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STUDIES ON BORON NUTRITION IN *RABI* SORGHUM TO ANALYSE ITS MORPHOLOGICAL ATTRIBUTES

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ABSTRACT

In order to evaluate the studies on boron nutrition in *rabi* sorghum to analyse its morphological attributes cv. PKV-Kranti at the experimental field of Sorghum Research Unit, Dr. P.D.K.V. Akola, India a Pot experiment was executed out during the *rabi* season in 2020-2021. There were nine possible treatment combinations in this research study namely, (T_1) RDF Only, (T_2) RDF+ soil application of boron @ 1 kg ha^{-1}, (T_3) RDF+ soil application of boron @ 2 kg ha^{-1}, (T_4) RDF + foliar application of boron at 0.1 ppm at PI and flowering stage, (T_5) RDF + foliar application of boron at 0.2 ppm at PIand flowering stage, (T_6) RDF+ soil application of boron @ 1 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage, (T_7) RDF+ soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage, (T_8) RDF+ soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.2 ppm at PI and flowering stage and (T_9) RDF + soil application of boron @ 1 kg ha^{-1} + foliar application of boron at 0.2 ppm at PI and flowering stage. The research study was set up in a completely randomized block design, with three replications. The findings suggested that the treatment T_7 (RDF+ soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage) significantly enhanced morpho-physiological parameters *viz*., plant height, leaf area plant^{-1}, in comparison to remaining treatment.

Key words : Sorghum, Boron, Genotypes, Morpho-physiological parameters, Foliar application.

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is considered the "King of Millets" and the fourth most extensively produced crop in the country. Sorghum is known as a "camel crop" because of its ability to withstand drought and waterlogging. This plant, which belongs to the cereal family, can be used for energy, forage and food in multiple ways. Sorghum's energy content and feed quality are comparable to those of maize.

Sorghum is also valued for its use as fresh and dry feed, silage and direct grazing (Rad *et al*., 2021). Sorghum is a promising crop for agricultural growth in marginal areas to meet future energy and food needs (Bibi *et al*., 2012; Qadir *et al*., 2015). Due to its seeming enormous potential, sorghum (*Sorghum bicolor* L.) has the fifth-highest grain yield globally (Dahlberg *et al*., 2011; Avila *et al*., 2021). In India, sorghum is planted on 4.82 million hectares and yields 4.60 million tonnes with a productivity of 991 kg ha^{-1} (Anonymous, 2021). *Rabi* sorghum is a major dry land crop in the Deccan plateau, produced in Maharashtra (2.29 million ha), Karnataka (0.82 million ha), and Andhra Pradesh (0.15 million ha) (Anonymous, 2021).

Boron stimulates plant growth and cell division. Boron deficiency symptoms may impacts both vegetative and reproductive portions, including stunted shoot and root growth. Boron is necessary for plant growth, but excessive amounts can be hazardous to plants. Micronutrients, in addition to macronutrients, are necessary for optimal biological and grain productivity. Boron promotes plant growth and cell division. Vascular plants continuously require boron (B), an essential microelement, to build a variety of fundamental physiological processes throughout their life cycle, including RNA metabolism and carbohydrates (Tanaka and Fujiwara, 2008).

Materials and Methods

A pot experiment was carried out during *rabi*-2021-2022 at the experimental field of AICRP, sorghum research unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, India. The experiment was set up using a completely randomized design with nine treatments and three replications. The trial has nine treatments, namely; (T_1) RDF Only, (T_2) RDF + soil application of boron @ 1 kg ha^{-1}, (T_3) RDF + soil application of boron @ 2 kg ha^{-1}, (T_4) RDF + foliar application of boron at 0.1 ppm at PI and flowering stage, (T_5) RDF + foliar application of boron at 0.2 ppm at PIand flowering stage, (T_6) RDF + soil application of boron @ 1 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage, (T_7) RDF + soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage, (T_8) RDF + soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.2 ppm at PI and flowering stage and (T_9) RDF+ soil application of boron @ 1 kg ha^{-1} + foliar application of boron at 0.2 ppm at PI and flowering stage. Each pot had three seeds set 15 cm apart. From then on, intercultural operations were carried out as needed. Seeds of sorghum variety 'PKV-Kranti' were sown at a 45 cm × 15 cm spacing. The observations were recorded at 15, 30, 45, 60, 75 and 90 DAS. Several morphological measures include plant height (cm), leaf area (dm^2) and total dry matter (g) were recorded per replication and treatment wise.

Estimation of plant height

Plant heights were measured at 15, 30, 45, 60, 75 and 90 DAS. The heights of all five plants from each replication and treatment were measured from the base of the plant to the highest developing node. The mean height of these five plants in each treatment was computed and documented in centimetres.

