MINERAL FERTILIZER AND INTER-ROW SPACING EFFECTS ON VEGETATIVE GROWTH, NODULATION AND DRY MATTER YIELD OF COWPEA (*Vigna Unguiculata* Walp)

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Abstract
The research was undertaken with the aim of assessing the effects of inter-row spacing and nitrogen on growth and dry matter production of cowpea in the Teaching and Research Farm of the Faculty of Agriculture, Delta State University, Anwai Campus in the 2014 and 2015 cropping seasons. Nitrogen fertilizer and inter-row spacing were the two factors with nitrogen fertilizer consisting of four application rates at 10, 20 and 30kgN ha^{-1}, while the zero application rate served as the control. Three inter-row spacings made up of three treatments consisting of 80cm, 60cm and 40cm while an intra-row spacing of 30cm was maintained. The results of this study indicated significant ($P< 0.05$) increase in the number of leaves, stem girth and canopy height of cowpea with increase in nitrogen rate. These vegetative parameters decreased when inter-row spacing was reduced from 80cm to 30cm. Nodule number and efficiency initially increased with application of 10 kgN/ha, however higher rates of nitrogen application (30 kgN/ha) reduced both parameters. Biomass yield of 2261.70 kg/ha was achieved with 30 kgN/ha. Total dry matter yield had positive correlation ($P<0.01$) with canopy height, number of branches, unit shoot dry matter and days to 50% ripening. Inter-row spacing of 30cm indicated the highest agronomic efficiency index (AEI) of 30.02 kg kg^{-1} at 20kgN/ha. Inter-row spacing of 60cm with nitrogen application rate at 20kgN/ha was recommended for better vegetative growth and dry matter yield.

Keywords: *Vigna unguiculata*, dry matter yield, Inter-row spacing, agronomic efficiency index

Introduction

Cowpea (*Vigna unguiculata* L. Walp) is one of the most important legume crops cultivated for its use as food and animal feed in Africa. The name "cowpea" probably must have been derived from when it was an important feed for cows in the United States. Its wide cultivation among small holder resource poor farmers in different agro-ecological zones in Africa is due to its adaptability to a wide range of environmental conditions, including under conditions where water is a limitation (Sithomola and Odhiambo, 2011). The adaptation mechanisms to drought include its long tap roots, turning of leaves and closing of stomata. The crop, being a legume can also grow in a wide variety of soils due to its ability to replenish soils of low fertility through nitrogen fixation and root decay. Its haulm is also a rich material for green manuring. During the dry season, the stems and leaves of cowpea are usually sold as animal feed by farmers, thus providing additional source of income for the farmers. Due to its rich nutrient and fibre content Africans generally consume the young leaves and the mature dried seeds. Hence cowpea is the major legume seed in human nutrition consumed as plant protein (Awodun, 2007).

Seed yield of about 1.0 t/ha can be achieved with minimal rainfall of 300mm, during hot weather while fodder yield of 5t hay/ha can also be obtained under same environmental conditions (Abah and Tor, 2012). The use of cowpea as a dual-purpose crop, being a source of grain and fodder, is increasing becoming acceptable in mixed crop-livestock systems where availability of productive resources such as water, land and fodder are becoming limited in supply and resulting in severe shortage of fodder, especially in the dry season (Samireddypalle *et al.* 2017).

Despite its importance in nutrition to both humans and livestock, and contribution in increasing soil fertility, cowpea growth, biomass and grain yield has been hampered by several constraints such as poor soil fertility status (Haruna and Usman, 2017) and inefficient crop management practices such as inappropriate crop density spacing (Sithomola and Odhiambo, 2011). Previous study by Grafton *et al*. (1988) have demonstrated that appropriate crop spacing which ultimately results in optimum crop density can increase growth and dry matter yield of cowpea.

Higher performance of cowpea has been reported by several researchers with application of mineral fertilizers (Madukwe *et al.*, 2008; Singh *et al.*, 2011). The ability of a legume to produce large quantity of biomass indicates its potential for livestock feeding and soil improvement (as mulching material, green manure). This explains why the shoot dry matter production of cowpea and other legumes are usually considered as trait for screening legumes for fodder production and soil improvement.

The objective of the study was to examine the effect of inter-row spacing and nitrogen on growth and dry matter production of cowpea.

