

**EFFECT OF PHOSPHORUS APPLICATION AND RHIZOBIA INOCULATION ON
GROWTH AND YIELD OF SOYBEAN (*Glycine max* L. Merrill)**

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ABSTRACT

An experiment was conducted in the major and minor cropping seasons of 2012 and 2013 under field conditions at Bolgatanga Polytechnic, to study the effect of phosphorus fertilizer and Rhizobia inoculation on growth and yield of soybean using randomized complete block design in three replication. The soybean variety used was 'Jenguma HSCII51'. The seed, Triple Superphosphate fertilizer and the Rhizobia inoculant were obtained from the Ministry of Food and Agriculture (MOFA), Navrongo. The experiment was laid in a Randomized Complete Block Design (RCBD) with three replications. The treatments studied were: Soybean + phosphorus fertilizer + Rhizobia inoculation (+P/+I), Soybean + phosphorus fertilizer only (+P/-I), Soybean inoculated with Rhizobia (-P/+I) and the control-Soybean only (-P/-I). Parameters measured included: plant height, nodule number, pod number per meter square, number of seeds/pods, 100-seed weight, shelling %, grain yield and harvest index. Results indicated that Phosphorus fertilizer application is required was a requirement for shoot growth, pod and seed yield. Nodulation and root growth were significantly increased by Phosphorus + Rhizobia inoculation (+P/+I), but P fertilizer only did not enhance root growth. Dry matter accumulation was highest between onset of flowering and Podding (42 to 70 DAP), irrespective of the treatments. Phosphorus fertilizer treatment only (+P/-I) and Rhizobia inoculation plus phosphorus fertilizer (+P/+I) produced significantly more pods (3903.7 Kg/ha) and (3858.3 Kg/ha) respectively than the Rhizobia inoculation only which recorded (2301.0 Kg/ha). The

~~control recorded grain yield of (2130.7 Kg/ha).~~ Grain yield was again highest for Rhizobia inoculation plus Phosphorus fertilizer (+P/+I) and Phosphorus fertilizer only (+P/-I) recording 7.61 t/ha and 7.30 t/ha respectively while Rhizobia inoculation only (-P/+I) and the control (-P/-I) produced the lowest grain yield (4.41 t/ha) and (3.80 t/ha) respectively.

~~The treatments did not have any significant effect on number of seeds per pod, 100 seed weight and harvest index (HI). Shelling percentage was significant for Phosphorus fertilizer treatment only (+P/-I) (69%) and the Rhizobia inoculation only (-P/+I) (67%) but was not significant for the control (-P/-I) (68%) and Rhizobia plus phosphorus (+P/+I) (67%).~~

Keywords: Cultivation Soybean, fertilizer, harvest index, inoculation, nodulation, phosphorus, rhizobia, soybean, protein energy malnutrition, soil fertility improvement

INTRODUCTION

Soybeans (*Glycine max* L. merr) is an ancient leguminous crop and ~~possibly~~ originated from temperate China ~~where it was believed to be one of the five sacred grains which the country's ancient civilization depended on (Tweneboah, 2000).~~ About 70% of the world's soybean is now produced in the USA, ~~with the mainland and~~ China being the second largest producer. In terms of production, consumption and trade, soybean is the world's most important grain legume (Tweneboah, 2000).

Soybean ~~is relatively a recommended crop in Ghana, referred to as the 'golden bean', 'miracle bean' and in some areas, the crop of the 'planet'.~~ It was initially introduced ~~to Ghana into the country~~ in 1909 for export and for animal feed but failed due to poor understanding of its cultivation and utilization; it had been tried a few more times ~~after this~~ in 1930s, 1950s, 1970s and the 1990s but ~~had failed due was unsuccessful due to several reasons (such as the unsuitable~~ rainfall pattern, soil type ~~and~~ technique of cultivation) (Woomer, 2010).

Soybeans have many industrial uses and ~~are important sources of vegetable oil and protein~~ importance for human use. The beans has an oil content of about 20%, protein content of 40-45% ~~and carbohydrate~~ carbohydrate ~~e, of~~ 30 % and total sugars of about 10% (Haas et al., 2006). ~~It~~ The bean is also a good source of calcium, phosphorus, copper, potassium, magnesium and thiamine. Van Gerpen and Krah (2005); Haas et al. (2006) stated that soybean oils can be converted to biodiesel and glycerol. In the US, the major biofuel for transportation is soybean biodiesel, which displaces petroleum and diesel ~~(needs citation here).~~

61 Soybean has a great potential for the alleviation of Protein Energy Malnutrition (PEM) in Ghana because
62 animal sources of proteins are scarce and expensive. In Ghana, soybeans is used in the preparation of
63 soy paste, soy milk, soy custard, soy kebab, soy cheese, soy palaver sauce and many others.

