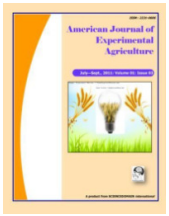

American Journal of Experimental Agriculture
5(5): 459-465, 2015, Article no.AJEA.2015.045
ISSN: 2231-0606

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Percentage Yield Difference, an Index for Evaluating Intercropping Efficiency

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEA/2015/12405
Editor(s):
(1) Mirza Hasanuzzaman, Department of Agronomy, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.
(2) Daniele De Wrachien, Full Professor of Irrigation and Drainage State University of Milan, Italy.
Reviewers:
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Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=738&id=2&aid=6843

Original Research Article

Received 30th June 2014
Accepted 11th October 2014
Published 6th November 2014

ABSTRACT

Aim: To evaluate intercropping efficiency using percentage yield difference (PYD) and to compare the index with other indices.
Study Design: The design was a 2 X 5 factorial in a randomized complete block design, and replicated three times.
Location: The study was carried out at the Lower Niger River Basin Development Authority, Ejiba (18°18°N, 5°39°E), Kogi State in the Southern Guinea Savannah Zone of Nigeria in 2008 and 2009 cropping seasons.
Methodology: Erect and prostrate cowpeas and maize were mixed at five population ratios. The five population ratios were: 100%C: 75%M, 100%C:50%M, 100%C:25%M, 75%C:25%M and 50%C:50%M (were C and M represented Cowpea and Maize respectively). Sole crops of each crop at full population were included as control treatments. Land Equivalent Ratio (LER), Area Time Equivalent Ratio (ATER), Monetary Equivalent Ratio (MER) and Percentage Yield Difference (PYD) were estimated and compared.
Results: Results of this study showed that LER, ATER, and PYD values were similar for the two cultivars in the two years.

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LER values ranges between 1.18 and 1.27 in 2008 and 1.12 and 1.30 in 2009. MER did not follow the same trend as LER and ATER. Lower values were obtained particularly in 2009. However, the highest MER 1.35 and 1.23 in 2008 and 2009 respectively were obtained in prostrate cowpea / maize mixture at population ratio of 100:50. The PYD advantage varies between 5-33% in the two years.

Conclusion: The comparable values of PYD with other indices suggest that it can be used to evaluate/ intercropping efficiency in crop mixture.

Keywords: Land equivalent ratio; area time equivalent ratio; monetary equivalent ratio.

1. INTRODUCTION

Intercropping as types of mixed cropping is the practice of growing more than one crop on the same field at the same time. This practice is widely practiced among small holder and peasant farmers in the tropics [1,2]. Mutsears et al. [3] pointed out the potential advantages of the system such as better utilization of natural resources (solar radiation, mineral nutrients and water), higher labour productivity and reduced risk of crop failure as compared with sole cropping. [4] Reported the superiority of the system over sole cropping in early and late maturing cowpea/maize mixture. In another study, [5] also noted that intercropping could be an eco-friendly approach at reducing weed problem through non-chemical methods.

Efficiency of intercropping over sole cropping has been assessed by various indices. Mead and Willey [6] use the concept of land equivalent ratio (LER) defined as the total land area required under sole cropping to give the yield obtained in the intercrop mixture. Adetiloye and Ezedima [7] use the concept of land equivalent coefficient (LEC) defined as the product of land equivalent ratio in the intercrop. It was developed to assess the interaction and productive potential in crop mixtures. Hiebsch and Mc Collum [8] proposed the concept of area time equivalent ratio (ATER), as a modification for LER. This takes into consideration the crop dimension in the field that is, the time the crop occupies the field from planting to harvesting. Ofori and Stern [9] observed and noted that this index was appropriate in crop mixture where component crops have different maturity dates.

Monetary equivalent ratio (MER) defined as the sum of the ratio of intercrop monetary returns to the highest sole crop monetary return to the entire land area occupy by all intercrops per unit time [10].

While all these indices and others relate with the yield differences that exist between the component crops in the mixture, percentage yield difference (PYD) as an index has not been documented, recognised and compared to interpret intercropping advantages. This research was therefore designed to interpret/ evaluate intercropping advantages using percentage yield difference between the component intercrop and the sole crop and to compare the advantage with other indices.

