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MAIZE GROWTH IN RESPONSE TO CROPPING SYSTEM, SITE AND NITROGEN FERTILIZATION

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ABSTRACT

Maize is often grown on the same land year after year as sole crops and this result in lower yield from monocropped maize. An experiment was conducted to investigate the effects of cropping system, location and nitrogen fertilization on maize growth parameters. The study comprised three cropping systems (cowpea-maize rotation, monocropping maize and intercropped maize), three locations (Potchefstroom, Taung and Rustenburg) and two rates of nitrogen fertilizers applied at each location (0 and 95 kg ha^{-1} at Potchefstroom, 0 and 92 at Rustenburg, 0 and 113.5 at Taung). The study was a factorial experiment randomised in complete block design with three replications, conducted during 2011/12 and 2012/13 planting seasons. Measured parameters were days to 100% tasseling, maize plant height, number of leaves per plant, leaf area and stem diameter. Cropping system, location, nitrogen fertilizer and season had significant effects ($p<0.05$) on maize leaf area and plant height. Maize planted at Potchefstroom had significantly larger stem diameter than maize planted at Taung and Rustenburg. Rotational cropping system had significant role in terms of maize phenological growth. Location and nitrogen fertilization also had a significant influence on growth of maize plants.

Key words: cropping system, leaf area, plant height, stem diameter.

INTRODUCTION

Maize growth affects the yield production at the end of the season during harvest period. Maize grown as sole crop under rainfed upland conditions was found to be rather risky due to erratic rainfall (Haque et al., 2013). The practice of intercropping of compatible crops is considered viable option to overcome the situation (Brintha and Seran, 2008). Intercropping significantly increases plant height in maize (Hamd-Alla et al., 2014). Plant height is an important maize yield component (Rehman et al., 2010). The height of corn was significantly greater under intercropping treatments than in sole crops (Ariel et al., 2013). The rotation of early season sole cowpea crop with the late season sole maize crop gave the highest maize plant survival and plant height (Kureh et al., 2006). Continuous intercropping of maize on the same strip in the early and late cropping seasons gave very poor growth of maize. The leaf area of corn was found to be significantly higher under intercropping treatments than in its respective sole crop (Valadabadi and Farahani, 2009). Leaf area is influenced by plant population and soil fertility. Plant height and leaf area per plant were reported to be significantly influenced by the previous legume crop (Adeleke and Haruna, 2012). They further indicated that this could be attributed to higher nitrogen fixed into the soil by legume through symbiotic nitrogen fixation. This confirms the fact that nitrogen is an essential element needed for plant growth and development. Nitrogen fertilizer application improved plant growth by increasing plant height and stem diameter at the end of vegetative growth (Widowati et al., 2012). Maize physiological growth during previous studies was not extensively compared among intercropping and rotation in relation to nitrogen fertilization. The objective of this study was to determine the effects of cropping system, location and nitrogen fertilization on maize phenological growth.

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MATERIAL AND METHODS

Experimental sites

The study was conducted at three dryland locations in South Africa, namely the department of Agriculture experimental station in Taung situated at 270 30′S and 240 30′E, Agriculture Research Council-Grain Crops Institute (ARC-GCI) experimental station in Potchefstroom situated at 270 26′S and 270 26′E and the Agricultural Research Council-Institute for Industrial Crops (ARC-IIC) experimental station in Rustenburg 250 43′S and 270 18′E (Sebetha et al., 2015). The ARC-GCI experimental station has soil 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., 1997). The ARC-IIC experimental station has soil clay percentage of 49.5 and receives an annual mean rainfall of 661 mm. Taung experimental location is situated in grassland savannah with annual mean rainfall of 1061 mm that begins in October. 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 climatic data at the three locations during the study were different (Table 1), as described by (Sebetha et al., 2015).

