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Effect of row spatial arrangements on agromorphological responses of maize (*Zea mays* L.) and cowpea [*Vigna unguiculata* (L.) Walp] in an intercropping system in Southern Cote d'Ivoire

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Field trials were conducted at the University Nangui Abrogoua, Abidjan, southern Cote d'Ivoire during the 2015 and 2016 short rainy season to study the performance of maize (*Zea mays* L.) and cowpea [*Vigna unguiculata* (L.) Walp] intercrop as influenced by row arrangement. A randomized complete block design (RCBD) with five treatments (SM; SC; MC; 1M1C and 2M4C) and three replications was used. SM was sole maize, SC was sole cowpea, MC was intra-line pattern, 1M:1C was inter-line pattern and 2M4C was strip-intercropping maize-cowpea. The results revealed that there were significant effects of cropping patterns on growth and yield components of maize and cowpea crops. Among the cropping systems studied during both years growing seasons 2015 and 2016, the highest yield advantage for cowpea and maize (land equivalent ratio = 1.62; 1.10) was obtained from intercropping pattern 2M:C4. The observed Land equivalent ratio (LER) values correspond to 38.27 and 9.90 % of lands saved which could be used for other agricultural purposes. With this cropping pattern, land equivalent coefficient (LEC) values (0.62 and 0.30) indicated that, greatest productivity per unit area was achieved by growing the two crops together. In this cropping pattern, both crops were highly complementary and most suitable in mixture as confirmed by competitive ratio (CR) values of 0.72.

Key words: Crop row arrangement, yield component, maize, cowpea, system productivity.

INTRODUCTION

During the recent decades, food requirements have increased sharply, while the availability of cultivated land has decreased considerably. Thus, the increase in yield per unit area remains the main way of increasing agricultural production. Due to this high pressure of food, agriculture is now intensive with high inputs in irrigation, seeds and chemicals. This has caused serious environmental problems (Zhang et al., 2004), including groundwater pollution by soil nitrates (Ju et al., 2006), the emission of gases into the air (Zhang et al., 2012) and soil acidification (Blumenberg et al., 2014). To ensure food security and environmental quality, it is essential to search best management practices which involve suitable cropping systems that can efficiently utilize solar and soil resources with minimum nutrient inputs.

In cropping systems, there are often two or more crop species grown in the same field for a certain period of time, even though the crops are not necessarily sown or harvested simultaneously. In practice, most intercropping systems involve only two crops, as inclusion of more crops results in higher labor costs (Wu and Wu, 2014).

Traditionally, small farmers used intercropping to increase the density of their products and to ensure the stability of their output. The success of intercropping systems is due to an enhanced temporal and spatial complementarity of resource capture, for which both above-ground and belowground parts of crops play an important role (Midega et al., 2014).

Cereal crops intercropping with legumes are a popular option in intercropping. Even though the two crops compete for soil N as they both need it for the growth, the competition drives legumes to fix atmospheric N_2 in symbiosis with Rhizobium (Caviglia et al., 2011). This actually results in complementary utilization of N by the crops, which is of particular importance in soils where inorganic N is limited or over-fertilized.

Numerous studies have reported that intercropping can increase crop yield (Zhang et al., 2007) because of efficient utilization of nutrients (Zhang and Li, 2003) and light (Zuo and Zhang, 2008), and enhanced positive interactions between crops (Betencourt et al., 2012). However, most of these studies were focused on effects of different intercrop species (Zhang and Li, 2003). Despite the importance of intercropping, very few reports are found in the literature concerning the effect of the pattern of intercropping system on the growth parameters and productivity of the component species. The available data refer mainly to plant resources availability, planting date (Maurice et al., 2010) and plant density (Ewansiha et al., 2015). Thus, rare studies have been undergone to investigate effects of ratio of rows between crops within a specific intercropping system.

Row arrangement is one of the important management tools that could be explored to minimize competitive pressure created by a component crop in an intercropping system (Maluleke et al., 2004).

