Acta Agrobotanica

Article ID: 7338
DOI: 10.5586/aa.7338

Publication History
Received: 2019-12-29
Accepted: 2020-07-28
Published: 2020-10-06

Handling Editor
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Authors' Contributions
MNJ, KH, and SB designed the research program, did field works and collected data; HA, MNA, MSHC, and FSE contributed to field works and data collection; MMH and AK analyzed data; AK, KH, and TF wrote and edited the manuscript; AK and FSE contributed to the discussion of the study; KH supervised the research

Funding
This research did not receive any external funds. The research was fully covered by authors.

Competing Interests
No competing interests have been declared.

ORIGINAL RESEARCH PAPER in PHYSIOLOGY

Effects of Phosphorus Fertilization on Hybrid Varieties of mungbean [*Vigna radiata* (L.) Wilczek] in a Salinity Prone Area of the Subtropics

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Abstract

A field experiment was conducted comprising two varieties of mungbean, BARI Mung-5 (V1) and BARI Mung-6 (V2), and five levels of phosphorus fertilizer: triple super phosphate [$Ca(H_2PO_4)$] viz. T1 (control), T2 (42.5 kg P ha^{-1}), T3 (85 kg P ha^{-1}), T4 (127.5 kg P ha^{-1}), and T5 (170 kg P ha^{-1}). The experiment was organized in a randomized complete block design with three replications. V1 produced the highest number of pods per plant (7.65), whereas the maximum 1,000-seed weight (49 g) was produced by V2. The maximum plant height (30.89 cm), number of branches per plant (8.55), number of leaves per plant (19.05), number of pods per plant (10.25), pod length (8.95 cm), number of seeds per pod (9.11), 1,000-seed weight (48.17 g), and yield (1.05 t ha^{-1}) were obtained from the T4 treatment. The interaction of phosphorus levels and varieties had a considerable effect on the growth, yield, and yield attributes of mungbean. The highest number of leaves (20.44) and number of pods (10.39) were obtained from V1 when 127.5 kg P ha^{-1} (T4) was applied, whereas the maximum number of seeds per pod (9.25) and maximum pod length (9.09 cm) were obtained when 85 kg P ha^{-1} and 42.5 kg P ha^{-1}, respectively, were used. The highest number of branches per plant (8.87), 1,000-seed weight (52.83 g), and the maximum seed yield (1.14 t ha^{-1}) were achieved from the treatment V2T4 owing to the interactive effect of phosphorus dose and mungbean variety.

Keywords
mineral fertilizers; phosphorus; productivity; salt stress; seed; yield

1. Introduction

Mungbean (*Vigna radiata* L. Wilczek) being a legume crop does not require high doses of nitrogenous fertilizer if inoculated properly (Sehrawat et al., 2015). It also improves soil fertility by fixing atmospheric nitrogen through the process of symbiosis with the appropriate *Rhizobium* strain (Mishra & Ahmed, 1994). Like other pulses, it is high in fiber and low in carbohydrates, thus useful for patients suffering from difficulty in digestion (Keys & Margrate, 1967). Mungbean is a short-lived leguminous plant and can be grown in various cropping patterns owing to its ability to adapt to poor environmental conditions, such as low soil fertility and drought (Bourgault et al., 2010; Nair et al., 2012). In rainfed regions with a limited availability of water, mungbean becomes the primary choice of farmers to plant in the next season after rice or soybean. Rainfed regions are one of the potential land resources for the development of mungbean production in Indonesia. However, according to Badan Pusat Statistik (2013) the average mungbean productivity is low – only about 1 t ha^{-1}. The rainfed condition is a fluctuating hydrological environment of completely flooded to dry conditions in a season or between seasons. These conditions reduce soil organic matter content and increase the immobilization of nutrients such as phosphorus (Zhou et al., 2014). Phosphorus is one of the nutrients that limit plant productivity, because of its essential role in the process of flowering and seed formation. It is a vital element and is classified as a macronutrient on account of the relatively large amounts required by the plants (Rajkhowa, 1992). It functions as one of the key elements in the process of photosynthesis, nutrient transport, and energy transfer (Klimek-Kopyra et al., 2016). Phosphorus is a vital macronutrient that is required to meet global food supplies and make crop and livestock production lucrative (Raj & Tripathi, 2005). The plant cells need to have a sufficient level of this element before they split. Moreover, phosphorus can increase root growth, grain, fiber, and forage yield, enhance early plant maturity and stalk strength, and promote resistance to root rot disease and winter kill (Ram & Dixit, 2001). A deficiency of this macronutrient causes yield reduction by limiting plant growth and development (D. G. Rao & Subramanian, 1991).