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
Potchefstroom	2011/12	Rainfall (mm)	35.58	66.29	75.95	19.05	33.78	66.29	4.32	0
		Max T (˚C)	28.64	29.45	28.57	30.42	29.11	28.72	25.00	25.00
		Min T (˚C)	11.19	13.78	15.81	16.22	16.30	13.59	8.05	5.17
	2012/13	Rainfall (mm)	21.84	13.46	42.42	45.72	28.70	43.94	47.50	8.14
		Max T (˚C)	29.01	30.21	27.99	30.11	31.03	28.43	24.32	22.61
		Min T (˚C)	12.43	14.62	15.41	16.81	15.50	14.58	9.12	3.86
Taung	2011/12	Rainfall (mm)	3.05	36.07	71.37	7.87	40.89	12.45	5.08	0.51
		Max T (˚C)	31.05	33.28	32.80	36.12	32.87	32.96	28.02	27.65
		Min T (˚C)	9.25	10.60	14.79	16.19	17.01	13.75	8.24	4.48
	2012/13	Rainfall(mm)	0.25	8.89	14.99	40.89	32.00	14.20	9.20	8.40
		Max T (˚C)	32.5	34.98	32.86	36.29	31.50	31.80	27.30	26.80
		Min T (˚C)	10.74	14.27	15.71	17.83	17.70	15.00	9.40	6.20
Rustenburg	2011/12	Rainfall (mm)	23.37	49.79	47.24	19.30	6.35	27.94	6.60	0.25
		Max T (˚C)	28.68	30.18	28.28	30.20	30.95	29.00	25.04	25.13
		Min T (˚C)	11.71	14.91	17.00	15.34	17.21	14.37	9.34	6.58
	2012/13	Rainfall (mm)	21.08	25.91	48.01	37.34	20.58	10.92	46.48	0
		Max T (˚C)	28.28	29.95	28.13	29.90	31.05	29.05	25.48	23.23
		Min T (˚C)	12.82	14.76	16.14	17.38	16.28	14.67	10.17	4.68

Max T (˚C) = Maximum temperature in degrees Celsius, Min T (˚C) = Minimum temperature in degrees Celsius, mm = millimetres.

Experimental design

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 experiment consisted of three cropping systems (monocropping, rotational and intercropping), three locations Potchefstroom, Taung and Rustenburg and two levels of nitrogen fertilizer at each site, which were 0 and 95; 0 and 92; 0 and 113.5 kg N ha^{-1} applied on maize plots at Potchefstroom, Rustenburg and Taung respectively. Maize cultivar (PAN 6479) and cowpea (Bechuana white) were used as test crops.

Data collection and analyses

Maize plant height and stem diameter were recorded from three selected plants from harvest area of 12 m^2 of each maize plot during maturity stage. Leaf area was recorded from three randomly selected plants from harvested area and averaged. Leaves per plant were measured by length (L) and width (W) corrected to 0.75, as described by (Saxena and Singth, 1965).

Analysis of variance was performed using GenStat 14th edition (2012). Least significant difference (LSD) was used to separate means. A probability level of less than 0.05 was considered as significant statistically (Gomez and Gomez, 1984). The main treatment factors and the first order interactions were considered on days to 100% tasseling, number of leaves per maize plant, maize plant height and stem diameter. The main treatment factors and the second order interactions were considered on maize leaf area.

RESULTS

Days to 100% tasseling

Cropping system had significant effect (p=0.005) on days to 100% tasseling of maize (Table 2.1). Cowpea-maize rotation had tasseled significantly earlier at 72.1 days than intercropped and monocropped maize. Days to 100% tasseling of maize were significantly affected ($p \leq 0.001$) by location effect. Maize planted at Rustenburg and Potchefstroom had tasselled significantly earlier at 67.2 and 73.7 days respectively than maize planted at Taung. Nitrogen fertilizer application had significant effect ($p \leq 0.001$) on days to 100% tasseling of maize. Maize treated with nitrogen fertilizer tasselled significantly earlier at 70.1 days than maize without nitrogen fertilizer treatment. Maize planted during 2012/13 planting season tasselled significantly earlier at 71.6 days than maize planted in 2011/12 planting season.

Days to 100% tasselling of maize were significantly ($p \leq 0.001$) affected by the interaction of location x nitrogen fertilizer (Table 2.2).

Days to 100% tasseling of maize were also significantly ($p \leq 0.001$) affected by the interaction of location x season (Table 2.3).

