



## Effect of Nitrogen Fertilizer Applications on Nitrogen Remobilization and Grain Yield in Soybean (*Glycine max* [L] Merrill) in the Savelugu-Nanton Municipality in Northern Region of Ghana

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### ABSTRACT

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Two experiments were conducted in the Savelugu-Nanton Municipality of the Northern Region of Ghana in 2012 and 2013 to assess the effect of N fertilizer on growth, N remobilization and grain yield of three local varieties of soybean (*Glycine max* [L] Merrill). The experiments were a 3 x 4 factorial laid in Randomized Complete Block Design (RCBD) with four replications. Factor A was soybean varieties (Jenguma, Quarshie, Ahotor); Factor B was 0, 15, 30 and 45 kg N ha<sup>-1</sup>. The experimental fields were planted manually on the flat by drilling and later thinned to 2 plants hill<sup>-1</sup> at 0.50 m x 0.10 m with a population of about 400 000 plants ha<sup>-1</sup>. Growth and yield parameters measured were plant height, nodule number plant<sup>-1</sup>, nodule dry weight plant<sup>-1</sup>, percent nodule effectiveness, number of pods plant<sup>-1</sup>, number of seeds pod<sup>-1</sup>, 100 seed weight, harvest index and grain yield. The results showed that the control recorded lower figures in all growth parameters. Nitrogen remobilization was also observed in all plots, which indicate that soybean needs greater levels of N during grain filling. Again, N remobilization and soybean yield were highest in the 45 kg N ha<sup>-1</sup> treatment compared to the other treatments. However, considering the overall yields, farmers in the study area should be advised to adopt starter N fertilization of soybean for higher yields as the soils are highly degraded in soil fertility.

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## Introduction

Soybean (*Glycine max* [L] Merr) is described as the 'golden bean', 'miracle bean', 'crop of the planet', 'God sent golden bean', etc., with much promise in Tropical Africa and in many parts of Asia and Latin America (Singh et al., 1987). It is a source of high value protein that can substitute for meat and fish to reduce malnutrition for humans and high-quality feed for livestock and poultry. It has 40% protein and 20% oil which are highly digestible with no cholesterol while the remainder consists of carbohydrates, soluble sugars and ash and grown in tropical and subtropical areas of the world (Singh et al., 1987; Bain, 2005).

Today, fertilizer use is directly responsible for most of the world's food production and will be a more significant factor in future yield increases (Korkmaz et al., 2008, Korkmaz et al., 2021). In most crop plants, during grain development nutrients needed to support seed protein

synthesis come from either new assimilation or redistribution from other tissues. Nitrogen is an essential element for all organisms, which composes proteins, nucleic acids and other important organic compounds (İbrıkci et al., 2012). Remobilization of N is important in soybean (*Glycine max* [L.] Merr) growth because N assimilation declines during seed development and new assimilation is not sufficient to meet seed needs (Zeihner et al., 1982). Reserves mobilized from vegetative tissues usually account for 50 to 90% of the N found in mature seeds though environment and genotype can influence this (Zeihner et al., 1982; Jeppson et al., 1978). While the occurrence of mobilization of nitrogen from vegetative tissues to seeds is well established, less is known about the source and availability of other elements which are needed by developing seeds. Along with leaves and stems, pods

are important contributors to the pool of reserves available to seeds. They account for up to 30% of the N that is mobilized to soybean seeds (Hanway and Weber, 1971; Zeiher et al., 1982), and pods begin losing N earlier than stems or leaves (Seddigh and Jolliff, 1986). Pods are a temporary sink for N, which can be stored as either soluble compounds or proteins (Simpson, 1986). Nitrogen remobilization to grain is said to promote early senescence that reduce photosynthetic activities and therefore reduce yield (Sinclair and de Wit, 1976). Therefore, management practices that would reduce this phenomenon (known as self-destruction) in soybean must be investigated especially in poor soils.

In most of the soybean growing areas in Ghana smallholder farmers generally do not use chemical fertilizers (IITA, 1992; Mercer-Quarshire, 1992, Mbanaya, 2011). In recent times there has been a remarkable increase in the demand for soybean by local industries such as Ghana Nuts Limited and other local vegetable and feed processing mills (MiDA, 2010). Ghana has the potential of increasing her soybean production and reduce imports from the US and Brazil and even export some to neighboring West African countries for foreign exchange if small scale and commercial farmers increase their productivity using improved agronomic practices (MOFA, 2006; Mbanaya, 2011). Sadly, average soybean yields in Africa are low ranging from 900-1,800kg ha<sup>-1</sup> mostly due to low soil fertility and low fertilizer rates (Sanginga and Woomeer, 2009). In Ghana, under subsistence agriculture yields can be as low as 800 kg ha<sup>-1</sup> (MiDA, 2010), unlike average yields of 4, 600 kg ha<sup>-1</sup> in the USA (Richard et al., 1984).