Mungbean responds favorably to phosphorus fertilization (G. R. Rao, 1993). Variety is a significant genetic factor because it contributes substantially in producing higher yield (Bhowmick et al., 2006). In Bangladesh, only 12 g of pulse is available per capita per day. Approximately 6.01 million metric tons of pulse is necessary to meet the present per capita requirement of Bangladesh (Gomez & Gomez, 1984). There has been a continuous decrease in the production of pulses in Bangladesh during the last decade (Gupta et al., 2006). At the farmer's level, the average yield of mungbean is very low owing to the lack of knowledge in selecting and planting the suitable variety and using proper agronomic practices (Habibullah et al., 2014). Variety is the key element to produce a higher yield of any product depending upon their differences in genetic constituents, input requirements, and response on growth process and of course the prevailing environmental conditions during the growing season. The growth and development of mungbean under a given agroclimatic condition differs with variety (Habibullah et al., 2014). The use of competitive crop varieties to suppress weed population is now thought to be an avenue for weed control and along with avoiding weed infestation, to obtain the maximum or expected yield from mungbean, the appropriate variety should be selected for cultivation (Kalita, 1989). Different varieties of mungbean such as BARI Mung-2, BARI Mung-3, BARI Mung-4, BARI Mung-5, and BARI Mung-6 have been released by the Bangladesh Agriculture Research Institute (BARI). The BARI Mung-5 variety requires the shortest growth duration (79.00 days) followed by BARI Mung-2 (86.50 days), BARI Mung-3 (87.19 days), and BARI Mung-4 (87.25 days). Variation in growth duration of varieties might have occurred because of their differences in genetic diversity (Luikham et al., 2005; Malik et al., 2003). Recently, with the introduction of some high yielding varieties like BARI Mung-5 and BARI Mung-6, increasing attention is being paid to the cultivation of this crop in order to reduce the alarmingly protein shortage in the diet of the Bangladeshi population.

Salinity is another very important yield limiting factor in crop lands, principally in arid and semiarid regions of the world (Baghel et al., 2019). Salinity stress not only influences vegetative growth, but also affects reproductive structures and translocation of C and N to developing seeds and fruits. High soil salinity levels can be a main environmental restriction to further crop productivity (Parvez et al., 2013). Most crops are susceptible to salt stress and either die or reduce yield in these conditions (Patel, 1984). A low level of salinity may not decrease grain yield, whereas the leaf area and shoot biomass are reduced; it may occur in a crop or plant that the yield may not decrease until a given threshold salinity is reached (Rahman et al., 2008). Considering these factors, the high yielding varieties, BARI Mung-5 and BARI Mung-6, were chosen for the present experiment (Rahman et al., 2008). Bearing in mind the influence of stress, the current study was designed to evaluate the appropriate dose of phosphorus for different mungbean varieties.

2. Material and Methods

2.1. Experimental Site Characteristics

The trial was conducted at the Agriculture Field Laboratory, Noakhali Science and Technology University, Noakhali from February to April 2018. Geographically, the experimental field was located at 24°75′ latitude and 90°50′ longitude at a mean altitude of 18 m above the sea level within AEZ (Agro-Ecological Zone) 18, i.e., the Young Meghna Estuarine Floodplain. The soil type is loam with organic matter (0.68%), total nitrogen of 0.04 g kg^{-1}, available P of 27.79 μg g^{-1}, and available K of 0.18 mEq/100 g soil, and pH 7.5. The soil indexes were determined before fertilization. The experimental area is under the tropical climate and it has considerable rainfall most months with a short dry season. The average annual temperature is 25.6 °C and the average annual rain fall is approximately 3,302 mm.