Table 2.1. The effects of cropping system, location, nitrogen fertilization and season on days to 100% tasseling of maize

Cropping system	Intercropping maize	Monocropping maize	Rotational maize
Means	74.64	74.14	72.14
LSD $_{(0.05)}$	1.56		
Location	Potchefstroom	Rustenburg	Taung
Means	73.72	67.19	80.00
LSD $_{(0.05)}$	1.56		
Nitrogen	N-fertilizer	Zero-nitrogen	
Means	70.06	77.22	
LSD $_{(0.05)}$	1.28		
Season	2011/12	2012/13	
Means	75.67	71.61	
LSD $_{(0.05)}$	1.28		

Table 2.2. The interaction effects of location x nitrogen fertilizer on days to 100% tasseling

Location	Nitrogen fertilizer	
	N-Fertilizer	Zero-Nitrogen
Potchefstroom	72.67	74.78
Rustenburg	63.11	71.28
Taung	74.39	85.61
LSD $_{(0.05)}$	2.20	

Table 2.3. The interaction effects of location x season on days to 100% tasseling

Location	Season	
	2011/12	2012/13
Potchefstroom	77.72	69.72
Rustenburg	67.72	66.67
Taung	81.56	78.44
LSD $_{(0.05)}$	2.2	

Maize plant height

Cropping system had significant effect ($p<0.001$) on maize plant height (Table 3.1). Cowpea-maize rotation and monocropping maize had significantly taller plant height of 191.6 and 182.6 cm respectively than intercropping maize. Maize plant height was significantly affected ($p<0.001$) by the effect of location. Maize planted at Potchefstroom and Rustenburg had significantly taller plant height of 199.7 and 187.4 cm respectively than maize planted at Taung. Nitrogen fertilizer also had significant effect ($p<0.001$) on maize plant height. Maize treated with nitrogen fertilizer had significantly taller plant of 191.7 cm than maize without nitrogen fertilizer treatment. Maize planted during 2011/12 planting season had significantly taller plants of 196.3 cm than maize planted in 2012/13 planting season.

Table 3.1. The effects of cropping system, location, nitrogen fertilization and season on maize plant height in centimeters

Cropping system	Intercropping maize	Monocropping maize	Rotational maize
Means	172.5	182.6	191.6
LSD $_{(0.05)}$	8.31		
Location	Potchefstroom	Rustenburg	Taung
Means	199.7	187.4	159.7
LSD $_{(0.05)}$	8.31		
Nitrogen	N-fertilizer	Zero-nitrogen	
Means	191.7	172.8	
LSD $_{(0.05)}$	6.79		
Season	2011/12	2012/13	
Means	196.3	168.2	
LSD $_{(0.05)}$	6.79		

Maize plant height was significantly ($p \leq 0.001$) affected by the interaction of location x season (Table 3.2).

Maize plant height was also significantly ($p \leq 0.001$) affected by the interaction of nitrogen fertilizer x season (Table 3.3).

Table 3.2. The interaction effects of location x season on maize plant height

Location	Season	
	2011/12	2012/13
Potchefstroom	226.8	172.5
Rustenburg	189.2	185.6
Taung	172.9	146.6
LSD $_{(0.05)}$	11.8	

Table 3.3. The interaction effects of nitrogen fertilizer x season on maize plant height

Nitrogen	Season	
	2011/12	2012/13
N-fertilizer	202.1	181.3
Zero-Nitrogen	190.5	155.1
LSD $_{(0.05)}$	9.6	

Number of leaves per maize plant

Number of leaves per maize plant was significantly affected ($p \leq 0.001$) by the effect of location (Table 4.1). Maize planted at Potchefstroom and Rustenburg had significantly higher number of leaves per plant of 15.1 and 12.8 respectively than maize planted at Taung.

Table 4.1. The effects of cropping system, location, nitrogen fertilization and season on number of leaves per maize plant

Cropping system	Intercropping maize	Monocropping maize	Rotational maize
Means	13.8	14.0	14.4
LSD $_{(0.05)}$	0.56		
Location	Potchefstroom	Rustenburg	Taung
Means	15.1	14.3	12.8
LSD $_{(0.05)}$	0.56		
Nitrogen	N-fertilizer	Zero-nitrogen	
Means	14.2	13.9	
LSD $_{(0.05)}$	0.46		
Season	2011/12	2012/13	
Means	14.2	13.9	
LSD $_{(0.05)}$	0.46		

Number of leaves per maize plant was significantly ($p=0.03$) affected by the interaction of location x nitrogen fertilizer (Table 4.2). Maize planted at Taung had significantly higher number of leaves (13.3) when treated with nitrogen fertilizer than maize without nitrogen fertilizer.