These low yields can be increased by improving on the agronomic practices such as the use of chemical fertilizers like N, P and K (Sanginga and Woomeer, 2009), to enhance biological nitrogen fixation (BNF). Research has revealed that symbiotic N<sub>2</sub> fixation may not meet soybean N requirement during early and late phases of growth (Keyser and Li, 1992; Osborne and Riedell, 2006), and so small amounts of N fertilizer supplied early to start the crop often promote growth and N<sub>2</sub> fixation in legumes (Sanginga, 2003; Okugun and Sanginga, 2003; Tahir et al., 2009).

For the enhancement of soybean production in the Guinea Savanna zone, there should be improved agronomic practices such as timely planting of improved seeds, application of chemical fertilizers especially N, good pests and diseases control management, etc. Therefore, investigating for the recommended N fertilizer levels for soybean in the Guinea Savanna zone of Ghana is appropriate since the cultivation of the crop has increased tremendously in recent years.

The general objective of the study was to determine the response of three common soybean varieties to N fertilizer and the impact on growth, N remobilization, and grain yield.

The specific objectives are

- To determine if N remobilization occurs during the podding period
- To determine which parts of the plant remobilizes more N to the seed
- To determine the N level that produces the highest grain yield

## Materials and Methods

### Description of Study Site

Two experiments were conducted in 2012 and 2013 cropping seasons in the Savelugu-Nanton Municipality of the northern region of Ghana. The fields were located between latitude 09° 63' 65" N and 0.7° 99' 17" W with an elevation of 186 m above mean sea level. The study area has a unimodal type of rainfall that range from 800-1000 mm annum<sup>-1</sup> and temperatures ranging from 26-42°C.

### Experimental Design and Treatments

Soil samples were taken before planting at the plow depth (0-30 cm) in a zigzag (W pattern) manner across the field with a soil auger to ensure the sample truly represents the entire field. These were bulked, mixed thoroughly and a representative sample taken for soil nutrients determination in the laboratory at the beginning of the experiment in each cropping year. The soil samples were prepared by air-drying, removal of gravel and undecomposed plant parts and stored in black polythene bags and used for chemical analysis to determine the level of soil nutrients on the field.

Another sampling was done after harvesting to determine the effects of the treatments on the soil properties. These were taken across the 12m<sup>2</sup> plots were each treatment was applied and samples pooled and thoroughly mixed and a representative sample taken, labeled accordingly and sent to the laboratory for analysis.

Each experimental field measured 20 m × 90 m (1800 m<sup>2</sup>) and was plowed using a disc plow and harrowed two weeks later with a disc harrow. The experiment was a 3 × 4 factorial arranged in Randomized Complete Block Design (RCBD) with four replications. The factors were three soybean varieties (Jenguma, Quarshie and Ahotor) and four levels of N fertilizer (urea) at 0, 15, 30 and 45 kg N ha<sup>-1</sup>. Each replication had the three soybean varieties with the four N fertilizer treatments totaling 12 treatment plots of 4.0 m × 3.0 m (12m<sup>2</sup>) each. The alleys separating the replications were 2.0 m while those separating the varieties and the fertilizer levels were 1.5 m and 1.0 m respectively. Planting of the fields were done manually on the flat by drilling on the 15<sup>th</sup> and 8<sup>th</sup> July 2012 and 2013 respectively. The seedlings were later thin to 0.1m within rows 2 weeks after planting (WAP). The spacing between rows was 0.5 m and that of hills (stands) was 0.1 m (0.5 m × 0.1 m). Each plot had 8 rows with 30 stands with an estimated plant population of 400,000 plants ha<sup>-1</sup>.

### Measurement of Some Plant Growth Attributes

Five plants were randomly selected in the second and seventh rows of each plot and tagged. The heights were measured at 20, 40 and 60 days after planting (DAP). The plant height was measured using a graduated meter from the soil to last terminal leaf of the plant. The average height of the five plants was recorded to represent the treatment during the period. At 60 DAP, the roots of five randomly selected plants were carefully removed with a shovel and all nodules picked and put in transparent polythene sacks and again put in brown labeled envelopes and sent to the laboratory. The roots and all nodules from each sample were put under a tap over a sieve and washed to remove soil particles and dirt. Nodules were then dried under a ceiling fan after which they were counted and the means recorded.

Ten nodules were taken randomly from each sample and cut open with a small knife to determine the functional ones. Those with reddish or pinkish color were considered functional while grey, greenish or dark color was considered non-functional (Gwata et al., 2003). Percentage functional nodules were therefore computed as:

$$\text{Functional nodules\%} = \frac{\text{Number of functional nodules}}{10} \times 100$$

The weights (g) of the fresh nodules were taken using an electric balance and then put in labeled brown envelopes. These envelopes were put in an oven to dry to a constant weight at 65°C for 72 hours in the laboratory and the dry weight (g) recorded.

