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Influence of Management Practices on Selected Cowpea Growth Attributes and Soil Organic Carbon

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Abstract

Cowpea is a multi-purpose nitrogen fixing crop that can be grown as a vegetable, grain legume and a fodder. The objectives of this study were to investigate the growth response of cowpea to different cropping systems at different locations and determine nitrogen fertilization on cowpea growth and soil organic carbon content. Three cropping systems were used, namely, maize-cowpea rotation, cowpea monocropping and maize-cowpea intercropping at three locations (Potchefstroom, Taung, and Rustenburg) in South Africa during 2011/12 and 2012/13 planting seasons. Nitrogen fertilizer was applied at two rates where no application was the control at all locations and application according to soil analysis recommendation for maize requirement was applied at each location. The variables measured for cowpea growth were days to 100% flowering and physiological maturity, number of leaves and nodules per cowpea plant. Soil organic carbon was determined for each treatment. The results showed that, maize-cowpea rotation and monocropping reached days to 100% flowering and maturity significantly earlier compared to intercropping. Cowpea planted at Potchefstroom and Rustenburg reached days to 100% flowering and physiological maturity significantly earlier than cowpea planted at Taung. Cowpea planted at Taung had significantly higher number of nodules per plant than cowpea planted at Potchefstroom and Rustenburg. There was also a positive correlation between soil organic carbon and cowpea growth. It is concluded that the positive effect of cowpea in agronomic systems is enhanced by the correct cropping system, although it is affected by location.

Keywords: flowering, monocropping, nodules, organic carbon, rotation

1. Introduction

Cowpea is grown traditionally by small scale farmers as mixed or relay crop in association with cereals. 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 & Elemo, 2013). Analysing growth help to monitor the independent and interactive effects of various factors affecting yield (Addo-Quaye et al., 2011). Ghanbari et al. (2009) reported that intercropped species might utilize the growth resources more efficiently than sole crops and resources may support a greater number of plants. It was further indicated that intercrops utilize plant growth resources such as light, water and nutrients more efficiently than the equivalent sole crops. In other studies, Cowpea growth parameters such as plant height and days to flowering were not significantly affected by intercropping (Alhaji, 2008). Cowpea is highly sensitive to high moisture condition because it enhances high vegetative growth with negative effect on final yield (Oyelade & Anwanane, 2013). Cowpeas that are planted in intercropping flowered later than those in sole crops (Moriri et al., 2010). Sole cowpea reaches physiological maturity earlier than those planted in intercropping. They indicated that shading effect causes by taller maize plants delays flowering and maturity of cowpeas. The competitive relationships between the non-legume and the legume affect the growth of the leguminous crops in close proximity (Tosti et al., 2010). Fertilizer application results in significant improvement of plant height, number of leaves per plant and reduces days to flowering (Abayomi et al., 2008). Legumes require nitrogen at early vegetative stage and phosphorus fertilizers to enhance the processes of nodulation in legumes (Abayomi et al., 2008). The high amount of nitrogen application has been reported to reduce nodulation in legumes but as little as 20-25 kg N/ha has been reported to enhance early vegetative growth and increases nodulation without compromising the process of nitrogen fixation in legumes (Amba et al., 2013). According to Liu et al. (2006) a productive soil should have an organic matter content of at least 4% (2.32% soil organic carbon). The correlation between soil organic carbon and cowpea growth has not been investigated extensively. In this study, the interaction effects of location, cropping system, and nitrogen fertilizer on cowpea growth and soil organic carbon were evaluated. The objective of this study therefore was to determine the effect of location, cropping system and nitrogen fertilization on cowpea physiological growth and soil organic carbon.

2. Materials and Methods

2.1 Experimental Sites

The study was conducted at three dryland locations in South Africa, namely Taung situated at 27°30′S and 24°30′E, Potchefstroom situated at 27°26′S and 27°26′E and Rustenburg situated at 25°43′S and 27°18′E. Taung experimental site is situated in grassland savannah with annual mean rainfall of 1061 mm that begins in October. 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). Rustenburg has clay percentage of 49.5 and receives an annual mean rainfall of 661 mm. Potchefstroom 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 has dark, olive grey and clay soil, bristle consistency, medium granular structure (Botha et al., 1968).