2. MATERIALS AND MEHTODS

Field trials involving erect and prostrate cowpea in an intercrop with maize were evaluated for the efficiency of intercropping system using the Land Equivalent Ratio (LER), Area Time Equivalent Ratio (ATER), Monetary Equivalent Ratio (MER) indices in Ejiba, Southern Guinea Savannah agro ecological zone, Kogi State, Nigeria during 2008 and 2009 cropping season. The percentage yield difference of the treatments were also calculated and compared with the LER, ATER and MER values. The treatments consist of five population ratios of cowpea and maize combined. The population ratios consist of 100%C: 75%M, 100%C:50%M, 100%C:25%M, 75%C:25%M and 50%C:50%M (were C and M represented Cowpea and Maize respectively) in a 2 x 5 factorial and arranged in a randomized complete block in three replicates. Sole crops of cowpea and maize at full population were included as control treatments. The annual rainfall during the 2008 and 2009 cropping season were 1276mm and 1166.9mm respectively. The temperature ranges between 29.7 and 31.3 in 2008 and 29.1 and 32.9 in 2009 (Table 1). Phosphorous was applied as Single Super Phosphate at the rate of 60 kg/ha of P_20_5 two days before planting. Urea was applied in two split to the maize at 3 and 6 weeks after planting at the rate of 120kgN/ha. Pendimethalin was applied as pre-emergence herbicide at the rate of 1.5 kg Active Ingredient per hectare to control weeds immediately after planting.

Table 1. Meteorological data for Ejiba area, 2008 And 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Mean
Rainfall (mm)														
2008	-	-	-	48.70	156.2	196.8	247.3	228.4	205.1	164.8	28.7	-	1276	106.3
2009	-	-	21	39.00	147.2	204.2	223.3	196.4	207.3	144.0	3.4	-	1166.9	97.24
Temperature (oC)														
2008	30.6	31.4	31.6	32.3	31.8	31.6	30.4	30.2	30.2	29.7	30.8	30.8	371.4	31.0
2009	31.9	32.4	32.9	32.2	32	31.3	30.6	29.6	29.1	29.3	30.9	31.6	373.8	31.15
Sunshine (hr/month)														
2008	279	286	304	312	285	276	293	286	274	286	298	294	3468	289.0
2009	263	276	303	301	293	284	287	263	277	294	302	294	3437	286.42
Sunshine (hr/day)														
2008	9	9.9	10	10.4	9.2	9.2	9.5	9.2	9.1	9.2	9.9	9.5	113.9	9.5
2009	8.5	9.5	9.8	10.03	9.45	9.47	9.26	8.77	9.23	9.8	9.74	9.48	113.03	9.42
No of Rainfall Days (day)														
2008	-	-	-	03	12	10	16	16	09	07	02	-	75	6.3
2009	-	-	01	03	14	12	14	20	13	11	01	-	89	7.42

Source: Meteorological station, Lower Niger River Basin Development Authority Area office, Ejiba

Cylothrin was sprayed at the rate of 2 ml/L of water using knapsack sprayer at the onset of flowering till harvesting of cowpea to control insect pests. Cobs from maize plants at the inner rows (1.5m^2) were harvested while all the pods in each plot of cowpea (21.25m^2) were also harvested. Yield data collected were statistically analysed using [11] models and treatment means compared at P = .05 using Duncan's Multiple Range Test.

LER was estimated as $= \frac{Y_{ij}}{Y_{ii}} + \frac{Y_{ji}}{Y_{jj}}$

Where:

Y = yield per unit area
Y_{ii} and Y_{jj} = sole crop yield of component crops i and j
Y_{ij} and Y_{ji} = intercrop yield

ATER $=(Y_i/T_t)/(Y_s/T_i)$

Where:

Y_i= Grain yield of intercrop species i
T_t = Duration in days of the species with the longest growing period.
Y_s = Grain yield of the sole cropped species
T_i = Duration of growth cycle of species i.

