EFFECT OF PHOSPHORUS AND RHIZOBIUM INOCULATION ON YIELD AND YIELD COMPONENTS OF MUNGBEAN VARIETIES AND WEEDS BIOMASS

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https://doi.org/10.28941/24-4(2018)-10

ABSTRACT

Microorganisms play vital role in improving soil properties and enhancing agricultural productivity through nitrogen (N) fixation and phosphorus availability. A Field experiment was laid out at Agronomy Research Farm of The University of Agriculture, Peshawar, Pakistan during kharif 2016. Randomized complete block (RCB) design was used with split plot arrangement keeping three replications. Three varieties (NM-11, CHK-06 and Ramzan) inoculated with rhizobium strain were allotted to main plots while four phosphorus levels (0, 30, 60 and 90 kg ha^{-1}) were designed as sub plots in the form of single super phosphate (SSP). Phosphorus (P) levels, rhizobium inoculation and varieties significantly ($P \leq 0.05$) affected the performance of mungbean. More days to flowering (48), pods formation (60) and physiological maturity (74) were recorded for Ramzan variety while less days to flowering (46), pod formation (56) and physiological maturity (68) with highest leaves $plant^{-1}$ (24), branches $plant^{-1}$ (15), plant height (70 cm), nodules $plant^{-1}$ (15), pods $plant^{-1}$ (19), biological yield (2756 kg ha^{-1}), seed yield (842 kg ha^{-1}), weeds fresh (55.7 kg ha^{-1}) and dry weight (22.8 kg ha^{-1}) was recorded for variety NM-11. Among phosphorus levels, more days to flowering (50), pod formation (62) and maturity (74) was recorded in control plot while less days to flowering (43), pod formation (57) and maturity (70) with highest leaves $plant^{-1}$ (24), branches $plant^{-1}$ (15), plant height (68.3 cm), nodules $plant^{-1}$ (17), pods $plant^{-1}$ (22), biological yield (3063 kg ha^{-1}), seed yield (910 kg ha^{-1}), weeds fresh (64.5 kg ha^{-1}) and dry weight (25.4 kg ha^{-1}) was recorded in plots which received P @ of 90 kg ha^{-1}. Inoculated plots performed better for all the studied parameters than un-inoculated plots. It can be concluded from the experiment that inoculating Mungbean variety NM-11 with rhizobium (Phaseoli) along with P application @ of 90 kg ha^{-1} resulted in better yield and yield components.

Keywords: Rhizobium, physiological maturity, leaves $plant^{-1}$, nodules $plant^{-1}$, pods $plant^{-1}$, seed yield.

Citation: Khan, F.U., A. A. Khan, M. F. Jan, W. Liaqat and Inamullah. 2018. Effect of phosphorus and rhizobium inoculation on yield and yield components of mungbean varieties and weeds biomass. Pak. J. Weed Sci. Res. 24 (4):409-427.

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INTRODUCTION

Maize (Zea mays L.) is the third Mungbean (Vigna radiata L.) has been considered as vital pulse crop of Pakistan and other regions of South Asia. The richness of protein (24%) makes it prominent with excellent digestibility as compared with soybean. It has dual purpose applicability used for both green manuring as well for livestock fodder (Sarwar et al., 2004). The presence of lysine along with bundle of other amino acids, which cereal grains are lacking gives it a unique status (Malik et al., 2004). The proportion of other components via; fats (1-30%), fibers (3.5-4.5%), ash (4.5-5.5%) and carbohydrates (50.5%) with a considerable quantity of phosphorous (367) and calcium (132) mg 100^{-1} g of seed respectively are present in mungbean (Frauque et al., 2000). This is generally the most cultivated pulse crop of the arid regions of Pakistan, particularly in kharif season (Khattak et al., 2004). In Pakistan, during 2014-15, 0.098 million tons production was obtained from the area of 0.127 million hectares with average yield of 776 kg ha^{-1}. While in the province of Khyber Pakhtunkhwa (KP), the area under mungbean cultivation was 0.0088 million hectares with total production of 0.0058 million tons having average yield of 619 kg ha^{-1} (MNFSR, 2014-15).

The use of biological nitrogen fixation technology in the form of Rhizobium inoculants in grain legumes can be an alternative of nitrogenous fertilizers. Mungbean, like other legumes improves soil fertility by fixing atmospheric nitrogen through the process of symbiosis. Leguminous crops meet up their nitrogen requirement through biological nitrogen fixation depending on proper growth, development and leghemoglobin content of the root nodules (Hussain et al., 2014b). The estimation of nitrogen fixed by rhizobium estimated to be much as produced by commercial fertilizer units (Gordon et al., 2001). Inoculation with rhizobium strains plays vital role in disease suppression, enhanced production of growth regulators and more biological fixation of nitrogen to ammonia or nitrate and ultimately in yield improvement (Naz et al., 2009). Different studies showed significant effect of rhizobium inoculation on growth enhancement, yield and yield components of mungbean (Malik et al., 2006).

Phosphorus (P) performs various functions either related to growth and development or flowering and ripening. It is the constituent of photosynthetic apparatus and a unit of ATP, the energy production and carrying system (Raboy, 2003). Phosphorus limitations reduced mungbean production by about 50% in almost all growing areas of tropic soils (Uchida, 2000). Phosphorus is mainly responsible for the enhancement of nodule growth, development and dry matter production in legumes. It also enhances the energy production system of the crop as ATP needs phosphorus for energy which is assimilated to seeds in reproductive stage (Schulze et al., 2006). In soil, increase in P level trigger nitrogen absorption, pod formation and energy process (Anetor and Aknirinde, 2006). Limitations of P results in restricted root growth, low photosynthetic efficiency and other growth and development related function which in other way affect nitrogen fixation in legumes (Aziz et al., 2016).

Combined studies of phosphorus and rhizobium strains revealed improved nodulation, enhanced nitrogen fixation and more specifically nodule activity is boosted (Zahran, 2000). Also, literature available showed that process of photosynthesis and chlorophyll content of legume increased with combined application of rhizobia and phosphorus (Nyoki and Ndakidmi, 2014). The objective of the present study was to determine the effect of P application on various mungbean varieties inoculated with rhizobium.