2.2 Experimental Design

The experiment was established in 2010/11 planting season and data 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 location, *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. Maize cultivar (PAN 6479) and cowpea (Bechuana white) were used as test crop.

2.3 Agronomic Practices

Cowpea and maize seeds were sown at the same time during planting in all cropping systems. Two seeds of cowpea were sown per hole and thinning was performed after emergence to maintain one plant on the intra-row spacing. Cowpea seeds were sown at inter-row and intra-row spacing of 0.9 and 0.3 meters respectively under monocropping and rotational systems. In intercropping plots of cowpea, seeds were sown at inter-row and intra-row spacing of 0.45 and 0.3 meters respectively. The previous crop planted at Potchefstroom before the establishment of the experiment was drybean while at Taung was maize. At Rustenburg, the previous crop planted before the establishment of the trial was cotton. The herbicide that was used before and during the experiment was Roundup.

2.4 Data Collection and Analysis

Days to 100% flowering were recorded during 2011/12 and 2012/13 planting seasons. Three plants (one per middle row) were dug by their roots to determine nodule per plant during five weeks after planting, before flowering. Inoculation was performed during the first planting season of 2010/11 and no inoculants were applied to cowpea seeds during the second and third season of 2011/12 and 2012/13 planting season. Number of leaves per plant was recorded from three plant harvested in the middle rows prior to flowering period. Days to physiological maturity were recorded when the cowpea pods were matured and brown in colour. The cowpea plant height was recorded prior to 100% flowering. The data was not considered since there were no significant interactions between treatment factors.

Soil samples were collected at the depth of 0-30 cm at each plot of cowpea for organic carbon analysis. Soil samples were air-dried and grinded using mortar and pestle (porcelain). Samples were weight at the quantity of 0.5 g into the glass beakers with capacity of 250 cm^3. The laboratory procedure used to determine organic carbon was Walkley Black method (Walkley, 1935).

$$\text{Organic C\%} = \frac{\text{cm}^3\ \text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2\ \text{blank} - \text{cm}^3\ \text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2\ \text{sample} \times M \times 0.3 \times f}{\text{Soil mass (g)}}$$

Where, M = Concentration of Fe $(NH_4)_2(SO_4)_2$ in mol dm^{-3}.

Analysis of variance was performed using GenStat 15th edition (2012). Least significant difference (LSD) was used to separate means. A probability level of less than 0.05 was considered as significant statistically (K. A. Gomez & A. A. Gomez, 1984). The first and second order interactions were considered on days to 100% flowering. Only second order interactions were considered on days to physiological maturity. The first and second order interactions were also considered on number of leaves, nodules per plant and soil organic matter.

3. Results

3.1 Days to 100% Flowering

Interaction of cropping system × nitrogen had significant effect ($P = 0.033$) on days to 100% flowering as indicated in Table 1. Rotational cowpea without nitrogen fertilizer flowered significantly early at 71.4 DAP than other cropping system. Interaction of cropping system × location had significant effect ($P = 0.005$) on days to 100% flowering. Cowpea monoculture and rotational cowpea planted at Potchefstroom significantly flowered earlier at 68.8 and 66.3 DAP respectively than other cropping system. Cowpea monoculture and rotational cowpea planted at Rustenburg significantly flowered earlier at 64.8 and 64.3 DAP respectively than other cropping system. Interaction of nitrogen × location had significant effect ($P < 0.001$) on days to 100% flowering. Cowpea supplemented with nitrogen fertilizer at Potchefstroom, Rustenburg and Taung had significantly flowered early at 67.3, 62.2 and 71.7 DAP respectively as compared to cowpea without nitrogen fertilizer. Interaction of nitrogen × season had significant effect ($P = 0.003$) on days to flowering. Cowpea supplemented with nitrogen fertilizer during 2011/12 and 2012/13 planting seasons flowered significantly earlier at 66.9 and 67.2 DAP respectively than cowpea without nitrogen fertilizer. Interaction of location × season had significant effect ($P < 0.001$) on days to flowering. Cowpea planted at Rustenburg during 2011/12 planting season flowered significantly earlier at 63.7 DAP as compared to other locations. Cowpea planted at Potchefstroom and Rustenburg during 2012/13 planting season flowered significantly early at 62.7 and 66.5 DAP respectively than other location.