64 Soybean is produced by small holder farmers in Ghana, under rain fed conditions. Under these
65 subsistence methods, soybean ~~yield provided~~ averagely ~~yield of~~ 0.8 metric ton per hectare. FAO
66 estimates~~ed~~ that Ghana imports 2700 gallons of soybean oil. There is ~~also~~ limited supply of soybean feed
67 for the poultry industry ~~in Ghana~~—resulting in major constraints in the growth of the industry. This has
68 resulted in significant growth of import of poultry and other ~~meat products~~ (protein sources) for
69 consumption (~~MiDAMIDA~~, 2013).

70 Poor soils has become a problem as a result of poor land management which leads to continuous loss of
71 soil nutrients through the activities of soil erosion, ~~by rain~~, leaching, ~~and~~ crop removal ~~and bad cultural~~
72 ~~practices~~. The resultant effected ~~in~~ ~~is~~ the decline ~~in of~~ crop yields. Ohyama *et al* (2013); stated that
73 soybean seed yield can reach 4.6 t/ha with well managed fields under good climatic and soil conditions.
74 The highest yield of soybean was recorded in Japan at 7.8 t/ha (Ohyama *et al.*, 2013). Recently, an
75 amazing high soybean seed yield over 10 t/ha was recorded in 2008 and 2010 by a farmer in Missouri,
76 USA. Therefore the potential productivity of soybean should be higher than we have thought (Ohyama *et*
77 *al.*, 2013).

78 In view of the above, measures must be taken to improve BNF because when nitrogen is lost from soils;
79 leguminous plants however, are not able to convert atmospheric N into absorbable forms of NH₄⁺ and
80 NO₃⁻ before used by plants.

81 Natural reserves of soil N are normally low in many African soils and again phosphorus fertilizers which are
82 important elements necessary for plants' growth are also lacking ~~in many African soils~~ (Hardarson *et al.*
83 1987). Since the crop has immeasurable potential in Africa at large and Ghana in particular, ~~therefore, this~~
84 ~~the~~ study was conducted ~~with the objectives~~ to ~~provide useful information~~ ~~study on~~ the effects of P fertilizer
85 application on nodulation, shoot growth and yield; to evaluate the effects of Rhizobia inoculation on
86 nodulation and yield.

87 ~~The need for Phosphorus and rhizobia inoculation treatment, particularly to a crop such as soybean, has~~
88 ~~become essential due to the immeasurable benefits the crop provides; income to resource poor farmers;~~
89 ~~an important source of protein, and its ability to fix atmospheric nitrogen to the soil.~~

90 ~~Phosphorus is an important requirement for shoot growth and the subsequent yield of soybean.~~
91 ~~Phosphorus and Rhizobia application (to soybean) is reported to increase nodulation, pod formation and~~
92 ~~development, and a subsequent grain yield (Ajeigbe and Woomer, 2010; Cassman et al., 1981).~~

93 | It is therefore envisaged the study would provide an important first step at improving the crop in Ghana,
94 | particularly the North, where there is seasonal food scarcity, and also serve as a foundation to enhance
95 | their potential cultivation and use in future, thus contributing to food security.

96

97 | MATERIALS AND METHODS

98 | The study was conducted in the major and minor cropping seasons of 2012 and repeated in 2013, at the
99 | experimental field of the Bolgatanga Polytechnic which resides in Sumbrungu, located 7 km away from
100 | Navrongo. It shares boundaries with Kassena-Nankana district at the north, Bongo district at the East,
101 | south to Bolgatanga Municipality and West to Sirigu and lies between latitude 10°45' North and longitude
102 | 0°51' West of Ghana. The experiment was laid in a Randomized Complete Block Design (RCBD) with
103 | three replications.

104 | The land was slashed, ploughed and harrowed, and then finally raked, lined and pegged before planting at
105 | the appropriate spacing and; the experiment was laid in a Randomized Complete Block Design (RCBD)
106 | with three replications. Seeds were planted in rows on flat field; spaced 5cm x 75cm apart, 3 seeds
107 | were planted per hill and were not thinned. Each plot in a block measured 3m x 3m and was contiguous to
108 | one another in each block; there were 4 plots in each replication. The distance between the blocks was 1
109 | meter making a total of 12 plots.

