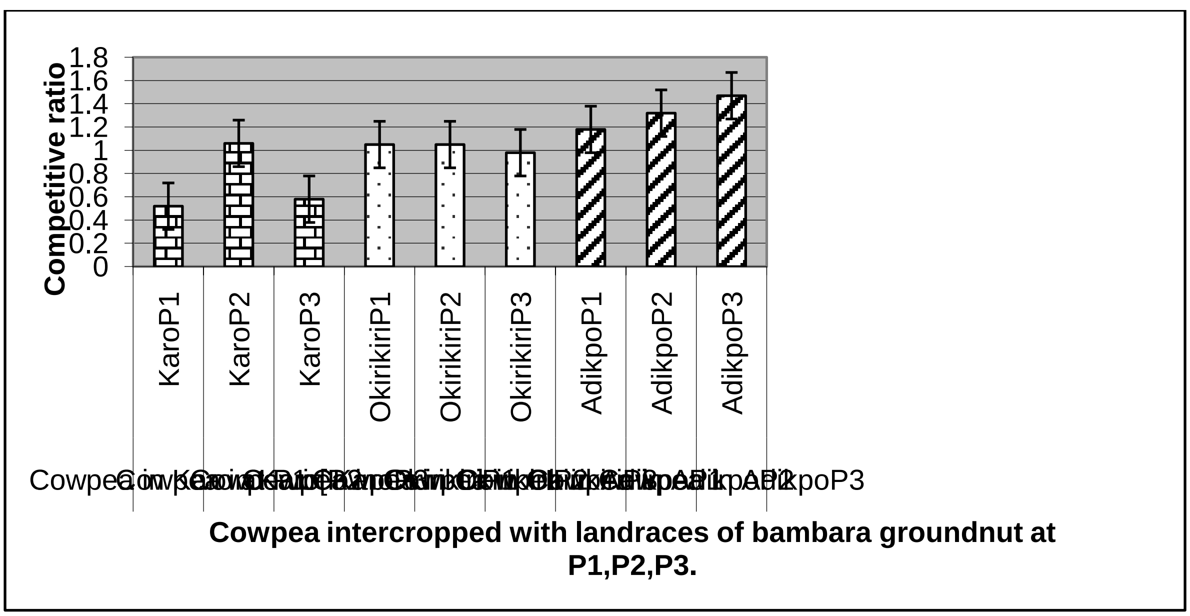

Figure 4. Competitive ratio of intercropped cowpea with bambara groundnut landraces with cowpea at P1 (200,000 plantsha-1), P2 (100,000 plantsha-1) and P3 (50,000 plantsha-1)

