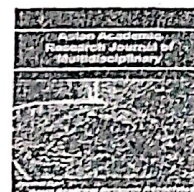


A Peer Reviewed International Journal of Asian
Academic Research Associates

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**ASIAN ACADEMIC RESEARCH
JOURNAL OF MULTIDISCIPLINARY**



ASSESSING INTERCROPPING POPULATION MODELS WITH DIFFERENT INTERCROPPING EFFICIENCY INDICES IN A COWPEA/MAIZE CROPPING SYSTEM

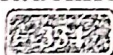
A.I. AFE*

*Department of Crop Production,
Kwara State University, P.M.B, 1530, Malete, Nigeria

Abstract

Five component population ratios of cowpea and maize at two intercropping population models were studied during the 2008 and 2009 cropping seasons at Ejiba, located in southern Guinea savanna agro-ecological zone of Nigeria. The two intercropping models were: (i) additive at component population ratios of 1.00C: 0.75M, 1.00C: 0.50M and 1.00C:0.25M and (ii) replacement at population ratios of 0.75C:0.25M and 0.50C:0.50M. Sole cowpea and maize were included as control treatments. The treatments were factorially combined in a randomized complete block in three replicates. The intercropping efficiency was estimated using Land Equivalent Ratio (LER), Land Equivalent Coefficient (LEC), Area Time Equivalent Ratios (ATER) and Monetary Equivalent Ratio (MER). The additive population model was consistently superior to replacement model in the system suggesting its preference in cowpea/maize intercropping system. The results of the study also showed that the biological yield advantage translated to monetary advantage only in the late maturing cowpea/maize system in the additive population model of 1.00C:0.25M (1.35 and 1.33 in 2008 and 2009, respectively). Based on this study, the MER is a good index to measure profitability in intercropping system.

Keywords: Additive, Replacement, LER, ATER, LEC, MER. Intercropping Efficiency.



Introduction

The performance of a crop in a mixture involves the ability of the crop to efficiently convert the natural resources (light, water and nutrients) into usable by products. Studies on intercropping (Adeniyi *et al.*, 2004; Mohammed *et al.*, 2009, Seran and Brintha, 2009a) have shown that intercrop may give higher, more stable yield and net returns than when any of the components is grown as sole crop due to complementarity effect of the system, partitioning of the limiting resources among component crops (Blade, 1997) and better exploration of soil mass (Francis, 1989). The system is recognized and continuously emphasized in recent time as one of the strategies to be adopted to increase crop yield per unit area with a view of meeting the food requirement of the growing population.

Component crops in the mixture are mixed in either additive or replacement series. In the additive series, the addition of the proportion of component crops exceeds the sole crop population. However, in the replacement series, the proportions of the component crops complement one another to give sole crop population equivalent. While increased population pressure in additive model may lead to increased competition among component crops and difficulty in management and consequent low yield of the dominated crop, the low population of replacement model is often associated with low overall yield of the system (Jeyakumaran and Seran, 2007). These conflicting reports on the intercropping models are frequent in intercropping research, hence suitable intercropping models appeared to be in-conclusive, thus the need for further investigation.

Land Equivalent Ratio (LER) is the most widely adopted index that is often used as an indicator to determine the efficacy of the production system in crop mixture (Seran and Brintha, 2009b). This index has however, earlier been recognized as insufficient and may be misleading to interpret intercropping efficiency to satisfy different objectives of the end users (McCollum, 1987). Although, indices such as Land Equivalent Coefficient (LEC), Area Time Equivalent Ratio (ATER), Monetary Equivalent Ratio (MER), Crop Performance Ratio (CPR), Aggressivity (A) among others have been used to evaluate the biological and monetary advantages in crop mixtures, comparative assessment of these indices have not been

documented particularly in cereal-legume based system. Hence, this study was designed to evaluate the intercropping advantage in cowpea/maize system using different indices and two intercropping population models.

Materials and methods

The experiment was carried out during 2008 and 2009 cropping seasons at the Lower Niger River Basin Development Authority, Ejiba. The study area is situated at latitude 18° , $18'N$ and longitude 5° , $39' E$ in the Southern Guinea Savanna agro-ecological zone of Nigeria. The experiment was carried out to assess the intercropping efficiency in cowpea/maize system using four intercropping efficiency indices in additive and replacement intercropping population models.

The treatments were factorially combined in a randomized complete block design (RCBD) in three replicates. Five (5) population mixtures of cowpea and maize were tested using three additives and two replacements intercropping population models. Sole cowpea and maize at full populations were included as control treatments. The additive treatment combinations were ;(i) full population of cowpea + 75% full population of maize,(ii) full population of cowpea +50% full population of maize, and (iii) full population of cowpea +25% full population of maize. The replacement model consists of 75%full population of cowpea +25%full population of maize and 50% full population of cowpea + 50% full population of maize.

