



Techno Science Africana Journal

Journal homepage: www.technoscienceafricana.com



GROWTH AND YIELD RESPONSE OF INOCULATED SOYBEAN [*Glycine max*(L.) Merrill] VARIETIES TO INORGANIC NITROGEN IN THE SEMI-DECIDUOUS FOREST ZONE OF GHANA

Muhammad, A.,¹ Sarkodie-Addo, J.² and Ewusi-Mensah, N.²

¹Department of Crop Science, Kano University of Science and Technology, Wudil, Nigeria.

²Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

ARTICLE INFO

Keywords:

Growth, yield, inoculated soybean and inorganic N

***Corresponding Author:**

ABSTRACT

Field experiment was conducted at the Plantation Crops Section of the Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in 2015 major rainy season to evaluate the growth and yield response of inoculated soybean to inorganic N. Four varieties of soybean (Quashie, Songda, Salintuya-1 and Sonqu-panqu) were inoculated at a rate of 10g of inoculant (legume fix) per 1 kg of soybean seeds and three levels of inorganic N (0, 30 and 60 kg/ha) were laid out in a randomized complete block design and replicated four times. Recommended agronomic practices were carried out. Plant height, canopy diameter, number of branches, crop growth rate, relative growth rate, grain yield, mean seed weight, pod number and haulm yield were measured. Results of the study indicated that there was no consistent pattern in growth of soybean under all conditions. Sonqu-panqu produced significantly the highest grain yield than Quashie, Songda and Salintuya-1 varieties under all conditions. In conclusion, differences in response to growth and yield of soybean varieties exist under inoculated soybean and inorganic N, Sonqu-panqu is recommended for grain yield in the study area.

INTRODUCTION

The incorporation of soybean into the cropping system has been due to its high ability to fix atmospheric nitrogen through the symbiotic association with rhizobia (Dugje *et al.*, 2009). In addition, its ability to withstand insect attack has made the cultivation more attractive among the poor farming families. It can also be grown in between trees to improve the fertility of the plantation fields (Shurtleff and Aoyagi, 2009). One of the major problems with soybean is the

yield gap within and between countries because of differing environmental conditions. This can be closed by improving crop management practices that will address specific site constraints (Baijukya *et al.*, 2013).

Maximum yield and utilization can be achieved by selecting among different varieties to obtain the most suitable variety based on the soil and climatic conditions of the local environment (Mapuwei *et al.*, 2014).

Notwithstanding, other management practices may need to be employed to further improve yields.

Artificial inoculation of legumes with appropriate strain of rhizobium can be effective way of increasing growth and yield thereby closing the yield gap (Tairo and Ndakidemi, 2013). Improved yields of some legumes have been reported with inoculation (Ahlam *et al.*, 2004; Albareda *et al.*, 2009; Solomon *et al.*, 2012). Although yield increment has been reported due to use of inoculants, there is still potential for further yield increase when additional avenues are explored (Mweetwa *et al.*, 2014).

It has also been shown that supplementary fertilization with nitrogen during early growth can lead to improved performance (Cheema and Ahmad, 2000; Ruark, 2009). Previous workers have studied the effect of inorganic dose of N among soybean varieties. However, most of the N level used might have been too low. An improved approach of this study was to increase the N levels to investigate the effects of such higher levels of N on the soybean performance. This experiment was therefore set up to determine the effect of inoculated soybean varieties and inorganic N on the growth and yield of some selected soybean varieties.

MATERIALS AND METHODS

The study was conducted at the Plantation Crops Section of the Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana during the major season of 2015. Random samples of the soil of the experimental site were collected at depths of 0–15 cm and 15–30 cm, following ploughing and harrowing of the field to determine initial fertility status of the soil. Four varieties of soybean (Salintuya-1, Songda, Sonqu-panqu and Quashie) were inoculated with legume fix inoculant at 10g/ 1kg of seeds and three levels of inorganic N fertilizer at the rate of 0, 30 and 60 kg N ha⁻¹. The inoculant was applied using the method of Woomer *et al.* (1994). Soybean seeds were

obtained from the Crops Research Institute of the Council for Scientific and Industrial Research. Treatments were arranged in a randomized complete design (RCBD) and replicated four times. Seeds were sown on 11th May 2015 at 2 seeds per hole at a spacing of 75 cm x 5 cm in plots measuring 2 m x 5 m. Thinning was done to one plant per hill two weeks after seedling emergence. Plots were weeded with a hoe twice at four and eight weeks after planting.

