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Effect of varying levels of nitrogen and phosphorus in combination with *Rhizobium* in different varieties of mung bean (*Vigna radiata* L.) Wilczek

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Abstract
Nitrogen and phosphorus fertilizers have great importance in mung bean. The use of nitrogen and phosphorus fertilizers not only increases the yield and yield attributes but also improves seed quality. Therefore, this experiment was conducted to determine the influence of nitrogen and phosphorus fertilizers along with rhizobium. The nutrients (N, P) can be supplied through Urea, P_2O_5 fertilizers, Nano fertilizer, with the combination of *Rhizobium*. The production of mung bean is influenced by the genotype of varieties and agronomic management. The seed yield is influenced by the nutrient levels both applied and present in soil, the nutrient source and the method of application including basal foliar and nano based fertilizers. Therefore, comparative effects of varying different levels of nitrogen and phosphorus in combination with Rhizobium in different varieties of mung bean is warranted to identify the growth patterns, yield attributes, quality parameters and economics that will favourably influence the grain yield and biomass in mung bean under different nutrient level conditions. This review examines response of mung bean varieties to nutrient management practices on different levels of nitrogen, phosphorus with combination of *Rhizobium* in different varieties of mung bean crop sown under normal conditions.

Keywords: Yield attributes, *Rhizobium*, genotype, nano based fertilizers, varieties

Introduction

Pulses play important role in elevating protein energy malnutrition for the large Indian population in general and for vegetarian population in particular. In order to achieve this goal, minimum of 55 g pulses/capita/day should be available in addition to other sources of protein such as cereals, milk, meat and egg. At present per capita pulses availability in India is only 45g/day. In order to fill the gap between the supply and requirement, India imported pulses worth over Rs. 166.28* billion in the financial year 2022.Hence, there is great need to improve pulses production in India.

Among the various pulses, mungbean has a major role in fulfilling the pulses requirement in India and is evident from the fact that during 2021-22 out of the total pulses production 27.3mt (DPD) the mungbean contributed to extent of 20.4%. Mungbean (*Vigna radiata*. L) a member of Fabaceae family is known by various names. in different languages *viz*. green gram, moong, golden gram etc. Cultivated mungbean is a self-pollinated annual pulse crop (IIPR, 2022) [13]. Mungbean is relished for easy digestibility as dhal or split seeds and green pods used as vegetable. Haulm of mungbean is used as fodder husk and split beans are useful as livestock feed. Mung bean is an excellent green manure as it is easily decomposed when incorporated (biomass has 1.5% N), Seed contains 25% protein, 1.15% fat and 62.6% carbohydrate. Seeds are boiled and used in soups or made into porridge with rice or wheat, sprouted seeds which are rich in vitamins are consumed as salad.

India has about 16% of the world area under mungbean production which is about 10% of total global production (Annual report IIPR, 2022) during 2022. Similarly, comparison among countries reveals that Asia is the major contributor to the area (5.5 m ha) and production (3.17 mt) of mungbean (IIPR, 2022) [13]. India being the high-strung bean producing country of the Asia, it accounts for 10% of production (3.17 mt) and Area16% (5.5 m ha) percent of the area and production (IIPR, 2022) [13].

India ranks first in area, production and productivity of 570 kg/ha in 2022 (IIPR, 2022) [13] of mungbean among the top five mungbean producing countries i.e. Myanmar, China, Indonesia, Thailand and Kenya (IIPR, 2022) [13]. The dominant contributors to mungbean cultivation in terms of area and production are Rajasthan (46% and 45% respectively), Madhya Pradesh (9% and 14%), Maharashtra (9% and 8%), Karnataka (9% and 6%), Odisha (5% and 4%), Bihar (4% and 5%), Tamil Nadu (4% and 3%), Gujarat (3% and 4%), Andhra Pradesh (3% for both), and Telangana (2% for both) also playing significant roles, as stated in the Annual Report (2022-23) by AICRPR on kharif pulses.

