RESEARCH ARTICLE

STUDY THE EFFECT OF PHOSPHORUS, SULPHUR AND PSB ON GROWTH ATTRIBUTING CHARACTERS OF MUSTARD

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Abstract: A field experiment was carried out at Agronomy Instructional Farm, School of Agricultural Sciences, Career Point University, Kota, Rajasthan during Rabi season of 2019-20 and 2020-21 to Studies on the Effect of Phosphorus, Sulphur and PSB on Mustard [Brassica juncea (L.)] growth, Yield and Quality. The experiment was laid out in Split plot design with four levels of phosphorus (RDF-N constant, 20 kg, 40 kg, 60 kg) and two levels of sulphur (40 kg, 60 kg) and phosphate solubilizing bacteria (control and inoculation) with three replications. The experiment results revealed that the growth parameters such as plant height (154.66, 199.61), fresh weight of shoots(127.28, 189.15), Dry weight of shoots(16.46, 24.56), Number of green leaves per plant(17.79, 20.82), number of branches per plant(23.29, 26.81) maximum was recorded under the treatment T4 (RDF (N constant) + 60 Kg Sulphur ha-1 + PSB Inoculation). However, it was at par recorded under treatments T15 (60 kg P2O5 ha-1 + 40 kg Sulphur ha-1 + Inoculation with PSB), at 60 days and 75 days after sowing in 2019-20 and same treatments shows tremendous result in 2020-21. During the year 2019-20 and 2020-21 earliest 50 per cent flowering (52.63, 55.82 days) was observed and Minimum days taken to maturity were recorded (102.72, 106.03) in the treatment T4 (RDF (N constant) + 60 Kg Sulphur ha-1 + PSB Inoculation) which was statistically at par with treatment T12 (40 kg P2O5 ha-1 + 60 kg Sulphur ha-1 + Inoculation with PSB). Treatment T4 was statistically significant especially when compared to treatments where no inoculation with PSB was done.

Keywords: Mustard, Phosphorus, Sulphur, PSB, RDF

INTRODUCTION

Rapeseed mustard (Brassica spp.) belongs to the family of Cruciferae is a major group of oilseed crops of the Globally, India continues to be rank 2nd after Canada in acreage (19.81%) and rank 4th after Canada, European Union and China in production (10.37%).Rapeseed mustard contributed 27 % in total oilseed production in the country. Indian mustard is preferred due to its high yield potential and oil content. Indian mustard has multiple uses as a spice or condiment in preparation, seasoning and stuffing of several foods and pickles. Yield potential of this crop can be explored by the use of organic techniques.

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is an important *rabi* oilseed crop in India. The maximum average yield of 2,606 kg/ha from the IP under irrigated conditions was in Haryana followed by 2,372 kg/ha in Rajasthan, and average yield of 1,544 kg/ha from the IP of WP under rainfed conditions was in Rajasthan followed by 1,227 kg/ha in Assam, However, production got slightly decreased from 9.26 mt (2018-19) to 9.12 mt (2019-20), It has been observed that during last 10 years (2010-11 to 2019-20), at country level, the acreage of rapeseed-mustard slightly decreased by -0.64. However, increase in yield by 11.0% and production by 10.36% (AICRP-RM-AR 2021). Mustard is nutritionally very rich and its oil content varies from 37-49% belong to the family of Cruciferae. Crucifers containing high amounts of glucosinolates have a high sulfur demand (Rathore *et al.*, 2015). Indian mustard [*Brassica juncea*(L.)] is predominantly cultivated in Rajasthan, UP, Haryana, Madhya Pradesh, and Gujarat. It has good yield potential, wide adaptability and possesses high oil content of good quality. The country witnessed yellow revolution through a phenomenal increase in production and productivity from 5.08 MT and 1002 kg ha^{-1} in 2001-02 to 8.18 MT and 1185 kg ha^{-1} in 2010-11, respectively.

To meet up the growing demand of oilseed, it is urgent to ensure its higher production. It is almost impossible to increase production by increasing area because of crop competitions. Therefore, production per unit area can be increased by adopting improved technology and inputs.

Among the primary nutrients, phosphorus is the most important constraint for increasing oilseed production because of the nutrient's requirement of oilseeds, in general is high. Phosphorus has been referred as 'King Pin' in Indian agriculture and is one of the 'big three' in crop nutrition. It is also referred as the 'Master Key' element in crop production (Gangwal *et al.*, 2011). Phosphate fertilizers being a source of major nutrients are of paramount importance in increasing yields. Several researches have observed favorable response to applied phosphorus by mustard (Jaggi and Sharma, 1997).

