

Effect of spatial arrangement on the performance of cowpea /maize intercrop in derived savannah of Nigeria

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Comment [E1]: Author's contribution?

Author's contribution: Adigbo, S.O conceptualizes the idea of the study. But the field layout was put in place by Adigbo, Iyasere and Fabunmi. The data collection and field maintenance were done by Iyasere while analysis and interpretation were done by Adigbo and Iyasere. Olowe, Fabunmi and Adejuyigbe contributed to literature, editing and useful suggestions

Abstract

Promising varieties of cowpea were found to be adaptable in the derived savannah; however, their performances in intercropping systems have not been investigated. A field experiment was conducted during the late cropping season at Federal College of Education, Osiele, Abeokuta in 2009 and 2010 to investigate the effect of spatial arrangement of maize/cowpea on the performance of maize and cowpea. The experiment was a 2 x 5 factorial in randomized complete block design. The intercrop proportion mixture and population adopted in this study were additive and replacement series while Oloyin and Sokoto cowpea varieties were combined with TZESR-W maize variety. The grain yield of cowpea obtained from alternate row intercrop and sole cowpea for 2009 and 2010 were similar. However, the grain yield of cowpea obtained from alternate row was 33, 37 and 59% higher than alternated stand, alternate row replacement and strip crop, respectively. Oloyin variety had significantly higher grain yield than Sokoto. Interaction of cowpea variety x spatial arrangement x cropping season was significant on 1000-seed weight. The two additive series had higher land equivalent ratio compared to replacement series. Maize yield was not affected in two additive series. In conclusion, intercrop was more productive than sole. The two additives arrangement enhances the performance grain yield of maize, Oloyin and Sokoto cowpea varieties.

Key words: intercrop, cowpea, maize, additive, replacement

1.0 Introduction

Cowpea (*Vigna unguiculata* (L) Walp) grain contain about 24% protein (Bressani, 1985), making it extremely valuable where people cannot afford animal protein from meat and fish. Cowpea is a major food legume in central and West Africa, where more than 60% of world cowpea were cultivated. The total world production of dry cowpea grain in 2002 was about 5 million tonnes from 14 million ha of which 64%

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37 was produced in west and central Africa. The dry savannah region of Nigeria (Northern Nigeria) alone
38 produce 2.1 million tonnes from 5 million ha (Grubben and Denton, 2004).

39 Most of the cowpea consumed in southern Nigeria (derived savannah) were produced and transported
40 from the northern part (dry savannah). Adigbo and Adigbo (2011) evaluated seven varieties in upland and
41 inland valley ecologies during the rainy and dry seasons, respectively and reported that the grain yields of
42 Oloyin, and Sokoto varieties were economically superior to the two improved varieties. But the
43 performances of these two varieties (Oloyin and Sokoto) have, however, not been investigated in
44 intercrop which is the common practice by majority of the farmers in the derived savannah.

45 Intercropping is the agricultural practices of cultivating two or more crops in the same period of time.
46 Cowpea is mainly grown in mixtures with other crops and a great diversity of crop mixtures has been
47 reported (Mortimore *et al.* 1997). Intercropping offers farmers the opportunities to engage nature's
48 principle of diversity on their farms. ~~Intercropping system proves to be a sustainable agricultural system~~
49 ~~that does not only moderate the environment but also maximizes productivity (Orji, 2003).~~

Comment [E2]: lack in the reference list

50 Nitrogen from legume fixation is essentially "free" N for use by the host plant or by associated or
51 subsequent crops. Replacing it with fertilizer N would cost \$7 to 10 billion annually, whereas even modest
52 use of alfalfa in rotation with corn could save farmers \$200 to 300 million (Peterson and Russelle, 1991).
53 The movement of potash from the legume root zone to the root zone of non-legume crops provides a
54 source of K (Allison, 1990). The most common goal of intercropping is to produce a greater yield on a
55 given piece of land by making use of resources that would otherwise not be utilized by a single crop.

