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Effect of intercropping bambara groundnud (*Vigna subterranea* (L.) Verdc) and maize (*Zea mays* L.) on the yield and the yield component in woodland savannahs of Côte d'Ivoire

By Kouassi N'dri Jacob[1*] ,Tonessia Dolou Charlotte [1], Kouassi Kouadio Henri[1] , Zoro Bi Irie Arsène[2]

[1]*Université Jean Lorougnon Guedée,UFR Agroforesterie, Bp 150 Daloa, Côte d'Ivoire*

[2]*Université Nangui Abrogoua,UFR Sciences De La Nature, 02Bp 801 .Abidjan,Côte d'Ivoire*

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Abstract

The development of simple and profitable crop combinations for increasing crop productivity is one of the ways to improve these systems. A good management system combination to reduce overhead and underground competitions for the resources was the main objective that motivated the conduct of this experiment. Experiments are described in which the possible yield benefits of intercropping bambara groundnut [*Vigna subterranea* (L.) Verdc)] and maize (*Zea mays* L.) were determined under dryland conditions in Manfla (Côte d'Ivoire). A replacement series of sole crop bambara groundnut, bambara groundnut and maize (75B/25M), bambara groundnut and maize (50B/50M), bambara groundnut and maize (25B/75M), sole crop maize and the space provision were studied over three years period (2005, 2006 et 2007). The space provision is plant in the same row and plant in the row different. Grain yield advantage due to intercropping was assessed using the Land Equivalent Ratio. The systems of association of cultures were more productive in term of production out of seeds than the pure cultures. Nevertheless, among the farming systems associated, associations in the row different are more productive than associations in the same row. The productivity of the voandzou is more significant with the small proportions of maize. Grain yield of maize is higher when the proportion of maize in the association is higher, however the highest weight of the grains were observed when the proportion of voandzou is higher.

* **Corresponding Author:** By Kouassi N'dri Jacob ✉ kouassindrijacob@yahoo.fr

Introduction

The increasing human population pressure and its ramifications resulted in a demand for more food. To solve this problem, there is the increasing of the food production in these developing countries (Brink, 1998). Thus, the use of the ground was causing its degradation (Bado *et al.*, 1997, Bazoumana *et al.,* 2009). Indeed, the traditional practices of the farmers drop the outputs. The intercropping system seems to be a way of interesting research. However, they are not done according to a very suitable diagram. Many investigations were carried out on the development and on the characterization of the intercropping that increases productivity of food (Karikari *et al.*, 1999, Karikari *et al.*, 2002; Ghosh, 2004, Gebeyehu *et al.*, 2006). Taking into account the importance of cereals in the food and the economy of the development countries and the low fertility of the grounds, the majority of the intercropping system was based on the intercropping legumes with non-legumes (Santalla *et al.*, 2001, Banik *et al.*, 2006). The evaluation of the potential of several legumes as a component of the intercropping was tested. The groundnuts were evaluated with the corn (Goran and Guessan, 1999). That work showed that the groundnut fixed the quantity of N and increased corn production. However, one legume called bambara groundnut was not evaluated in Côte d'Ivoire. Two studies were conducted in Botswana in intercropping bambara groundnut and several cereals (corn, millet and sorghum). One of these studies related to the effect of the bambara groundnut on the productivity of the cereals (Karikari *et al.*, 1999) while other related to the effect of the shade brought by these cereals on the output of the bambara groundnut (Karikari *et al.*, 2002). Mkandawire (2007) showed that bambara groundnut has less important in many parts of Africa because of its tolerance of drought and ability to produce a reasonable yield in poor soils. The potentialities of that legume showed that it adapts to the fluctuations climatic (Collinson *et al.*, 1996). In farming rotation, it contributes to increase the fertility of the soil (Kumaga *et al.*, 1994). The seeds are used for the human consumption. It is rich in vitamins and protein (Poulter and Caygill, 1980, Onimawo *et al.*, 1998, Minka and Bruneteau, 2000). In spite of these many advantages, the bambara groundnut is studied little (Azam-Ali *et al.,* 2001). Apart from relatively recent information on the morphological variability (Djè *et al.*, 2005, 2006, Koné *et al.*, 2007), little is known about the improvement of the farmers techniques for the increase the yield. The present study aims to explore the possibility of providing green fodder during three years of an intercropping system, and to assess the groundnut/cereal fodder intercropping system as a means of better resource management with respect to growth, productivity, competition and advantage.