The management of mixed crops in the traditional agricultural systems of Cote d'Ivoire is unpredictable and without sufficient attempt to model crops for an effective interception of essential resources. There is neither report in literature about optimum row ratio of maize intercropping with cowpea, nor explanation of the processes behind. Therefore, the objective of this study was to investigate the effects of row arrangement on the growth and yield of the maize and cowpea crops, in intercropping trials at University Nangui Abrogoua. Information on these subjects is essential for a better understanding of the system that will help management decisions.

MATERIALS AND METHODS

Description of the study site

The experiment was conducted during the 2015 and 2016 short rainy season at the research farm of the Natural Sciences Unit of Formation and Research (UFR SN), University Nangui Abrogoua, (5°23 N latitude, 4°11 W longitude and 100 m above the sea) in the southern of Cote d'Ivoire. The site is characterized by two rainy seasons and dry seasons.

The first and second growing seasons (herewith referred to as long and short rainy season, respectively) last typically from March to July and October to November, respectively. A short dry spell occurs from August to September. The major dry season starts in December and lasts through end of February or beginning of March. The total rainfall registered was 2161.86 and 1433.34 mm and the average annual temperature was 26.7 and 27°C in 2015 and 2016, respectively (Figure 1).

Plant material, experimental design and treatments

Maize cultivar "EV8728" (early-maturing, 90 to100 days) and cowpea cultivar "Touba" (early maturing, erected) were used in this study. Both seeds were obtained from the National Center of Agronomic Research (CNRA), Korhogo Regional Office (Cote d'Ivoire). Experiments were carried out from September to December 2015 and 2016 and were arranged each year in randomized complete blocks design (RCBD) with three replications which included five treatments with different planting patterns. A constant 75 x 50 cm inter and intra-row spacing, respectively, was maintained in both cropping systems. Experimental plots used for this study were 15 m^2 (3 × 5 m) sizes each.

The treatments were: maize and cowpea in sole culture (SM, SC) population (49231 plants/ha), maize and cowpea in intra-row pattern M:C (maize holes alternating with those of cowpea) population (24615 plants/ha), maize and cowpea in single-line pattern 1M:1C (a line of maize alternating with a cowpea line) population (24615 plants/ha) and strip-intercropping maize-cowpea 2M:4C (2 rows of maize alternating with 4 rows of cowpea) population (19692 maize plants/ha and 29538 cowpea plants/ha). Before the start of the study in September 2015, soil was sampled randomly in the field by using a soil auger to determine basic

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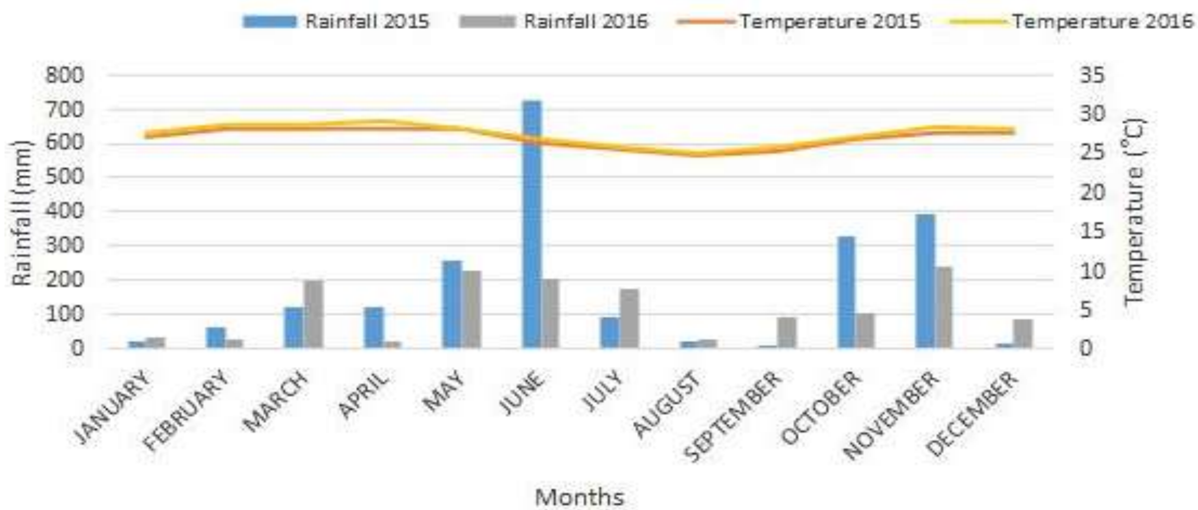

Figure 1. Monthly precipitation (bar) and air temperature (curve) of the experimental site in 2015 and 2016 (Source: www.tutiempo.net)

physical and chemical properties of soil.