56 Spatial arrangement of component crops is one of the most important agronomic factors that determine
57 whether an intercrop system will be advantageous or not with regard to yield gains (Natarajan and
58 Shumba, 1999). Row arrangement, in contrast to arrangement of component crops within rows (farmers'
59 practice), improved the amount of light transmitted to the lower legume. ~~Such arrangements can enhance~~
60 ~~legume yields and efficiency in cereal/legume intercrop systems (Mohta and De, 1998).~~ Hence agronomic
61 manipulation of the dominant component (maize) can strongly affect growth of the suppressed
62 component (cowpea). This therefore suggests the need for greater attention to the effect of the dominant

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63 component in modifying the growth environment of and resource availability to the suppressed
64 component and the implications for growth and yield of the latter

65 Maize is a principal cereal in the south western Nigeria. Previous research work had shown that
66 improving the productivity of cowpea/cereal intercropping lies in the performance of the cowpea

67 component which include among other things the choice of appropriate genotype (Egbe and Idoko, 2012,

Comment [E4]: lack in the reference list

68 Dahmardeh *et al.*, 2009). Elemo and Olufajo (1991) reported that maize/cowpea intercrop had no effects

69 on the performance of maize. Consequently, the thrust of this study is to evolve spatial arrangement(s)

70 that will boost the productivity of the two cowpea varieties (Sokoto and Oloyin) without reducing the yield

71 of maize. The objectives of this study were to determine the: 1) effect of spatial arrangement on the

72 performance of two cowpea varieties and 2) row arrangement(s) that will give the highest yield of both

73 component crops

74

75 2.0 Materials and Methods

76 The experiment was conducted during the second cropping season, which commences from mid-August

77 and end in mid-October to early November) at Federal College of Education, Osiele, Abeokuta (7°20'N,

78 3°23'E) in 2009 and 2010. Cowpea is best grown in this period to reduce challenges of diseases and

79 pests, high quality of grains because the crop matures into dry season. The textural class of the soil was

80 loamy sand. The 2 x 5 factorial experiment was laid out in RCBD design. The two local varieties (Oloyin

81 and Sokoto) constituted a factor while five levels spatial arrangement was the second factor. The intercrop

82 proportion mixture and population adopted in this study were additive and replacement series. The two

83 varieties were majorly grown in the dry savannah region of Nigeria (Northern Nigeria). They had

84 comparable grain yield with the improved varieties. Moreover, they are preferred in the market by

85 consumers because of their taste. TZESR-W is an early maturing variety of maize and is normally planted

86 by farmers during the short second cropping season (Mid-August to early November). The Table 1 show

87 the treatment combinations.

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91 Table.1: Treatments combinations for the study

S/No	Crop combinations	Maize plant population (no ha ⁻¹)	Cowpea plant population (no ha ⁻¹)	Series
1	Oloyin + maize in alternate row	31250 (50%)	62500 (50%)	Replacement
2	Oloyin + maize in alternate row	62500 (100%)	125000 (100%)	Additive
3	Oloyin + maize in alternate stand	62500 (100%)	62500 (50%)	Additive
4	Oloyin + maize in strip cropping	41667 (67%)	41667 (33%)	Replacement
5	Sokoto + maize in alternate row	31250 (50%)	62500 (50%)	Replacement
6	Sokoto + maize in alternate row	62500 (100%)	125000 (100%)	Additive
7	Sokoto + maize in alternate stand	62500 (100)	62500 (50%)	Additive
8	Sokoto + maize in strip cropping	41667 (67%)	41667 (33%)	replacement
9	sole maize	62500 (100%)		
	Sole cowpea.		125000 (100%)	

92 Values in parentheses are the population in percentage per plot

93 The field was ploughed and harrowed in both years. The plot size was 6.4 m x 3 m. The spacings

94 for the various spatial arrangements used were as follows:

95 **Strip cropping:** 80 cm X 20 cm for both cowpea and maize. There were nine rows in all. Three rows of
 96 cowpea occupied the three central rows while the first and last three rows were planted to maize. In order
 97 words, three rows of cowpea were planted in-between six rows of maize. Cowpea had two seedling per
 98 hole while maize was one seedling i.e 3 rows of cowpea were sandwiched by 3 rows of maize on both
 99 sides.

100 Sole cropping cowpea and maize was 80 cm X 20 cm. however, the number of cowpea seedlings were
 101 thinned to two while maize was thinned to one per stand

102 **Alternate row (additive series):** Maize to maize and cowpea to cowpea on the same row was 20 cm
 103 while the inter row was 40 cm for maize and cowpea whereas inter row spacing of maize to maize or
 104 cowpea to cowpea was 80 cm.

105 **Alternate stand (additive series):** within each row, maize follows cowpea (i.e. maize to maize was 40
 106 cm on the same row while between maize and cowpea was 20 cm. This is the farmers' practice. Number
 107 of maize plants per stand was thinned to two whereas other spatial arrangements were thinned to one
 108 plant per stand. Thus, maize plant population for alternate stand was same as sole.