#### **Nitrogen Remobilization Determination**

Five plants from each plot were randomly select at 80 and 120 DAP and cut at ground level and separated into pods, leaves and stems (Seddigh and Jolliff, 1986) and dried at 65°C for 72 hours in the laboratory. The sample dry weights (g) were recorded before samples were milled for N determination. Total N accumulation at each sampling period was calculated as the sum of the N yield in all the parts. Nitrogen remobilization was calculated as the difference in N yield between the sampling periods, thus N yield at 120 DAP- N yield at 80 DAP and the difference converted to g N five plants<sup>-1</sup> and then scaled up to kg N ha<sup>-1</sup>.

#### **Yield Parameters and Grain Yield Determination**

The yield parameters determined were number of pods plant<sup>-1</sup>, number of seeds pod<sup>-1</sup> and 100 seed weight. During harvesting five plants were randomly taken from the four outer rows in each plot and put in large brown envelopes and taken to the laboratory. The pods were detached from the five plants, counted and the means recorded for each plot. All pods from the five plants were threshed and the seed removed, counted and recorded. The number of seeds pod<sup>-1</sup> was calculated as follows: Number of seeds pod<sup>-1</sup> = total No. of seeds counted/ No. of pods counted. The seeds from each treatment were then put in small labelled envelopes and sun-dried for a week to a moisture level of about 13%. One hundred (100) seed grains were counted from each envelop and weighed on an electric balance and the weight (g) recorded.

#### **Grain Yield**

Grain yield was determined from a net plot of 2 m × 2 m (4 m<sup>2</sup>) measured within the four middle rows of each plot of 12 m<sup>2</sup>. Plants within the net plot were harvested at ground level and put in labeled sacks and sent to the CSIR-Savanna Agricultural Research Institute's yard for drying. After sun-drying for one week, the weight (kg) of each harvest was taken with a spring balance and recorded. The samples were then threshed and the grain also sun-dried for one week to a moisture level of about 13% and the weight (kg) also taken. The grain yields in kg from the net plots were extrapolated into kg ha<sup>-1</sup>.

The crop residue yield was arrived at, by subtracting the grain weight from the weight before threshing. A sample residue from each plot was taken and weight recorded before oven-drying at 65°C for 72 hours. The weights of the oven-

dried samples were finally recorded using an electric balance and the weight scaled up and expressed in kg ha<sup>-1</sup>.

Harvest index (HI%) was determined using the formula suggested by Donald (1963) and expressed as a percentage as follows:

$$\text{Harvest Index (HI \%)} = \frac{\text{Economic yield (grain)} \times 100}{\text{Total biological yield}}$$

where the economic yield is the grain yield whilst total biological yield is the grain yield plus the biomass yield.

#### **Data Analysis**

The collected data were subjected to analysis of variance (ANOVA) using Gen stat 2009 package. The Least Significant Difference (LSD) at 5% probability was used to compare treatment means and the term 'significant' is used in the text to denote this level of significance.

#### **Results**

##### **Climatic Data of the Study Area in 2012 and 2013**

The results showed that the climatic data of the study area were not very different in both years (Table 1). The year 2012 recorded slightly higher amount of rainfall than 2013. Again, the number of rainy days was more (54 days) in 2012 than in 2013 which recorded 50 days.

##### **Pre-Planting Soil Analysis**

The results of the soil analysis of the study areas as presented in Table 2 indicate that both soils were acidic with pH values ranging from 5.37 to 5.28 at both locations in 2012 and 2013. The common characteristics of savanna soils are evident as percent total nitrogen ranged from 0.04 to 0.05% and organic carbon from 0.51 to 0.54% in 2012 and 2013 respectively.

Available phosphorus was also very low ranging from 3.24 to 4.18 mg/kg at both locations, hence the need for P fertilization, especially for crops like soybean. Exchangeable bases were also very low (< 2 Cmol/kg soil) in both areas during the periods.

##### **After Harvest Soil Analysis**

The final (after harvest) soil analysis indicated that soil pH was 5.10 and 6.33 in 2012 and 2013 cropping seasons (Table 3). In 2012, the effect of Jenguma on pH differed significantly (P<0.05) from Quarshie and Ahotor varieties, while in 2013, the effect of Jenguma on pH did not differ significantly (P>0.05) from Quarshie. It was significantly (P<0.05) lower than the effect of Ahotor (5.27).

The results also indicated that the three varieties were not significantly (P>0.05) different in their contribution to soil organic carbon in 2012 and 2013. Similarly, the three varieties were not significantly (P>0.05) different in percent total N in 2012. However, in 2013 Quarshie and Ahotor significantly (P<0.05) contributed higher soil total N than the Jenguma variety. Also, the N fertilizer levels did not differ significantly (P>0.05) in percent organic carbon in 2012 but were significantly different in 2013. The control (0 kg N ha<sup>-1</sup>) however, differed significantly (P<0.05) from all the N levels in percent organic carbon in 2012 but was not significantly different in 2013.