110 | **TREATMENTS:** A - Control plot which is planted to soybean only (-P/-I). B - Plot planted to soybean
111 | seed which is inoculated (-P/+I). C - Plot planted to soybean and Triple Superphosphate (TSP) is applied
112 | and inoculated (+P/+I). D - Plot planted to soybean and TSP is applied (+P/-I)

113 | SOYBEAN INOCULATION WITH RHIZOBIA

114 | One (1 kg) kilogram of soybean seed was weighed and placed in a rubber container, and three 3 spoonful
115 | of sugar solution was added as an adhesive and 40 ten gram g of inoculants was also weighed and added
116 | to the soybean seeds. It was then stirred with a spoon until the seeds were evenly coated with the
117 | Rhizobia. After coating, the seeds where were spreaded onto a clean surface and air dried under a shade
118 | for about one an hour. The inoculated air dried seeds where were then planted, three seeds per stand.

119 | FERTILIZER APPLICATION

120 | Triple Superphosphate (TSP) fertilizer was applied after two weeks at a rate of 139.4 g per plot in a band,
121 | 10cm away from the planting line in a 2cm deep trench and covered with moist soil after application. The
122 | application was done after seedlings developed ten to eleven leaves to enable effective use of the
123 | fertilizer.

124 | WEED AND PESTS MANAGEMENT

125 | All plots were weeded by hand and using (hoe), at least three times (state exactly what was done). The
126 | Insecticide, Cyperdicot (Cypermethrin); SPCT as an active ingredient, was used, at a recommended rate of

127 | 25ml per half knapsack sprayer [\(put the volume in number\)](#), to control insects, particularly at the flowering
128 | stage.

129 | [DATA COLLECTION](#)

130 | **Growth Parameters** measured included plants height, number of leaves [per](#) [_____](#), number of nodules
131 | [per](#) [_____](#), leaf dry weight [per](#) [_____](#), stem dry weight, roots dry weight and nodule dry weight.

132 | **Yield Parameters** measured also included number of pods per plant, number of pods per meter square,
133 | number of plants per meter square, number of seeds per pods, 100 seeds weight and mean seed weight.

134 | [DATA ANALYSIS](#)

135 | [Averages, range, standard deviation and coefficient of variation were computed for the measurement data.](#)
136 | [Quantitative data was subjected to analysis of variance \(ANOVA\) using GenStat discovery edition 4.0](#)
137 | [\(GenStat 5 Committee, 2000\). Means were separated by least significant difference at 5%.](#)

138 |

139 |

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142 | RESULTS AND DISCUSSION

143 | **Table 1: [Average Climatic data for 2012 and 2013 \(Upper East Region\)](#) [\(this table need to be put in](#)
144 | [the Material and Method, preferably, in line graph\)](#)**

Months	Average Temperature (°c)	Total Rainfall (mm)	Sunshine / hrs	Relative Humidity (%)
January	27.5	0.0	9.5	23.0
February	30.7	0.9	7.9	24.3
March	33.1	0.0	6.5	24.8
April	31.8	99.9	6.7	54.0
May	29.1	154.4	7.4	70.8
June	28.9	79.3	8.1	69.0
July	27.1	241.9	6.3	78.5
August	26.7	128.8	6.8	80.3
September	26.9	235.1	5.8	80.0

October	28.5	47.7	7.7	71.5
November	30.1	0.0	9.9	50.3
December	28.6	0.0	9.5	27.5

Source: Navrongo Meteorological Station, [year 2012 and 2013](#)

Table 2: Chemical Properties of Soil at the Experimental Site [\(this table need to be included in the result and discussion part following the appropriate text that support the information in the table\)](#)

Chemical Composition	(0-15 cm) depth
pH	6.1
*Available P (mg/kg)	2.3
Organic Carbon (%)	0.36
Organic matter (%)	0.62
Total N (%)	0.03
Exchangeable Bases (Cmol/kg/Me/100g)	
Ca	3.2
K	0.1
Mg	1.34
Na	0.04

*Available P (mg/kg), from 20.0 mg/kg and above is = Adequate to high

EMERGENCE AND FLOWERING

Emergence was complete within 10 days after planting; all the treatments recorded 50% emergence at 4–the fourth days. The Rhizobia inoculated treatment significantly increased the number of seedlings that emerged, but there was no significant difference between the rest of the treatments, that is P fertilizer (+P/-I) application, the control (-P/-I) and both P and Rhizobia inoculated treatment (+P/+I) as shown in Table 3. This may be attributed to inoculants' effect or Rhizobia effect which enhanced emergence and germination. However, the treatments did not have any effect on 50% flowering. All the treatments took 47days to attain 50% flowering. Nevertheless, Rhizobia-rhizobia inoculation only recorded the highest number of flowers of 281 followed by the other treatments and this has a relationship with emergence (Table 3).

