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Nodulation, growth and yield response of soybean [(*Glycine max* l. (merril)] to inoculum (*Bradyrhizobium japonicum*) under phosphorus levels and compost amendment in Northern Ghana

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ABSTRACT

The need for the use of fertilizers in soybean cultivation is inevitable in soils inherently low in soil fertility status. This experiment was conducted at Cheshegu in the Northern region of Ghana (2011 planting season) to determine the effectiveness of *Bradyrhizobium japonicum* (INO) on soybean, under four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) and two levels of compost (0 and 3 tons ha^{-1}). The experimental layout was randomized complete block design arranged in split-plot and replicated four times. The main plot is *B. japonium* (+ and -) and the combinations of compost and phosphorus levels were the split plots, parameters measured were; number of nodule $plant^{-1}$, nodule dry weight kg ha^{-1}, biomass yield kg ha^{-1}, pod number $plant^{-1}$, pod weight kg ha^{-1}, grain yield kg ha^{-1} and hundred seed weight. The results obtained indicated significant ($P < 0.05$) nodule dry weight with the use of sole compost (COM) and *B. japonium*+compost. Biomass yield was significantly enhanced with the use of sole compost and compost+P_2O_5–levels with and without inoculum, with the absolute control having the lowest value in all. Also, the application of 30 kg P_2O_5 ha^{-1} + *B. japonium* and 30 kg P_2O_5 ha^{-1}+COM led to the highest pod number. Treated plots with and without *B. japonium* recorded significant ($P < 0.05$) pod weight and grain yield which were not less than 55 and 26% increase over the control plots, respectively. This study concludes that the use of compost combined with inorganic fertilizer (30 kg P_2O_5 ha^{-1}) and/or *B. japonicum* inoculum enhances soybean nodulation, growth and yield in the study area.

Keywords: *Bradyrhizobium japonicum* inoculum, compost (Fertisol), phosphorus levels, soybean.

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INTRODUCTION

Soybean (*Glycine max* (L) Merril) is an important economic crop among grain legumes, mostly grown in a wide range of environments all over the world. Beside its nutritional value; it has the potential to restore soil fertility through N_2 fixation process (Giller, 2001). Nitrogen fixation is a process which demands an enabling environment for an efficient symbiotic relationship between the host plant and the rhizobia in the plant rhizosphere, to maximize soybean potential effectively. Soybean according to Giller (2001) is relatively a host specific plant and does not nodulate when grown for the first time in many parts of Africa. It was reported that the native *Bradyrhizobium* populations often do not meet N demand of the tested TGx genotypes in many parts of

Nigeria (Okereke and Eaglesham 1993, Sanginga et al., 1996), Eastern and Southern Africa Mpepereki et al. (2000), a condition which might not be too different from what exists in Ghana. However, a lot of success stories have been reported about the use of inoculants in Brazil, USA, (Ferreira and Hungria. 2002), Argentina, (Melchiorre et al., 2011) and Zimbabwe (Mpepereki et al., 2000). Yet, the benefits of *Bradyrhizobium japonicum* inoculum to boost soybean potentials have not been adequately exploited in the context of Ghana's agriculture. This may in part be explained by the limited nutrients and organic matter content in the soil at the time of sowing. The climatic or edaphic factors that are un-favourable for plant establishment and growth, especially at seedling stage will restrict nodulation and indirectly affect the plant's potential for yield increase as suggested by Woomer et al. (1997) and Gentili et al. (2006). The edaphic instability of soils in Ghana due to inherently low fertility status, degradation and nutrient depletion resulting from continuous use of farmland with little or no soil amendments, could limit the response of soybean to inoculants. Hence, production of soybean in Ghana is far below its potential yield. Phosphorus, in particular, is highly required for soybean production because the process of symbiosis (N_2 fixation) is a high energy demanding process; it also enhances energy metabolism, synthesis of nucleic acids and membranes, photosynthesis, respiration and enzyme regulation (Raghothama, 1999). Certainly, the use of chemical fertilizers alone may not keep pace with time in sustaining soil health and consequently improving and increasing soybean production in Ghana. The low adoption of mineral fertilizer was attributed to the wide gap between farmers' yields and crops' potential yields Bationo et al. (2006). It therefore becomes imperative to source cheaper resources to meet the demand of soybean nutrient requirements so as to close the gap between the farmers' yields and the crops' potential yields especially with the introduction of *B. japonicum* inoculum.