Table 1. The interaction effect of cropping system × nitrogen, cropping system × location, nitrogen × location, nitrogen × season and location × season on cowpea days to 100% flowering

Cropping system	Nitrogen fertilizer		
	N-Fert	Zero-N	
Intercowpea	66.6	72.7	
Monocowpea	66.7	73.2	
Rotation	65.9	71.4	
$LSD_{(0.05)}$	1.26		
Cropping system	**Location**		
	Potch	Rust	Taung
Intercowpea	70.5	66.2	75.3
Monocowpea	68.8	64.8	76.1
Rotation	66.3	64.3	75.3
$LSD_{(0.05)}$	1.54		
Nitrogen	**Location**		
	Potch	Rust	Taung
N-Fert	67.3	62.2	71.7
Zero-N	69.8	68.1	79.4
$LSD_{(0.05)}$	1.26		
Nitrogen	**Season**		
	2011/12	2012/13	
N-Fert	66.9	67.2	
Zero-N	73.4	71.4	
$LSD_{(0.05)}$	1.03		

Location	Season	
	2011/12	2012/13
Potch	74.4	62.7
Rust	63.7	66.5
Taung	72.4	78.8
$LSD_{(0.05)}$	1.26	

Note. N-Fert = Nitrogen fertilizer; Zero-N = Zero nitrogen fertilizer; Potch = Potchefstroom; Rust = Rustenburg; Intercowpea = Intercropped cowpea; Monocowpea = Monocropped cowpea.

3.2 Days to Physiological Maturity

The interaction of cropping system × nitrogen × location had significant effect ($P < 0.001$) on days to physiological maturity as indicated in Table 2. Cowpea monoculture and rotational cowpea planted at Potchefstroom supplemented with nitrogen fertilizer had reached physiological maturity significantly early at 91.3 and 91.7 days respectively than other cropping system. At Rustenburg, cowpea monoculture and rotational cowpea supplemented with nitrogen fertilizer reached physiological maturity significantly early at 89.7 and 89.8 days respectively. At Taung, cowpea monoculture and rotational cowpea supplemented with nitrogen fertilizer reached physiological maturity significantly early at 111.7 and 111.5 days respectively than other cropping system. Cowpea monoculture and rotational cowpea planted at Potchefstroom without supplement of nitrogen fertilizer reached physiological maturity significantly early at 98.0 and 98.2 days respectively than intercropping. At Rustenburg, cowpea monoculture and rotational cowpea without supplement of nitrogen fertilizer reached physiological maturity significantly early at 96.8 and 96.0 days than other cropping system. At Taung, cowpea monoculture and rotational cowpea without supplement of nitrogen fertilizer reached physiological maturity significantly early at 120.3 and 120.2 days respectively than intercropping. Interaction of cropping system × location × season had significant effect ($P < 0.001$) on days to physiological maturity. Cowpea monoculture and rotational cowpea planted at Potchefstroom during 2011/12 planting season, reached physiological maturity significantly early at 101.7 and 101.8 days respectively than intercropping. During 2012/13 planting season, cowpea monoculture and rotational cowpea planted at Potchefstroom reached physiological maturity significantly early at 87.7 and 88.0 days respectively. At Rustenburg, cowpea monoculture and rotational cowpea planted during 2012/13 planting season reached physiological maturity significantly early at 81.3 and 80.7 days. At Taung, rotational cowpea planted during 2011/12 planting season reached physiological maturity significantly early than other cropping systems. During 2012/13 planting season, cowpea monoculture and rotational cowpea planted at Taung reached physiological maturity significantly early at 104.3 and 104.5 days respectively. The interaction of nitrogen × location × season had significant effect ($P < 0.001$) on days to physiological maturity. Cowpea planted at Potchefstroom during 2011/12 and 2012/13 planting seasons and supplemented with nitrogen fertilizer significantly reached physiological maturity significantly early at 99.2 and 88.6 days respectively than cowpea without nitrogen supplement. Cowpea planted at Rustenburg during 2011/12 and 2012/13 planting seasons and supplemented with nitrogen fertilizer significantly reached physiological maturity significantly early at 101.9 and 82.8 days respectively. Cowpea planted at Taung during 2011/12 and 2012/13 planting seasons and supplemented with nitrogen fertilizer also significantly reached physiological maturity significantly early at 122.2 and 105.0 days respectively than cowpea without nitrogen fertilizer.