MATERIALS AND METHODS

Experimental details

To evaluate the effect of phosphorus levels and rhizobium inoculation on mungbean varieties, an experiment was conducted at Agronomy Research Farm, The University of Agriculture Peshawar during summer 2016. Mungbean seeds and rhizobium (Phaseoli) inoculant were collected from National Agriculture Research Centre, Islamabad. Randomized complete block (RCB) design with split plot arrangement having three replications was used. Subplot size was kept 9 m^2 having 6 rows, 30 cm apart. Plant to plant distance was kept 10 cm. Crop was sown on 18 June 2016 and harvested on 5 September 2016. Varieties were allotted to main plot along with rhizobium (Phaseoli) inoculation and phosphorus was applied to sub plot. Seed was used @ 30 kg ha^{-1}. Phosphorus was applied in the form of single super phosphate (SSP) @ of (0, 30, 60 and 90 kg ha^{-1}) respectively all at sowing. Rhizobium (Phaseoli) inoculation was done by seed treatment @ of 30 g kg^{-1} using 10% sugar solution as sticker. Basal dose of nitrogen was applied @ of 30 kg ha^{-1} from urea source only once at the sowing time. All other agronomic practices were kept constant for each treatment for successful crop production.

Procedure for recording data

Data regarding weeds fresh weight (kg ha^{-1}) and dry weight (kg ha^{-1}) were determined through randomly used self designed ring quadrat of 25cm x 25cm in each sub plot. Weeds were harvested from each quadrat ring, weighed in the field with an electronic balance and averaged to determine weeds fresh weight per quadrat. The harvested weeds were then kept in oven for 24 hours at 105ºC for drying which were then weighed and averaged to determine weeds dry weight per quadrat. The obtained data was converted into kg ha^{-1}. Data pertaining days to flowering initiation was observed by counting number of days from date of sowing till 50% plants produced flowers. Pod initiation was noted from emergence till formation of 50% pods in each sub plot. Physiological maturity was observed by counting days from sowing day till appearance of light brown color in 50% pods. Leaves $plant^{-1}$ was recorded by counting leaves in ten randomly selected plants and then averaged for a single value. Branches $plant^{-1}$ was recorded by randomly selecting ten plants in each sub plot. Branches were counted and branches $plant^{-1}$ was worked out. Ten random plants were selected for measuring average plant height. Height of plants were recorded with the help of measuring tape from ground to tip of plant. Pods $plant^{-1}$ was recorded by counting pods in ten randomly selected plants and averaged for a single value. Nodules $plant^{-1}$ were recorded by uprooting ten random plants with the help of spade and washed out without having any damage to roots. The nodules $plant^{-1}$ was counted and averaged for a single reading. Biological yield was recorded by harvesting four central rows in each sub plot. Materials were sun dried up to constant weight, weighed and converted into kg ha^{-1}. Seed yield was recorded from four rows harvested for biological yield by threshing the crop. The seeds obtained were weighed for calculating seed yield (kg ha^{-1}).

STATISTICAL ANALYSIS

Analysis of variance procedure was followed for RCB design with split plot arrangement to analyze the data. Mean comparison was carried out using Least Significant Difference (LSD) test at $P \leq 0.05$ when F-test was found significant (Jan et al., 2009).

RESULTS AND DISCUSSION

Weeds fresh and dry weight (kg ha^{-1})

Phosphorus (P) levels and rhizobium inoculation significantly ($P \leq 0.05$) affected weeds fresh and dry weight while varieties had no significant effect on weeds fresh and dry weight (Table 1). Highest weeds fresh (64.5) and dry (25.4) weight was recorded in plots treated with phosphorus @ of 90 kg ha^{-1} followed by plots which received P @ of 60 kg ha^{-1} while lowest weeds fresh (57.8) and dry (18.9) weight was recorded in control plots. Highest weeds fresh (55.4) and dry (22.8) weight was recorded in rhizobium inoculated plots as compared to un-inoculated plots. Possible reason for more weeds fresh and dry weight with increased P might be due to the fact that P enhances plant growth and development while weeds are strong competitors for different sources like water, space, nutrients and other prerequisites necessary for production, with all these requirements available in sufficient quantity weeds weight tends to increase. Our results are in agreement with findings of Amanullah et al. (2016) who reported that application of phosphorus fertilizer significantly increase weeds fresh and dry weight.

Leaves plant^{-1}

Varieties (V), rhizobium inoculation (I) and phosphorus (P) levels significantly ($P \leq 0.05$) affected leaves plant^{-1} (LP) of mungbean (Table 1). V x P interaction was found significant (Figure 1) while remaining interaction remained non-significant. Among varieties, NM-11 produced more LP (24) followed by CHK-06 (20) which was statistically similar with Ramzan (20). Plots inoculated with rhizobium strains produced more LP (22) as compared to un-inoculated plots (21). Phosphorus application increased LP. More LP (24) was recorded in plots which received P at the rate of 90 kg ha^{-1} succeeded by 60 kg ha^{-1} (22) and 30 kg ha^{-1} (20) respectively. While lowest number of LP were observed in control plots. Leaf is primary source of photosynthetic accumulation. Literature depicts that more luxurious vegetative growth which is defined by leaves number leads to pronounced reproductive growth. In case of P, more LP (24) was recorded in plots treated with P at the rate of 90 kg ha^{-1} while less LP (18) was recorded where no P was applied. The possible reason might be that P enhanced growth and development which resulted in more numbers of LP. Moreover, P application also enhanced uptake of other nutrients like N which contributed to vegetative growth of the plant. As P application has positive effect on P and N uptake which resulted in improved vegetative and reproductive attributes of crop such as leaves, branches, pods and seeds (Uddin et al., 2014). Our results are similar to that of Amanullah et al. (2014) who recorded more leaves plant^{-1} with increasing P levels.

