EVALUATING THE EFFECT OF DIFFERENT RATES OF PHOSPHORUS INTEGRATED WITH INOCULUM ON GROWTH AND YIELD OF BUSH BEANS IN SOUTH PROVINCE OF RWANDA

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ABSTRACT

Bush bean (phaseolus vulgaris) is a leguminous grain crop which belongs to the fabaceae family. Agriculture in Rwanda remains unproductive due to intensive exploitation of shrinking land brought about mainly by high population density. This study was carried out at, to evaluate the effect of different rates of phosphorus integrated with rhizobium strain on growth and yield of bush bean. The field experiment was designed in a randomized complete block design (RCBD) with 8 treatments and 3 replications. The treatments used during the study includes T1:Seed only as control (Without phosphorus and inoculum), T2: Inoculated seeds (1.33g of rhizobium), T3:Rate I of phosphorus (19.5t.ha-1 of TSP) with non-inoculated seeds, T4:Rate II of phosphorus(21.66.t.ha-1 of TSP) with non-inoculated seeds, T5:Rate III of phosphorus(23.5.t.ha-1 of TSP) with non-inoculated seeds, T6:Rate I of phosphorus(19.5t.ha-1 of TSP) with inoculated seeds (1.33g of rhizobium), T7:Rate II of phosphorus(21.66.t.ha-1 of TSP) with inoculated seeds (1.33g of rhizobium), T8:Rate III of phosphorus(23.5.t.ha-1 of TSP) with inoculated seeds (1.33g of rhizobium). Growth parameters evaluated include number of leaves, number of branches, leaf area index, while yields related parameters were biomass accumulation, number of seeds per pod, number of nodules per plant, number of viable seeds, and a sample of 100 seeds from each experimental plot were tested for further evaluation. The results revealed a significant increase of bush bean by 21.666kg/ha due to integration of phosphorus and seeds inoculation (1.33g of rhizobium) when compared to other treatments. The observed results also indicated non-significant effect on plant height and the number of pods among tested parameters in the experiment. Therefore, farmers who need to produce animal feeds can be recommended to use the combination of phosphorous (23.5.t. ha-1 of TSP + 1.33g rhizobium) as observed in T8 which recorded highest biomass during the study. The influence of these outputs was due to significance interaction between phosphorus fertilizer and bacteria species (rhizobium) in amazing action of fixing atmosphere nitrogen in the soil and crop (bush beans) could benefit in its growth and yield. It can be concluded that, to get high yield of bush bean, integration of phosphorus and rhizobium at 21.66. t. ha-1 of TSP should be used by the farmers. The different types of rhizobium strains combined with adequate rates of phosphorus can be tested for further research.

Keywords: Bush beans, Phosphorus, Inoculum, Integration.

1. INTRODUCTION

Bush bean (*Phaseolus vulgaris.L*) is a grain legume crop belong to the family of fabaceae (ITIS 2014). Bean is a key staple crop in Rwanda and it is mainly cultivated under smallholder farmers across the country (Singirankabo, et al., 2020). The production and availability of bush bean can vary depending on ongoing farming season and other factors like weather conditions and market demand and it can be grown twice per year in season A and B (Larochelleet al., 2016). According to FAOSTAT (2019) estimates, the global bean production has risen from 16.6 million tons (Mt) in 1988 and 29.3 Mt in 2015. Bush bean is one of the mostly grown and consumed legumes in the worldwide (Roberts,1970). The crop plays a pivotal role in providing protein, fiber, vitamin and other minerals for people around the planet for staying healthy. Global production of dry beans has increased significantly by 10% with of 24.3million metric tons (FAOSTAT, 2019). Myanmar is a leading producer of bush beans with an estimation of 5,846,622 tons produced 2024, followed by India with 5,310,000 tons, Brazil 2,906,508 tons, china with 1,297,867 tons and Tanzania 1,197,489 respectively (FAO, 2024). Bush bean is an important crop in East Africa, it provides source food and income for small holder farmers (Kirkby et al., 2000). In recent years, bush bean production and productivity has increased significantly in the region (Katungiet al., 2009). The average annual consumption of bush beans per capita in Rwanda is approximately 29kg (Palmer, 2014). This increase is largely due to improved variety, better agronomic practices, and increased access to input such as fertilizer and cheap labour (Katungi et al., 2023). In Rwanda bean productivity was 1.03 tons per hectare in 2016/2017 fiscal year but was decreased to 0.6 tons per hectare, the target was 1.69 tons per hectare in the 2020/2021 fiscal year, but the production remains low (Nkurunziza, 2021). According to annual Rwanda's Seasonal Agriculture Survey (SAS) 2019/20 edition that covers three main agricultural 2020 seasons A, B and C, the average yield of beans was estimated at 626 kilograms per hectare in season A and 740 kilograms per hectare season B (Nkurunziza, 2021). Thus, beans are considered as meat for poor people because they can be easy to obtain Nsengiyumva et al, (2017). Bush bean is one of the best crops for the beginning gardener to grow, starting them from seed is easy, they don't require large maintenance, and they will give an easy return on your investment (Hicks-Hamblin, 2023). The people consume a lot of beans while the arable land is too small, due to the population density (Weatherspoon et al., 2021). Beans farmers do not have enough knowledge to use additional agricultural inputs such as fertilizers like NPK (Nitrogen, Phosphorus and Potassium), Urea and other essential inputs like rhizobium that have an ability to fix natural atmospheric nitrogen for the crop and other succeeding cereal crops. The use of chemical fertilizers mainly urea as source of nitrogen can pollute the environment due to leaching and they are far below the reaching of most smallholder farmers. Inorganic fertilizers and rhizobium are still not efficiently used in terms of rates, time of application as well as choice of the right fertilizer by the smallholder farmers. This research hypothesizing that different rates of phosphorus integrated with inoculated seeds may be used to produce high yield of beans and minimizing the cost of nitrogen where it is fixed naturally by rhizobium bacteria.