Table 2. The interaction effects of cropping system × nitrogen × location, cropping system × location × season and nitrogen × location × season on cowpea days to physiological maturity

Cropping system	N-Fert			Zero-N		
	Potch	Rust	Taung	Potch	Rust	Taung
Intercowpea	98.7	97.5	117.7	99.5	102.7	122.8
Monocowpea	91.3	89.7	111.7	98.0	96.8	120.3
Rotation	91.7	89.8	111.5	98.2	96.0	120.2
$LSD_{(0.05)}$	1.13					
Cropping system	Potch		Rust		Taung	
Intercowpea	103.2	95.0	105.3	94.8	128.5	112.0
Monocowpea	101.7	87.7	105.2	81.3	127.7	104.3
Rotation	101.8	88.0	105.2	80.7	127.2	104.5
$LSD_{(0.05)}$	1.13					
Nitrogen	Potch		Rust		Taung	
	2011/12	2012/13	2011/12	2012/13	2011/12	2012/13
N-Fert	99.2	88.6	101.9	82.8	122.2	105.0
Zero-N	105.2	91.9	108.6	88.4	133.3	108.9
$LSD_{(0.05)}$	0.92					

Note. N-Fert = Nitrogen fertilizer; Zero-N = Zero nitrogen fertilizer; Potch = Potchefstroom; Rust = Rustenburg; Intercowpea = Intercropped cowpea; Monocowpea = Monocropped cowpea.

3.3 Number of Leaves per Cowpea Plant

Number of leaves per cowpea plant was significantly affected ($P < 0.001$) by the interaction of location × season as indicated in Table 3. Cowpea planted at Rustenburg and Potchefstroom during 2011/12 planting season had significantly higher number of leaves per plant of 50.9 and 49.0 respectively than cowpea planted at Taung. Cowpea planted at Potchefstroom and Taung during 2012/13 planting season had significantly higher number of leaves per plant of 50.0 and 56.6 respectively than cowpea planted at Rustenburg.

Table 3. The interaction effect of location × season on cowpea number of leaves per plant

Location	Season	
	2011/12	2012/13
Potch	49.0	50.0
Rust	50.9	38.3
Taung	43.7	56.6
$LSD_{(0.05)}$	7.65	

Note. Potch = Potchefstroom; Rust = Rustenburg.

3.4 Number of Nodules per Cowpea Plant

Number of nodules per cowpea plant was significantly affected by the interaction of nitrogen × location ($P = 0.017$) as indicated on Table 4. Cowpea planted at Potchefstroom and not supplemented with nitrogen fertilizer had significantly higher number of 8.0 than cowpea supplemented with nitrogen fertilizer. There were no significantly difference between cowpea supplemented with nitrogen fertilizer and cowpea without nitrogen fertilizer at both Rustenburg and Taung. Interaction of location × season had significant effect ($P < 0.001$) on number of nodules per plant. Cowpea planted at Taung during 2011/12 planting season had significantly higher number of nodules of 7.1 per plant than cowpea planted of other locations. During 2012/13 planting season, cowpea planted at Taung and Potchefstroom had significantly higher number of nodules per plant of 17.2 and 10.9 as compared to other location.