In order to improve soil structure and enhance its capacity to store adequate moisture and nutrients, Tabo et al. (2007) suggested the addition and incorporation of organic fertilizer to soil as an option of immense potential. The use of compost from organic wastes has been declared as one of the most promising methods of improving soil fertility in intensified cropping systems (Summer, 2000; Adediran et al., 2003). Aside the fact that the unpleasant conditions of waste materials would have been well managed if materials are allowed to cure before usage, It also supplies nutrients to the soil and has lasting effects than inorganic fertilizers because they are slow releasers (Deksissa et al., 2008; Adeyemo and Agele, 2010). However, International fertilizer development centre (2012) reported that in Sub-Sahara Africa, high prices of commercial fertilizers and limited availability of quality organic inputs (manure, crop residues, etc) have resulted in the overall low use of organic inputs. Therefore, due to the limitations of inorganic and organic resources, it will be worthwhile to establish if a synergy will result from the integration of minimal quantity of inorganic fertilizer, compost and bio-fertilizer to help farmers save cost and at the same time optimize soybean potential for increased soybean nodulation, growth and yield. Hence, the objective of this study is to determine the effectiveness of *B. japonicum* inoculum on nodulation, growth and yield of soybean in a soil amended with compost (Fertisoil) and the optimum rate of phosphorus applied.

MATERIALS AND METHODS

Experimental site

A field trial was carried out at Cheshegu in the Northern region of Ghana during 2012 planting season. Cheshegu is located on latitude 09° 27′ 17.3" N, and longitude 00° 57′ 23.0" W at an elevation of 187 m above sea level. The average annual rainfall is 1200 mm with mean monthly minimum and maximum temperature of 26 and 39°C, respectively. Most inhabitants of the study area are peasant farmers who carry out farming activities year in year out as their major source of livelihood.

Field description, soil sampling and chemical analyses

A field of unknown history of soybean cultivation and *Bradyrhizobium* inoculation was chosen. Soil samples (Changnalili soil series classified as Gleyic luvisol [FAO/UNESCO, 1988]) were randomly collected from the experimental field at a depth of 0 to 20 cm with the use of a soil auger. The soil was bulked together, air dried, sieved with 2 mm diameter mesh and analysed for its physical and chemical properties as follows; Soil pH was measured in the supernatant suspension of 1:2.5 soil:water mixture by pH meter. Soil organic carbon was determined by Walkley and Black method (Walkley and Black, 1934). Total nitrogen was determined by Kjeldahl procedure. Available phosphorus determined by Bray 1 procedure (Bray and Kurtz, 1945; Olsen and Sommers, 1982) and soil texture was determined following Bouyoucous hydrometer method. The estimation of rhizobia populations in the study area was carried out using the most probable number method (MPN) according to Vincent (1970).

Seed source and inoculation application

An improved soybean with very high shattering resistance variety of 115 days maturity period called "Jenguma" was used as a test crop. The seed was obtained from CSIR-Savanna Agricultural Research Institute, Nyankpala. The seeds were inoculated with commercial *B. japonicum* inoculant (*Legumefix)* at the rate of 5 g of inoculants to 1 kg seed (Lamptey, 2014) before sowing. The soybean seeds were put in a plastic bucket and moistened with ordinary tap water, stirred uniformly with a wooden spatula. The inoculants were added to the moistened seeds, stirred gently and uniformly, until the seeds were evenly coated. The seeds were then spread on a sheet of canvas material under a shade for at least one hour to allow the inoculants adequately adhere to the surface of the seeds. The sowing was done early in the morning to avoid exposing the inoculants to direct sunrays, which might affect the quality of the inoculants. Sowing was done on ridges at a distance of 75 cm between ridges and 50 cm within ridges. To avoid contamination of the un-inoculated treatments with the inoculants that might get stuck to the hand during sowing, the un-inoculated seeds were sown before the inoculated ones. The plants were allowed to grow to maturity under rain-fed conditions while the recommended management practices like supplying, thinning, weeding etc were observed.

