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Response of *Rhizobium* Inoculation and Boron Application on Yield and its Attributes and Root Morphology in Pea (*Pisum sativum* L.)

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ABSTRACT

Healthy growth and yield of pulse crop depend on many factors, in which one of them is morphological growth of roots including number of root nodules. Keeping in view, an experiment was conducted to explore the impact of *Rhizobium* inoculation and boron application on root morphology, growth, yield and yield attributes in pea. The results obtained from the study showed that morphological growth of roots like root length (cm), root volume (cm^3) and root nodules/plant were positively influenced with the treatments and gradually increased as the amount of boron in combination with *Rhizobium* increased up to 2 kg/ha as compared to control. The best performance related to root morphological characters over control was recorded in T_5 followed by $T_4 > T_3 > T_2 > T_1$ as compared to control T_0 in V_1, while T_4 was recorded best in V_2. The response of treatments with respect to yield and yield attributes was same as morphological growth of root in both the varieties. Comparative analysis among the best varieties showed that V_2 performed well for most of the parameters as compared to V_1 except to root length.

Key words : Boron, grain yield, HI%, *Rhizobium*, root nodules, root volume

INTRODUTION

Pea (*Pisum sativum* L.) is one of the world's most important legumes grown extensively in temperate region in over 85-90 countries. Being a rich source of protein, it is not only valuable for human being but also for animals. There are certain traits of the plant which play a vital role during the establishment of better plant stand, while its positive impact also appears in succeeding growth stages of plant up to yield (Singh *et al.,* 2015; Pandey *et al.,* 2021). Healthy root growth is important for all the plants but it is most crucial for the pulse crops because roots of pulse crops not only perform normal activities as other plant, while it produces root nodules (Pooniya *et al.,* 2015; Khiangte and Siddique, 2020). The importance of root nodules is already established well because it has enough potential to fix freely available nitrogen in to the soil from open atmosphere, while the number and size of the nodules are equally important for accelerating the rate of nitrogen fixation. The growth of nitrogen fixing nodules and its further process is a consequence of interactions between *Rhizobium* and the roots of pulse crops which is known as symbiotic nitrogen fixation process. The yield contributing characters in pulse crops are directly influenced with the growth of root length, root volume, number and size of root nodules consequently influence the yield of pulse crops (Chatterjee and Bandyopadhyay, 2017; Elhady *et al.,* 2020).

MATERIALS AND METHODS

A field experiment was conducted on the research farm of Lovely Professional University to evaluate the impact of *Rhizobium* inoculation in combination with boron application on morphological growth of roots, yield and yield attributes in pea. The experiment was laid out in randomized block design with six treatment combinations of *Rhizobium* and boron in two popular varieties of pea (i. e. Arkel and Azad Pea-3). Seeds were treated with *Rhizobium* @ 75 ml by placing the seeds in liuque warm jaggery slurry followed by drying under the fan, while different amounts of boron ranging from 0.5 to 2.0 kg/ ha were applied in the soil by using boric acid. The morphological observations of root were recorded by considering the parameters of length of root (cm), root volume (cm^3) and number of root nodules/plant. The root volumes were recorded by water displacement method and it was expressed in cm^3. The average value of root nodules was counted by collecting the nodules by forceps. After harvest of the crop, yield attributes were recorded by counting the primary branches, number of pods/plant and average number of grains/pod, while average length of pod (cm) was recorded by using the measuring scale. However, the biological and grain yield was recorded by the use of weighing balance, while the harvest index was calculated as per the formula given below, while 100-grain was used to express test weight (g). The SPSS software was used to analyze the significance of the results at P<0.05%.