Agronomic practices

Three maize seeds were sown per hole and later thinned to one plant per stand at two weeks after planting (WAP). Cowpea seeds were sown at six weeks after maize was sown. Four seeds of cowpea were sown and later thinned to two plants per stand at two WAP. Cowpea was harvested when the pods turned brown and seeds were at the hard-dough stage, which indicated that moisture content is between 14 and 16% (Dugje et al., 2009). Maize was harvested when the signs of senescence appeared at cob maturity (Ijoyah and Jimba, 2012).

Data collection and analysis

Measurement of plant growth parameters and yield and yield components

To determine the response of maize and cowpea crop in row arrangement intercropping, data were collected on growth parameters, yield and yield components, vis., plant height (PH), stem diameter (SD), leaf area (LA), total above-ground biomass (TB), 100-seeds weight (100 SW) and total grain yields (TGY).

Leaf area of cowpea (LAC) was calculated by the formula: 0.662 x $L^{0.952}$ x $l^{1.052}$ (Dagba, 1974). Leaf area of maize (LAm) was calculated by the formula: L x l x 0.75 (Bonhomme et al., 1982).

Assessment of the advantages of maize/cowpea intercropping system

Land equivalent ratio: Land equivalent ratio (LER) is the most common index adopted in intercropping to measure the land productivity. The LER is a standardized index that is defined as the relative area required by sole crops to produce the same yield as intercrops (Mead and Willey, 1980). The LER is the ratio of land required by pure (sole) crop to produce the same yield, where intercrop was determined according to the following formula:

LER = Ym-ic/Ym-sc + Yn-ic/Yn-sc
Ym-ic = intercropped yield of maize;
Ym-sc = sole yield of maize;
Yn-ic = intercropped yield of cowpea;
Yn-sc = sole yield of cowpea;

If LER is greater than 1.00, there is a yield advantage by intercropping; otherwise there is no yield advantage. The data on land equivalent coefficient (LEC) and percentage land saved were determined as described by Ijoyah et al. (2013) and Workayehu (2014) using the formulae below:

LEC = LERm × LERc

Where LERm is the partial LER of maize and LERc is the partial LER of cowpea

Land saved (%) =100 − (1/LER×100)

The competitive ratio (CR) as described by Willey and Rao (1980) was determined using the formula: CR = Lm/Lc, where Lm: Partial LER for maize; Lc: Partial LER for cowpea. Data collected were subjected to analysis of variance (ANOVA) using the software Statistica version 7.1. Differences between treatment means were separated using the Newman-Keuls test procedure at 95% confidence interval.

RESULTS

Physico-chemical characteristics of the soil of the experiment site

Physico-chemical analysis of the soil samples collected

Table 1. Physical and chemical properties of the experimental soil.

Components	values
pH	4.83
N(%)	0.37
NO_3 (méq/100g)	0.05
C (%)	1.91
K (%)	0.12
Na (%)	0.02
Ca (%)	0.02
P (%)	0.16
Mg (méq/100g)	0.26
CEC (méq/100g)	1.43

at 0 to 30 cm soil depth indicated that, the soil reaction was acidic with pH values of 4.83. In both trials Total nitrogen (N) content, organic carbon (C), potassium (K) and available phosphorus (P) were high. Cation exchange capacity (CEC) and exchangeable bases (Na, Ca and Mg) were low (Table 1).

Effect of cropping systems on the growth of maize and cowpea plants

The growth of maize and cowpea plants evaluated in terms of plant height, stem diameter and leaf area is recorded in Table 2. The analysis of the results showed that plants height of maize in sole culture during the 2015 and 2016 rainy short seasons was significantly lower than those of the plants in intercropping systems with the cowpea.