Estimation of leaf area plant^{-1} (dm^2)

The plant's leaf area was estimated via calculating the maximum length and width at the widest point of the green leaves and multiplying by 0.747 (Stickler *et al.*, 1961).

Estimation of total dry matter (g plant^{-1})

For the dry matter experiment, five plants from every treatment and replication were uprooted. The plant samples were thoroughly cleaned with tap water to eliminate any soil or dust particles that had stuck to them. The samples were dried individually at room temperature for 48 hours. The plant samples were then packed in large, brown paper perforated bags. After drying the sample in open air, the plant sample was dried in a hot air oven at 70°C until the sample weight was constant. The total dry matter was measured as g per plant. This observation yielded the total dry matter production plant^{-1}, which was then utilized to compute other growth measures.

Results and Discussion

Plant height

Plant height is a key characteristic in the vegetative phase that affects indirectly aspects of yield. It is the shortest vertical distance between the upper limit of a plant's major photosynthetic tissue and the stem or shoot base from the ground.

Plant height was measured at six stages of crop growth (15, 30, 45, 60, 75 and 90 DAS) and statistically analysed. The data are shown in Table 1.

Data on plant height collected at 15, 30 and 45 DAS were determined to be insignificant because boron treatments began at this point.

At 60 DAS, plant height was considerably higher in treatment T_7 (RDF + soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage) than in the other treatments under study except T_3. Treatment T_7 and T_3 were determined to be comparable. It was followed by T_6 (RDF + Boron Soil Application at 1 Kg ha^{-1} + Boron Foliar Application at 0.1 ppm during PI and Flowering Stage). Treatment T_1 (97.8 cm) had the lowest value compared to other treatments. Treatments T_1 and T_4 were equivalent.

The observed rise in plant height following boron fertilizer can be explained by Gupta and Lipsett's (1979) study on barley. Their findings indicate that boron, an essential element, has an important role in increasing overall plant growth, including stem elongation, which leads to an increase in plant height. The effects of boron on cell elongation and structural development contribute to increased plant stature. In their study, Shivasimpiger *et al.* (2023) examined the effects of varying boron concentrations on sorghum crops and found that applying 1.0 kg ha^{-1} of boron (soil) and 0.1 percent boron foliar spray throughout the PI and flowering stages improved plant height. Gurjar *et al.* (2022) conducted a study to evaluate the influence of boron on peal millet and

Table 1 : Effect of soil and foliar applied boron on plant height.

Plant height (cm)						
Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T_1	17.7	22.4	52.1	97.8	138.9	141.6
T_2	15.6	22.2	52.4	100.4	147.7	154.2
T_3	18.8	23.5	54.6	112.6	158.0	173.2
T_4	17.9	25.4	59.8	97.8	149.9	159.9
T_5	16.7	27.1	64.9	99.7	147.7	156.8
T_6	15.2	28.5	63.9	106.4	157.5	168.6
T_7	15.8	23.0	58.8	**115.6**	**161.8**	**178.7**
T_8	15.4	22.3	55.6	101.5	151.1	157.4
T_9	19.7	22.6	57.9	99.0	139.9	141.8
S.E.(m) ±	**1.09**	**1.64**	**3.29**	**1.10**	**1.38**	**1.28**
C.D. at 5%				**3.26**	**4.10**	**3.81**

Table 2 : Effect of soil and foliar applied boron on leaf area plant^{-1}.

Leaf area plant^{-1} (dm^2)						
Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T_1	1.95	4.49	14.36	17.12	18.78	20.63
T_2	1.76	4.64	14.58	18.45	20.78	21.27
T_3	2.08	5.58	14.62	20.32	22.69	23.2
T_4	2.29	4.57	15.76	19.76	21.48	22.51
T_5	2.1	4.36	15.96	19.35	21.02	21.32
T_6	2.58	4.11	15.89	20.2	21.67	23.16
T_7	1.86	5.07	16.68	**20.68**	**23.26**	**25.43**
T_8	1.53	4.67	15.23	20.16	21.89	22.73
T_9	1.9	5.13	15.45	17.76	20.46	20.89
S.E.(m) ±	**0.22**	**0.3**	**0.96**	**0.51**	**0.55**	**0.44**
C.D at 5%				**1.53**	**1.63**	**1.3**

Table 3 : Effect of soil and foliar applied boron on total dry matter plant^{-1}.

