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Effects of Triple Super Phosphate and inoculant on yield of soybean seed in Northern Region of Ghana

Paul Yao ANANI[1*], George NYARKO[2] and Hypolite BAYOR[2]

[1]*Agribusiness Expert. P. O. Box TL 1853. Tamale, Ghana*

[2]*Faculty of Agriculture, University for Development Studies, P.O Box TL1882. Nyankpala Campus, Ghana*

[*]*Correspondence: ananipaul@gmail.com*

ABSTRACT

The research was conducted to establish the effects of triple super phosphate and rhizobia inoculant on yield of soybean (Glycine Max (L)) seed quality in the Northern region of Ghana. Multi-locational trials were adopted and three different locations were used. Soybean foundation seeds obtained from Savannah Agriculture Research Institute were subjected to three different treatments on the field. These treatments were TSP + Inoculant, TSP only, Inoculant only and a control plot as a check. Randomize complete block design was used to allocate the treatments to the various plots. Data collected from the field included: number of days from seeding to germination, flowering and pod formation; nodule formation; plant height, number of pods per plant per treatment (Pod load), number of days to maturity, seed weight at harvest per plant per treatment (1000 seed weight) and finally, the yield was determined after harvest. Results revealed that the treatments (TSP + Inoculant, TSP only and Inoculant only) generally enhanced growth, development and yield of soybean seed as compared to the control plots in almost all the locations. The application of Rhizobia inoculant contributed significantly to the development of the soybean plant. It aided the fixation of atmospheric nitrogen into the soil which improved its fertility that led to the significant increase in the number of nodules that were formed by the plant. The pod load was very high for all the treated plots. They were fully filled with seeds which were evidence in the yield obtained from the trials. TSP in combination with inoculants gave a very good yield of 2.66 Mt/ha and was significantly higher than all the other treatments. This result is a clear indication of how phosphorus fertilizer and inoculant positively affected the yield. Seed producers should be encouraged, in addition to good agronomic practices, to apply the recommended dosage of inoculant and TSP to their seeds and soybean fields respectively. This would lead to early maturity and high yields.

Keywords: *Soybean seed, Northern region of Ghana, Phosphorus, Inoculant, Yield*

INTRODUCTION

Soybean (*Glycine max* (L.)), globally, is regarded as a very significant leguminous crop that grows very well in the tropical, subtropical and temperate climates. Soybean finds itself in a large botanical family, Leguminosae, in the sub-family Papilionideae. According to Shurtleff and

Aoyagi (2007), soybean has 40 chromosomes and is a self-fertilized species with less than 1% out-crossing. There are numerous benefits, nutritionally for man and livestock, as well as other commercial and industrial uses. Soybean contains significant amounts of all the essential amino acids, minerals and vitamins for human nutrition. According to Adu-Dapaah et al. (2004), it also functions as a major source of 40% average human dietary protein, 30% carbohydrate and 20% oil content. In Ghana, the source of protein feed for the livestock industry (MoFA and CSIR, 2005) is the soy cake. Like all other legumes, soybean absorbs atmospheric nitrogen into the soil for its consumption, thus significantly improving soil fertility. This is a major benefit in this region of our planet-Africa, where nutrient-poor soils and fertilizers are not readily available or costly for farmers (MoFA and CSIR, 2005; IITA, 2009). Despite the many benefits of soybean, the grain yield per unit area in Ghana is low, with an average of 1.65 tons per hectare (SRID, 2015), while that of Africa is 1.1 tons per hectare on average (IITA, 2009). According to FAO (2007), the average production of soybean per hectare in Argentina, the United States and Brazil is 2.20, 2.80, and 2.30 tons respectively.

Total domestic soybean demand for oil, seasoning and animal feed cake is estimated at 178,401 metric tons per year but Ghana's soybean production is 142,360 metric tons of soybean grain per year (SRID, 2015). The low soybean yields in Ghana are attributed to several reasons. These include poor germination due to rapid loss of seed viability, drought pressure, the low population of plants per hectare for different crop cultivars, shattering and poor nodulation among others (Addo-Quaye et al., 1993).