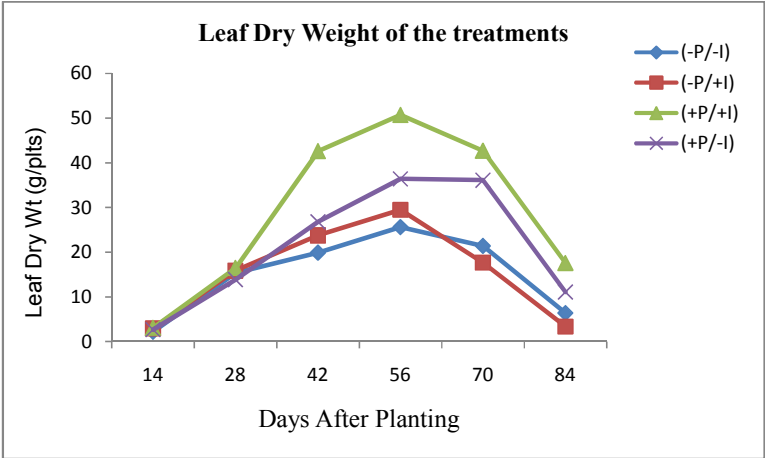
Table 3: Effect of phosphorus and Rhizobia inoculation on emergence and flowering of soybean

Treatments	50 % Seedling Emergence (4 days)	50% flowering (47 days)
(-P/-I) No Inoculation and No P fertilizer	78.1	238
(-P/+I) Rhizobia inoculation only	109.3	281
(+P/+I) Rhizobia Inoculation + P fertilizer	80.3	264
(+P/-I) P fertilizer Only	76.0	233
Lsd (5%)	28.7	99.1
CV (%)	19.4	19.1

174 NS = Not Significant, P > 0.05

175 LEAF DRY WEIGHT

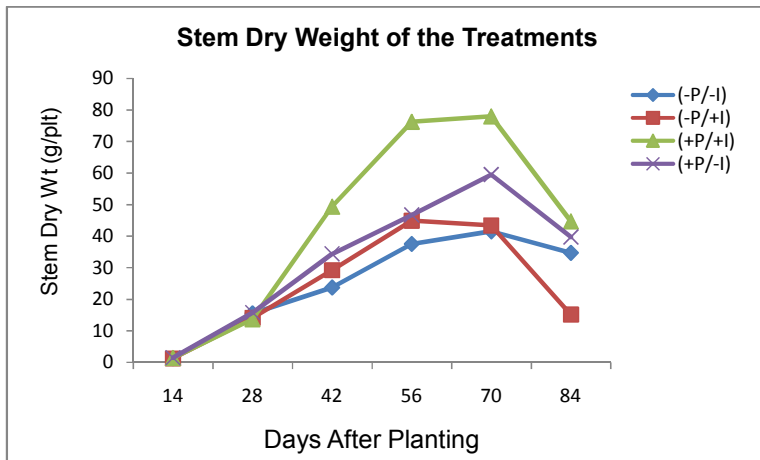
176 In all the treatments, leaf dry weight increased to a peak 84-56 DAP and declined at
177 70 started to decline after it DAP owing to onset of senescence (Figure 1). Phosphorus
178 plus Rhizobia inoculation recorded the highest leaf dry weight of 50.7 g/plant and was
179 followed by phosphorus application only which recorded a weight of 36.4 g/plant and
180 peaked at 70 DAP. Rhizobia inoculation alone also took the same trend, recording a leaf
181 dry weight of 29.5 g/plant. The control (-P/-I) recorded the lowest leaf weight of 20.70
182 g/plt as shown in Figure 1. The results showed that the phosphorus application plus
183 Rhizobia inoculation produced the greatest shoot leaf dry matter. Field observations also
184 showed that phosphorus and rhizobia inoculation enhanced dark green colour of the
185 leaves. It appeared, therefore that rhizobia inoculation enhances P uptake leading to
186 the development of a larger photosynthetic area. Phosphorus application has been
187 reported to increase shoot growth or leaf growth of soybeans and other leguminous
188 crops (Othman, 1991; Cadish et al., 1992).