Effect of Nitrogen

The inorganic fertilizers are applied to fulfil the plant requirement of nitrogen, but excessive use of chemical fertilizers reduces soil fertility by affecting the soil's physical and chemical properties. Nitrogen fertilizer can affect the seed quality of mung bean. However, the effects of nitrogen fertilizer on the properties of mung bean protein (MBP). We investigated the effects of nitrogen fertilization levels on the physicochemical, structural, functional, thermal, and rheological properties of MBP (Jiahao Ge).

Yomso *et al*. (2023) [7] conducted a field experiment to determine the best fertilizer combination and cropping system for mung bean production. The experiment comprised eight treatments and three replications arranged in a split- plot design. While in the case of different fertilizer levels, the treatment with the combination of nano fertilizers and NPK fertilizers produced higher yield attributes than all other treatments. In contrast, the control (no fertilizer) produced lower yield and yield attributing characters. The study concluded that the combination of 50% recommended dose of fertilizer + 50% nano NPK fertilizers + sole mung bean produced the highest yield. The present research showed that foliar spray of nano NPK fertilizers affected mung bean growth, leading to favourable changes in yield attributes, and yield. Thus, the experiment concluded that the combination of 50% RDF + 50% nano NPK fertilizers + sole mung bean was found to be the best fertilizer combination and cropping system for increasing mung bean yield, which can be followed for higher mung bean production.

Merhej *et al.* (2021) [23] conducted a field experiment in the summer season The results showed that adding urea gave significantly higher number of pod per plant, seeds per pod and seeds yield (27.5, 7.2 and 1395 kg. ha^{-1}) as compared to control. Spraying foliar fertilizer gave higher number of pods per plant, seeds per pod and seeds yield as compared to control and spraying three times was superior by sgiving 28.6, 7.2 and 1454 kg ha^{-1}seed yield. Spraying seaweed extract caused significant increase number of pod per plant, seeds per pod and total seed yield compared to control. The combination of adding urea and foliar fertilizer 2 or 3 times was superior in total seed yield (1503 and 1513.8 kg ha^{-1}). The combination of three times foliar fertilizer and spraying seaweed extract at 1000 or 2000 mg L^{-1} gave the highest total seed yield (1529 and 1546.5 kg ha^{-1}). The combination of adding urea and spraying seaweed extract at 2000 mg L^{-1} gave the highest total seed yield (1464 kg ha^{-1}).

Bahadari *et al.* (2019) [35] conducted a field experiment in 2017 at ANASTU, Afghanistan to find the productivity and profitability of foliar application of nitrogen on different varieties of mung bean (*Vigna radiata* L. Wilczek) crop. The results showed that the variety Mash 2008 showed significantly higher seed and stover yields, harvest index, gross and net returns, production and monetary efficiency compared to NM 94. Among the nitrogen application treatments, 3 times foliar application of 2% urea at pre-flowering + flowering + pod development stages (40, 50 and 60 DAS) was most suitable treatment to get highest growth, productivity, profitability and production and monetary efficiency of mung bean. It was concluded that the 3 times foliar application of 2% urea at pre -flowering + flowering + pod development stages (40, 50 and 60 DAS) may be applied to the variety Mash 2008 to get highest productivity and profitability of mung bean and this combination may be recommended under the semi-arid conditions of Afghanistan.

Effect of Phosphorus

Phosphorus (P) is a macronutrient required by plants for its growth. Phosphorus has been pointed out as one of the most important nutrients in pulse production, which is responsible for vegetative growth, reproduction and consequently yield of mungbean. It helps in nodule development, root growth and it further accelerate the crop maturity (Singh *et al*. 2017) [31]. It plays a vital role in energy movement, stimulation of primary growth and progress, fruiting and seed production.

Ranjan *et al.* (2024) [1] conducted a field experiment over two-years at Rama University's farm in Kanpur, Uttar Pradesh during the kharif seasons of 2022 and 2023 aimed to assess the impact of different nutrient management strategies on nutrient uptake. The study incorporated four varieties - PDM-139, IPM 2-3, Meha, and IPM 2-14 alongside varying levels of nutrient management practices. These practices involved N_0 (Control), N_1, N_2, and N_3, each with distinct combinations of nitrogen, phosphorus, zinc, seed treatment with *Rhizobium* culture, and phosphate-solubilizing bacteria (PSB). The experiment followed a factorial randomized block design with three replications. Findings indicated that the application of 20 kg N + 40 kg P_2O_5 + 25 kg $ZnSO_4.H_2O$ ha^{-1}, coupled with seed treatment involving rhizobium culture and PSB at 2.5 kg ha^{-1} in soil, significantly enhanced nutrient uptake in the Central alluvial tract of Uttar Pradesh.

