**Effect of Phosphorus Levels and Foliar Application of Boron on Nutrient Content and Uptake in Summer Green gram [*Vigna radiata* (L.)]**

**Abstract**

Phosphorus and boron are essential nutrients that play a crucial role in improving nutrient enrichment, and seed quality in legumes, especially under low-productivity conditions. Therefore, to evaluate the effect of phosphorus and boron application on enrichment of seed and straw of green gram, a field experiment was conducted at Agronomy Research Farm, MJRP College of Agriculture and Research, Achrol, Jaipur, Rajasthan. The experiment comprised of three levels of phosphorus (40, 50 and 60 kg ha-1) and 4 foliar applications of boron (0, 0.2% at 20, 0.2% at 35 and 0.2% at both 20 & 35 days after sowing) under a Factorial Randomized Block Design (FRBD) with three replications. The results of the study revealed that application of phosphorus and boron have synergistic effect on P and B content in seed and straw of green gram. Highest content of P and B in seed and straw was found when 60 kg ha-1 P along with foliar application of boron at 0.2% at 20 and 35 DAS (days after sowing). Application of P and B also improve protein content but their interaction was found non-significant. The combined application of 60 kg ha⁻¹ phosphorus and foliar boron at 0.2% at both 20 and 35 days after sowing significantly enhances phosphorus and boron content in seed and straw of green gram, thereby improving nutrient enrichment under low-productivity conditions.

**Keywords**: Phosphorous, boron, green gram, uptake, content, nutrients

**Introduction**

*Vigna radiata* (L.), commonly known as green gram or mungbean, is a legume crop belonging to the family *Leguminosae*. It has special importance for its short duration crop which responds well to added phosphorus (Kaur *et al*., 2023). “Among the cultivated pulse crops, green gram is rich source of protein (24.5%), fat (1.3%), minerals (3.5%) and carbohydrates (56.7%). It also provides high quality of some essential amino acids like lysine (460 mg/g N) and tryptophane (60mg/g N). It can provide some of the antioxidant in the form of ascorbic acid when sprouted and also contains riboflavin (0.21 mg/100 gm)” (Mekkara nikarthil Sudhakaran and Bukkan, 2021). Since the plant forms root nodules that fix atmospheric nitrogen, it requires an adequate supply of phosphorus to support this process (Guan *et al*., 2013). Fertilizer dosage and other environmental conditions can directly influence plant growth and development (Coskun and Toprak, 2023). “Phosphorus (P) is an essential plant nutrient required for optimum growth and production of crop plants. Plants need phosphorus for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division” (Atif *et al*., 2014). Whereas, “Boron (B) also play an important role within the plant includes cell wall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, regulation of plant hormone levels and generative growth of plants” (Shireen *et al*., 2018; Vera-Maldonado *et al*., 2024). “Phosphorus deficiency causes yield reduction by limiting plant growth” (Malhotra *et al*., 2018). “It influences nutrient uptake by promoting root growth and nodulation” (Sathiyavani *et al*., 2017; Liu *et al*., 2018).

“Various soil factors influence the availability of B to plants i.e., soil pH, native soil B contents, organic matter, carbonates, clay mineralogy, soil moisture, temperature and soil texture” (Matula, 2009). “The rapid fixation of applied B on calcareous soils is a serious problem to maintain adequate B concentration in soil solution” (Majidi *et al*., 2010). “Interaction of B with other nutrients could be antagonistic or synergistic depending upon soil type, crop species, growth stages, plant tissues and environmental conditions” (Kumar and Debbarma 2023). “Type of B interaction with other nutrients results in shifting of internal physiological balance between certain elements causing secondary alterations in the absorption and accumulation of other ions” (Hamza, *et al*., 2016). Huang *et al*. (2012) have reported “the increase in P uptake by plants under B application indicating their synergistic relationship”. “Positive interaction of adequate P and B levels has been found in brassica resulting in enhanced biomass production” (Lei *et al*., 2009).

“The response to a particular nutrient not only depends on its own level but also on the levels of other nutrients present in soil. Interaction occurs when the level of one production factor influences the response to another factor” (Satya, 2020, Phogat *et al.*, 2020). “These interactions may be synergetic (positive) leading to the increased availability of other plant nutrient or antagonistic (negative) in which availability of other plant nutrient adversely affected” (Padbhushan and Kumar, 2015). Therefore, the present study was undertaken to see the interaction effect of P and B on the nutrient content and uptake in summer green gram.