Table 4. The interaction effects of nitrogen × location and location × season on number of nodules per cowpea plant

Nitrogen	Location		
	Potch	Rust	Taung
N-Fert	4.8	5.7	12.7
Zero-N	8.0	6.3	11.6
$LSD_{(0.05)}$	2.07		
Location	**Season**		
	2011/12	2012/13	
Potch	1.8	10.9	
Rust	3.7	8.3	
Taung	7.1	17.2	
$LSD_{(0.05)}$	2.07		

Note. N-Fert = Nitrogen fertilizer; Zero-N = Zero nitrogen fertilizer; Potch = Potchefstroom; Rust = Rustenburg; Intercowpea = Intercropped cowpea; Monocowpea = Monocropped cowpea.

3.5 Soil Organic Carbon Content at Harvest

The interaction of location × season ($P < 0.001$) had significantly affected soil organic carbon as indicated in Table 5. Soil collected at Potchefstroom and Rustenburg during 2011/12 planting season had significantly higher organic carbon of 0.75 and 0.57 % respectively than Taung. During 2012/13 planting season, Potchefstroom and Rustenburg also had significantly higher soil organic carbon of 0.66 and 0.58% respectively than Taung.

Table 5. The interaction effect of location × season on soil organic carbon content during harvest

Location	Season	
	2011/12	2012/13
Potch	0.75	0.66
Rust	0.57	0.58
Taung	0.29	-0.08
$LSD_{(0.05)}$	0.109	

Potch = Potchefstroom; Rust = Rustenburg.

3.6 Correlation between Soil Organic Carbon and Cowpea Growth

The correlations between soil organic carbon and cowpea days to 100% flowering was weak ($R^2 = 0.064$) during 2011/12 planting season as indicated in Figures 1-4. The correlation between soil organic carbon and cowpea days to 100% flowering was strong ($R^2 = 0.814$) during 2012/13 planting season. The correlations between soil organic carbon and cowpea number of days to physiological maturity were low positive, $R^2 = 0.470$ and $R^2 = 0.624$ during 2011/12 and 2012/13 planting seasons, respectively. The correlations between soil organic carbon and cowpea number of leaves per plant were weak, $R^2 = 0129$ and $R^2 = 0.164$ during 2011/12 and 2012/13 respectively. The correlations between soil organic carbon and cowpea number of nodules per plant were low positive, $R^2 = 0.688$ and $R^2 = 0.483$ during 2011/12 and 2012/13 planting seasons, respectively.

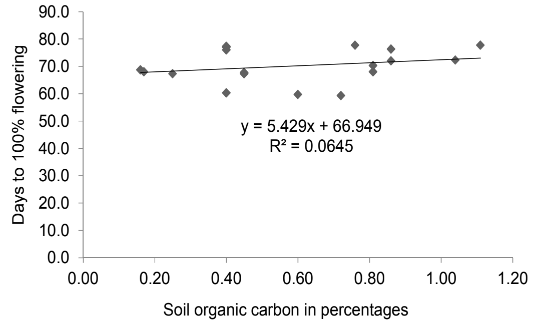

Figure 1A: Correlation of soil organic carbon and days to 100% flowering of cowpea during 2011/12 planting season.

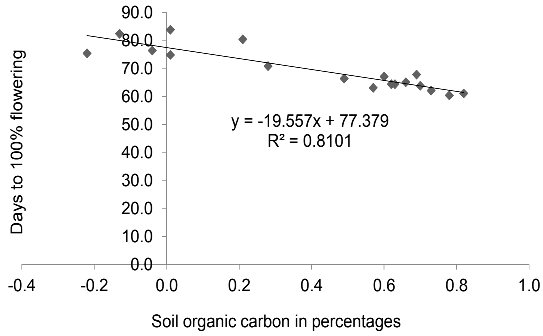

Figure 1B: Correlation of soil organic carbon and days to 100% flowering of cowpea during 2012/13 planting season.

