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Cowpea yield under the influence of cropping system, location and nitrogen fertilization

Erick Sebetha* and Albert Modi[1]

Crop Science Department, School of Agriculture, Science and Technology,
North-West University, Mafikeng Campus, Private Bag x 2046, Mmabatho 2735.
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ABSTRACT

Yield production of cowpea depends largely on the environmental factors, cropping systems and soil type of the location. In this way, an experiment was conducted to investigate the interaction effect of cropping system, location, season and nitrogen fertilization on cowpea yield. The study comprised of three cropping systems (Maize-cowpea rotation, monocropping cowpea and intercropped cowpea), three locations (Potchefstroom, Taung, and Rustenburg, South Africa) and two rates of nitrogen fertilizers applied in kg ha^{-1} at each site (0 and 20 at Potchefstroom, 0 and 17 at Rustenburg, 0 and 23 at Taung). A factorial experiment randomized in complete block design with three replications was conducted during 2011/12 and 2012/13 planting seasons. The measured yield and yield components were pod length, seed per pod, pods mass at harvest, grain yield and field biomass yield. Cowpea planted on monocropping and rotational systems had significantly ($P < 0.05$) higher seed number per pod at harvest, grain yield and field biomass yield than cowpea planted on intercropping. The interaction of location x season plays a vital role on cowpea production by increasing yield. A single cultivar might differ significantly across different locations due to different soil types and climatic factors.

Key words: Intercropping, Location, Monocropping, Rotational, Yield.

INTRODUCTION

Cowpea is a crop that play diverse role in contributing to the food security, income generation and soil amelioration for small-scale farming conditions (Amajoyegbe and Elemo, 2013). The practice of increasing yield by crop rotation has been known for many years. The positive effect of crop rotation on yield arises from the added nitrogen from legume in the cropping system. According to Birteeb *et al*. (2011) intercropping system significantly reduces the biomass yield of the intercropped legumes. The yields advantage in cowpea sole crop is explained not only by the high plant density but also by the absence of competition with other crops (Egbe *et al*., 2010). Other potential benefits of intercropping include high productivity and profitability, increase in soil fertility through nitrogen fixation by addition of leguminous crop in intercropping system (Aziz *et al*., 2015).

Intercropping decreases bean biomass yield at all bean population and all N level as compared to sole cropping system. Katsaruware and Manyanhaire (2009) reported that the competitive effects of the cowpea intercrop, particularly on drought sensitive lands, are enhanced by increasing cowpea density and by lowering cereal density. According to Martellotto (2010) increasing yield by practicing crop rotation has been known for many years. It has been assumed that the positive effects of rotations arise from the added N from legumes in the cropping system (Blesh and Drinkwater, 2013).

Cowpea yield significantly responds to crop rotation, indicating that factors other than N alone contribute to the yield increases in cereal-legume rotation (Yusuf *et al*., 2009). According to Kureh *et al*. (2006) cowpea is the best rotated crop, followed by sunflower, mungbean and soybean. Cowpea grain and stover yield are not influenced by nitrogen application as would be expected for a legume crop (Abayomi *et al*., 2008). According to Hasan *et al*. (2010) biomass yield of cowpea increases with increasing level of nitrogen fertilizer. Biomass yield of beans increases progressively and significantly as bean population increased at all N level (Gidago *et al*., 2011).

When pure nitrogen is applied at a rate of 45 kg/ha, it has ability to increase seed yield, plant height, number of pods per plant, number of seeds per pod and pod length (Azarpour *et al*., 2011). According to Chianu *et al*. (2010), in agriculture adverse is taken of the ability to fix nitrogen by legume crops like soybean, cowpea and common beans, all of which generally have the ability to nodulate with a wide variety of rhizomes strains in the soil. According to Nyoki and Ndakidemi (2014) nitrogen fixation is of particular relevance in providing an important source of N, especially in Africa where fertilizers are often not affordable to smallholder farmers and where fertilizer input remains at

*Corresponding author's e-mail: Erick.Sebetha@nwu.ac.za. [1]Crop Science, School of Agriculture, Earth and Environmental Sciences, University of KwaZulu-Natal, Private Bag x 01, Scottsville 3209.

a very low level. The study was conducted to determine the interaction effect of cropping system, location, season and nitrogen fertilizer on yield and yield components. It was also aimed to determine the effect of different climatic and environment factors on cowpea yield performance by conducting the study at different locations.

