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RESPONSE OF SOYBEAN (*Glycine max)* TO RHIZOBIAL INOCULATION AND PHOSPHORUS APPLICATION

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ABSTRACT

Experiment was conducted in the 2012 raining season under rainfed conditions in the Guinea Savanna zone of Northern Ghana to investigate the influence of phosphorus at different source, rates and rhizobium inoculants on performance and yield of soybean (*Glycine max)*. The experiment was a factorial laid in a randomized complete block design with eight treatments and three replications. Parameters measured were plant height, leave area, number and weight of nodules, shoot weight and total grain yield. The results indicate significant increase in number of nodules, weight of dry nodules, weight of dry shoots and yield weight with rhizobium inoculants and application of phosphorus from different source. The present study recommends the use of rhizobium inoculants in treating soybean seeds before sowing and application of Triple superphosphate fertilizer at 30kg P/ha.

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1 Introduction

Soybean (*Glycine max)* is an important legume crop in the world in terms of total production and international trade (Simmond et al., 1999). Soybean contains about 20% oil on dry matter basis with 30-50% of protein (Kwarteng & Towler, 1994). It also has superior amino acid profile and its protein has great potential as a major source of dietary protein and can play an important role to solve malnutrition problems (Ruhul et al., 2009). Soybean is eaten in many forms which include soy sauce, soy milk, bean sprouts and meat analogs. It can also be incorporated in bread, cookies, pancakes, beverages and also in traditional dishes such as "Tubani", "Koose", "Tuo-Zaarfi" and "Gabelei" (Mercer-Quarshie, 1989). A temperature of 26.5 - 30°C appears to be the optimum for most of the varieties and a well drained and fertile loam soils with pH of 6.0 - 7.5 are most suitable for the cultivation of soybean.

Rhizobium inoculation is a significant technology for the manipulation of rhizobia for improving crop productivity and soil fertility. Rhizobium inoculation can lead to establishment of large rhizobia in the rhizosphere and improved nodulation and nitrogen fixation even under adverse soil conditions (Peoples et al., 1995). Soybean rhizobium inoculation is the process of applying rhizobium inoculants to the soybean seed before planting in order to increase the nitrogen fixation and nodulation of the soybean roots. Inoculating soybean provides adequate number of bacteria in the soybean root zone, so that effective nodulation will take place. Phosphorus has a key role in the energy metabolism of all plant cells, particularly in nitrogen fixation as an energy-requiring process (Dilworth, 1974). Nodules are strong sinks for phosphorus which reaches concentrations three fold higher in other organs (Vadez et al., 1999). On the other hand, nodule number, as well as total and specific nitroginase activity increased with the addition of phosphorus, implying more efficient nitrogen fixation (Israel, 1987). According to Pereira & Bliss (1989); Ankomah et al. (1995) soil deficient in phosphorus (p) limit the extent of nodulation, nitrogen fixation and seed yield of legume crops. Phosphorus, apart from its effect on nodulation process and plant growth, has been found to exert some direct effects on soil rhizobia (Singleton et al., 1992). Phosphorus deficiency is common in most West African soil (Adetunji, 1995). According to Kamara et al. (2007), application of phosphorus significantly improved the performances of soybean. The present study was undertaken to determine the effect of various phosphorus sources, its levels and rhizobium inoculation on nodulation and yield of soybean.

2 Materials and Methods

2.1 Experimental Site

The experiment was conducted at experimental field of the Faculty of Agriculture, University for Development Studies, Nyankpala in the Guinea Savannah zone of Ghana, West-Africa. Nyankpala lies on the altitude of 200 m above sea level, within latitude 09°25' N and longitude 0°58' W of the equator. It has uni-modal rainfall pattern with mean annual rainfall of 1000 mm distributed from April to September. The temperature and relative humidity lies between 23.4^{o}C - 34.5^{o}C and 46% - 76.8 % respectively (SARI, 2008). Physical properties of soils are loamy sand textural class derived from voltaian sandstone and classified as Nyankpala series (SARI, 2008). Rainfall was high and well distributed during the cropping season (Table 1).

