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Effect of nitrogen and phosphorus fertilizers on nodulation of some selected grain legumes at Bauchi, Northern Guinea Savanna of Nigeria

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Abstract

Nodules were collected at bi weekly intervals from legumes grown in three rainy seasons in Northern Guinea Savanna of Nigeria. The legumes include cowpea (*Vigna unguiculata* (L.) Walp), groundnut (*Arachis hypogea* (L.)) and soybean (*Glycine max* (L.)) treated with nitrogen fertilizer at 0 and 20kgN/ha and phosphorus fertilizer at 0, 13.2, 26.4 and 39.6kgP/ha. The treatments were laid out in a split-split plot design and replicated three times. The legumes were randomly allocated to the main plot, the phosphorus fertilizer levels to the sub plot and the nitrogen level to the sub-sub plot. The results showed that application of nitrogen at 20kgN/ha significantly (P≤0.05) reduced number of nodules at 2week after sowing (WAS) only. On the other hand, application of phosphorus at 26.4kgP/ha significantly (P≤0.05) produced higher number of nodules throughout the study period than the other levels used. Amongst the legumes, groundnut consistently and significantly (P≤0.05) gave higher number of nodules than cowpea and soybean. The cropping season of 2005 significantly (P≤0.05) produced higher number of nodules than 2004 and 2006 rainy seasons.

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Introduction

Soil fertility in West Africa is traditionally maintained through shifting cultivation and fallow. Increase in demand for land for agricultural activities and for other human activities has resulted in shortened periods available for land fallow. This has ultimately raised the need for intensive land cultivation to cater for the ever-increasing human population. Maintenance of high crop yields under intensive cultivation is possible only through the use of fertilizers. The use of chemical fertilizers to sustain cropping systems on a long term basis has not been very effective (Peck and Macdonald, 1984). On the other hand, organic fertilizers can be used as an alternative for the inorganic fertilizer but they release nutrients rather slowly and steadily over a long time. However, they are required in large quantity to meet up with crops' nutrient supply and very difficult to manage because of its bulkiness. Legumes offer the potentials of fixing atmospheric nitrogen to the soil through biological fixation process which provides a more sustainable nutrient recycling that can enhance crop yields and improve soil fertility, with the ability to fix. Legumes require nitrogen at early vegetative stage (Atkins, 1996) and phosphorus fertilizers to enhance the processes of nodulation in legumes. The high amounts of nitrogen has been reported to reduced nodulation in legume but as little as 20-25kgN/ha has been reported to enhanced early vegetative growth and increase nodulation without compromising the process of nitrogen fixation in legumes. Nodulation is an energy driven process and phosphorus nutrition is needed to provide the energy required for the fixation process. Important as this nutrient, it is readily fixed in soil at low soil pH thereby rendered unavailable to plants. This has reduced the potential of legumes to fix atmospheric nitrogen in the soil. Many studies have concentrated on the effect of nitrogen and phosphorus on yield and growth parameters of legumes and their subsequent contributions to nitrogen fixation in the different ecological zones of Nigeria. There is paucity of work on the nodules which is the site for nitrogen fixation in legumes and the effect of mineral fertilizers especially Nitrogen and phosphorous are understudied(Agboola and Obigbesan, 1977, Fagam *et al.*, 2007, Abayomi *et al.*, 2008). Therefore this study was carried out to determine the effect of nitrogen and phosphorus fertilizers on nodules formation of some grain legumes in the Northern Guinea Savanna of Nigeria.

Materials and methods

Experimental site

A field experiment was conducted at the Abubakar Tafawa Balewa University, Bauchi Research and Training Farm during the raining seasons of 2004, 2005 and 2006 cropping seasons. Bauchi State is located between latitude 10°74'N-13°30'N and longitude 9°47E-11°50'E and situated at 690.3m above sea level in the Northern Guinea savanna zone of Nigeria. The experimental site was previously cropped with maize and the soils are generally classified as altisols Kowal and Knabe, 1972.