Table 1. Climatic data of Savelugu-Nanton during the 2012 and 2013 cropping seasons

Month	Temperature (°C)		Rainfall (mm)		Relative humidity (%)		Number of rainy days	
	2012	2013	2012	2013	2012	2013	2012	2013
June	27.9	27.7	145.5	151.9	81.0	80.2	7.00	6.0
July	27.4	27.6	186.0	183.8	83.0	84.1	13.0	14.0
August	26.2	26.4	178.5	210.4	82.0	85.0	6.00	9.0
September	27.6	26.8	210.0	194.1	83.0	80.3	12.0	10.0
October	27.8	27.7	148.3	139.7	79.0	79.7	13.0	9.0
November	29.6	27.5	1.5	2.8	72.0	69.0	1.0	2.0
December	27.8	26.6	0.0	0.0	51.0	60.0	0.0	0.0
Total	-	-	899.8	882.7	-	-	54.0	50.0

Source: Department of Agriculture, Savelugu-Nanton Municipality, 2012 and 2013

Table 2. Initial soil chemical properties at experimental sites in 2012 and 2013 cropping seasons

Soil chemical property	2012	2013
Soil pH (1:2.5; H <sub>2</sub> O)	5.37	5.28
Total N	0.04	0.05
Organic carbon	0.51	0.54
Organic matter	0.88	0.93
Available P (mg/kg)	3.44	4.18
Exchangeable bases (Cmol/kg)	0.04	0.17
K	0.05	0.16
Na	1.54	1.48
Ca	0.50	0.14
Mg	0.04	0.05

Source: Field data, 2012/2013

Table 3. Effect of variety and N fertilizer on pH, Organic carbon, and total N at, Savelugu in 2012 and 2013

Treatment	2013			2012		
	pH	%O.C	%Total N	pH	%O.C	%Total N
Variety Jenguma	6.10	0.75	0.06	5.10	0.74	0.05
Quarshie	6.11	0.76	0.07	5.18	0.78	0.06
Ahotor	6.33	0.63	0.07	5.27	0.65	0.07
LSD (5%)	0.07	NS	NS	0.17	0.15	0.01
N level (Kg ha <sup>-1</sup> )						
0	5.21	0.23	0.02	5.19	0.61	0.05
15	5.27	0.33	0.03	5.22	0.73	0.05
30	5.31	0.34	0.03	5.24	0.78	0.06
45	5.22	0.37	0.03	5.10	0.75	0.07
LSD (5%)	NS	0.04	0.01	NS	NS	0.01
CV (%)	3.20	0.30	9.90	2.30	2.70	10.50

Source: Field data, 2012/2013, NS= Not significant at 5% probability.

Table 4. Effect of variety and N fertilizer on plant height at 20, 40 and 60 DAP in 2012 and 2013

Treatment	2012 Cropping season plant height (cm)			2013 Cropping season plant height (cm)		
	20 DAP	40 DAP	60 DAP	20 DAP	40 DAP	60 DAP
Variety						
Jenguma	12.80	35.70	66.00	12.30	32.30	44.60
Quarshie	13.30	35.90	66.60	12.67	33.10	46.50
Ahotor	13.40	40.90	69.10	12.80	33.20	49.70
LSD (5%)	NS	2.30	NS	0.40	NS	2.90
N Level (kg /ha)						
0	11.70	28.10	57.30	11.32	24.82	37.70
15	13.30	39.90	68.40	12.87	34.58	46.60
30	13.90	42.10	68.80	13.58	36.97	51.40
45	14.20	43.00	70.10	13.79	38.56	55.30
LSD (5%)	0.53	2.84	4.82	0.50	1.79	3.68
CV (%)	3.50	6.50	2.80	5.80	7.70	8.40

Source: Field data, 2012/2013, NS= Not significant at 5% probability.

In terms of percent total N, the treatments were not significantly different ( $P>0.05$ ) in their contribution to total N in 2012. The control ( $0 \text{ kg N ha}^{-1}$ ) however recorded numerically lower amount of organic carbon than the N levels in 2013. The  $45 \text{ kg N ha}^{-1}$  level contributed significantly ( $P<0.05$ ) higher total N than the other N fertilizer levels.

The interactive effect of variety and N fertilizer on the soil parameters determined was not significant.

### ***Plant Height***

The results of plant height at 20, 40 and 60 DAP are presented on Table 4. At 60 DAP the crop is at full bloom and growth increase is not significant as resources are channeled towards fruiting and seed formation. At 20 DAP variety was not significantly ( $P>0.05$ ) different in plant height. At 40 DAP, the Ahotor variety was significantly higher than the other varieties, both of which recorded similar plant height, while all varieties recorded similar height at 60 DAP. Nitrogen fertilizer treatments had significant effect on plant height on all sampling days in both years and showed greater effects than control at 20 and 40 DAP. The results showed that variety x N fertilizer interaction was not significantly ( $P>0.05$ ) different on plant height on all sampling days in both years.

