Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 1352-1354
Received: 16-11-2020
Accepted: 18-12-2020

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Effect of PSB seed inoculation and phosphorus levels on growth and productivity of mungbean (*Vigna radiata* L.)

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Abstract
A field experiment was conducted at Research Farm, College of Agriculture, Guru Kashi University, Talwandi Sabo, Bathinda to study the different levels of phosphorus and PSB seed inoculation on growth and yield of mungbean during *kharif* season in 2019 and 2020. The trial was laid out in split plot design with two levels of PSB (control and seed inoculation with PSB) in main plots and four phosphorus levels (0, 20, 40 and 60 kg/ha) in sub plots, replicated thrice. The seed inoculation with PSB and phosphorus @ 60 kg/ha recorded significantly higher plant height, leaf area index, dry matter accumulation/plant, number of branches/ plant, number of pods/plant, number seeds/pod, number of nodules/plant, seed yield, haulm yield and biological yield than other treatments. Phosphorus @ 60 kg/ha resulted in 43.73% higher seed yield than 0 kg/ha (control). Dry matter accumulation/ plant, number of branches/ plant, number of nodule/ plant, number of pods /plant, were recorded significantly higher in seed inoculation with PSB and phosphorus 60kg/ha but it was statistically at par with the application of phosphorus 40 kg/ha. The application of phosphorus @ 60 kg/ha resulted in 43.73, 21.79 and 0.8% higher seed yield than 0, 20 and 40 kg/ha, respectively.

Keywords: PSB seed inoculation, phosphorus, mungbean and seed yield

Introduction
India is major pulse growing country of the world, accounting one third of the total world area under pulses and one fourth of the total world production. Green gram (*Vigna radiata* L.) is one of the most ancient and extensively grown leguminous crop of Indian. It is native of Indian and Central Asia and commonly known as mungbean. It is the third important pulse crop after chickpea and pigeon pea. It is cultivated for multipurpose uses as green manure, fodder, pulse and for fodder. Its seed has more nutritive value, more palatable and easily digestible than other pulses grown in India. It is a good source of protein (20-24%), water (10%), fat (1.0%), carbohydrate (60-62%), fiber (4.0%) and ash (3.0%). Green gram protein rich in lysine but deficient in cystein and methionin. It is a good source of minerals, pro-vitamin A, B complex and ascorbic acid. Besides being a rich source of minerals, vitamins and protein, it play major role in biological nitrogen fixation in soil (Kannaiyan, 1999). In India, it is cultivated in Andhra Pradesh, Orrissa, Karnatka and Maharashtra. It is usually as rainfed crop and can be grow in as pre-monsoon (summer) and late monsoon crop. In India, it is cultivated over an area of 3 to 4 million ha with total production of 1.5 to 2.0 million tonnes and productivity 5 q/ha (Anonymous 2020) [1]. In Punjab, green gram crop is grown in an area of 3.5 thousand ha with total production of 3 thousand tonnes and average productivity is 8.45 q/ha during 2018-19 (Anonymous 2020) [1]

It is well known fact that bio-fertilizers play vital role for supplementing the essential plant nutrients for sustainable agriculture, economy and eco-friendly environment. Phosphorus helps in better nodulation and efficient functioning of nodule bacteria for fixation of N to be utilized by plants during grain- development stage, which in turn led to increase in green yield. Plants acquire phosphorus from soil solution as phosphate and anion. It is the least mobile element in plant and soil contrary to other macronutrients. It precipitates in soil as orthophosphate or is adsorbed by Fe and AI oxides through legend exchange. Phosphorus solubilizing bacteria play important role in phosphorus nutrition by enhancing its availability to plants through release from inorganic and organic soil P pools by solubilization and mineralization. Principle mechanism in soil for mineral phosphate solubilization is lowering of soil pH by microbial production of organic acids and mineralization of organic Phosphorus by acid phosphatases. Use of phosphorus solubilizing bacteria as inoculants increases phosphorus uptake. These bacteria also increase prospects of using phosphatic rocks in crop production. Greater efficiency of phosphorus solubilizing bacteria has been shown through co-inoculation with other beneficial bacteria and mycorrhiza (Khan *et al*., 2017) [6].