No. of Branches plant^{-1}

Statistical analysis revealed that varieties, rhizobium inoculation and phosphorus significantly ($P \leq 0.05$) affected branches plant^{-1} (Table 1). Among interactions, V x P was found significant (Figure 2) for branches plant^{-1}. In case of varieties, NM-11 produced more branches plant^{-1} (15) followed by CHK-06 (14) while less branches plant^{-1} was recorded for Ramzan (13). Inoculation increased number of branches plant^{-1}. More branches plant^{-1} (14) was recorded in inoculated plots which were statistically ($P \leq 0.05$) different from un-inoculated plots (13). In case of phosphorus, branches plant^{-1} increased with increase in P level. More branches plant^{-1} (15) was recorded with P applied at the rate of 90 kg ha^{-1} followed by 60 kg ha^{-1} (14). While less branches plant^{-1} was recorded in control plots (13) which was statistically similar to plots treated with 30 kg ha^{-1} P. Variety and phosphorus interaction revealed that variety CHK-06 showed no increased in branches plant^{-1} with increasing P levels. The response of variety Ramzan in terms of branches plant^{-1} to P increment was linear. However, sharp increased in branches plant^{-1} was recorded for variety NM-11 with inclination of P from 60 to 90 kg ha^{-1}. Branching is basically a genetic character but environmental conditions may also have an influence on branches plant^{-1}. Branches play an important role in increasing seed yield. Among varieties, NM-11 produced more branches plant^{-1} (15) while less branches plant^{-1} (13) was observed in Ramzan. Our results are similar to (Kabir and Sarkar, 2008) who concluded that different varieties varied in leaves plant^{-1}. Inoculation also significantly increased branches plant^{-1} over un-inoculated plants. The higher phosphorus availability and enhanced N uptake in soil help plants to uptake other nutrients which contribute to improved growth and enhanced production of branches (Uddin et al., 2014). Our findings are supported by (Hamza et al., 2016) who stated that branches plant^{-1} varied significantly due to the different levels of P. The lowest values of branches plant^{-1} were recorded under control plots, while highest values with more phosphorus application. The No. of branches plant^{-1} significantly increased through P (Kumar et al., 2012).

Days to flowering (DTF)

Varieties, rhizobium inoculation and phosphorus fertilization significantly (P≤0.05) affected days to flowering (DTF) as indicated in Table 2. All interactions were found non-significant for DTF. Among Varieties, Ramzan took more (50) days to flowering followed by CHK-06 (48) while NM-11 took less days to flowering (46). Our results are in line with (Ndlovu, 2015) who reported differences in cultivars for phenological traits due to their genetic variations. Khan et al. (2008) reported that crop phenology is genetics dependent which is influenced greatly by environment and genetic makeup of cultivars. Less days to flowering (47) was observed in inoculated plots as compared to un-inoculated plots which took (49) days to flowering. Ndlovu (2015) reported that inoculation caused significant decrease in days to flowering. In case of P levels, increase in P rate decreased days to flowering. More days to flowering (50) was observed in control plots while less days to flowering (43) were observed in plots treated with P at the rate of 90 kg ha^{-1}. Phosphorus role in plant development from root emergence to seed production is well known, as it is the main component of ATP (energy currency), drive the whole life cycle of crop plants. It enhanced transition from vegetative to reproductive stage of plants, with more P, growth and development improved as plants have sufficient energy to carry out its metabolic process necessary to reproduce. These results are strongly supported by (Amanullah et al., 2014) who stated that increased in P level decreased days to phenological traits.

Days to pod formation (DPF)

Varieties, rhizobium inoculation and various phosphorus levels significantly (P≤0.05) affected days to pod formation (DPF) as exhibited in Table 2. However, all interactions were found non-significant for DPF. Among varieties, Ramzan took more (60) days to pod formation which was statistically similar to CHK-06 (60) while NM-11 took less days to pod formation (56). Less days to pod formation (57) was observed in plots received rhizobium inoculation as compared to un-inoculated plots which took maximum (61) days to pod formation. Significant variation was observed in days to pod formation with P application at different rates. Increase in P level decreased days to pod formation. Less days to pod formation (57) was recorded in plots supplied with 90 kg ha^{-1} P followed by plots treated with P at the rate of 60 kg ha^{-1} (58) while more days to pod formation (62) was recorded in plots having no P. These results are supported by Amanullah et al. (2014) who stated that application of P significantly decreased days to phenological traits.

Days to physiological maturity (DPM)

Data concerning days to physiological maturity (DPM) is presented in Table 2. Statistical analysis revealed that varieties, rhizobium inoculation and phosphorus significantly (P≤0.05) affected DPM. Interactions among V x P, V x I, I x P and V x I x P were found non-significant for DPM. Among varieties, RAMZAN took more (74) days to physiological maturity which was statistically similar to CHK-06 (72) while NM-11 took less days to physiological maturity (68). Less days to physiological maturity (70) was observed in inoculated plots as compared to un-inoculated plots which took (73) days to physiological maturity. Increase in P level decreased days to physiological maturity. Minimum days to physiological maturity (70) was recorded in plots applied with P at the rate of 90 kg ha^{-1} which was statistically at par with plots treated with P at the rate of 60 kg ha^{-1} (70) while more days to physiological maturity (74) was recorded in plots having no P. These results are in line with Amanullah et al. (2014) who documented that P fertilizer have linear relationship with phenological traits up to limit. Application of phosphorus significantly reduced days to physiological maturity.

Plant height (cm)

Significant ($P \leq 0.05$) difference was observed in plant height in response to varieties, rhizobium inoculation and phosphorus levels (Table 2). Interaction of V x P was found significant (Figure 3) for plant height while other interactions remained non-significant. Among varieties, NM-11 produced taller plants (70 cm) followed by CHK-06 with plant height (65.8 cm) while variety Ramzan produced shorter plants (62.8 cm). Inoculation of rhizobium strain increased plant height. Taller plants (67.5 cm) was recorded in inoculated plots as compared to un-inoculated plots (64.8 cm). Among phosphorus levels, increased in P increased plant height. Tallest plants (68.3 cm) recorded in plots treated with P at the rate of 90 kg ha^{-1} which was statistically similar with P applied at the rate of 60 kg ha^{-1} (68.3 cm) followed by plant height of (65.6 cm) in plots fertilized with 30 kg ha^{-1} P while plants in control plots attained shortest height (62.4 cm). In case of V x P interaction, variety NM-11 showed linear increased in plant height with increasing level of phosphorus while varieties CHK-06 and Ramzan showed linear increased in plant height with phosphorus increment up to 60 kg ha^{-1} beyond which no further increased in plant height was observed. This difference in plant height might be due to hereditary superiority and genetic makeup of the varieties. Cultivar did significantly affected plant height (Ndlovu, 2015; Kabir and Sarkar, 2008).