### ***Nitrogen Remobilization Between 80 and 120 DAP***

Table 5 presents the results of N remobilization as influenced by variety and N fertilizer applications. It showed that variety did not significantly ( $P>0.05$ ) affect N remobilization in all the plant parts. Nitrogen fertilizer application had no significant effect ( $P>0.05$ ) on pod N remobilization in the soybean. Leaf N remobilization was greatest in the  $45 \text{ kg N ha}^{-1}$ . Stem N remobilization was also high in the  $45 \text{ kg N ha}^{-1}$ . The  $30 \text{ kg N ha}^{-1}$  was greater than the control treatment effect. Variety and N fertilizer interaction on N remobilization from the plant parts were not significant.

### ***Yield Components***

The results showed that there was no significant ( $P>0.05$ ) varietal difference in the number of pods as well as number of seeds  $\text{pod}^{-1}$  (Table 6). The Ahotor variety produced significantly ( $P<0.05$ ) high 100 seed weight than Jenguma and Quarshie varieties. The application of N fertilizer produced similar pod numbers  $\text{plant}^{-1}$  among the various rates but recorded significantly higher number of pods than the control treatment.

The  $45 \text{ kg N ha}^{-1}$  treatment produced the greatest number of seeds  $\text{pod}^{-1}$  which was significantly higher than those of the  $15 \text{ kg N ha}^{-1}$  and the control treatments. The control treatment effect had lower number of seeds  $\text{pod}^{-1}$  than the  $15 \text{ kg N ha}^{-1}$  and the  $30 \text{ kg N ha}^{-1}$  treatments. The 100 seed weight was not significantly affected by the N fertilizer treatment effects. It was observed that variety x N fertilizer interaction was not significant ( $P>0.05$ ) in the yield components measured.

### ***Grain Yield, Crop Residue and Harvest Index***

The results of the grain yield as influenced by the variety and N fertilizer applications as presented on Table 7 showed that Jenguma variety produced the greatest grain yield of 2160 and 2066  $\text{kg ha}^{-1}$  in both years. This treatment

effect was similar to that of Quarshie but about 5% greater than that of Ahotor. The  $45 \text{ kg N ha}^{-1}$  treatment significantly produced more grain yield than the other N fertilizer treatments and control. The  $15 \text{ kg N ha}^{-1}$  treatment effect had the least response among the N fertilizer treatments.

The effects of variety were not significantly ( $P>0.05$ ) different in crop biomass yield. In terms of other treatments, Nitrogen fertilizer application at  $45 \text{ kg N ha}^{-1}$  treatment produced the greatest yield of 4378  $\text{kg ha}^{-1}$  which was significantly higher than only the control treatment effect. The other N fertilizer treatments effects were not significant at 5% level of probability. In respect of the harvest index, varietal effects were also not significantly different among the N fertilizer treatments. Variety x N fertilizer interaction was also not significant.

## **Discussion**

### ***Soil Chemical Properties***

As seen in Table 3, the final soil test (after harvest) as expected showed that the soils were acidic at the experimental sites. There was, however, a slight increase in the pH level that could not be attributed to the varietal effects. In 2012, the soil pH ranged from 5.10 to 5.27 among the varieties over the initial value of 5.37 (Table 2) indicating a slight decrease in pH level. There was an increase ranging from 6.10 to 6.33 in 2013 which was higher than the initial pH of 5.28. The increase in pH level could be attributed to the dissolution of wood ash from burnt crop residue and yam stakes from the previous season where the field was put to yam. It has been reported that wood ash contains about 20% calcium and could raise the pH level of soils (Griffin, 2006; Campbell, 1990).

It was established that the varietal effects on organic carbon at the experimental sites after harvest increased over the initial organic carbon level. In 2013, Quarshie contributed to increasing organic carbon from the initial level of 0.51 to 0.76% (32%), which was similar to that of Jenguma, while Ahotor increased it by 19%. Similarly, in 2012, Quarshie contributed 31% of organic carbon over the initial value while Jenguma and Ahotor recorded 27% and 17%, respectively of organic carbon increase. Obalum et al. (2011) reported that soybean enhanced organic carbon level relative to sorghum when grown in the South-eastern Nigeria since sorghum does not add much biomass to the soil. However, Conti et al. (2014) in their work in Argentina indicated that there was a significant reduction in total organic carbon in cropped soybean plots as compared with grassland plots, as a consequence of low amount of soybean stubble. From these current studies, the return of crop residues to the soil would significantly improve the organic matter content.