Treatment, layout and experimental design

The following treatments were used; compost (0 and 3 tons ha^{-1}), inorganic fertilizer; triple super phosphate at the rate of 0, 30, 60 and 90 kg P_2O_5 ha^{-1}, and *B. japonicum* (un-inoculated and inoculated). Ammonium sulphate at the rate of 25 kg ha^{-1} and, muriate of potash at the rate of 30 kg K_2O ha^{-1} were used as basal application. The land was ploughed, harrowed and ridged; in order to allow easy uprooting of the nodules, plots were 7 m long and 7 m wide. The soil was amended with compost (Fertisoil) two weeks before planting while the inorganic fertilizer was applied two weeks after planting and the inoculant was applied at planting. Planting was done by dibbling (2 seeds per hill) and later thinned to one per hill. The design was Randomized Complete Block Design arranged in split-plot, with *B. japonicum* inoculum (- and +) as the main plot and compost with P_2O_5-levels as sub-plots, replicated four times.

Data collection

Nodule count, nodule dry weight and shoot biomass yield

In the assessment of nodulation and shoot biomass, ten plants were randomly selected and sampled at 50% flowering by carefully pulling them out of the ground after loosening the soil around the plants gently. The detached nodules from the roots in the process of uprooting are ensured collected. The shoots from each plot were then separated from the root system, bulked and weighed on a digital scale, after which they were air-dried for one day, followed by oven-drying at 80°C for 48 h (to a constant weight) and the weights recorded. The nodules were detached from the roots and carefully washed using sieve, counted, weighed and then oven-dried at 70°C for 48 h and dry weights also recorded.

Number of pods, pod weight and grain yield

At maturity, all the pods from the plants of the two innermost ridges of each plot were harvested manually and counted after which they were sun-dried in the glass house for 24 h followed by oven-drying at 80°C for 48 h and weighed on a digital scale. The dried pods were threshed and winnowed to separate the grains from the husk and the former weighed to obtain the grain yield. Then hundred seeds were selected according to the treatments applied, weighed and recorded.

Data analysis

Data were statistically analyzed using GENSTAT (2008 Edition). The analysis of variance (ANOVA) was carried out to find out the significance of variation among the treatments, while the significant means were separated using the Least Significance Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984). Number of nodule counted was transformed.

Estimation of indigenous rhizobia population

The most-probable-number (MPN) method (Woomer et al., 1990) was used to determine the population of native rhizobia by the most probable number enumeration system (MPNES).

RESULTS AND DISCUSSION

Compost analysis

The compost (Fertisoil) was analysed before it was incorporated into the soil, the three major elements (N, P, K) were reported. The compost contains 2.5% nitrogen with phosphorus of 1.2% and potassium of 1.9%. This is an indication that it can be used as organic fertility amendment material for a depleted soil like in the case of the study area according to the soil analysis carried out.

Physical, chemical and MPN analysis of pre cropping soil

The soil of the experimental site was slightly acidic (pH 5.5). Measured chemical parameters were less than the required rate for most crop cultivation according to Landon (1991) and Buri et al. (2009). The organic carbon (< 20 g kg^{-1}), total nitrogen (< 1 g kg^{-1}) and extractable P (< 10 mg kg^{-1}) were low. The physical analyses showed that the soil was sandy loam in texture and the soil most probable number count for the native rhizobia at planting was 5.5×10^1 cells per gram of soil, a little above the value termed low rhizobia population (< 50 cells g^{-1} soil) according to Lamptey et al. (2014)

Hence, production is faced with a number of constraints including low soil fertility according to Lawson et al. (2008), irregular rainfall patterns, drought, inadequate access to certified seed and poor agronomic practices which result in poor yields especially in the Northern savannah zones of Ghana. Hence, the need for soil fertility amendments to boost the production of agriculture produce.

Nodule formation

Soybean did not positively respond to the applied treatments with regards to nodule formation (Table 1). The effect of compost might not immediately reflect on soybean nodulation because the release of nutrients in organic manure is a slow process, coupled with the slightly acidic nature of the soil at the study area. Likewise, the application of inorganic fertilizer (P_2O_5 levels) and *B. japonicum* were not positively responded to possibly due to the soil inherently low nutrient characteristics. This finding is similar to that of Otieno et al. (2009) who observed that inorganic fertilizer and organic fertilizer application had no significant effect on number of nodules per plant in all the legumes tested. Similarly, earlier study has suggested that inoculation does not always enhance nodulation (Chemining'wa et al., 2004). Hence, the noticeable number of nodules in the control reflects the nodule formation ability of the indigenous rhizobia present in the soil. This indicates that the soil contained indigenous rhizobia that nodulated the

Table 1. Effect of phosphorus, inoculum and compost on soybean number of nodule.