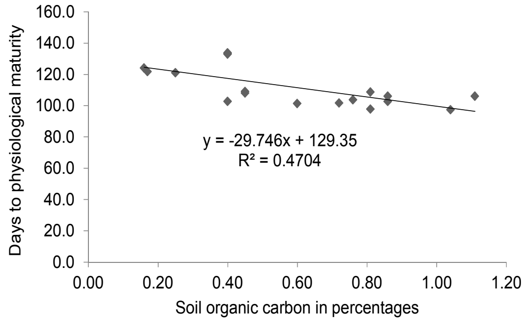

Figure 2A: Correlation of soil organic carbon and cowpea days to physiological maturity during 2011/12 planting season.

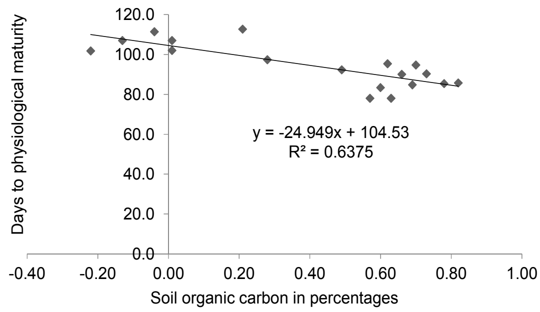

Figure 2B: Correlation of soil organic carbon and cowpea days to physiological maturity during 2012/13 planting season.

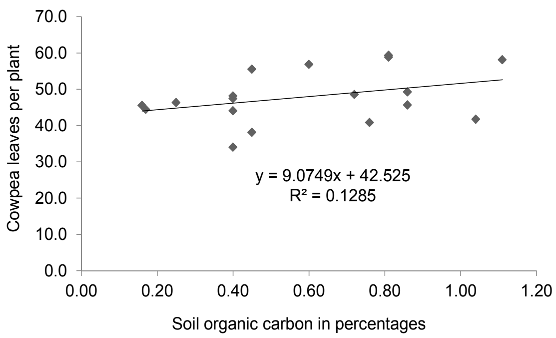

Figure 3A: Correlation of soil organic carbon and cowpea leaves per plant during 2011/12 planting season.

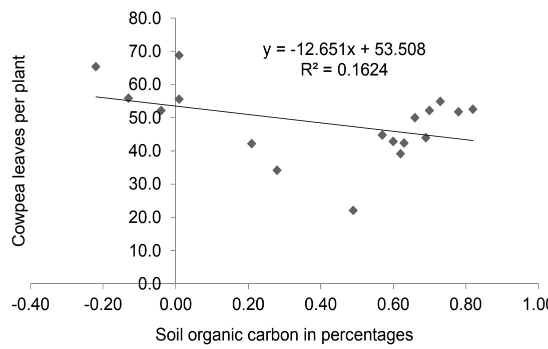

Figure 3B: Correlation of soil organic carbon and cowpea leaves per plant during 2012/13 planting season.

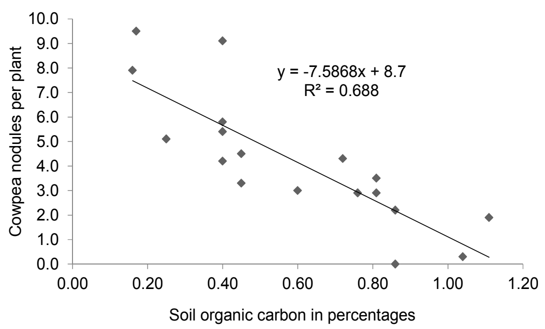

Figure 4A: Correlation of soil organic carbon and cowpea nodules per plant during 2011/12 planting season.

