# EFFECTS OF INTEGRATED APPLICATION OF RHIZOBIUM AND PHOSPHATIC FERTILIZER ON GROWTH, NODULATION AND YIELDS OF SOYBEAN IN MERU SOUTH KENYA


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## ABSTRACT

The cultivation of soybean is increasing in Kenya due to its widespread use in the food and feed industry. Production is, however, constrained by low soil nitrogen (N) and phosphorus (P) levels. A field trial was conducted at Chuka University Research farm to determine effects of integrated application of rhizobium and phosphatic fertilizer on growth, nodulation and yields of soybean. Treatments included three rates of Triple superphosphate fertilizer (0, 20 and 30 kg$^{-}$ ha$^{-1}$), and three rates of rhizobia (0, 100 and 200 g ha$^{-1}$) using two soybean varieties (SB19 and SB24). Each treatment combination was replicated three times in a randomized complete block design in a split plot arrangement and the experiment was repeated once. Data collected included the plant height, number of branches, number and weight of nodules, number of pods, fresh and dry shoot weight and grain yield. The data was subjected to analysis of variance using SAS statistical programme and significantly different means were separated using Tukey's Studentized range test. It was observed that rhizobia and phosphatic fertilizer had significant effect (*p=0.05*) on the plant height, number of nodules, fresh and dry weight of nodules and mean number of branches and pods, fresh and dry weight of shoots and weight of seed plant$^{1}$. The overall means for plant heights, nodule number, fresh and dry nodule weights, number of branches and pods, fresh and dry weight of shoots and weight of seeds plant$^{1}$ were 29.35 cm and 26.79 cm, 38.71 and 35.14, 0.51 and 0.38, 5.5 g and 12.54g, 49.13 and 59.18, 77.65 and 90.91, 56.99 and 69.33g, 168.9g and 148.13g for SB19 and SB24 respectively. The SB24 genotype remained significantly superior to SB19, with same treatment levels employed. From the results, it can be concluded that integrated application of rhizobia and phosphatic fertilizer (TSP) has significant effect on growth, nodulation and yield of soybean.



**Keywords:** Rhizobia, Triple Super Phosphate, Nodulation, Growth, Yields


## INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is the most important grain legume crop in the world in terms of total production and international trade (Kaleem and Tahir, 2010). The crop responds well to inoculation with rhizobia and play very important roles in natural resource management due to its contribution to biological nitrogen fixation (Walangululu *et al*., 2014). It can fix over 300 kg of N ha$^{-1}$ each year, providing up to 94 % of total plant N (Hungria *et al*., 2017). It is grown as food plants for multiple uses, forage (fodder) plants and as green manure (Mudibu *et al*., 2018). Soybean is protein and energy rich crop and have nutrient requirement especially the phosphorus in adequate amount and which is an essential element for legume growth (Giller, 2001). Phosphorus is the most limiting nutrient governing the yield of soybean. It has greater significance than other plant nutrient for higher yield of oilseed crop like soybean which enhances growth and biological nitrogen fixation (Suhana, 2016). Soybean yielded 1.2 tons/ha on high fertile soil in Kenya with no P applied, versus 2.8 tons with an addition of 30 kg/ha of P; on a low fertility soil, the yield was 0.8 tons in case of 0 kg P supply, versus 1.2 tons with 30 kg/ha of P (Walangululu *et al*., 2014).

Rhizobia integrated with P has had a positive respond, however, presence of a high level of indigenous rhizobia can curtail the positive response to introduced elite strains coupled with low level of phosphorus (Leggett *et al*., 2017). Application of rhizobia with phosphorus increased plant height considerably but the values for different combinations of rhizobia and phosphorus were higher than the control and rhizobia and phosphorus treatments used alone (Leggett *et al*., 2015). Therefore, prior knowledge of the population of native rhizobia and provision of appropriate amount of phosphorus must be put into consideration to achieve an optimum growth and yield of soybeans, which remains a challenge in the study area. A maximum shoot dry weight per plant compared to the control where rhizobia strain was applied with phosphorus was confirmed (Salih *et al*., 2015). Rhizobium increased nodule weight, while when integrated with phosphorus, weight increased with maximum specific nitrogenase activity compared with control (Masresha, 2017).