Mustard is responsive to sulphur in comparison to other crops. Sulfur fertilization has also been shown to increase the oil content in seeds of rapeseed-mustard (Singh *et al.*, 2015). Sulphur is the key component of balanced nutrient application for higher yields and superior quality produce of mustard. Sulphur plays a vital role in the synthesis of amino acids (Rathore *et al.*, 2015), chlorophyll and

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certain vitamins (Tiwari and Gupta 2006) in mustard plant.

Biofertilizer are known to play a number of vital roles in soil fertility crop productivity and production in agriculture as they are eco-friendly but cannot at any cost replace chemical fertilizers that are indispensable for getting maximum crop yields. They supplement chemical fertilizers for meeting the integrated nutrient demand of the crops, they also promote seed germination and initial vigor of plant by producing growth promoting substances (Yadav *et al.*,2010)

Use of biofertilizer can have a greater impact in increasing fertilizers use efficiency. Phosphate solubilizing bacteria-PSB (microorganisms) is distributedwell in several ecosystems. Bacteria (*Bacillus, Pseudomonas, Micrococcus, Flavobacterium* etc.) have been isolated, which have consistent capacity to solubilize insoluble phosphorus such as a rock phosphate, tricalcium phosphate, iron phosphate, aluminum phosphate etc. Phosphate solubilising bacteria (PSB) are solubilising the unavailable phosphates in the soil through excretion of organic acids such as butyric, tartaric, aspartic, glutamic, lactic, citric, fumaric, oxalic, glucolic, malic, fumaric and a-ketobutyric acids (Bardiya and Gaur, 1972; Gaur and Pareek, 1974) which lower down the soil pH and liberate bound phosphate. Besides, some of the hydroxy acids may chelate calcium and iron resulting in effective solubilization and thereby higher utilization of soil phosphates by plants.

MATERIALS AND METHODS

The experiment was laid out at the agriculture research farm of Career Point University, Kota, Rajasthan during the years 2019-20 and 2020-21. The experimental site lies 25.0112° N, 75.9139° E at an elevation of 271 meters above msl. The site was levelled having good irrigation facilities. Geographically Kota lies in the humid south eastern plains of Rajasthan. Kota has dry period in January, February, March, April, May, November and December. July is the wettest month of the region whereas March is the driest month of the region. Mostly rainfall is seen in the months of July and August.Present study consisted of 16 treatments laid in a split plot design (SPD) having three number of replications.Fertilizers were applied as per the treatment details to the crop. Inoculation of the seeds of mustard was done with PSB before sowing. Urea, DAP and MOP were used as sources of nitrogen, phosphorus and potassium. Observations were recorded on vegetative characters Plant height, Fresh weight of shoots,Dry weight of shoot, Number of green leaves per plant, Number of branches plant, Days taken to 50 per cent flowering, Days to maturityand Seed yield (q ha-1). The data had been statistically analysed adopting procedure as given by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Plant height

Data pertaining to plant height under the effect of phosphorus, sulphur and PSB on mustard at different intervals has been presented under the Table 1. A keen observation of the data reveals that application of phosphorus and sulphur along with inoculation with PSB had a significant effect on the plant height in mustard. During 2019-20, at 30 DAS, maximum plant height was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) where 28.72 cm of plant height was recorded. However it was at par with the plant heights recorded under treatments T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB), T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB), T_{12} (40 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) and T_3 (RDF (N constant) + 40 Kg Sulphur/ha^{-1} + PSB Inoculation) recording a plant height of 27.59 cm, 27.28 cm, 26.47 cm and 26.38 cm, respectively. The increment in plant height of mustard followed a similar trend at 45 DAS with maximum plant height being recorded under treatment T_4 (71.68 cm) followed by treatments T_{15} (68.75 cm), T_{16} (66.47 cm), T_{12} (66.21 cm) and T_3 (66.02 cm). Minimum plant height (19.32 cm and 40.68 cm at 30 DAS and 45DAS, respectively) was recorded in the treatment T_1 (RDF (N constant) + 40 Kg Sulphur ha^{-1} + No Inoculation). Treatment T_4 continued to perform numerically superior compared to all other treatments at 60 DAS and 75 DAS. At harvest, maximum plant height of 221.76 cm was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) followed by the treatment T_{15}comprising of application of 60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB which was at par with treatment T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) where plant height of 219.79 cm and 219.45 cm, respectively was recorded.