2.2. Experimental Design and Treatments

The experiment was laid out in a randomized complete block design with three replications. Five levels of phosphorus in the form of triple superphosphate (T1 to T5; 0, 42.5, 85, 127.5, and 170 kg ha^{-1}, respectively) and two varieties of mungbean, BARI Mung-5 (V1) and BARI Mung-6 (V2), were used with a plot size of 3 m × 2 m, having an area of 6 m^2. There were 10 treatment combinations. There were three replications for individual treatment combinations because each different fertilizer dose treatment was considered one experiment. Each of the replications represented a block in the experiment. Ten treatment combinations were randomly assigned in each replication. Thus, the total number of unit plots was 30 (2 × 5 × 3) for this experiment. A spacing of 1.0 m and 0.5 m was maintained in between the replications and unit plots, respectively.

2.3. Seed Germination

The collected seeds were soaked in water for 24 hr before planting for sprouting. The seed started sprouting after 35 hr and almost all seeds had sprouted after 40 hr. The sprouted seeds were ready to sow. This method is effective for seed vigor, helps to break dormancy, and increases germination percentages.

2.4. Fertigation

The entire granular phosphorus fertilizer (according to treatment) was broadcasted at the time of land preparation.

2.5. Sampling and Harvesting

The crop was harvested at full maturity. Different varieties matured in different dates. Generally, mungbean started to ripen after April 17, 2018. The date of harvesting was confirmed when 90% of the pods became black in color and 10 plants were selected randomly from each unit plot and uprooted before harvesting for recording data. Then, the required data were recorded on April 23, 2018. After that, the total yield of each plot for the two varieties was also recorded.

2.6. Growth and Yield Parameters

Experimental plants (n = 10) were randomly selected soon after maturation and marked with bamboo sticks in each plot excluding the border rows for determining growth parameters as well as yield and yield components. The yield parameters were recorded individually for each plant. After that, the total yield per plot was also recorded and 1,000 seeds were weighed (grams) for the two varieties. The data were collected on April 23, 2018.

2.6.1. Plant Height

The plant height was measured using a measuring tape from the ground level to the top. The heights of 10 plants were measured randomly from each plot. This was done at the ripening stage of the crop.

2.6.2. Number of Pods per Plant

At the ripening stage, pods were counted. Pods of 10 randomly selected plants from each plot were counted and averaged.

2.6.3. Pod Length

Lengths of pods of 10 plants from each plot were measured randomly. Then, they were averaged after harvesting.

2.6.4. Number of Seeds per Pod

This was measured after harvesting. First, the number of seeds per pod was counted. Then, the number of seeds from 10 random plant pods from each plot was counted and averaged.

2.6.5. Thousand-Seed Weight

Thousand seeds of mungbean were counted randomly and then weighed plot wise.

2.6.6. Seed Yield

Seeds obtained from different plots were dried properly. After that, they were weighed carefully and converted into t ha^{-1}.

2.7. Statistical Analyses

Data recorded for growth parameters, yield, and yield contributing characteristics were compiled and tabulated in a proper form for statistical analysis. Analysis of variance was performed using MSTAT-C. The mean differences among the treatments were determined using the Duncan's new multiple range test (Gomez & Gomez, 1984; Reddy & Swamy, 2000).

3. Results

3.1. Effect of Phosphorus Fertilization on Mungbean Height

The statistical analysis showed that there was no interactive effect of variety and phosphorus fertilization on plant height. The slightly taller plants (30.89 cm) were found in the treatment combination of V1T4. In contrast, the lowest plant height (25.53 cm) was observed in V1, when 170 kg P ha^{-1} was applied (Figure 1).