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Comment [E5]: This is confusing and should be presented in the form of illustration

Comment [E6]: The distance between rows and between plants in the row is the same for both plants. Why, then, the number of corn plants is 62,500 while the cowpea 125000?

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109 **Alternate row (replacement series):** Maize to maize or cowpea to cowpea on same row was 20 cm
110 while the inter row was 80 cm (i.e. between maize and cowpea inter row).

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112 **2.1 Data collection on cowpea**

113 Number of seeds per pod: Five pods were selected randomly from the field and threshed. The total
114 number of seeds was divided by five.

Comment [E7]: The number of pods in which the seeds were counted should be greater. Why? 5 pods were sample and not population.

115 Pod length: Five pods were selected randomly from the field and length were measured with aid of ruler.

116 1000-seed weight: After threshing, 1000-seed were counted and weighed with sensitive balance.

117 Threshing percentage: The weight of threshed grains obtained from the net plot divided by dry pod weight

118 Grain yield: The harvested dried pods obtained from the net plot were threshed, weighed and converted
119 to kg ha⁻¹

120 **Data collection on maize**

121 Cob diameter: Five cobs were randomly selected from the field, de-husked and the diameter was
122 determined using venier caliper

123 Cob length: Five cobs were randomly selected from the field, de-husked and the length of de-husked
124 cobs was measured with aid of ruler.

125 1000-seed weight: After de-husking, the seeds were shelled; 1000-seed were then counted and weighed
126 with sensitive balance.

127 Threshing percentage: The weight of dried de-husked cobs obtained from the net plot was divided by
128 weight shelled grains and then multiplied by 100

129 Grain yield: The dry pods harvested from the net plot were sun dried, threshed, weighed and converted to
130 kg ha⁻¹

131 **Land equivalent ratio (LER)**

132 $LER = (\text{intercrop yield maize} / \text{sole yield maize}) + (\text{intercrop yield cowpea} / \text{sole yield of cowpea})$

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134 **Statistical analysis**

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135 Data collected on cowpea and maize for each cropping season was analyzed separately using Analysis
136 of variance with variety and spatial arrangement as factors in a factorial design. Furthermore, for the
137 purpose of comparison of varieties and spatial arrangement between cropping seasons 2 x 5 x 2 factorial
138 was analyzed. All means were separated using Turkeys (Minitab version 16)

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140 3.0 RESULTS

141 3.1 Response of cowpea in the different spatial arrangements

142 Table 2 shows the effect of spatial arrangement of cowpea/maize intercrop on the yield and yield
143 components of cowpea in 2009 and 2010. The Oloyin variety of cowpea consecutively had heavier 1000-
144 seed weight than that of Sokoto in both cropping seasons whereas the 1000-seed weights were not
145 influenced by the spatial arrangements in 2009. But in 2010, 1000-seed weight observed in alternate row
146 additive was significantly higher than the others except sole cropping ($P < .05$). The interaction of variety
147 by spatial arrangement on seed-weight was significant in 2010 cropping season. Oloyin variety in 2010
148 had longer pod lengths than those observed in Sokoto whereas the two varieties had similar pod lengths
149 in 2009. Inversely, the spatial arrangement had significantly different pod lengths in 2009 whereas it was
150 similar in 2010. Alternate stand additive had significantly higher pod length than that of alternate
151 replacement. Other arrangements had similar pod lengths.

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152 The two varieties had similar number of seeds per pod in 2009 but Oloyin variety had significantly
153 higher number of seeds per pod than Sokoto in 2010. The number of seed per pod observed in alternate
154 row additive was significantly higher than strip cropping, alternate stand and alternate replacement. It is
155 important to note that all the various row arrangement had suppressive effects on the number of seeds
156 per pod compared to sole. The interaction of variety by row arrangement was significant. The two
157 varieties had similar threshing percentage in 2009. However, Oloyin variety had significantly higher
158 threshing percentage than Sokoto in 2010. The sole cropping had higher threshing percentage than the
159 spatial arrangements in 2009, whereas in 2010, alternate additive had significantly higher threshing
160 percentage than Strip cropping whereas other spatial arrangement had similar threshing percentage.

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161 The grain yields obtained in 2009 were similar but significantly different in 2010 cropping season.
162 The row arrangements had significantly different grain yields in both cropping seasons. In 2009, alternate
163 row additive had similar grain yield with alternate stand, sole cropping and alternate replacement but
164 significantly higher than strip cropping. However, in 2010, alternate row additive and sole cropping had
165 similar grain yield which were superior to the other row arrangement.