Total dry matter plant^{-1} (g)						
Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**75 DAS**	**90 DAS**
T_1	2.21	4.19	17.00	35.75	53.29	76.87
T_2	2.20	4.30	18.38	36.78	53.76	77.41
T_3	2.38	4.16	20.20	38.50	57.41	80.69
T_4	2.62	4.76	18.10	35.86	55.19	78.56
T_5	2.46	4.28	17.53	37.21	54.68	77.86
T_6	2.00	5.36	16.39	37.90	56.43	79.90
T_7	2.70	4.68	15.79	**38.87**	**58.19**	**81.49**
T_8	2.35	4.37	17.88	37.93	56.02	79.35
T_9	2.46	4.47	18.03	36.38	53.96	77.04
S.E (m) ±	**0.15**	**0.27**	**1.15**	**0.58**	**1.09**	**0.68**
C.D at 5%				**1.71**	**3.25**	**2.01**

discovered that foliar treatment of 0.5% boron at FL greatly improved plant height. Khan *et al*. (2019) also investigated the effect of zinc and boron applications on wheat crops, discovering that foliar treatment of boric acid 20g L^{-1} in wheat considerably boosted plant height.

Leaf area plant^{-1} (dm^2)

Leaf area is determined by the quantity and size of leaves. Leaves perform a crucial function in absorbing light energy and utilizing it in the photosynthetic process. Light, moisture and nutrient levels all impact leaf size. Thus, yield is determined by the crop's leaf area.Data on leaf area collected at 15, 30, and 45 DAS were determined to be insignificant because boron treatments began at this point. The data are shown in Table 2.

At 60 DAS, leaf area was considerably higher in treatment T_7 (RDF+ soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage) than in control. Treatment T_7 is comparable to T_6, T_8, T_4 and T_5. However, treatment T_1 had a much lower value (17.12 dm^2), while treatments T_2 and T_9 were comparable to T_1.

At 75 DAS, leaf area was significantly higher in treatment T_7 (RDF+ soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at pi and flowering stage) than in the other treatments, with the exception of treatments T_3, T_8 and T_6. Treatments T_3, T_8 and T_6 were on par with T_7. However, treatment T_1 showed a substantially lower value (18.78 dm^2).

At 90 DAS, treatment T_7 (RDF+ soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage) had the highest leaf area compared to the other treatments, followed by treatments T_3 and T_6, respectively. However, treatment T_1 had a much lower value (20.63 dm^2), while treatments T_5, T_2 and T_9 were determined to be comparable to T_1.

The increased chlorophyll levels of both hybrids most likely contributed to the increase in leaf area brought about by the exogenous administration of boron. These results corroborate those of Sayed (1998), who found that boron application boosted the chlorophyll and relative water levels in maize plants, increasing their leaf area. Riwad *et al*. (2023) investigated the effects of boron utilizing nano-boron concentrations (5 and 10 mgL^{-1}), metal boron concentrations (20 and 40 mgL^{-1}) and

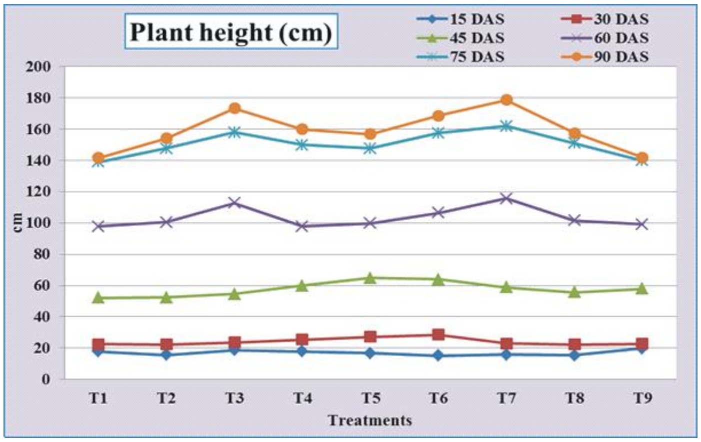

Fig. 1 : Effect of soil and foliar applied boron on plant height.

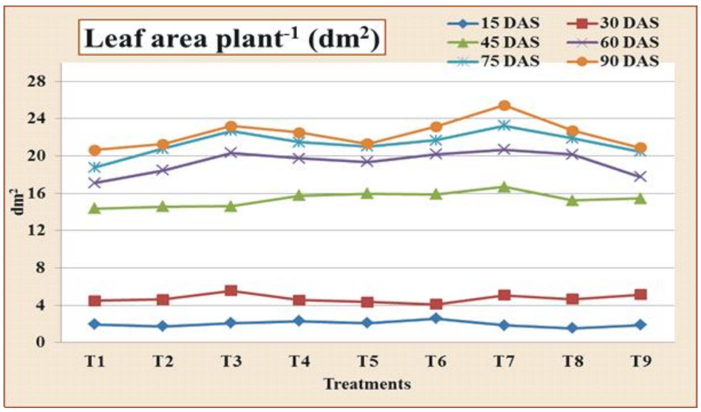

Fig. 2 : Effect of soil and foliar applied boron on leaf area plant^{-1}.