$$HI\% = \text{Economic yield/Biological yield}$$

RESULTS AND DISCUSSION

Data depicted from Table 1 represent the effect of *Rhizobium* and boron application on root morphology i. e. root length (cm), volume (cm^3) and number of nodules/plant. Results indicated that the root length (cm), volume (cm^3) and number of nodules/plant (cm) in V_1 increased gradually along with the increasing the amount of boron in combination with *Rhizobium* up to T_5 i. e. 36.5, 4.8 and 40.7/plant. Similarly, there was increase up to T_4 i. e. 35.2, 5.3 and 43.0/plant in variety V_2. The maximum increase in morphological growth of roots was found in the same treatments T_5 and T_4 in both the varieties with reference to control (data presented in parenthesis). Statistical analysis of these parameters showed that the parameters were not only highly significant for the parameters but also significant among the treatments at P < 0.05% (Fig. 1).

Data depicted from Table 2 represent the effect of *Rhizobium* and boron application on yield attributing characters i. e. primary branches, number of pods/plant and average number of grains/pod. It indicated that the yield attributing characters studied were gradually increased along with the increasing the amount of boron in combination with *Rhizobium* up to T_5 i. e. 9.0, 23.3, 8.3 cm and 8.7/pod in V_1. However, the same have been increased up to T_4 i. e. 10.0, 25.0, 9.0 cm and 9.7/pod in V_2. The maximum increase in yield attributes was found in the same treatments T_5 and T_4 in both the varieties with reference to control. Statistical analysis of these parameters showed that the parameters were not only

Table 1. Effect of *Rhizobium* and boron application on root length, volume and nodules/plant

Treatment		Root length (cm)	Root volume (cm^3)	No. of root nodules/plant
V_1	T_0	25.4±1.55^a	2.7±0.17^a	34.0±1.73^a
	T_1	29.9±1.07^c (+14.96)	4.5±0.29^{bc} (+40.74)	35.3±0.33^{abc} (+3.77)
	T_2	29.7±1.45^{bc} (+14.38)	4.3±0.23^b (+37.50)	35.0±1.53^{ab} (+2.86)
	T_3	31.8±1.53^{cde} (+20.04)	4.7±0.23^{bcde} (+43.65)	38.0±2.08^{abcd} (+10.53)
	T_4	34.6±1.34^{def} (+26.52)	4.7±0.17^{bcd} (+42.86)	36.3±1.33^{abc} (+6.42)
	T_5	36.5±2.88^f (+30.35)	4.8±0.12^{bcde} (+44.44)	40.7±1.76^{bcd} (+16.39)
V_2	T_0	24.2±0.15^a	3.2±0.17^a	35.7±0.88^{abc}
	T_1	29.0±0.50^{bc} (+16.44)	4.9±0.06^{cdef} (+35.81)	36.7±1.45^{abc} (+2.73)
	T_2	30.5±0.06^{cd} (+20.55)	5.5±0.29^f (+42.42)	38.7±3.67^{abcd} (+7.76)
	T_3	33.5±1.21^{cdef} (+27.66)	5.1±0.13^{def} (+38.31)	41.3±0.88^{cd} (+13.71)
	T_4	35.2±1.64^{ef} (+31.16)	5.3±0.17^{ef} (+40.63)	43.0±1.53^d (+17.05)
	T_5	29.0±0.20^{bc} (+16.53)	5.1±0.06^{cdef} (+37.50)	38.3±2.19^{bcd} (+6.96)

V_1T_0=Control, V_1T_1=*Rhizobium*, V_1T_2=*Rhizobium*+0.5 kg boron, V_1T_3=*Rhizobium*+1.0 kg boron, V_1T_4=*Rhizobium*+ 1.5 kg boron, V_1T_5=*Rhizobium*+2.0 kg boron, V_2T_0=Control, V_2T_1=*Rhizobium*, V_2T_2=*Rhizobium*+0.5 kg Boron, V_2T_3= *Rhizobium*+1.0 kg boron, V_2T_4=*Rhizobium*+1.5 kg boron and V_2T_5=*Rhizobium*+2.0 kg boron.
The same superscripts in the same col. indicate that the differences are not significant.