Soybean is a legume that obtains its nitrogen needs through the symbiotic relationship between soybeans and the Bradyrhizobium species, bacteria within the nodules of soybean roots. The soybeans get needed nitrogen and the bacteria get some carbohydrates in return (Sarkodie-Addo et al., 2006).

The bacterium that fixes nitrogen with soybean is Bradyrhizobium japonicum. The bacterium establishes a symbiotic or beneficial relationship with roots that allows biological fixation of nitrogen to take place. Growing soybean successfully depends heavily on the existence of symbionts such as soil rhizobia. Malik et al., (2006) reported that soybean seed inoculated with Rhizobium and further combined with phosphorus application at 90 kg per hectare gives a better yield under irrigated conditions. Phosphorus application is not likely to increase seed yield at soil phosphate concentrations above 12 ppm P (Bray-1 test) but unfortunately, most soils in northern Ghana have less than 10 ppm of phosphorus concentration (Adu, 1995; Benneh et al., 1990). Therefore, there is a need to incorporate phosphorous into the soil to boost soybean production. Hence, the study sought to determine the effects of Triple Super Phosphate (TSP) and Rhizobia inoculant on growth, development and yield of soybean seed.

MATERIALS AND METHODS

Experimental Site

The field experiment was conducted in a metropolis and two districts in northern Ghana; namely, Tamale metropolis (in the Gbanshei community), Saboba (in the Nayeeni community) and Gusheigu (in the Zantili community). These districts were purposively selected because they were known to be the main soybean growing areas in the northern region. Human activities such as bush burning, tree felling for fuel, sand and gravel winning and, of recent, small scale

mining, contribute immensely to the destruction of the vegetation and consequently the environment.
Further, the poor farming practices such as slash and burn, shifting cultivation, and also farming along the banks of streams and other water bodies are being practiced by farmers in the Region. The impact of these human activities on the natural environment has been the loss of vegetation cover, soil erosion, reduction in soil fertility and desertification (Population and housing census, 2010).

Experimental Material

The planting material (soybean) used was obtained from the Savannah Agricultural Research Institute (SARI), Ghana. The variety was 'Jenguma'. It is a cream grain and fairly spherical. It has 40 % protein and 20 % oil content and very suitable for industrial use. Thousand-grain weight is between 130 – 140 g and it takes about 100 – 117 days to mature after emergence and 45 – 48 days to flower after emergence. 'Jenguma' responds to the agroecology of Ghana and was developed to withstand the specific stresses of the climate conditions of the region. It is high yielding, field tolerant to shattering of pods and Striga resistant that hinders crop performance and yield. It is also tolerant of a bacterial pustule, (Northern Ghana soybean technical brief, 2017).

Rhizobia inoculant was also sourced from SARI in Nyankpala. Legumes growing together with soil bacteria called rhizobia work together to take atmospheric nitrogen (N_2) found in soil air spaces and transform it into a plant-available form through the process called Biological Nitrogen Fixation**.** Even though the atmosphere is almost 80% N, the N_2 gas is such that plants can't use it for their own growth and development unless it is fixed. However, neither legumes nor the rhizobia can do the job alone. The process must occur as part of a mutually beneficial relationship with soil-dwelling rhizobia bacteria. Rhizobia form root nodules on the host legume, thereby providing the plant with transformed N in exchange for a portion of the carbohydrates made by the plant (Grossman et al., 2011)

Triple Superphosphate was bought from Ganorma Agro Limited in Tamale. TSP is produced by reacting finely ground phosphate rock with concentrated phosphoric acid. TSP in its granular form has excellent storage and handling properties. It is highly suitable for crop grown in acidic soil conditions and deficient in phosphorous and sulphur (FOA, 1984).