MATERIALS AND METHODS

The study was conducted at three dryland sites in South Africa, namely the department of Agriculture experimental station in Taung situated at 27^0 30′ S and 24^0 30′ E, Agriculture Research Council-Grain Crops Institute (ARC-GCI) experimental station in Potchefstroom situated at 27^0 26′ S and 27^0 26′ E, and the Agricultural Research Council-Institute for Industrial Crops (ARC-IIC) experimental station in Rustenburg 25^0 43′ S and 27^0 18′ E. Taung experimental site is situated in grassland savannah with annual mean rainfall of 1061 mm that begins in October. The ARC-GCI experimental station (Potchefstroom) has clay percentage of 34 and receives annual mean rainfall of 622.2 mm, with daily temperature range of 9.1 to 25.2°C during planting (Macvicar *et al*., 1977). The ARC-IIC experimental station (Rustenburg) has clay percentage of 49.5 and receives an annual mean rainfall of 661 mm. Potchefstroom (ARC-GCI) has plinthic catena soil, eutrophic, red soil widespread (Pule-Meulenberg *et al*., 2010). The soil at Taung is described as Hutton, deep, fine sandy dominated red freely drained, eutrophic with parent material that originated from Aeolian deposits (Staff, 1999). The soil at Rustenburg (ARC-IIC) has dark, olive grey and clay soil, bristle consistency, medium granular structure (Botha *et al*., 1968). The weather data recorded at three sites during the course of the study is indicated in Table 1.

The experiment was established in 2010/11 planting season and data considered for experiment was collected during 2011/12 and 2012/13 planting seasons. The experimental design was factorial experiment laid out in random complete block design (RCBD) with three replicates. The statistical method was based on the previously published study by Blade *et al*. (1997). This technique allows accurate randomisation and analysis of variance for a multivariate design.

The experiment consisted of three cropping systems (monocropping, rotational and intercropping), three locations (Potchefstroom, Taung, and Rustenburg) and two levels of nitrogen fertilizer (urea) at each site, *i.e*., the amount of 0 and 20; 0 and 17; 0 and 23 kg N ha^{-1} applied on cowpea plots at Potchefstroom, Rustenburg, and Taung respectively. The amount of 0 and 95; 0 and 92; 0 and 113.5 kg N ha^{-1} were applied on maize plots (Monocropping, rotational and intercropping) at Potchefstroom, Rustenburg and Taung respectively. Maize cultivar (PAN 6479) and cowpea (Bechuana white) were used as test crop.

Grain yield was recorded from the harvest area of 12 m^2 within each plot of rotational and monocropping cowpea. The harvest area of cowpea in intercropping plots was 8 m^2. Dried pods of cowpea were harvested, weight and recorded. Pods length and seeds per pod were recorded and thereafter pods were shelled and weighed for grain yield. The mass of grains per plot was converted to kg ha^{-1}. After harvesting of pods, the remaining plants at harvest area constituted for the field biomass yield. Analysis of variance was performed using GenStat 14^{th} edition (2012). Least significant difference (LSD) was used to separate means. A

Table 1: The mean temperature and rainfall data for Potchefstroom, Taung and Rustenburg for the duration of experimental period.