The trend in the plant height of mustard plants as affected by the application of phosphorus, sulphur and PSB application continued during 2020-21 (Table 1). At 30 DAS, maximum plant height of 29.48 cm was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation). It was followed by treatments T_{15} (27.84 cm), T_{16} (27.62 cm), T_{12} (26.81 cm) and T_3 (26.76 cm). Similar trend of increment in plant height was observed at 45 DAS, 60 DAS and 75 DAS with treatment T_4 maintaining its numerical superiority over the other treatments. Minimum plant height during all these observation intervals was recorded under the treatment T_1. At harvest, maximum plant height of 224.47 cm was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation). This treatment was closely

followed by treatment T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB) and treatment T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) wherein plant height of 222.12 cm and 221.59 cm, respectively was recorded. Minimum plant height during both the years of the study (2019-2020 and 2020-21) i.e. 197.64 cm and 201.42 cm, respectively, were recorded under the treatment T_1 (RDF (N constant) + 40 Kg Sulphur ha^{-1} + No Inoculation).

Application of nitrogen as per the recommended dose resulted in maximum plant height as evident from the data presented in Table 1. Nitrogen plays a vital role in affecting the growth characters of a plant as evidenced through supporting literature which justifies the role of nitrogen as an essential nutrient for plant growth and development. Application of nitrogen resulted in vigorous growth of mustard plants which resulted in maximum plant height. Nitrogen is an integral component of chlorophyll molecule and plays role in carbohydrate synthesis and enhancing seedling vigour. It is clear understanding from the results achieved that recommended dosage of nitrogen alongwith other nutrients resulted in elevated plant height and production of primary and secondary branches. Higher levels of phosphorus along with PSB inoculation also resulted in elevated values for plant height as evident from the data. PSB aids in better allocation of phosphorus to the plant and hence enhances the uptake response of the mustard crop. Application of higher levels of nitrogen has been reported to increase the plant height in mustard as reported by the studies of Kumar *et al.* (2017). Higher levels of nitrogen @120 kg/ha resulted in maximum plant height for mustard plants. Potdar *et al.* (2021) also confirmed that application.

Fresh weight of shoots

Data pertaining to the fresh weight of shoots of mustard at harvest is presented in Table 1. A keen observation of the data reveals that nitrogen application resulted in elevated levels of shoot fresh weight. During the year 2019-20, maximum fresh weight of the shoots (11.19 g) was recorded with the application of RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation (T_4) which was closely followed by treatment T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB), T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB), T_{12} (40 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) and T_3 (RDF (N constant) + 40 Kg Sulphur/ha^{-1} + PSB Inoculation) recording a fresh shoot weight of 11.09 g, 11.05 g, 10.89 g and 10.76 g, respectively. However, statistically, all the treatments were at par and having non-significant differences among themselves. The increment in fresh shoot weight of mustard followed a similar trend at 45 DAS with maximum plant height being recorded under treatment T_4 (103.61 g) followed by treatments T_{15} (101.28 g), T_{16} (99.71 g), T_{12} (98.21 g) and T_3 (96.47 g). Minimum fresh shoot weight (9.13 g and 49.28 g at 30 DAS and 45DAS, respectively) was recorded in the treatment T_1 (RDF (N constant) + 40 Kg Sulphur ha^{-1} + No Inoculation). Treatment T_4 continued to perform numerically superior compared to all other treatments at 60 DAS and 75 DAS. At harvest, maximum fresh shoot weight of 189.15 g was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) followed by the treatment T_{15}comprising of application of 60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB which was at par with treatment T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) where plant height of 168.68 g and 171.96 g, respectively was recorded.

The trend in the fresh weight of shoots in mustard plants as affected by the application of phosphorus, sulphur and PSB application continued during 2020-21 (Table 4.2). At 30 DAS, maximum fresh shoot weight of 13.21 g was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation). It was followed by treatments T_{15} (13.17 g), T_{16} (12.98 g), T_{12} (11.86 g) and T_3 (11.64 g). Similar trend of increment in plant height was observed at 45 DAS and 60 DAS with treatment T_4 maintaining its numerical superiority over the other treatments. Minimum plant height during all these observation intervals was recorded under the treatment T_1. At 75 DAS, maximum fresh shoot weight of 191.27 g was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation). This treatment was closely followed by treatment T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB) and treatment T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) wherein plant height of 179.05 g and 178.85 g, respectively was recorded. Minimum fresh shoot weight during both the years of the study i.e. 155.74 g and 161.79 g, respectively, were recorded under the treatment T_1 (RDF (N constant) + 40 Kg Sulphur ha^{-1} + No Inoculation).Availability of nitrogen alongwith higher doses of phosphorus and sulphur resulted in increased plant biomass which in turn increased the fresh weight of the shoots. Incorporation of biofertilizers inoculation resulted in increased availability of nutrient to the mustard plants which enhanced the uptake capacity of the plants thereby increasing the build-up mass of the plant. Similar effects of higher doses of phosphorus and sulphur on the mustard plant biomass have been reported by researchers like Khatkar *et al.* (2009) and Kishanrao *et al.* (2009) wherein they reported increased fresh and dry weight of the plants due to increased phosphorus and sulphur application.