Design, Field Layout and Planting

Multi-locational experiments with three replications at each location were conducted using randomized complete block design (RCBD). The field was demarcated and each plot size was 10 m x 5.5 m. The plots were labelled, TSP, INO, TSP+INO and C as shown below:

The treatments were:

TSP: Triple Super Phosphate only (TSP) (125 kg/ha)

INO: Inoculant only (175 g/ha)

TSP+INO: Triple Super Phosphate (125 kg/ha) plus Inoculant (175 g/ha)

C: Control (without TSP nor inoculants)

Planting and Fertilizer Application

The seeds for plots INO and TSP+INO were inoculated at the rate of 175 g / ha. The inoculated soybean was left to dry in shade so that the rhizobium can stick to the soybeans. After 30 minutes of shade drying, the seeds were planted. All seeds were planted on the same day. Dibbling was done and two seeds were planted in each hole with inter and intra spacing of 65 cm and 10 cm respectively. After two weeks of seeds emergence, TSP fertilizer was applied to the soybeans on plots TSP and TSP+INO. A hole was dug about 5 cm away from the plant and at a depth of 10 cm and the fertilizer was buried into the holes at the rate of 125 kg/ha. Soybeans on control plots neither received Rhizobium inoculant nor TSP fertilizer.

Field Data Collection

Number of days of seedling emergence

Seeds started emerging from the 6th day. A first count was made on that day for each plot and the number of emerged seeds were taken daily. On the 9th day, all viable seeds emerged and these were also counted and recorded. Few seeds that did not germinate were replanted immediately.

Number of days to 50 % flowering

Observation of the plants started from the first day of flowering to 50 % flowering. This was counted for each plot and recorded accordingly.

Average number of pods per plant per treatment (Pod load)

At maturity, 20 plants were selected randomly from each of the plots and pods on each of them were counted and recorded. The filled and matured pods were those that were counted and recorded.

Average plant height at harvest

When the plants attained physiological maturity, ten (10) plants were randomly selected and tagged from the inner rows of each of the plots for this activity. A measuring rule was used to determine the height of the selected plants. The tape was set at the base of the plant to the tip of the plant. The average heights were obtained and recorded for each plot.

Average number of nodules formed per plant per treatment

When the soybean plants attained 50% podding and nodules were expected to be functional, crop cut was used to select samples from each plot. The plants were uprooted gently to ensure no nodule was lost into the soil. The nodules were counted and recorded for each plot. Nodule biomass was also taken.

Number of days to 50 % physiological maturity

The soybean plots were observed from time to time as the pods were maturing. When 50 % of the plants from any of the plots started turning brownish, the physiological maturity was attained on that plot. The number of days the plots took to attain 50 % physiological maturity was recorded.

Harvesting and Weighing

All the soybean seeds from the various plots were harvested at all three locations. The harvested soybean seeds from each of the plots were then allowed to dry further before shelling them. The shelled beans were weighed and recorded for each plot. The seeds were then put in different sacks, labelled and transported to Tamale to prepare them for storage.

Yield Determination

After weighing each soybean from each plots from the three locations, the yields were calculated based on the unit area (0.0055 ha) cultivated, extrapolated and recorded to ascertain the yields of each treatment per hectare.

Data Analysis

Analysis of variance from GenStat statistical package (VSN International, Hemel

Hempstead, UK) was used to analyse the data. LSD was used to separate the means at 5% significance level.

RESULTS AND DISCUSSIONS

Effects of TSP and Inoculant on Days to 50 % flowering of Soybean seed

The results of the effects of TSP and Inoculant on days to 50 % flowering revealed that there was no significant difference among the interactions ($P>0.05$), however, the TSP and Inoculant were significant and is shown in Figure 1. It could be seen from the figure that the control plots took longer number of days to flowers while the rest of the treatments flowered earlier.