Materiels and methods

Study site

A bambara groundnut landrace with a semi-bunch growth habit designated on the basis of seed colour pattern as BgR (creamy coloured seed with red spots), and widely cultivated in Côte d'Ivoire and Burkina Faso, was evaluated. Seeds were obtained from the collection of the University of Abobo-Adjame, Abidjan, Côte d'Ivoire. The corn used was bought at the market. The farm experiments were conducted in 2005, 2006 and 2007 in the village of Manfla (6°49 34.38 N, 5°43 47.68 W) situated at 400 km north Abidjan (Côte d'Ivoire). There are two rainy seasons separated by a short dry period (July–August) and a long dry season (December–February) at the target site. Annual rainfall varies from 800 to 1400 mm with a long-term mean of 1200 mm, and the annual mean temperature is 27°C. Over the experimental periods (March–July each year), the mean monthly temperature was 26.5°C, and mean monthly rainfall ranged from 100.8 mm to 117.5 mm with total rainfall per experimental period of 504.2 mm to 586.3 mm. Mean relative humidity was 81%. The vegetation is a woodland savanna. The study site is a natural fallow plot with vegetation mainly composed of *Chromoleana odorata* and *Panicum maximum*. Soils in the study area were deep, friable and sandy-silt. Analysis at a soil depth of 20 cm indicated the following characteristics: pH 6.45, 57% sand, 36% silt, 7% clay, 6%organic matter, 3.5 g/kg of total N, 24.4 g/kg of available P and 0.45 g/kg of K. In the study area, bambara groundnut is usually produced during two cropping seasons in a year. In the first cropping season corresponding to the long rainy period, planting and harvest take place in March and July, respectively. The second cropping season corresponds to the short rainy season; seeds are sown in July–August and harvested in November–December. All experiments were conducted during the first cropping season, and seeds were sown on the first day of the significant rainfall. This was 15 March, 17 March and 17 April, in 2005, 2006 and 2007, respectively.

Experimental design and cultural practice

The experience were conducted over a three year period during the 2005, 2006 and 2007 cropping seasons to study the effects of intercropping bambara groundnut with corn. Two studies were carried out. They are the sowing density and the space provision. For each treatment, a block completely randomized with three repetitions was set up. The blocks were separated from 2 m. One planting method regularly used by farmers from the study site to grow bambara groundnut were used: sowing on the flat. In this experiment, the row spacing was 50 cm. Four seeds per hole were sown directly and thinned to the final stands at the first leaf-stage. The thinning of the young seedlings was made two weeks after sowing. The combinations for intercrops 25%, 50% and 75% row of bambara groundnut to 75, 50% and 25% row of the cereal crop and 25%, 50% and 75% feet of bambara groundnut to 75, 50% and 25% feet of the cereal crop in the same rows, respectively. Two intercropping system was studied: plants in the same row and plants in different row. The sole crop of Bambara groundnut and corn were made.

Data collection

Eight characters selected starting from work of Ghosh (2004) and Hauser *et al.* (2006) were retained for the agronomic evaluation of corn. It is about the weight of the dry plant (PDM), the weight of dry ear (PES), the length of the ear (LE), the diameter of ear (DE), the weight of dry seeds (PGr), the ratio length/width (L/d) of ear, the seed yield ((YLD)) and of the index of harvest (InR). The outputs (seeds production and plant dry biomass) and nine characters agronomic were selected in the list of the descriptors of voandzou (IITA *et al.*, 2000). These characters were identified like components of output (Ofori I, 1996, Karikari and Tabona, 2004, Cornelissen 2005, Ouégraogo *et al.*, 2008). Combined analysis of variance appropriate to a split-plot design was performed using the general linear model procedure of the SAS statistical package (SAS, 2004). Least significant difference multiple range-tests were used to identify differences among the means of the parameters examined, according to the different intercropping system. Further details of the selected traits and related measurement approaches are indicated in Table 1 for bambara groundnut and Table 2 for maize. In order to compare biological and efficiency and productivity of different bambara groundnut-maize combinations, partial (individual crop's) land equivalent ratio (LER) and total were calculated using the three years yields data of the two crops. The yield advantage of intercropping was calculated according to Ofori and Stern (1987). The land equivalent ratio (LER) gives an accurate assessment of the greater biological efficiency of the intercropping situation and was calculated as