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2. MATERIALS AND METHODS

Description of Study site

This research was carried out at University of Rwanda, Tonga station which is located at Huye district of Rwanda during 2022/2023 growing season. Basically, the site is located at an average of altitude of 1600 m-2500 m above sea level, the district includes both higher altitude area and lower altitude region. The annual rainfall of the area is around to 1200 mm, average temperature 18 -23^{0}C and it can vary slightly throughout the year, December to February and the coolest month is June to (Huye ye-DDS, 2024).

Trial Establishment

The experiment was laid out in a randomized complete block design (RCBD) using 8 treatments and 3 replications with 2 blocks to give a total of 24 plots. Each plot was measuring 2.8m*3m (8.4m^2) and experimental gross plot area of 67.2 m^2. Each plot was separated from one another by 0.5 m and 0.5 m from block to block. Each plot contained 7 rows planted with 15 plants per each row resulting to a total of 315 plants in each plot. All agronomic practices were respected as per recommendation of Rwanda Agriculture Board (RAB, 2020). In this study, tested variety was obtained from RAB, it is known as NUA566 which is released in 2021. The variety matures within 85-90 days after planting. The treatments used during the study includes T1:seed only as control (Without additional of phosphorus rate and inoculum), T2: Inoculated seeds (1.33g of rhizobium), T3:Rate I of phosphorus(19.5t.ha-1 of TSP) with non-inoculated seeds, T4:Rate II of phosphorus(21.66.t.ha-1 of TSP) with non-inoculated seeds, T5:Rate III of phosphorus (23.5.t.ha-1 of TSP) with non-inoculated seeds, T6:Rate I of phosphorus(19.5t.ha-1 of TSP) with inoculated seeds (1.33g of rhizobium), T7:Rate II of phosphorus(21.66.t.ha-1 of TSP) with inoculated seeds (1.33g of rhizobium), T8:Rate III of phosphorus(23.5.t.ha-1 of TSP) with inoculated seeds (1.33g of rhizobium).

Data collection

The data collected were growth parameters and yield parameters. For the growth parameters plant height, number of leaves, number of branches and leaf area were measured, while yield had the following parameters mainly, biomass, number of pods number of seeds per pod, number of nodules per plant, number of viable seed.

Data analysis

The data collected were analyzed by using GENSTAT statistical software package version 15th edition (Genstat 1995), to determine the relationship of different treatments and ANOVA was used to separate treatments means and were performed using the least significant difference (LSD) test (P= 0.05).

3. RESULTS

Soil analysis

Soil samples were collected from 0 to 20 cm depth within the area of experiment, using a zigzag system. The collected soil was mixed to obtaining composite sample to represent the layout for the purpose physiochemical analysis. Therefore, the samples were dried in an oven and then after grounded to pass into 2 mm sieve in size for analysis of the following, total nitrogen(%), available Phosphorus (ppm), available Potassium (ppm), Organic Carbon (%), Cation Exchange

Capacity(CEC), pH, available calcium (%), Magnesium (%), and other micro elements such Sodium (meq/100gr), Aluminium (meq/100gr), Hydrogen, (meq/100gr), and Iron (%) (Table 1).