With regards to the effects of varieties on total N, the effects were not significant among the varieties in both cropping seasons. However, there was a marginal improvement on the total N from 0.04 and 0.05% to 0.07 and 0.07 in 2013 and 2012 respectively. That was an increase of 75 and 40% in total N for 2013 and 2012 cropping seasons respectively. The findings are in line with the work of Adeleke and Haruna (2012) in the Northern Guinea Savanna agroecological zone in Nigeria, where four legumes (soybean, cowpea, lablab and groundnuts) were found to increase total N after harvest.

Table 5. Effect of variety and N fertilizer on N remobilization from plant parts between 80 and 120 DAP in 2012 and 2013

Treatment Variety	2012 cropping season			
	Pods	Leaves	Stems	Total remobilized N (kg ha <sup>-1</sup> )
Jenguma	39.0	13.7	13.7	66.4
Quarshie	34.6	13.2	14.2	62.1
Ahotor	47.0	13.1	16.0	76.1
LSD (5%)	NS	NS	NS	NS
N level (kg ha <sup>-1</sup> )				
0	39.9	11.0	11.8	62.7
15	44.5	13.1	13.9	71.6
30	45.7	14.3	17.0	77.0
45	47.3	14.7	18.2	80.0
LSD (5%)	NS	1.9	4.9	-
CV (%)	22.7	11.5	27.2	-
Treatment Variety	2013 cropping season			
	Pods	Leaves	Stems	Total remobilized N (kg ha <sup>-1</sup> )
Jenguma	33.0	23.3	26.7	83.0
Quarshie	37.0	19.6	37.2	94.8
Ahotor	39.0	18.2	41.4	99.6
LSD (5%)	NS	NS	12.34	-
N level (kg ha <sup>-1</sup> )				
0	37.0	19.3	30.2	86.5
15	54.0	27.3	30.6	111.9
30	56.0	19.8	36.6	112.4
45	58.1	14.6	43.2	115.7
LSD (5%)	NS	7.7	17.2	-
CV (%)	20.8	30.5	30.8	-

Source: Field data, 2012/2013, NS=Not significant

Table 6. Effect of variety and N fertilizer on number of pods plant<sup>-1</sup>, number of seeds pod<sup>-1</sup> and 100 seed weight (g) at the study site

Treatment	2012 cropping season		
	Number of pods plant <sup>-1</sup>	Number of seeds pod <sup>-1</sup>	100 seed weight (g)
Variety			
Jenguma	68.30	1.76	12.10
Quarshie	71.70	1.63	12.10
Ahotor	65.00	1.83	11.20
LSD (5%)	NS	0.12	0.40
	N level (kg ha <sup>-1</sup> )		
0	54.00	1.70	11.50
15	70.90	1.71	11.80
30	75.70	1.81	11.80
45	79.90	1.77	12.30
LSD (5%)	8.90	NS	NS
CV (%)	15.90	11.10	6.00
Treatment	2013 cropping season		
	Number of pods plant <sup>-1</sup>	Number of seeds pod <sup>-1</sup>	100 seed weight (g)
Variety			
Jenguma	58.10	1.76	13.65
Quarshie	52.90	1.63	13.85
Ahotor	51.60	1.83	13.60
LSD (5%)	5.92		NS
	N level (kg ha <sup>-1</sup> )		
0	40.20	1.70	12.00
15	56.30	1.71	13.67
30	58.40	1.81	14.50
45	66.20	1.77	14.75
LSD (5%)	7.64	NS	0.75
CV (%)	17.20	11.10	6.60

Source: Field data, 2012/2013, NS= Not significant at 5% probability level

Table 7. Effect of variety and fertilizer N on grain yield, crop residue and harvest index at the study site

Treatment	2012 Cropping season		
Variety	Grain yield (kg ha <sup>-1</sup> )	Crop residue (kg ha <sup>-1</sup> )	Harvest index (HI%)
Jenguma	2160	4093	30.98
Quarshie	2078	4085	31.16
Ahotor	1976	4006	29.08
LSD (5%)	82.3	NS	NS
N level (kg ha-1)			
0	1719	3465	29.00
15	2062	4074	29.99
30	2211	4230	30.86
45	2302	4378	31.79
LSD (5%)	106.2	511	NS
CV (%)	6.3	15.3	16.40
Treatment	2013 Cropping season		
Variety	Grain yield (kg ha <sup>-1</sup> )	Crop residue (kg ha <sup>-1</sup> )	Harvest index (HI%)
Jenguma	2066	3983	43.53
Quarshie	1993	4037	44.85
Ahotor	1965	3900	45.56
LSD (5%)	79.4	NS	NS
N level (kg ha-1)			
0	1553	3219	41.97
15	2152	4038	44.35
30	2187	4225	45.48
45	2294	4281	48.52
LSD (5%)	103.2	572	4.42
CV (%)	6.5	17.5	12.00

Source: Field data, 2012/2013, NS=Not significant,

Nitrogen fertilizers did not also significantly differ in the soil pH across the experiments but significantly affected the organic carbon in 2013 but did not affect organic carbon in 2012. On the part of total N in 2013, the treatments had no significant effect on it whilst it was significantly different in 2012, though the parameters were minimal improvement over the initial values. These findings were in sync with Umeh et al. (2011) who indicated that soils with very low total N and organic carbon meant for soybean should be applied with N fertilizer.