2.2 Experimental Design

The experiment was a factorial laid out in a randomized block design (RBD) with 8 treatments and three replicates. Each replicate was 12 m × 12 m with a distance of 2 m between replicates. The soybean seeds (Janguma variety) and rhizobium inoculants were obtained from Savanna Agricultural Research Institute (SARI). The rhizobium inoculation was done in the Soil Microbiology laboratory of SARI at the rate of 5g of rhizobium inoculants per 1kg of soybean seed. Rhizobium inoculated seeds were spread on flat plywood to air dry for 30minutes after which they were planted in rows at three seeds per hill with spacing of 30cm X 10cm. There were two sources of phosphorus which were applied at three levels with or without rhizobium inoculants. The treatments were Yara legume at 0kg P/ha, 15kg P/ha and 30kg P/ha with or without rhizobium inoculum and Triple superphosphate (TSP) at 0kg P/ha, 15kg P/ha and 30kg P/ha with or without rhizobium inoculum. TSP and Yara legume contain 46% and 18% P_2O_5, respectfully. The P rates were calculated from these figures using a conversion factor of 0.4373 (i.e $P_2O_5 \times 0.4373 = P$). Yara legume and TSP were applied two weeks after planting.

Table 1 Climatic data during the study period from experimental areas.

Month	Mean Maximum Temperature ^{0}C	Mean Maximum Relative Humidity %	Total Rainfall (mm)	Rainy days
June	32.2	91	250.9	11
July	30.6	93	145.7	8
August	29.7	94	255.7	14
September	31.0	93	210.1	13
October	32.7	89	102.4	8

2.3 Data Collection

Plant samples were tagged for data on percentage crop establishment (% CE), plant height (PH) and leaf area (LA).

Samples were also taken from the two outermost rows of the five inner ridges from the three replicate in each treatment, uprooted once at full pod stage for determination of fresh and dry shoot weight, number of nodules, fresh and dry nodule weight. Harvesting was done at full maturity for number of pods, weight of pods, 100 seed weight and total grain yield from the two middle rows of each plot.

2.4 Data analysis

Data collected were subjected to analysis of variance using Genstat statistical software (9^{th} edition) and means were separated using the LSD values at 5% level of significance.

3 Results and discussion

3.1 Crop establishment, plant height and leaf area

Increased application of triple superphosphate and Yara legume fertilizer increased plant height and leaf area. Among all tested fertilizer rates and source, highest dose of both sources shows higher growth traits. These were not significantly different from the other treatments. On the application of 30kg P/ha Triple superphosphate (TSP) highest growth traits were recorded which was followed by Yara legume at 30kg P/ha (Figure 1, 2 and 3).

Rhizobium inoculation of soybean significantly increased percentage crop establishment, plant height and leaf area (Table 2). Rhizobium inoculation treatment recorded the maximum plant height of 35.12cm and leaf area of 22.38cm^2 as compared to uninoculated check with plant height of 34.25cm and leaf area of 20.92cm^2.

The increase in plant height and leaf area due to rhizobium inoculation and increased phosphorus application may be ascribed to pronounced vegetative growth. This finding is in agreement with the observation made by Quershi et al. (1986).

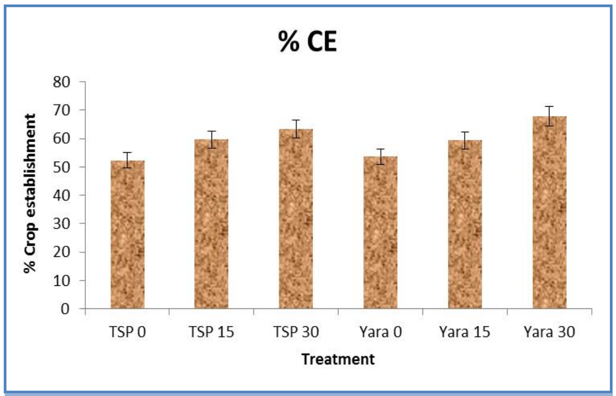

Figure 1 Influence of fertilizer source and rates on crop establishment of soybean.

