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Effect of Nitrogen and Boron Fertilization on Yield and Quality of Mustard (*Brassica juncea*) in Chitrakoot Area, Madhya Pradesh, India

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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

A field experiment was conducted in year 2022 in Rabi season at Rajaula Agriculture farm, Mahatma Gandhi Chitrakoot Gramoday Vishwavidyalaya Chitrakoot, Satna (M.P.). Experiment was laid out in randomized block design with thirteen treatment combinations, varying levels of nano-urea and boron application, alongside a standard 100 % NPK as per RDF treatment as the control. Results showed significant differences in seed and oil yield across treatments. The highest seed yield of 1523.81 kg/ha was achieved with T_{12} (½ RDN + two nano-urea sprays + 1.25 kg B), a

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notable improvement over the control (T0) at 958.73 kg/ha. Oil content ranged from 13.1% to 35.6%, with the highest in T_{12}, which also produced the maximum oil yield of 542.48 kg/ha. The lowest oil content (13.1%) and oil yield (190.47 kg/ha) were observed in T_{11} (½ RDN + one nano-urea spray + one water spray + 1.25 kg B). Treatments incorporating nano-urea and higher levels of boron showed the most pronounced increases in both oil content and yield, suggesting a synergistic effect of these nutrients on mustard productivity. Statistical analysis confirmed significant improvements in yield and oil quality with combined boron and nano-urea applications, indicating that T_{12} is the optimal treatment for maximizing mustard production under similar agro-climatic conditions.

Keywords: Nitrogen; boron; yield; oil content; oil yield; mustard crop.

1. INTRODUCTION

Indian mustard is one of the most important edible oilseed *rabi* crop of North India commonly known as *Sarson*, *Rai* or *Laha*. It belongs to the family Brassicaceae and genus *Brassica*. The oil content in mustard seeds varies from 37-49 percent (Singh *et. al.,* 2023), the seeds are highly nutritive containing 38-57 % eruric acid, and 27 % oleic acid. The seed is used as a condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is utilized for human consumption throughout the northern India for cocking purpose. This is a potential crop in winter (Rabi) season due to its wider adaptability and suitability to exploit residual moisture (Mukherjee, 2010). Oil and fats comprise a vital component of human diet as these are good source of energy and act as carriers of fat-soluble vitamins. Oil cake or meal has high nutritional values in animal diet. Seed owing to its high content of good quality protein. In general, 55g edible oil per day head is essential for human diet.

India ranks third in terms of area and production of rapeseed-mustard after Canada and China. Globally, the area and production of rapeseed-mustard is 36.81 million hectares and 72.61 million tonnes, respectively (USDA, 2020). Rapeseed mustard is the second most consumed edible oilseed crop in India, after soybean. India has 6.23 million hectares area under rapeseed mustard and 9.34 million tonnes production with average productivity of 1499 kg ha^{-1}, which is about three-fourth of the world's average productivity (1960 kg ha^{-1}) (DAC & FW, 2020). In the Madhya Pradesh, it is grown on an area 1038.15 thousand hectares with a production of 1.69 million tonnes (Anonymous 2021-22).

Urea is a rich source of nitrogen, an essential nutrient for plant growth. Nitrogen is a crucial component of chlorophyll, the green pigment in plants responsible for photosynthesis. Adequate nitrogen supply helps mustard plants produce more chlorophyll, leading to improved photosynthesis and overall plant growth. Mustard plants respond well to nitrogen fertilizers like urea during their vegetative stage (Shorna et al*.,* 2020). This can lead to better light interception and more efficient utilization of sunlight. The application of urea at the right time and in the right amount can significantly increase mustard crop yield. One of the most common symptoms of nitrogen deficiency is the yellowing of older leaves, starting from the tips and progressing towards the base of the plant. Urea deficiency can lead to reduced plant height, fewer branches, and a generally stunted appearance. Mustard plants may fail to reach their full growth potential (Iqbal et al*.,* 2011).