#### **Plant Growth**

Plant height as a growth parameter was measured and showed significant difference in variety and N fertilizer application levels (Table 4). The Jenguma variety was generally shortest while the Ahotor was tallest. Varietal difference in plant height has been observed in several crops and in soybean in particular where several workers have attributed this to genotypic difference among varieties (Ahmed et al., 2010; Ponnuswamy et al., 2001). It was observed that plant height increased in all the varieties across the sampling periods. Researchers are of the view that when plants are small at the beginning of their growth, they are unable to use all the environmental resources available (Gardener et al., 1985; Hopkins, 1999). So plant height increased greatly (about 300%) between 20 and 40 DAP which meant that growth was very rapid between the period than between 40 and 60 DAP since plants were approaching reproductive stages. This study showed a consistent plant height increase across the sampling periods and in all varieties. However, Talaka et al. (2013) and Umeh et al. (2011) reported of no significant difference

in plant height at the early stages of growth and no plant height difference at later stages which they attributed to the plants approaching reproductive stage. Plant height also showed increase following the N fertilizer application over the control. On all sampling days, the plant height was greatest in the 45 kg N ha<sup>-1</sup> treatment. In addition, plant heights of all N fertilizer treatments were greater than the control. The results agree with the reports of other workers that soybean height increases with increasing N fertilizer rates (Umeh et al., 2011; Startling et al., 2000). However, Sij et al. (1979) indicated that starter N fertilizer application increase initial vegetative growth but had no effect on plant height. Contrary to Sij et al. (1979), Achakzai et al. (2012) indicated that there was a significant difference in plant height among N fertilizer treatment levels when compared with the control.

#### **Nodule Numbers, Nodule Dry Weight and Percent Nodule Effectiveness**

Nodulation was measured as nodule number, nodule dry weight and percent nodule effectiveness. Nodule numbers plant<sup>-1</sup> were not significantly affected by variety which is in contrast with earlier researchers' reports (Chemining'wa et al., 2012; Sarkodie-Addo et al., 2006), which indicated that variety significantly affected nodule numbers per plant. It has also been established that the environment has a profound impact on the crop and its nodulation (Salvucci et al., 2012) and therefore these varieties under investigation within the same environment most likely performed similarly.

The application of N fertilizer to the soybean resulted in significantly ( $P < 0.05$ ) different in the nodule numbers as the 15 kg N ha<sup>-1</sup> recorded relatively greater number of nodules

than 30 and 45 kg N ha<sup>-1</sup>. The control showed significantly greater number of nodules than the N fertilizer levels. Even though all the fertilizer levels recorded comparatively low nodule numbers their effect did not totally inhibit nodulation. The results agree with Diep et al. (2002) when working on N fertilization of vegetable soybean in Vietnam realized that increasing N levels reduces nodule numbers. The results also confirm workers like Bekere et al. (2013); Sartling et al. (1998) who indicated that N fertilizer reduces nodulation. This also agrees with several workers who recommend N fertilization of soybean at small amounts at the early stage as a starter, especially in N deficient soils that improves growth and subsequently yield but may reduce nodulation (Osborne and Riedell, 2006; Pikul et al., 2001; Riedell et al., 1998).

This study showed that the control treatment produced nodules significantly higher than the N fertilizer treatments which indicate the presence of indigenous rhizobia in the area. This agrees with the work of Muhammad (2010) in the Nigerian Southern Guinea Savannah where the control plots significantly produced higher number of nodules compared to the N fertilizer treated plots. Nodule dry weight did not vary with the soybean genotypes. This could be as a result of genotypic similarity and environmental influence. Work by Abdul-Latif (2013) in the Guinea Savannah zone of Ghana indicated that variety did not significantly affect nodule dry weight. In this study visual observation of nodule sizes confirm reports of other studies which indicated that some varieties that produced greater number of nodules had smaller nodule dry weight because their nodules were small, whilst those that produce less number of nodules were bigger (Blair, 1989; Sarkodie-Addo, 1991; Giller, 2001). In respect of the percent nodule effectiveness, variety did not also show significant difference in both years. The control recorded over 75% nodule effectiveness which was significantly higher than the N fertilizer treatments.