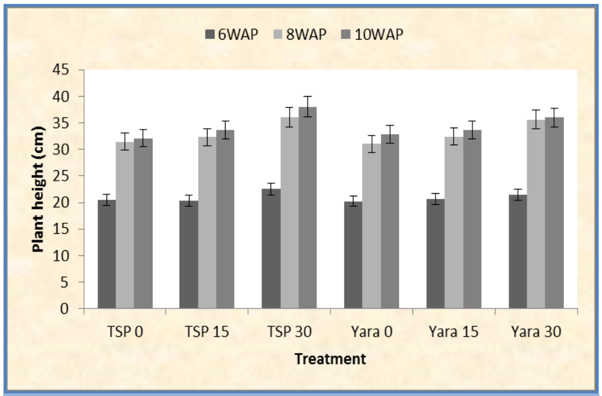

Figure 2 Influence of fertilizer source and rates on plant height of soybean.

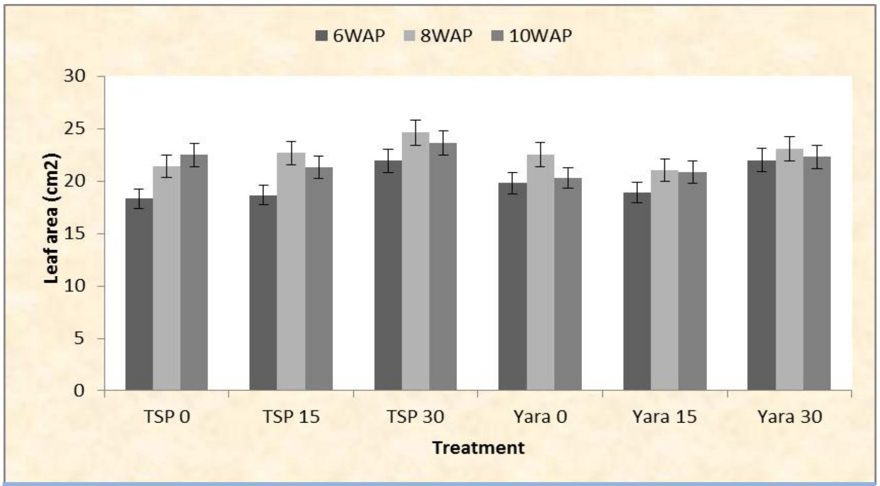

Figure 3 Influence of fertilizer source and rates on leaf area of soybean.

Table 2 Influence of Rhizobium inoculants on growth traits of soybean.

Treatment	% CE	PH 6WAP	PH8WAP	PH10WAP	LA6WAP	LA8WAP	LA10WAP
Uninoculant (check)	49.15	20.49	32.26	34.12	19.95	22.16	20.92
Rhizobium inoculants	58.57	20.58	32.34	34.28	18.73	22.49	21.38
LSD	2.99	1.36	1.87	1.82	2.14	2.41	1.76
CV%	0.7	3.4	6.5	6.7	4.8	12.7	1.2

% CE-crop establishment, PH-plant height (cm) and LA-leaf area (cm^2)

Table 3 Influence of fertilizer source, rates and rhizobium inoculants on yield and yield components of soybean.

Treatment	Days to 50% flowering	Fresh shoot weight (g)	Dry shoot weight (g)	No. of nodules	Nodule fresh weight (g)	Nodule dry weight (g)	% N
Control (TSP)	47	1456	40.45	180	3.33	0.92	0.95
TSP 15	47	1500	41.67	197	3.67	1.11	1.03
TSP30	47	1745	48.47	213	3.93	1.23	1.08
Control (Yara)	48	1302	36.17	197	3.65	0.90	0.97
Yara 15	48	1529	42.47	186	3.15	0.05	1.05
Yara 30	47	1790	49.72	220	4.42	1.45	1.06
LSD	1.4	255.9	7.11	21.7	1.63	0.31	0.29
Uninoculant (check)	47	1201	33.37	152	3.86	0.92	1.02
Rhizobium inoculants	47	1906	52.94	245	3.53	1.31	1.03
LSD	0.8	147.7	4.10	12.5	0.94	0.18	1.17
CV%	2.1	8.9	8.9	1.7	11.3	8.6	3.2

3.2 Shoot and nodule weight

Rhizobium inoculated soybean plots produced significantly higher growth characters especially high number of nodules (245), fresh shoot weight (1906g) and dry shoot weight (52.94g). While in uninoculated check plots, the number of nodules, fresh shoot weight and dry shoot weight recorded 152, 1201g and 33.37g respectively (Table 3).