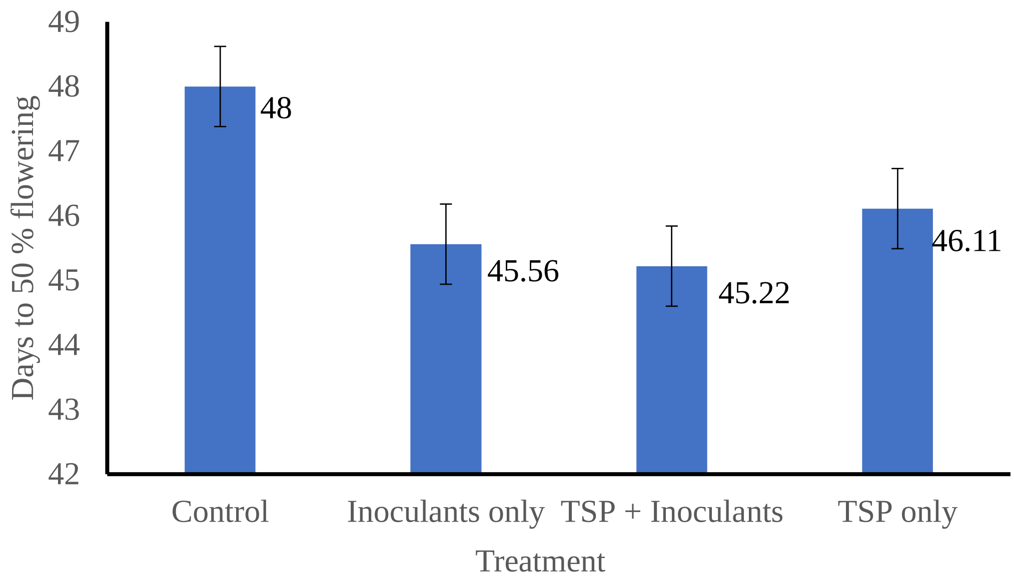

FIGURE 1. **Effects of treatments on Days to 50 % flowering of Soybean Seed**

The error bars represent the Least Significant difference

The fact that almost all the treatments applied led to shorter days of the soybean plant to reach 50 % flowering as compared to the control (though it also attained its 50 % flowering within the number of days this variety flowers) might be attributed to the fact that the treatments applied to the soybean had a positive impact on the number of days it took it to flower. The application of phosphorus fertilizer has the tendency to decrease the days it takes for plants to flower. This was corroborated by the research done by Nowak (2001) which stated that the number of days from planting to flowering decreased with increasing concentration of phosphorus. The result conformed to the work done by Osei et al (2014) that, application of inoculants hastened plant growth and development.

Effects of TSP and Inoculant on the number of pods per crop of Soybean seed

The analysis of variance (ANOVA) shows that there was significant different between TSP and Inoculant (P>0.05) in the number of pods formed. It could be seen from figure 2 that application of 'TSP + Inoculant' produced the highest number of pods per plant and was significantly higher than 'TSP only' and 'Inoculant only'. There was no significant difference between 'TSP only' and 'Inoculant only' however, the number of pods per crop from both was significantly higher than that of 'Control' plot.

