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Full Length Article

Yield and Economic Assessments of Five Cowpea Varieties in Cowpea-Maize Strip Intercropping in Limpopo Province, South Africa

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Abstract

Farmers' traditional cropping practice in Limpopo Province is to mix and broadcast crops at planting without definite row arrangement. Although this practice is very easy and cost-saving, it leads to low plant density, hinders farm input application, and results in low crop yields and poor return on investment. Strip intercropping, where crops are planted with definite row arrangement, reduces inter-species competition, optimises plant population, and increases crop yield. Five cowpea varieties *i.e*. 'TVu 13464', 'IT86D-1010', 'Glenda', 'IT82E-16' and 'IT87K-499-35' and maize was grown under strip intercropping, monocropping, and mixed intercropping as a control during two seasons. During both years, significant interactions were obtained between the cowpea varieties and the cropping systems in most of the variables measured. Cowpea sown in the strip intercropping performed better compared those sown in mixed intercropping. Cowpea varieties 'IT86D-1010', 'IT82E-16' and 'IT87K-499-35' harvested more grain yield under monocropping and strip intercropping than under mixed intercropping. The land equivalent ratio (LER) of strip intercropping during the two seasons ranged between 1.25 and 2.29 and was higher compared to mixed intercropping, which ranged between 0.50 and 1.32. In conclusion, cowpea varieties 'IT86D-1010', 'IT82E-16' and 'IT87K-499-35' sown with maize as strip intercropping resulted more profits under intercropping systems and were recommended for cultivation by farmers in the Limpopo region with low rainfall. Moreover, grain yield, LER, and net profit achieved by strip intercropping was three-fold more than mixed intercropping.

Keywords: Economic analysis; Grain yield; Land equivalent ratio; *Vigna unguiculata; Zea mays*

Introduction

Cowpea (*Vigna unguiculata* L.) is a protein-rich grain that complements staple cereal and starchy tuber crops. Cowpea is commonly used as a companion crop in many intercrop systems in sub-Saharan Africa (SSA), because of its ability to provide fixed atmospheric nitrogen to cereal crops in rotation (Asiwe 2009).

Many smallholder farmers in Limpopo Province practise intercropping of maize (*Zea mays* L.) with legumes to reduce the risk of crop failure, and enhance their production. Cereal-legume intercropping is commonly practised in South Africa, including the Limpopo Province, because of its yield advantage, greater stability, and lower risk to crop failure compared to monoculture (Kermah *et al*. 2017). Several research works have been reported recently on cereal-legume intercropping systems in South Africa and elsewhere. These include maize and pigeonpea (Kiwia *et al*. 2019); maize and dry bean (*Phaseolus vulgaris* L.) intercropping (Kutu and Asiwe 2010; Nthabiseng *et al.* 2015); and wheat (*Triticum aestivum* L.)-canola (*Bracica juncea* L.) intercropping (Khan *et al.* 2012; Tripathi *et al*. 2016). The traditional practice of farmers in Limpopo Province is the mixed intercropping, whereby crops are broadcasted at planting without definite row arrangement (Mucheru-Muna *et al.* 2010). Mixed intercropping hinders farm input application, results in non-optimal plant population (Mahapatra 2011), as well as intra and inter species competition (Muhammad *et al*. 2008; Chitra and Shrestha 2014), which lead to low crop yield and poor return on investment. This practice is not sustainable and economically viable.

Therefore, farmers in Limpopo Province are in dire need of an innovative intercropping system that is more sustainable and profit-oriented. Strip intercropping is a promising intercropping system where crops are planted with definite row arrangement, and has the potential of reducing inter-species competition, optimising plant population, and increasing crop yield and cash return (Singh and Ajeigbe 2007; Iderawumi and Friday 2013). The hypothesis of the study was to investigate whether the performance of the novel strip intercropping system would be better than or same as the traditional mixed intercropping currently being practised by farmers. Therefore, the objective of the study was to assess the performance and economic feasibility of five improved cowpea varieties under a cowpea-maize strip intercropping system compared to mixed intercropping system in Limpopo Province, South Africa.