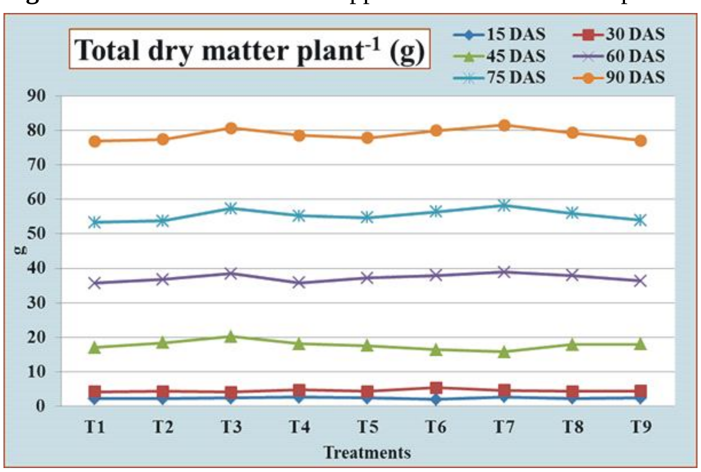

Fig. 3 : Effect of soil and foliar applied boron on total dry matter plant^{-1}.

distilled water as a control treatment. He claimed that using nano boron greatly increased the leaf area of maize. Marofi *et al.* (2019) evaluated the consequences of two different boron concentrations (1 and 1.5 ppm) using water sprays as a control and found that applying 1 ppm boron increased leaf area. Shabbir *et al.* (2020) conducted field research on two maize hybrids using boron during the tasselling stage at concentrations of 0, 0.3, 0.6, 0.9, 1.2 and 1.5 kg ha^{-1} in a randomized completely block design. The study showed that the application of boron @ 0.6 kg ha^{-1} had a beneficial effect on leaf area in maize.

Total dry matter (g plant^{-1})

Data on total dry matter collected at 15, 30 and 45 DAS were determined to be non-significant because boron treatments began at this time. The statistics are reported in Table 3. At every stage of the findings, treatment T_7 generated much more dry matter and ranked first.

At 60 DAS, total dry matter per plant was considerably higher in treatment T_7 (RDF+ soil application of boron at 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage) than with T_1. While treatments T_4, T_8, T_6 and T_5 were comparable to T_7. However, treatment T_1 had a much lower value (35.75 g), although treatments T_2 and T_9 were comparable to T_1.

At 75 DAS, total dry matter per plant was considerably higher in treatment T_7 (RDF + soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage) than in the remaining treatments, with the exception of T_3, T_6, T_8 and T_4. Treatments T_3, T_6, T_8 and T_4 were found to be on par with T_7. Fortunately, treatment T_1 had a much lower value (53.29 g), while treatments T_2, T_5 and T_9 were comparable to T_1.

At 90 DAS, treatment T_7 (RDF + soil application of boron @ 2 kg ha^{-1} + foliar application of boron at 0.1 ppm at PI and flowering stage) had the highest total dry matter per plant compared to the rest of the treatments, with the exception of T_3 and T_6. Treatments $T_3$and T_6 were found to be on par with T_7. It was followed by treatments T_8 and T_4. Yet therapy T_1 had a substantially lower value (76.87 g).

The application of boron facilitates the production of chlorophyll, the photosynthetic process, the stimulation of enzymes, the development of grains and the metabolism of carbohydrates, all of which contribute to the absorption of nutrients and, ultimately, to a rise in growth and dry weight. Naiknaware *et al.* (2015) provided evidence for similar findings.In a field experiment, Nawaz *et al.* (2017) evaluated two doses of boron (1 and 2 kg ha^{-3}) in conjunction with zinc (Zn). Applying 2 kg ha^{-1} of boron and 10 kg ha^{-1} of zinc together had noticeable impacts on maize, increasing the amount of dry matter produced. Shashma *et al.* (2023) investigated the effect of boron on foxtail millet growth and effective yield using boron concentrations of 0.01%, 0.02%, 0.03% and found that boron at 0.03% increased dry matter production per plant. Kumar *et al.* (2023) conducted a field experiment to investigate the influence of boron on the growth and development of three maize cultivars. He observed that applying boron at 0.2% and 0.3% greatly increased dry matter yield per plant.

Conclusion

Research on the nutritional effects of boron in *rabi* sorghum extends beyond the immediate farming challenges. It is a critical undertaking with far-reaching consequences for environmental sustainability, global food systems and the well-being of farming communities, as well as a positive impact on many other sectors of society. The study provides farmers with useful insights into prudent boron application, resulting in a lower ecological footprint and enhanced resource utilization. Boron deficiency in soil has a negative impact on plant growth and development, which is a common challenge. Assessing and correcting boron deficiency in *rabi* sorghum-growing areas can greatly increase crop health and yield.

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