Treatments and experimental design

The treatments consisted of two levels of nitrogen (0 and 20kgN/ha) applied as urea and four levels of phosphorus fertilizer (0, 13.2, 26.4 and 29.6kgP/ha) applied as single super phosphate and three legumes cowpea (*Vigna unguiculata* L. Walp) variety Yar-Sokoto, groundnut (*Arachis hypogea* L.) variety Ex-Dakar and soybean (*Glycine max* L.) variety TGX1448-2E. The treatments were randomly laid-out in a split-split plot design and replicated three times. The legumes were randomly allocated to the main plot, phosphorus levels to the sub plot and nitrogen to the sub-sub plot. The total number of plots were 24, with an area of 6m² (2m×3m) in each replication. Alleys were allowed of 0.5m within the plots and 1m between replications in the experimental design. Land preparations included ploughing and harrowing using tractor driven equipments. Nitrogen fertilizer was applied a week after sowing while the single super phosphate fertilizer was applied at land preparation according to the treatments. The plots were kept weed free, throughout the growing period by manual weeding. The nodules were collected bi weekly and washed with distilled water to remove

surface soil and counted physically. The nodules were weighed using an electronic weighing balance.

Results

Effect of nitrogen and phosphorus fertilizers on nodulation in three legumes

As shown in Table i, the application nitrogen had a significant (P≤0.05) effect on number of nodules at 2 WAS only and the control plots significantly (P≤0.05) gave higher number of nodules than the application of 20kgN/ha. Phosphorus fertilizer application also had a significant (P≤0.05) effect on number of nodules. The application of 26.4kgP/ha consistently gave a significantly (P≤0.05) higher number of nodules than the other levels considered throughout the study period. On the other hand, significantly (P≤0.05) fewer nodules were consistently produced when 39.6kgP/ha phosphorus was applied throughout the study. Number of nodules was observed to significantly (P≤0.05) differ among the three legumes used. Groundnut was observed to consistently produce higher number of nodules than cowpea and soybean throughout the study period. The three cropping seasons also affected number of nodules throughout the study period. In 2005 cropping season consistently produced higher number of nodules significantly (P≤0.05), followed by 2006 cropping season while 2004 cropping season was the lowest in nodule production in all the sampling period except at 2 WAS.

Table 1. Effect of nitrogen and phosphorus fertilizers on number of nodules/plant of three legumes grown in the rainy seasons of 2004, 2005 and 2006 at Bauchi, Nigeria.

	Number of nodules/plant				
Treatment	2WAS	4WAS	6WAS	8WAS	10WAS
Nitrogen (kgN/ha)					
0	17.37^{a}	76.10^{a}	119.83^{a}	144.26^{a}	147.05^{a}
20	15.04^{b}	75.64^{a}	118.99^{a}	145.35^{a}	148.56^{a}
LS	**	NS	NS	NS	NS
SE(±)	0.64	1.25	1.62	1.64	1.82
Phosphorus (kgP/ha)					
0	7.93^{d}	53.54^{d}	95.57^{d}	119.02^{d}	132.67^{d}
13.2	18.43^{b}	79.56^{b}	124.35^{b}	146.37^{b}	150.69^{b}
26.4	25.93^{a}	104.28^{a}	150.02^{a}	179.46^{a}	166.44^{a}
39.6	12.54^{c}	66.11^{c}	107.70^{c}	134.37^{c}	141.43^{c}
LS	*	**	**	**	**
SE(±)	0.90	1.77	2.29	2.32	2.58
Legume					
Cowpea (Yar-Sokoto)	19.56^{b}	44.32^{b}	59.99^{b}	23.22^{c}	-
Groundnuts (Ex-Dakar)	28.39^{a}	165.17^{a}	264.75^{a}	355.72^{a}	405.93^{a}
Soybean (TGX 1448-2E)	0.67^{c}	18.12^{c}	33.50^{c}	55.47^{b}	37.49^{b}
LS	**	**	**	**	**
SE(±)	0.78	1.54	1.99	2.01	2.23
Year					
2004	23.17^{b}	66.29^{b}	109.11^{c}	111.42^{c}	117.03^{c}
2005	25.44^{a}	79.58^{a}	129.97^{a}	179.36^{a}	184.74^{a}
2006	0.0	81.74^{a}	119.15^{b}	143.64^{b}	141.65^{b}
LS	*	*	**	**	**
SE(±)	0.78	1.54	1.99	2.01	2.23

Means in each column followed by same letter (s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT), Key: WAS = weeks after sowing, SE= standard error, LS= level of significance (* at 5% and ** at 1%), NS= not significant (P≤0.05).