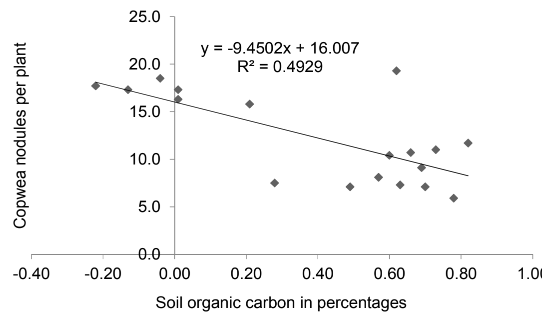

Figure 4B: Correlation of soil organic carbon and cowpea nodules per plant during 2012/13 planting season.

Figures 1-4. The correlation between cowpea growth and soil organic carbon

4. Discussion

The earlier days to 100% flowering under cowpea planted on rotational system may have been attributed to improvement of soil structure caused by previous crops. The shading by maize under intercropping plots caused delay in days to 100% flowering. This contradicts the findings by Njouku and Muoneke (2008) who reported that there was no effect on cowpea intercropping on days to 50% flowering. Moraditochaee et al. (2012) reported that nitrogen deficiency lead to premature flowering. Cowpea planted on Monocropping and rotational systems had reduced competition for resources such as sunlight and soil nutrients, and these resulted in earlier days to physiological maturity (Sarkar et al., 2013).

The earlier physiological maturity of cowpea planted on monocropping system confirms the statements by Moriri et al. (2010) that sole cowpea reached physiological maturity earlier than those planted in intercropping. According to Amujoyegbe and Elemo (2013) site and time of introduction of cowpea affected growth of cowpea. Higher number of leaves under monocropping and rotational cowpea may have been attributed to fertility of soil (Pereira vaz Ferreirra et al., 2015) that led to increase in growth of cowpea (Abraha, 2013). The production of more leaves under monocropping and rotational cowpea means higher light interception and more photo-assimilate production (Babaji et al., 2011; Kouyate et al., 2012). Blade et al. (1992) reported that cowpea growth was severely depressed by competition with other plants. The higher number of nodules per plant on cowpea planted at Taung may have been attributed to sandy soil on that site. The differences of soil organic carbon by sites corroborate the findings by Fu et al. (2004) who reported that soil organic carbon is affected by environmental factors such as topography, parent material, soil depth and land use. Topography influences precipitation and temperature, both of which will affect the soil carbon (Tsui et al., 2004). The differences in soil organic carbon by seasons may have been attributed to soil temperatures and rainfall. This supports the statement by Fang et al. (2008) who reported higher soil microbial biomass carbon in rainy season than in dry season. It was also revealed that soil carbon was significantly positively correlated with soil temperature. The higher soil organic carbon at Potchefstroom and Rustenburg may have been attributed to clay content on those sites. The higher soil organic carbon in monocropping cowpea plots was due to improved soil structure and fertility, which led to high carbon content. Soil carbon increases was found to be generally greater with higher level of soil fertility. Alvarez (2005) reported that carbon sequestration increases as nitrogen fertilizer was applied to the system, and this contradicted the findings of this study. Nitrogen fertilization had no effect on soil organic carbon. This corroborates the findings by Russell et al. (2009) who reported that N fertilization offset gains in carbon inputs to the soil in such a way that soil carbon sequestration was virtually nil despite up to 48 years of N addition.

5. Conclusions

It has been shown that cowpea growth and soil organic carbon were higher under monocropping and rotational systems. The application of nitrogen fertilizer played a significant role on improvement of cowpea growth. Cowpea nodulation tends to be higher under location with higher percentage of sandy soil. Intercropping system suppresses the growth of cowpea and also results with reduced soil organic carbon. In this study, it was found that, the application of nitrogen fertilizer has no influence on soil organic carbon. Organic carbon tends to increase on site with higher soil clay percentage. Interaction of location × season plays a vital role on improvement of cowpea growth and soil organic carbon. There is positive correlation between soil organic carbon and cowpea days to flowering, physiological maturity, and number of nodules per plant.

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