As regarding inoculation tallest plants (67.5 cm) was noted in plots inoculated with rhizobium strains as compared to un-inoculated plots (64.8 cm). The increased in plant height due to rhizobium inoculation could be supported by the argument that microorganisms carry out nutrients decomposition in soil and fix nitrogen which is considered prominent factor influencing vegetative growth specifically plant height. Moreover, microorganisms also produces phytohormone which further promotes plant growth. Rhizobium inoculant alone gives higher plant height than control (Bhuiyan et al., 2008b).

Nodules $plant^{-1}$

Statistical analysis showed that varieties, rhizobium inoculation and phosphorus levels significantly ($P \leq 0.05$) affected nodules $plant^{-1}$ (NP) as presented in Table 3. Among interactions V x P interaction was found significant (Figure 4) for nodules $plant^{-1}$. Among varieties, NM-11 produced more NP (15) succeeded by Ramzan (14) and CHK-06 (13). Inoculated plots produced more NP (14) as compared to non-inoculated plots (13). NP increased with increased in P levels. Plots treated with P @ of 90 kg ha^{-1} produced more NP (17) subsequently followed by 60 kg ha^{-1} (16) and 30 kg ha^{-1} (12) while lesser NP was recorded in control plots (10). Interaction of V x P indicated that all varieties showed linear increased in NP with increased in P levels. However, variety NM-11 showed no further increase beyond 60 kg ha^{-1} P level. This significant positive effect of P on nodulation underlines the influence of P on nodule development through its basic functions as an energy source (Malik et al., 2004). Ahmad et al. (2015) reported that nodules increased with increased in P and argued that increased nodule number with higher levels of phosphorus may be attributed to supply of P to the plant roots at various growth stages specially at the time of nodule formation.

Pods $plant^{-1}$

Data on pods $plant^{-1}$ is presented in Table 3. Result showed that pods $plant^{-1}$ was significantly ($P \leq 0.05$) affected by varieties, rhizobium inoculation and various phosphorus levels. Interaction of V x P was found significant (Figure 5) while other interaction remained non significant. Among varieties, NM-11 produced more pods $plant^{-1}$ (19) which was statistically at par with CHK-06 (17). Inoculated plots produced more pods $plant^{-1}$ (18) as compared to un-inoculated plots (17). Pods plant^{-1} increased with increased in P levels. More pods plant^{-1} (22) was recorded in plots treated with 90 kg P ha^{-1} followed by plots treated with 60 kg ha^{-1} P (19). However, less pods plant^{-1} (14) was recorded in control plots. Interaction of V x P showed that all varieties showed linear increased in pods plant^{-1} with increasing P levels from 0 to 90 kg ha^{-1}. However, sharp increased was observed in pods plant^{-1} of NM-11 with P increased from 30 kg ha^{-1} to 60 kg ha^{-1}. Performance of legumes can be determined by the number of pods and seeds pod^{-1}. The findings of Bhuiyan et al. (2008b) are in line with our results who reported varied pods plant^{-1} in different varieties. In case of inoculation more pods plant^{-1} was recorded in rhizobium treated plots as compared to control. Bhuiyan et al. (2008a) reported that rhizobium inoculation significantly increased pods plant^{-1}.

Biological yield (kg ha^{-1})

Significant ($P \leq 0.05$) effect of varieties, rhizobium inoculation and phosphorus levels on biological yield of mungbean is exhibited in Table 3. V x P interaction was found significant (Figure 6) for biological yield while remaining interactions were found non-significant. Among varieties, NM-11 produced highest biological yield (2756) while, Ramzan and CHK-06 produced biological yield of (2622) and (2583) respectively which were statistically similar to each other. Seeds treated with rhizobium produced highest biological yield (2742) in contrast to un-inoculated plots (2565). Among P levels, increased in P level resulted in more biological yield. Maximum biological yield (3063) was obtained in plots treated with P @ of 90 kg ha^{-1} followed by 60 kg ha^{-1} (2690) while minimum biological yield (2414) was recorded in control plots which was statistically similar with 30 kg ha^{-1}. Interaction of V x P indicated that varieties NM-11 and CHK-06 showed linear increased in biological yield with P increment up to 30 kg ha^{-1}. Further increased triggered biological yield and sharp increased was observed in biological yield up to 60 kg ha^{-1}. In variety Ramzan, increased in biological yield was not observed with increment up to 60 kg ha^{-1}. Similar findings are presented by (Bhuiyan et al., 2008b; Ara et al., 2009; Ali et al., 2000) who stated that seed inoculation significantly increased biological yield. Phosphorus fertilizer helps the crop to produced more seeds and other reproductive parts that ultimately contributed to total biological yield and other yield components (Khan et al., 2015). Ahmad et al. (2015) documented that highest biological yield was recorded in plots treated with higher rates of phosphorus fertilizer.

Seed yield (kg ha^{-1})

Statistical analysis of data showed that seed yield was significantly ($P \leq 0.05$) affected by varieties, rhizobium inoculation and phosphorus levels (Table 3). Interaction of V x P was significant (Figure 7) while all other possible interactions were found non-significant for gain yield. Among varieties, NM-11 produced highest seed yield (842) which was statistically at par with CHK-06 (803) while variety Ramzan produced lowest seed yield (686). Plants inoculated with rhizobium strain produced highest seed yield (825) as compared to un-inoculated plots (729). In case of P levels, increased in P level increased seed yield significantly. Highest seed yield (910) was recorded in plots treated with P @ of 90 kg ha^{-1} followed 60 kg ha^{-1} (837) and 30 kg ha^{-1} (712) while lowest seed yield (648) was recorded in control plot. V x P interaction indicated that varieties performed linear response in seed yield up to 90 kg ha^{-1} while variety CHK-06 showed sharp increased in seed yield with increasing levels of P up to 60 kg ha^{-1}. Seed yield is an automated output of any crop under study and depends upon various factors such as soil nutritional status, environmental factors and plant genetic makeup. Naeem et al. (2000) stated that genetic inheritance, rate of crop growth, potential of crop, capability of plants nutrient translocation and all other attributes contribute to differences in performance of various varietes. Seeds inoculated with rhizobium produced highest seed yield as compared to un-inoculated plots. Soil micro-organisms have the ability of mobilizing the unavailable forms of nutrients to available forms and used by plants to increase crop productivity (Fardous et al., 2010; Ibrahim et al., 2010). El-Kramany et al. (2001) reported that crop growth and total dry matter production was higher in plots treated with phosphorus fertilizer as compared to control plot.