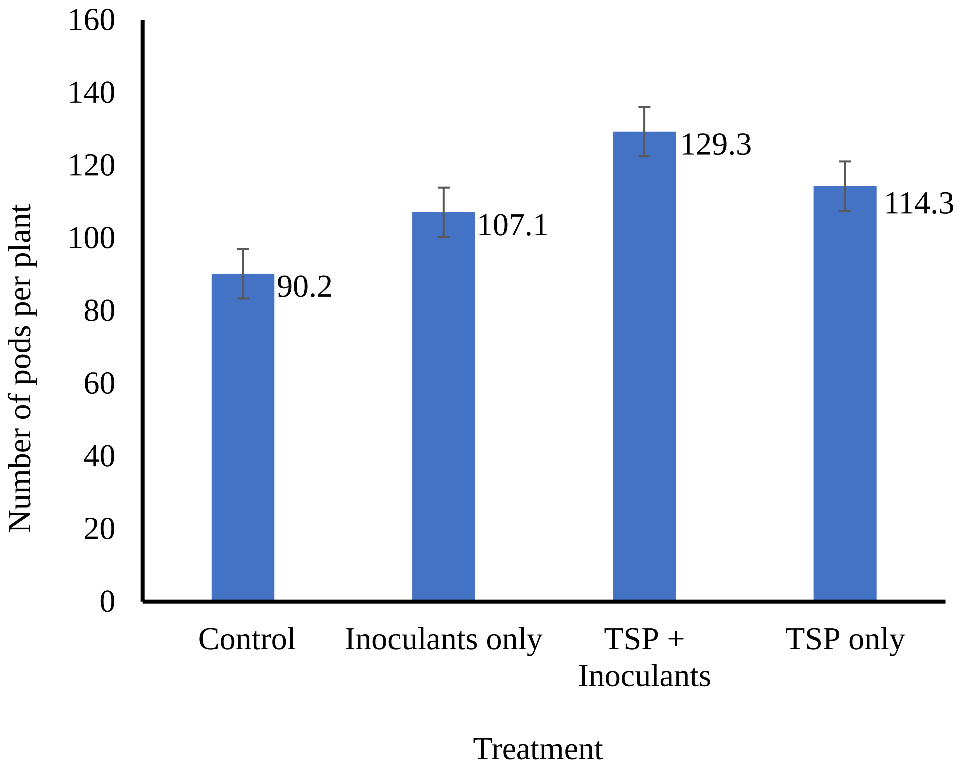

FIGURE 2. **Effects of Treatment on Number of Pods per plant of soybean seed**

The error bars represent the Least Significant difference

Again, the treated plants (especially 'TSP + Inoculant') produced more pods per plant as compared to the control. This might be as a result of the fact that inoculation of soybean with rhizobia also trigged the plant growth, development through nodulation and symbiotic fixation of nitrogen the phosphate activated photosynthetic process in the plants by increasing its branches that host the pods. This conforms to work done by Nadia (2012) that phosphorus enhances the efficiency of photosynthesis in plants and increased number of branches and pods per plant and Malik et al. (2006), stated that large quantities of phosphorus are found in seeds and fruits and are considered essential for pod formation. Tairo et al. (2013) on his part said in his publication that inoculation of soybean is the best substitute for mineral nitrogen fertilizer which is often costly since it triggers plant growth, development and yield.

Effects of TSP and Inoculant on plant height at maturity of Soybean

The results obtained from the heights of soybean crop showed that there was significant (P>0.05) difference between TSP and Inoculant as shown in Figure 3 below The plant heights recorded when phosphorus and inoculation were combined (TSP + Inoculant) were significantly higher than the all other treatments. All three treatments recorded higher plant heights than the absolute control (Figure 5).