189 Figure 1: The effect of phosphorus and Rhizobia inoculation on leaf dry weight of soybean.

191 STEM GROWTH

192 Stem dry weight also followed the same trend as leaf growth but the peak stem growth
 193 was recorded at 70 DAP and at 84 DAP for all the treatments except Rhizobia
 194 inoculation only which peaked 56 DAP and remained sturdy until 70 DAP and dropped
 195 (Figure 2). Initial stems growths experienced almost the same dry matter accumulation
 196 ~~and on until~~ 28 DAP ~~and then,~~ all the treatment begun to split as a result of stem dry
 197 weight differences. Phosphorus plus Rhizobia inoculation (+P/+I) recorded the highest
 198 dry matter residues to point at 56 DAP (Figure 2). On 56 DAP, there was stability in dry
 199 matter accumulation to 70 DAP which marked ~~the period of the end of~~ vegetative
 200 growth ~~and commencement of~~ -flowering and pods development, therefore dry matter
 201 accumulation was more rapid between 28 and 56 DAP, hence the steady weight drop
 202 because soybean stems loss their green colour as the crop matures or senescence sets
 203 ~~in since the level of stem enlargement ceases at onset of reproductive growth.~~
 204 The acute deficiency of phosphorus can prevent nodulation ~~by in~~ legumes. Phosphorus
 205 is required for nodule metabolism and tends to be concentrated in the nodules when the
 206 plant is deficient in these nutrients (Hara *et al.*, 1988; Cassman *et al.*, 1981).



207

208 Figure 2: Effect of phosphorus and Rhizobia inoculation on stem growth of soybeans.

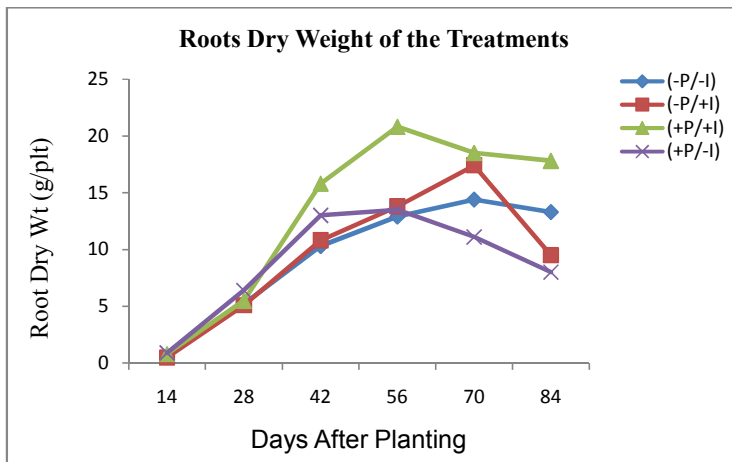
209 ROOT GROWTH

210 Comparing root growth of the treatments, the Rhizobia plus phosphorus (+P/+I)
 211 treatment again produced the highest root dry matter of ~~6.93 ??~~ g/plt at 56 DAP. The

212 Rhizobia inoculated treatment alone recorded the next higher value of ~~6.47-??~~ g/plt but
 213 at 70 DAP when the (+P/+I) treatment was gradually ~~dropping-dropped~~ (Figure 3). The
 214 growth may be attributed to increase in cell dry matter accumulation with well-developed
 215 tap root during growth of the plant. The control was the next highest, while phosphorus
 216 application only increased root growth up to 42 DAP and begun to drop. Rhizobia
 217 inoculation might have led to increased root growth of the plant. This finding is in line
 218 with Okagun *et al.*, (2004) who observed a significant increase in root dry matter yield of
 219 inoculated improved soybean over uninoculated improved variety.

220 The drop in root growth at 84 DAP may be due to senescence. Plant roots get dried in
 221 the soil and lose its weight as the crop matures. Therefore, as the plants mature, the
 222 more it loses dry matter leading to significant drop in dry weight at different growth
 223 stages leading to maturity and senescence.

224



225

226 Figure 3: The effect of phosphorus and Rhizobia inoculation on root growth of soybean.

227

228 NUMBER OF NODULES

229 From Figure 4, on 14 days-after-planting, treatment (+P/-I) recorded a slightly sharp
 230 increase in number of nodules produced per plant. This may be due to bacteria
 231 inoculation having been less effective in nodulating at the second week of growth. The

ineffectiveness of the Rhizobia bacteria during the two weeks was due to the period of bacteria incubation in the soil, hence at this stage, plant roots, after two weeks, did not use these bacteria much, and therefore recorded less number of nodules produced as shown in (figure 4).