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178 Table 2: Effect of spatial arrangement on yield and yield component of Cowpea in 2009 and 2010 cropping seasons

Treatments	Weight of 1000-seed (g)		Pod length (cm)		No of seeds per pod		Threshing %			Grain yield (t/ha)		
	2009	2010	2009	2010	2009	2010	2009	2010	Average	2009	2010	Average
Variety (V)												
Oloyin	252.27 ^a	243.80 ^a	10.63	9.93 ^a	9.20	8.40 ^a	72.1	73.0 ^a	72.6	0.57	0.71 ^a	0.64
Sokoto	160.53 ^b	118.53 ^b	10.09	8.53 ^b	8.33	7.20 ^b	72.9	69.6 ^b	71.3	0.50	0.50 ^b	0.50
Average	206.40	181.17	10.36	9.23	8.77	7.80	72.5	71.3	71.9	0.54	0.61	0.58
SEM	0.74	2.103	0.27	0.371	0.31	0.141	1.17	0.764		0.443	0.03	
P Value	.00	.00	.16	.02	.06	.00	.59	.00		.29	.00	
Spatial arrangement (S)												
Strip cropping replacement	205.50	172.67 ^b	10.38 ^{ab}	8.67	8.67	7.33 ^c	72.6 ^b	69.1 ^{bc}	70.9	0.31 ^b	0.33 ^b	0.32
Alternate row (additives)	205.83	197.33 ^a	11.33 ^a	9.50	9.33	8.33 ^b	71.3 ^b	76.0 ^a	73.7	0.67 ^a	0.89 ^a	0.78
Alternative stand	206.00	175.00 ^b	10.17 ^{ab}	10.17	8.33	7.33 ^c	73.0 ^b	66.6 ^c	69.8	0.50 ^{ab}	0.54 ^b	0.52
Alternative replacement	205.00	175.83 ^b	9.25 ^b	8.17	8.00	6.67 ^c	68.5 ^c	71.8 ^{ab}	70.2	0.49 ^{ab}	0.49 ^b	0.49
Sole cropping	209.67	185.00 ^{ab}	10.67 ^{ab}	9.67	9.50	9.33 ^a	77.1 ^a	73.1 ^{ab}	75.1	0.72 ^a	0.77 ^a	0.75
Average	2206.4	181.17	10.36	9.24	8.77	7.80	72.5	71.3	71.9	0.54	0.60	0.57
SEM	1.16	3.326	0.422	0.587	0.49	0.224	1.85	1.208		0.70	0.049	
P value	.07	.00	.03	.15	.19	.00	.05	.00		.02	.00	
V x S	NS	*S	NS	NS	NS	**S	NS	NS		NS	NS	

NS = Not significant, S = significant

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186 When the means of the data generated from the two cowpea varieties and spatial arrangements
187 were pooled across the two cropping seasons, 1000-seed weight, pod length and number of seeds per
188 pod observed in 2009 were significantly higher than those of 2010 cropping season. Oloyin variety
189 consistently had significantly heavier seeds, longer pods, and higher number of seeds per pod and grain
190 yield than Sokoto (Table 3). Weights of 1000-seed observed in strip cropping, alternate stand and
191 alternate row replacement were similar but significantly lower than alternate row additive. The alternate
192 row additive had significantly longer pod than alternate row replacement while the other spatial
193 arrangements had similar pod length. The numbers of seeds per pod recorded in alternate row additive
194 and sole cropping were similar but significantly higher than that of alternate row replacement. The sole
195 cropping, alternate row additive and strip had similar threshing percentage whereas alternate stand and
196 alternate replacement series had similar threshing percentage but significantly lower than sole cropping.

197 The sole cropping and alternate row additive had highest grain yield whereas strip cropping had
198 the lowest. Comparatively, the grain yield of cowpea obtained from alternate row was 33, 37 and 59%
199 higher than alternated stand, alternate row replacement and strip crop, respectively.

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Table 3: Effects of cropping seasons and spatial arrangement on the yield and yield components of cowpea varieties.