The tallest plants were observed in cropping system M: C (intra row). With cowpea, the results obtained in 2015 revealed that the plant height was increased in 1M: 1C maize: cowpea intercrops (37.46 cm) but was reduced in MC (32.50 cm) and 2M: 4C (32.33 cm) cropping patterns. In year 2016, no statistical difference was noted in the cowpea plant height under monocropping and the cropping systems 1M: 1C and 2M: 4C. The highest cowpea plant height was obtained with M: C cropping system.

During the year 2015, monocropped maize gave the same stem diameter (8.25 cm) compared to those obtained with M: C maize: cowpea intercrop (8.30 cm) and 1M: 1C maize: cowpea intercrop (8.72 cm). These values were significantly higher than the stem diameter of maize plant obtained in 2M: 4C maize: cowpea intercrops (7.44 cm). Compared to maize monoculture achieved during the year 2016, an increasing of plant stem diameter was recorded with M: C (20.53 cm); 1M: 1C (19.9 cm) and 2M: 4C (19.54 cm) cropping systems.

In both years, measurements of cowpea plant stem diameter revealed that values obtained with 1M: 1C maize: cowpea intercrops (9.09 and 6.36 cm) were statistical higher than that observed with the other cropping systems.

In contrary to 2015 where a decrease was reported in maize leaf area with the cropping systems M: C, 1M: 1C and 2M: 4C, an increase of the leaf area in these cropping systems was observed during the 2016 short rainy season, comparing to the monocropped maize. No statistical difference was noticed between these cropping systems. In cowpea, increasing of leaf area was obtained with the M: C and 1M: 1C cropping systems during the 2015 and 2016 short rainy season.

Effect of cropping systems on the yield and yield components of maize and cowpea

Yield and yield components of maize and cowpea as a sole crop and in intercrop at Abidjan, in 2015 and 2016 cropping seasons are given in Table 3. Compared to the tested cropping systems, lowest total above-ground biomass was recorded with monocropped maize (58.80 g) during 2015 growing season. In 2016, highest total above-ground biomass was obtained with M: C and 2M: 4C cropping patterns and the lowest were observed with 1M: 1C cropping pattern.

Total above-ground biomass obtained in 2015 with monocropped cowpea (23.08 g) was not statistically different to those recorded with the cropping systems M: C (24.77 g) and 2M: 4C (20.88 g). But these values were lower than that observed with 1M: 1C maize-cowpea (29.00 g). The cropping pattern 1M:1C (28.54 g) followed by 2M:4C (20.00 g) produced during 2016 short rainy season, a total above-ground biomass significantly superior than those of cowpea monoculture (19.06 g) and MC maize-cowpea intercropped (16.57 g).

Concerning 100 seeds weight, no significant difference was observed between monocropped maize (15.87 g) and the maize-cowpea cropping systems MC (14.35 g) and 2M:4C (15.71 g) in 2015. But these values were lowest than that of 1M: 1C cropping pattern (16.02 g). During this same year, an increase in one hundred seeds weight was obtained with MC (14.26 g) and 1M:1C (14.29 g) cropping systems compared to sole cowpea (13.21 g) and 2M:4C maize-cowpea intercropped (13.24 g). The cropping patterns MC (20.57 g) and 2M: 4C (20.56 g) increased maize to one hundred seeds weight during 2016 rainy season. On the other hand, no statistical difference was observed between the cropping systems tested and the cowpea monoculture.

During the 2015 and 2016 growing seasons, all the cropping systems studied, decreased the grain yield of maize and cowpea in pure culture. In 2016, planting maize and cowpea in M: C, 1M: 1C or 2M: 4C arrangement, depressed grain yield of maize by 55.30,

Table 2. Effect of cropping pattern on maize and cowpea plant height, stem diameter and leaf area during the short rainy seasons of 2015 and 2016 in Abidjan.