Treatment P_2O_5 (kg ha^{-1})	Compost (t ha^{-1})	Number of nodule plant^{-1}				
		0P	30P	60P	90P	Mean
Uninoculated	0	1.23	0.98	1.25	0.75	1.05
	30	1.43	0.58	1.00	1.48	1.12
	Mean	1.33	0.78	1.13	1.11	
Inoculated	0	1.38	1.35	0.33	0.68	0.93
	30	0.43	0.80	1.13	1.03	0.84
	Mean	0.9	1.08	0.73	0.85	
CV%		24.6				
LSD(0.05)		0.85				

grain legume species. Such nodules according to Chemining'wa et al. (2004) are of smaller sizes, formed on lateral roots and most of them are ineffective (white/brown in colour) as was also observed in this study. It was also reported that soils colonized by indigenous rhizobia nodulated the grain legumes species used resulting in more nodule number in control plot than the treated plots Chemining'wa et al. (2004), similar to the observation in this study.

Nodule dry weight

The cultivation of *B. japonicum* inoculated seeds in soil treated with compost (COM+INO) resulted in the highest nodule weight (118 kg ha^{-1}) leading to 87 and 314% increase in nodule weight over *B. japonicum* inoculated soybean and control, respectively. Likewise, the application of phosphorus, irrespective of the level (30, 60 and 90 kg P_2O_5 ha^{-1}) to inoculated seeds led to high nodule weight than the sole use of phosphorus (Table 2). This implies that the combination of either compost or the phosphorus positively influenced the nodule weight of the inoculated soybean. This can be attributed to the fact that there is a synergy result, thereby secreting different organic acids (Arora and Gaur, 1979) like carboxylic acid and thus lowering the rhizosphere pH (He and Zhu, 1988). Such organic acids have the possibility of enhancing the dissociation of the bound forms of phosphate like Ca_3 $(P0_4)_2$ thereby making more phosphorus available for nodulation. This conforms with Kumaga and Ofori's (2004) report, which states that among various factors that can contribute to soybean success, phosphorus and inoculation had quite prominent effects on nodulation, growth and yield parameters. Likewise, the combination of COM+INO+P-levels (30, 60, 90 kg P_2O_5 ha^{-1}) resulted in significant increase in nodule weight as compare to when the seeds were not inoculated (COM+P-levels), similar to Tahir et al. (2009) finding. However, no significant differences were recorded with respect to increase in phosphorus levels, hence, the lowest phosphorus level used (30 kg P_2O_5 ha^{-1}) produced nodule dry weight which was not significantly different from that produced by the plots with higher phosphorus levels while combined with COM+INO (Table 2). Similarly, Manochehr et al. (2013) reported that when seeds were inoculated with *B. Japonicum*, dry weight of nodule at 33, 66 and 100% of chemical fertilizers were statistically similar and further increase in chemical fertilizer reduced nodule dry weight. Likewise, Ahiabor et al. (2014) reported that the highest percent increase in nodule biomass (105%) due to inoculation occurred with P rate of 30 kg P_2O_5 ha^{-1}. This implies that the application of *B. japonicum* is essential for enhancing nodule weight accumulation with the use of compost or with as low as 30 kg P_2O_5 ha^{-1}, Sobral et al. (2004) explained that the use of *Bradyrhizobium* isolates were able to produce IAA, solubilise phosphate and fix nitrogen which could be used for soybean growth promotion.

Shoot biomass

The treated plots resulted in some level of increase in soybean biomass accumulation than the control. For improved shoot biomass, phosphorus is essential. The application of 30 kg P_2O_5 ha^{-1} resulted in 5064 kg ha^{-1} biomass, which gave 100% increase over control (Table 3). This is an indication that omission of phosphorus from soybean nutrition can drastically reduce shoot dry matter yield of soybean as suggested by Bekere et al (2012). This report is similar to the observation made in the Northern Guinea Savanna of Nigeria by Weber (1996) where legumes required about 30 kg P ha^{-1} for optimal growth and N_2 fixation. The compost amendment of soil in combination with phosphorus (COM+P-levels) resulted in high biomass ranging from 5520 to 7160 kg ha^{-1} and was significantly higher than the biomass gotten from the control (2531 kg ha^{-1}). Possibly due to microbial population (Mabood et al., 2005) and organic colloids

Table 2. Effect of phosphorus, inoculum and compost on soybean nodule dry weight.