Phosphorus deficiencies in the soil restrict the development of a population of free-living rhizobia in the rhizosphere, limit the growth of the host plant, restrict nodulation and cause an impaired nodule function (Getachew *et al*., 2017). Phosphorus availability increases the number and size of nodules and the amount of nitrogen assimilated per unit weight of nodules, increasing the percent and total amount of nitrogen in the harvested portion of the host legume and improving the density of rhizobia bacteria in the soil surrounding the root (Bashir *et al*., 2011).

Rhizobium and phosphorus applications induce a pronounced effect on yield components (Korir *et al*., 2017). The use of rhizobium inoculants in treating soybean seeds before sowing and application of triple superphosphate fertilizer at the rate of 30 kg P $ha^{-1}$ has been recommended (Lamptey *et al.*, 2014). However, the optimal rate of combination of rhizobium and phosphorus remains scanty in the study area prompting need for this study for appropriate technical information for enhancing soybean production.

Yield components are directly correlated with nodulation because components contain nitrogenous compounds (proteins) that are affected by formation of nodules on plant root to fulfill nitrogen requirement (Masresha, 2017). Because there is a positive effect in integrated application of rhizobium and phosphorus the research intended to ascertain the response of different genotypes in the study area.

The SB24 is bushy, high yielding and matures few days after, compared to SB19 (Ndusha *et al.*, 2017). However, it was imperative to test and find out if difference in growth, nodulation and yield parameters among genotypes can vary at same levels of treatment. Results of this research forms a basis on recommendation of integrated application of rhizobia and phosphatic fertilizer for optimum soybean production in Meru South.

## MATERIALS AND METHODS

### Study Site

The experiment was conducted at Chuka University, Meru South Sub-County, March - June 2018. It lies at an altitude of 1452 m above sea level with temperature range of 20.97ºC to 27.25ºC. Four soil samples were taken before and after planting the experimental field at Chuka University farm at a depth of 1-30 cm using a soil auger. Soil analysis was done at Kenya Agricultural Research and Livestock Organization-Embu. Soil pH was determined using Mclean method (McLean, 1982). Total N was determined by Kjeldah method (Bremner and Mulvaney, 1982).

### Experimental Design

The experiment was laid out in a randomized complete block design (RBD) in a split plot arrangement with each treatment replicated three times. The treatments included integrated application of different rates of rhizobia (R) and Triple superphosphate (TSP) fertilizer with or without rhizobium inoculum. These included 0 g rhizobia per ha + 0 kg triple superphosphate per ha, 0 g rhizobia per ha + 20 kg triple superphosphate per ha, 0 g rhizobia per ha + 30 Kg triple superphosphate per ha, 100 g rhizobia per ha + 0 kg triple superphosphate per ha, 100 g rhizobia per ha + 20 kg triple superphosphate per ha, 100 g rhizobia per ha + 30 kg triple superphosphate per ha, 200 g rhizobia per ha + 0 kg triple superphosphate per ha, 200 g rhizobia per ha + 20 Kg triple superphosphate per ha, and 200 g rhizobia per ha + 30 kg triple superphosphate per ha. The variety was assigned the main plots, fertilizer rates the sub-plots and rhizobium rates to sub-subplots. The size of experimental plot was 1.5 x 1.3 m. Path between main plots was 1 m while between subplots and sub-subplots was 0.5 m.

### Planting Materials, Planting and Crop management

Certified soybean seeds and inoculant was obtained from KALRO-Kakamega and MEA Limited-Nakuru respectively. The inoculation was done in Plant Science Laboratory of Chuka University using 4% gum arabica at the rate of 10 g per kg and 20 g per kg inoculant of soybean seed. Inoculated seeds were spread on flat plywood to air dry for 30 minutes before planting. A basal application of TSP at the rate of 0, 20, and 30 Kg P/ha was done during planting to the assigned treatment plots. Two seeds were sown at inter and intra row spacing of 0.5 m and 0.1 m respectively giving a plant population of 200,000 plants/ha or 39 plants per plot. All treatments were applied separately to avoid cross contamination. Seedlings were thinned to one per hill one week after emergence. The first and last rows, first and last plants formed guard rows. Data was taken from the middle plants. Routine field maintenance practices; weeding and spraying against diseases and insect pests was done as need arises.