Bhuvan *et al*. (2023) [11] conducted a field experiment at Crop Research Farm Institute of Agriculture Training in Dehradun, Uttarakhand, India. The experiment followed a Factorial Randomized Block Design (RBD) with 12 treatments each with three replications in a plot size of 2m x 2m. The treatments included *Rhizobium* inculcation (inoculated and uninoculated) phosphorous (50,60,70 kg/ha) and sulphur (5,10 kg/ha) dose. The results demonstrated the significant role of these nutrients in enhancing green gram productivity offering valuable insights into sustainable crop management practices. The result showed that highest plant height was observed in treatment *Rhizobium* + phosphorous @ 60 kg/ha + Sulphur @ 5 kg/ha. The maximum dry weight was observed in treatment *Rhizobium* inoculation + P @ 60 kg/ha and sulphur @ 5 kg/ha. The highest number of pods/plant was observed in treatment *Rhizobium* + phosphorous @ 70 kg/ha + sulphur @ 5kg/ha. Highest gross return, net return and benefit cost ratio were observed in treatment *Rhizobium* + phosphorous @ 60 kg/ha + sulphur @ 5 kg/ha).

Samim *et al.* (2023) [6] conducted a field experiment during the spring season of 2020 at research farm of Badghis Institute of Higher Education, Badghis, Afghanistan to evaluate the effect of phosphorus levels and varieties on yield and yield attributes of mung bean [*Vigna radiata* (L.) R. Wilczek]. The experiment was laid out in a randomized complete-block design with 3 replications. The experiment comprised 2, *viz*. varieties 'Mai 08' and 'Nayab 98' of mung bean with 4 phosphorus levels *viz*. control, 40, 60 and 80 kg P2O5/ha. The results revealed that mung bean crop fertilized with 80 kg/ha P_2 O_5 gave the maximum branches/plant (6.4), pods/plant (24.88), pod length (6.28), seeds/plant (243.3), 1,000-grain weight (32.74), grain yield (1230.43 kg/ha), and harvest index (39.42%). Phosphorus @80 kg P_2O_5/ha was found to be more economical for getting higher grain yield of mung bean crop. The maximum and higher number of branches per plant, number of pods per plant, number of seeds/plant, 1,000-grain weight, grain yield kg/ha, and harvest index were recorded with 'Mai 08' variety.

Bilal *et al.* (2021) [22] conducted a field experiment at University of Agriculture, Faisalabad Pakistan This study explained the effect of inoculation of phosphorus-solubilizing bacteria (PSB; *Pseudomonas* spp.) and phosphorus (P) on four different varieties of mung bean to increase its cultivation and gain yield. The general conclusion of the study was that PSB inoculation of mung bean genotypes resulted in increased seed yield, 1000-grain weight and biological yield. It was also revealed that PSB inoculation increased the shoot and root P concentration and uptake in mung bean varieties. Based on the results, the farmer could use PSB to enhance mung bean yield with the help of PSB inoculation even with less P fertilization.

Effect of Nano fertilizer

Nanotechnology is an emerging field of science with a variety of applications in various disciplines, including agriculture. Recently some nano-fertilizers are available in the market, which may be highly effective in improving crop productivity in a more economical manner than the conventional fertilizers. The present investigation was carried out to evaluate the impact of seed priming using urea and zinc, when applied in the form of nano-fertilizers on the growth, quality and yield related attributes in mung bean (Upasna 2023) [4].