$$mLER = \frac{Y\,\mathrm{Im}}{YSm} \qquad vLER = \frac{YIv}{YSv}$$

$$tLER = mLER + vLER$$

$Y\,\mathrm{Im}$ corn yield in intercropping, YSm : YSm corn yield in sole crops, YIv : yield of the bambara groundnut in intercropping, YSv : output of the bambara groundnut in sole crops, $mLER$: LER of corn, $vLER$: LER of the bambara groundnut and $tLER$: Total LER. LER values greater than 1 are considered advantageous.

Results

Effect of planting density on the growth parameters of bambara groundnut and maize

All the variables analysed were significantly influenced by the sowing density (Table 3). The highest values of these variables were obtained with the highest plant density of bambara groundnut and decreased with decreasing of bambara densities. Bambara groundnut seed yield was higher in the high density than in the low density. Six variables analysed were significantly influenced by the sowing density on the maize (Table 4). The highest values of the weight of dry seeds (PGR) and the diameter of ear (DES) were obtained at the highest plant density of bambara groundnut and decreased with increasing corn densities. No significant difference was found between the three densities for the seed harvest index and largest diameter of ear and the heaviest seeds were observed with increasing bambara densities.

Table 1. Method of Measurement of Yield and yield components of bambara groundnut in response to plant density and landraces.

Yield and yield components	Measurement approach and sample size per plot
Yield: YLD (t ha−1)	Recordedat12±2% moisture content of seeds, on the yield of each treatment
Plant dry matter: PDM	Recorded at harvest, after drying plants until constant weight, on 30 plants randomly selected in each treatment
Plant spread: PS (cm)	Recorded 10 weeks after sowing; average of 30 plants randomly selected in each replicate plot. The estimate is the widest length between two opposite points
Plant height: PH (cm)	Measured from the ground level (at the base of the plant) to the tip of the highest point, including the terminal leaflet. Recorded 10 weeks after sowing; average of 30 plants randomly selected in each replicate plot
Number of leaves per plant: NLP	Direct counting, six weeks after first flowering on 30 plants randomly selected in each treatment
Number of pods per plants: NPP	Direct counting at harvest on 30 plants randomly selected in each treatment
Number of seeds per plant: NSP	Direct counting at harvest; average of 30 plants randomly selected in each treatment
Pods weight per plant: PWP (g)	Recorded at harvest, after drying pods to constant weight, on 30 plants randomly selected in each treatment
Seeds weight per plant: SWP (g)	Recorded at harvest, after drying seeds at 12±2% moisture, on 30 plants randomly selected in each treatment
Pod fill ration: PFR	Calculated on 5 sets of 50 seeds per treatment, by subtracting the seed weight from the corresponding pod weight and dividing the result by the pod weight
Seed harvest index: SHI	Ratio between seeds yield and plants' total biomass. Recorded on 30 plants randomly selected in each treatment bean yield and harvest components

Table 2. Method of Measurement of Yield and yield components of maize in response to plant density and landraces.

Yield and yield components	Measurement approach and sample size per plot
Plant dry matter: PDM	Recorded at harvest, after drying plants until constant weight, on 30 plants randomly selected in each treatment
Weight of dry ear : PES (g)	The average weight of dry ear was given. It was given on 30 ears
Length of ear : LE (cm)	The length of dry ear was measured. It was given on 30 ears
Diameter of ear : DE (cm)	The average diameter of dry ear was measured. Measurements were made on 30 ears
Seeds weight per plant: PGr (g)	Recorded at harvest, after drying seeds at 12±2% moisture, on 30 plants randomly selected in each treatment
Yield: YLD (t ha−1)	Recordedat12±2% moisture content of seeds, on the yield of each treatment
Seed harvest index: InR	Ratio between seeds yield and plants' total biomass. Recorded on 30 plants randomly selected in each treatment bean yield and harvest components
Length / Diameter: L/d	The relationship between the lengths of ear on the diameter of ear considered. It was given on 30 ears resulting each one from a plant