Site	Season	Climate data	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Potch	2011/12	Rainfall(mm)	35.6	66.3	75.9	19.1	33.8	66.3	4.3	0.0
		Max T (°C)	28.6	29.5	28.6	30.4	29.1	28.7	25.0	25.0
		Min T (°C)	11.2	13.8	15.8	16.2	16.3	13.6	8.1	5.2
	2012/13	Rainfall(mm)	21.8	13.5	42.4	45.7	28.7	43.9	47.5	8.1
		Max T (°C)	29.0	30.2	27.9	30.1	31.0	28.4	24.3	22.6
		Min T (°C)	12.4	14.6	15.4	16.8	15.5	14.6	9.1	3.9
Taung	2011/12	Rainfall(mm)	3.1	36.1	71.4	7.9	40.9	12.5	5.1	0.5
		Max T (°C)	31.1	33.3	32.8	36.1	32.9	32.9	28.0	27.7
		Min T (°C)	9.3	10.6	14.8	16.2	17.0	13.8	8.2	4.5
	2012/13	Rainfall(mm)	0.3	8.9	14.9	40.9	32.0	14.2	9.2	8.4
		Max T (°C)	32.5	34.9	32.9	36.3	31.5	31.8	27.3	26.8
		Min T (°C)	10.7	14.3	15.7	17.8	17.7	15.0	9.4	6.2
Rust	2011/12	Rainfall(mm)	23.4	49.8	47.2	19.3	6.4	27.9	6.6	0.3
		Max T (°C)	28.7	30.2	28.3	30.2	30.9	29.0	25.0	25.1
		Min T (°C)	11.7	14.9	17.0	15.3	17.2	14.4	9.3	6.6
	2012/13	Rainfall(mm)	21.1	25.9	48.0	37.3	20.6	10.9	46.5	0.0
		Max T (°C)	28.3	29.9	28.1	29.9	31.1	29.1	25.5	23.2
		Min T (°C)	12.8	14.8	16.1	17.4	16.3	14.7	10.2	4.7

Potch = Potchefstroom, Rust = Rustenburg, Max T (°C) = Maximum temperature in degrees Celsius, Min T (°C) = Minimum temperature in degrees Celsius, mm = millimetres.

probability level of less than 0.05 was considered as significant statistically (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Cowpea pod length: Cowpea pod length was significantly affected (P = 0.034) by the interaction of cropping system x nitrogen fertilizer as indicated in Table 2. Monocropped cowpea supplemented with nitrogen fertilizer during planting had significantly longer pod length of 17.7 cm than other cropping systems.

Cowpea seed per pod: Cowpea seed per pod was significantly affected by the interaction of location x season (P = 0.012) and the interaction of cropping system x location x season (P = 0.004) as indicated in Table 3. Cowpea planted at Taung and Potchefstroom during 2012/13 planting season had significantly higher seed per pod of 14.5 and 13.2 respectively than other location. Intercropped and monocropped cowpea planted at Rustenburg during 2011/12 planting season had significantly higher seed per pod of

Table 2: Analysis of variance on cowpea pod length as affected by cropping system, location, season and nitrogen fertilization.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
RP stratum	2	1.2702	0.6351	1.36	
RP.*Units* stratum					
CS	2	2.5302	1.2651	2.71	0.074
LN	2	15.7480	7.8740	16.84	<.001**
N	1	0.4033	0.4033	0.86	0.356
SN	1	0.0448	0.0448	0.10	0.758
CS.LN	4	0.9259	0.2315	0.50	0.739
CS.N	2	3.3050	1.6525	3.53	0.034*
LN.N	2	2.3439	1.1719	2.51	0.089
CS.SN	2	1.7646	0.8823	1.89	0.159
LN.SN	2	1.9302	0.9651	2.06	0.135
N.SN	1	0.0004	0.0004	0.00	0.978
CS.LN.N	4	1.2344	0.3086	0.66	0.622
CS.LN.SN	4	3.4404	0.8601	1.84	0.131
CS.N.SN	2	0.9180	0.4590	0.98	0.380
LN.N.SN	2	1.4246	0.7123	1.52	0.225
CS.LN.N.SN	4	0.7570	0.1893	0.40	0.805
Residual	70	32.7298	0.4676		
Total	107	70.7707			

CS = Cropping system, LN = Location, N = Nitrogen fertilizer, SN = Season, RP = Replication, *Significant at < 0.05 probability level, **Significant at ≤ 0.001 probability level.