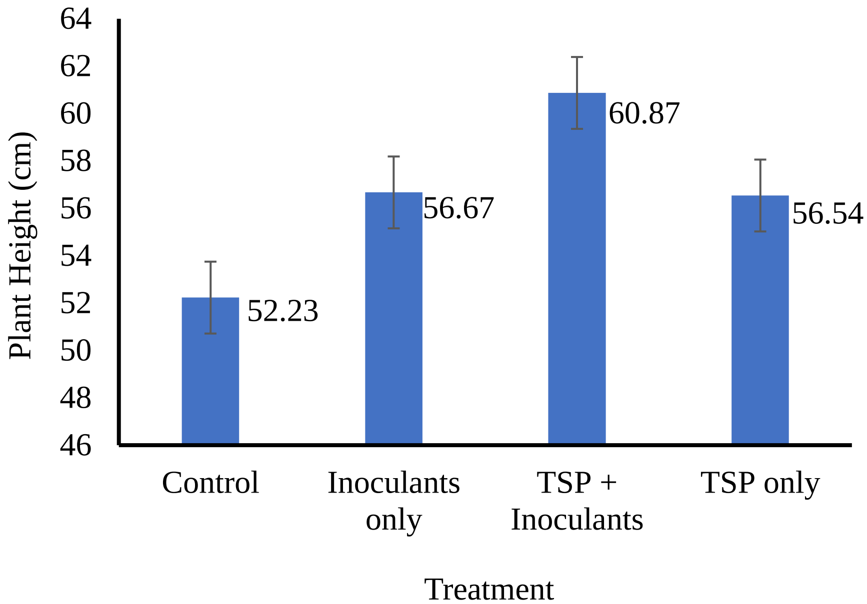

FIGURE 3. **Effects of Treatment on Plant Height at Maturity of Soybean**

The error bars represent the Least Significant difference

Plants treated with phosphorus and Rhizobium inoculant were significantly taller than all the other treatments. Because Phosphorus is noted for the promotion of growth and development while inoculants support the formation of nodules that help the plants to fix atmospheric nitrogen into the soil for its use to promote vegetative growth. The adequate supply of phosphorus in early plant life was very important in the development of vegetative parts and this resulted in the taller plants at maturity recorded under 'TSP + Inoculant'. The observation is in line with a research conducted by Razaq et al., (2017) that seedlings not treated with phosphorus have taunted plant height and those treated one with phosphorus have great plant height.

Effects of TSP and Inoculant number of nodules formed on the roots of Soybean plant

Analysis of variance conducted for the number of nodules formed on the roots of the soybean plants across the various plots shows significant difference among the treatment means. The numbers of nodules formed from all the treated plots were significantly higher than the 'control' plots. It could be seen from figure 4 below that application of 'TSP + Inoculant' produced the highest number of nodules per plant and was significantly higher than 'TSP only' and 'Inoculant only'. The number of nodules formed from 'Inoculant only' was also significantly higher than 'TSP only'.

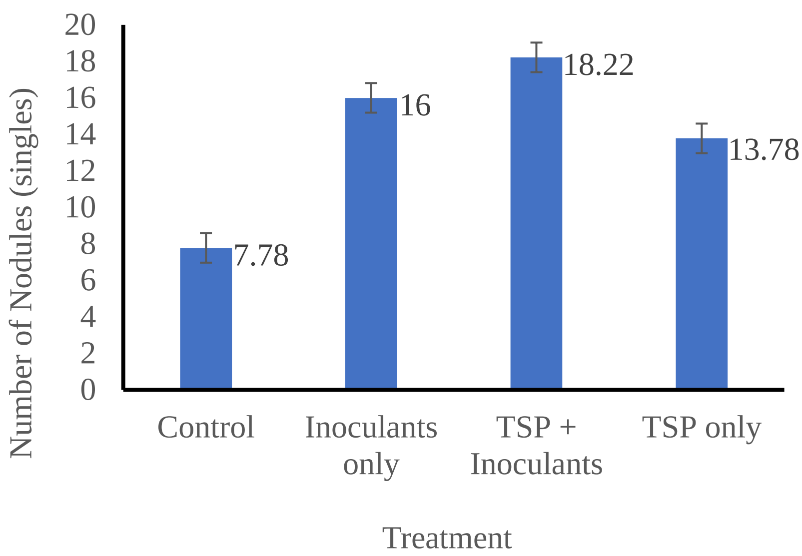

FIGURE 4. **Effects of TSP and Inoculant on number nodules formed on the roots of Soybean plant**

The error bars represent the Least Significant difference

The results show that TSP and Inoculant contributed immensely to the nodulation of the soybean. The observation from the 'control' plots which had very minimal number of nodules across all the locations was a clear indication that the application of TSP and Rhizobia inoculant increased the quantities of nodules that were formed on the roots of soybean plants. The rhizobium activity and N_2 fixation are enhanced when the soil has adequate phosphorus because phosphorus serves as energy source for the rhizobia and also stimulates early root growth and enhances the formation of lateral and fibrous root systems which are essential for nodule formation. This observation was in line with research conducted by Bishnoi et al. (2007) and Baijukya et al. (2010) that phosphorus deficiency in the soil and lack of response to inoculants respectively may result in poor nodulation.

Effects of TSP and Inoculant on number of Days to 50 % physiological maturity of soybean seed

There was significant difference between the 'control' and the 'treatments' and presented in Figure 5 below. 50 % of the plants from all the treatments ('Inoculants only', 'TSP + Inoculants', 'TSP only') attained physiological maturity earlier than the 'control' plot.