Effect of space provision on the growth parameters of bambara groundnut and maize

The influence of spatial distribution was observed on five of the eleven analyzed characters (Table 5). The biomass dries (PDM), the scale of the plant (PS), the number of pods (NPP) and of seeds (PWP), the rate of filling (TxR) and the index of harvest (SHI) did not make the difference on the two spatials distribution. Four characters gave the highest values with the provision on line. They are the seed yield (Rdt), the height of the plant (Hau), the weight of the pods dries (NPP) and the weight of the seeds (PGr). On the other hand, the greatest number of leaves was observed at the disposal in the same row. Four of the eight characters analyzed on maize were influenced by the space provision (Table 6). The seed yield, the weight of the dry plant, the index of harvest and the length report/ratio on diameter did not show a difference between the two space provisions. The length of dry ear, the diameter of dry ear and the weight of seeds are higher when sowing was made in the different row. On the other hand, the dry ear heaviest was observed with the provision in the same row.

Table 3. Yield and yield components as affected by sowing density of bambara groundnut.

	Mean (± SD) according to sowing density			ANOVA results	
yield components	25%M/75%B	50%M/50%B	75%M/25%B	*F*	*P*
YLD (t/ha)	1,03±0,31^{c}	0,29±0,05^{b}	0,12±0,01^{a}	3,07	<0,001
PDM (t/ha)	0,79±5,75^{c}	0,26±6,63^{b}	0,18±4,94^{a}	19,49	<0,001
PS (cm)	62,92±4,27^{c}	57,47±6,74^{b}	52,82±7,33^{a}	26,08	<0,001
PH (cm)	31,37±3,07^{b}	30,15±3,00^{b}	28,00±3,84^{a}	10,52	<0,001
NLP	127,07±23,8^{c}	93,85±25,3^{b}	76,02±16,6^{a}	54,16	<0,001
NPP	49,85±18,79^{c}	26,00±8,48^{b}	19,97±6,59^{a}	63,88	<0,001
NSP	50,25±18,7^{c}	26,15±8,66^{b}	20,07±6,6^{a}	65,23	<0,001
PWP (g)	46,05±17,98^{c}	20,15±7,27^{b}	16,79±6,92^{a}	72,52	<0,001
SWP (g)	34,56±13,46^{c}	14,71±5,42^{b}	12,62±5,14^{a}	74,18	<0,001
PFR	0,55±0,10^{b}	0,38±0,12^{a}	0,40±0,10^{a}	23,8	<0,001
SHI	0,74±0,03^{b}	0,72±0,04^{a}	0,74±0,04^{b}	2,97	0,041

Yield (YLD), Plant dry matter (PDM), Plant spread (PS), Plant height (PH), Number of leaves per plant (NLP), Number of pods per plants (NPP), Number of seeds per plant (NSP), Pods weight per plant (PWP), Seeds weight per plant (SWP), Pod fill ration (PFR), Seed harvest index (SHI)

Mean values within rows by parameter followed by the same superscripted letter were not significantly different at $p = 0.05$ level, on the basis of the least significant difference test.

Table 4. Yield and yield components as affected by sowing density of maize.

	Mean (± SD) according to sowing density			ANOVA results	
yield components	25%M/75%B	50%M/50%B	75%M/25%B	*F*	*P*
Yield (t/ha)	1,26±0,10^{a}	2,16±0,08^{b}	2,64±0,14^{c}	6,10	0,005
PDM (g)	125,00±33,96^{b}	138,87±64,06^{b}	87,50±43,11^{a}	11,91	<0,001
PES (g)	183,75±66,15^{b}	185,75±62,94^{b}	131,25±112,4^{a}	5,46	<0,001
LE (cm)	15,25±0,89^{b}	15,00±1,17^{b}	14,15±1,12^{a}	11,56	<0,001
DE (cm)	15,80±2,30^{c}	14,77±2,13^{b}	13,17±1,89^{a}	15,66	<0,001
PGr (g)	126,75±34,98^{c}	108,25±25,95^{b}	88,12±29,45^{a}	16,20	<0,001
InR	0,50±0,10	0,46±0,14	0,51±0,12	1,91	0,153
L/d	0,98±0,12^{b}	1,02±0,14^{b}	0,86±0,46^{a}	3,33	<0,001