Treatment P_2O_5 (kg ha^{-1})	Compost (t ha^{-1})	Nodule dry weight (kg ha^{-1})				
		0P	30P	60P	90P	Mean
Uninoculated	0	28.5	7.8	7.2	9.8	13.3
	30	20.5	9.0	15.0	16.8	15.3
	Mean	24.5	8.4	11.1	13.3	
Inoculated	0	63.0	62.0	44.5	59.5	57.3
	30	118.0	88.5	72.0	73.2	88.0
	Mean	90.5	75.3	58.3	66.4	
CV%		23.1				
LSD(0.05)		39.5				

Table 3. Effect of phosphorus, inoculum and compost on soybean shoot biomass.

Treatment P_2O_5 (kg ha^{-1})	Compost (t ha^{-1})	Shoot biomass (kg ha^{-1})				
		0P	30P	60P	90P	Mean
Uninoculated	0	2531	5064	4959	4165	4180
	30	6381	5520	7160	5640	6175
	Mean	4456	5292	6060	4903	
Inoculated	0	4117	4486	4545	4262	4353
	30	6120	6693	6138	7956	6727
	Mean	5119	5590	5341	6109	
CV%		24.4				
LSD (0.05)		1754				

during decomposition (Botha et al. 2004) and moisture/water relations. Similarly, Whalen and Chang (2001) observed that the effectiveness of inorganic phosphorus fertilizer was increased by the addition of organic fertilizer. The sole application of inoculum also resulted to 62% increase in biomass over the control, while the combination of INO+COM+P-LEVELS also lead to substantial level of increase in biomass yield, in fact the highest rate of P used (INO+COM+90 kg P_2O_5 ha^{-1}) recorded the highest biomass in all (7956 kg ha^{-1}), however, it was at par with the performance observed when the lowest P rate was used (INO+COM+30 kg P_2O_5 ha^{-1}). This is a proof that some levels of positive reactions are ignited when the treatments are combined resulting in a complementary effect of the various fertilizers applied leading to soybean growth and development enhancement.

Pod number

Response of soybean number of pod to the applied treatments indicated some level of increase over the untreated plot (Table 4), therefore, the control recorded the least number of pod in all (53 $plant^{-1}$). This suggested a reduction in crop productivity under a condition of limited nutrients. This is in line with the observation of Smith et al. (1992), Makinde et al. (2001) and Daramola et al. (2006). They reported that availability of adequate nutrients could improve crop growth and yield parameters. Among the different levels of phosphorus used, 90 kg ha^{-1} gave 89 pods per plant which was similar to Ramasamy et al. (2000) findings, where 80 kg P ha^{-1} produced significant higher number of pods of soybean. Likewise, Mohan and Rao (1997) and Rani (1999) reported that higher number of pods per plant was produced when higher doses of phosphorus were applied. This implies that different levels of phosphorus applied to inoculated seeds and its combination with compost must have stimulated pod filling and thereby will improve pod weight. However, the combination of INO+30 kg P_2O_5 ha^{-1} to soybean and its application to soybean cultivated on soil amended with compost (INO+30 P_2O_5 kg ha^{-1}+COM) resulted in the highest number of pod (100 and 90 $plant^{-1}$) respectively in this study. The former treatment was also confirmed by Tahir et al. (2009) were 67% increase was recorded when INO+P was used. All treated plots gave numbers of pod which were significantly higher than the control plot. Though, number of pod produced when higher levels of P

Table 4. Effect of phosphorus, inoculum and compost on soybean number of pod.

Treatment P_2O_5 (kg ha^{-1})	Compost (t ha^{-1})	Pod number $plant^{-1}$				
		0P	30P	60P	90P	Mean
	0	52.8	73.2	67.0	88.5	70.4
Uninoculated	30	76.5	69.0	76.5	66.5	72.1
	Mean	64.7	71.1	71.8	77.5	
	0	69.0	99.5	78.0	68.5	78.8
Inoculated	30	74.5	90.2	74.5	55.8	73.8
	Mean	71.8	94.9	76.3	62.2	
CV%		32.4				
LSD(0.05)		30.2				