Cropping systems	Plant height (cm)				Stem diameter (cm)				Leaf area (cm)			
	2015		2016		2015		2016		2015		2016	
	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea
Sole	118.75± 8.54[c]	35± 2.59[b]	102.84 ± 14.10[d]	28.95 ± 3.53[b]	8.25 ± 1.25[a]	7.64 ± 0.72[b]	16.20 ± 1.53[b]	5.37 ± 1.00[b]	283.44 ± 14.44[a]	58.41 ± 10.50[b]	318.76 ± 17.016[b]	59.93 ± 7.95[b]
M : C	140.0 ± 11.46[a]	32.50 ± 2.16[c]	131.27± 6.93[a]	32.88± 4.3[a]	8.30 ± 0.00[a]	5.226 ± 0.85[c]	20.53 ± 2.70[a]	4.897 ± 0.78[c]	219.23 ± 14.99[b]	69.41 ± 10.62[a]	447.97 ± 23.93[a]	70.67 ± 11.24[a]
1M : 1C	127.66 ± 0.5[b]	37.46± 1.11[a]	115.6± 6.51[c]	28.73 ± 3.59[b]	8.72 ± 0.91[a]	9.09 ± 0.2[a]	19.94 ± 2.1[a]	6.36 ± 1.26[a]	269.73 ± 9.48[a]	69.41 ± 5.54[a]	391.04 ± 21.3[a]	69.79 ± 4.07[a]
2M : 4C	132.66 ± 12.43[b]	32.333 ± 0.5[c]	124.32± 10.25[b]	30.02 ± 4.59[b]	7.44 ± 0.5[b]	7.92 ± 1.84[b]	19.54 ± 2.05[a]	5.39 ± 0.71[b]	189.47 ± 14.63[c]	60.01 ± 8.68[b]	416.487 ± 26.4[a]	61.696 ± 10.61[b]

In the same column, the figures followed by the same letters are statistically identical (Newman-Keuls, 5%). M: C (intra row); 1M: 1C (inter row); 2M: 4C (2 rows of maize alternating with 4 rows of cowpea).

Table 3. Effect of cropping pattern on maize and cowpea total above-ground biomass, 100-seeds weight and total grain yields during the short rainy seasons of 2015 and 2016 in Abidjan.

Cropping systems	Total above-ground biomass (g)				100-seeds weight (g)				Total grain yields (kg/ha)			
	2015		2016		2015		2016		2015		2016	
	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea	Maize	Cowpea
Sole	59.92 ± 2.79[d]	23.08± 2.02[b]	57.67 ± 4.69[b]	19.06 ± 1.6[c]	15.87± 1.1[b]	13.21± 1.94[b]	16.38 ± 0.78[b]	12.26 ± 7.05[a]	180.4 ± 14.44[a]	217.69 ± 10.50[a]	500.87 ± 17.016[a]	458.57± 7.95[a]
M : C	86.45 ± 0.87[c]	24.77± 2.10[b]	74.5± 12.19[a]	16.57± 0.91[c]	14.35 ± 1.33[b]	14.26± 1.39[a]	20.57± 2.39[a]	11.76± 0.95[a]	139.40 ± 0.1[b]	172.15 ± 3.00[b]	223.88± 10.26[b]	228.07± 37[d]
1M : 1C	96.04 ± 2.5[b]	29.00± 4.8[a]	48.79± 5.73[c]	28.54± 1.26[a]	16.02± 1.06[a]	14.29± 1.32[a]	15.5± 0.83[b]	12.77 ± 1.05[a]	85.21 ± 3.00[c]	164.3 ± 17.95[b]	181.89± 17.03[c]	261.01± 16.36[c]
2M : 4C	106.39 ± 5.20[a]	20.88 ± 10.53[b]	72.94± 5.62[a]	20.00± 2.7[b]	15.71 ± 0.61[b]	13.24 ± 2.83[b]	20.56± 3.65[a]	11.53± 1.14[a]	182.18 ± 6.00[a]	134.35 ± 7.65[c]	231.22± 10.6[b]	292.78 ± 32.13[b]

In the same column, the figures followed by the same letters are statistically identical (Newman-Keuls, 5%). M: C (intra row); 1M: 1C (inter row); 2M: 4C (2 rows of maize alternating with 4 rows of cowpea).