Interaction between nitrogen and phosphorus fertilizers on nodulation in three legumes

As also presented in Table ii, the interaction between nitrogen and phosphorus fertilizers on number of nodules taken at 6WAS in 2004, 2005 and 2006 cropping seasons. It was observed that at the two nitrogen levels (0 and 20kgP/ha), phosphorus applications at 0kgP/ha significantly (P≤0.05)

produced lower number of nodules. Similarly, application of phosphorus at 39.6kgP/ha also significantly (P≤0.05) produced lower number of nodules irrespective of the levels of nitrogen applied. However, application of phosphorus at 26.4kgP/ha under controlled N-plots significantly (P≤0.05) produced highest number of nodules than the other levels used. Similarly, the in Table iii shows the interaction between nitrogen and phosphorus fertilizers on number of nodules of groundnut taken at 6WAS grown in the rainy seasons of 2004, 2005 and 2006. The interaction showed a significant (P≤0.05) effect on the number of nodules in groundnut. The application of phosphorus at 13.2kgP/ha consistently produced the same number of nodules irrespective of the levels of nitrogen applied. On the other hand, the application of phosphorus at 39.6kgP/ha under control N-plots also gave lower number of nodules. However, application of phosphorus at 26.4kgP/ha under controlled N-plots significantly (P≤0.05) produced highest number of nodules than the other treatments applied.

Table 2. Interaction between nitrogen and phosphorus fertilizers on number of nodules/plant of cowpea at 6WAS grown in the rainy seasons of 2004, 2005 and 2006 at Bauchi.

	Nitrogen (kgN/ha)	
Treatment	0	20
Phosphorus (kgP/ha)		
0	41.67^{fg}	37.56^{g}
13.2	65.89^{c}	59.78^{d}
26.4	95.11^{a}	88.44^{b}
39.6	44.00^{ef}	47.44^{e}
LS	**	
SE(±)	2.47	

Means in each column followed by same letter (s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT), Key: WAS = weeks after sowing, SE= standard error, LS= level of significance (* at 5% and ** at 1%), NS= not significant (P≤0.05).

Table 3. Interaction between nitrogen and phosphorus fertilizers on number of nodules/plant of groundnut at 6WAS grown in the rainy seasons of 2004, 2005 and 2006 at Bauchi.

	Nitrogen (kgN/ha)	
Treatment	0	20
Phosphorus (kgP/ha)		
0	220.56^{f}	237.44^{ef}
13.2	268.33^{c}	275.44^{c}
26.4	315.11^{a}	296.22^{b}
39.6	244.89^{de}	260.80^{cd}
LS	**	
SE(±)	8.83	

Means in each column followed by same letter (s) are not significantly different at 5% level of probability by Duncan Multiple Range Test (DMRT), Key: WAS = weeks after sowing, SE= standard error, LS= level of significance (* at 5% and ** at 1%), NS= not significant (P≤0.05).

Discussion

Effect of nitrogen fertilizer on the production of nodules in three legumes

Application of nitrogen was observed to have a significant (P≤0.05) influence on number of nodules/plant. Nitrogen application at 20kgN/ha did not significantly (P≤0.05) affect number of nodules of

the three legumes in the sampling dates except at 2WAS where 20kgN/ha produced lower nodules than the no nitrogen plots as recorded in Table i. Many studies have been performed to test the effect of nitrogen on root nodulation and nitrogen fixation in nodules. However, it is generally accepted that when sufficient levels of nitrogen are present in the soil, nodulation is inhibited (Gentili and Huss-Danell, 2002, Laws and Graves, 2005). In the present study, application of nitrogen at 20kgN/ha depressed nodulation only at 2WAS, but did not affect nodulation in the subsequent sampling dates. This finding agreed with report of Atkins, 1986, that in soil with very low soil nitrogen, application of 5-10kgN/ha is necessary for early vegetative growth so that both yield and nodulation are enhanced at latter stage of growth. Pal *et al*., 1989, reported that application of nitrogen at 15kgN/ha did not affect nodulation in soybean. Similarly, results were obtained by Malik *et al*., 2006, that application of 30kgN/ha as starter dose did not affect nodulation of soybean grown under phosphorus nutrition. Furthermore, Njobdi, 1990, also reported that 20kgN/ha of nitrogen fertilizer was the best level of obtaining yield in cowpea without comprising nodulation. However, he noted that application of nitrogen at 40kgN/ha depressed both yield and number of nodules but significantly increase vegetative growth. Abayomi *et al*., 2008, also obtained higher yield and nodulation with the application of nitrogen at 30kgN/ha than at 60kgN/ha. This result was contrary to the report of Otieno *et al*., 2007, that application of 20kgN/ha as ammonium nitrate depressed nodulation and nitrogen fixation in soybean. Peck and Macdonald, 1984 observed that French beans plant grown without N-fertilization had many nodules on the roots than these that received nitrogen fertilization. Fagam *et al*., 2007 also reported decrease in number of nodules with increased level of nitrogen at 30, 60 and 90kgN/ha of soybean varieties cultivated in the same study area.