Materials and Methods

This experiment was undertaken at the Teaching and Research Farm of the Delta State University, Anwai Campus, Delta State, Nigeria in the 2014 and 2015 cropping seasons. Anwai is situated between latitude 06^0 14' N and longitude 06^0 49'E in the humid rainforest agro-ecological zone with annual rainfall of 1505-1849mm, temperature ranging between 22^0C and 34^0C. Two factors were considered in the study; namely nitrogen fertilizer and inter-row spacing. The nitrogen fertilizer had four treatments with nitrogen applied in form of urea at the rate of 10, 20 and 30kgN ha^{-1} ,while the zero application rate served as the control. The source of nitrogen was urea (46%N). Three inter-row spacings made up of three treatments consisting of 80x30cm (41666 plants ha^{-1}), 60x30cm (55555 plants ha^{-1}) and 40 x 30cm (111111 plants ha^{-1}) with the variations only between rows while within rows were maintained. Vegetative parameters such as number of leaves, number of branches, canopy height, and stem girth were collected at two weeks interval. Days to 50% flowering and 50% ripening were obtained when half of the plants in each plot has flowered and ripened. Number of nodules and weight of nodules of cowpea were obtained by uprooting three randomly selected plants. Nodules were detached from plants, washed and counted before weighing. Nodule efficiency was assessed by the visual observation method as earlier described in other works (Omokaro, 1990; Athar and Shabbir, 1997; Oroka 2015). After harvest of pods, five selected plant shoots were cut 5cm above the ground and oven dried for 72hours at 60^0C to obtain constant weight. Dry weights of plants per plot were converted to per hectare basis. Data were presented as average of two cropping seasons.

Nutrient efficiency is one of the key indices of any sustainable cropping system, since fertilizer is a major input. In view of the fact that it estimates the amount of farm product per unit of utilized resource, this study used the agronomic efficiency index (AEI) to quantify and explain cowpea dry matter yield (product) relative to the resource used (nitrogen fertilizer).

Agronomic efficiency Index (AEI) of cowpea was assessed using the formula:

$AEI = Y_{Fr}-Y_{UF}/N_{Fr}-N_{UF}$,

Where Y_{Fr} is dry matter yield (kg/ha) of cowpea at fertilized rate (Fr) and Y_{UF} is yield of the cowpea at control or zero fertilizer (UF) application (kg). N_{Fr} and N_{UF} are nitrogen application rates at fertilizer rate and zero application rates respectively in kgN/ha.

Results and Discussion

The results of this study indicated an increasing trend in the number of leaves, number of branches, stem girth and canopy height with increase in nitrogen rate. However significant ($P<0.05$) increase in number of leaves with applied nitrogen was only obtained from 6WAP till 10WAP (Table 1). Maximum leaf number achieved at 10WAP was in the range of 35.83 (control) and 49.41(30kgN ha^{-1}). Inter-row spacing did not show any significant effect on leaf number within the first 6WAP, however a significant increase was observed at 8WAP and 10WAP. A decrease in inter-row spacing from 80cm to 60cm increased leaf number but further decrease in inter-row spacing significantly ($P<0.05$) decreased leaf number of cowpea

Table 1: Nitrogen and Inter-row spacing effects on number of leaves of cowpea

	Weeks after planting (WAP)				
	2	**4**	**6**	**8**	**10**
Nitrogen rate (kgN/ha)					
0	1.92	6.05	19.67	33.51	35.83
10	2.40	6.27	22.92	43.12	45.19
20	2.15	6.11	23.98	46.23	47.92
30	2.21	6.11	26.10	47.46	49.41
LSD (5%)	1.85	2.01	2.43	2.67	3.06
Inter-row spacing(cm)					
80	2.07	6.69	23.74	43.16	45.58
60	2.17	6.45	23.70	45.17	46.69
30	2.28	6.00	22.06	39.42	41.43
LSD (5%)	1.56	1.43	1.88	2.67	3.33
Nitrogen x inter-row spacing	ns	ns	ns	*	*

ns- not significant; *- significant at 5% level of probability

There was a non-significant increase in number of branches with increasing rate of applied nitrogen up to 20kgN/ha, however application beyond this level did not increase branch number (Table 2). Number of branches of cowpea was not significantly influenced by nitrogen rate or inter-row spacing. The least number of branches was obtained from the lowest inter-row of 30cm, while the 80cm inter-row showed more number of branches. This trend was obtained up till 8 WAP with mean number of branches ranging from 4.17 (80cm) to 4.26 (60cm). Number of branches indicated a non-significant interaction between nitrogen and inter-rowing spacing in this study.