(60 and 90 kg P_2O_5 ha^{-1}) were combined with INO+COM was at par with the treatments (INO+30 kg P_2O_5 ha^{-1} and INO+30 P_2O_5 kg ha^{-1}+COM) that produce the highest pod. This is also similar to the report of Tahir et al. (2009) where 94% pod per plant was reported with the application of INO+P+N. This implies that the lowest level of P used (30 kg P_2O_5 ha^{-1}) when combined with INO and COM was sufficient to induce increase in soybean pod production in the study area, thereby reducing cost of production. Sharma et al. (1999) also reported that pods $plant^{-1}$ of soybean were greatest with 75 kg P ha^{-1} and *Rhizobium*+FYM+PSB. Furthermore, the findings in this study with regards to the use of inoculum is consistent with that of Singh et al. (2005) who reported that there was no significant difference between pod yield of non-inoculated and inoculated soybean seeds with the use of *B. japonicum* only. Possibly due to biological antagonism from other microorganisms indigenous to the soil used, this can further be investigated.

Pod dry weight

Pod dry weight was also positively influenced by the application of the different treatments compared to the control (Table 5). The control plot gave the lowest pod weight in all (4141 kg ha^{-1}). This implies that the soil status as at the point of planting is not suitable for soybean growth and yield improvement without amendment. Hence, the amendment of soil with COM yielded 57% increase in pod weight than the control. The application of P-levels (30, 60 and 90 kg P_2O_5 ha^{-1}) on COM amended soil also resulted in 58, 57 and 66% increase in pod weight over the control, respectively; however, increase in P rates was not necessary because they were all at par. The use of inoculated seeds in a COM amended soil yielded 71% increase in pod dry weight, which was highly significant ($P<0.05$) compared to control (Table 5). More so, the combination of INO+COM+P-levels gave higher pod weight than COM+P, INO+P and their sole use and were significantly higher than the control, again the increase in P rate was not of significant influence since the P-levels resulted in pod weights which were at par with one another while combined with *B. japonicum* inoculant in an amended (COM) soil. Therefore INO+COM or INO+COM+30 kg P_2O_5 ha^{-1} is sufficient for soybean pod weight increase in the study area (Table 5). This is an indication that a synergy is been stimulated by the combination of the different materials used which results in the enhancement of soybean response to the fertilizers used. Compost improves soil structure and in turn soil porosity. These allow better root growth and hence high nutrient uptake and better performance. Lourduraj (2000) also reported that the combined application of organic and inorganic fertilizers significantly enhanced the growth attributes and yield of soybean as compared to the sole application.

Grain yield

The final seed yield of a crop is a function of cumulative contribution of its various growth and yield parameters, which are influenced by various agronomic practices and environmental conditions Shahid et al. (2009). The use of sole phosphorus produced grain yield which were insignificantly higher than the untreated plot. But when the soil was treated with compost before applying phosphorus it resulted in significant ($P < 0.05$) grain yield over control leading to 29, 39 and 40% increase (30, 60 and 90 kg P_20_5 ha^{-1}) respectively, however, the phosphorus levels gave grain yield which were at par with one another statistically while combined with COM. Furthermore, the use of INO+COM and INO+COM+P (30 kg P_20_5 ha^{-1}) also resulted in 32% increase in grain yield over the Control (Table 6). This suggested that the nutrient use efficiency as a result of applied fertilizer by soybean plants improved the synthesis and translocation of photosynthesis from the sources to the sink and significantly increased number and weight of pods and

Table 5. Effect of phosphorus, inoculum and compost on soybean pod weight.

Treatment P_2O_5 (kg ha^{-1})	Compost (t ha^{-1})	Pod weight (kg ha^{-1})				
		0P	30P	60P	90P	Mean
	0	4141	5827	5232	6061	5315
Uninoculated	30	6480	6532	6508	6861	6595
	Mean	5311	6180	5870	6461	
	0	4554	5716	5410	5113	5198
Inoculated	30	7071	6954	8123	8350	7625
	Mean	5813	6335	6767	6732	
CV%		29.3				
LSD (0.05)		2603				

Table 6. Effect of phosphorus, inoculum and compost on soybean grain yield.

Treatment P_2O_5 (kg ha^{-1})	Compost (t ha^{-1})	Grain yield (kg ha^{-1})				
		0P	30P	60P	90P	Mean
	0	270	330	315	335	3125
Uninoculated	30	3066	3492	3750	3783	2577
	Mean	2883	3396	3250	3567	
	0	2892	3433	3142	3485	3238
Inoculated	30	3550	3556	3416	3392	3479
	Mean	3221	3495	3279	3439	
CV%		14.5				
LSD(0.05)		656				

seeds (Babatola and Olaniyi, 1997). Tran et al. (2001) stated that the lower dose of inorganic fertilizer in conjunction with composted paddy straw or inoculants could achieve same grain yield of soybean under rice-based cropping system. This is Similar to the findings in this study and also in line with some other researchers' reports (Son and Ramaswami, 1997).