Dry weight of shoot

Data pertaining to the fresh weight of shoots of mustard at harvest is presented in Table 2. A keen observation of the data reveals that nitrogen application resulted in elevated levels of shoot fresh weight. During the year 2019-20, maximum dry

weight of the shoots (1.51 g) was recorded with the application of RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation (T_4) which was closely followed by treatment T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB), T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB), T_{12} (40 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) and T_3 (RDF (N constant) + 40 Kg Sulphur/ha^{-1} + PSB Inoculation) recording a shoot dry weight of 1.50 g, 1.48 g, 1.45 g and 1.44 g, respectively. However, statistically, all the treatments were at par and having non-significant differences among themselves. The increment in dry weight of shoots of mustard followed a similar trend at 45 DAS with maximum plant height being recorded under treatment T_4 (10.27 g) followed by treatments T_{15} (8.43 g), T_{16} (8.34 g), T_3 (8.15 g) and T_{12} (8.14 g). Minimum dry shoot weight (1.29 g and 5.29 g at 30 DAS and 45DAS, respectively) was recorded in the treatment T_1 (RDF (N constant) + 40 Kg Sulphur ha^{-1} + No Inoculation). Treatment T_4 continued to perform numerically superior compared to all other treatments at 60 DAS. At 75 DAS, maximum dry shoot weight of 24.56 g was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) followed by the treatment T_{15} comprising of application of 60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB which was at par with treatment T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) where dry shoot weight of 23.86 g and 23.24 g, respectively was recorded.

The trend in the dry weight of shoots in mustard plants as affected by the application of phosphorus, sulphur and PSB application continued during 2020-21 (Table 2). At 30 DAS, maximum dry shoot weight of 1.81 g was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation). It was followed by treatments T_{15} (1.79 g), T_{16} (1.76 g), T_{12} (1.73 g) and T_3 (1.71 g). Similar trend of increment in shoot dry weight was observed at 45 DAS and 60 DAS with treatment T_4 maintaining its numerical superiority over the other treatments. Minimum shoot dry weight during all these observation intervals was recorded under the treatment T_1. At 75 DAS, maximum shoot dry weight of 29.27 g was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation). This treatment was closely followed by treatment T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB) and treatment T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) wherein dry shoot weight of 28.56 g and 27.98 g, respectively was recorded. Minimum dry shoot weight during both the years of the study i.e. 155.74 g and 161.79 g, respectively, was recorded under the treatment T_1 (RDF (N constant) + 40 Kg Sulphur ha^{-1} + No Inoculation).

Shoot dry weight corresponds to the fresh weight of the plant as well as the biomass of the plant. Plentiful availability of nutrients leads to superior biomass build up in plants resulting in increased fresh and dry weights of the plants. Similar effects of higher doses of phosphorus and sulphur on the mustard plant biomass have been reported by researchers like Khatkar *et al.* (2009), Kishanrao *et al.* (2009) and Trivedi and Sharma (1997) wherein they reported increased fresh and dry weight of the plants due to increased phosphorus and sulphur application.

Number of green leaves per plant

Data pertaining to number of green leaves in mustard plant under the effect of phosphorus, sulphur and PSB application has been presented under the Table 2. Perusal of the data reveals an increasing trend in the total number of leaves during the growth cycle of the crop during both the years of the study. Data on number of green leaves per plant was recorded at 30, 45, 60 and 75 DAS. In the first year of the study, at 30 DAS, maximum number of green leaves (9.56) were recorded under the treatmentT_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) which were at par with treatment T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB), T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) and T_{12} (40 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) where 9.47, 9.32 and 9.08 number of green leaves were recorded, respectively. Minimum number of green leaves (7.68) was recorded under treatment T_1 (RDF (N constant) + 40 Kg Sulphur ha^{-1} + No Inoculation). At 45 DAS, similar trend was observed among all the treatments with maximum number of green leaves being recorded under treatment T_4 (13.49) followed by T_{15} (13.38) and T_{16} (13.29). Minimum number of green leaves was recorded under treatment T_1 (10.27). At 60 DAS, similar trend in number of green leaves was observed under all the treatments. Maximum number of green leaves were recorded under treatment T_4 (17.79) followed by treatments T_{15} and T_{16} having a value of 17.68 and 17.35, respectively. Minimum number of green leaves (15.76) at 60 DAS was observed under treatment T_1. At 75 DAS, there was a slight variation in the already exhibited trend for number of green leaves. Maximum number of green leaves (21.54) was recorded under treatment T_{15} which was statistically at par with treatment T_{16} (21.29) and T_4 (20.82). Minimum number of green leaves was recorded under treatment T_1. During the next year (2020-21), similar trend was observed with respect to number of green leaves in mustard. At 30, 45 and 60 DAS, maximum number of green leaves were recorded under treatment T_4 but at 75 DAS, maximum number of green leaves were recorded under the treatment T_{15} (25.89) followed by T_{16} (25.43) and T_4 (24.88). Minimum number of green leaves was recorded for the treatment T_1. Treatments T_{15}, T_{16} and T_4 were statistically significant as compared to treatment T_1.Although nitrogen stimulates the vegetative growth in plants and is responsible for cell