CONCLUSIONS

Among varieties, NM-11 produced highest seed yield (842 kg ha^{-1}) while the lowest seed yield (686 kg ha^{-1}) was produced by variety Ramzan. Seeds inoculated with rhizobium strain (Phaseoli) produced highest seed yield (825 kg ha^{-1}) as compared to un-inoculated seeds (729 kg ha^{-1}). In phosphorus levels, highest seed yield (910 kg ha^{-1}) was recorded in plots treated with 90 kg P ha^{-1} while lowest seed yield (648 kg ha^{-1}) was produced in control plots. It can be concluded from the experiment that Mungbean variety NM-11 should be inoculated with rhizobium (Phaseoli) along with application of P @ of 90 kg ha^{-1} for attaining higher yield and yield components of mungbean.

Table-1. Weeds fresh weight (kg ha^{-1}), weeds dry weight (kg ha^{-1}), leaves $plant^{-1}$ and branches $plant^{-1}$ of mungbean varieties as affected by rhizobium inoculation and phosphorus levels.

Mungbean varieties	Weeds fresh weight (kg ha^{-1})	Weeds dry weight (kg ha^{-1})	No. of Leaves $Plant^{-1}$	No. of Branches $Plant^{-1}$
NM-11	55.7	22.8	24 a	15 a
CHK-06	54.9	22.4	20 b	14 b
Ramzan	55.2	22.5	20 b	13 c
Inoculation				
Inoculated	55.4 a	22.8 a	22 a	14 a
Un-inoculated	54.6 b	22.2 b	21 b	13 b
Phosphorus levels (kg ha^{-1})				
0	57.8 d	18.9 d	18 d	13 c
30	60.4 c	20.8 c	20 c	13 c
60	63.2 b	24.7 b	22 b	14 b
90	64.5 a	25.4 a	24 a	15 a
$LSD_{0.05}$ for V	0.94	0.61	0.59	0.72
$LSD_{0.05}$ for I	0.64	0.49	0.61	0.54
$LSD_{0.05}$ for P	1.2	0.53	0.87	0.77
$LSD_{0.05}$ for V x I	NS	NS	NS	NS
$LSD_{0.05}$ for V x P	NS	NS	1.51*	1.33*
$LSD_{0.05}$ for I x P	NS	NS	NS	NS
$LSD_{0.05}$ for V x I x P	NS	NS	NS	NS

Mean values of the same category followed by different letters are significantly different at $P \leq 0.05$ level. *= significant at 5% level of probability.

Table-2. Days to flowering (DTF), days to pod formation (DPF), days to physiological maturity (DPM) and plant height (cm) of mungbean varieties as affected by rhizobium inoculation and phosphorus levels.

Mungbean varieties	Days to flowering (DTF)	Days to Pod formation (DPF)	Days to physiological maturity (DPM)	Plant height (cm)
NM-11	46 b	56 b	68 b	70.0 a
CHK-06	47 ab	60 a	72 a	65.8 b
Ramzan	48 a	60 a	74 a	62.8 c
Inoculation				
Inoculated	46 b	57 b	70 b	67.5 a
Un-inoculated	48 a	61 a	73 a	64.8 b
Phosphorus levels (kg ha^{-1})				
0	50 a	62 a	74 a	62.4 c
30	49 a	59 b	72 a	65.6 b
60	45 b	58 b	70 b	68.3 a
90	43 b	57 b	70 b	68.3 a
$LSD_{0.05}$ for V	1.24	3.33	3.23	1.61
$LSD_{0.05}$ for I	1.02	2.72	2.64	2.04
$LSD_{0.05}$ for P	1.8	2.67	1.67	1.98
$LSD_{0.05}$ for V x I	NS	NS	NS	NS
$LSD_{0.05}$ for V x P	NS	NS	NS	3.42*
$LSD_{0.05}$ for I x P	NS	NS	NS	NS
$LSD_{0.05}$ for V x I x P	NS	NS	NS	NS

Mean values of the same category followed by different letters are significantly different at $P \leq 0.05$ level. *= Significant at 5% level of probability.

Table-3. Nodules plant^{-1}, pods plant^{-1}, biological yield (kg ha^{-1}) and seed yield (kg ha^{-1}) of mungbean varieties as affected by rhizobium inoculation and phosphorus levels.

Mungbean varieties	Nodules plant^{-1}	Pods plant^{-1}	Biological yield (kg ha^{-1})	Seed yield (kg ha^{-1})
NM-11	15 a	19 a	2756 a	842 a
CHK-06	13 b	17 b	2583 c	803 b
Ramzan	14 ab	17 b	2622 b	686 c
Inoculation				
Inoculated	14 a	18 a	2742 a	825 a
Un-inoculated	13 b	17 b	2565 b	729 b
Phosphorus levels (kg ha^{-1})				
0	10 d	14 d	2414 d	648 d
30	12 c	16 c	2447 c	712 c
60	16 b	19 b	2690 b	837 b
90	17 a	22 a	3063 a	910 a
$LSD_{0.05}$ for V	1.2	1.12	19.61	20.62
$LSD_{0.05}$ for I	0.98	0.76	16.01	16.84
$LSD_{0.05}$ for P	0.9	0.94	20.3	14.01
$LSD_{0.05}$ for V x I	NS	NS	NS	NS
$LSD_{0.05}$ for V x P	1.56*	1.63*	34.69***	24.2***
$LSD_{0.05}$ for I x P	NS	NS	NS	NS
$LSD_{0.05}$ for V x I x P	NS	NS	NS	NS

Mean values of the same category followed by different letters are significantly different at $P \leq 0.05$ level.
*= significant at 5% level of probability. ***=significant at 0.01% level of probability