On the other hand the control treatment (-P/-I) recorded the lowest number of nodules showing that the soil did not contain much bacteria to produce more nodules at this stage, but the application of P increased nodulation. On 28 days after planting, phosphorus plus rhizobia inoculation (+P/+I) treatments recorded a tremendous increase in number of nodules produced. Higher values were recorded again for the same treatments at 42 and 56 days after planting (Figure 4), indicating effective utilization of the bacteria and fertilizer.

On 70 days after planting, there was a sharp drop in the number of nodules recorded as a result of the use of more energy to convert protein into food reserves that the plants required, therefore, nodules number degenerated or disappeared indicating the point of maturity. This agrees with the research findings of Fournier *et al*, (2008).

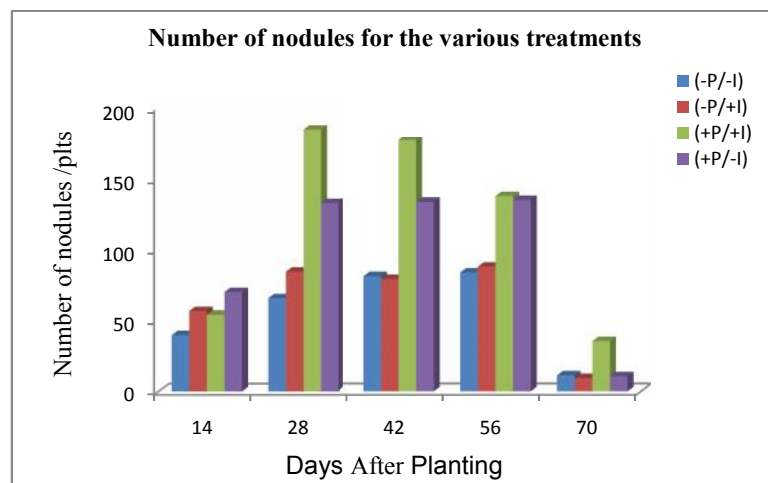


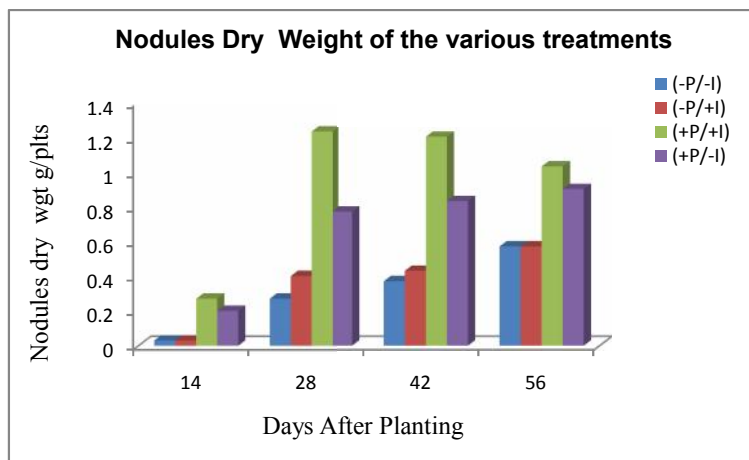
Figure 4: The effect of phosphorus and Rhizobia inoculation on of nodule number of soybean.

NODULE GROWTH

250 At different growth stages, there was [no significant increase](#) in Rhizobia effect for the
251 treatment (-P/-I) and (-P/+I) on [nodulation-nodule growth](#) at 14 DAP, but treatments
252 (+P/+I) and (+P/-I) had attained a slight increase of (0.3g/plt) and (0.29g/plt) respectively
253 (Figure 5). The increase in growth of nodules was equivalent to increased nodule dry
254 weight of the plants. Therefore, on 28 DAP, (+P/+I) had a significant increase in dry
255 weight of 1.3g/plt and treatment (+P/-I) with 0.8g/plt. [Nodulation-Nodule growth](#) therefore
256 increased between the pre-flowering and early pod-forming stages. ~~This suggests that,~~
257 ~~after the flowering stage, the main nitrogen fixing activity of the whole root system~~
258 ~~reduced. The results also indicated that it~~ was necessary to analyse the origin of
259 nodules on the various parts of the root system independently in order to establish
260 clearly the effectiveness of the Rhizobia inoculation in terms of nodulation.