**Materials and Methods**

Field experiment was conducted during summer season (March-June, 2022) at Agronomy farm, College of Agriculture & Research, (Mahatma Jyoti Roa Phoole University) Achrol, Jaipur (Rajasthan). The experimental site is located at 30 km from Jaipur at 26005' North latitude, 75028' East longitude and at an altitude of 427 meters above mean sea level. The place falls in agroclimatic zone III A (Semi-arid eastern plain zone) of Rajasthan. The long-term average annual rainfall of the locality ranges between 400-500 mm, 85 per cent of which is received from south-west monsoon during the months of July and Sept but has declined over recent years. The soil of the experimental field was loamy sand in texture having alkaline pH (7.6), low in organic carbon (0.20%) and available nitrogen (127.23 kg ha-1), available phosphorus (18.21 kg ha-1) and available potassium (192.15 kg ha-1) and available sulphur in form of sulphate (8.0 ppm) content. A recommended green gram variety (RMG-268) was taken for the study. The experiment was laid out in Factorial Randomized Block Design (FRBD) with two factor different levels of phosphorus *viz*. 40, 50, 60 kg ha-1 and boron [no application, 20 & 35 DAS, 0.2 % foliar spray of borax] with twelve treatments combination on a plot size of 3 x 3 m2. Crop was sown in line and covered with the soil. The total quantity of nitrogen, phosphorus and potassium as per treatment in the form of urea, single super phosphate and MOP, respectively were applied below the seeds at the time of sowing. The initial B status was 498 ppm. Boron spray 0.2% solution of borax was prepared and spraying was done at 20, 35 and both 20 & 35 days after sowing. All the agronomic practices were carried out uniformly to raise the crop.

**Phosphorus (P) content**

Phosphorus concentration in seed and straw was determined by Vanadomolybdo phosphoric acid, yellow colour method. Digestion of samples was done by tri-acid mixture and the intensity of colour was measured by Spectrophotometer (Jackson, 1973).

**Boron content (B)**

B contents of the seed and straw were determined by dry ashing of the samples according to the method outlined by Gaines and Mitchell (1979). In a silica crucible, 0.5 g of the dried samples was placed and ashed at 550 0C in a muffle furnace. The gray-white ash was dissolved in 10 ml of 6 N hydrochloric acid (HCl) (distilled HCl) and heated to 80 0C on a hot plate to evaporate the content to dryness. The residue was dissolved in deionized water and transferred to a 25-ml volumetric flask, and volume was made to the mark with deionized water. The solution was then filtered through Whatman no. 42 filter paper. The B in the extract was determined by using azomethine-H as proposed by Gupta (1980).

**Nutrient uptake**

The uptake of phosphorus and boron by green gram crop at harvest was computed using the following formula:

|  |  |  |  |
| --- | --- | --- | --- |
| Nutrient uptake (kg ha-1) = | Per cent nutrient content in seed or straw | x | Seed or straw yield (kg ha-1) |
| 100 |

**Seed protein content**

 The per cent crude protein in seed from each plot was worked out by multiplying the nitrogen content in seed with conversion factor 6.25. (A.O.A.C, 1960).

|  |  |  |  |
| --- | --- | --- | --- |
| Protein yield (kg ha-1) = | Per cent crude protein in seed  | x | Seed yield (kg ha-1) |
| 100 |

**Results and Discussion**

**Boron content**

The maximum boron content in seed and straw was observed when P was applied @ 60 kg ha-1 (P3) and B @ 0.2% foliar spray of borax at 20 and 35 days after sowing (DAS). The significant increase in boron content of seed and straw was ranges from 51.04 mg kg-1 and 52.72 mg kg-1 boron in control to 58.32 mg kg-1 and 58.91 mg kg-1 boron at P3. Similarly, with increasing level of boron application there was significant increase in boron content in seed and straw in plants from 36.99 to 43.68 mg kg-1 boron in control whereas, highest was observed in B @ 0.2% foliar spray of borax at 20 and 35 days after sowing (DAS) with 67.02 and 64.74 mg kg-1 boron at highest level of applied boron, respectively (Table 1). Our results are in line with the results of Singh *et al*., (2006) who found “an increase in available P2O5 decreased the magnitude of B deficiency by 42% when available P2O5 was less than 30 kg ha-1, 38% when P2O5 ranging from 30-40 kg ha-1 and 29% above 40 kg P2O5 ha-1”. The results of Kamboj and Malik, 2018 also supported the present study.