DATA COLLECTED

Plant Height

Five plants were randomly selected from the second rows in each plot and tagged. The plant height was measured using a measuring tape. The height was obtained by measuring from the ground level to the highest growing point.

Canopy Diameter

The tagged plants were used to measure the canopy diameter. Canopy diameter was obtained by measuring the width of the canopy of each plant.

Number of Branches

Number of branches were counted using the tagged plants.

All growth parameters were measured in 2015 cropping seasons.

Shoot Dry Weight

Five plants were randomly selected from the second row at 4, 6 and 8WAP. These were dug, washed and dried to constant weight at 80° C for 3 days. The dried plant materials were weighed to determine the shoot dry weight for each treatment.

Crop Growth Rate

The shoot dry weight taken at 4, 6 and 8WAP was used to calculate the crop growth rate.

$$CGR = \frac{W_2 - W_1}{T_2 - T_1}$$

where:

W₁ and W₂ = dry weight at first and second sampling (in grams)

T₁ and T₂ = Time of first and second sampling (in weeks)

Relative Growth Rate

The shoot dry weight taken at 4, 6 and 8 WAP was used to calculate the relative growth rate.

$$RGR = \frac{(\ln W_2 - \ln W_1)}{T_2 - T_1}$$

where;

W_1 and W_2 = dry weight at first and second sampling (in grams)

T_1 and T_2 = Time of first and second sampling (in weeks)

Number of Pods Per Plant

The number of pods per plant was obtained by the average of number of pods obtained from the five tagged plants.

Mean Seed Weight

Mean seed weight was obtained by counting 100 seeds, five times from each treatment. These were weighed individually and from which the mean weight was obtained.

Grain Yield

Plants from the central rows of each plot excluding the two border rows on each side were harvested and sun dried for two weeks, threshed and weighed at about 13% moisture content. This was converted to per hectare basis to obtain the grain yield per hectare.

RESULTS AND DISCUSSION**Plant Height**

Plant height results following inoculated soybean and inorganic N application measured at 8WAP are presented in Table 1. Varietal differences following sole inoculation was not significantly different ($P > 0.05$). Inoculated soybean and inorganic N application at the two rates did not result in significant changes except Sonqu-panqu that produced significantly taller plants than all other varieties at 60 kg/ha N application. Significant increase in plant height because of sulphur fertilizer applied to inoculated soybean has been reported (Hussain *et al.*, 2011). Mandicet *al.* (2015) reported significant interaction of soybean cultivars and fertilizer treatments on plant height when they applied 45 kg N ha⁻¹ urea prior to planting. The result obtained with Sonqu-panqu in this study conforms to earlier findings of Mehmet (2008) who reported maximum plant height of a soybean variety at 60 and 90 kg/ha N at an arrived optimum plant spacing. Mehmet (2008) reported that nitrogen increases yield by influencing some agronomic and quality parameters. Utilization of more nitrogen in some varieties may coincide with the high N demand of the crop and this may consequently translate to high yield (Ruark, 2009).

Table 1. Plant height of soybean as affected by inoculated soybean and inorganic N at 8 WAP in 2015 major rainy season.

Inoculated soybean	Plant height (cm)		
	N rates in kg/ha		
	0	30	60
Quashie	59.8	60.9	56.3
Salintuya-1	59.7	59.6	61.7
Songda	62.0	60.6	59.6
Sonqu-panqu	60.7	66.0	73.8
LSD (0.05)	7.8		
CV (%)	8.7		

Canopy Diameter

The results of canopy diameter measured at 8WAP are presented in Table 2. Sole inoculation did not significantly affect canopy diameter. Inorganic N application significantly affected canopy diameter at the two rates.