261 ~~Several studies have reported that soybean grown under field conditions and inoculated~~
262 ~~with the rhizobia sometimes failed to show a positive response to inoculation, in terms of~~
263 ~~nitrogen fixation and crop yield (Weaver and Frederick, 1974; Cassman et al., 1981).~~

264 On 28 DAP, treatment (+P/+I) recorded an increase in dry matter residue while
265 treatment (+P/-I) recorded the second highest dry weight of nodules produced (Figure 5).
266 Treatments (-P/-I) and (-P/+I) obtained the lowest of 56 DAP, but as the trend continued,
267 there was a slow dropped in weight to about 1.0 g/plts for (+P/+I) and 0.83 weight g/plt
268 for (+P/-I). This may be as a result of plant senescence or ageing because much [energy](#)
269 [photosynthetic product](#) is absorbed to forming pods.



270

271 *Figure 5: Effect of phosphorus and rhizobia inoculation on nodule growth of soybean.*

272 **EFFECT OF PHOSPHORUS AND RHIZOBIA INOCULATION ON POD NUMBER, NUMBER**
 273 **OF SEEDS PER POD, 100 SEED WEIGHT AND SHELLING %.**

274 Phosphorus fertilizer treatment only (+P/-I) and Rhizobia inoculation plus phosphorus
 275 (+P/+I) produced significantly more pods (3903.7 Kg/ha) and (3858.3 Kg/ha) than the
 276 rhizobia inoculation only which recorded 2301.0 Kg/ha and the control (2130.7 Kg/ha).
 277 But there was no significant difference between the phosphorus fertilizer treatment only
 278 (+P/-I) and Rhizobia inoculation plus phosphorus (+P/+I). There was again no significant
 279 difference between the control and the Rhizobia inoculated treatment only (Table 4).
 280 Phosphorus fertilizer application therefore had an influence on pod formation and pod
 281 number, and P availability also encourages nodulation; this was the reflection on the high
 282 number of pods produced by the rhizobia inoculation plus phosphorus (+P/+I) treatment
 283 but rhizobia inoculation alone recorded a lower pod number. However, the treatments did
 284 not have any significant effect on number of seeds per pod and 100 seed weight (Table
 285 4). But there were significant effects on shelling percentage with the P fertilizer treatment
 286 only.

287 Treatment (+P/-I) recording the highest shelling percentage of 69% followed by the
 288 control. It showed; therefore, that yield of soybean depended on pod number per

unit area. This finding is in line with that of Ohyama *et al.* (2013) who stated that soybean yield depends mostly on pod number per unit area (Cassman *et al.*, 1981).

Table 4: Effect of phosphorus and rhizobia inoculation on yield components of soybean (Jenguma HSCII51); at final harvest.

Treatments	Pod No./m ²	Number of seeds/pod	100 Seed wt	Shelling %
(-P/-I) No Inoculation and No P fertilizer	2130.7	2.000	10.67	0.68
(-P/+I) Rhizobia inoculation only	2301.0	1.833	10.83	0.66
(+P/+I) Rhizobia Inoculation + P fertilizer	3858.3	1.967	10.97	0.67
(+P/-I) P fertilizer Only	3903.7	1.900	11.60	0.69
Lsd (5%)	1278.5	NS	NS	0.02
CV (%)	10.5	3.4	1.8	0.9

NS = Not Significant, $P > 0.05$

EFFECT OF PHOSPHORUS AND RHIZOBIA INOCULATION ON SEED YIELD COMPONENTS OF SOYBEAN.

Seed yield is a function of determined by number of plants per unit area, the mean number of pods per plant, the mean number of seeds per pod and the mean individual seed weight. Rhizobia inoculation plus P fertilizer (+P/+I) and P fertilizer only (+P/-I) Once again recorded significantly the highest pod dry weight of (1131.1 Kg/ha) and (1054.8 Kg/ha) respectively. But there was no significant difference between the two. Again, there was no significant difference between the control (-P/-I) and the Rhizobia inoculation only (-P/+I) (Table 5).

306

307 Grain yield was highest for Rhizobia inoculation + P fertilizer (+P/+I) and P fertilizer only
 308 (+P/-I), recording 7.61 t/ha and 7.30 t/ha respectively, while Rhizobia inoculation only
 309 and the control recorded the lowest grain yields of 4.41 t/ha and 3.80 t/ha respectively
 310 (Table 4). [Ohyama *et al.* \(2013\)](#), reported that soybean seed yield can reach 4-6 t/ha
 311 with well a-managed field under good climatic and soil conditions. They again stated that
 312 the highest yield of soybean of (7.8-)t/ha were recorded in Japan. The yield obtained in
 313 this study was much close to that recorded in Japan and this could be considered as the
 314 highest yield reportedly obtained in the current study.