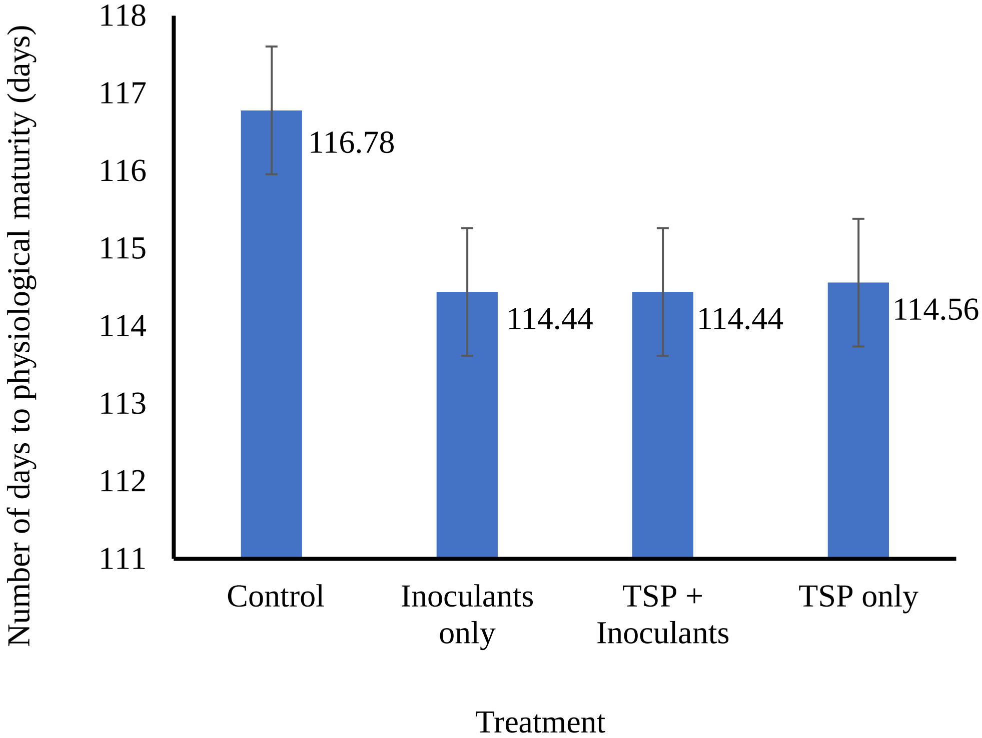

FIGURE 5. **Effects of Treatment on number of Days to 50 % physiological maturity of Soybean seed**

The error bars represent the Least Significant difference

It was realized that all the plots that had treatments matured earlier while the control plots took longer days to mature. With regards to the treatments, the days required to reach 50 % physiological maturity was decreased in response to the effect of inoculants and phosphorus in the soil. Attaining early physiological maturity may be due to faster development of leaves which might have diverted plant nitrogen to the reproductive organs for development (Alemu, 2018). This was made possible due to the contributions of inoculant and phosphorus since adequate amount of phosphorus in soybean supports early plant maturation. The longer crop maturity duration or delayed maturity observed in the 'Control' plots was at a result of deficiency of phosphorus in the soil and low activities of Nitrogen-fixing bacteria. This observation conforms to a research conducted by Dorivar et al., (2011) that deficient soybeans display many characteristics which include necrotic spots on the leaves and may lead to delayed blooming and maturity.

Effects of Triple Superphosphate and Inoculant on Yield of Soybean Seed

There was significant ($P<0.05$) difference between TSP and Inoculant when ANOVA was conducted for yield and this is shown Figure 6. In general, the yields obtained under the application of the treatments were significantly higher than those obtained in 'Control' plot in all locations. The yields obtained from 'TSP + Inoculant' and 'TSP only' were also significantly higher than those from the 'Inoculant only', however, there was no significant difference between the yields of 'TSP + Inoculant' and 'TSP only'.