An increasing trend in the stem girth and canopy height with increase in nitrogen rate was observed in this study (Table 3). Canopy height was significantly increased by nitrogen with 30kgN ha^{-1} showing the most canopy height of 85.36cm. Increasing nitrogen rate from $10kgNha^{-1}$ to $20kgNha^{-1}$ resulted in 8% increase in canopy height, while a further increase in nitrogen to $30kgNha^{-1}$ increased canopy height by 12%. Canopy height was significantly ($P<0.05$) reduced by 7% when inter-row spacing decreased from 80cm to 30cm. Interaction of nitrogen and spacing was significant for cowpea height.

Results of this study showed that vegetative growth parameters such as number of leaves, number of branches, stem girth and canopy height were significantly enhanced by application of inorganic nitrogen. This can be attributed to the increased mineral nitrogen assimilation during the early growth cycle of the crop. This confirms earlier reports of other researchers (Dart *et al*., 1977; Abayomi, *et al.* 2008) that though cowpea has the capacity to symbiotically fix nitrogen; the plant cannot solely depend on symbiotically fixed N at the early stage of the growth. In situations when soil natural environmental resources are limiting and the food reserves on the cotyledons are exhausted, cowpea seedlings will ordinarily show signs of temporary N deficiency. Hence when soil reserves are deficient of nitrogen and phosphorus, the main limiting nutrients for legume growth in the tropics (Fox and Kang, 1977), the need for application fertilizers containing small quantities of these nutrients is necessary for enhancement of vegetative growth. In a related study, Vasileva and Pachev (2015) noted that Alfalfa needs nitrogen during its early vegetative development in other to prevent retardation of root growth. The positive effect of nitrogen in enhancing root activity and rooting pattern may have contributed to the pronounced vegetative of growth of cowpea with nitrogen application.

On the average, decreased inter-row spacing and the corresponding increased plant density among the cowpea plants, resulted in increased competition for environmental resources such as space, soil moisture, carbon (iv) oxide, light and applied nutrients. Besides cowpea crops cultivated at wide inter-row spacing (having low population) started their early vegetative growth as isolated units with minimal interference from adjacent plants hence grew faster than those with low inter-row spacing (having high population). These results are in consonance with earlier reports by Malami and Samaila (2012) who also observed highest vegetative growth parameters in wider inter-row spacing of 100cm and 75cm compared to 50cm and 25cm. Other research results of Futuless *et al*. (2010) and Sithomola and Odhiambo (2011) agree with these findings.

Table 2: Nitrogen and Inter-row spacing effects on number of branches of cowpea

	Weeks after planting			
	2	**4**	**6**	**8**
Nitrogen rate (kgN/ha)				
0	2.58	3.57	3.78	3.78
10	3.23	3.81	4.17	4.17
20	3.30	4.07	4.46	4.46
30	3.63	4.14	4.53	4.53
LSD $(_{0.05})$	1.34	0.98	0.87	0.87
Inter-row spacing (cm)				
80	3.17	3.94	4.17	4.17
60	3.23	3.97	4.26	4.26
30	3.17	3.78	4.18	4.18
LSD $(_{0.05})$	0.38	0.68	0.22	0.22
Nitrogen x inter-row spacing	ns	ns	ns	ns

ns- not significant

Non-significant longer days to flowering and ripening were observed in cowpea with higher nitrogen rate (Table 3). Cowpea plants in this study took 45-46 days and 54 to 56 days to flower and ripen respectively. Plants sown at wider inter-row spacing of 80cm took longer days to flower relative to 30cm inter-row spacing.