Table 4. Land productivity potential in maize-cowpea intercropping during the 2015 and 2016 short rainy seasons in Abidjan.

Cropping systems	Total grain yields (kg/ha)		LERm		LERc		LER		LEC		CR		Land saved (%)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Sole maize	180.4	500.87	-	-	-	-	-	-	-	-	-	-	-	-
Sole cowpea	217.69	458.57	-	-	-	-	-	-	-	-	-	-	-	-
Maize M:C	139.40	223.88	0.77(49%)	0.47(48.45%)	-	-	-	-	-	-	-	-	-	-
Maize1M:1C	85.21	181.89	0.47(38.52%)	0.36(38.71%)	-	-	-	-	-	-	-	-	-	-
Maize 2M:4C	182.18	231.22	1.00(61.73%)	0.46(41.81%)	-	-	-	-	-	-	-	-	-	-
Cowpea M:C	172.15	228.07	-	-	0.80(50.95%)	0.50(51.54%)	-	-	-	-	-	-	-	-
Cowpea 1M:1C	164.3	261.01	-	-	0.75(61.47%)	0.57(61.63%)	-	-	-	-	-	-	-	-
Cowpea 2M:4C	134.35	292.78	-	-	0.62(38.2 %)	0.64(58.18%)	-	-	-	-	-	-	-	-
M:C	-	-	-	-	-	-	1.57	0.97	0.61	0.23	0.96	0.94	36.30	-3.1
1M:1C	-	-	-	-	-	-	1.22	0.93	0.35	0.20	0.62	0.20	18.03	-7.5
2M:4C	-	-	-	-	-	-	1.62	1.10	0.62	0.30	1.61	0.72	38.27	9.90

63.68 and 53.83%, respectively, and cowpea yield by 50.26, 43.08 and 36.15%, respectively.

Productivity of Maize-Cowpea Intercropping

The results of the effect of intercropping systems on land productivity potential are presented in Table 4. Analysis of these results has shown that in year 2015, the cropping systems (maize-cowpea) namely, MC, 1M1C and 2M: 4C gave respectively LER values of 1.57, 1.22 and 1.62. With these LER values, 36.30, 18.03 and 38.27% of lands were saved, which could be used for other agricultural purposes.

In year 2016, a reduction of the LER was observed with the values of 0.97, 0.93 and 1.10, respectively with MC, 1M1C and 2M: 4C cropping systems. Among these cropping systems, land was only saved (9.90%) with 2M: 4C intercropped maize-cowpea.

For year 2015, LEC values of 0.61, 0.35 and 0.62 were obtained in MC, 1M1C and 2M: 4C cropping systems, respectively. These values of LEC decreased in year 2016 to 0.23, 0.20 and 0.30, respectively for MC, 1M1C and 2M: 4C cropping systems

The CR between the two crops when inter-cropped during 2015 short rainy season were 0.96, 0.62 and 1.61 in MC, 1M: 1C and 2M: C cropping patterns, respectively. In year 2016, these values were 0.94, 0.20 and 0.72.

DISCUSSION

Intercropping is one of the most common practices used in sustainable agricultural system which has an important role in increasing the productivity and stability of yield, in order to improve resource utilization and environmental factors (Qin et al., 2013).

In this study, growth, yield components and system productivity of maize and cowpea were estimated in a cropping patterns consisted of MC (intra row), 1M: 1C (inter row) and 2M: 4C (strip intercropping).

Effect of cropping systems on the growth of maize and cowpea plants

In our experimental conditions, growth parameters evaluated in the different cropping systems during the cropping season 2015 were higher than those for 2016. On the other hand, yield parameters recorded during the cropping season 2016 were higher than those in 2015.

These interactions might have been due to the differences in rainfall both in the amount and distribution between the two years, where there was a high amount of rainfall from October to November in 2015 compared to 2016. The rainfall differences may have caused cross ranking of maize and cowpea populations and cropping patterns between the two years. Moreover, the year-to year variation in temperature may have influenced cropping systems performance in the two different years. The differences observed in 1000-seed weight between the two cropping seasons could be attributed to the role of environment during seed development (Tang, 1982).