elongation, during the later stages, higher doses of sulphur increased the number of leaves in the mustard crop leading to elevated numbers. Such results are in conformity to the earlier reported findings of Dubey *et al.*(2013) where application of higher dosage of sulphur (60 kg per ha) resulted in higher number of green leaves in mustard plant.

Number of branches plant

Data pertaining to effect of phosphorus, sulphur and PSB on number of branches per plant in mustard is presented under Table 3. Data was recorded on primary and secondary branches in mustard plant. A keen observation of the data reveals that there were no significant differences among treatments at 30 DAS for number of branches. However, maximum number of branches were recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) where 8.02 number of branches were recorded. This was followed by treatments T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB), T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) and T_{12} (40 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) recording a branch number of 8.01, 7.93 and 7.79, respectively. Minimum number of branches (6.14) was recorded for the treatment T_1 (RDF (N constant) + 40 Kg Sulphur ha^{-1} + No Inoculation). At 45 DAS, similar trend was observed and maximum number of branches (16.65) were recorded for treatment T_4 which was closely followed by treatments T_{15} (16.21), T_{16} (16.06) and T_{12} (15.92). Minimum number of branches was recorded under the treatment $T_{.1}$. The trend followed for number of branches at 60 DAS, 75 DAS and at harvest. At harvest, maximum number of branches were recorded for treatment T_4 (28.81) followed by T_{15} (27.67) and T_{16} (27.21) which were at par with treatment T_4. However, there was a significant difference with other treatments especially with treatment T_1 where 18.75 number of branches was recorded.

During the next year (2020-21), similar trend in the number of branches as affected by different treatments was observed (Table 3). However, at 30 DAS, the data was statistically nonsignificant. Numerically, maximum number of branches were recorded under the treatment T_4 (9.36) which was followed by treatments T_{15} (9.24) and T_{16} (9.12). At 45 DAS, a maximum of 17.61 number of branches were recorded under treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) followed by treatments T_{15} and T_{16} recording a branch number of 17.24 and 17.14 branches, respectively. Minimum number of branches (11.24) was recorded for treatment T_1. At 45 DAS and 60 DAS, treatment T_4 maintained its supremacy with maximum number of branches per plant which were statistically significant when compared to most of the treatments especially T_1 (13.86 and 17.21, respectively). At harvest, maximum number of branches were recorded for treatment T_4 (30.64) followed by T_{15} (30.21) and T_{16} (29.64) which were at par with treatment T_4. However, there was a significant difference with other treatments especially with treatment T_1 where 19.61 number of branches was recorded.Apparent availability of nitrogen along with higher doses of phosphorus and sulphur resulted in higher number of branches (primary as well as secondary) in mustard plant. Higher doses of sulphur and phosphorus favour formation of new branches and are particularly having an impact on secondary branches in mustard plant. Singh *et al.*(2015)reported an increased number of branches with the application of P_2O_5 applied at 100 per cent equivalent to nitrogen along with *azotobacter* and PSB application. Application of PSB resulted in increased number of branches as reported by Solanki and Sharma (2016).

Days taken to 50 per cent flowering

Data pertaining to flowering is presented in Table 3. Mustard plants responded to the application of sulphur, phosphorus and PSB for flowering intensity. During the year 2019-20, earliest 50 per cent flowering (52.63 days) was observed in the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) which was statistically at par with treatment T_{12} (40 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB), T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB), T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB), T_3 (RDF (N constant) + 40 Kg Sulphur/ha^{-1} + PSB Inoculation) and T_8(20 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) where days to 50 per cent flowering were recorded as 52.84, 53.17, 53.56,53.87 and 54.29 days, respectively. Maximum number of days to 50 per cent flowering (67.24) were recorded under the treatment T_5 (20 kg P_2O_5 ha^{-1} + 40 Sulphur ha^{-1} + No Inoculation).