Yield (YLD), Plant dry matter (PDM), Weight of dry ear (PES), Length of ear (LE), Diameter of ear (DE), Seeds weight per plant (PGr), Seed harvest index (InR), Length / Diameter (L/d)

Mean values within rows by parameter followed by the same superscripted letter were not significantly different at $p = 0.05$ level, on the basis of the least significant difference test.

Evaluation of the biological effectiveness of bambara groundnut and maize

The land equivalent ratio (LER) values of bambara groundnut and corn intercropped at three different planting densities and the space provision are presented in Table 7. All intercrop combinations had LER greater than unity. The LER of bambara groundnut increased with decreased planting density of corn, while the LER of the corn decreased with increased planting density of bambara groundnut. The LER values declined with declining planting densities of bambara groundnut. The greatest value of the LER on the bambara groundnut was obtained in intercrop 75B/25C in the same line and weakest with association 25B/75C in checkerwork. The highest value on corn was observed in intercrop 25B/75C. The total LER highest was observed with association 75B/25C in the different row.

Table 5. Yield and yield components as affected by space provision of bambara groundnut.

	Mean (± SD) according to space provision		ANOVA results	
Yield and yield components	Same row	Different row	*F*	*P*
YLD (t/ha)	0,40±0,37	0,55±0,46	4,46	0,033
PDM (t/ha)	0,39±0,29	0,40±0,25	0,02	0,880
PS (cm)	58,26±6,07	58,26±7,25	2,01	0,157
PH (cm)	27,24±2,92	27,57±3,32	45,83	<0,001
NLP	132,23±40,47	113,33±34,16	45,83	<0,001
NPP	45,63±27,94	47,49±25,24	0,88	0,34
NSP	27,21±13,65	29,38±16,24	3,77	0,052
PWP (g)	25,36±12,07	28,86±15,72	5,72	0,017
SWP (g)	20,54±9,37	23,57±11,43	15,05	<0,001
PFR	0,72±0,06	0,74±0,15	2,51	0,113
SHI	0,52±0,14	0,54±0,14	2,05	0,152

Yield (YLD), Plant dry matter (PDM), Plant spread (PS), Plant height (PH), Number of leaves per plant (NLP), Number of pods per plants (NPP), Number of seeds per plant (NSP), Pods weight per plant (PWP), Seeds weight per plant (SWP), Pod fill ration (PFR), Seed harvest index (SHI)
The abbreviations are defined in Table 1.
Means per space provision were calculated independently of sowing density.

Discussion

The statistical tests carried out showed a significant difference between the three densities for the seed yield. Increasing crop plant densities did not increase bambara groundnut seed yield. The correlations between the components were all negative, particularly between maize plant density and bambara yield parameters. This result was explained by the fact that maize is taller than groundnut and thus aggravates competition for nutrients by reducing light availability for the bambara groundnut. The high proportions of corn depressed bambara groundnut growth as evidenced by the dry matter production and consequently the grain yield. This negative influence of the vegetable cover of corn had already been reported at groundnut by Nambiar *et al.* (1983) and at the bambara by Karikari *et al.* (1999). These authors showed that in various type of associations, when the proportion of corn is raised, the quantity of light which arrives to groundnut is very limited, thus reducing photosynthesis. That reduction of the photosynthetic activity decreases the metabolism of the plant and consequently, a weak production of the dry matter causes. These observations were also evoked by Tsubo *et al.* (2003), Ghosh (2004) and Muoneke *et al.* (2007) respectively in association corn-bean, corn-groundnut and corn-soya.