Table 3: Analysis of variance on cowpea seeds per pod as affected by cropping system, location, season and nitrogen fertilization.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
RP stratum	2	2.389	1.195	0.80	
RP.*Units* stratum					
CS	2	11.747	5.874	3.94	0.024*
LN	2	46.559	23.280	15.60	<.001**
N	1	2.225	2.225	1.49	0.226
SN	1	11.021	11.021	7.39	0.008*
CS.LN	4	2.495	0.624	0.42	0.795
CS.N	2	1.872	0.936	0.63	0.537
LN.N	2	8.801	4.401	2.95	0.059
CS.SN	2	2.276	1.138	0.76	0.470
LN.SN	2	14.137	7.069	4.74	0.012*
N.SN	1	0.033	0.033	0.02	0.881
CS.LN.N	4	0.231	0.058	0.04	0.997
CS.LN.SN	4	24.792	6.198	4.15	0.004*
CS.N.SN	2	0.367	0.184	0.12	0.884
LN.N.SN	2	4.036	2.018	1.35	0.265
CS.LN.N.SN	4	10.406	2.601	1.74	0.150
Residual	70	104.451	1.492		
Total	107	247.839			

CS = Cropping system, LN = Location, N = Nitrogen fertilizer, SN = Season, RP = Replication, *Significant at < 0.05 probability level, **Significant at ≤ 0.001 probability level.

14.2 and 14.1 respectively than rotational cowpea. During 2012/13 planting season, cowpea planted at Rustenburg under rotational system had significantly higher seed per pod of 12.9 than intercropping and monocropping cowpea.

Cowpea pod mass at harvest: Cowpea pod mass was significantly affected by the interaction of cropping system x location (P = 0.013) and the interaction of location x season (P ≤ 0.001) as indicated in Table 4. Monocropped and rotational cowpea planted at Potchefstroom had significantly higher pod mass of 2212.5 and 2142.7 kg/ha respectively than intercropped cowpea. Monocropped and rotational cowpea had significantly higher pod mass of 2166.0 and 2096.2 kg/ha respectively than intercropped cowpea. Cowpea planted at Taung under rotational and monocropping also had significantly higher pod mass of 3852.1 and 3018.0 kg/ha than intercropping. Cowpea planted at Potchefstroom had significantly higher pod mass of 2996.0 kg/ha during 2011/12 planting season than other locations. Cowpea planted at Taung during during 2012/13 planting season had significantly higher pod mass of 3086.6 kg/ha than other locations.

Cowpea grain yield: Cowpea grain yield was significantly affected by the interaction of cropping system x location (P = 0.037); cropping system x season (P = 0.026) and location x season (P ≤ 0.001) as indicated in Table 5. Monocropped and rotational cowpea planted at Potchefstroom had significantly higher grain yield of 1470.4 and 1429.0 kg/ha than intercropped cowpea. Monocropped and rotational cowpea planted at Taung had significantly higher grain yield of 1652.1 and 1714.4 kg/ha respectively than intercropped cowpea. Monocropped and rotational cowpea planted at Taung also had significantly higher grain yield of 2084.9 and 2571.5 kg/ha respectively than intercropped cowpea. Monocropped and rotational cowpea had significantly higher grain yield of 2199.8 and 2429.8 kg/ha respectively during 2011/12 planting season. During 2012/13 planting season, monocropped and rotational cowpea also had significantly higher grain yield of 1271.9 and 1380.2 kg/ha respectively than intercropped cowpea. Cowpea planted at Taung during 2012/13 planting season had significantly higher grain yield of 2118.3 kg/ha than other locations.