The land was ploughed and harrowed twice. Planting was carried out manually by planting four seeds per stand at single alternate rows. Each stand was thinned at two weeks after planting to two plants per stand to give the desired number of plant per hectare.

Phosphorous fertilizer as single supper phosphate ($18\% P_2O_5$) was broadcast uniformly at the rate of $60kg P_2O_5$ per hectare into all the plots two days before planting, while urea ($46\%N$) was applied split to the maize at the rate of $120kgN/hectare$ at 3 and 6 weeks after planting(WAP). Pendimethalin (500EC) was applied the second day after planting at the recommended rate of $1.5kgai/ha$. This was supplemented with hoeing and hand pulling at 5(WAP) to keep the experimental plot weed free. Cyalothrin, was applied at the rate of $40ml/20liters$ of water at flowering using knapsack sprayer and was followed by fortnight application until harvesting of cowpea for effective control of foliage and pod sucking insect pests.

At maturity, all the pods in each plots of cowpea were harvested, while the cobs from the two inner rows of maize were harvested for yield data. The moisture contents of harvested grains were adjusted to 15% and 13% for maize and cowpea respectively and the yield converted to tones per hectare. Intercropping advantage of the system was evaluated using the following:

$LER = Y_{ij} / y_i + Y_{ji} / y_j$ (Ofori and Stern, 1987). where Y =yield per unit area, Y_{ii} and Y_{jj} are sole crops yield of component crops i and j , Y_{ij} and Y_{ji} are intercrops yield. LEC developed to assess the interaction and potential of production was estimated as: $Y_{ij} / Y_{ii} \times Y_{ji} / Y_{jj}$ (Adetiloye and Ezedima, 1983). In crop mixture, yield advantage is obtained with $LEC > 0.25$. This is with the assumption that the inter and intra specific competitions are equal, that is, $0.5 \times 0.5 = 0.25$. ATER takes into consideration the crop duration in the field was calculated as: $(L_i + L_j) / T$ (Hiesch and Mc Collum, 1987) where; L_i and L_j are the partial yield of component crops i and j , t_i and t_j is the duration in days for crops i and j and T duration in days of the whole intercrop system. MER is the sum of the ratio of intercrop monetary returns to the highest sole crop monetary return to the entire land area occupied by all the intercrops per unit time and was estimated as $= (r_a + r_b) / R_a$ (Adetiloye and Adekunle, 1989).

Where: R_a =highest sole crop monetary return obtained from crop a compared with the sole crop monetary return of crop b (R_b). $y_a = p_a \times x_a$; $y_b = p_b \times x_b$; $R_a = p_a \times x_a$; $R_b = p_b \times x_b$. r_a and r_b are monetary returns of crops a and b under intercropping while p_a , p_b are the current market prices of unit weight of crops a and b . y_a , y_b are the intercrop yields of crops a and b and Y_a is the sole crop yield of the most economic sole crop from the land area equivalent that is occupied by all intercrop for same given period of time.

Economic analysis of cost and returns of producing one hectare of cowpea and maize including the prevailing market prices during the growing seasons were estimated.

All the data were subjected to analysis of variance (ANOVA) for test of significance using the PROC GLM procedure (SAS, 1989) and treatment means compared using Duncan's Multiple Range Test at five percent (5%) level of probability ($p \leq 0.05$).



RESULTS

Significant yield differences of cowpea were observed between the two intercropping population models (Table 1). Replacement model of 0.50C:0.50M was inferior to the additive population ratios of 1.00C:0.50M and 1.00C:0.25M in the two cropping seasons. The highest grain yield of cowpea was recorded in the additive population ratio of 1.00C:0.25M. The effects of intercropping population models on intercropping efficiency indices (Land Equivalent Ratio (LER), Land Equivalent Coefficient (LEC), Area Time Equivalent Ratio (ATER) and Monetary Equivalent Ratio (MER) in 2008 and 2009, are presented in Tables 2-5

Based on the LER, LEC and ATER value, intercropping was superior to sole cropping in all additive population model treatments for early and late maturing cowpeas. The intercropping advantage derived from the early cowpea/maize intercropping system using replacement population model were inferior to those obtained from the same intercropping system using the additive population model. There were no intercropping advantages from intercropping medium maturing cowpea with maize, using the replacement or additive population model in the two years. Intercropping maize at 75% maize population with late maturing cowpea at full population had the highest LER of 1.33 and 1.34 in 2008 and 2009, respectively.