Table 4.2. The interaction effects of location x nitrogen fertilizer on number of leaves per maize plant

Location	Nitrogen fertilizer	
	N-Fertilizer	Zero-Nitrogen
Potchefstroom	15.0	15.3
Rustenburg	14.4	14.2
Taung	13.3	12.2
LSD $_{(0.05)}$	0.8	

Number of leaves per maize plant was also significantly ($p \leq 0.001$) affected by the interaction of location x season (Table 4.3).

Table 4.3. The interaction effects of location x season on number of leaves per maize plant

Location	Season	
	2011/12	2012/13
Potchefstroom	15.2	15.1
Rustenburg	15.2	13.4
Taung	12.2	13.4
LSD $_{(0.05)}$	0.8	

Maize leaf area

Cropping system had significant effect (p=0.02) on maize leaf area (Table 5.1). Cowpea-maize rotation had significantly larger leaf area of 724.7 cm^2 than intercropping and monocropping maize. Maize leaf area was also significantly affected (p<0.001) by the effect of location. Maize planted at Potchefstroom had significantly larger leaf area of 896.2 cm^2 than maize planted at Rustenburg and Taung. Nitrogen fertilizer had significant effect (p<0.001) on maize leaf area. Maize treated with nitrogen fertilizer had significantly larger leaf area of 796.1 cm^2 than maize without nitrogen fertilizer treatment. Maize planted during 2011/12 planting season had significantly large leaf area of 735.9 cm^2 than maize planted in 2012/13 planting season.

Maize leaf area was significantly (p=0.03) affected by the interaction of cropping system x location x nitrogen fertilizer (Table 5.2).

Table 5.1. The effects of cropping system, location, nitrogen fertilization and season on maize leaf area in centimeter squared

Cropping system	Intercropping maize	Monocropping maize	Rotational maize
Means	643.6	667.9	724.7
LSD $_{(0.05)}$	45.34		
Location	Potchefstroom	Rustenburg	Taung
Means	896.2	547.9	592.1
LSD $_{(0.05)}$	45.34		
Nitrogen	N-fertilizer	Zero-nitrogen	
Means	796.1	561.4	
LSD $_{(0.05)}$	37.02		
Season	2011/12	2012/13	
Means	735.9	621.5	
LSD $_{(0.05)}$	37.02		

Table 5.2. The interaction effects of cropping system x location x nitrogen fertilizer on maize leaf area

Cropping system	Potchefstroom		Rustenburg.		Taung	
	N-fertilizer	Zero-itrogen	N-fertilizer	Zero-itrogen	N-fertilizer	Zero-nitrogen
Intercropping maize	965.1	681.5	642.7	418.1	632.6	521.6
Monocropping maize	1053.7	748.6	620.3	476.0	748.3	360.3
Rotational maize	1097.6	830.7	659.0	471.3	745.3	544.6
LSD $_{(0.05)}$	111.0					

Maize stem diameter

Maize stem diameter was significantly affected (p<0.001) by location effect (Table 6.1). Maize planted at Potchefstroom had significantly lar ger stem diameter of 2.0 cm than maize planted at Taung and Rustenburg. Nitrogen fertilizer had significant effect (p<0.001) on maize stem diameter. Maize treated with nitrogen fertilizer had significantly larger stem diameter of 2.0 cm than maize without nitrogen fertilizer treatment. Maize planted during 2011/12 planting season had significantly larger stem diameter of 1.9 cm than maize planted in 2012/13 planting season.

Maize stem diameter was significantly (p≤0.001) affected by the interaction of location x nitrogen fertilizer (Table 6.2).

Maize stem diameter was also significantly (p=0.02) affected by the interaction of cropping system x season (Table 6.3).

Table 6.1. The effects of cropping system, location, nitrogen fertilization and season on maize stem diameter in centimeters

Cropping system	Intercropping maize	Monocropping maize	Rotational maize
Means	1.70	1.8	1.8
LSD $_{(0.05)}$	0.10		
Location	Potchefstroom	Rustenburg	Taung
Means	2.0	1.5	1.8
LSD $_{(0.05)}$	0.1		
Nitrogen	N-fertilizer	Zero-nitrogen	
Means	2.00	1.5	
LSD $_{(0.05)}$	0.08		
Season	2011/12	2012/13	
Means	1.90	1.6	
LSD $_{(0.05)}$	0.08		

Intercropping maize had significantly larger stem diameter of 1.9 cm during 2011/12 planting season than in 2012/13 planting season. Rotational maize also had significantly larger stem diameter of 1.9 cm during 2011/12 planting season than in 2012/13 planting season.