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Treatments	Weight of 1000-seed (g)	Pod length (cm)	No of seeds per pod	Threshing %	Grain yield (t/ha)
Cropping season (C)					
2009	206.40 ^a	10.36 ^a	8.77 ^a	72.5	0.54
2010	181.17 ^b	9.23 ^b	7.80 ^b	71.3	0.60
SEM	1.114	0.229	0.170	0.699	0.04
P Value	.00	.01	.00	.20	.28
Variety (V)					
Oloyin	248.63 ^a	10.28 ^a	8.80 ^a	72.5	0.63 ^a
Sokoto	139.55 ^b	9.31 ^b	7.77 ^b	71.2	0.50 ^b
SEM	1.114	0.229	0.170	0.699	0.027
C x V	**S	NS	NS	NS	NS
Spatial arrangement (S)					
Strip cropping replacement	189.08 ^c	9.53 ^{ab}	8.00 ^{bc}	70.8 ^{ab}	0.32 ^e
Alternate row additive	201.58 ^a	10.42 ^a	8.83 ^{ab}	73.7 ^{ab}	0.78 ^a
Alternate stand	190.50 ^{bc}	10.17 ^{ab}	7.83 ^{bc}	69.8 ^b	0.52 ^b
Alternate row replacement	190.42 ^{bc}	8.71 ^b	7.33 ^c	70.1 ^b	0.49 ^{bc}
Sole	197.35 ^{ab}	10.17 ^{ab}	9.42 ^a	75.1 ^a	0.74 ^a
SEM	1.762	0.362	0.269	1.105	0.043
P value	.00	.01	.00	.00	.00
C x S	**S	NS	NS	NS	NS
V x S	*S	NS	NS	NS	NS
C x V x S	*S	NS	NS	NS	NS

Comment [E8]: These data have been presented in Table 2. In the scientific papers results can not be presented twice.

S - Significant (* $P < 0.05$, ** $P < 0.01$), NS = Not significant ($P > 0.05$)

Values with similar alphabets vertically are not significantly different from each other

The interactions of cropping season by variety on 1000-seed weight and threshing percentage were significant (Fig.1). It is pertinent to note that the performance of cowpea in alternate row and sole cropping were consistently similar in all the parameters considered whereas alternate stand, strip cropping and alternate replacement were comparable. The interactions of cropping season x spatial arrangement (Fig. 2), variety x spatial arrangement (Fig. 3), cropping season x variety x spatial arrangement (Fig. 4) were significant on 1000-seed weight.

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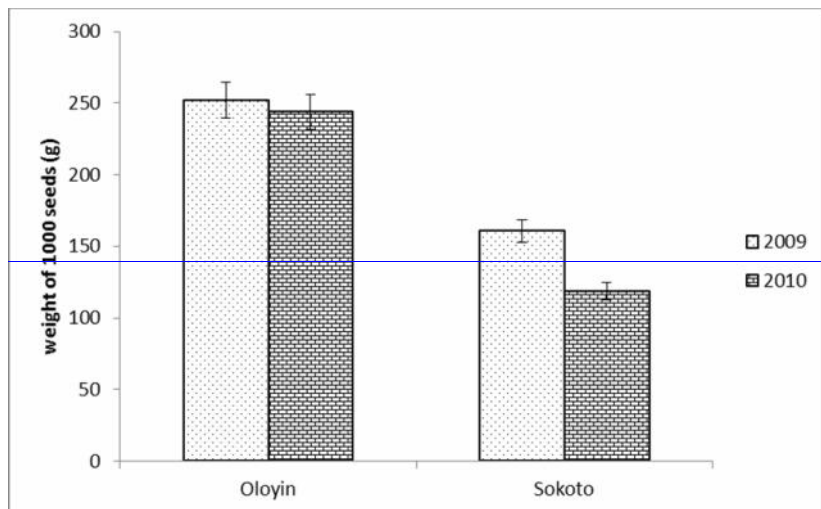


Figure 1: Interaction of cropping season by cowpea variety on weight of 1000 seeds of cowpea

Comment [E9]: These data have been presented in Table 2. Thus this fig. should be removed.