315 The control and the Rhizobia inoculation (-P/+I) treatments, did not have any significant
 316 increase on grain yield; hence phosphorus fertilizer can be said to have a greater
 317 influence on grain yield of soybean. This is because the impact of phosphorus fertilizer
 318 was significant across board in terms of dry matter produced, pod yield and grain yield.
 319 According to the soil analysis results of the experimental site (Table 2), the P content of
 320 the soil was very low (2.3 mg/kg) as compared to 20 mg/kg regarded as adequate or the
 321 standard.

322

323 Adequate phosphorus application and Rhizobia will lead to effective pod dry matter
 324 accumulation, and subsequently to higher grain yield.

325 The yield characteristics are a reflection of shoot dry weight which was increased by P
 326 fertilizer application. This may indicate that when shoot growth is limited by P
 327 unavailability, pod filling (Shelling %) and total seed yield will be accordingly limited. This
 328 shows the importance of P supply in improving the production of soybean in Ghana. The
 329 poor yields obtained by farmers may be attributed to P unavailability in most soils
 330 particularly during the period of high shoot growth rate (42 to 70 DAP).

331

332 **Table 5: Effect of phosphorus and Rhizobia inoculation on pod dry weight, grain yield and harvest**
 333 **index of soybean**

Treatments	Pod Dry wt. (g/m ²)	Grain Yield (g/m ²)	Grain Yield (t/ha)	Harvest Index
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(-P/-I) No Inoculation and No P fertilizer	562.2	379.9	3.80	0.54
(-P/+I) Rhizobia inoculation only	668.7	441.7	4.41	0.52
(+P/+I) Rhizobia Inoculation + P fertilizer	1131.1	763.6	7.61	0.52
(+P/-I) P fertilizer Only	1054.8	727.9	7.30	0.50
Lsd (5%)	385.2	253.6	0.30	NS
CV (%)	6.0	6.2	6.2	3.8

NS = Not Significant, P > 0.05

CONCLUSION AND IMPLICATIONS OF THE STUDY

~~The results have shown P requirement for shoot growth and yield of soybean. Based on the study, phosphorus and Rhizobia application to soybean played a very significant role in increasing nodulation, pod formation and development, and a subsequent grain yield.~~

~~Soybean is a relatively new crop in Ghana. Presently, inoculation is not largely practiced by farmers.~~

~~Promiscuous soybean cultivars were proposed as alternatives to the use of inoculants.~~

~~Nonetheless, there seems to be P requirement for shoot growth, nodule formation and yield. The results have shown P requirement for shoot growth and yield of soybean.~~

~~Based on the study, phosphorus and Rhizobia application to soybean played a very significant role in increasing nodulation, pod formation and development, and a subsequent grain yield.~~

~~Conversely, m~~Most savannah soils, lack of P; under the low-input agricultural

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351 systems, farmers do not apply fertilizers to soybean, they generally use the limited
352 amount of fertilizer available for staple cereal crops like millet, sorghum, and rice and
353 maize. Promiscuous soybean cultivars were proposed as alternatives to the use of
354 inoculants and there seems to be P requirement for plant growth and development.
355 The field experiment results have shown P requirement for shoot growth and yield of
356 soybean. Based on
357 the study, phosphorus and Rhizobia application to soybean played a very significant role
358 in increasing nodulation, pod formation and development, and a subsequent grain
359 yield. Furthermore, the

360 This study has shown that in order to derive full benefit from biological nitrogen fixation
361 and hence to maximize soybean productivity in these soils, it is necessary to apply
362 Phosphorus as part of a deliberate programme to improve soil fertility levels. It is
363 recommended that farmers apply phosphorus fertilizer to their crop (soybean) so as to
364 increase their harvest and income level affording them, the edge to go into large scale
365 production of the crop. Nevertheless, for proper establishment, soybean seeds could
366 be inoculated with appropriate Rhizobia.

367 ~~Efforts should be made by extension officers and other stakeholders to increase farmers'~~
368 ~~awareness and appreciation of the technology. Because of an ever increasing population~~
369 ~~in Africa and the world, with limited farm lands, it is very important to increase~~
370 ~~productivity of crops per unit area in order to feed the large population as well as~~
371 ~~increase protein source in diets in order to guarantee food security in Ghana particularly,~~
372 ~~and Africa at large.~~

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