### Data Collection

The data recording was done on qualitative and quantitative parameters. The net plot was the two middle rows of each plot.

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#### *Plant height*

Four plants were randomly selected from two inner rows after the border rows from each plot and tagged for data collection on plant height (PH). These selected plants per treatment was measured using a meter rule on 7, 14 ,21, 28, 35, 42, 49, 56, 63, 70, 77 and 84 days after emergence (DAE) to determine the treatment effects starting two weeks after emergence. Height was measured from the ground level to the tip of each plant and recorded using a meter rule.

***Number and weight of nodules***

Four plants were randomly selected from two inner rows after the border rows from each plot for data collection on number and nodule weight. The selected plants were uprooted 40 days after emergence from each treatment to determine number of nodules, fresh and dry nodule weight.

Roots of uprooted plants per treatment were washed and the nodules detached, number ascertained and recorded. The detached nodules per plot were put in labelled khaki envelopes, fresh nodule weight ascertained and recorded. The nodules were oven dried at 60 $^{o}$C for 48 hours and their dry weight recorded.

***Number of branches***

Four plants were randomly selected for the determination of the number of branches per plot to ascertain treatment effect. The selected plants were uprooted from each treatment branches counted and recorded per plant 80 days after emergence for the two soybean genotypes.

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***Number of pods, fresh and dry shoot weight***

Four plants from each plot were randomly selected for determination of the number of pods, fresh shoot and dry shoot weight. These selected plants were uprooted 40 days after emergence. Number of the pods per plant was counted and recorded.

The shoots were put in khaki bags and their fresh weight ascertained using weighing balance and recorded. These bagged shoots were put in the oven at 60$^{o}$C for 48 hours and then dry shoot weight was ascertained and recorded.

**Data Analysis**

The data values collected were subjected to analysis of variance (ANOVA) using the SAS system for windows Version 8 (1999-2001) by SAS Institute Inc., Cary, North Carolina, USA. Thereafter, significantly different means were separated using the Tukeys test at $P$=0.05.

**RESULTS**

**Climatic Data and Soil Analysis**

After analysis the soil at the site had a pH of 5.31, total nitrogen of 0.23%, and organic carbon content of 2.54% and available P of 27 ppm (Table 1). The site had a mean temperature of 22.6$^{o}$C and received a total rainfall of 1148.1 mm

**Table 1: Soil analysis data of the site**

| Soil properties | Values |
|---|---|
| pH | 5.31 |
| Nitrogen (N) % | 0.23 |
| Organic Carbon (OC) % | 2.54 |
| Potassium (K) (cmol/ kg) | 0.88 |
| Magnesium (Mg) (cmol/kg) | 1.28 |
| Calcium (Ca) (cmol/kg) | 3.00 |
| Aluminum (Al) (cmol/kg) | 2.45 |
| Manganese (Mn) (ppm) | 73.15 |
| Phosphorus (P) (ppm) | 27 |
| Sand % | 14.01 |
| Clay % | 55.77 |
| Texture | Clay |

**Effect of Integrated Application of Rhizobium and Phosphatic Fertilizer on Growth and Nodulation of Soybean**

***Plant height***

Plant height was significantly affected by rhizobia and TSP especially where rhizobia and TSP were integrated. Application of R and P alone significantly increased plant height from 24.22 cm and 21.07 cm to 29.69 cm and 27.37 cm and to 28.40 cm and 25.85 cm with low rate of 0 g R/ha and 0 kg TSP/ha compared to high rate of R and P of 200 g/ha and 30 kg/ha respectively (Table 2). Therefore, R and P rates from 0 g R/ha and 0 kg P/ha compared to high rates of 200 g/ha and 30 kg/ha increased plant height by 5.47 cm, 6.3 cm and 4.18 cm, 4.78 cm for SB19 and SB24 soybean genotypes respectively (Table 2).