Cowpea field biomass yield at harvest: Cowpea field biomass yield was significantly affected (P ≤ 0.001) by the interaction of location x season as indicated in Table 6. Cowpea planted at Taung and Potchefstroom during 2011/12 planting season had significantly higher biomass yield of 6398.6 and 5864 kg/ha respectively than other location. Cowpea planted at Taung during 2012/13 had significantly higher biomass yield of 3219.4 kg/ha than other locations.

The higher number of seeds per pods, pod mass, grain yield and field biomass yield under cowpea planted on monocropping and rotational systems might have been attributed to improved soil structure and fertility by cowpea. Vesterager *et al*. (2007) stated that the N-value of growing cowpea monocropping was equivalent to the application of 50 kg N ha^{-1} as mineral fertilizer. It was further indicated that cowpea cultivation result in a net N drain to the system and result in a considerable net N contribution to the system.

Cowpea planted on monocropping system might enhance soil nitrogen status and could benefit a subsequent

Table 4: Analysis of variance on cowpea pods mass during harvest as affected by cropping system, location, season and nitrogen fertilization.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
RP stratum	2	273484.	136742.	0.33	
RP.*Units* stratum					
CS	2	26993921.	13496961.	32.74	<.001**
LN	2	31220042.	15610021.	37.86	<.001**
N	1	15853.	15853.	0.04	0.845
SN	1	33278356.	33278356.	80.72	<.001**
CS.LN	4	5678917.	1419729.	3.44	0.013*
CS.N	2	454351.	227175.	0.55	0.579
LN.N	2	851303.	425651.	1.03	0.362
CS.SN	2	472761.	236381.	0.57	0.566
LN.SN	2	24785824.	12392912.	30.06	<.001**
N.SN	1	67106.	67106.	0.16	0.688
CS.LN.N	4	914209.	228552.	0.55	0.696
CS.LN.SN	4	1753872.	438468.	1.06	0.381
CS.N.SN	2	807553.	403777.	0.98	0.381
LN.N.SN	2	185227.	92613.	0.22	0.799
CS.LN.N.SN	4	2714564.	678641.	1.65	0.172
Residual	70	28860375.	412291.		
Total	107	159327719.			

CS = Cropping system, LN = Location, N = Nitrogen fertilizer, SN = Season, RP = Replication, *Significant at < 0.05 probability level, **Significant at ≤ 0.001 probability level.

Table 5: Analysis of variance on cowpea grain yield as affected by cropping system, location, season and nitrogen fertilization.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
RP stratum	2	69067.	34533.	0.22	
RP.*Units* stratum					
CS	2	16913954.	8456977.	52.87	<.001**
LN	2	11951214.	5975607.	37.36	<.001**
N	1	21885.	21885.	0.14	0.713
SN	1	19126707.	19126707.	119.58	<.001**
CS.LN	4	1732081.	433020.	2.71	0.037*
CS.N	2	385583.	192792.	1.21	0.306
LN.N	2	754949.	377475.	2.36	0.102
CS.SN	2	1234462.	617231.	3.86	0.026*
LN.SN	2	15477192.	7738596.	48.38	<.001**
N.SN	1	1934.	1934.	0.01	0.913
CS.LN.N	4	84999.	21250.	0.13	0.970
CS.LN.SN	4	719240.	179810.	1.12	0.352
CS.N.SN	2	434420.	217210.	1.36	0.264
LN.N.SN	2	308425.	154212.	0.96	0.386
CS.LN.N.SN	4	1266337.	316584.	1.98	0.107
Residual	70	11196108.	159944.		
Total	107	81678559.			

CS = Cropping system, LN = Location, N = Nitrogen fertilizer, SN = Season, RP = Replication, *Significant at < 0.05 probability level, **Significant at d" 0.001 probability level.