Material and Methods

The present investigation entitled "Effect of PSB seed inoculation and phosphorus levels on the growth and seed yield of mungbean (*Vigna radiata* L.)" was conducted at Guru Kashi University, Talwandi Sabo (Bathinda). The farm is located at 29º57 N latitude and 75º7 E longitude and altitude of 213 meters above the sea level. The experimental site belongs to sub-tropical semi-arid climate having extreme winters and summers.

The experimental site belongs to semi-arid climate, where both summers and winters are acute. A maximum temperature of about 45º is very common during summer, while freezing temperature accompany by frost happening may be in the months of December and January.

The monsoon season normally starts from the first week of July. However, a few showers received during winter season also. The temperature and rainfall both were found to be optimum for cotton crop.

The soil was slightly alkaline (pH 8.32) with normal electrical conductivity (0.19dSm^{-1}). The soil was medium in organic carbon content (0.31%). The available nitrogen (228.0 kg ha^{-1}) was low, whereas the available phosphorus (14.4 kg ha^{-1}) and available potassium (225 kg ha^{-1}) were both medium. The experiment was laid out in split plot design with three replications. The treatments comprised of two levels of Seed inoculation (control, PSB) and four levels of Phosphorus (control, P_2O_5 @ 20 kg/ha, P_2O_5@ 40kg/ha and P_2O_5@ 60kg/ha).

The height (cm) of five randomly selected plants was measured at maturity. Dry matter accumulation was recorded from each plot, one plant was selected at random from a row ear marked for destructive sampling was uprooted and different plant parts viz. stem and leaves were separated. These samples were first air-dried and then oven dried to constant weight at 65 ^{0}C in hot air oven and their by weight was recorded. The branches were counted at the time of 30, 45, 60 DAS and at the time of maturity from the five selected plant and average number of branches per plant was calculated.

The average value was recorded as number of pods plant^{-1} was counted on five randomly selected plants in each plot. Grain yield from harvesting was weighed separately and obtained by totaling these in kg plot^{-1} was calculated and converted it into q ha^{-1}. The total weight of crop biomass from each plot was weighed separately and straw yield in kg plot^{-1} was calculated and converted it into q ha^{-1}. The biological yield obtained from the addition of grain yield and straw yield.

Results and Discussion

Growth parameters of mungbean

The interaction effect of PSB and phosphorus levels on plant height found non-significant. The PSB inoculation significantly increased plant height at 30, 45, 60 DAS and at harvest. The minimum plant height was recorded in control during the growth stages of plant almost similar trend was noticed with PSB

Table 1: Effect of different levels of phosphorus and PSB seed inoculation on growth parameters of mungbean (pooled analysis of two years)

Treatment	Plant height (cm)	Number of branches/plant	Dry matter accumulation (g plant^{-1})
Seed inoculation			
Control	67.5	31.9	31.0
Seed inoculation with PSB	78.6	41.7	34.7
LSD (P=0.05)	3.3	0.6	0.7
Phosphorus levels (kg P_2O_5/ha)			
Control	71.1	30.1	29.6
20	69.1	34.7	31.4
40	73.2	39.3	33.9
60	78.9	41.1	30.4
LSD (P=0.05)	3.1	1.9	1.1
Interaction	NS	2.7	NS

The increase in levels of phosphorus significantly increased plant height up to 60 kg/ha at all the observation days. At 30 and 45 DAS, the maximum plant height recorded with application of 40kg phosphorus/ha(50.3cm), which significantly higher over all the phosphorus levels but at par with 60kg phosphorus/ha. At subsequent growth stages, the maximum plant height recorded with the application of 60 kg phosphorus/ha (78.9cm), which significantly higher over the lower levels of phosphorus but at par with 40kg P/ha.

Table 2: Effect of different levels of phosphorus and PSB seed inoculation on yield attributes of mungbean (pooled analysis of two years)

Treatment	Number of pods plant^{-1}	Seed yield (q ha^{-1})	Biological yield (q ha^{-1})
Seed inoculation			
Control	37.1	1924	4992
Seed inoculation with PSB	68.4	2177	5575
LSD (P=0.05)	10.4	36.2	168
Phosphorus levels (kg P_2O_5/ha)			
Control	40.3	1660	4332
20	45.8	1959	4990
40	58.9	2196	5629
60	65.9	2386	6183
LSD (P=0.05)	7.6	46	98
Interaction	10.7	66	138

Due to the solubilization of phosphorus by PSB there may be higher uptake of NPK, which resulted in better growth of the plant. The PSB inoculation and phosphorus fertilizer increased the availability of soluble phosphorus which help in increasing the growth of plant resulted in more plant height. Similar results were also observed by Shaktawat and Sharma (2001) [8].