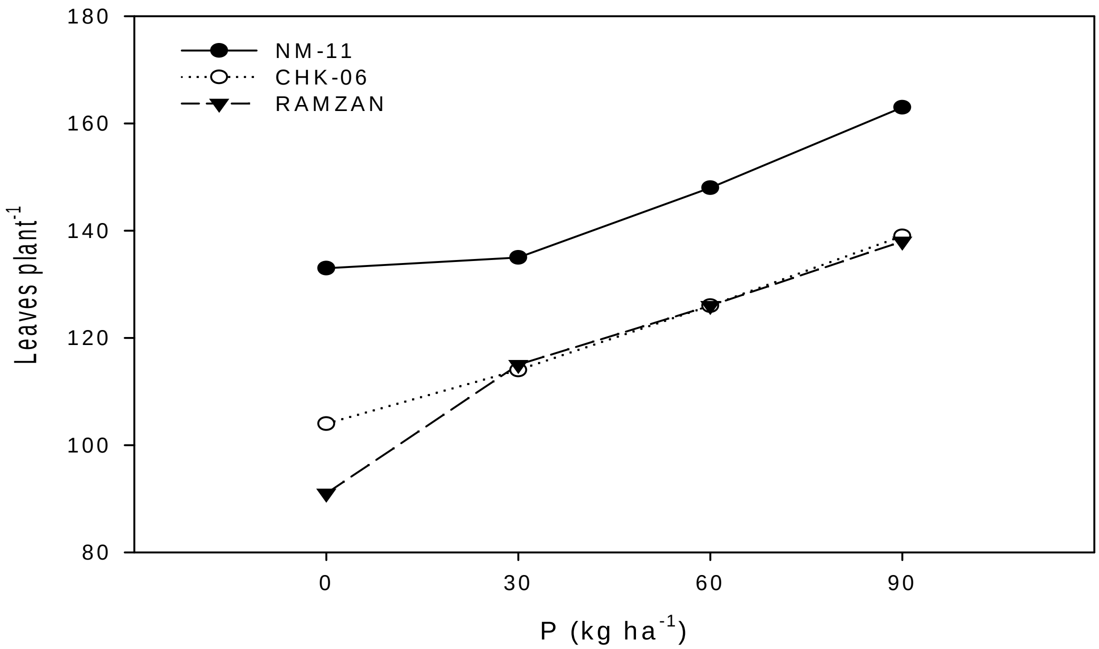

Figure 1. Interaction of mungbean varieties and phosphorous for leaves plant^{-1}.

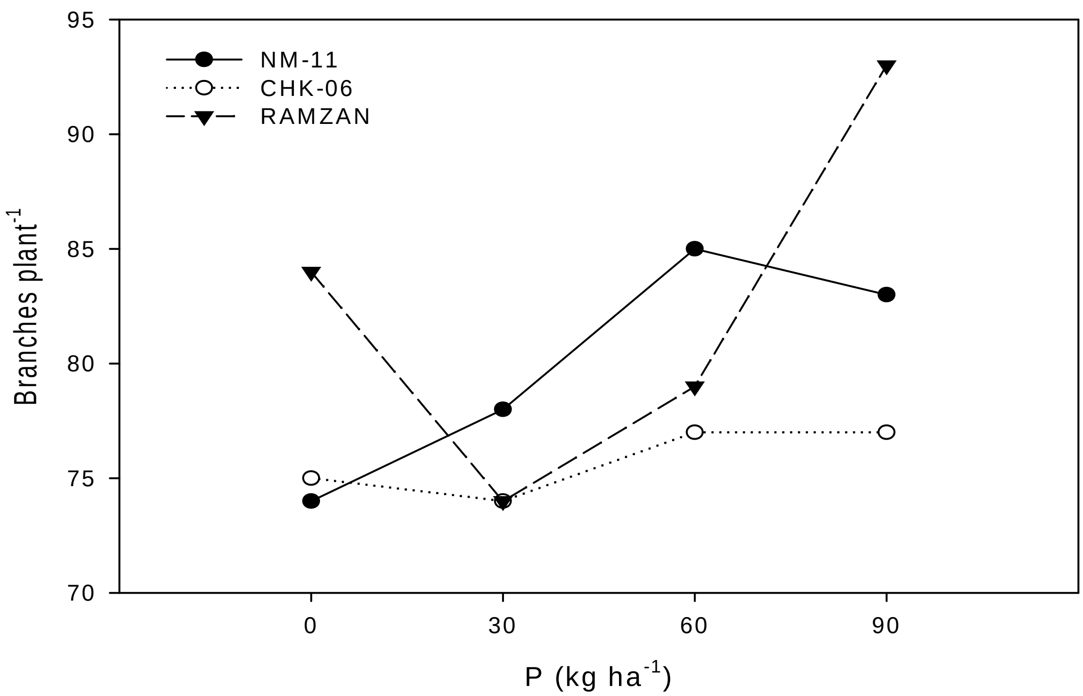

Figure 2. Branches plant^{-1} of mungbean varieties in response to phosphorus levels.