Khatri *et al.* (2022) [3] Conducted a field experiment at Maharshi Dayanand University, Rohtak Global agricultural production cannot catch the increasing population's exigency. At different times, the world has faced food crises of varying intensity. Many steps have been taken after that to encounter the rising concerns. Nowadays, nano fertilizers are being experimented with as an alternative to conventional fertilizers. Nano fertilizers can be classified as macronutrients and micronutrients nano fertilizers. Synthesis of macronutrient nano fertilizers (nitrogen, phosphorus, potassium, calcium, magnesium, etc.) and micronutrient nano fertilizers (iron, boron, zinc, copper, silicon, etc.) can be done using chemical and green synthesis methods, which involves reducing agents, capping agents, dendrimers, microbial synthesis, solvents, and others. Composition of the nano fertilizers can be done using top-down and bottom-up approaches incorporating hydrocarbon polymer, dendrimers, microbes, etc., which decides their usage in various crops depending upon the requirement of the plant. Engineered nano fertilizers can improve crop yield by mitigating environmental pollution, environmental stress, and plant diseases. However, the unsystematic use of nano fertilizers can be a hurdle in its utilization. This article discusses various types of nano fertilizers with their unique properties and applications. Each category of nano fertilizers is explained considering their composition, particle size, concentrations applied, benefited plant species, and plant-growth enhancement aspects.

Roll of Biofertilizer

Biofertilizers are living creatures that has various microbial cells which plays crucial role in agriculture. These are preparation entities, which has microbial strains of living and latent cells that may be helpful in uptake of nutrients from root rhizosphere zone and majorly fix from atmosphere where nutrients in the gaseous form. A lot of microorganism species that are beneficial by stimulating plant growth plethora of mechanism (Vessey, 2003) [34]. Biofertizers can be used for treating seeds and directly applied to soil or mixed with organic manures and applied in field. As chemical fertilizers provide nutrients directly to plants when we apply in soil, but these are non eco -friendly which can cause harm to soil biota. Whereas biofertizers may be helpful in nutrients uptake by fixing them from atmosphere where most of nutrients are in gaseous form. Biofertilizers with pulse crops have done symbiotic relationship mainly Rhizobium and others has capacity to fix on an average of 40- 250 kg N/ha/ year (Raju 2020) [26].

Bhuvan *et al*. (2023) [11] conducted a field experiment at Crop Research Farm Institute of Agriculture Training in Dehradun, Uttarakhand, India. The experiment followed a Factorial Randomized Block Design (RBD) with 12 treatments each with three replications in a plot size of 2m x 2m. The treatments included *Rhizobium* inculcation (inoculated and uninoculated) phosphorous (50, 60, 70 kg/ha) and sulphur (5, 10 kg/ha) dose. The results demonstrated the significant role of these nutrients in enhancing green gram productivity offering valuable insights into sustainable crop management practices. The result showed that highest plant height was observed in treatment *Rhizobium* + phosphorous @ 60 kg/ha + Sulphur @ 5 kg/ha. The maximum dry weight was observed in treatment *Rhizobium* inoculation + P @ 60 kg/ha and sulphur @ 5 kg/ha. The highest number of pods/plant was observed in treatment *Rhizobium* + phosphorous @ 70 kg/ha + sulphur @ 5kg/ha. Highest gross return, net return and benefit cost ratio were observed in treatment *Rhizobium* + phosphorous @ 60 kg/ha + sulphur @ 5 kg/ha).

Tomar *et al*. (2022) [14] suggested Integrated use of organic, inorganic and biological sources of nutrients for higher yield along with overall betterment of summer mung bean crop. Based on the findings of the study, it was observed that different treatments influenced significantly in respect to yield, yield contributing and quality characters. The above studies showed that bio-inorganic combinations have their own roles towards higher productivity, not only to solely supply all the nutrients to the soils but also create favourable conditions for better crop growth. Increased growth, yield and nutrient parameters of mung bean in this study, might have been associated with the supply of essential nutrients by continuous mineralization of organic manures, enhanced inherent nutrient supplying capacity of the soil and its favourable effect on soil physical and biological properties to better yield.