Table 6.2. The interaction effects of location x nitrogen fertilizer on maize stem diameter

Location	Nitrogen fertilizer	
	N-Fertilizer	Zero-Nitrogen
Potchefstroom	2.4	1.7
Rustenburg	1.6	1.4
Taung	2.0	1.6
LSD $_{(0.05)}$	0.14	

Table 6.3. The interaction effects of cropping system x season on maize stem diameter

Cropping system	Season	
	2011/12	2012/13
Intercropping maize	1.9	1.5
Monocropping maize	1.8	1.7
Rotational maize	1.9	1.7
LSD $_{(0.05)}$	0.14	

DISCUSSION

The early tasseling of maize fertilised with N fertilizer agrees with similar findings by Gajri et al. (1994) who reported that maize phenological parameters were significantly affected by the amount of N fertilizer. Rustenburg and Potchefstroom climatic factors such as rainfall and temperatures were favourable for maize to reach tasseling earlier. This agrees with similar findings by Kirtok (1998) and Tufekci (1999), who reported that tasseling period might vary depending on variety, climate and environment. The early tasseling of maize during 2012/13 may be attributed to favourable climatic factors during that period which took place in January (Table 1).

The taller maize plant height under rotational system may be attributed to soil fertility, since crop rotation improves soil structure, increased soil organic matter and increased water use efficiency (Roder et al., 1989; Varvel, 1994). A critical finding in this study was that although maize plant height was expected to be reduced under monocropping system, since monocropping of maize results in depletion of soil fertility, our results showed that it was higher under that system. In other studies, continuous cultivation of maize contributed to the rapid depletion of soil N (Logrono and Lothrop, 1997). The taller plant height under N fertilizer application corroborates the findings by Gozubenli (1997) and Tufekci (1999) who reported that plant height of corn was increased when application of N rates were increased.

The higher number of leaves per plant of maize planted at Potchefstroom followed by Rustenburg may have been caused to better soil structure and climatic factors, which led to better maize plant development. Stickler (1964) reported that number of leaves produced per maize plant was mainly affected significantly by cultivar.

The large leaf area under rotational system may be attributed to improvement of soil structure due to the rise of total nitrogen after harvesting of previous cowpea, which was indicated on soil analysis report. The large leaf area under N fertilizer plots agrees with similar findings by Adeleke and Haruna (2012), who reported that the significant response of maize leaf area to applied N fertilizer could be due to its role in promoting rapid vegetative growth and its direct effect on cell division. Asim et al. (2012) reported variations for season, plant population and N fertilizer and interaction on leaf area. They further indicated treatment interactions of season x plant population, season x nitrogen, plant population x nitrogen and season x plant population x nitrogen to be significant on maize leaf area.

Carpici et al. (2010) reported that response of stem diameter to N fertilization was statistically significant. They further indicated that stem diameter increased up to 300 kg N ha^{-1} and then stayed stable at 400 kg ha^{-1}. The large stem diameter during 2011/12 planting season was due to the favourable climatic factors such as rainfall of 33.78 and 66.29 mm at Potchefstroom, 40.89 and 12.45 mm at Taung and 6.35 and 27.94 mm at Rustenburg during vegetative growth of maize (Table 1). Due to taller plant height of maize at Potchefstroom, it was likely for the plants of that location to have large stem diameter. This agrees with similar findings by Abdelmula and Sabiel (2007) who reported that, there was positive and significant correlation between stem diameter and plant height.

CONCLUSIONS

In this study, cropping system played a significant role on the growth of maize since it affected days to 100% tasseling, plant height and leaf area. Days to 100% tasseling, leaf area and plant height were significantly improved under rotational cropping system, more than with other cropping systems investigated. Location affected all the parameters that were measured, Potchefstroom and Rustenburg produced better maize growth parameters. The good maize growth parameters in both locations were due to climatic factors such as rainfall and temperatures. Nitrogen fertilization also played a pivotal role since it improved measured parameters except leaves number per plant. The growth of maize was also influenced by the seasonal changes.

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