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Effect of Nitrogen and Boron on Growth and Yield of Foxtail Millet (*Setaria italica* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The field experiment titled "Effect of Nitrogen and Boron on Growth and Yield of Foxtail Millet" was conducted during *Zaid* 2023 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.8), low in organic carbon (0.62%), available nitrogen (225 kg/ha), available phosphorus (38.2 kg/ha) and available potassium (240.7 kg/ha). The experiment was laid out in Randomized Block Design with ten treatments which are replicated thrice. Results obtained that significantly higher plant height (83.52 cm), plant dry weight (14.06 g), length of ear head (15.70 cm), number of grains/ear head (1,413.09), test weight (3.64 g), grain yield (1.68 t/ha), stover yield (3.88 t/ha), harvest index (33.79%) higher gross return (69,291.48 INR/ha), net return (48,099.98 INR/ha) and B:C ratio (2.27) were recorded in treatment 9 with the application of (Nitrogen 60 kg/ha + Boron 0.03%).

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1. INTRODUCTION

“Foxtail millet (*Setaria italica* L.) is an important crop used as a staple food in many parts of the world including arid and semi-arid areas of China, some part of India and Japan, and is grown for silage and hay in South and North America. Foxtail millet is commonly known in India as Kangni (Hindi), Kang (Gujrati), Navane (Kanada), Tenai (Tamil). It is the second most cultivated millet after pearl millet” [1]. “Foxtail millet grain is rich in protein (14-16%), crude fat (6-8%), and iron along with zinc and calcium” Muthamilarasan et al*.* (2016). “Foxtail millet bran contains 8-10% crude oil and is rich in linoleic (66.5%) and oleic (13.0%) acids Liang et al. (2010). In addition to that, the grains of foxtail millet require only 26% of their grain weight in water to germinate, whereas other major cereals such as rice, wheat, and maize require a minimum of 45% of their grain weight. Similarly, to produce 1g dry biomass, foxtail millet requires only 257g of water, which is the minimum among other cereals, as wheat and maize requires 470 and 510 g, respectively” [2]. “Being a C_4 photosynthetic crop, foxtail millet is naturally equipped with excellent water use efficiency and nitrogen use efficiency, in addition, several morpho-physiological traits including dense and deep root systems, smaller leaf area, and thickening of cell walls which were thought to lead to durable tolerance to a range of abiotic stresses mainly drought, heat, and salinity” [3].

“Foxtail millet is a native of China and is one of the world’s oldest known cultivated crops. It ranks second in the total world production of millets and continues to have an important place in world agriculture providing approximately six million tons of food per annum. It can grow at any altitudes from sea level to 2000 m above sea levels, escapes drought due as its early maturity but cannot tolerate water logging. The quick growth and its adaption to a wide range of elevations, soils and temperature makes it a short-term catch crop for humans and as feed to poultry and cage birds” [4]. Currently, “foxtail millet is distributed in most of China, some parts of India, USA, Canada, the Korean Peninsula, Japan, Indonesia, Australia, and the northern part of Africa” [5].

“Nitrogen is an essential macronutrient for plant growth, development, and production. As an essential component of nucleic acids and proteins, actively participates in most physiological and biological processes in crop production including photosynthesis, carbohydrate allocation, root patterning, and flower development, and hence signifies itself as a critical macronutrient controlling crop yield and quality (Stitt [6]; Miller and Cramer, 2004). Nitrogen fertilizer is one of the most yield limiting nutrients for crop production and it is applied in large quantity for most annual crops” [7]. “It plays an important role in building units of proteins in the plant system. Thus, Nitrogen nutrition not only influences productivity but also quality (Hari Prasanna, 2016). Nitrogen is the major nutrient required by the millets which positively increases the growth, yield attributes and finally improve the yield” [8].

“Boron plays an important role in plant growth and nutrition and it promotes cell division, cell elongation, cell wall resistance, flowering, pollination, fruit set and sugar translocation. The main function of boron in plant growth and development is its ability to form complexes with compounds with the cis diol configuration. It has been observed that in most plant species, the boron requirement for reproductive development is much higher than the boron requirement for vegetative growth. Boron is one of the most important micronutrients for plant growth and plays an important role in the physiological processes within plant (Tanaka and Fujiwara, 2007). According to some studies, boron sorption heightens due to elevated levels of calcite in soil and liming diminished the water-soluble boron content of soils” [9,10].