Table 3: Nitrogen and Inter-row spacing effects on canopy height, stem girth and flowering of cowpea

	Canopy height(cm)	Stem girth(cm)	D-50-F	D-50-R
Nitrogen rate (kgN/ha)				
0	69.43	0.67	45.85	54.78
10	76.26	0.85	45.78	55.23
20	82.42	0.90	45.78	55.45
30	85.36	0.93	46.33	56.00
LSD ($_{0.05}$)	5.33	0.11	1.88	1.93
Inter-row spacing(cm)				
80	79.28	0.89	45.99	55.58
60	82.36	0.86	46.25	55.92
30	73.47	0.79	45.57	54.59
LSD ($_{0.05}$)	3.79	0.21	1.76	1.66
Nitrogen x inter-row spacing	*	ns	Ns	ns

D-50-F: Days to 50% flowering; D-50-R: Days to 50% ripening; ns- not significant; *- significant at 5% level of probability

The results as shown in Table 4 indicates that nodule number initially increased by 29% with application of 10 kgN/ha, however higher rates of nitrogen application (30 kgN/ha) reduced nodule number by 10.6%. Nodule efficiency of cowpea was more pronounced with nitrogen application rate of 10 kgN/ha as indicated with the highest percentage of nodules with pink colour, while 30kgN/ha showed the least nodulation efficiency as indicated by the highest percentage (22.70%) of nodules with green colour. More nodules were produced from cowpea plants cropped under wider spacing (80cm). Nodule number decreased with reduction in inter-row spacing of cowpea. The cowpea plants sown at the lowest inter-row spacing of 30cm showed the lowest nodule efficiency with 16.70% green coloured nodules.

The results of this study showed depression in nodule performance, in terms of number and efficiency with increased application of nitrogen fertilizer. Earlier reports of other researchers (Athar and Shabbir, 1996; Weria *et al*., 2013) has shown that the application of mineral nitrogen 3 weeks after emergence decrease nodulation and nitrogenase activity. Rodrignez-Barnard *et al.* (1970) observed that the number and efficiency of nodules and nodule tissues decreased with higher amount of ammonium-nitrogen fertilizer applied to *Casuarina* and *Ceanothus*. Abayomi et al. (2008) further observed significant depression in number of nodules of cowpea when nitrogen application increased from 0 to 60 kg ha^{-1}. Nodulation in cowpea was also observed to be retarded by nitrogen application above 30 kg ha^{-1}. Earlier works of Sithomola and Odhiambo (2011) which indicated lower nodulation when cowpea was planted more closely were confirmed in this study. Raun *et al*. (1999) also observed that supplementary application of nitrogen fertilizer resulted alfalfa plants with higher dry matter when harvested.

Table 4: Nitrogen and Inter-row spacing effects on nodulation of cowpea

	Number of nodules	Nodule efficiency (%)		
		Pink	White	Green
Nitrogen rate (kgN/ha)				
0	17.39	66.80	14.60	14.30
10	22.47	79.90	10.97	15.73
20	18.16	76.90	12.00	11.07
30	15.55	60.50	16.76	22.70
LSD ($_{0.05}$)	1.85			
Inter-row spacing (cm)				
80	19.99	73.18	13.58	14.30
60	18.70	70.70	13.58	15.73
30	16.48	68.65	14.65	16.70
LSD ($_{0.05}$)	1.46			
Nitrogen x inter-row spacing	*			

*- significant at 5% level of probability

Increase in nitrogen rate significantly increased cowpea unit shoot dry matter and total biomass yield of cowpea. Nitrogen applied at the rate of 10, 20 and 30 kgN/ha increased the biomass yield of cowpea by 11.3%, 22.2% and 27.8% respectively. Reduced inter-row spacing, resulted in significant reduction in unit plant dry weight, but showed significant increase in biomass yield per plot (expressed in kg/ha). Unit shoot dry matter ranged from 25.28 to 36.60g per plant while biomass yield per plot varied from 1633 to 2261.70 kg/ha.

Nitrogen nutrition has significant role to play in biomass accumulation in cowpea. To achieve sufficient biomass accumulation, efficient nitrate assimilation is needed during the vegetative growth period of the crop (Fabre and Planchon, 2000). Abayomi *et al.* (2008) observed significant increase in biomass production in different cowpea varieties with higher N fertilizer rate. Being a principal factor affecting dry matter production in legumes, crop density affects nutrient uptake and organ development decreases with increase in closer spacing of crops. At wider inter-row spacing, there must have been gross underutilization of solar radiation, soil nutrients and moisture, subsequently resulting in low biomass production, while at closer inter-row spacing intra-species competition for same resources must have been optimal leading to higher biomass production (Squire, 1993; Fabunmi and Obisesan, 2011). In this study, the biomass- density response did not obey the sigmoid curve were biomass production and density shows an optimum, above which the biomass production declines (Squire, 1993).