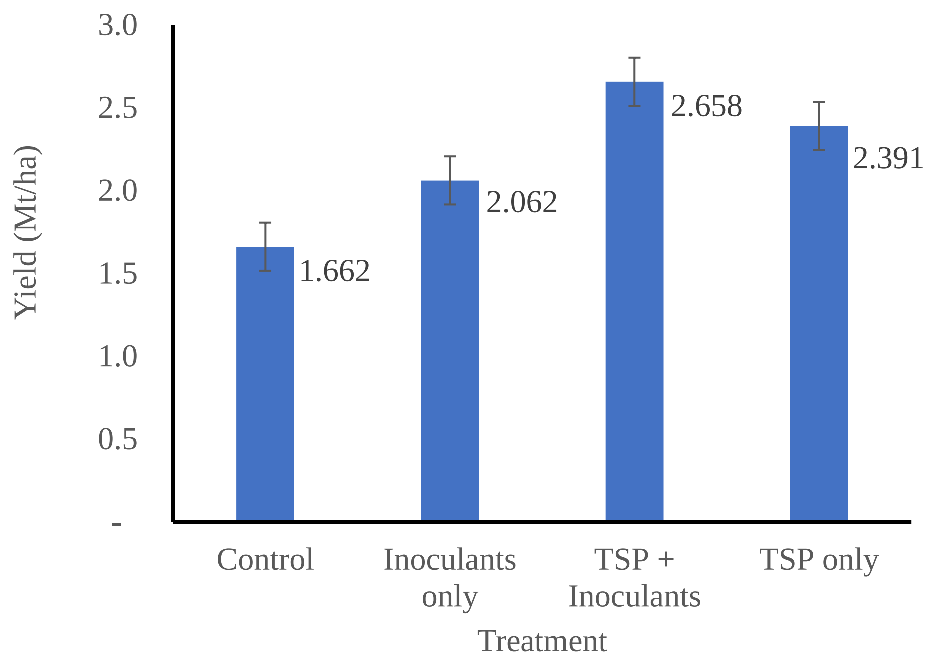

FIGURE 6. **Effects of treatment and location on the yield of soybean seed**

The error bars represent the Least Significant difference

The treatment combination of 'TSP + Inoculant' performed better than all the other treatments. It recorded a mean yield of 2.66 Mt/ha. This was followed by 'Triple superphosphate only' which recorded a yield of 2.39 Mt/ha. This outstanding performance of 'TSP + Inoculant' observed in the field might probably be because phosphorus promotes root growth and increases the amount of nutrients absorbed. This, eventually, created the environment for the development of more nodules on the roots as a result of the application of the inoculants which supports biological nitrogen fixation for vegetative growth and this allows the translocation of more phosphorus to form seeds. This observation conforms to the research by Morais et al. (2016) that increase dose of phosphorus in the soil is related to increased nodulation, growth and yield components in soybean seed. In this experiment, 'TSP + Inoculant' promoted taller plants, more numbers of pod/plant and seed/pod that translated to higher yield. This agrees with Yohanes and Richer (1999) that, phosphorus promotes pulse production, growth, nodule formation and development and N-fixation. The yield from the field of 'Inoculant only' though low was significantly higher than the control as well. This might be attributed to the fact that inoculating soybean before planting leads to the rapid development of rhizobia bacteria in the nodules which help the crop to fix nitrogen in the air into the soil and make it available for the development of the crop. The contribution of fixed N is a key factor in low input agricultural systems to sustain long-term soil fertility. Inoculants play a very key role here. A research conducted by Mburu et al (2011) also agreed with present research that, soybean grain yield increases after the application of commercial rhizobia inoculants (legume fix) with P fertilizers.

Conclusion and Recommendation

The treatments (TSP + Inoculant, TSP only and Inoculant only) generally enhanced growth, development and yield of soybean seed as compared to the control plots in almost all the locations. The application of all the treatments led to a shorter number of days to 50 % physiological maturity, increased in plant height at maturity, early flowering, a greater number of pods per crop, greater number of nodules formed as well as had a significant increase in yield of Soybean seed as compared to the control plots. Generally, plots that were applied with TSP + Rhizobia Inoculant were outstanding in the various plant parameters that were measured. This was followed by plots treated with TSP only.

Seed producers should be encouraged, in addition to good agronomic practices, to apply the recommended dosage of inoculant and triple superphosphate to their seeds and soybean fields respectively. This would lead to early maturity and high yields.

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***Competing Interest*: None**

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