Nano fertilizers possess unique feature which enhance plant performance in terms of ultrahigh absorption, increase in production, rise in the leaves surface area. Beside the controlled released of nutrients contributes in preventing eutrophication and pollution in water resources. Replacement of traditional fertilizers by nano fertilizer is beneficial as upon application, it releases nutrients into the soil steadily and in a controlled way, thus, preventing the water pollution (Naderi and Danesh Shahraki 2013, Moaveni and Kheiri, 2011).

The use of nano fertilizers not only causes increased use efficiency through ultra-high absorption of the nutrients, increase in photosynthesis caused by expansion in surface area of the leaves (INIC 2009) but also reduce the toxicity generated due to over application in the soil as well as reduces the split application of fertilizer (Naderi and Danesh Shahraki, 2013). Nano fertilizers and nanocomposites can be used to control the release of nutrients from the fertilizer granules so as to improve the nutrient use efficiency while preventing the nutrient ions from either getting fixed or lost to the environment (Subramanian et al. 2008).

Boron is essential for the formation and stability of plant cell walls. It is involved in the cross-linking of pectin molecules, which helps maintain the structural integrity of plant cells. In mustard plants, this is especially important for maintaining stem and seed pod strength. Adequate boron levels promote efficient pollination and higher seed set, ultimately contributing to increased yield. Boron aids in the uptake and translocation of other essential nutrients within the plant. It helps in the movement of calcium, which is important for cell division and overall plant growth (Sharma et al., 2020).

Boron is unique among the essential mineral nutrients because it is the only element that is normally present in soil solution as a non- ionised molecule over the pH range suitable for plant growth. In soil solution, boron mainly exists as undissociated boric acid (H_3BO_3). Boric acid is the major form of boron in soils with H_2BO_3 being predominant only above pH 9.2. Boron occurs in aqueous solution as boric acid $B(OH)_3$, which is a weak monobasic acid that acts as an electron acceptor or as a Lewis acid (Rathore, 2015).

2. MATERIALS AND METHODS

The experiment was carried out at Rajaula Agriculture farm, Mahatma Gandhi Chitrakoot Gramoday Vishwavidyalaya Chitrakoot, Satna (M.P.) which lies in the semi- arid and sub-tropical region of Madhya Pradesh between 25.148° North latitude and 80.855° East longitude. The altitude of town is about 190-210 meter above mean sea level. Soil Characteristics; pH is soil 7.4, EC 0.34; OC 0.31; Total N 97.68; Available P 16.25; Available K 292.90 and available boron is 0.38. The field was prepared by ploughing with a tractor drawn disc plough by cross harrowing and planking. After preparation of land, the experiment was laid out as per treatment combinations, there were 39 plots and the gross size of each plot was 5.0 m x 4.0 m and the net plot size was 4.5 m x 3.5 m. FYM was applied @ 10 q ha^{-1} as basal dose. After the layout of experimental plot, the fertilizers were weighed and applied in the plots and thoroughly mixed with soil. As per the experimental recommended doses of Nitrogen, Phosphorus, Potassium were applied to assigned plots. Recommended dose of Nitrogen, Phosphorus and Potassium were applied through Urea, DAP and MOP (60:40:40 kg ha^{-1}) whereas boron was applied through borax (0, 0.5, 1.0, 1.25 kg B ha^{-1}). The seed was sown in line after making a narrow furrow with the help of pointed wooden stick at different row spacing. No irrigation was given to entire experimental field. The crop was harvested on 14th Feb., 2023 when it reached to its physiological maturity i.e. when the leaves were turned yellow and more than 70 % capsules were full matured to avoid shattering of the crop.

The 13 treatments combination of nutrient management practices. Experiment was laid out in Randomized Block Design with three replications. i.e. T0; control, T1; ½ of RDN + (2 water spray + 0.0 kg B), T2; ½ of RDN + (2 water spray + 0.0 kg B), T3; ½ of RDN + (Ist nano-urea spray + 2nd nano-urea spray + 0.0 kg B), T4; ½ of RDN + (2 water spray + 0.5 kg B), T5; ½ of RDN + (Ist nano-urea spray + 2nd water spray + 0.5 kg B), T6: ½ of RDN + (Ist nano-urea spray + 2nd nano-urea spray + 0.5 kg B), T7; ½ of RDN + (2 water spray + 1.0 kg B), T8; ½ of RDN + (Ist nano-urea spray + 2nd water spray + 1.0 kg B), T9; ½ of RDN + (Ist nano-urea spray + 2nd nano-urea spray + 1.0 kg B) T10; ½ of RDN + (2 water spray + 1.25 kg B), T11; ½ of RDN + (Ist nano-urea spray + 2nd water spray + 1.25 kg B), T12; ½ of RDN + (Ist nano-urea spray + 2nd nano-urea spray + 1.25 kg B). Collected data and observations i.e. Oil content in seed (%), Oil Yield (kg ha^{-1}),