The interaction effect of PSB and phosphorus levels on No. of branches/plant found significant effect on later growth stages of plants. The highest No. of branches/plant was obtained with PSB inoculation (41.7 plant^{-1}) respectively. It was significant higher than control. The lowest No. of branches/plant was observed with application of control (31.9 plant^{-1}). The highest branches per plant recorded with application of 60 kg phosphorus/ha (41.1 plant^{-1}). At subsequent growth stages The maximum branches per plant recorded with the application of 60kg phosphorus/ha. which significantly higher over the lower levels of phosphorus.

Increase in the number of branches per plant due to phosphorus and PSB inoculation may be attributed to the conversion of unavailable phosphorus to available forms particularly during the early crop growth phase which would have helped in the absorption of all major and minor nutrients required of all major and minor nutrients required for the growth and development. Similar trend was also noticed by Naik and Rajput (2003) [7].

The data revealed that the maximum dry matter accumulation recorded with inoculation of PSB (4.9q/ha) as compared to uninoculation during all the growth stages of plants. The phosphorus levels also show significant effect on dry matter accumulation. The maximum dry matter recorded when phosphorus applied at 60 kg P per ha (5.2q/ha). this may be due to the increasing number of branches per plant, more plant height resulted in more dry matter accumulation. The interaction effect on dry matter accumulation found significant effect during early growth stage and 60DAS but it found non significant effect at 45 DAS and at harvesting stage. The dry matter increased might have resulted from increasing the growth attributes viz; more plant height, more number of branches per plant, leaf area index which subsequently increased dry matter accumulation. Similar results were also observed by Deka and Kakati (1996) [3]

Yield attributes of mungbean

The PSB inoculation recorded the maximum number of pods per plant (68.36) over uninoculated (control).The phosphorus application significantly influenced the number of pods per plant. it was observed that the application of phosphorus levels up to 60kg/ha significantly increased the number of pods per plant. The maximum number of pods per plant was observed with the application of 60kg/ha (65.9 pods) of phosphorus while the lowest number of pods per plant recorded in control (40.3pods/plant). The interaction effect of phosphorus levels and PSB on number of pods per plant found significant effect. The maximum number of pods per plant recorded with the application of 60kg/ha phosphorus and inoculation of PSB. The lowest number of pods per plant recorded in control. The phosphorus is essential for nodulation and contributed to more fixing of atmospheric nitrogen which enhances photosynthesis, pod development and eventually more number of pods per plant. Similar finding were also observed by the Gupta *et al*., (2006) [4]

Data related to the seed yield of mungbean revealed that the inoculation with PSB significantly increased the seed yield than control. The maximum yield recorded (2177kg/ha) with the inoculation of seed while the lowest yield recorded in control (1924kg/ha).The phosphorus levels also significantly influenced the seed yield of mungbean. The maximum seed yield recorded when then phosphorus applied at the rate of 60kg/ha (2386kg/ha), which significantly higher over the lower phosphorus levels. The lowest yield recorded in control (1660kg/ha).The intraction effect of PSB and phosphorus levels on seed yield found significant effect. The maximum seed yield recorded when the PSB inoculation and phosphorus 60kg/ha applied. The lowest seed yield recorded in control. The increase in seed yield of mungbean resulted from increasing the number of branches per plant, more number of pods per plant, pod length and more number of seeds per plant subsequently increased the seed yield of mungbean. Bhuiyan *et al* (2006) [2].

The data related to the biological yield of mungbean revealed that the inoculation with PSB significantly increased the biological yield than control. The maximum biological yield recorded (5575kg/ha) with the inoculation of PSB while the lowest biological yield recorded (4992 kg/ha) in control. The phosphorus levels also significantly influenced the biological yield of mungbean. The maximum biological yield recorded when the phosphorus applied at the rate of 60 kg/ha (6183kg/ha), which significantly higher over the lower phosphorus levels. The lowest biological yield recorded in control (4332 kg/ha).The PSB seed inoculation and phosphorus levels on biological yield found significant effect. The maximum biological yield recorded when the PSB seed inoculation and phosphorus 60 kg/ha applied. The lowest biological yield recorded in control. The biological yield increased might be due to more dry matter accumulation, more leaf area index, number of branches, seed yield more plant height and higher which ultimately increased the biological yield.

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