At 30 kg/ha, the Quashie produced significantly higher effect than both Salintuya-1 and Songda varieties. At 60 kg/ha, the varietal effect of Sonqu-panqu was significantly higher than all other varieties except Salintuya-1.

Generally, canopy diameter at 30 kg/ha were higher than at 60 kg/ha application. Application of phosphorus has been reported to significantly affect canopy spread of inoculated soybean. In a study, Ahiaboret *al.* (2014) found that optimum canopy was obtained at 45 kg P

ha⁻¹. Benefits of higher plant density in soybean include contribution to early canopy closure, so that weeds are smothered and yield increase that may emanate from high density due to increased number of seeds per area rather than increase by plant (Mehmet, 2008).

Table 2. Canopy diameter of soybean as affected by inoculated soybean and inorganic N at 8 WAP in 2015 major rainy season.

Inoculated soybean	Canopy diameter (cm)		
	N rates in kg/ha		
	0	30	60
Quashie	51.80	53.97	49.56
Salintuya-1	49.28	50.47	53.06
Songda	51.59	50.61	47.04
Sonqu-panqu	50.47	52.99	55.30
LSD (0.05)	2.93		
CV (%)	4.0		

Number of Branches

Number of branches were significantly affected by sole inoculation (Table 4.3). The Sonqu-panqu varietal effect was significantly lower than those of Quashie and Songda varieties. The effect of soybean genotype on number of branches was found significant (Ngalamu *et al.*, 2013). The result contradicts that of El-shaboury and El-

ela(2015) who reported that differences in branches number/plant recorded by inoculated soybean genotypes was insignificant. Inorganic N application did not, however, affect branch production. Achakzai (2012) reported that interaction between fertilizer N and pea cultivars was found non-significant for number of primary branches.

Table 3. Number of branches of soybean as affected by inoculated soybean and inorganic N at 8 WAP in 2015 major rainy season.

Inoculated soybean	Number of branches		
	N rates in kg/ha		
	0	30	60
Quashie	19.70	18.55	18.90
Salintuya-1	17.65	19.60	20.35
Songda	20.40	17.35	16.40
Sonqu-panqu	14.25	16.95	18.40
LSD (0.05)	4.11		
CV (%)	15.7		

Crop Growth Rate

Crop growth rate (CGR) is regarded as one of the most meaningful growth functions because it represents the net results of photosynthesis, respiration and canopy area interaction. It depends on the amount and intensity of intercepted energy and photosynthetic efficiency of the canopy. Hence, higher CGR may be due to higher production of dry matter

owing to higher LAI and higher light interception. The result for crop growth rate is shown in Table 4. There was significant interaction between soybean varieties and inorganic N on CGR at the two sampling periods.

At the first stage (4-6WAP), under sole inoculation, the effect of Songda was the highest. Quashie significantly recorded the least dry matter accumulation. At 30 kg/ha, the effects of Salintuya-1 and Songda was similar and significantly higher than the effects of Quashie and Sonqu-panqu varieties, though the effect of Quashie was significantly similar to that of Songda. At 60 kg/ha N application, the Salintuya-1 varietal effect was significantly higher than all other varieties.

The second stage of CGR showed significant ($P < 0.05$) interaction of inoculated soybean and inorganic N application. Salintuya-1 accumulated significantly the highest dry matter under inoculated treatment only except that of Quashie. At 30 kg/ha N application, the results were similar to the inoculation only treatments except that Sonqu-panqu varietal effect was higher than that of Songda. At 60 kg/ha, the Sonqu-panqu varietal effect was the highest, and this was significantly higher than all other varietal effects except Salintuya-1. The Songda varietal effect was the least.

Generally, CGR values starts from a lower value, reaches a certain peak and decline at later stages of growth (Gupta and Gupta, 2005; Panda, 2010). Similar observations were made in the present study where the CGR at stage one was generally higher than at the second stage. There was an average decline in CGR from sole inoculation to combined N rates which contradicts the findings of Namvar and Sharifi (2011) who reported that inoculation with rhizobium increased CGR of chickpea at all levels of N application. Differences in crop growth rate among the soybean varieties conforms to the findings of many workers. Açıkgözet *al.* (2013) reported that crop growth rates of soybean vary with cultivar. Differences in crop growth rate were reported with P application on soybean genotypes (Mahamood *et al.*, 2009).