MER= $\frac{r_a + r_b}{R_a}$

Where:

R_a = Highest sole crop monetary return obtain from a; compared with the sole crop monetary return of crop b (R_b)
$Y_a = p_a \times y_a$
$Y_b = p_b \times y_b$
$R_a = p_a \times Y_a$
$R_b = p_b \times Y_b$
r_a and r_b = monetary returns of crop a and b under intercropping.
p_a, p_b = current market price of unit weight of crop a and b
y_a, y_b = intercrop yield a and b
Y_a = sole crop yield of most economic sole crop from the land area equivalent that is occupied by all intercrop for the same given period of time.

PYD= $100 - \left[\frac{Y_{sa} - Y_{ja}}{Y_{sa}} + \frac{Y_{sb} - Y_{jb}}{Y_{sb}}\right] \times \frac{100}{1}$

Where:

Y_{sa} = sole crop yield of crops A
Y_{sb} = sole crop yield of crops B
Y_{ia} = intercrop yield of crops A
Y_{ib} = intercrop yield of crops B

PYD is defined as the yield difference between sole crop at full population (100%) and the intercrop expressed in percentage. It is based on the understanding that yield differences exist in crop mixture between the sole crop and the intercrop and that the sole crop was assumed to be hundred percent. Irrespective of the component population ratio employed, time of planting of component crop, plant geometry etc. the reduction of one crop is usually compensated by increased yield of the other crop. When this yield difference is expressed in percentage, the efficiency of the system in numerical value is shown. The PYD value gave the numerical value of intercropping advantage when the percentage intercrop was deducted from the sole crop. PYD value is inversely proportional to yield advantage that is, the lower the value the higher the efficiency of the system and vice versa.

3. RESULTS

LER, MER, ATER and PYD values for 2008 and 2009 cropping seasons are presented in Tables, 2, 3, 4 and 5. The LER values varied between 1.18 and 1.27 for erect cowpea in 2008 and ranges from 1.12 to 1.30 in 2009. Similar values of ATER were recorded for the prostrate cowpea/ maize mixture in the two years. In contrast, MER did not follow similar trend with ATER and LER, particularly for intercropping involving erect cowpea / maize intercropping. Indeed, there was no monetary advantage of intercropping of this cultivar over the two years except at 100:75 population ratios in 2009 where appreciable MER was recorded (1.07). However, reasonable MER values were obtained in prostrate cowpea/maize mixture in all the component population ratios in the two years except 50:50 population ratios in 2009. The value varied between 1.03 and 1.27 in 2008 and 0.94 and 1.16 in 2009.

The PYD showed similar trend with LER and ATER in all the treatment combinations in the two years. Yield advantage (19-27%) was obtained for erect cowpea in 2008 and 12-30% in 2009, while prostrate cowpea had 8-33% in 2008 and 12-33% in 2009.

4. DISCUSSION

The compared values of LER and ATER in all the parameters follow similar trend to the obtained percentage yield difference. This indicates that the yield reduction of component crop A was compensated by increased yield of component crop B. This yield difference when expressed in percentage will give the intercropping efficiency for the intercrop in land and in time dimensions.

The efficiency of the mixture when evaluated with MER did not follow similar trends with percentage yield difference values. The obtained values (MER) were lower than the percentage yield difference in all the parameters. This contrast suggests that the percentage yield difference cannot be used as an index to interpret intercropping efficiency when the objective of the end user is monetary advantage. This assumption is also valid for LER and ATER. This corroborated with the earlier findings of [8,12],who observed that the efficiency of intercropping might be misleading when LER alone is used, particularly when monetary gain is the primary objective of the end user.

These comparable similar values of PYD with LER and ATER make it a valid index for interpreting intercropping advantage in crop mixture. This simple and reliable method is adaptable for a wide range of crop mixtures.

Table 2. PYD, LER, ATER and MER in erect cowpea/ maize intercrop in 2008

Population Ratio	Yield		PYD**	LER*	MER*	ATER*
C : M	C	M				
100 : 75	.76	2.80	27.19ab	1.27a	.90e	1.27a
100 ; 50	.93	2.18	29.78a	1.31a	.80f	1.31a
100 ; 25	1.08	1.61	31.58a	1.32a	.71g	1.32a
75 : 25	1.02	1.67	27.38ab	1.16b	.67gh	1.27bc
50 : 50	.78	2.32	16.97c	1.18b	.80e	1.21b
Sole	1.10	4.82	100	1.00c	1.00c	1.00c
Mean			38.82	1.21	.81	1.23