When the number of feet of corn is weak, the number of pods, the seed yield of bambara groundnut and the weight of seeds of corn are very high. This was indicated by the higher dry matter production of bambara groundnut. There was no depression of grain yield by maize on bambara groundnut. That may be explained by the fact that the densities of corn were weak and has smaller and more vertically disposed leaves and therefore allowed greater light penetration into the lower canopy strata. The output raised out of seeds of corn would be due to a great production of the biomass of the leguminous plant (bambara groundnut). That production of biomass could put for the cereal a small quantity of nitrogen (Brophy *et al.*, 1987). Karikari *et al.* (1999) in a study of association bambara groundnut with several cereals (millet, sorghum and corn), showed that the seed yield of the bambara groundnut increase when their proportion increase. During this study, these authors also showed that the weight of 100 seeds of corn is higher in strong density of bambara groundnut.

Table 6. Yield and yield components as affected by space provision of maize.

	Mean (± SD) according to space provision		ANOVA results	
Yield and yield components	Same row	Different row	*F*	*P*
Yield (t/ha)	2,66±1,38	2,88±1,34	2,56	0,106
PGr (g)	126,63±41,89	137,91±45,88	11,86	<0,001
PDM (g)	305,19±241,32	333,13±222,36	2,61	0,166
PES (g)	196,73±67,93	133,10±104,42	93,92	<0,001
LE (cm)	15,43±2,29	15,52±112,58	189,03	<0,001
DE (cm)	14,67±1,80	18,60±20,70	12,84	<0,001
SHI InR	0,67±0,49	0,65±0,55	0,23	0,628
L/d	1,06±0,17	1,05±0,52	0,01	0,934

The abbreviations are defined in Table 2.

Yield (YLD), Seeds weight per plant (PGr),Plant dry matter (PDM), Weight of dry ear (PES), Length of ear (LE), Diameter of ear (DE) , , Seed harvest index (SHI), Length / Diameter (L/d)

Means per space provision were calculated independently of sowing density.

The average values of the seed yields of the bambara groundnut are higher in association in the different row than association in the same row. This provision appears more advantageous for the bambara groundnut. The arrangement of the associated species in distinct band allowed a better production out of seeds of the bambara groundnut, contrary at their disposal in the same row. This result could be explained by the fact that the sheets of the corn do not cover the bambara groundnut. This provision allows a good transmission of the light of the plant of small size (Tsubo *et al.*, 2001, Tsubo *et al.*, 2003). The distribution of the light between the components of farming association plays a major role in the photosynthetic capacity and the energy balance of each plant (Tournebize *et al.*, 1996).

Table 7. LER as affected by space provision of the two species.

	Mean (± SD) according to LER		
Treatments	LER bambara groundnut	LER Maïs	LER Total
25%M/75%B same row	0,83	0,32	1,15
25%M/75%B different row	0,97	0,37	1,34
50%M/50%B same row	0,32	0,70	1,02
50%M/50%B different row	0,36	0,73	1,09
75%M/25%B same row	0,13	0,95	1,08
75%M/25%B different row	0,14	0,95	1,09

Means per LER were calculated independently of sowing density and space provision, LER= land equivalent ratio, M= Mays ,B = Bambara groundnut.

The increase efficiency of the bambara groundnut-maize intercrop and the corresponding high LER occurred because bambara groundnut was able to produce almost the equivalent of a full sole crop yield while growing in only 25M/75V ratios. This result would be explained by a weak interspecific competition for the resources. This weak competition involved a better allocation of resources available (Rout *et al.*, 1990, Agbaje *et al.*, 2002). Various associations are thus qualified the advantageous

(Mazaheri *et al.*, 2006, Adeniyan *et al.* 2007, Muoneke *et al.*, 2007). The beneficial effect of the association of leguminous plants with corn had been also observed by Goran and Guessan (1999). These authors showed that the corn associated with groundnut increase the yield of corn.

Conclusion

The biological effectiveness of association maize-bambara groundnut expressed in LER can also be improved by laying out the components in alternating band. This effectiveness is more significant when the maize is sown with a proportion of 25%. The integration of herbaceous leguminous plants in the farming systems in Côte d'Ivoire could thus made up a way of improvement of the output of the cereal culture.

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