During the 2015 and 2016 short rainy seasons in Abidjan, the tallest mean plant height was observed from intercropped compared to monocropping maize and cowpea. This justifies the assertion that as the intra and inter row competition increases; so does the height of the plant linearly due to competition of natural resources. The height of maize plant under intercropping system was more than that in the sole maize due to competition of associated crops for intercepted light intensity, therefore leads to an increase in maize plant (Hamd Alla et al., 2014).

In line with this study, Lulie et al. (2016) reported that intercropping increased the plant height of maize as compared to monocropping. In contrary to our findings, Lemlem (2003) found that intercropping maize with cowpea reduced maize plant height as determined by environmental factors and competition between the two crops.

To our knowledge, leaf area (LA) is an important agronomic parameter which reflects crop growth and has great influence on crop yields (Fageria et al., 2006). The results on leaf area of maize plant in cropping systems compared to monoculture indicated a decrease and an increase, respectively during the cropping seasons 2015 and 2016. In cowpea, increasing of leaf area was obtained with the cropping systems during the 2015 and 2016 short rainy season. These results revealed that LA was affected by intercropping. Similar results were reported in intercropping Sorghum and Bambara groundnut (Karikari, 2000).

During the year 2015, intercropping decreases the leaf area of the maize crop; this is because, this could be influenced by high competition of the component crops and shading effect of maize over cowpea that leads to decreased photosynthetic capacity of the crops (Ali et al., 2003). Such a severe impact of intercropping on LA could be one of the major factors for the low yield, recorded by the cowpea component. The increasing LA of cowpea plant when intercrop with maize could be explained by the fact that, plants with different heights make more use of light when intercropped than when monocropped. The spatial advantage was due to the differences in the height of the cowpea and maize.

Effect of cropping systems on the yield and yield components of maize and cowpea

Above-ground, total biomass of maize varied depending on the cropping system. Generally, the resulted obtained in this study revealed that total above-ground biomass in cropping system was higher than that observed in sole culture. Contrary to our results, a decrease in total plant biomass of maize under maize/cowpea intercropping had been reported by Egbe et al. (2010).

One hundred seeds weight varied depend on the cropping patterns. Highest one hundred seeds weight was obtained with 1M: 1C cropping pattern in 2015. Singh et al. (2000) reported that 100 grain weight of maize was also increased by intercropping with legumes. On the other hand, there were no significant differences in the weight of one hundred seeds weight between treatments. This is in agreement with Chakma et al. (2011) who observed no significant difference in weight of 100 seed weight in a popcorn-mungbean/cowpea intercropping system.

All the cropping systems tested during this study decreased the grain yield of maize and cowpea in pure culture. The maximum grain yield was obtained from sole cropping system of maize and cowpea while the lower grain yield was maintained for intercropped maize-cowpea. This suggests lower intra-specific competition of sole maize and sole cowpea for natural resources (light, water and nutrients) compared to maize intercropped with cowpea.

Yield reduction in an intercropping could be due to a more extensive root system; particularly a larger mass of fine roots of maize which compete more for soil nutrients. Kheroar and Patra (2014), in line with this finding, reported that yield of intercrops were reduced by intercropping with maize that was caused due to receipt of lower amount of solar radiation.

The reduction in seed yield by intercropping could be due to interspecific competition and depressive effect of maize, as C4 species on cowpea as C3 crop. Crops with C4 photosynthetic pathways such as maize have been known to be dominant when intercropped with C3 crops like cowpea.

System productivity

The productivity of intercropping maize with cowpea in the present study was assessed using LER and related attributes described in previous sections. According to Workayehu (2014), when LER < 1 there is obvious disadvantage of the intercropping and the available resources are used more efficiently by the sole crop than may be used by the intercrop. In addition, Mariotti Ariotti et al. (2006) and Kitonyo et al. (2013) stressed that when LER = 1 there is no advantage or disadvantage of the intercropping in respect to sole crop but when LER > 1, an intercropping warrants an advantage in terms of the improved use of available resources for plant growth and development.