Integration of rhizobia with TSP at 100 g R/ha and 200 g R/ha with 20 kg TSP/ha and 30 kg TSP/ha significantly increased plant height. Integration of rhizobia and TSP at the rate of 100 g R/ha + 20 kg TSP/ha and 100 g/ha + 30 kg/ha increased plant height of 29.79 cm and 27.12 cm compared with low R and P rate of 0 g R/ha + 0 kg TSP/ha of 24.22 cm and 21.07 cm. While integrated application of R and TSP at the rate of 200 g R/ha + 20 kg TSP/ha and 200 g R/ha + 30 kg TSP/ha increased plant height form control of 24.22 cm and 21.07 cm to 32.10 cm, 29 41 cm and 34.04, 32.06 for SB19 and SB24 respectively (Table 2). SB 19 had a higher mean height of 29.35 cm compared to 26.79 of SB24 (Table 2).

**Table 2: Effect of rhizobia and phosphorus on soybean height, nodule number and mean fresh weight**

| Variety | Treatment | Height(cm) | Number of nodules | Fresh nodule wt (g) |
|---|---|---|---|---|
| SB19 | 1 | 24.22[c] | 9.0[e] | 0.23[e] |
| SB19 | 2 | 26.29[c] | 17.92[d] | 0.29[e] |
| SB19 | 3 | 28.40[b] | 26.25[c] | 0.36[d] |
| SB19 | 4 | 27.35[c] | 15.5[e] | 0.34[d] |
| SB19 | 5 | 29.79[b] | 37.5[c] | 0.49[c] |
| SB19 | 6 | 32.28[a] | 69.67[b] | 0.79[b] |
| SB19 | 7 | 29.69[b] | 25.16[d] | 0.39[c] |
| SB19 | 8 | 32.10[a] | 57.42[b] | 0.65[b] |
| SB19 | 9 | 34.04[a] | 90.0[a] | 1.04[a] |
| **Mean** | | **29.35** | **38.71** | **0.51** |
| SB24 | 1 | 21.07[c] | 9.25[e] | 0.23[e] |
| SB24 | 2 | 23.79[c] | 18.33[d] | 0.27[e] |
| SB24 | 3 | 25.85[b] | 25.25[c] | 0.35[d] |
| SB24 | 4 | 25.21[c] | 13.58[e] | 0.32[d] |
| SB24 | 5 | 27.12[b] | 33.83[c] | 0.48[c] |
| SB24 | 6 | 29.30[a] | 55.25[b] | 0.73[b] |
| SB24 | 7 | 27.37[b] | 22.83[d] | 0.49[c] |
| SB24 | 8 | 29.41[a] | 55.75[b] | 0.68[b] |
| SB24 | 9 | 32.06[a] | 82.16[a] | 1.0[a] |
| **Mean** | | **26.79** | **35.14** | **0.51** |

Means with the same letter along a column are not significantly different at $P$=0.05. 1- Control; 2 and 3 - is where Triple Superphosphate was applied alone at the rate of 20 kg TSP/ha and 30 kg TSP/ha respectively; 4 and 7 is where rhizobia was applied alone at the rate of 100 g R/ha and 200 g R/ha respectively; 5-100 g/ha R + 20 kg TSP/ha, 6- is where 100 g R/ha + 30 kg TSP/ha; 8- is where 200 g R/ha + 20 kg TSP/ha and 9- is where 200 g R /ha + 30 kg TSP/ha was applied respectively.

***Number, fresh and dry nodule weight***

The number of nodules, fresh nodule weight and dry nodule weight were significantly affected by rhizobia and TSP especially where rhizobia and TSP were integrated. Application of R alone significantly increased nodule number from 9.0 and 9.25 at low rate of 0 g R/ha to 25.16 and 22.83 at a higher rate of 200 g R/ha for SB19 and SB24 soybean genotypes respectively. Application of TSP alone significantly increased nodule number to 26.25 and 25.25 at 30 Kg TSP/ha compared to 9.0 and 9.25 at 0 TSP/ha (Table 2). Integration of rhizobia with TSP at the rate of 100 g R/ha and 200 g R/ha with 20 kg TSP/ha and 30 Kg TSP/ha significantly increased nodule number.