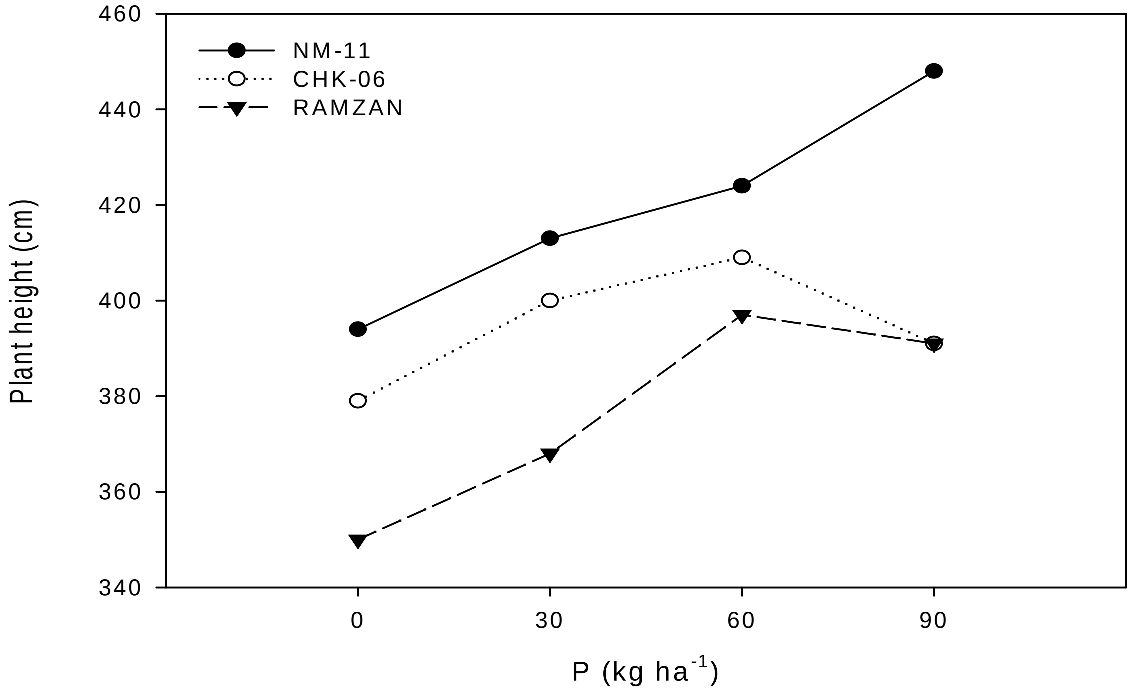

Figure 3. Interaction of mungbean varieties and phosphorus levels for plant height (cm).

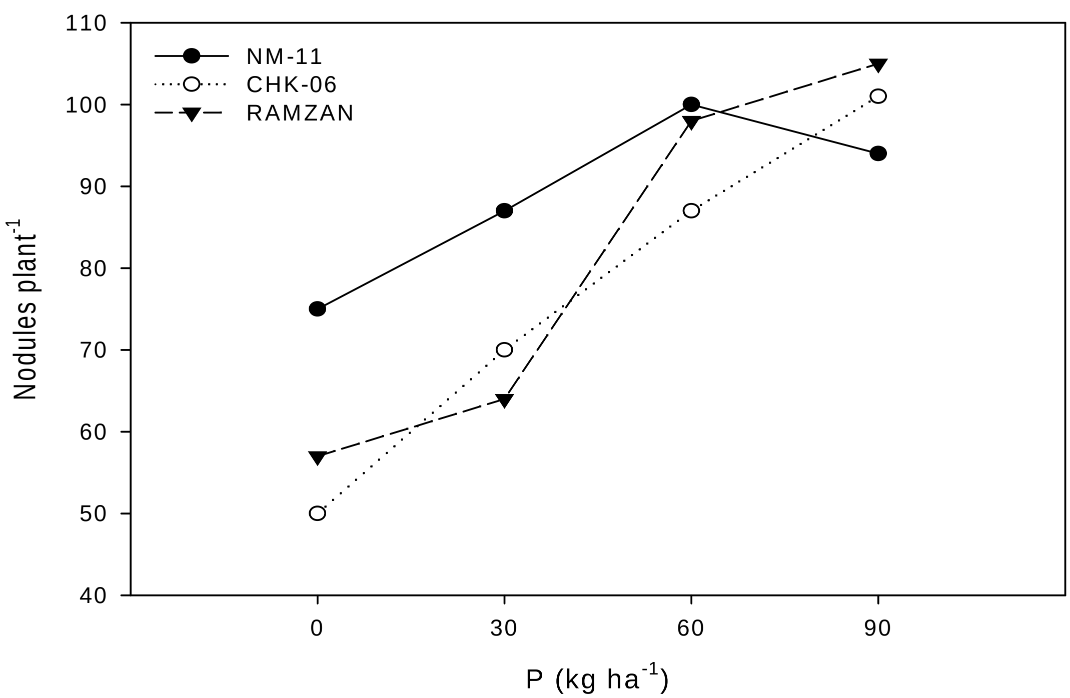

Figure 4. Interaction of varieties and P levels for nodules plant^{-1} of mungbean.

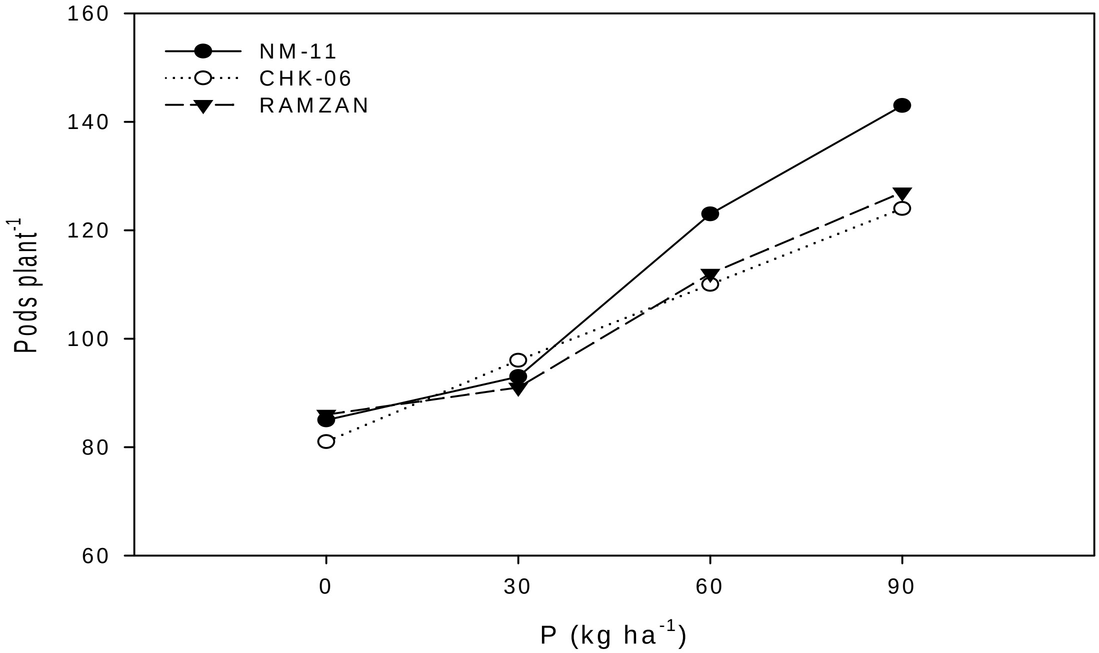

Figure 5. Varieties and P interaction for pods plant^{-1} of mungbean.