During the cropping season 2015, the total LER of the different cropping systems were greater than 1 which shows an advantage of intercropping maize with cowpea compared with growing each crop. In other words, these results signify that it is advantageous having both crops in mixture than growing them separately. This could be due to greater efficiency of resource utilization in intercropping.

The highest yield advantage for cowpea and maize (LER=1.62) was obtained from intercropping pattern 2M: C4. The observed LER values correspond to 36.30, 18.03 and 38.27% of lands saved, could be used for other agricultural purposes. Similar to the results obtained in 2015 growing season, Ijoyah et al. (2013) found that 28.6 and 22.5% of lands were saved in two separate growing seasons of intercrops suggesting that these saved lands could be used for other production activities. According to Matusso et al. (2014), one of the most important reasons for intercropping is to ensure that an increased and diverse productivity per unit area is obtained compared to sole cropping.

In year 2016, a reduction of the LER was observed with the MC, 1M1C cropping systems with values < 1. LER values less than 1.0 indicate that there was an intercropping disadvantage at the MC and 1M1Ccroppins patterns, presumably due to high intra and inter specific competitions in the maize/cowpea intercropping. Thus, the available resources are used more efficiently by the sole crop than may be used by these intercropping systems. The LER reduction observed with the MC, 1M1C cropping systems would be linked to insufficient rainfall during the year 2016. However, the lower LER obtained in 2016 could also be explained by the findings of Ofori and Stem (1986) who reported that light is the most important factor determining LER of maize and soybean intercropping and LER declines, when legume becomes severely shaded.

In 2015, LEC values of 0.61, 0.35 and 0.62 were obtained in MC, 1M1C and 2M: 4C cropping systems, respectively. These values of LEC decreased in year 2016 to 0.23, 0.20 and 0.30, respectively for the MC, 1M1C and 2M: 4C cropping systems. LEC values which exceeded 0.25 indicate yield advantage of the intercropping systems MC, 1M1C and 2M: 4C during the same year.

But in 2016, yield advantage was only obtained with the 2M4C cropping system. Thus, the LER and LEC values obtained during both years 2015 and 2016, indicate that greatest productivity per unit area was achieved by growing the two crops together in 2M: 4C cropping system. In this cropping pattern, both crops were highly complementary and most suitable in mixture.

Willey and Rao (1980) suggested CR instead of "aggressivity" to indicate the degree that one species competes with the other in an intercrop system. The CR represents the ratio of individual LERs of the two intercropped components. The CR between the two crops when intercropped during 2015 short rainy season were 0.96, 0.62 and 1.61 in MC, 1M: 1C and 2M: C cropping patterns, respectively. In year 2016, these values were 0.94, 0.20 and 0.72, respectively. Excepted the cropping pattern 2M: 4C in 2015, CRs in this study were less than 1 in all intercrop treatments in both years. This index measures the existence of a yield advantage, such that if the competitive ratio is less than 1, then there is an advantage in intercropping (Reddy and Willey, 1981). Thus in this study, all intercropping patterns were advantageous over sole cropping.

Conclusion

For farmers who have limited sources, income and stability yield of agricultural systems is very important. Several crops grown together, fail to produce a product, could be compensated by other crop, and thereby reduce risk. Risk of agronomy, failure in multi cropping systems is lower than pure cropping systems. The results reported in this study showed that the optimal intercropping system was strip intercropping of 2 maize rows with 4 cowpea rows (2M: 4C), which had positive effects on yield and environment.

In general, even though yields of the intercrop components were lower than their sole crop counterparts, the intercrop components were more productive than the sole crop components as evidenced by the LERs and the land saved is obtained with the 2M: 4C cropping system. It can be concluded that in Abidjan a location within the Forest agro-ecological zone of Cote d'Ivoire, for higher yield, maize should be introduced with cowpea using cropping pattern 2M: 4C. It is however suggested that further investigation could be conducted across different agro ecological zones of Cote d'Ivoire.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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