Effect of phosphorus fertilizer on the production of nodules in three legumes

Phosphorus application was also had a significant ($P \leq 0.05$) influence on nodulation of these legumes. Application of phosphorus at 26.4kgP/ha produced higher number of legumes that other treatments used in all the sampling dates. Phosphorus nutrition has also been reported by many researchers to enhance nodulation of legumes. Singh and Jain, 1966, Chaudhary *et al*., 1974 reported that application of phosphorus as single super phosphate increased number of branches, dry weight of shoot, nodules/plant of cowpea and soybean plant. Kang *et al*. 1977 also confirmed that application of phosphorus at 22.9kgP/ha significantly increased nodulation, nodules weight/plant and nitrogen fixation of soybean. Tenebe *et al*., 1995 reported that application phosphorus at 37kgP/ha increased nodulation of cowpea varieties. Similar results were obtained by Luse *et al*., 1975, Agboola and Obigbesan, 1977, Osiname, 1978, Ankomah *et al*., 1996, Okeleye and Okelana, 1997. Owolade *et al*., 2006, also reported that a high rate of phosphorus at 120kgP_2O_5/ha (52.8kgP/ha) applied by both broadcasting and foliar spray to significantly produced higher nodules of cowpea than the other treatments used.

Pattern of nodules formation among the three legumes

On the other hand, legumes were observed to significantly ($P \leq 0.05$) differ on number of nodules. Groundnut consistently produced higher number of nodules than cowpea and soybean in all the sampling dates. This can be attributed to agronomic difference between the three legumes. It was observed from the study that cowpea and groundnuts initiates early nodulation than soybean. However, prior to seed formation, nodulation in cowpea ceases, while in groundnut the nodules are much smaller in size therefore reducing the surface for nitrogen fixation than cowpea and soybean. Late nodules formation in soybean can be attributed to slow rate of root establishment in the early growth stage of soybean compare to cowpea and groundnut. It was also observed that nodules formation increases during the growth steadily with increase root mass of soybean.

The irregular pattern of nodules formation has resulted in variation on the number of nodules produced by the legumes in all the sampling dates. Cropping seasons was also observed to significantly (P≤0.05) affects number of nodules. The cropping season of 2005 consistently produced higher number of nodules in all the dates of sampling than the other seasons. Environmental conditions and edaphic factors have been reported to influence nodules formation of legumes. Chiezey and Odunze, 2009, reported a significant (P≤0.05) difference in nodulation of soybean at different seasons.

Interaction between nitrogen and phosphorus fertilizers on nodulation in cowpea

The interaction between nitrogen and phosphorus fertilizers had a significant (P≤0.05) effect on the number of nodules of cowpea in Table ii. It was observed that the application of phosphorus at 26.4kgP/ha under control nitrogen level produced higher number of nodules in cowpea than the other level of interactions. This has confirmed the importance of phosphorus fertilizer application to cowpea. Phosphorus application has been reported to increase nodules of cowpea (Ankomah *et al.*, 1996 and Tenebe *et al.*, 1995). The response at cowpea to the application of phosphorus can be attributed to low level of available phosphorus in the soil before sowing.

Interaction between nitrogen and phosphorus fertilizers on nodulation in groundnut

The Interaction between nitrogen and phosphorus fertilizers application had a significant (P≤0.05) effect on the number nodules in groundnut as shown in Table iii. Application of phosphorus at 26.4kgP/ha under control nitrogen application produced higher number of nodules in cowpea than the other level of interactions. Groundnuts have been reported to response adequately to increase phosphorus nutrition. Kang *et al.*, 1977, reported an increase in growth yield and oil content of groundnut. The respond of groundnut to increase phosphorus application can be attributed to low level of phosphorus in the soil. Furthermore, it also revealed that application of phosphorus without nitrogen will produce higher nodules at active stage of groundnut, but at higher phosphorus concentration (39.6kgP/ha) the nodules number decrease.

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