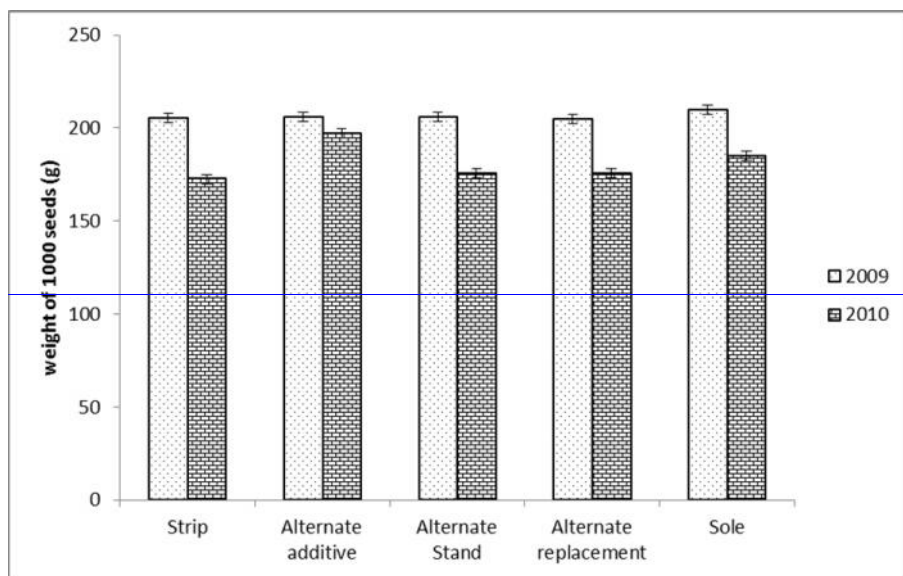


Figure 2: Interaction of cropping season by spatial arrangement on weight of 1000 seed of cowpea

Comment [E10]: These data have been presented in Table 2. Thus this fig. should be removed.

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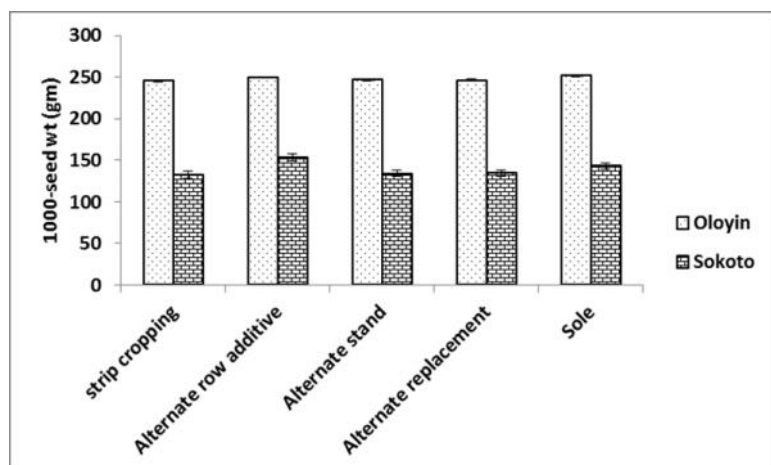


Fig. 3 Interaction of variety by spatial arrangement on weight of 1000-seed weight of cowpea

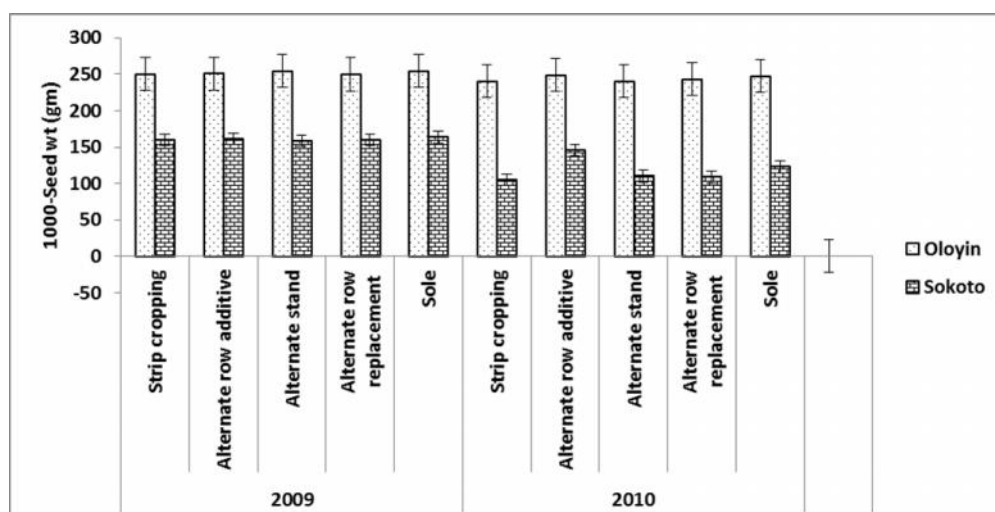


Figure 4: Interaction of spatial arrangement x cropping season x cowpea variety on 1000-seed weight of cowpea. How about: The 1000 seed weight of cowpea varieties depending on spatial arrangement and cropping season. ?? It is indicating that something within the micro-environment in the spatial arrangement and the macro- environment are responsible for seed weight (which is a function of seed size)