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Materials and Methods

Description of the study area

The study was conducted at the University of Limpopo's (23°53' 9.6" S, 29°43' 4.8" E and 24°01' 59" S, 29°47' 56" E, respectively) Experimental Farm (UL-Farm's) during 2015–2016 and 2016–2017. The site is characterised by erratic low rainfall, which ranges between 450 and 650 mm per annum, and falls predominantly during summer (Table 1).

Experimental materials

This consisted of five cowpea varieties (Glenda (check), IT87K-499-35, IT82E-16, IT86D-1010, and TVu-13464, a maize cultivar, and PAN 6479, obtained from PANNAR Seed Ltd., South Africa). The cowpea varieties were obtained from the gene bank of the University of Limpopo, South Africa.

Treatments

The experiment was laid out following randomized complete block design under split plot arrangement with three replications. The main plot factor was cropping system (intercrop and monocrop; the mono and mixed cropping systems were included as standard control practices) and the subplot factor was the varieties ('Glenda' (check), 'IT87K-499-35', 'IT82E-16', 'IT86D-1010', and 'TVu-13464). The maize cultivar was planted at a spacing of 0.9 m × 0.3 m with 4 m row length, giving a plant population of 52 and 40 plants per intercrop plot for maize and cowpea, respectively; and each plot area was 5.6 m × 4.0 m. The intercrop plots consisted of four rows of cowpea, sandwiched between two rows of maize. The monocrop plots consisted of six rows of cowpea and maize planted at an inter-row spacing of 0.75 m × 0.2 m and 0.9 m × 0.3 m, respectively. The net plot for each intercrop was 4.8 × 4.0 m, while that for monocrop (maize) was 4.8 m × 4.0 m, and 3.0 m × 4.0 m for the cowpea monocrop.

Crop management

The land was conventionally tilled with tractor-mounted implements (disc plough and harrow) to enhance germination and seedling emergence. The trial was planted on 11 January 2016 during the 2015–2016 cropping season; whereas during the 2016–2017, it was planted on 13 December 2016. Roundup (isopropyl amine salt of glyphosate) and Dual (S-Metalachlor) were applied at the rates of 3 L ha^{-1} and 0.5 L ha^{-1}, respectively, to control weeds before crop emergence. Manual weeding was subsequently conducted to control emerged weeds. Karate (Lambda-Cyhalothrin) and Aphox (Pirimicarb) were applied at the rate of 1 L ha^{-1} and 500 g ha^{-1} to control insect pests (blister beetles, aphids, and pod-sucking bugs) on cowpea from seedling stage until pod maturity. The trial was conducted under rain-fed conditions, and no fertilisers or irrigation were applied. Soil samples were collected from the experimental area, and the results of the analysis are shown in Table 2. The organic carbon, matter and available P were too different during the two years probably because the plots used during the two years were separate and different.

Data collection

The following parameters were measured in the same way during the two seasons to achieve the research study objectives. The number of days to 50% flowering was determined by counting the number of days from the date of plant emergence to the date that 50% of the plant population in each plot flowered. The number of days to 90% maturity was calculated by counting the number of days from plant emergence date to the date that 90% of the plant population in each plot matured. Plant height was determined by measuring the height of five plant samples with a meter rule.

Plant harvesting

Five plants from each plot were sampled randomly at maturity and total number of pods of these plants was counted and averaged to record number of pods/plants. The cowpea varieties were harvested in May of each year. For grain yield, sun-dried samples were harvested from four middle rows of each plot and threshed manually to obtain grain yield per plot. Weight of grains per plot was determined by weighing the grains on an electronic weighing balance, and the net yield was converted to kg ha^{-1} using the following formula:

$$\text{Grain yield} = (\text{grain weight [kg]}) / (\text{area harvested } [m^2]) \times 10000\ m^2$$

Maize grain was taken at maturity after harvesting the cobs. The yields were determined by weighing the grain from each net plot; and the weight was converted into kg/ha using the following formula:

$$\text{Grain yield} = (\text{grain weight [kg]}) / (\text{area harvested } [m^2]) \times 10000\ m^2$$