At the rate of 100 g R/ha + 20 Kg TSP/ha and 100 g/ha + 30 Kg/ha nodule number was higher than control with 37.5, 33.83 and 69 67, 55.25 for SB19 and SB24 respectively. Integration of R and TSP at the rate of 200 g R/ha + 20 Kg TSP/ha and 200 g R/ha + 30 Kg TSP/ha increased nodule number of 57.42, 55.75 and 90.0, 82.16 (Table 2). There was significant increase in fresh nodule weight with increase in the application of R and TSP alone. Nodule fresh weight increased from 0.23 g to 0.39 g, 0.49 g and 0.36 g, 0.35 g where R and TSP was applied alone. Highest fresh weight was observed where integration of R and TSP was applied. However, application of 200 g/ha R had a higher fresh nodule weight of 0.49 g compared to 0.48 g at 100 g R/ha + 20 Kg TSP/ha (Table 2).

Rhizobia and TSP fertilizer had significant influence on dry nodule weight. Application of R and TSP alone significantly increased dry nodule weight from 0.12 g and 0.11 g at control to 0.27 g, 0.41 g and 0.25 g, 0.23 g for SB19 and SB24 respectively (Table 3). Integration of rhizobia with TSP at the rate of 100 g R/ha and 200 g R/ha with 20 kg TSP/ha and 30 Kg TSP/ha significantly increased dry nodule weight. At the rate of 100 g R/ha + 20 Kg TSP/ha and 100 g/ha + 30 Kg/ha dry nodule weight was higher than control with 0.37 g, 0.36 g and 0.65 g, 0.61 g for SB19 and SB24 respectively. Integration of R and TSP at the rate of 200 g R/ha + 20 Kg TSP/ha and 200 g R/ha + 30 Kg TSP/ha increased dry nodule weight of 0.53 g, 54 g and 0.81 g compared with control respectively (Table 3).

***Number of branches***

Branches were significantly affected by Rhizobia and TSP rates and especially where R and TSP were integrated. Number of branches increased from 3.75 and 8.33 to 4.83 and 12.33 with low R rate of 0 g R/ha compared to high R rate of 200 g R/ha, while branches increased to 5.50 and 11.33 with high rate of 30 Kg TSP/ha for SB19 and SB24 respectively (Table 3).

**Table 3: Effect of rhizobia and phosphatic fertilizer on soybean nodule dry weight and number of branches**

| Variety | Treatment | Nodules dry wt (g) | Mean number of branches |
|---|---|---|---|
| SB19 | 1 | 0.12$^{f}$ | 3.75$^{e}$ |
| SB19 | 2 | 0.16$^{fe}$ | 5.41$^{cd}$ |
| SB19 | 3 | 0.25$^{ed}$ | 5.50$^{cd}$ |
| SB19 | 4 | 0.22$^{fe}$ | 4.58$^{d}$ |
| SB19 | 5 | 0.37$^{c}$ | 5.00$^{c}$ |
| SB19 | 6 | 0.65$^{b}$ | 5.25$^{bc}$ |
| SB19 | 7 | 0.27$^{dc}$ | 4.83$^{dc}$ |
| SB19 | 8 | 0.53$^{b}$ | 5.66$^{dc}$ |
| SB19 | 9 | 0.81$^{a}$ | 6.33$^{a}$ |
| **Mean** | | **0.37** | **5.14** |
| SB24 | 1 | 0.11$^{f}$ | 8.33$^{e}$ |
| SB24 | 2 | 0.14$^{fe}$ | 11.33$^{cd}$ |
| SB24 | 3 | 0.23$^{ed}$ | 11.33$^{cd}$ |
| SB24 | 4 | 0.22$^{fe}$ | 11.50$^{d}$ |
| SB24 | 5 | 0.36$^{c}$ | 13.50$^{c}$ |
| SB24 | 6 | 0.61$^{b}$ | 13.58$^{bc}$ |
| SB24 | 7 | 0.41$^{dc}$ | 12.33$^{dc}$ |
| SB24 | 8 | 0.54$^{b}$ | 14.25$^{bc}$ |
| SB24 | 9 | 0.81$^{a}$ | 16.66$^{a}$ |
| **Mean** | | **0.38** | **12.54** |

Means with the same letter along a column are not significantly different at P=0.05.
1 is control; 2 and 3 is where Triple Superphosphate was applied alone at the rate of 20 kg TSP/ha and 30 kg TSP/ha respectively; 4 and 7 is where rhizobia was applied alone at the rate of 100 g R/ha and 200 g R/ha respectively; 5- 100 g R/ha + 20 kg TSP/ha, 6- is where 100 g R/ha + 30 kg TSP/ha, 8 is where 200 g R/ha + 20 kg TSP/ha and 9 is where 200 g R /ha + 30 kg TSP/ha was applied.