Table 6: Analysis of variance on cowpea field biomass yield as affected by cropping system, location, season and nitrogen fertilization.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
RP stratum	2	7011917.	3505958.	1.08	
RP.*Units* stratum					
CS	2	45671257.	22835629.	7.05	0.002*
LN	2	131527574.	65763787.	20.30	<.001**
N	1	4260248.	4260248.	1.32	0.255
SN	1	231514912.	231514912.	71.48	<.001**
CS.LN	4	17979226.	4494806.	1.39	0.247
CS.N	2	3117689.	1558844.	0.48	0.620
LN.N	2	828028.	414014.	0.13	0.880
CS.SN	2	14998033.	7499016.	2.32	0.106
LN.SN	2	79496295.	39748147.	12.27	<.001**
N.SN	1	919806.	919806.	0.28	0.596
CS.LN.N	4	5615967.	1403992.	0.43	0.784
CS.LN.SN	4	25132053.	6283013.	1.94	0.113
CS.N.SN	2	652438.	326219.	0.10	0.904
LN.N.SN	2	1430887.	715444.	0.22	0.802
CS.LN.N.SN	4	5839227.	1459807.	0.45	0.772
Residual	70	226716949.	3238814.		
Total	107	802712506.			

CS = Cropping system, LN = Location, N = Nitrogen fertilizer, SN = Season, RP = Replication, *Significant at < 0.05 probability level, **Significant at ≤ 0.001 probability level.

cereal in legume/cereal crop rotation, provided the high N content stover is restored to the soil (Mwanarusi *et al*., 2010). The main effect of legume is commonly attributed to an increase in soil N fertility as a result of biological N_2 fixation (Bado *et al*., 2011). The higher yield of cowpea planted on monocropping system than cowpea planted on intercropping system confirms the statements by Nyasasi and Kisetu (2014) that yield of intercropped cowpea was less than half that of monocropping cowpea at the same row spacing. They reported that cowpea could not maintain its yield potential when intercropped with maize.

According Egbe *et al*. (2010) intercropping depressed the number of branches per plant and the dry grain yield of cowpea, but did not influence the number of seed per pod and the pod length of cowpea. Better environmental factors such as rainfall and temperature during 2012/13 as indicated in Table 1, might have contributed towards higher seed per pod, pods weight, grain yield, field and biomass

yield. Even though one cultivar of cowpea was planted at different locations, the yield performance differed across the locations due to different soil types, soil temperature and rainfall. The lower cowpea yield at Potchefstroom and Rustenburg during 2012/13 planting season may have been attributed to severe birds attack during maturity stage. The higher cowpea yield at Taung during both planting seasons may have been attributed to climatic condition as indicated in Table 1. According to Adeoye *et al*. (2011) cowpea has ability to tolerate drought and the fact that it fixes atmospheric nitrogen if allowed to grow on a poor soil. All cultivated cowpea varieties are considered warm season and adapted to heat and drought condition and better adapted to sandy soil (Ishiyaka and Aliyu, 2013). The new information revealed in this study was that, the interaction of location x season played a significant role on yield production of cowpea as indicated on Table 3, 4, 5 and 6. The interaction of location x season in this study affected cowpea seed per pod, pod mass, grain yield and field biomass yield. The interaction of cropping x location and cropping system x season in this study played a role on cowpea grain yield.

In this study, it was concluded that the interaction of location x season had significant contribution towards increase in cowpea yield, since such interaction affected cowpea seed per pod, pod mass at harvest, grain yield and field biomass yield. The application of nitrogen fertilizer has no role on improvement of cowpea yield at different sites. Intercropping of cowpea suppressed the growth and yield of cowpea. Higher yield of cowpea is expected in the soil with high percentage of sand since cowpea is well adapted to sandy soil. There is strong correlation between soil organic carbon and cowpea yield. A single cultivar might differ significantly across different locations due to different soil types and climatic factors. The future study should focus on the effect of organic fertilizers, different planting dates and climatic factors on cowpea yield improvement.

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