Assessment of intercrop productivity

For the assessment of the LER, the relative yields of cowpea and maize with their sole treatments were determined by using the following formulae (Mead and Willey 1980):

$$\text{LER (Strip)} = \frac{Intercropped\ yield\ of\ crop\ A}{Sole\ yield\ of\ crop\ A} + \frac{Intercrop\ yield\ of\ crop\ B}{Sole\ yield\ of\ crop\ B}$$

$$\text{LER (Strip)} = \frac{Mixed\ intercropping\ yield}{Monocropping\ yield} + \frac{Mixed\ intercropping\ yield}{Monocropping\ yield}$$

Data analysis

Data collected during the two seasons were subjected to an analysis of variance technique using the Genstat 18 Version software to check the overall significance of data. Means that showed significant differences were separated using

Duncan's new multiple range test (MRT) at $P \leq 0.05$ (Steel *et al*. 1997).

Economic analysis

A benefit-cost analysis was conducted to estimate the economic achievements of the different crop mixtures in the intercropping systems. The production costs of cowpea and maize included the cost of field preparation, seed, sowing, crop protection measures, harvesting, and processing. The total cost or revenue was estimated using the prevailing average market prices in Rand for the grain yield of cowpea and maize in South Africa. The amount in Rand was converted to USD$ by dividing with the average exchange of 14.01 ZAR/$. The total profit was calculated by subtracting the total cost from the total revenue, while the benefit-cost ratio (BCR) was calculated by dividing the total revenue by the total cost.

Results

The results showed that interactions between varieties and cropping system were significant ($P \leq 0.05$) for most of the variables except plant height (during 2017) (Table 3). During the 2015/2016 season, varieties planted in the mixed intercropping plots flowered later than strip intercropping or monocropping. However, during 2016/2017, varieties planted in the mixed intercropping plots were the earliest to flower, followed by strip intercropping and monocropping. Similar trend was observed for the maturity of the varieties among the cropping systems. Maturity was later in the mixed intercropping than strip intercropping or monocropping. During 2017, mixed intercropping matured earlier than strip intercropping or monocropping. Results also show that plant height was observed to be shorter among plants in the mixed intercropping followed by strip intercropping. Varieties in the monocrop plots exhibited the tallest plants (Table 3). However, during 2017, no significant interaction was observed between varieties and cropping systems. The number of pods obtained from strip intercropping plots during 2015–2016 was highest followed by monocropping, and the lowest was obtained from mixed intercropping. However, during 2016–2017 season, mixed intercropping exhibited the highest number of pods followed by strip intercropping and monocropping. With respect to grain yield, the interaction results showed that during both seasons (Table 3) grain yield was consistently highest in the monocrop plots, followed by strip intercropping, while mixed intercropping achieved the lowest yield. Maize grain yield was significantly lower in mixed intercropping compared to strip intercropping or monocropping during both seasons (Table 3).

There were no significant ($P \leq 0.05$) interactions observed between the varieties in the crop mixtures and cropping systems for LER during 2016–2017 while the effect was significant during 2015–2016 (Table 4). Higher

Table 1: Mean monthly rainfall, and minimum and maximum temperatures during both seasons

Months	Minimum temperature (ºC)		Maximum temperature (ºC)		Total rainfall (mm)	
	2016	2017	2016	2017	2016	2017
Dec	-	16.9	-	27.2	-	120.9
Jan	17.0	12.1	28.6	25.3	87.4	101.7
Feb	17.6	12.2	29.1	24.6	57.9	40.3
Mar	15.7	06.0	28.1	24.0	126.7	23.1
Apr	11.6	9.67	26.2	23.5	5.3	30.4
May	13.5	3.4	25.8	21.4	1.0	11.4
Jun	7.4	5.43	19.1	19.7	3.2	1.04

Source: Agricultural Research Council - ISCW and the University of Limpopo Weather Station

Table 2: Pre-sowing physio-chemical analysis of soil in both seasons

Soil attributes	2015-2016	2016-2017
Clay	3	2
Silt	13	14
Sand	84	84
Textural class	Sandy loam	Sandy loam
Chemical composition		
pH	7.4	8.2
Organic carbon (%)	1.84	0.58
Organic matter (%)	3.17	1.00
Available P (mg/kg)	2.05	1.19
Ammonium N (mg/kg)	0.95	0.79
Nitrate N (mg/kg)	0.19	0.16

*P= Phosphorus; N= Nitrogen

LER were obtained from strip intercropping which was consistently higher than that obtained from mixed intercropping and monocropping (Table 4).