Integration of R and TSP rates significantly increased number of branches in the trial. At the rate of 100 g R/ha + 20 Kg TSP/ha and 100 g/ha + 30 Kg/ha branches increased to 5.00, 13.50 and 5.25, 13.58 compared to control of 3.75 and 8.33 for SB19 and SB24 soybean genotypes respectively. Similarly, integration of R and TSP at the rate of 200 g R/ha + 20 kg TSP/ha and 200 g R/ha + 30 kg TSP/ha increased number of branches of 5.66, 14.25 and 6.33, 16.66 compared to control respectively. SB24 had more number of branches than SB19 of 12.54 and 5.14 respectively (Table 3).

**Effect of Integration of Rhizobium and Phosphatic Fertilizer on Yield Components of Soybean**

***Number of pods, fresh and dry shoot weight***

The number of pods, fresh shoot weight and dry shoot weight were significantly affected by rhizobia and TSP especially where rhizobia and TSP were integrated. Application of R alone significantly increased pod number from 29.85 and 43.17 at low rate of 0 g R/ha to 25.16 and 22.83 at a higher rate of 200 g R/ha for SB19 and SB24 soybean genotypes respectively. Application of TSP alone significantly increased number of pods to 40.08 and 54.83 at 30 Kg TSP/ha compared to 29.85 and 43.17 at 0 TSP/ha (Table 4). Integration of rhizobia with TSP at 100 g R/ha and 200 g R/ha with 20 kg TSP/ha and 30 kg TSP/ha significantly increased nodule number. At 100 g R/ha + 20 kg TSP/ha and 100 g/ha + 30 kg/ha pod number was higher than control of 52.92, 55.17 and 66.00, 75.33 for SB19 and SB24 respectively. Integration of R and TSP at 200 g R/ha + 20 kg TSP/ha and 200 g R/ha + 30 kg TSP/ha increased nodule number of 63.25, 69.67 and 76.33, 82.75 compared to control (Table 4).

There was significant increase in fresh shoot weight with increase in the application of integrated R and TSP or applied alone. The higher fresh Shoot weight of 70.73 g and 78.55 g was recorded where R was applied alone at the rate of 200 g R/ha. While the higher fresh shoot weight was recorded where TSP was applied alone at the rate of 30 Kg TSP/ha of 75.62 g and 75.85 g for SB19 and SB24 soybean genotypes respectively. However, the highest fresh shoot weight was observed where integration of R and TSP was applied at 200 g R/ha + 30 Kg TSP/ha of 100.72 g and 116.17 g compared to control of 61.52 g and 73.17 g for the two soybean genotypes respectively (Table 4).

**Table 4: Effect of rhizobia and phosphatic fertilizer on soybean means number of pod, shoot fresh weight (g) and dry weight (g)**

| Variety | Treatment | Number of pods | shoot fresh wt (g) | shoot dry wt (g) |
|---|---|---|---|---|
| SB19 | 1 | 29.85$^{f}$ | 61.52$^{f}$ | 39.38$^{d}$ |
| SB19 | 2 | 30.83$^{ef}$ | 63.26$^{f}$ | 42.12$^{d}$ |
| SB19 | 3 | 40.08$^{cde}$ | 75.62$^{cde}$ | 52.53$^{cd}$ |
| SB19 | 4 | 39.08$^{de}$ | 69.25$^{ef}$ | 54.56$^{cd}$ |
| SB19 | 5 | 52.92$^{c}$ | 82.55$^{bcd}$ | 59.33$^{bc}$ |
| SB19 | 6 | 66.00$^{b}$ | 90.85$^{ab}$ | 68.59$^{a}$ |
| SB19 | 7 | 44.08$^{cd}$ | 70.73$^{def}$ | 50.80$^{cd}$ |
| SB19 | 8 | 63.25$^{b}$ | 84.25$^{abc}$ | 65.00$^{ab}$ |
| SB19 | 9 | 76.33$^{a}$ | 100.72$^{a}$ | 80.57$^{a}$ |
| Mean | | **56.98** | **77.65** | **49.13** |
| SB24 | 1 | 43.17$^{f}$ | 73.17$^{f}$ | 49.15$^{d}$ |
| SB24 | 2 | 49.5$^{ef}$ | 92.00$^{f}$ | 50.65$^{d}$ |
| SB24 | 3 | 54.83$^{cde}$ | 75.85$^{cde}$ | 61.21$^{cd}$ |
| SB24 | 4 | 50.17$^{de}$ | 92.25$^{ef}$ | 55.87$^{cd}$ |
| SB24 | 5 | 55.17$^{c}$ | 108.03$^{bcd}$ | 70.80$^{bc}$ |
| SB24 | 6 | 75.33$^{b}$ | 111.55$^{ab}$ | 91.60$^{a}$ |
| SB24 | 7 | 52.00$^{cd}$ | 78.55$^{def}$ | 58.51$^{cd}$ |
| SB24 | 8 | 69.67$^{b}$ | 108.03$^{abc}$ | 87.58$^{ab}$ |
| SB24 | 9 | 82.75$^{a}$ | 116.17$^{a}$ | 98.59$^{a}$ |
| Mean | | **69.33** | **90.90** | **59.17** |