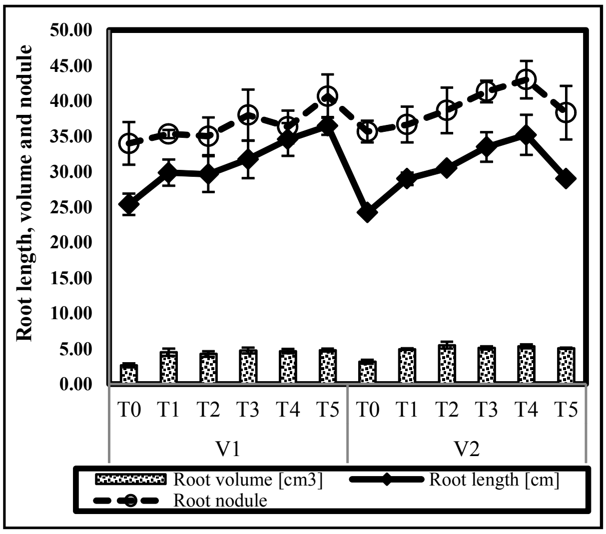

Fig. 1. Effect of *Rhizobium* and boron application on root length (cm), volume and number of nodules/plant.

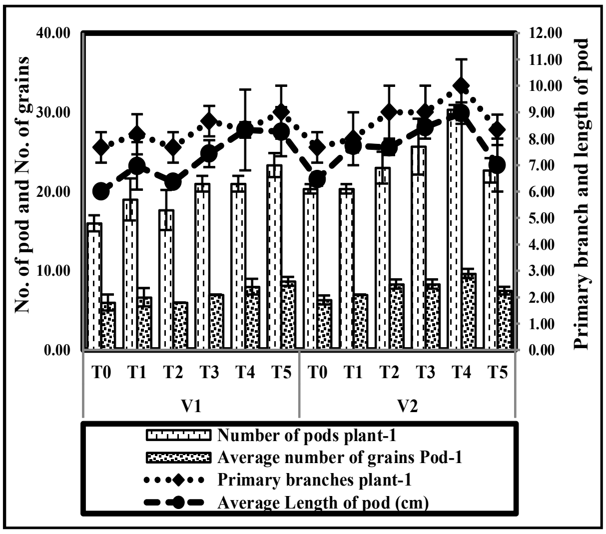

Fig. 2. Effect of *Rhizobium* and boron application on primary branches, no. of pods, length of pod/ plant and no. of grains/pod.

highly significant for the parameters but also significant among the treatments at P<0.05% (Fig. 2).

Table 3 represents the effect of *Rhizobium* and boron application on yield and their derivatives. It indicated that the grain yield, biological yield/plant, HI% and test weight were gradually increased along with the increasing the amount of boron in combination with *Rhizobium* up to T_5 i. e. 64.9, 133.4, 38.9 (g) and 49.2 (%) in V_1. However, the same have been increased up to T_4 i. e. 69.4, 141.0, 40.9 (g) and 49.2% in V_2. It was also depicted from the data that the maximum increase in yield and their derivatives was found in the same treatments T_5 and T_4 in both the varieties with reference to control. Statistical analysis of these parameters showed that the parameters were not only highly significant for the parameters but also significant among the

Table 2. Effect of *Rhizobium* and boron application on number of primary branches, number of pods/plant, average length of pod and number of grains/pod