The LEC showed more clearly that intercropping medium maturing cowpea with maize in replacement population model was disadvantageous while there was no appreciable advantage in intercropping same, using the additive population model. The highest LEC value of 0.42 and 0.44 in 2008 and 2009, respectively, were recorded in the late maturing cowpea/maize intercropping system under the additive population model with 1.00C:0.75M component population ratio. The highest ATER value of 1.33 was also recorded in this variety at the same component population ratio of in 2008, but in 2009, the highest value of 1.35 was obtained in the additive component population ratio of 1.00C:0.25M.

The MER did not follow similar trends as the LER, LEC and ATER, particularly for intercropping system involving maize/ early and medium maturing cowpeas. There was no monetary advantage of intercropping over the most economic sole crop when the two cultivars

were intercropped with maize at the two intercropping population models tested in 2008 (Table 5). Indeed, intercropping the two cowpeas with maize was not economically advisable.

Intercropping late maturing cowpea with maize in additive population model was consistently better monetarily than the sole crops in 2008 and 2009. The highest MER values of 1.35 in 2008 and 1.23 in 2009 were recorded in the component population ratio of 1.00C:0.25M. While the replacement population model at component population ratio of 0.50C: 0.50M did not have monetary advantage over the sole crop in the two years, replacement population ratio of 0.75C:0.25M produced some monetary advantages in the two years.

DISCUSSION

The efficiency of the intercropping systems showed that, combined biological and monetary advantages were those which involved late maturing cowpea and maize in additive population model and replacement population ratio of 75% full cowpea population plus 25% full maize population. The superiority of the intercropping system could be attributed to an increased efficiency in the conversion of natural resources into dry matter production.

Biological and monetary advantages of intercropping over sole cropping systems in cowpea/maize intercropping systems have been reported (Adeniyi, *et al.*, 2004; Mohammadu *et al.*, 2009 Bamik and Shama, 2009). However, the biological advantage only translated to monetary advantage, as measured by the Monetary Equivalent Ratio (MER) for only the late – maturing cowpea/Maize intercropping system in which the best component population ratio was 100% cowpea population with 25% maize population (1.00C : 0.25M).

The intercropping advantages in early and late maturing cowpea/ maize intercropping in additive intercropping population model could be ascribed to the ability of the cultivars to withstand shade or because they make use of resources at different times. Nitrogen, phosphorous and potassium have been reported to be efficiently utilized in cowpea/maize mixture compared to sole crop stand (Dahmardeh *et al.*, 2010). In another study, Jial *et al.*, (2008) reported efficient utilization of strong light by maize and weak light by groundnut in a maize-groundnut system.

Table 1: Interactive effect of intercropping at two intercropping population models on grain yield of cowpea in a cowpea / maize system in 2008 and 2009*

Intercropping		2008				2009			
Population		Cowpea maturity dates				Cowpea maturity dates			
Models									
		Early	Medium	Late	mean	Early	Medium	Late	Mean
C	M								
Additives									
1.00	0.75	0.76f	0.88ef	2.09b	1.24de	0.82g	0.94g	2.08bc	1.28ef
1.00	0.50	0.93f	1.19ef	2.38ab	1.53cd	1.09fg	1.38ef	2.55ab	1.67d
1.00	0.25	1.08ef	1.48ef	2.65a	1.73cd	1.15fg	1.51def	2.80a	1.82cd
Replacement									
0.75	0.25	1.02ef	1.10ef	2.13b	1.42de	1.09fg	1.18fg	2.25bc	1.51def
0.50	0.50	0.78f	0.92ef	1.67d	1.12ef	0.85g	1.14fg	1.90cd	1.30ef
Sole		1.10ef	2.15b	2.71a	1.98c	1.28ef	2.18bc	2.88a	2.11bc
Mean		0.95ef	1.28de	2.22b		1.02fg	1.39ef	2.32bc	
Se			0.22				0.19		
C.V (%)			19.72				18.65		

*Values with the same letter(s) in the same column or row are under the year are not significantly different at 5% level of probability by Duncan's Multiple Range Test(DMRT).

C=Cowpea=maize.