During 2021-21, similar trend related to 50 per cent flowering in mustard plant under the effect of phosphorus, sulphur and PSB was observed. Minimum days to 50 per cent flowering (55.82) was recorded under the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) which was statistically at par with treatment T_{12} (40 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB), T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB), T_{15} (60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB), T_3 (RDF (N constant) + 40 Kg Sulphur/ha^{-1} + PSB Inoculation) and T_8(20 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) where days to 50 per cent flowering were recorded as 56.03, 56.36, 56.75, 57.06 and 57.48 days, respectively. Maximum number of days for 50 per cent flowering were recorded under treatment T_5 (20 kg P_2O_5 ha^{-1} + 40 Sulphur ha^{-1} + No Inoculation). Nutrient availability at the right stage of plant growth results in timely completion of the phonological events in a crop. Under current experiment, different combinations of phosphorus, sulphur and PSB resulted in availability of nutrients to the mustard

plant which resulted in earliest 50 per cent flowering in some of the treatments. Beenish*et al.*(2019) reported similar findings with the application of biofertilizers where plants treated with *azotobacter*recorded earliest 50 per cent flowering. Application of sulphur @ 60kg per ha resulted in earliest 50 per cent flowering as reported by Dubey *et al.*(2013).

Days to maturity

Data pertaining to days taken to maturity for mustard crop during 2019-20 and 2020-21 season has been presented in Table3.A keen observation of the data reveals significant effect of sulphur, phosphorus and PSB on days taken for crop maturity in mustard. During the year 2019-20, it was observed that the trend followed as observed in 50 per cent flowering. The plants which were earliest in 50 per cent flowering were also the earliest to mature as compared to other treatments. Minimum days taken to maturity were recorded for the treatment T_4 (RDF (N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation) where 102.72 days were recorded. Treatment T_4 was statistically significant especially when compared to treatments where no inoculation with PSB was done. It was followed by treatments T_{12}, T_{16} and T_{15} with number of days as 104.93, 105.26 and 107.65 days were recorded. Maximum days to maturity (122.95) were recorded under the treatment T_5 (20 kg P_2O_5 ha^{-1} + 40 Sulphur ha^{-1} + No Inoculation).

During the next year of study (2020-21), similar trend in days taken for maturity was observed in mustard crop under the effect of different treatments. Minimum number of days to maturity were recorded again for treatment T_4 (106.03) followed by T_{12} (107.24), T_{16} (108.57) and T_{15} (110.96). Maximum number of days taken to maturity for mustard crop was recorded under the treatment T_5 with 130.64 days. Treatment T_4 was statistically significant when compared to treatments with low doses of sulphur or phosphorus and without inoculation.

During the analysis of the results, it was clear that higher levels of phosphorus and sulphur along with inoculation with PSB resulted in earlier maturity of the mustard crop. This may also be linked with the similar results obtained with earliest 50 per cent flowering as the crops that flowered earlier reached maturity earlier. Singh &Thenua (2016) also reported similar finding when 60 kg of phosphorus was applied to mustard which resulted in minimum days taken to maturity of the mustard crop.

Table 1. Effect of Phosphorus, sulphur and PSB on Plant Height and fresh weight of shoots (g) in mustard