#### **Nitrogen Remobilization**

Nitrogen remobilization is an important phenomenon especially in annual plants for seed production and seed N content. Nitrogen content in the seed further determines germination efficiency and survival of young seedlings (Masclaux-Daubresse et al., 2010). Nitrogen remobilization has been studied in several plants using different methods including the 'apparent remobilization' method where the determination of the amount of total N present in the different organs at different times of the plant's development (Gallais et al., 2006), as in this study. A study by Diaz et al. (2008) showed that N can be remobilized from the senescing leaves to growing leaves during the vegetative stage and also from senescing leaves to the seeds at reproductive stage as found in this study. It was realized that the pods at 80 DAP contained higher total N than the other plant organs and so reflected in its contribution to the amount of N remobilized to the seed at harvest (120 DAP) which confirms the findings of Diaz and et al. (2008). The non-significant effect of variety on N remobilization in this study is in contrast with the finding of Sarvestani and Pirdashty (2001) who found that variety of rice significantly affected N remobilization. Earlier works considered genetic difference as a factor that contributes to N remobilization in wheat (Masclaux-Daubresse et al., 2010), which is in contrast with these results.

There are different schools of thought concerning N remobilization with regards to annual plants especially soybean. Whereas one school believes in reducing N remobilization to prevent early leave senescence (the 'self-destruction' phenomenon) and prolong photosynthetic activities to provide assimilate for the developing seed (Sinclair and de Wit, 1976), the other believes N remobilization should be promoted to provide adequate N for the developing seed since N determines the quality of seed and also contributes to seedling vigor and vitality (Masclaux-Daubresse et al., 2010). It is therefore suggested that breeders must develop varieties that would remobilize enough N during seed filling period. The results further shows that the N remobilization to the seed as influenced by the N fertilizer increases as the N level increased. Nitrogen application rates were reported to significantly affect grain protein in a study by Bahrani and Hagh Joo (2010).

#### **Grain Yield, Harvest Index and Crop Residue**

The results of this study in terms of soybean yield showed improvement over what currently prevails in the Guinea Savanna zone of Ghana which range between 800 and 900 kg ha<sup>-1</sup> (MiDA, 2010, Mbanya, 2011). Jenguma recorded 2160 kg ha<sup>-1</sup>, while Quarshie and Ahotor recorded 2070 kg ha<sup>-1</sup> and 1976 kg ha<sup>-1</sup> respectively indicating that the varieties were significantly different in the grain yield. Works by several scientists indicate varietal difference in grain yield of soybean and mungbean (Wood et al., 1993; Rahman et al., 2012 and Achakzai et al., 2012). Sanginga et al. (2000) and Nirmal et al. (2001) also reported of varietal differences in cowpea grain yield.

The N fertilizer treatments effects differed significantly from the control. However, the 30 kg N ha<sup>-1</sup> and the 45 kg N ha<sup>-1</sup> did not produce grain yield that was significantly different. Since the N fertilizer was applied as a starter, the results of the study agrees with earlier works by Sij et al. (1979), Umeh et al. (2011) whose works showed that N fertilizer significantly increased grain yield of soybean. Also, Pikul et al. (2001) and Riedell et al. (1998) reported that applying N fertilizer increased grain yield compared to no fertilization.

Harvest index (HI) was not significantly affected by variety which might be due to their maturity group similarities and environmental similarities they were grown. White and Wilson (2006), however, found that variety significantly affected HI in wheat as high yielding varieties were found to have both greater biomass and HI. The N fertilizer treatments did not have significant effect on the HI, which is in contrast with the report by Ahmed et al. (2005) who indicated that apart from environmental challenges associated with chemical fertilizers HI could be improved when N fertilizers are used in accordance with the crop type and soil fertility levels.

There was non-significant effect of variety on biomass (residue yield) at harvest which is in contrast with previous works that indicated plant varieties showed differences in dry matter accumulation (Haizel, 1972, Behera et al., 2007, Yildirim et al., 2007). The non-significant effect of variety at the site could be due to their similarity in the maturity group and hence similarity in biomass accumulation. The application of N fertilizer would promote vegetative growth since the soil N level was very low prior to planting. The 45 kg N ha<sup>-1</sup> significantly recorded the highest biomass than that of control while the other treatments produced similar yields.

## Conclusions

Nitrogen remobilization was evident in all the treatments, a common phenomenon in annual plants especially soybeans. Indeed, greater N remobilization was observed in the 45 kg N ha<sup>-1</sup> treatment which made more N available during pod filling. It showed that N needs of soybean during grain filling period are immense and should be met for optimum soybean yield. Therefore, farmers within the area must note this for improved grain yield. It also emerged that soybean grain yield was greatest with the application of the 45 kg N ha<sup>-1</sup> at the site in both years.

Based on the results, the study has brought to the fore that, due to the poor nature of the soils in the municipality, starter N fertilizer application is necessary for growth and yield of soybean and so farmers in the area are encouraged to adopt the practice. Further investigations in greater levels of N fertilizer applications to soybeans in the highly N deficient soils of producing districts of the Savanna zone should be undertaken.

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