Means with the same letter along the column are not significantly different at *P*=0.05. 1- Control; 2 and 3 - is where Triple Superphosphate was applied alone at the rate of 20 kg TSP/ha and 30 kg TSP/ha respectively; 4 and 7 is where rhizobia was applied alone at the rate of 100 g R $ha^{-1}$and 200 g R $ha^{-1}$ respectively; 5- 100 g/ha R+ 20 kg TSP/ha; 6- is where 100 g R/ha+ 30 kg TSP/ha; 8- is where 200 g R/ha + 20 kg TSP/ha and 9- is where 200 g R /ha + 30 kg TSP/ha was applied respectively.

Rhizobia and TSP significantly affected the dry shoot weight of soybean in the trial. Where R and TSP was applied alone dry shoot weight increased from 39.38 g, 49.15 g to 50.80 g, 58.51 g at the rate of 0 g R/ha, 0 kg TSP/ha compared to rate of 200 g R/ha and 30 kg TSP/ha was applied for two soybean. Integration at the rate of 100 g R/ha + 20 kg TSP/ha and 100 g R/ha + 30 kg TSP/ha increased dry shoot weight from 59.33 g, 70.80 g and 68.59 g, 91.60 g to 65.00 g, 87.58 g and 80.57 g, 98.59 g where 200 g R/ha + 20 kg TSP/ha and 200 g R/ha + 30 kg TSP/ha was applied (Table 4).

**DISCUSSION**

The significant (*P*=0.05) differences in the variables measured is evident that application of rhizobia and phosphatic fertilizer affected the plant height, nodule number, fresh and dry nodule weights, number of branches and pods, fresh shoot weight and dry shoot weight of SB19 and SB24 soybean genotypes. Plots with integrated application of inoculant and TSP showed higher performance compared to where rhizobia and TSP was applied alone and control. This was probably because of the adequacy in nutrient which might have positively influenced the growth, nodulation and yield components of soybean plants.

Progressive increase in height with increasing inoculant and phosphorus (TSP) levels were recorded. This can be attributed to nitrogen and phosphorus availability which play a very important role in biochemical processes, including chlorophyll formation and root development respectively. The application of rhizobia and TSP probably potentially improved soil fertility enhancing availability of plant N and P. This enhanced growth in the plots it was applied by supplying N and P which in return positively increased the height of the plants. These results were in agreement with (Walangululu *et al.*, 2013 and Shahid, et al., 2009) who reported that there was increase in height of legumes such as soybean with increase in rhizobia and TSP application. These findings are in conformity with Leggett *et al.* (2015) who reported that phosphorus increased plant height considerably but the values for different combinations of rhizobia and phosphorus were higher than the control and rhizobia and phosphorus treatments used alone.

The number, fresh and dry weight of nodules per plant as affected by different inoculant and phosphorus levels were observed, which varied significantly. There was low number of nodules, fresh and dry weight of nodules in plots with low levels of rhizobia and TSP application. This was probably because phosphorus deficiencies in the soil restricted the development of a population of free-living rhizobia in the rhizosphere, limited the growth of the host plant, restricted nodulation and caused an impaired nodule function (Getachew, *et al*., 2017). However, maximum number of nodules, fresh nodule weight and dry nodule weight per plant was higher where maximum integration of R and TSP was applied.