Relative Growth Rate

The relative growth rate (RGR) as affected by soybean and inorganic N are presented in Table 5. There was significant ($P < 0.05$) interaction at the two stages of RGR. At the first stage (4-6WAP), under sole inoculation Songda and Sonqu-panqu varieties, which had similar effects, produced significantly higher RGR than both Quashie and Salintuya-1 varieties. At 30 kg/ha N, the Salintuya-1 varietal effect was significantly higher than all other varietal effects. All other varietal effects were similar.

At the second sampling under sole inoculation, Quashie and Salintuya-1 varieties had similar effects and this was significantly the highest. The effect of Songda was significantly higher than that of Sonqu-panqu. Following the application of 30 kg/ha N, Sonqu-panqu varietal effect was the highest, while the effect of Songda was the least. At 60 kg/ha N, the effect of Sonqu-panqu was the highest, followed by Salintuya-1 and the least effect was produced by Quashie and Songda varieties. Differences in relative growth rate of the soybean varieties is an important indicator of plant productivity in relation to environmental stress and disturbances. Oyaet *al.* (2004) suggested that relative growth rate could be a good index for evaluating drought tolerant varieties. Soybean varieties with RGR of $6-46 \text{ mg g}^{-1} \text{ day}^{-1}$ under drought were considered as drought resistant. Differences in relative growth rate of soybean varieties conforms to the findings of many workers. Olayinka and Etejere (2015) reported similar pattern of relative growth rate of groundnut varieties. Varietal differences in relative growth rate among the landraces of Bambara groundnut were also reported; however, no effects were observed with phosphorus application (Gyimah, 2013). Differences in relative growth rate of soybean genotypes were reported with P application (Mahamood *et al.*, 2009).

Table 4. Crop growth rate of soybean as affected by inoculated soybean and inorganic N in 2015 major rainy season.

Variety	Crop growth rate (g m ² wk ⁻¹)					
	4-6WAP (N rates kg/ha)			6-8 WAP (N rates kg/ha)		
	0	30	60	0	30	60
Quashie	1.50	3.25	3.75	11.25	11.38	7.25
Salintuya- 1	2.38	4.38	6.25	12.38	12.62	13.88
Songda	5.88	3.75	4.12	9.88	8.50	6.00
Sonqu- panqu	4.38	2.62	3.38	4.75	10.50	14.75
LSD(0.05)	1.05			1.52		
CV (%)	19.2			10.3		

Table 5. Relative growth rate of soybean as affected by inoculated soybean and inorganic N in 2015 major rainy season.

Variety	Relative growth rate (g g ⁻¹ wk ⁻¹)					
	4-6WAP (N rates kg/ha)			6-8 WAP (N rates kg/ha)		
	0	30	60	0	30	60
Quashie	0.05	0.10	0.10	0.27	0.24	0.16
Salintuya- Songda	0.07	0.15	0.18	0.27	0.24	0.26
Songda	0.18	0.11	0.12	0.21	0.19	0.14
Sonqu- panqu	0.19	0.10	0.12	0.16	0.29	0.36
LSD(0.05)	0.02			0.03		
CV (%)	10.2			8.8		

Mean Seed Weight

The results for 100 seed weight of as affected by inoculated soybean and inorganic N are presented in Table 6. Significant ($P < 0.05$) interaction between the two factors was observed. Under all conditions, Sonqu-panqu produced significantly the heaviest seeds than the other varieties, all of which had similar seed weight. Non-significant difference in seed weight among soybean genotypes was reported

(Haruna *et al.*, 2015), which contradicts the above findings. However, seed weight among soybean varieties was found to be significantly affected by inoculation of *Bradyrhizobium* strains alone (Solomon *et al.*, 2012). A contradictory report indicates that interaction of soybean variety and nitrogen rates have no significant effect on 100 seed weight (Bekele *et al.*, 2016).