**Table 1. Effect of phosphorus and boron application on green gram seed and straw boron content**

|  |  |  |
| --- | --- | --- |
| **Phosphorus levels** | **Boron levels** | **Mean** |
| B1 | B2 | B3 | B4 |
| Boron content (mg kg-1) in Seed |
| P1 | 36.12 | 49.61 | 56.27 | 62.18 | 51.04 |
| P2 | 37.21 | 53.72 | 60.52 | 67.01 | 54.61 |
| P3 | 37.65 | 56.57 | 67.18 | 71.89 | 58.32 |
| **Mean** | 36.99 | 53.30 | 61.32 | 67.02 |  |
| SE(m)± | P=0.39 | B=0.45 | PxB=0.78 |  |  |
| CD @ 5% | P=1.15 | B=1.33 | PxB=2.30 |  |  |
| Boron content (mg kg-1) in Straw |
| P1 | 43.18 | 51.92 | 55.02 | 60.77 | 52.72 |
| P2 | 43.82 | 55.76 | 58.16 | 64.71 | 55.61 |
| P3 | 44.05 | 57.99 | 64.89 | 68.74 | 58.91 |
| **Mean** | 43.68 | 55.22 | 59.35 | 64.74 |  |
| SE(m)± | P=0.53 | B=0.62 | PxB=1.07 |  |  |
| CD @ 5% | P=1.59 | B=1.83 | PxB=3.18 |  |  |

**Phosphorus content**

The phosphorus (P) content in seed and straw of green gram plants significantly increases with application of graded level of phosphorus (Table 2). The maximum P content was found in P3 0.46% to 0.20% which was significantly higher than control P1 0.34% to 0.12%. Synergistic effect was of boron was also observed with phosphorous application and significantly maximum P content was found in 0.48% and 0.19% in seed and straw, respectively. In control, minimum P content was observed in both seed (0.28%) and straw (0.10%). The interaction was found significant at 5% CD. The present study was supported by the investigation of Kamboj and Malik, 2018 and Malhotra *et al*., 2018 who have showed the synergistic effect of P and B on availability of phosphorus content in plants.

**Table 2. Effect of phosphorus and boron application on green gram seed and straw phosphrous content**

|  |  |  |
| --- | --- | --- |
| **Phosphorus levels** | **Boron levels** | **Mean** |
| B1 | B2 | B3 | B4 |
| Phosphorous content (%) in Seed |
| P1 | 0.28 | 0.31 | 0.38 | 0.39 | 0.34 |
| P2 | 0.34 | 0.37 | 0.48 | 0.52 | 0.42 |
| P3 | 0.36 | 0.43 | 0.51 | 0.55 | 0.46 |
| **Mean** | 0.32 | 0.37 | 0.45 | 0.48 |  |
| SE(m)± | P=0.008 | B=0.009 | PxB=0.016 |  |  |
| CD @ 5% | P=0.023 | B=0.027 | PxB=0.035 |  |  |
| Phosphorous content (%) in Straw |
| P1 | 0.10 | 0.11 | 0.14 | 0.15 | 0.12 |
| P2 | 0.13 | 0.14 | 0.17 | 0.18 | 0.15 |
| P3 | 0.15 | 0.19 | 0.22 | 0.24 | 0.20 |
| **Mean** | 0.12 | 0.14 | 0.17 | 0.19 |  |
| SE(m)± | P=0.006 | B=0.007 | PxB=0.012 |  |  |
| CD @ 5% | P=0.018 | B=0.020 | PxB=0.036 |  |  |