Table 5: Nitrogen and inter-row spacing effects on dry matter yield of cowpea

	Shoot dry matter (g/plant)	**dry matter yield (kg/ha)**
Nitrogen rate (kgN/ha)		
0	25.28	1633.60
10	28.87	1842.49
20	33.90	2100.03
30	36.60	2261.70
LSD ($_{0.05}$)	4.72	23.42
Inter-row spacing (cm)		
80	39.70	1648.52
60	31.70	1760.96
30	22.22	2468.89
LSD ($_{0.05}$)	3.81	28.98
Nitrogen x inter-row spacing	*	*

*- significant at 5% level of probability

Results of simple linear correlation coefficients between dry matter biomass yield and other parameters of cowpea are presented in Table 6. Total biomass yield was found to be significantly positively correlated (P<0.01) with canopy height, number of branches, unit shoot dry matter and days to 50% ripening. The performance of these attributes was enhanced by application of nitrogen fertilizer which contributed to the final biomass yield.

The significant correlation between cowpea biomass yield and other parameters shows that these parameters enhanced biomass yield. The significance of plant height and number of branches as an indicator of biomass and grain yield has been reported for several crops (Blum *et al.* 1989; Raun *et al.* (1999). Increased soil nutrients and moisture, ultimately resulted in higher final canopy height and branches which produce more leaves. The leaf is the site of photosynthate production, hence the more leaves, the greater the biomass accumulation (Oke and Eyitayo, 2010).

Table 6: Simple linear correlation coefficients between growth and flowering parameters and dry matter yield

Dry Matter Yield vs	R
Canopy height	0.994**
Number of leaves	0.928
Number of branches	0.972*
Stem girth	0.927
Days to 50% flowering	0.649
Number of nodules	-0.427
Days to 50% ripening	0.972*
Shoot dry matter	0.997**

*, ** denote effects significant at 0.05 and 0.01 level of probability, respectively

Table 7 shows that nitrogen fertilization of cowpea increased AEI. Results showed that increasing nitrogen rate from 10kgN/ha to 20kgN/ha increased the AEI by 11.6% , however a further increase to 30kgN/ha only resulted in an increase of 0.19%. AEI did not show any consistent trend with inter-row spacing in this study. Inter-row spacing of 80cm indicated the least AEI at both 10kgN/ha and 20kgN/ha. Except at 10kgN/ha, where 60cm had recorded the highest AEI of 27.54 kg kg^{-1}, inter-row spacing of 30cm indicated the highest AEI of 30.02 kg kg^{-1} and 24.07 at 20kgN/ha and 30kgN/ha respectively.

The agronomic efficiency index (AEI) of nitrogen explains the ratio of cowpea biomass yield obtained in relation to applied nitrogen. Similar research reports had shown higher agronomic efficiency of applied mineral nitrogen and phosphorus at higher rates usually confirmed by higher dry matter and seed yield of the legume (Estrada and Rodriguez, 1992; Haruna and Usman, 2013; Vasileva and Pachev, 2015). The higher agronomic efficiency of nitrogen at closer spacing was reported in previous studies of Estrada and Rodriguez (1992). They observed increase in agronomic efficiency of nitrogen in *Phaseolus vulgaris* when plant population was increased.

Table 7: Agronomic efficiency index

Nitrogen rate (kgN/ha)	Inter-row spacing (cm)	AEI (kg kg^{-1}) for inter-row	AEI (kg kg^{-1}) for nitrogen
10			20.89
	80	10.64	
	60	27.54	
	30	24.49	
20			23.31
	80	16.49	
	60	23.43	
	30	30.02	
30			20.93
	80	20.07	
	60	18.67	
	30	24.07	

Conclusion

Results from this study showed that nitrogen and inter-row spacing had significant effects on vegetative, dry matter production and agronomic efficiency index of cowpea. Planting at inter-row spacing of 30cm seems to most suitable in terms of dry matter production per unit area at nitrogen rate of 30kgN/ha for the purpose of green manuring and forage production. Planting cowpea at narrow inter-row spacing cannot make up for the nutrient losses that would occur if the green manure is not incorporated into the soil or not used in feeding animals. Research effort should rather be directed towards cheaper and easier methods of incorporation and also promoting its use among resource poor farmers.

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