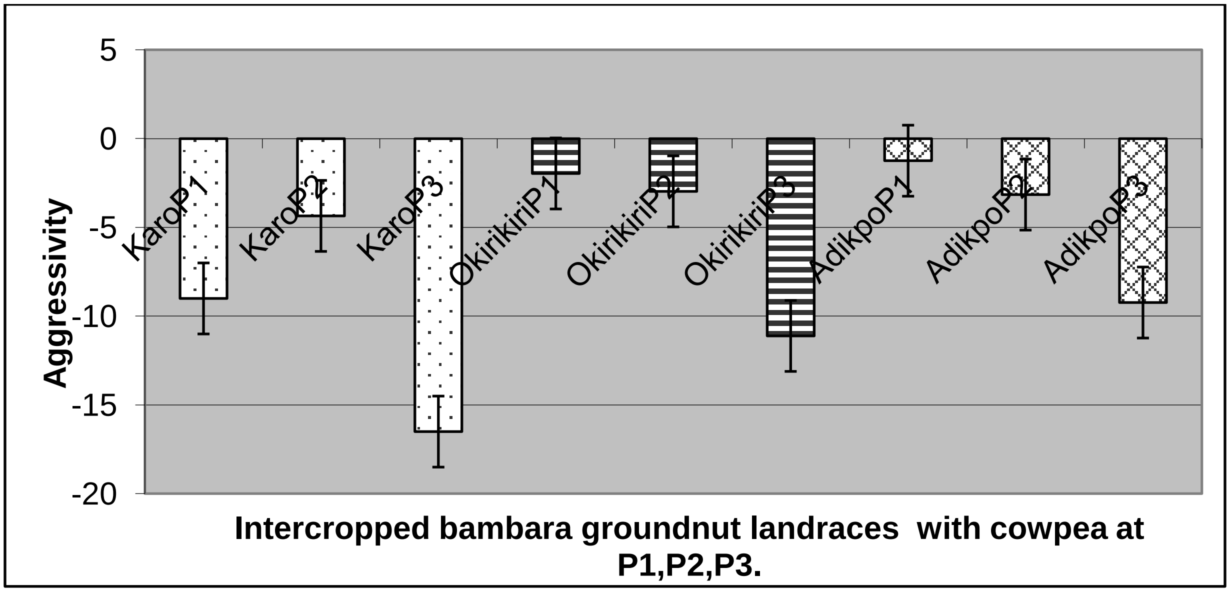

Figure 5. Aggressivity of intercropped bambara groundnut landraces with cowpea at P1 (200,000 plantsha-1), P2 (100,000 plantsha-1) and P3 (50,000 plantsha-1)

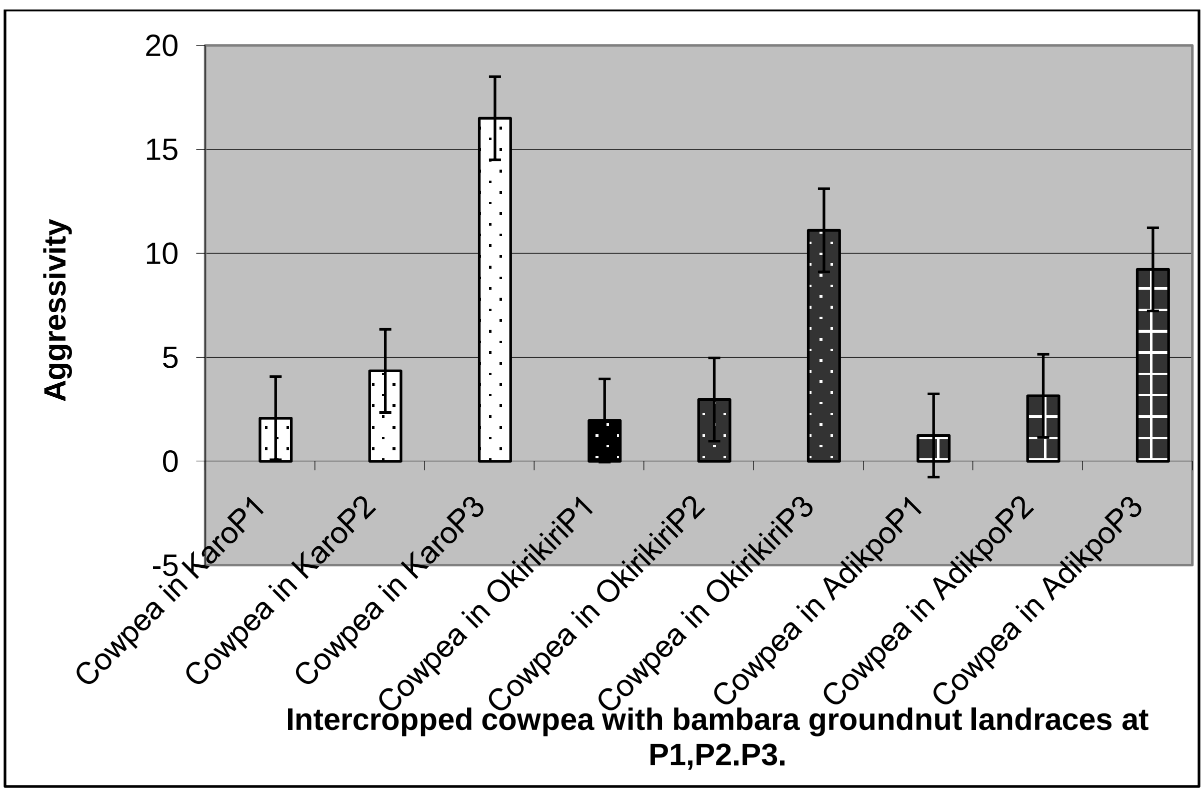

Figure 6. Aggressivity of intercropped cowpea with bambara groundnut landraces at P1 (200,000 plantsha-1), P2 (100,000 plantsha-1) and P3 (50,000 plantsha-1)