Treatments	Plant Height										Fresh weight of shoots (g)							
	30 DAS		45 DAS		60 DAS		75 DAS		At harvest		30 DAS		45 DAS		60 DAS		75 DAS	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1	19.32	19.56	40.68	41.82	119.64	121.62	162.13	168.27	177.64	179.42	9.13	9.89	49.28	55.63	63.48	72.47	155.74	161.79
T_2	22.98	23.21	55.47	56.21	135.24	136.89	180.66	182.47	209.24	212.35	10.12	11.05	72.97	84.32	85.23	102.69	168.89	170.96
T_3	26.38	26.76	66.02	66.81	150.28	152.61	192.47	194.28	212.79	214.32	10.76	11.64	96.47	104.27	111.91	122.36	172.09	177.13
T_4	28.72	29.48	71.68	72.49	154.66	155.24	199.61	201.23	221.76	224.47	11.19	13.21	103.61	109.74	127.28	159.65	189.15	191.27
T_5	20.22	20.48	47.26	47.81	125.28	126.58	172.81	174.26	181.47	184.47	9.34	10.27	55.27	64.21	72.41	81.96	168.19	172.28
T_6	21.47	21.35	52.76	53.47	130.51	132.21	177.64	179.28	201.67	203.28	9.89	10.72	65.47	76.29	80.47	92.66	162.34	165.47
T_7	23.46	23.82	57.26	57.88	137.64	138.59	182.89	184.13	209.58	211.69	10.19	11.09	79.64	89.28	89.47	104.68	152.27	168.38
T_8	26.05	26.24	65.12	65.47	147.26	148.79	190.64	191.96	211.96	213.64	10.58	11.24	92.58	102.99	109.63	119.47	159.41	175.47
T_9	21.09	21.34	50.64	51.12	129.54	131.22	175.29	176.87	193.38	195.64	9.75	10.52	61.04	72.17	76.48	89.73	147.39	158.32
T_{10}	25.62	25.47	60.47	61.23	141.57	142.64	186.81	188.27	210.42	212.51	10.27	11.21	87.21	96.49	99.67	112.46	149.45	171.42
T_{11}	22.44	22.53	54.23	54.78	132.47	132.69	179.28	181.47	205.68	207.68	10.05	10.98	69.28	81.42	81.58	99.47	161.62	168.75
T_{12}	26.47	26.81	66.21	66.59	150.47	151.69	194.69	195.92	214.38	216.55	10.89	11.86	98.21	105.79	116.49	128.64	177.71	178.78
T_{13}	23.89	24.17	59.89	59.74	139.82	141.28	184.33	186.29	209.82	210.47	10.18	11.17	85.49	93.76	92.51	109.86	148.59	168.62
T_{14}	25.88	26.01	61.39	61.88	144.28	145.37	189.28	190.55	211.78	213.79	10.31	11.28	89.47	98.29	102.68	117.59	159.62	174.58
T_{15}	27.59	27.84	68.75	69.26	152.89	153.64	198.47	200.58	219.79	222.12	11.09	13.17	101.28	106.89	124.47	141.59	168.68	179.05
T_{16}	27.28	27.62	66.47	67.23	151.67	151.86	195.49	197.23	217.45	219.59	11.05	12.98	99.71	103.24	122.75	139.63	171.96	178.85
S.Em (±)	1.07	1.17	2.09	2.18	5.14	5.29	7.81	8.02	9.01	9.23	0.48	0.55	1.09	1.36	2.96	3.48	3.81	3.24
C.D. (@5%)	2.86	3.24	8.18	8.76	14.69	15.14	20.24	21.47	24.68	25.21	NS	NS	3.21	4.01	3.94	4.21	5.97	5.46

Table 2. Effect of Phosphorus, sulphur and PSB on Dry weight of shoots (g) and green leaves per plantin mustard

Treatments	Dry weight of shoots (g)								Green leaves per plant							
	30 DAS		45 DAS		60 DAS		75 DAS		30 DAS		45 DAS		60 DAS		75 DAS	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1	1.29	1.52	5.29	6.42	9.28	11.21	16.96	20.89	7.68	10.21	10.27	12.87	15.76	17.21	14.51	16.78
T_2	1.37	1.61	6.57	8.31	12.24	14.98	18.82	22.94	8.04	10.86	11.86	14.86	16.12	19.08	16.39	20.21
T_3	1.44	1.71	8.15	9.69	14.72	18.06	22.15	26.75	8.92	11.81	12.91	16.29	17.09	20.31	19.54	23.41
T_4	1.51	1.81	8.59	10.27	16.46	19.64	24.56	29.27	9.56	12.21	13.49	16.82	17.79	21.28	20.82	24.88
T_5	1.34	1.56	6.07	7.22	10.04	13.12	17.21	21.11	7.81	10.34	11.06	13.75	15.81	18.26	14.88	18.79
T_6	1.35	1.59	6.82	7.98	10.83	13.97	17.91	21.96	7.91	10.59	11.17	14.08	15.93	18.61	15.89	19.21
T_7	1.38	1.63	6.74	8.55	12.81	15.32	19.23	23.15	8.19	11.09	12.17	15.08	16.29	19.21	17.18	20.72
T_8	1.42	1.69	7.97	9.53	14.21	17.69	21.74	25.84	8.79	11.65	12.82	16.05	16.91	20.05	19.12	22.92
T_9	1.35	1.58	6.54	7.62	10.29	13.64	17.47	21.32	7.88	10.47	11.12	13.97	15.90	18.42	15.18	19.08
T_{10}	1.40	1.68	7.21	9.05	13.51	16.86	20.12	23.96	8.49	11.42	12.56	15.65	16.74	19.71	18.54	22.09
T_{11}	1.37	1.62	7.78	8.06	11.67	14.21	18.55	22.56	7.98	10.72	11.64	14.55	16.02	18.84	16.14	19.83
T_{12}	1.45	1.73	8.14	9.82	15.14	18.65	22.91	27.24	9.08	11.96	13.05	16.55	17.21	20.68	19.86	23.87
T_{13}	1.40	1.65	6.88	8.79	13.12	15.96	19.85	23.51	8.31	11.27	12.41	15.32	16.31	19.37	17.79	21.56
T_{14}	1.41	1.65	7.55	9.48	14.02	17.27	20.85	24.66	8.62	11.61	12.72	15.92	16.82	19.86	18.83	22.64
T_{15}	1.50	1.79	8.43	10.18	15.98	19.02	23.86	28.56	9.47	12.18	13.38	16.71	17.68	21.09	21.54	25.89
T_{16}	1.48	1.76	8.34	9.98	15.65	18.82	23.24	27.98	9.32	12.04	13.29	16.64	17.35	20.97	21.29	25.43
S.Em (±)	0.02	0.07	0.32	0.39	0.72	0.79	0.89	1.12	0.26	0.43	0.52	0.65	0.69	0.82	0.91	1.14
C.D. (@5%)	NS	NS	0.96	1.17	1.82	2.29	2.61	3.24	0.64	1.21	1.57	1.91	2.02	2.79	2.63	3.21