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255 **3.2 Response of maize to spatial arrangements**

256 Table 4 shows the performance of maize in various cropping season and spatial arrangements. The
 257 seed weight observed in 2010 was significantly higher than that 2009. Maize + Oloyin and maize +
 258 Sokoto combination in strip cropping had significantly lower 1000-seed weight than maize + Oloyin
 259 alternate stand additive whereas other arrangements had similar seed weight. However, cob weights
 260 observed in the 4 replacement series were significantly lower than maize + Oloyin alternate row additive
 261 while the others were similar. The grain yields obtained from the 4 additive series and the sole maize
 262 were similar but significantly higher than most of the replacement series except maize + Oloyin
 263 replacement series.

264 **3.3 Intercrop productivity**

265 The overall productivity of Oloyin and Sokoto in combination with maize in the different spatial
 266 arrangement was similar in both cropping season (Table 4). However, Land Equivalent Ratio (LER) of
 267 alternate row additive and alternate stand had similar but significantly higher than strip cropping. The
 268 productivity of maize was affected by two additives series (alternate row additive and alternate stand

269 Table 4: Effects of maize/cowpea intercrop on maize agronomic parameters

Treatment	1000- seed weight (g)	Cob length (cm)	Cob ?? weight (kg) ???	Threshing %	Grain yield (Mg ha ⁻¹)
Cropping season (C)					
2009	206.82 ^d	13.82	1.01	78.52	2.24
2010	218.74 ^a	13.91	1.16	80.32	2.26
SEM	1.380	0.090	0.08	1.954	0.083
P Value	.00	.26	.19	.26	.80
Spatial arrangement (S)					
Maize + Oloyin (strip replacement series)	208.83 ^d	13.50	0.76 ^b	82.93	2.00 ^{bc}
Maize + Oloyin (alternate row additive)	213.33 ^{ab}	15.35	1.64 ^a	80.37	2.42 ^{ab}
Maize + Oloyin (alternate stand- additive)	223.67 ^a	14.15	1.27 ^{ab}	79.33	2.57 ^a
Maize + Oloyin (alternate row replacement)	212.00 ^{ab}	13.75	0.75 ^b	81.94	1.77 ^c
Maize + Sokoto (strip replacement series)	207.50 ^b	14.00	0.86 ^b	81.28	1.91 ^c
Maize + Sokoto (alternate row additive)	213.00 ^{ab}	13.79	1.14 ^{ab}	80.38	2.44 ^{ab}
Maize + Sokoto (alternate stand- additive)	216.00 ^{ab}	13.87	1.27 ^{ab}	80.36	2.71 ^a
Maize + Sokoto (alternate row replacement)	210.67 ^{ab}	16.43	0.82 ^b	81.39	1.88 ^c
Sole	210.00 ^{ab}	14.10	1.28 ^{ab}	66.83	2.57 ^a

Comment [E11]: These data need to be checked.
 Cob mass is much greater. Thank you for this
 observation. They were samples/plot

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SEM	2.928	7.164	0.167	4.146	0.104
P value	.02	.47	.01	.25	.00
C×S	NS	NS	NS	NS	NS

Values with similar alphabets vertically are not significantly different from each other NS = Not significant ($P > 0.05$)

Table 5. Land Equivalent Ratio (LER) of maize/cowpea intercrop

Treatment	LER 2009	LER 2010
Variety (V)		
Oloyin + maize	1.56±0.05	1.56±0.06
Sokoto + maize	1.56±0.05	1.60±0.06
P Value	0.988	0.667
Row arrangement (S)		
Strip (replacement series)	1.27±0.07 ^b	1.12±0.09 ^c
Alternate row (additive series)	1.86±0.07 ^a	1.83±0.09 ^a
Alternate stand (additive series)	1.73±0.07 ^{ab}	1.73±0.09 ^{ab}
Alternate row (replacement series)	1.37±0.07 ^b	1.34±0.09 ^{bc}
P Value	.03	.01

Values with similar alphabets vertically are not significantly different from each other

DISCUSSIONS

The differences observed in 1000-seed weight, pod length and number of seeds per pods between the two cropping seasons could be attributed to the role of environment during seed development (Tang, 1982). The varietal difference in 1000-seed weight, pod length and number of seeds per pod could be attributed to yield contributing traits. This confirm the findings of Brolmarn and Stoffella (1986); Siddique and Gupta (1991); Akbar and Kamran (2006) who reported that the weight of 1000-seed was one of the prominent grain-yield determinants of cowpea. Moreover, demand for seed grains for human consumption is linked to size and shape (Shahin *et al.*, 2006). Thus, the preference for Oloyin in the market apart from it taste could be linked to heavy seed weight which is related to the seed size.