Table1. Soil analysis results at Tonga Station

Soil Properties	
N (%)	0,146
P(ppm)	0.551
K (%)	0.6
OC (%)	1.002
Ph	5.639
Ca (%)	0.281
Mg (%)	0.045
Na(meq/100gr)	0.027
Al(meq/100g)	0.046
H (meq/100g	0.657
CEC	3.4054
Fe (%)	0.678

The Response of Application of different phosphorus rates with inoculum on growth of bush beans

The results from this study revealed a significant $p<0.05$ effect on plant height, number of leaves, number of branches and leaf area index (Table 2). The Rate II of phosphorus (21.66.t. ha^{-1} of TSP) with inoculated seeds (1.33g of rhizobium) increased plant height (37.83 cm), number of leaves (2.583) , number of branches (6.983) and leaf area index (185.3) with , when compared to control where nothing added except seeds only. While plant height did not show any differences.

Table 2. The response of application of different rates of phosphorus on growth parameters on bush beans.

Treatments number	Plant height at (cm)	Number of leaves	Numbers of Branches	Leaf Area
8	37.5^{a}	2.5^{a}	6.25^{a}	189.1^{a}
2	37.83^{a}	2.1^{a}	5.5^{ab}	185.3^{a}
5	36.83^{a}	2.333^{ab}	6.083^{a}	165.4^{ab}
6	36.75^{ab}	2.333^{abc}	5.417^{ab}	173.7^{a}
7	38.17^{ab}	2.583^{a}	6.983^{b}	185.3^{a}
4	34.08^{ab}	2.25^{abc}	5.917^{ab}	147.3^{ab}
3	34^{b}	2.333^{ab}	5.167^{ab}	134.9^{a}
1	32.92^{b}	2.417^{a}	5.083^{b}	134.3^{a}

Cv%	4.7	0.4813	16.3	62.68
p-Value	0.4	0.003	0.03	0.03
L.s.d	5.393	0.2244	1.588	23

The Response of Application of different phosphorus rates on yield aspect

The results revealed significant p<0.05 effect on the number of seeds per pod, number of nodules, number of viable seeds and gram, but revealed non-significant effect on the number of pods (Table 3). Observed results indicated that treatment contained T7: Rate II of phosphorus (12.12g/ plot =21.66.t. ha-1 of TSP) with inoculated seeds (1.33g of rhizobium), increase number of nodules, viable seeds by and gram by when compared to other treatments. In contrast Number of pods didn't show any significance differences among the treatments with p> 0.05.

Table 3. The response of application of different phosphorus rate on yield parameters

Treatment number	Number of pods	Seed number per pod	Number of nodules	Viable seeds	Gram in 100 seeds(g)
8	7.417	1.896[ab]	0.4635[a]	80[a]	59.33[ab]
2	6	1.5[b]	0.375[b]	44.3[b]	62.67[a]
5	6.667	1.667[abc]	0.4167[a]	56.7[ab]	60[a]
6	7.583	1.542[ab]	0.474[a]	58.7[ab]	63.67[a]
7	8.5	2.125[a]	0.5312[a]	63.3[a]	64[a]
4	6.5	1.854[ab]	0.4062[ab]	57.3[ab]	62[a]
3	5.333	1.625[abc]	0.3854[b]	43.7[b]	58.67[ab]
1	6.167	1.333[b]	0.3333[b]	40.3[b]	52[b]
Cv%	17.1	17.1	17.1	35.6	8.94
p-Value	0.09	0.002	0.003	0.004	0.003
L.s.d	2.031	0.5077	0.1269	35.6	89.4

The effect of Application of different phosphorus rate and inoculated seed on beans Biomass production.

The results revealed a significant 0,002 <0.05 effect on biomass due to the application of phosphorus integrated with rhizobium (Table 4). Treatment eight (T8) with Rate III of phosphorus (23.5.t.ha-1 of TSP) with inoculated seeds (1.33g of rhizobium) had higher biomass while T3(Rate I of phosphorus(19.5t.ha-1 of TSP) with non-inoculated seeds had the low biomass accumulation compared to the other treatment tested.

Table 4. The effect of application of different phosphorus rate and inoculated seed on beans biomass accumulation.

Treatments number	Biomass (t/ha)
8	1.305[a]
6	1.296[a]
5	1.293[a]
7	1.254[ab]
4	1.22[ab]
1	1.079[ab]
2	1.045[b]
3	0.929[ab]
Cv%	20
p.Value	0.002
L.s.d	20

The effect of application of different phosphorus rates integrated with inoculum on bush beans yield.