Table 3. Effect of Phosphorus, sulphur and PSB onnumber of branches per plantand 50% flowering and days to maturityin mustard

Treatments	number of branches per plant										50% flowering and days to maturity			
	30 DAS		45 DAS		60 DAS		75 DAS		At Harvest		50% Flowering		Days to Maturity	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1	6.14	6.58	10.89	11.24	12.54	13.86	16.75	17.21	18.75	19.61	62.86	66.05	122.95	126.26
T_2	6.95	7.92	13.42	14.86	16.63	18.54	20.32	21.34	22.32	23.74	57.28	60.47	117.37	120.68
T_3	7.72	8.78	15.79	16.85	20.72	23.54	23.81	26.02	25.81	28.42	53.87	57.06	111.96	113.27
T_4	8.02	9.36	16.65	17.61	23.29	25.58	26.81	28.24	28.81	30.64	52.63	55.82	102.72	106.03
T_5	6.41	7.22	11.88	12.74	14.21	15.86	18.42	19.21	20.42	21.61	67.24	70.43	127.33	130.64
T_6	6.79	7.75	12.74	13.88	15.31	17.94	19.25	20.14	21.25	22.54	59.59	62.78	119.68	122.99
T_7	7.02	8.01	13.97	15.02	17.24	19.17	20.86	21.95	22.86	24.35	56.19	59.38	116.28	119.59
T_8	7.69	8.54	15.49	16.41	19.83	22.56	23.29	25.71	25.29	28.11	54.29	57.48	114.38	117.69
T_9	6.69	7.68	12.31	13.29	14.56	17.24	18.59	19.82	20.59	22.22	61.24	64.43	121.33	124.64
T_{10}	7.39	8.28	14.71	15.85	18.73	20.47	22.32	23.91	24.32	26.31	54.98	58.17	116.07	119.38
T_{11}	6.84	7.81	13.21	14.50	15.82	18.19	19.81	20.77	21.81	23.17	58.43	61.62	118.52	121.83
T_{12}	7.79	8.92	15.92	17.03	22.08	24.37	24.78	26.51	26.78	28.91	52.84	56.03	104.93	107.24
T_{13}	7.13	8.11	14.33	15.51	17.71	19.46	21.74	22.87	23.74	25.27	55.86	59.05	115.95	119.26
T_{14}	7.51	8.47	15.24	16.18	19.21	21.48	22.84	24.28	24.84	26.68	54.71	57.9	115.80	118.11
T_{15}	8.01	9.24	16.21	17.24	22.86	25.17	25.67	27.81	27.67	30.21	53.56	56.75	107.65	110.96
T_{16}	7.93	9.12	16.06	17.14	22.41	24.89	25.21	27.24	27.21	29.64	53.17	56.36	105.26	108.57
S.Em (±)	0.09	0.12	0.19	0.22	0.31	0.42	0.69	0.72	0.89	0.91	1.27	1.42	2.98	3.09
C.D. (@5%)	NS	NS	0.58	0.68	1.06	1.28	1.42	1.51	2.08	2.13	2.41	2.76	4.56	5.21

CONCLUSION

On the basis of the experimental findings, it may be concluded that application of recommended doses of fertilizers with optimum doses of phosphorus and Sulphur inoculation with PSB increase the growthof mustard. Phosphorus and Sulphur are important elements in sustaining growth of mustard. This is reflected in terms of significant increase in growthattributing characters,plant height, fresh weight of shoots, Dry weight,Number of green leaves per plant, number of branches per plant, earliest 50 per cent flowering and Minimum days taken to maturity. Maximum growth, 50 % of flowering and minimum maturity days of mustard was recorded in T4 (RDF (N constant) + 60 Kg Sulphur ha-1 + PSB Inoculation)application, thus the application of these elements in deficient areas is recommended to increase the growth and productivity of mustard in the region.

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