Economic analysis showed that revenue obtained was a function of the varieties' yield, and the variation was significant ($P \leq 0.05$) among varieties and cropping systems (Table 5). The highest profits were obtained from crop mixtures of 'IT86D-1010' with maize followed by the 'IT82E-16' mixture and 'IT87K-499-35' with maize as strip intercropping while the lowest revenue was obtained from Glenda during both seasons. Likewise, strip intercropping of cowpea varieties 'IT86D-1010' and 'IT82E-16 with maize provided the highest profit and benefit-cost ratio followed by monocropping, and the lowest profit and benefit-cost ratio were achieved from mixed intercropping (Table 5).

Discussion

Results of the study indicated that strip intercropping performed significantly better than the mixed intercropping with respect to grain yield, LER and net returns (Table 3–5) and have great potential or attributes of improving the livelihood of farmers in Limpopo Province. The performance of any crop variety in any environment or cropping system is interplay of the variety's genetic characteristics which are expressed through the crop's physiological and morphological attributes to take advantage of the resources supplied by the environment or

Table 3: Interactive effect of intercropping systems and cowpea varieties on days to 50% flowering, 90% maturity and yield component of cowpea, and maize yield

Varieties	201–2016			2016–2017		
	Mono cropping	Strip intercropping	Mixed intercropping	Mono cropping	Strip intercropping	Mixed intercropping
Number of days taken to complete 50% flowering (days)						
Glenda	53.00c	53.00c	53.00c	60.67a	60.00a	51.67ab
IT82E-16	50.33cd	51.33cd	53.00c	51.33ab	51.67ab	51.67ab
IT86D -1010	53.33c	52.67c	53.00c	52.33ab	52.00ab	51.50ab
IT87K-499-35	58.67a	56.67ab	53.00c	50.67ab	50.57ab	51.67ab
TVu 13464	47.67d	51.00cd	53.00c	48.67bc	48.67bc	51.48ab
Number of days taken to complete 90% maturity (days)						
Glenda	88.67bc	91.67ab	94.00a	103.67a	103.67a	85.67d
IT82E-16	85.33c	82.67cd	94.00a	98.00bc	98.00bc	85.67d
IT86D -1010	86.00c	85.00c	94.00a	88.00cd	88.00cd	84.50d
IT87K-499-35	95.00a	91.00ab	94.00a	101.33ab	101.00ab	85.67d
TVu 13464	82.00cd	82.00cd	94.00a	94.00c	96.33c	86.81d
Plant height (cm)						
Glenda	54.27c	57.73ab	40.53de	59.60[NS]	51.80	39.00
IT82E-16	54.4c	51.2cd	40.53de	35.87	34.47	39.00
IT86D -1010	61.73a	47.33d	40.53de	33.40	38.07	36.20
IT87K-499-35	52.2cd	60.13a	40.53de	41.07	41.27	39.00
TVu 13464	39.8de	39.93de	40.53de	29.60	29.53	39.95
Number of pods per plant						
Glenda	14.63bc	15.31bc	14.00c	9.33c	9.73c	16.13a
IT82E-16	16.57ab	18.77a	14.00c	10.87bc	12.13ab	16.13a
IT86D -1010	16.47ab	17.55a	14.00c	9.40c	9.53c	17.20a
IT87K-499-35	14.80bc	16.25ab	14.00c	10.47bc	12.07ab	16.13a
TVu 13464	16.07ab	11.20	14.00c	8.27cd	7.67cd	15.83a
Grain yield (kg ha^{-1})						
Glenda	1205bc	635de	157e	715c	573d	390e
IT82E-16	1995a	1140c	157e	1265a	1025ab	390e
IT86D -1010	1525ab	1052c	157e	1075ab	1124a	335e
IT87K-499-35	920cd	815d	157e	1280a	887bc	390e
TVu 13464	905cd	850d	157e	760c	680cd	409e
Maize grain yield (kg ha^{-1})						
PAN 6479	3112a	2996a	1320b	3237a	3564a	2237b