In addition, to include millets into the mainstream and exploit its nutritionally superior qualities and promote its cultivation, Government of India has declared Year 2018 as the “Year of Millets” and FAO Committee on Agriculture forum has declared Year 2023 as “International Year of Millets” [11].

2. MATERIALS AND METHODS

The experiment was conducted during *Zaid* 2023. The experiment was conducted in Randomized Block Design (RBD) consisting of ten treatments which are replicated thrice and was laid out with the different treatments allocated randomly in each replication. The soil of the experimental field was sandy loam in texture, slightly alkaline reaction (pH 7.1) with low level of organic carbon (0.62%), available Nitrogen (225 Kg/ha), Phosphorus (38.2 kg/ha) and higher level of potassium (240.7 kg/ha). The treatment combinations are T_1: Nitrogen 40 kg/ha + Boron 0.01%, T_2: Nitrogen 40 kg/ha + Boron 0.02%, T_3: Nitrogen 40 kg/ha + Boron 0.03%, T_4: Nitrogen 50 kg/ha + Boron 0.01%, T_5: Nitrogen 50 kg/ha + Boron 0.02, T_6: Nitrogen 50 kg/ha + Boron 0.03%, T_7: Nitrogen 60 kg/ha + Boron 0.01%, T_8: Nitrogen 60 kg/ha + Boron 0.02%, T_9: Nitrogen 60 kg/ha + Boron 0.03%, T_{10}: Control (RDF 50:30:20 NPK kg/ha). The observations were recorded on different growth parameters at harvest *viz.,* plant height(cm), plant dry weight (g/plant), ear head length(cm), no. of grains/ear head, test weight(g), grain yield(t/ha), stover yield(t/ha) and harvest index (%).

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height

The plant height measurements improved as per crop growth progressed. The significantly higher plant height (83.52 cm) was recorded in treatment 9 with application of Nitrogen 60 kg/ha + Boron 0.03% at 80 DAS. However, treatment 8 (82.86cm) Nitrogen 60 kg/ha + Boron 0.02% was found statically at par with treatment 9 in Table 1. The maximum plant height was attained by the regular supply of plant nutrients during all growth stages, through a supply of Nitrogen and Boron.

Nitrogen is a component of porphyrins of chloroplasts and hence increased nitrogen fertilization increased the growth and yield of crop due to maximum photosynthates production. This resulted in enhanced morphological characters i.e., plant height, leaf area and dry matter accumulation which was reflected in higher straw yield. These findings are in support of (Kalaghatagi et al*.,* 2000).

Boron enhances the differentiation of tissue cell division and nitrogen absorption from the soil [12].

3.1.2 Dry weight

The significantly higher plant dry weight (14.06 g) was recorded in treatment-9 with the application of (60kg/ha Nitrogen + 0.03 % Boron). However. Treatment 8 (13.48 g) 60kg/ha Nitrogen + 0.02 % Boron and treatment 6 (13.24 g) 50kg/ha Nitrogen + 0.03% Boron were found statically at par with treatment 9 in Table 1. This might be due to Nitrogen application which has many important functions in plant growth and development, such as involvement in the biosynthesis of chlorophyll, respiration, chloroplast development and improves the performance of photosystems, which resulted in higher dry weight (Srihari et al*.,* 2023).

Application of boron aids in the synthesis of chlorophyll, photosynthetic process, enzyme activation and grain formation, as well as carbohydrate metabolism, which leads to nutrient uptake and finally results in an increase in growth and finally resulting in increased dry weight. Similar results were supported by (Naiknaware et al*.,* 2015).