Gentili and Huss-Danell (2003) and Fatima et al. (2007) also concluded that combined application of P with Rhizobium inoculation increased growth, yield and nitrogenease activity as well as improved soil fertility for sustainable agriculture. Ganeshamurthy and Sammi Reddy (2000) reported that dry matter production and seed yield of soybean were increased significantly by the application of farm yard manure. The contribution of COM can be attributed to the fact that manure contains high amount of organic matter which increases the moisture retention of soil and improves dissolution of nutrients particularly phosphorus according to Nyende, (2001) and Olupot et al. (2004). More so, matured compost is reduced in bulk (Adediran et al., 2003) and highly regarded for its ability to improve soil fertility and plant growth. Aside their ability to release nutrients, they improve the physical properties of soil such as soil bulk density, water holding capacity, infiltration and aeration (Deksissa et al., 2008; Adeyemo and Agele, 2010). These factors tend towards enhancing and improving the soil rhizosphere making it conducive for healthy plant growth. These can be attributed to the ability of the inputs to supplement each other limitations, thereby resulting in positive influence on soybean nutrient uptake and use hence translating to increase in grain yield.

Hundred seed weight (HSW)

Number of seeds per pod is perceived a significant constituent that directly imparts in exploiting potential yield recovery in leguminous crops. Hundred seed weight (HSW) as a yield contributing component reflects the magnitude of seed development, which ultimately reflects the final yield of a crop. Seed inoculation with *B. japonicum* only has no significant effects on HSW of soybean, hence recorded the lowest hundred seed weight (13.73 HSW), while the control is next to it with 14.10 HSW; meaning that the *B. japonicum* alone is not sufficient to sustain soybean growth and development till maturity. However, the use of compost resulted in the highest HSW (16.08), which was comparable to the application of the various P levels (30, 60, 90 kg P_2O_5 ha^{-1}) in addition with compost and were all significantly higher compared to the HSW recorded from the control (14.10) plot (Table 7). Confirming the fact that phosphorus is involved in several energy transformation processes and biochemical reactions including nitrogen fixation, root development, stalk and stem strength which invariably will enhance the growth and yield parameters of especially legume. Tran et al. (2001) reported that the highest 100-grain weight value was obtained under (compost+60-60-30) and the lowest under (Inoculants+00-00-00). However, there were no significant different in 100-grain weight among treatments, except (Inoculants+00-00-00). Likewise the combination of INO+COM+Phosphorus levels recorded higher HSW significantly than the control, with the various phosphorus levels in the treatment combinations performing at par. Therefore, the combination of INO+COM+P (with at least 30 kg P_2O_5 ha^{-1}) is sufficient to enhance soybean hundred seed weight.

Table 7. Effect of phosphorus, inoculum and compost on soybean hundred seed weight (HSW).

Treatment P_2O_5 (kg ha^{-1})	**Compost (t ha^{-})**	**HSW**				
		0P	**30P**	**60P**	**90P**	**Mean**
Uninoculated	0	14.10	15.28	14.28	15.68	14.8
	30	16.08	15.50	15.60	15.68	15.7
	Mean	15.1	15.4	15.0	15.7	
Inoculated	0	13.73	14.88	14.50	14.78	14.5
	30	14.93	15.35	15.93	15.75	15.5
	Mean	14.3	15.2	15.2	15.3	
CV%		5.2				
LSD (0.05)		1.13				

CONCLUSION

This study evaluated the performance of *B. japonicum* inoculum under compost and phosphorus soil amendment, using soybean as a test crop. The result revealed that *B. japonicum* inoculated soybean positively responded to the combination of compost and phosphorus. Reduced level of phosphorus (30 kg P_2O_5 ha^{-1}) and compost collectively stimulated positive mechanisms which enhance nodulation, biomass/grain growth and development of soybean inoculated with *B. japonicum*. It therefore showed that the combination of INO+30 kg P_2O_5 ha^{-1}+COM is sufficient for soybean cultivation in the study area. Hence, the use of compost (fertisoil) and as little as 30 kg P_2O_5 ha^{-1} could further be promoted among soybean producing farmers in the study area, because it will reduce production cost and increase yield.

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