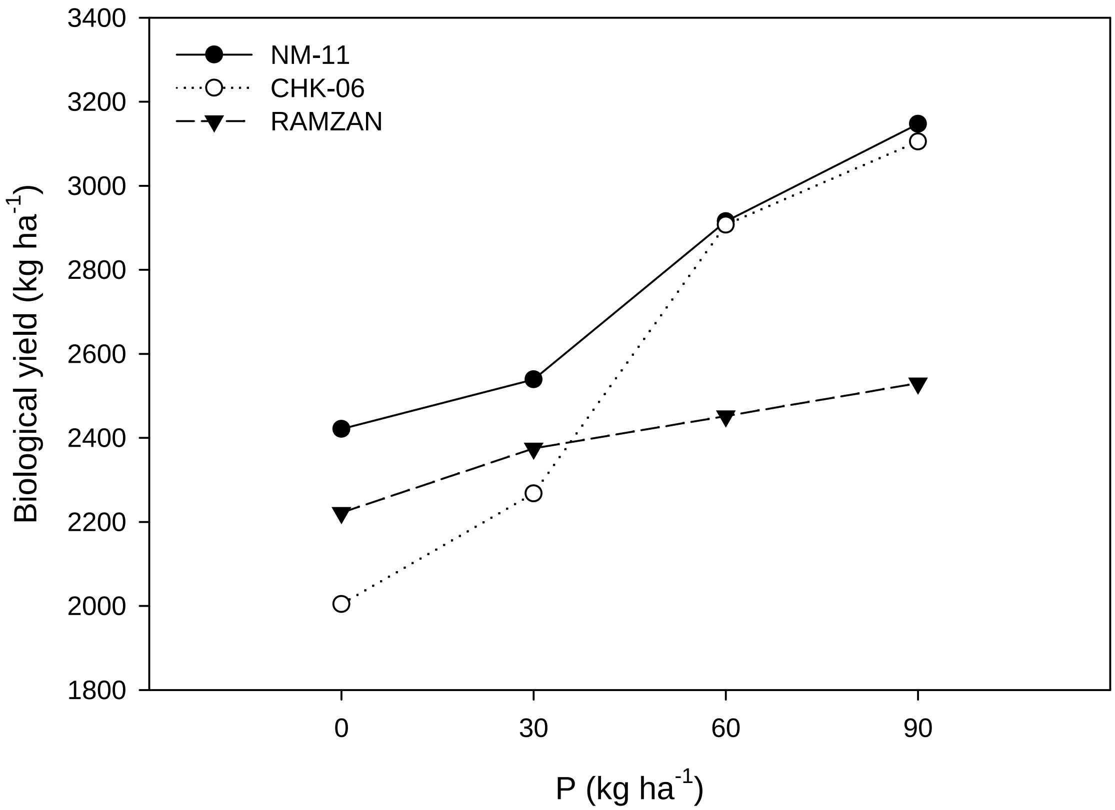

Figure 6. Interaction of varieties and phosphorus for biological yield (kg ha^{-1}) of mungbean.

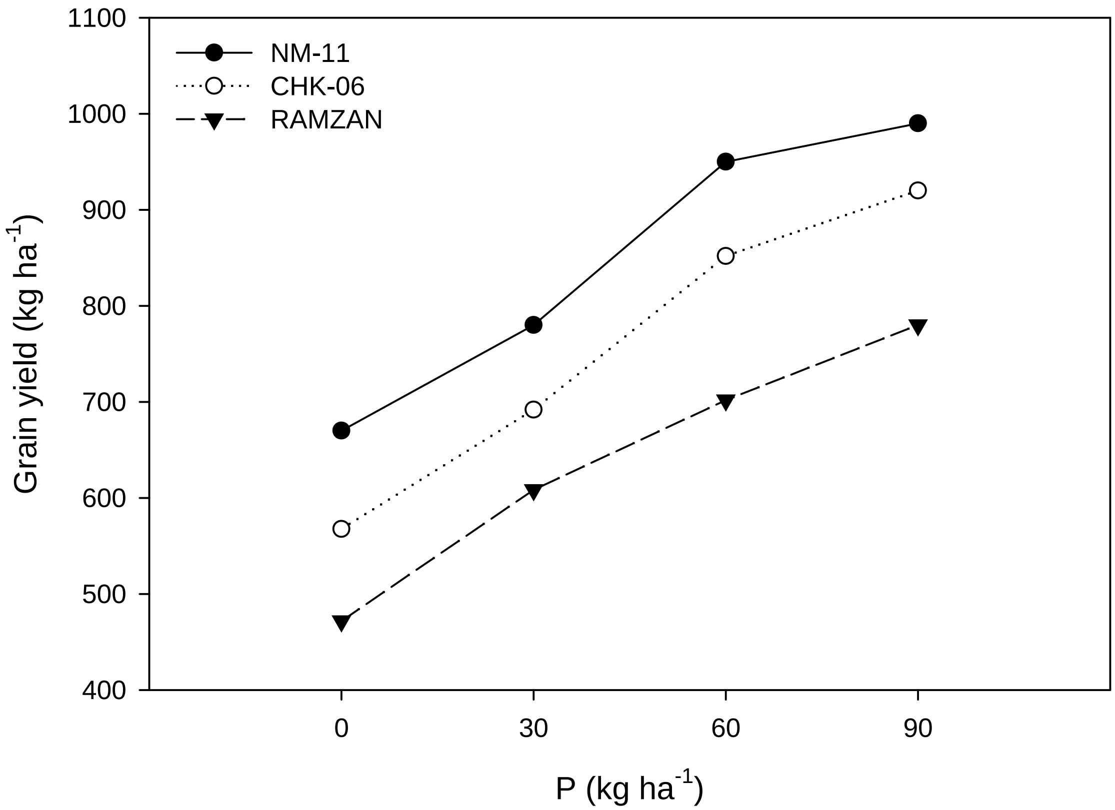

Figure 7. Seed yield (kg ha^{-1}) of mungbean in response to varieties and phosphorus interaction.

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