This was probably because increase in levels of R and TSP in the integration probably might have led to increased availability of N and P which increased the number and size of nodules and the amount of nitrogen assimilated per unit weight of nodules, and improving the density of rhizobia bacteria in the soil surrounding the root (Bashir, *et al*., 2011). The increase in nodule number and nodule mass with application of P could probably be because R and P is known to stimulate nodulation. This study is in agreement with Solaiman & Habibullah, (1990) who reported that integration of R and P influences nodulation and N fixation in legumes such as soybean.

Similar findings have been reported by (Kawaka, *et al*., 2018, Lamptey *et al*., 2014 and Waluyo *et al*., 2004) who reported that increase in rhizobia and TSP increased number of nodules, fresh nodule weight and dry nodule weight. The study is also in agreement with Hoque & Haq, (1994) who reported that when they treated several legumes such as soybean with rhizobia and P there was an increase in the number of nodules.

The number of nodules, fresh and dry nodule weight is more in this research, probably because improved soil nutrient as a result of the optimal application of R and P used (Walangululu *et al*., 2014). SB 19 had a higher number of nodules compared to SB24 while SB24 had a higher shoot dry weight compared to SB19. This is similar to the findings by Ndusha *et al*., (2017) who found SB19 superior in number of nodules but inferior in number of dry shoot weight. This means the influence of rhizobia and triple superphosphate did not interfere their respective superiority.

Branches increased with increased levels of rhizobia and TSP fertilizer. In this study probably application of inoculant and TSP fertilizer resulted to increased photosynthetic activity as a result of optimal availability of N and P. Probably this might have increased the photosynthates available for branch expansion and consequently greater branch numbers.

This result was in agreement with Lamptey *et al*., (2014) who reported that the increase in number of branches due to rhizobium inoculation and increased phosphorus application may be attributed to pronounced vegetative growth. This in conformity with Lamptey *et al*., (2014) who reported that increase in application of R and P enhanced vegetative development. SB24 was superior in the number of branches compared to SB19. This supports the observation by Mudibu *et al*., (2018) who reported that SB24 had more branches than SB19.

The higher number of pods, fresh and dry shoot weight was recorded at higher inoculant and P levels. This might have resulted to enhanced vegetative development and dry matter yield due to increased N and P in the soil. R and P probably might have provided a better habitat for the activity of biological nitrogen fixing bacteria hence enhanced availability of plant nutrient. This study is in agreement with Sabir *et al*., (2001) who reported that number of pods significantly increased by different P levels. Suhana, (2016) also reported that inoculated plants produce lower dry matter than uninoculated.

Lamptey *et al*. (2014) also reported that the improvement of nodulation by R resulted in higher N fixation and consequently enhanced vegetative and dry matter yield of soybean compared to uninoculated. They further reported that 30 Kg P/ha produced the highest fresh and dry shoot weight and lowest pod number from the application of 0 Kg P/ha.

Similar findings were also reported by Nasir *et al*., (2016) who reported that increased P resulted to higher number of pods, fresh and dry shoot weight. This result is in agreement with Dugje *et al*., (2009) who reported that P is the most deficient nutrient and when optimum level is applied it improves the weight of the shoot.

## CONCLUSIONS AND RECOMMENDATIONS

The integration of rhizobium at 200 g R/ha and phosphorus at 30 kg TSP/ha significantly increased plant height, nodule number, fresh and dry nodule weight, number of branches and pods, fresh shoot weight and dry shoot weight of soybean. Application of rhizobium inoculation and triple superphosphate increased nodulation, growth and yield components of soybean. Growth, nodulation and yield differences in terms of superiority or inferiority was not significantly influenced by the treatments. The research has shown that to increase soybean production, integrated application of rhizobia and TSP at higher application rate is recommended regardless of soybean genotype. The present study therefore recommends treating soybean seeds with rhizobium inoculants before planting and application of TSP fertilizer at the rate of 200 g R and 30 kg TSP/ha for increased production.

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