At the **table 5**, indicated that the data observed in the study were highly significant at where with value on p< 001. the significant effect among treatments were observed within experiment. Thus, Treatment seven (T7) had higher yield with average of 3.741t. ha-1 compared to the remaining treatments under study due to added phosphorus Rate II (21.66.t. ha-1 of TSP) with inoculated seeds (1.33g of rhizobium). Contrary treatment one (T1) had low yield as control

Table 5: Total yield of bush obtained due to influence of phosphorus rates integrated with inoculum

Treatments	Yea1 one (t/ha)	Year two(t/ha)	Average (t/ha)
T7	3,371[a]	4,111 [a]	3,741 [a]
T5	2,533[b]	3,440 [b]	2,986 [b]
T8	2,423[b]	3,419[b]	2,921 [b]
T4	2,406 [b]	3,148[b]	2,777[b]
T6	1,818[c]	2,219 [c]	2,019[c]
T3	1,799 [c]	2,217[c]	2,008 [c]
T2	1,455[d]	1,832[d]	1,643 [d]
T1	438 [e]	320 [e]	379[e]
CV%	6	7.6	6.2
p.value	<.001	<.001	<.001
lsd	212	346	248.9

4. DISCUSSION

Soil analysis was done to determine the status of chemical, physical and biological characteristics at the place where the experiment was carried. The laboratory results indicated that the site was characterized with slightly acidic soil (5.639) which favour availability of most nutrients and growing of crops as it was reported by (Johnson,1970). The soil analysis results indicated insufficient soil organic matter (1.002%) confirm the existence of depleted soil and this concurred with Nyamazi et al., 2020). The major nutrients nitrogen and phosphorus were found in limited quantities of 0.146 % and 0.551 ppm respectively, meaning the soil is poorly enriched with important nutrients required for plant growth and there will a limitation of nitrogen fixation in the soil. Okalebo et al. (2002) argued that, soils containing appropriates quantities of phosphorus promotes biological nitrogen fixation due to the presence of high rate of biologically fixing bacteria around the rhizosphere. The present results revealed that the treatment contained phosphorus Rate II (21.66.t. ha-1 of TSP) with inoculated seeds (1.33g of rhizobium) shown the significant differences on growth parameters mainly number of leaves, leaf is and number of branches while Plant height did not show any differences. The current findings agreeing the observation reported non significance response on plant height and number of pods as Birhan (2006) said in his results. The significance difference were also observed Treatment seven(T7) with rate of 21.666 t/ha with of rhizobium (1.33g) on number of leaves, number of branches and leaf area. Therefore, the same results reported by livera et al. (2004), argued that inoculation of rhizobium have a positive influence at vegetative stage of beans. Thus, both rates of phosphorus and inoculated seed influence yield parameters as similar findings revealed by Kumar et al (2015), and (Ndlovu, 2019) with their observation, rhizobium bacteria and phosphorus play significance variation in seeds formation of beans. Treatment eight with (23.5.t.ha-1 of TSP) with seeds coated with rhizobium(1.33g) had higher biomass accumulation due to adequate rate amount of phosphorus added. Bean plants grown in soils rich in phosphorus have higher chlorophyll content than those in soils poor in phosphorus, which may suggest that the presence of phosphorus greatly affects photosynthesis. Similar results also appeared in the research of Shital et al. (2021). The observation was revealed that a number seed of per pods, and number nodule, viable seeds, weight of 100 seeds and yield was significantly increased by respectively as a result of the integration of phosphorus and rhizobium at the rate of 21.666kg/ha and 1.33g of rhizobium showed a significant increase in production of nodules. Similar results obtained by Ndlovu (2019), found that effectiveness of inoculation together with phosphorus combined fertilizers can have a net positive effect on nodulation, number of seeds, pod numbers, seed quality and overall productivity of the crop. Shimelis (2019), contradicting with the results of this current research when she observed that inoculation combined with phosphorus had no effect on the yield of haricot beans. The positive impact on nodulation on this current study could be as a result of the variety used and spacing used which were favouring high rate of biological nitrogen fixation contributed to higher yields. Moreover, positive and significant relationships between inoculation with rhizobium and P fertilization was observed and promising robust sustainable ways of producing a bumper harvest of bush beans in Rwanda.

5. CONCLUSION

The results showed that the use of phosphorus integrated with rhizobium indicated significance differences among the treatments under test and revealed a positive impact on bush bean production in Rwanda as shown by the treatments involved phosphorus Rate II (21.66.t. ha-1 of

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TSP) with inoculated seeds (1.33g of rhizobium) show good results in both growth and yield of bush beans. Biomass is also important parameter in this research, for instance the farmers who need to produce animal feed can be recommended to use phosphorus at the rate of (23.5.t.ha-1 of TSP) with inoculated seeds (1.33g of rhizobium). Based on the findings, it can be concluded that to get best returns on bush bean farmers must use the rate of 21. 666kg/ha P integrated with rhizobium at 1.33g. Future researches should investigate other different types of rhizobia strain combined with upper rates of phosphorus to see their contributions to bush beans production in other provinces.

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conflict of interest statement

The authors state no conflict of interest among them.

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