The superior grain yield obtained from Oloyin was also reported by Adigbo and Adigbo (2011).. The consistent higher grain yield of cowpea in alternate row additive in all the parameters could be attributed to interaction between cowpea and maize (Anil *et al.*, 1998; Chen *et al.*, 2004) and partly because of the population of cowpea (i.e.100% plant population in relation to the sole) in the mixture. Moreover, the growth resources such as light, nutrient and water between the inter rows were efficiently utilized in alternate row additive. This confirms the findings of Midmore (1993) who reported that

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290 intercropping through more effective use of water, nutrients and solar energy can significantly enhance
291 crop productivity compared to the growth of sole crops.

292 The demand for seed grains for human consumption is linked to size and shape (Shahin *et al.*,
293 2006). Therefore the consistency of the seed size, which is a function of seed weight, in any cropping
294 season and spatial arrangement, is an essential parameter to be considered if the varieties are to be
295 adopted by farmers in the South western Nigeria. The significant interaction of cowpea variety x cropping
296 season on 1000-seed weight indicated that cowpea variety responded differently in the two cropping
297 seasons. The similarities in 1000-seed weight of Oloyin variety in the two cropping seasons suggest that
298 the variation between cropping seasons and perhaps different environments may not likely affect its seed
299 weight unlike Sokoto. The observed variation of 1000-seed weight among the spatial arrangement and
300 between the cropping seasons implies that the seed weights of two varieties were influenced differently.
301 While the seed weight of Sokoto variety ranged between 132.67 and 153.5 g whereas Oloyin had 245.5
302 and 251.67 g. It further indicated that the alternate row additive minimized the variation in seed weight of
303 both varieties in the two cropping seasons. Besides, the grain weight recorded for Oloyin cowpea variety
304 was indifferent to whatever spatial arrangement whereas Sokoto had reduction. The significant interaction
305 of cropping season by variety by spatial arrangement on seed-weight clearly revealed the superiority of
306 Oloyin grain weight stability between seasons and among spatial arrangements. Since seed weight, to a
307 large extent, is a function of seed size. Seed size and shape are important determinant of grain quality
308 grading (Wyllie-Echeverria *et al.*, 2003). Therefore, the seed size of Oloyin cowpea variety is likely to be
309 stable in any crop mixture and variation in weather parameters during the cropping seasons.

310 The similarity in grain yield of maize obtained from maize + Oloyin, maize + Sokoto in the additive series
311 and that of sole was as a result of the same population adopted. The results agreed with those of Elemo
312 and Olufajo (1991) who reported that cowpea/maize intercrop had no suppressive effect on the maize
313 yield.

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317 Land Equivalent Ratio

318 The land equivalent ratio in 2009 and 2010 was similar (Table 4). However, the land equivalent
319 ratio was affected by the spatial arrangement. Alternate row additive consistently had highest LER in both
320 in cropping seasons while strip cropping had the lowest. The higher LER observed in alternate row
321 (additive series) and alternate stand (additive series) could be attributed to the higher plant population of
322 cowpea plants (i.e. 100% and 50% of cowpea plants for alternate row additive and alternate stand,
323 respectively in relation to the plant population of sole cowpea). Although all the spatial arrangement
324 adopted in this study had LER greater than one suggesting that they are more productive than the sole.
325 Consequently, alternate row additive and alternate stand arrangement is efficient utilizer of growth
326 resources in the environment compared to the strip cropping (replacement series) and alternate row
327 replacement. This is in line with the opinion of Dhina *et al.*, (2007) who reported that LER verifies the
328 effectiveness of intercropping for using the resources of the environment compared to sole cropping.

329

330 Conclusion

331 The study shows that alternate row additive and alternate stand spatial arrangements have the potential
332 to enhance the productivity of the two cowpea varieties without reducing maize yield in derived savannah
333 of Nigeria. It also shows that Oloyin variety had a superior grain yield. The replacement series reduce the
334 productivity of maize. All the spatial arrangements are more productive than the sole.

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Comment [E12]: This is inconsistent to the results shown in Table 2, 3 and 4

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