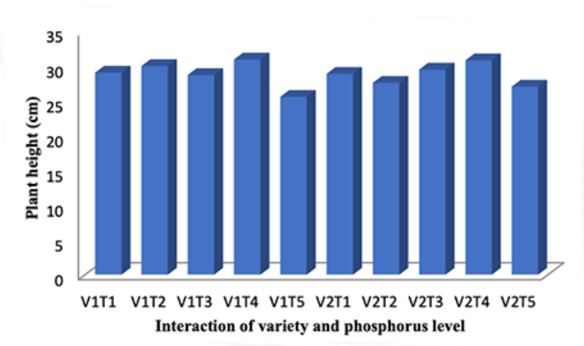

Figure 1 Interactive effect of varieties and different levels of phosphorus fertilization on mungbean height.

3.2. Effect of Phosphorus Fertilization on Number of Pods in the Two Mungbean Varieties

The study showed that phosphorus fertilizer had a significant influence on the number of pods per plant [significant difference at 1% level of probability, coefficient of variation (CV) = 8.49%; see Table S1]. The highest number of pods per plant was found in the treatment combinations of V1T4 and V2T4. Further increase in phosphorus fertilization was no longer effective in inducing an increase in pods (Figure 2).

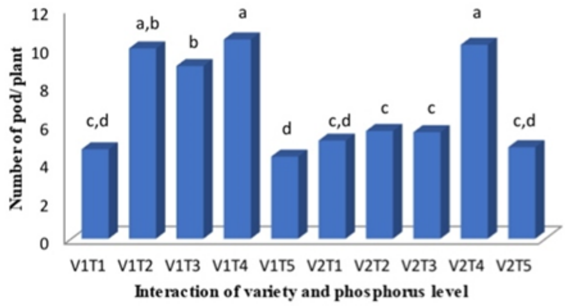

Figure 2 Interactive effect of varieties and different levels of phosphorus on the number of pods per plant in mungbean.

3.3. Effect of Phosphorus Fertilization on Length of Pods in the Two Mungbean Varieties

Phosphorus fertilizer had a significant influence on the length of pods (significant at 1% level of probability, CV = 7.18%; see Table S1). The maximum pod length (9.09 cm) was found in the treatment combination of V1T2; however, it was not significantly different from that of the control. Generally, the phosphorous treatments T2, T3, and T4 did not significantly affect pod length in V1. In contrast, the highest phosphorous level applied (170 kg P ha^{-1}) induced a considerable decrease in the length of pods (5.24 cm) in V1 in comparison to that in the control, but not in V2 (Figure 3). In V2, a significant increase in pod length was found with the T4 treatment.

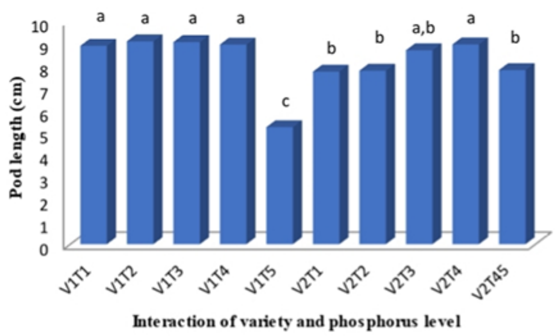

Figure 3 Interactive effect of varieties and different levels of phosphorus on the length of pods in mungbean.

3.4. Effect of Phosphorus Fertilization on Seeds per Pod in the Two Mungbean Varieties

The experiment revealed that the level of phosphorus fertilization had a significant influence on the number of seeds per pod (significant at 1% level of probability, *CV* = 5.80%; see Table S1). The phosphorus treatments T2, T3, and T4 did not affect the pod length of V1 significantly. The highest number of seeds per pod (9.25) was found in the treatment combination of V1T3. In contrast, the lowest number of seeds per pod (4.66) was observed in V1 when 170 kg P ha^{-1} was applied (Figure 4). In V2, the treatments T2, T3, and T4 induced an increase in the value of this parameter in comparison to that in the control and T1 treatment; however, the increase in the phosphorous level to 170 kg ha^{-1} no longer had a significant effect on the number of seeds in pods of V2 (Figure 4).