Treatment		Primary branches/plant	No. of pods/plant	Average length of pod (cm)	Average number of grains/pod
V_1	T_0	7.7±0.33^{a}	16.0±0.58^{a}	6.0±0.12^{a}	6.0±0.58^{a}
	T_1	8.2±0.44^{a} (+6.12)	19.0±1.53^{ab} (+15.79)	7.0±0.52^{abcd} (+13.88)	6.7±0.67^{ab} (+10.0)
	T_2	7.7±0.33^{a} (+0.0)	17.7±1.45^{ab} (+9.43)	6.4±0.07^{ab} (+5.76)	6.0±0.29^{a} (+0.0)
	T_3	8.7±0.33^{ab} (+11.54)	21.0±0.58^{bc} (+23.81)	7.4±0.29^{cde} (+19.28)	7.0±0.29^{abc} (+14.29)
	T_4	8.3±0.88^{ab} (+8.0)	21.0±0.58^{bc} (+23.81)	8.3±0.17^{ef} (+28.0)	8.0±0.58^{cd} (+25.0)
	T_5	9.0±0.58^{ab} (+14.81)	23.3±0.88^{cd} (+31.43)	8.3±0.53^{ef} (+27.42)	8.7±0.33^{de} (+30.77)
V_2	T_0	7.7±0.33^{a}	27.0±0.33^{bc}	6.5±0.15^{abc}	6.3±0.33^{ab}
	T_1	8.0±0.58^{a} (+4.17)	20.3±0.33^{bc} (+0.0)	7.7±0.15^{de} (+16.38)	7.0±0.29^{abc} (+9.52)
	T_2	9.0±0.58^{ab} (+14.81)	23.0±1.15^{cd} (+11.59)	7.7±0.17^{de} (+15.65)	8.3±0.33^{cd} (+24.0)
	T_3	9.0±0.58^{ab} (+14.81)	23.7±2.03^{bc} (+20.78)	8.4±0.33^{ef} (+23.32)	8.3±0.33^{cd} (+24.0)
	T_4	10.0±0.58^{b} (+23.33)	25.0±0.33^{e} (+32.97)	9.0±0.23^{f} (+27.88)	9.7±0.33^{e} (+34.48)
	T_5	8.3±0.33^{ab} (+8.0)	30.3±0.88^{cd} (+10.29)	7.0±0.58^{bcd} (+7.62)	7.5± 0.29^{de} (+15.56)

The same superscripts in the same col. indicate that the differences are not significant.

Table 3. Effect of *Rhizobium* and boron application on grain yield, biological yield, HI% and test weight (g)

Treatment		Grain yield (g)/plant	Biological yield (g)/plant	Test weight (g)	HI (%)
V_1	T_0	48.3±0.67^{a}	110.3±1.28^{a}	33.2±1.22^{a}	42.7±1.34^{a}
	T_1	54.5±0.58^{bcd} (+11.38)	119.1±2.09^{abc} (+7.33)	34.9±1.53^{ab} (+4.88)	45.8±1.30^{abc} (+6.64)
	T_2	51.3±1.05^{ab} (+5.97)	114.5±3.36^{ab} (+3.61)	33.2±1.22^{a} (+0.0)	43.8±0.34^{ab} (+2.46)
	T_3	58.2±1.57^{cde} (+17.04)	126.1±2.27^{def} (+12.48)	36.1±0.52^{abc} (+8.21)	46.2±0.82^{bcd} (+7.40)
	T_4	60.5±1.82^{ef} (+20.18)	127.0±1.96^{ef} (+13.12)	37.8±0.85^{bcd} (+12.18)	47.6±0.70^{cd} (+10.17)
	T_5	64.9±0.62^{g} (+25.67)	133.4±4.01^{fg} (+17.29)	38.9±1.43^{cd} (+14.67)	49.2±0.99^{d} (+13.17)
V_2	T_0	52.5±1.01^{b}	116.5±0.41^{abc}	34.1±0.22^{ab}	43.6±1.02^{ab}
	T_1	54.0±1.23^{bc} (+2.66)	119.3±1.68^{bcd} (+2.35)	35.8±0.70^{abc} (+4.93)	45.2±0.43^{abc} (+3.64)
	T_2	60.9±1.49^{f} (+13.79)	131.0±2.42^{fg} (+11.09)	39.2±1.12^{cd} (+13.10)	46.5±0.31^{bcd} (+6.26)
	T_3	65.1±0.94^{g} (+19.34)	136.1±2.54^{gh} (+14.40)	39.2±1.69^{cd} (+13.10)	47.9±0.86^{cd} (+8.97)
	T_4	69.4±2.25^{h} (+24.30)	141.0±2.37^{h} (+17.40)	40.9±1.68^{d} (+16.64)	49.2±1.17^{d} (+11.41)
	T_5	56.8±^{cde} (+7.57)	122.9±2.84^{cde} (+5.21)	37.8±0.65^{bcd} (+9.88)	46.3±1.28^{bcd} (+5.86)