Means, with in columns and rows for each trait, with same letters are statistically similar with each other according to DNMR test at $P \leq 0.05$
NS= Non-significant

Table 4: Interactive effect of intercropping systems and cowpea varieties on land equivalent ratio

Crop mixtures	2015–2016		2016–2017	
	Strip intercropping	Mixed intercropping	Strip intercropping	Mixed intercropping
Glenda + PAN 6479	1.25c	0.56d	2.29[NS]	1.32
TVu 13464 + PAN 6479	1.48b	0.61d	1.81	1.13
IT82E-16 + PAN 6479	1.58a	0.50d	1.98	1.00
IT86D -1010 + PAN 6479	1.65a	0.54d	1.97	1.07
IT87K-499-35 + PAN 6479	1.59a	0.60d	2.15	1.04

Means, with in columns and rows for each trait, with same letters are statistically similar with each other according to DNMR test at $P \leq 0.05$
NS= Non-significant

Table 5: Interactive effect of intercropping systems and cowpea varieties on net income and BCR

Crop mixture	Maize RY yield (kg ha^{-1})	Maize revenue (US$ ha^{-1})	Cowpea RY (kg ha^{-1})	Cowpea revenue (US$ ha^{-1})	Total revenue (US$ ha^{-1})	Total cost (US$ ha^{-1})	Total profit (USD$ ha^{-1})	BCR
Glenda + Pan 6479	2638.5	1412.5	604.0	1724.5	3137.0	1302.9	1834.0	2.41
IT82E-16 + Pan 6479	2872.0	1537.5	1082.5	3090.7	4628.1	1653.0	2975.2	2.80
IT86D -1010 + Pan 6479	2797.0	1497.3	1088.0	3106.5	4603.7	1612.5	2991.2	2.86
IT87K-499-35 + Pan 6479	2686.0	1437.9	851.0	2429.7	3867.6	1497.8	2369.8	2.58
TVu 13464 + Pan 6479	2733.0	1463.1	765.0	2184.2	3647.2	1453.3	2193.9	2.51
Mixed cropping	1778.5	952.1	269.9	770.6	1722.7	968.2	754.5	1.78
Monocropping	3174.5	1699.4	1164.5	3324.8	5024.2	2324.3	2699.8	2.16

*BCR= Benefit-cost ratio; 1 US$= 14.01 ZAR

the cropping system. In this study, we obtained significant interactions between the varieties and the cropping systems for most variables measured (the number of days to 90% physiological maturity, plant height, number of pods per plant, grain yield and profit). This is an indication that the cropping systems influenced the performance of the cowpea varieties. The earliness to flower and physiological maturity are phenologically linked to enable the plant produce, and avoid losses associated with pests, drought or frost damage. In this study, we found that cowpea varieties flowered and matured differently among the cropping systems. This will offer the farmers the opportunity to make selection among the cowpea varieties, as well as giving them the empirical data to make an informed decision regarding the adoption of strip intercropping. For instance, farmers can select promising varieties that flower and mature early in the strip intercropping to prevent drought and frost damage. In this regard, 'TVu 13464' which attained earlier maturity in all the cropping systems during 2015–2016 and 2016–2017 than the local variety Glenda is an ideal variety for drought or pest evasion, as well as indicating that it is well adapted to mature early under the strip intercropping systems (Idahosa *et al.* 2010; Agoyi *et al.* 2017). Varieties that exhibit late maturity are known to be more vulnerable to drought and frost damage (Agbogidi and Egho 2012; Mafakheri *et al.* 2017).