The improvement of nodulation by rhizobium inoculation resulted in higher nitrogen fixation and consequent increase in vegetative growth and dry matter yield of soybean compared to the uninoculated soybean plots. The results of present study are in conformity with the observation made by Hafeez et al. (1988) who had reported that uninoculated plants produced lower dry matter than inoculated ones. Similar types of findings are also reported by Eusuf Zai et al. (1999).

Among two tested fertilizer source and three application rates, Yara at 30 kg P/ha produced the highest fresh and dry shoot weight of 1790g and 49.72g along with high nodules number of 220 and fresh nodules weight of 4.42g. Dugje et al. (2009) reported that phosphorus is often the most deficient nutrients, and when an optimum level is applied, it improves the weight of shoot and grain yield. Sulaiman & Habibulah, (1990) reported that the application of phosphorus along with rhizobium inoculants influences nodulation and nitrogen fixation in legumes. Hoque & Haq (1994) also obtained the same results when they treated several legumes with rhizobium and phosphorus and they found an increase in the number of nodules and maximum growth features. In this experiment, the nodule dry weight did not increase linearly with nodule number. With respect to total nitrogen accumulation in shoot, the treatment did not follow any particular trend. Analysis of variance did not show any significant differences among treatment however, TSP at 30kg/ha recorded the highest percentage of 1.08.

3.3 Grain yield

The highest pod weight and grain yield (73.22g and 829kg/ha) was obtained from the application of Yara legume at the rate of 30 kg P/ha and lowest pod weight and grain yield (32.49g and 678kg/ha) was obtained from the application of TSP at the rate of 0 kgP/ha (Table 4).

This results is in agreement with Sabir et al. (2001) who reported similar findings and concluded that the number of pods per plant, seeds per pod, 100 grain weight and seed yield were significantly increased by different phosphorus levels. Rhizobium inoculated plots recorded the highest pod weight and grain yield (50.80g and 843kg/ha), which was significantly higher than the uninoculated.

Table 4 Influence fertilizer source, rates and Rhizobium rhizobium inoculants on yield of soybean.

Treatment	No. of pods Per plant	pod weight (g)	100 Seed weight (g)	Yield (kg/ha)
Control (TSP)	38	32.49	11.21	678
TSP 15	40	40.33	11.56	774
TSP 30	39	54.86	11.24	777
Control (Yara)	37	39.14	11.16	728
Yara 15	39	43.09	11.14	803
Yara 30	40	73.22	11.24	829
LSD	6.09	5.36	0.28	73.3
Uninoculant (check)	32	43.57	11.30	687
Rhizobium inoculant	46	50.80	11.22	843
LSD	3.5	3.09	0.16	43.5
CV%	5.1	3.5	1.5	0.5

This may be attributed to the symbiotic relationship of rhizobia (bacteria) with the roots of leguminous crops, which fixes atmospheric nitrogen into the roots of soybean and thus the yield increased. This is in agreement with Shehzadi et al. (2003) who reported that phosphorus and rhizobium inoculation induced a pronounced effect on grain yield. Also, Sabir et al. (2001) reported similar results and inferred that number of pods per plant, seeds per pod, 100 grain weight and seed yield were significantly increased by different phosphorus levels.

Conclusion

The application of rhizobium inoculation and phosphorus fertilizer at a rate of 30 kg P/ha significantly increased grain yield of soybean. A substantial increase in nodulation directly affected growth and yield due to the N_2 fixation potential of soybean. Application of rhizobium inoculation also increased nodulation, growth and yield of soybean. The study has shown that to increase soybean production, application of rhizobium inoculants and phosphorus at higher application rate is recommended. The present study therefore recommends treating soybean seeds with rhizobium inoculants before planting and application of phosphorus fertilizer at the rate of 30 kgP/ha for increased grain yield.

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