The same superscripts in the same col. indicate that the differences are not significant.

treatments at P<0.05% (Fig. 3). Close analysis of all the data showed that V_2 performed well as compared to $V_1$for all the parameters studied except for root length.

Root morphological characters like root length, volume and number of nodules were highly influenced with the gradual increase of boron along with the *rhizobium* inoculation and recorded highest value in T_5 and T_4 in V_1 and V_2 (Table 1; Fig. 1). According to Reddy *et al.* (2020) the growth and yield of pulse crop were positively linked with morphological growth of root. Root length and volume facilitated the nutrient and water uptake from soil (Verma *et al.,* 2019). Regarding the fixation of nitrogen, *Rhizobium* inoculation in combination with boron played a valuable role to enhance the growth of morphological growth of root including number of root nodules (Khiangte and Siddique, 2020; Zafari *et al.,* 2020; Pal *et al.,* 2021). Yield and yield attributes were also positively influenced with the given treatment (Tables 2 and 3, and Figs. 2 and 3). Results of the study are in line with the findings of Ganie *et al.* (2014) and Bai *et al.* (2016) who reported that the application of biofertilizer had positive impact on yield and yield attributes in pulse crop, while in combination with boron, additional benefit in term of yield in pea was recorded (Figs. 2 and 3). From the results, it was clear that growth of yield and yield attributes of pea plant depended upon the morphological growth of root especially on size and number root nodules. The growth of nodules under the deficient environment of boron was adversely affected, thereby reducing yield (Sreeharsha *et al.,* 2015; Islam *et al.,* 2021). The constructive role of boron in plants was well known for metabolic process like sugar translocation towards the reproductive part of the plant (Bariya *et al.,* 2014; Khaliq *et al.,* 2018), functional integrity to the cell wall and its membrane (Shireen *et al.,* 2018; Yin *et al.,* 2021). Therefore, its cumulative effect was reflected in HI% and test weight in the present study thus the final yield was affected

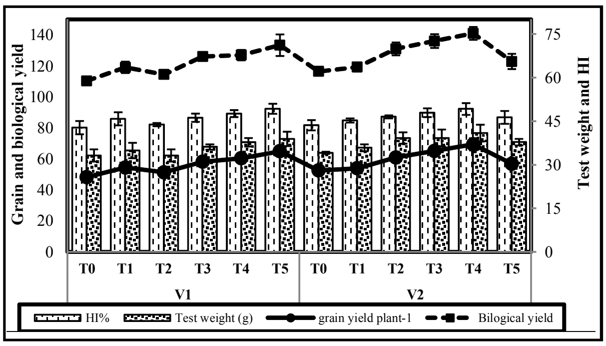

Fig. 3. Effect of *Rhizobium* and boron application on grain yield, biological yield/plant, HI% and test weight (g).

significantly as compared to rest of treatments including control.

CONCLUSION

Exponential growth of India's populations attracts the concentration of scientist to focus on this particular crop (pea) because the production of pulse crop is not up to the mark to fulfil the current demand due to many constraints. Therefore, morphological characters of root of pea plant were focused to enhance the root length, volume and number of nodules by the use of *Rhizobium* inoculation in combination with boron; which also improved yield and yield attributes.

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