The variations among the cowpea varieties in the yield components especially, the plant height, and the number of pods per plant as well as the grain yield point to the fact that the cropping systems influenced the performance of inherent genetic characteristics of the varieties, which were translated to their abilities to adapt to the environments (Fery 1985; Ichi *et al.* 2013). The cropping systems performed differently because the systems were able to discriminate the abilities of the varieties to compete for growth resources such as light, water, nutrients, space, and time. The results of this study corroborate the findings of past reports (Nwosu *et al*. 2013; Agyeman *et al*. 2014; Zerihun *et al.* 2016). Cropping systems (strip intercropping and monocropping) that supported higher plant height and pod numbers consistently produced higher grain yield, except during 2016–2017, when the number of pods was higher under mixed intercropping due to irregular plant density or no patterned plant arrangement, which led to less optimal plant population (Gabatshele *et al.* 2012). Iderawumi and Friday (2013) and Matusso *et al.* (2014) reported that mono-cropped cowpea plots produced significantly more pods per plant than those intercropped with maize. Consistently, higher grain yields obtained from cowpea varieties under monocropping during the two seasons is a clear indication that the varieties were bred and selected under a mono-cultural system. This may suggest that varieties to be utilised in an intercropping system must be developed and screened for selection under intercropping systems. This also justifies our decision to include several varieties so that farmers have the options to select the most promising and adapted varieties for cultivation.

In this study, strip intercropping produced three-fold more grain yield compared to the mixed intercropping. Nonetheless, maize grain yield was also higher in the case of strip intercropping compared with mixed intercropping due to efficient resource utilization and optimal plant population (Table 3). However, contrary to the observation of Matusso *et al.* (2014), Mango *et al*. (2018) reported that intercropping can generate higher crop yields and profits than monocropping.

The variations exhibited among the cowpea varieties during both seasons for most of the variables measured were due to their genetic characteristics and their interactions with weather variables (rainfall and temperature). A long period of rainfall during the reproductive phase is known to alter or extend the maturity of legumes, because it prolongs the flowering and podding period, which in turn leads to asynchronous maturity due to overlapping flowering. Therefore, more pods and grain yield were produced during the 2015–2016 cropping season, because rainfall and temperature distributions during the reproductive phase of the crop were better than they had been during the 2016–2017 season (Table 1). Zerihun *et al.* (2016) and Agoyi *et al*. (2017) also observed that adequate soil moisture during the reproductive stage is known to enhance grain filling, which can result in an increased grain yield.

Results of this study showed that the LER for strip intercropping system were greater than 1.00, which indicated that the system was more efficient in land and resource utilisation compared to mixed intercropping. According to Hamd *et al.* (2014), "when the LER < 1.00, there is an obvious disadvantage caused by intercropping, and the available resources were used more efficiently by the sole crop than intercropping". Mariotti *et al.* (2006) and Kitonyo *et al.* (2013) also report that "when the LER is equal to 1, there is neither an advantage nor a disadvantage of intercropping compared to a sole crop, but when the LER > 1.00, it indicates that intercropping system has an advantage in terms of improved use of available resources for plant growth and development". In this study, the higher LER values (two-fold) with a range between 1.25 and 2.29 during both seasons were obtained for strip intercropping thus indicating that available land resources were utilized more efficiently compared to mixed intercropping with LER values ranging from 0.50 to 1.32 for both seasons. In addition, this is an indication that the higher the yield and more adapted the varieties, the more advantageous the benefit-cost ratio, and the profit farmers would earn in cultivating such varieties. According to Zhang *et al*. (2015), intercropping cereals with grain legumes has superior yield and economic benefits compared to sole cropping. The prospect of any cropping system for adoption depends on its comparative advantage in terms of yields and cash return over the sole crops (Seran and Brintha 2010; Imran *et al*. 2011; Asiwe and Madimabe 2020). The findings from this study corroborate these reports. Higher profit and benefit-cost ratio were achieved from strip intercropping compared to the profit and benefit-cost ratio achieved from mixed intercropping.

Conclusion

Results revealed that grain yield, land equivalent ratio, net profits, and benefit:cost ratio obtained from strip intercropping were higher compared to mixed intercropping.

Among the five varieties, 'IT82E-16', 'IT86D-1010', and 'IT87K-499-35' out-performed Glenda in terms of grain yield, land equivalent ration and net returns in strip intercropping system grown under rain-fed conditions. Therefore, these varieties are recommended for cultivation under strip intercropping system and rain-fed conditions of Limpopo Province, South Africa.

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Author Contributions

Both authors contributed meticulously in the execution of the study during planting of the trial, data collection and collation, data analysis and the preparation of the First Manuscript Draft. The First author handled the corrections and correspondence from the reviewers.

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