Kishor *et al.* (2021) [19] conducted a field experiment in mung bean to investigate the effect of integrated nutrient management on growth, yield and economics of summer mung bean (*Vigna radiata*) at Research farm of Tirhut College of Agriculture, Dholi, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India during summer 2020. This study revealed that 100% RDF + 5 tonnes FYM/ha + Rhizobium and PSB seed inoculation significantly increased plant height, dry weight/plant, number and dry weight of root nodules. The same treatment combination also proved most effective in improving the yield and yield attributing parameters *viz*., number of pods/plant, number of grains/pod, pod length, test weight and harvest index. Thus, application of farm yard manure @ 5 tonnes/ha along with *Rhizobium* and PSB helped in increase in yield over control. However, application of 80% RDF along with bio-fertilizer and FYM @ 2.5 tonnes/ha significantly increased net returns and benefit: cost ratio. These results indicated that inorganic fertilizers along with bio-fertilizers and addition of organic matter proved to be useful in achieving the yields with integrated use of different sources of nutrients.

Singh *et al.* (2019) [36] conducted a field experiment during *kharif* 2019 at Research Farm, Guru Kashi University, Talwandi Sabo, Bathinda (Punjab) to evaluate the effect of rhizobium inoculation in combination with nitrogen levels on the performance of green gram. The maximum plant height (45.2 cm) was recorded in *rhizobium* seed inoculation which was significantly higher over the control. The highest plant height (52.1 cm) was recorded when nitrogen @ 18 kg/ha was applied. It was significantly higher than control and nitrogen @ 6 kg/ha and was statistically at par with nitrogen @ 12 kg/ha. Similarly, the *rhizobium* seed inoculation increased branches per plant and recorded a greater number of branches (6-7) as compared with control. The result showed that *rhizobium* seed inoculation recorded more dry matter accumulation (55.5 q/ha) which was significantly higher than control. Dry matter accumulation was significantly influenced by different nitrogen levels. Nitrogen @ 18 kg/ha recorded highest dry matter accumulation (66.1 q/ha), which was significantly higher than control and nitrogen @ 6 kg/ha but it was statistically at par with nitrogen @ 12 kg/ha(65.9 q/ha).

Kaur *et al*. (2017) [30] conducted a field experiment at Punjab Agricultural University, Ludhiana to study the response of summer mung bean (*Vigna radiata* L.) to rhizobium and PGPR under different planting methods. The experiment showed that seed yield increased with the inoculation of biofertilizers, however, combined inoculation of *Rhizobium* and PGPR produced significantly higher seed yield over all the other treatments. The interaction between planting method and bio-fertilizers was non-significant. Among the bio-fertilizer treatments, the net return of combined inoculation was maximum. The B:C ratio under Rhizobium + PGPR, rhizobium inoculation and PGPR inoculation were 2.67, 2.18 and 2.04, respectively. The combined inoculation of rhizobium and PGPR can be opted for flat/bed planted summer mung for getting maximum profitability while maintaining the soil health

Singh *et al.* (2014) [33] conducted a field experiment out to study the effect of sulphur (S) and cobalt (Co) fertilization in combinations with *Rhizobium* inoculant (RI) and recommended NPK fertilization (RDF) on growth, yield and nutrient uptake of mung bean in an acidic soil of north east India. Application of RI alone or in combination with S or Co (without NPK) could not significantly increase the grain yield, but combined application of RI + S + Co did increase it up to 450 kg ha-1 from 240 kg ha-1 at control. Noticeably, application of recommended NPK (without any other inorganic or organic inputs) led to a better grain yield (530 kg ha-1), which was more than twice the yield at control. And further addition of RI+ S+ Co along with NPK (RDF) nearly tripled the yield (730 kg ha-1) compared to that of control. Effect of RI, S and Co application on crop yield was mediated mostly through increased nodulation and nutrient uptake, which were correlated well with seed yield.

Conclusion

In conclusion, the collective findings from the reviewed studies provide strong evidence in support of effect of varying levels of nitrogen and phosphorus in combination with *Rhizobium* in different varieties of mung bean holistic approach for promoting productivity and sustainability in mung bean crop. By optimizing the use of nitrogen, phosphorus, biofertilizer (*rhizobium)* and nano fertilizer is responsible for improving crop productivity, helping the decrease cost of cultivation and providing the sustainable environment for crop production

Competing interests

Authors have declared that no competing interests exist.

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