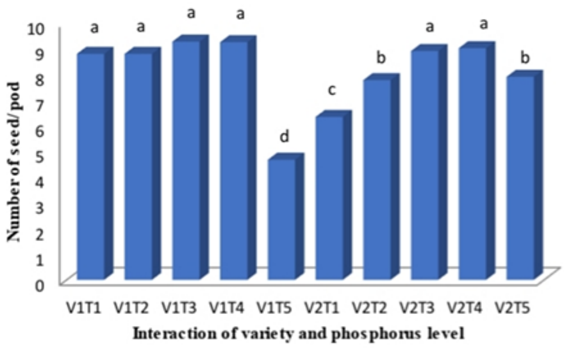

Figure 4 Interactive effect of varieties and different levels of phosphorus on the number of seeds per pod in mungbean.

3.5. Effect of Phosphorus Fertilization on 1,000-Seed Weight in the Two Mungbean Varieties

The interaction between varieties and phosphorus fertilizer had a significant influence on the 1,000-seed weight (*CV* = 1.57%; see Table S1). The maximum 1,000-seed weight (52.83 g) was found in the treatment combination of V2T4. In contrast, the lowest 1,000-seed weight (39.00 g) was observed in V1 when no phosphorus fertilizer was applied (Figure 5).

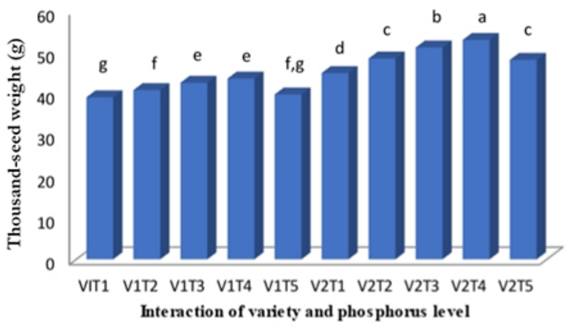

Figure 5 Interactive effect of varieties and different levels of phosphorus on 1,000-seed weight in mungbean.

3.6. Effect of Phosphorus Fertilization on the Yield of the Two Mungbean Varieties

The statistical analysis of the results showed that phosphorus fertilization had a significant influence on the yield (t ha^{-1}) of mungbean, which is presented in Figure 6. The maximum yield (1.14 t ha^{-1}) was found in the treatment combination of V2T4. In contrast, the lowest yield (0.187 t ha^{-1}) was observed in V1 when 170 kg P ha^{-1} was applied. Our results show that phosphorus fertilization at the levels T2, T3, and T4 had a beneficial influence on yield in both cultivars studied. Nevertheless, an increase in the phosphorus level to 170 kg ha^{-1} no longer exerted a positive effect on the yield (in V2) or even reduced it (in V1).

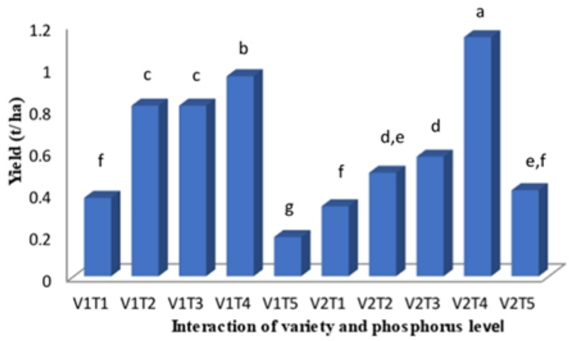

Figure 6 Interactive effect of varieties and different levels of phosphorus on mungbean yield.