Table 1. Effect of nitrogen and boron on growth and yield of foxtail millet

Treatment No	Treatments	Plant height (cm) At 80 DAS	Plant dry weight (g) At 80 DAS
1.	Nitrogen 40 kg/ha + Boron 0.01% 20DAS	72.60	9.80
2.	Nitrogen 40 kg/ha + Boron 0.02% 40 DAS	73.18	10.42
3.	Nitrogen 40 kg/ha + Boron 0.03% 60DAS	74.24	11.11
4.	Nitrogen 50 kg/ha + Boron 0.01% 20 DAS	75.40	11.95
5.	Nitrogen 50 kg/ha + Boron 0.02% 40 DAS	77.37	12.26
6.	Nitrogen 50 kg/ha + Boron 0.03% 60 DAS	78.47	13.24
7.	Nitrogen 60 kg/ha + Boron 0.01% 20 DAS	81.86	12.85
8.	Nitrogen 60 kg/ha + Boron 0.02% 40 DAS	82.86	13.48
9.	Nitrogen 60 kg/ha + Boron 0.03% 60 DAS	83.52	14.06
10.	Control (RDF 50:30:20 NPK kg/ha)	72.13	10.24
	SEm(±)	0.53	0.24
	CD (P=0.05)	1.62	1.13

Table 2. Effect of nitrogen and boron on growth and yield of foxtail millet

Treatment No	Treatments	Ear head length (cm)	No. of grains/ear head	Test weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1.	Nitrogen 40 kg/ha + Boron 0.01% 20DAS	11.42	1076.03	2.55	1.06	2.83	33.65
2.	Nitrogen 40 kg/ha + Boron 0.02% 40 DAS	11.64	1110.69	2.75	1.24	3.14	32.93
3.	Nitrogen 40 kg/ha + Boron 0.03% 60DAS	12.41	1169.36	3.26	1.31	3.34	32.48
4.	Nitrogen 50 kg/ha + Boron 0.01% 20 DAS	12.77	1190.69	3.06	1.38	3.69	31.33
5.	Nitrogen 50 kg/ha + Boron 0.02% 40 DAS	13.71	1226.42	3.19	1.45	3.85	31.28
6.	Nitrogen 50 kg/ha + Boron 0.03% 60 DAS	14.28	1286.42	3.24	1.51	4.18	30.24
7.	Nitrogen 60 kg/ha + Boron 0.01% 20 DAS	14.61	1309.76	3.30	1.58	4.14	31.17
8.	Nitrogen 60 kg/ha + Boron 0.02% 40 DAS	15.27	1373.76	3.40	1.61	3.78	33.60
9.	Nitrogen 60 kg/ha + Boron 0.03% 60 DAS	15.70	1413.09	3.64	1.68	3.88	33.79
10.	Control (RDF 50:30:20 NPK kg/ha)	12.90	1024.67	2.78	1.11	2.98	33.17
	SEm (±)	0.25	24.76	0.10	0.04	0.08	0.72
	CD (P=0.05%)	0.75	73.57	---	0.11	0.23	---

3.2 Yield Parameters

3.2.1 Ear head length

The significantly higher ear head length (15.70 cm) was recorded in treatment 9 with the application of (Nitrogen 60 kg/ha + Boron 0.03%). However. Treatment 8 (15.27 cm) Nitrogen 60 kg/ha + Boron 0.02% was found statically at par with treatment 9.

"Nitrogen provides potential for many of the enzymatic transformations. Several of these enzymes are involved in chlorophyll synthesis, grain formation and dry matter production, which ultimately lead to increase in yield characters like panicle length" (Maharana and Singh, 2021).

3.3 Number of Grains/Ear Head

The significantly higher no. grains/ear head (1413.09) was recorded in treatment 9 with the application of Nitrogen 60 kg/ha + Boron 0.03%. However, treatment 8 (1373.76) Nitrogen 60 kg/ha + Boron 0.02% was found statically at par with treatment 9.

"Boron, required for cell differentiation, development and growth of pollen grains. It acts as a greater role in translocation of photosynthates, resulting in increased pollination and seed setting and plant metabolism" [13]. Nitrogen provides potential for many of the enzymatic transformations. Several of these enzymes are involved in chlorophyll synthesis and grain formation resulting in higher grains/panicle. Similar results are observed by Vaja et al*.* [14].

3.3.1 Grain yield

The significantly higher grain yield (1.68 t/ha) was recorded in treatment 9 with the application of Nitrogen 60 kg/ha + Boron 0.03 %. However, treatment 8 (1.61 t/ha) Nitrogen 60kg/ha + Boron 0.02 % was found statically at par with treatment 9.