Table 2: Interactive effect of intercropping at two intercropping population models on land equivalent ratio (LER) in a cowpea / maize system in 2008 and 2009 *

Intercropping		2008				2009			
Population		Cowpea maturity dates				Cowpea maturity dates			
Models									
		Early	Medium	Late	mean	Early	Medium	Late	Mean
C	M								
Additives									
1.00	0.75	1.27a	0.97cd	1.33a	1.18b	1.30a	1.06ef	1.34a	1.25b
1.00	0.50	1.31a	1.04c	1.26ab	1.22b	1.29a	1.06ef	1.27a	1.21b
1.00	0.25	1.32a	1.04c	1.31a	1.22b	1.27ab	1.06ef	1.33a	1.21b
Replacement									
0.75	0.25	1.16b	0.82e	1.12b	1.03c	1.20c	0.91h	1.12de	1.08e
0.50	0.50	1.18b	0.87e	1.07cd	1.04c	1.12d	0.96g	1.05ef	1.04ef
Sole		1.00c	1.00c	1.00c	1.00c	1.00c	1.00fg	1.09fg	1.00fg
Mean		1.22ab	0.95d	1.19b		1.20ab	1.03ef	1.18cd	
Se			0.04				0.03		
C.V (%)			7.02				5.02		

* Values with the same letter(s) in the same column or row are under the year are not significantly different at 5% level of probability by Duncan's Multiple Range Test(DMRT).

C=Cowpea=maize.

Table 3: Interactive effect of two intercropping population models on land equivalent coefficient (LEC) in a cowpea / maize system in 2008 and 2009*

Intercropping		2008				2009			
Population		Cowpea maturity dates				Cowpea maturity dates			
Models									
		Early	Medium	Late	mean	Early	Medium	Late	Mean
C	M								
Additives									
1.00	0.75	0.40a	0.23d	0.42a	0.35bc	0.42ab	0.27d	0.44a	0.39b
1.00	0.50	0.39ab	0.26cd	0.37bc	0.34b	0.37bc	0.28d	0.33c	0.33c
1.00	0.25	0.33c	0.25d	0.26de	0.30cd	0.30bc	0.26d	0.33c	0.31c
Replacement									
0.75	0.25	0.28d	0.16f	0.29cd	0.23e	0.36b	0.20c	0.26d	0.26d
0.50	0.50	0.33c	0.19f	0.25cd	0.27d	0.30c	0.22c	0.26d	0.26d
Sole		0.25d	0.25d	0.25cd	0.25d	0.25c	0.25d	0.25d	0.25d
Mean		0.34b	0.22d	0.32bc		0.34bc	0.25d	0.31c	
Se			0.01				0.02		
C.V (%)			9.78				5.02		

*Values with the same letter(s) in the same column or row under the same year are not significantly different at 5% level of probability by Duncans Multiple Range Test (DMRT).

C=cowpea, M=maize

Table 4: Interactive effect of intercropping a two intercropping population models on area time equivalency ratio (ATER) in a cowpea / maize system in 2008 and 2009 *

Intercropping		2008				2009			
Population		Cowpea maturity dates				Cowpea maturity dates			
Models									
		Early	Medium	Late	* mean	Early	Medium	Late	Mean
C	M								
Additives									
1.00	0.75	1.27a	0.96f	1.33a	1.18b	1.30a	1.00de	1.33a	1.23b
1.00	0.50	1.31a	1.03de	1.23bc	1.19b	1.29a	1.02de	1.19b	1.17b
1.00	0.25	1.32a	1.09de	1.30a	1.22b	1.08ab	1.05de	1.35a	1.24b
Replacement									
0.75	0.25	1.17bc	0.73h	1.11c	1.00e	1.21b	0.84f	1.12c	1.06de
0.50	0.50	1.21b	0.87g	0.99de	1.02de	1.13c	0.86f	1.04de	1.01e

Table 5: Interactive effect of intercropping at two intercropping population models on monetary equivalent ratio (MER) in a cowpea / maize system in 2008 and 2009 *

Intercropping		2008				2009			
Population		Cowpea maturity dates				Cowpea maturity dates			
Models		Early	Medium	Late	mean	Early	Medium	Late	Mean
C	M								
Additives									
1.00	0.75	0.90e	0.87e	1.27b	1.01d	1.07c	1.03cd	1.16ab	1.08c
1.00	0.50	0.80f	0.90e	1.29ab	1.00d	0.97e	1.04cd	1.17ab	1.06c
1.00	0.25	0.71g	0.99d	1.35a	1.01d	0.94ef	1.05cd	1.23a	1.07c
Replacement									
0.75	0.25	0.67gh	0.64h	1.10c	0.80f	0.89d	0.84g	1.13b	0.95e
0.50	0.50	0.80e	0.06g	1.03d	0.87e	0.87g	0.92fg	0.94ef	0.91f
Sole		1.00d	1.00d	1.00d	1.00d	1.00de	1.00de	1.00de	1.00de
Mean		0.82e	0.86e	1.17c		0.95ef	0.98de	1.11b	
Se			0.03				0.04		
C.V (%)			8.26				6.11		

*Values with same letter(s) in the same column or row under the same year are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT).

C=cowpea, M=maize

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