**Values with the same letter(s) in the same column or row are not significantly different at P=.05 level of probability by Duncan's Multiple Range Test. **Values with the same letter(s) in the same column are not significantly different at P=.05 level of probability by Duncan's Multiple Range Test. C=Cowpea, M= Maize, PYD= Percentage Yield Difference, LER= Land Equivalent Ratio, MER= Monetary Equivalent Ratio, ATER= Area Time Equivalent Ratio*

Table 3. PYD, LER, ATER and MER in prostrate cowpea/maize intercrop in 2008

Population ratios	Yield		PYD**	LER*	MER*	ATER*
C : M	C	M				
100 : 75	2.09	2.68	32.78a	1.33a	1.27b	1.33a
100 : 50	2.38	2.01	29.52ab	1.26ab	1.29ab	1.23b
100 : 25	2.65	1.61	21.86c	1.31a	1.35a	1.30a
75 : 25	2.13	1.62	12.21d	1.12c	1.10c	1.11c
50 : 50	1.67	2.32	7.89e	1.07cd	1.03d	.99c
Sole	2.71	4.82	100	1.00c	1.00c	1.00c
Mean			33.94	1.19	1.17	1.16

**Values with the same letter(s) in the same column or row are not significantly different at P=.05 level of probability by Duncan's Multiple Range Test. **Values with the same letter(s) in the same column are not significantly different at P=.05 level of probability by Duncan's Multiple Range Test. C=Cowpea, M= Maize, PYD= Percentage Yield Difference, LER= Land Equivalent Ratio, MER= Monetary Equivalent Ratio, ATER= Area Time Equivalent Ratio*

Table 4 . PYD, LER, ATER and MER in erect cowpea/maize intercrop in 2009

Population ratios	Yield		PYD**	LER*	MER*	ATER*
C : M	C	M				
100 : 75	.82	2.72	30.08a	1.30a	1.07c	1.30a
100 : 50	1.09	1.83	29.58ab	1.29a	.97e	1.29a
100 : 25	1.15	1.56	27.70ab	1.27ab	.94ef	1.28ab
75 : 25	1.09	1.50	21.57b	1.20c	.89d	1.21b
50 : 50	.85	1.89	12.29	1.12d	.87g	1.13c
Sole	1.28		100	1.00efg	1.00ge	1.00e
Mean	1.02		36.87	1.2fg	.95	1.12

**Values with the same letter(s) in the same column or row are not significantly different at P=.05 level of probability by Duncan's Multiple Range Test. **Values with the same letter(s) in the same column are not significantly different at P=.05 level of probability by Duncan's Multiple Range Test. C=Cowpea, M= Maize, PYD= Percentage Yield Difference, LER= Land Equivalent Ratio, MER= Monetary Equivalent Ratio, ATER= Area Time Equivalent Ratio*

Table 5. PYD, LER, ATER and MER in prostrate cowpea/ maize intercrop in 2009

Population ratios	Yield		PYD**	LER*	MER*	ATER*
C : M	C	M				
100: 75	2.08	2.52	33.39a	1.34a	1.16ab	1.33a
100 :50	2.55	1.67	26.66ab	1.27ab	1.17ab	1.19b
100 : 25	2.80	1.43	31.93a	1.33a	1.23a	1.35a
75 : 25	2.25	1.40	12.17c	1.12de	1.13b	1.12c
50 :50	1.90	1.60	4.82d	1.07df	.94ef	1.04de
Sole	2.88	4.12	100	1.00fg	1.00de	1.00e
Mean			34.83	1.18	1.11	

**Values with the same letter(s) in the same column or row are not significantly different at P=.05 level of probability by Duncan's Multiple Range Test. **Values with the same letter(s) in the same column are not significantly different at P=.05 level of probability by Duncan's Multiple Range Test. C=Cowpea, M= Maize, PYD= Percentage Yield Difference, LER= Land Equivalent Ratio, MER= Monetary Equivalent Ratio, ATER= Area Time Equivalent Ratio*

4. CONCLUSION

The comparable values of PYD with other indices suggest that it can be used to evaluate/interpret intercropping efficiency in crop mixture.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=738&id=2&aid=6843