Number of Pods

Number of pods as affected by inoculated soybean and inorganic N dose are presented in Table 7. Significant ($P < 0.05$) interaction between the two factors was recorded. Under sole inoculation, Sonqu-panqu varietal effect was the highest but this was significantly higher than that of Quashie only. The effect of Quashie was as well significantly lower than those of Songda and Salintuya-1 varieties. Pod number of the Songda was the highest following

application of 30 kg/ha N. Varietal effect of Sonqu-panqu was also higher than those of Quashie and Salintuya-1. At 60 kg/ha N, pods number was the highest in the Sonqu-panqu, followed by those of Songda, Salintuya-1 and Quashie varieties. Recent works, however, reported that interactions between inoculated soybean and cultivar on pod number were not significant (Denwar and Buah, 2012; Sancholiet *al.*, 2015)

Table 6. Mean seed weight of soybean as affected by inoculated soybean and inorganic N in 2015 major rainy season.

Inoculated soybean	Seed weight (g)		
	N rates in kg/ha		
	0	30	60
Quashie	11.80	10.43	10.88
Salintuya-1	10.18	10.45	11.18
Songda	10.20	10.25	9.88
Sonqu-panqu	13.18	12.93	13.38
LSD (0.05)	1.55		
CV (%)	9.6		

Table 7. Number of pods of soybean as affected by inoculated soybean and inorganic N in 205 major rainy season.

Inoculated soybean	Number of pods		
	N rates in kg/ha		
	0	30	60
Quashie	122.19	129.74	103.62
Salintuya-1	154.55	102.45	134.29
Songda	155.70	205.42	153.16
Sonqu-panqu	158.55	162.29	185.20
LSD (0.05)	7.53		
CV (%)	3.6		

Grain Yield

The result of yield of soybean as affected by inoculated soybean and inorganic N are presented in Table 8. Significant ($P < 0.05$) interaction between inoculated soybean and inorganic N was observed in yield. Under inoculant alone, Sonqu-panqu produced significantly higher yield than all other varieties. Grain yield of Quashie and Salintuya-1 varieties were similar, but either effect was significantly higher than yield of Songda. At both N rates, yield of Sonqu-panqu was significantly higher than all other varietal yield. Again, under both rates, grain yield of Quashie was significantly higher than those of Salintuya-1 and Songda varieties. The lowest grain yield was produced by Salintuya-1 under 30 kg/ha N rate, and Songda under 60 kg/ha N rate.

Results from this study indicated different yield responses of inoculated soybean and combined N. Such inconsistencies can present challenge to

growers as at what variety to cultivate and what N rate to use. Different responses of the soybean varieties might indicate different compatibility of the soybean genotypes to the inoculant used. Differences in yield of soybean varieties under sole inoculation have been reported (Kumaga and Ofori, 2004; Solomon *et al.*, 2012). Different responses of soybean varieties were also observed with the combined application of inoculant and inorganic N at both rates. This means that some interactions between inoculants and the soybean varieties were more tolerant to combined N than others. Dogra and Dudeja (1993) observed that sensitivity of symbiosis in legumes to combined N is strongly dependent on the plant and *rhizobium* interaction not on the individual plant or microsymbiont. However, it has been reported that when an efficient symbiosis is established, it is not necessary to use starter N (Mendes *et al.*, 2003).

Table 8. Yield of soybean as affected by inoculated soybean and inorganic N in 2015 major rainy season.

Inoculated soybean	Grain yield (kg/ha)		
	N rates in kg/ha		
	0	30	60
Quashie	353.2	408.5	365.8
Salintuya-1	341.2	224.5	318.8
Songda	272.8	314.0	236.8
Sonqu-panqu	585.2	539.8	685.2
LSD (0.05)	33.62		
CV (%)	6.0		

CONCLUSION

Supplementation of inoculated soybean varieties with inorganic N has the potential to improve growth and yield of soybean. Generally, the effect of combined N rates differed among varieties of soybean, while N rates improved growth and grain yield in some of the varieties, in other varieties, there was a reduction in such

parameters. Such differences could have been due to differences in their host-*rhizobium* interactions. This is indication that for either sole inoculation, or application of N, significant interaction exists, hence there is need for further research to ascertain the best N application to each variety.

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