4. Discussion

It was found that mungbean can respond efficiently to phosphorus fertilization (G. R. Rao et al., 1993); however, this impact may depend on the plant variety. We demonstrated the effect of phosphorus fertilization on two varieties of mungbean (BARI Mung-5 – V1 and BARI Mung-6 – V2) in a agroecological zone (salinity prone area of the subtropics). The V1 variety responded better to increased phosphorus fertilization than did V2 for number of pods per plant and pod length under the phosphorus treatments used. The V2 variety was superior in relation to the phosphorus treatment for seed yield and 1,000-seed weight. The study reveals that both varieties responded best to the T4 treatment in comparison to other treatments. It was found that salinity causes a reduction in chlorophyll and carotenoid content, which in turn results in pronounced chlorosis and necrosis in the leaves of mungbean (Sehrawat et al., 2015). Salinity stress causes swelling of membranes in chloroplasts of sensitive plants causing reduced chlorophyll content, or it can occur owing to excessive accumulation of ions (Na^+ and Cl^-) in leaves which induces loss of chlorophyll (Arulbalachandran et al., 2009; Wahid et al., 2004). These adverse effects finally cause premature senescence and plant death (Sehrawat et al., 2015). The application of high concentration of nitrogen fertilizer can improve the water status and nutrient absorption of plants under salinity stress and improves the yield in subtropical conditions (Kabir et al., 2005). Root dry weight of *Vigna radiata* L. Wilczek increased with the combined application of N and K fertilizers in Bangladesh under saline stress and waterlogged conditions (Amin et al., 2015). Naeem et al. (2006) showed that inorganic fertilizers (NPK; 25–50–50 kg ha^{-1}) positively affected mungbean yield in Pakistan.

In a previous study, the tallest plants were obtained from the variety of BARI Mung-6 when 20 kg P ha^{-1} was applied (Rengasamy, 2010). In contrast, our study showed that phosphorus fertilization did not affect plant height in the two mungbean varieties studied. The highest number of pods per plant was obtained from V2. However, in this study, V1 reacted better than V2 under the phosphorus treatments used. The positive effect of phosphorus fertilization on the growth of mungbean has also been shown in other studies (Sarkar & Banik, 1991; Selvi et al., 2004). In other experiments, the highest values for length of pods per plant were obtained from summer mungbean when 50 kg P ha^{-1} was applied. The maximum number of seeds per pod was obtained from the mungbean cultivar NM-98 under the application of 100 kg P ha^{-1} (Ahmad et al., 2015; Senanayake et al., 1987), but V1 responded better under the particular treatment. The maximum 1,000-seed weight was obtained from mungbean NM-98 under the application of 100 kg P ha^{-1} (Ahmad et al., 2015) and V2 again showed the highest 1,000-seed weight when 127.5 kg P ha^{-1} was applied. This study was an attempt to evaluate the performances of V1 and V2 under different levels of phosphorus in a salinity prone area (Noakhali, Bangladesh). In relation to yield, the two varieties tested responded positively to phosphorus fertilization up to 127.5 kg P ha^{-1}; however, its positive effect diminished when the level was increased further to 170 kg ha^{-1}.

5. Conclusions

The interactive effects between phosphorus levels and varieties had a noteworthy effect on the number of branches and leaves per plant, number of pods per plant, pod length, number of seeds per pod, and 1,000-seed weight. The largest number of branches per plant and 1,000-seed weight were found in V2 when 127.5 kg P ha^{-1} was applied. The largest number of leaves and pods per plant were observed in V1 when 127.5 kg P ha^{-1} was applied. The maximum number of seeds in pods were found in V1 when 85 kg P ha^{-1} was introduced to the soil, and maximum pod length was obtained from V1 when 42.5 kg P ha^{-1} was applied. The yield was not notably influenced by varieties. Application of phosphorus fertilizer also significantly influenced the yield of mungbean varieties. The results of this experiment show that the highest yield was obtained from the V2T4 treatment. However, to arrive at a final decision, more research on mungbean varieties with the same phosphorus treatment should be performed in different agroecological zones of Bangladesh.

6. Supporting Material

The following supporting material is available for this article:

- Table S1. Effect of interaction between variety and level of phosphorus on the growth and yield of mungbean.

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