**Boron uptake**

The data shown in fig. 1 highlighted that the boron uptake in seed increased from 393.18 µg kg-1 in control to 505.29 µg kg-1 when P was applied @ 60 kg ha-1 (P3). Likewise, with the increasing level of boron application from 0 to 2 foliar spray of borax (0.2%) at 20 and 35 days after sowing (DAS) it was observed that the uptake of boron also increases significantly from 240.17 to 510.51 µg kg-1. Similarly, significantly increase in uptake of boron was also observed in straw with 2872.16 to 3405.96 µg kg-1 when P was applied @ 60 kg ha-1 (P3) and 2001.12 to 3614.98 µg kg-1 when the increasing level of boron application from 0 to 2 foliar spray of borax (0.2%) at 20 and 35 days after sowing (DAS) (Fig. 1). These results are in line with the results of Kumar *et al*., (2009) who showed “the increase in boron uptake up to application of 4 kg B ha-1 and 90 kg P2O5 ha-1 by grain and straw of lentil was noticed. This increase may be the result of increased grain and straw production with the addition B and P which enhance their availability in soil”.

**Phosphorus uptake**

The data highlighted in fig. 2 indicated that the significant increase in phosphorous uptake by the green gram plants with the increase in both phosphorous as well as boron application and showed synergistic effect with each other. The highest phosphorous uptake in seed (38332.65 µg kg-1) was noticed when P was applied @ 20:60:20 kg ha-1 (P3) and minimum was observed in P1 (25501.21 µg kg-1) when P was applied @ 20:40:20 kg ha-1. Likewise, with the increasing level of boron application from 0 to 2 foliar spray of borax (0.2%) at 20 and 35 days after sowing (DAS) it was observed that the highest uptake of phosphorous in seed was 36489.22 µg kg-1. Moreover, highest phosphorous uptake was also noticed in straw of green gram plants treated with P3 applied @ 20:60:20 kg ha-1 (P3) with 1388.18 µg kg-1 and minimum was observed in P1 (880.94 kg ha-1). The same trend was observed in case of foliar application of borax (0.2%) at 20 and 35 DAS with 1199.90 kg ha-1. The results of Mallick and Raj (2015), indicated that “phosphorus and boron application increased the seed uptake of P in rapseed and this increased in P uptake could be the response of variation in the availability of these nutrients in the soil and partly due to priming effect of one nutrient on the other on the uptake”. The results of Rana *et al*., (2005), also supported the present investigation who reported the similar effect of nutrient application. YuFan *et al*., (2012) also observed that “B application increased P uptake by plant. The interactive effect of P and B application on P uptake in seed of green gram was found significant”.

**Seed protein content**

The crude protein content in seed of green gram increases significantly from 20.81 to 22.35% when P was applied @ 20:60:20 kg ha-1 (P3). Whereas, with the application of boron the crude protein content in seed of green gram increases significantly and maximum was found when B applied with a foliar spray of borax (0.2%) at 35 days after sowing (DAS) *i.e.* 24.93% and after that there was a decrease in crude protein content occur with further addition of boron fertilizer (Table 3). The results of present investigation in line with the outcomes of Deo and Khaldelwal (2009), found that “application of P increased the number of nodules per plant of chickpea and protein content in grain”. Ganie *et al*., (2014), also reported “a significant increase in the crude protein content of French bean with graded level of boron application upto 1 mg B kg-1 which is statistically at par with 1.5 mg B kg-1 application”.

**Table 3. Effect of phosphorus and boron application on seed protein content (%) of green gram**

|  |  |  |
| --- | --- | --- |
| **Phosphorus levels** | **Boron levels** | **Mean** |
| B1 | B2 | B3 | B4 |
| P1 | 19.16 | 21.08 | 22.12 | 20.89 | 20.81 |
| P2 | 20.72 | 21.65 | 24.01 | 20.62 | 21.75 |
| P3 | 20.93 | 22.42 | 24.93 | 21.12 | 22.35 |
| **Mean** | 20.27 | 21.71 | 23.68 | 20.87 |  |
| SE(m)± | P=0.27 | B=0.32 | PxB=0.55 |  |  |
| CD @ 5% | P=0.82 | B=0.94 | PxB=NS |  |  |

**Conclusion**

The application of phosphorous at 60 kg ha-1 along with the two foliar sprays of boron at 0.2% increases the nutrient content and uptake in the seed as well as straw which ultimately increases the production and productivity of green gram.

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Fig. 1. Effect of phosphorous application on green gram seed and straw boron uptake

Fig. 2 Effect of phosphorous application on green gram seed and straw phosphorous uptake