Nitrogen plays a major role in the biosynthesis of IAA and especially due to its role in the initiation of primordial reproductive parts portioning of photosynthetic towards them which promotes the yield. Similar result was also observed by Rao et al*.* [13]. Boron involves in physiological processes and plant growth and adequate nutrition is a critical for increases yield and quality of crops. Similar result was reported by Banoth et al*.* [15].

3.3.2 Stover yield

The significantly higher stover yield (3.88 t/ha) was recorded in treatment 9 with the application of (Nitrogen 60 kg/ha + Boron 0.03 %). However. Treatment 8 (3.78 t/ha) (Nitrogen 60 kg/ha + Boron 0.02 %) was found statically at par with treatment 9.

This might be due to favourable effect of nitrogen on the proliferation of roots and thereby increasing the uptake of the plants nutrients from the soil supplying in to the aerial parts of the plant and ultimately enhancing the vegetative growth of the plant. Similar results are obtained by Rao et al*.* [13].

3.3.3 Harvest Index (%)

The higher harvest index (33.79) was recorded in treatment 9 with the application of (Nitrogen 60 kg/ha + Boron 0.03 %). However, there was no significant difference among the treatments.

3.4 Economic Analysis

Observations regarding economics of different treatments of foxtail millet are given in Table 3.

3.4.1 Cost of cultivation (INR/ha)

Data pertaining to the gross returns as influenced by various treatments are presented in Table.3

Cost of cultivation (INR/ha 21,191.50) was recorded higher in treatment 9 with application of Nitrogen 60 kg/ha + Boron 0.03% as compared to other treatments.

3.4.2 Gross return (INR/ha)

Data pertaining to the net returns as influenced by various treatments are presented in Table 3.

Higher gross return (INR/ha 69,291.48) was recorded in treatment 9 with the application of (Nitrogen 60 kg/ha + Boron 0.03%) as compared to other treatments.

Table 3. Effect of nitrogen boron on economics (INR/ha) of production of foxtail millet

Treatment No.	Treatment combinations	Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	Benefit: Cost ratio
1.	Nitrogen 40 kg/ha + Boron 0.01% 20DAS	20,261.50	49,949.43	29,687.93	1.48
2.	Nitrogen 40 kg/ha + Boron 0.02% 40 DAS	20,511.50	53,994.38	33,482.88	1.63
3.	Nitrogen 40 kg/ha + Boron 0.03% 60DAS	20,761.50	56,254.33	35,492.83	1.71
4.	Nitrogen 50 kg/ha + Boron 0.01% 20 DAS	20,481.50	58,942.22	38,460.72	1.88
5.	Nitrogen 50 kg/ha + Boron 0.02% 40 DAS	20,731.50	61,396.53	40,665.03	1.96
6.	Nitrogen 50 kg/ha + Boron 0.03% 60 DAS	20,981.50	63,366.10	42,384.60	2.02
7.	Nitrogen 60 kg/ha + Boron 0.01% 20 DAS	20,691.50	65,661.05	44,969.55	2.17
8.	Nitrogen 60 kg/ha + Boron 0.02% 40 DAS	20,941.50	66,874.15	45,932.65	2.19
9.	Nitrogen 60 kg/ha + Boron 0.03% 60 DAS	21,191.50	69,291.48	48,099.98	2.27
10.	Control (RDF 50:30:20 NPK kg/ha)	19,981.50	49,365.63	29,384.13	1.47

3.4.3 Net return (INR/ha)

Data pertaining to the B:C ratio as influenced by various treatments are presented in Table 3.

Net return (INR/ha 48,099.98) was recorded higher in treatment-9 with the application of (Nitrogen 60kg/ha + Boron 0.03%) as compared to other treatments.

3.4.4 Benefit cost ratio (B:C)

Data pertaining to the B:C ratio as influenced by various treatments are presented in Table 3.

Higher benefit cost ratio (2.27) was recorded in treatment 9 with the application of (Nitrogen 60 kg/ha + Boron 0.03%) as compared to other treatment.

4. CONCLUSION

Based on experimental findings it is concluded that Treatment (9) application of Nitrogen 60kg/ha + Boron 0.03% performed better in growth, yield parameters and economics.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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