2.1 Data Collection

2.1.1 Oil content in seed (%)

Oil content estimated by Soxhelt extraction method.

Oil content in seed (%) = $W_0 / W_S \times 100$

W_0 = weight of oil extracted in grams

W_S = weight of seed in grams

2.1.2 Oil Yield (kg ha^{-1})

Oil yield (kg ha^{-1}) = Oil content (%) × Seed yield (kg ha^{-1}) / 100

2.2 Statistical Analysis

The growth parameters and yields were recorded and analyzed as per Gomez (1984) the tested at 5% level of significance to interpret the significant differences.

3. RESULTS AND DISCUSSION

3.1 Seed Yield

The results revealed that the total seed yield (kg ha^{-1}) of mustard varied in between 958.73 to 1523.81 kg ha^{-1} all the treatments were significantly superior to T_0 [100 5 NPK as per RDF]. The treatment combination T_{12} [½ of RDN + (I^{st} nano-urea spray + 2^{nd} nano-urea spray + 1.25 kg B)] gave the maximum total seed yield (1523.81 kg ha^{-1}) followed by the treatment T_9 [½ of RDN + (I^{st} nano-urea spray + 2^{nd} nano-urea spray + 1.0 kg B)] with the value 1485.71 kg ha^{-1}. Minimum total seed yield (958.73 kg ha^{-1}) was found under the treatment T_0 [100 % NPK as per RDF].

Total seed yield increased significantly with the combined use of boron and 50 % nitrogen / urea spray. The minimum total seed yield was noted 1066.66 kg ha^{-1} in the treatment 0 kg B ha^{-1} + 50 % RDN + N_0 spray and maximum total seed yield 1523.80 kg ha^{-1} was noted in the treatment 1.25 kg B ha^{-1} + 50 % RDN + N_2 spray. Similar findings were reported by Kumar et al. (2016), Sinha et al. (2022) and Kumar et al. (2022).

3.2 Quality Parameters

3.2.1 Oil content (%)

The oil content ranged from 13.1 % to 35.6 % across the treatments. The lowest oil content (13.1 %) was recorded in treatment T_{11}, which combined half of the recommended dose of nitrogen (RDN) with one nano-urea spray, one water spray, and 1.25 kg of boron (B). The highest oil content (35.6 %) was observed in treatment T_{12}, which used half of the RDN with two nano-urea sprays and 1.25 kg B. Treatments with nano-urea sprays generally led to higher oil content, with T_9 and T_{12} yielding particularly high results (35.0 % and 35.6 %, respectively). Similar findings were reported by Kumar et al*.,* (2014), Yadav et al*.,* (2016) and Pandey et al*.,* (2022).

3.2.2 Oil yield (kg ha^{-1})

Oil yield ranged from 190.47 kg/ha to 542.48 kg/ha. T_{12} achieved the highest oil yield at 542.48 kg/ha, indicating that two nano-urea sprays combined with 1.25 kg B and half of the RDN is the most effective combination for maximizing oil yield. The lowest yield was observed in T_{11} (190.47 kg/ha), where one nano-urea spray, one water spray, and 1.25 kg B were applied. This treatment yielded lower both in oil content and oil yield. As with oil content, treatments incorporating nano-urea sprays and higher boron levels tended to produce higher oil yields. Similar findings were reported by Sachan et al*.,* (2022), Dhaliwal et al*.,* (2022) and Halim et al*.,* (2023).

Table 1. Effect of different treatment combination on number of total seed yield (kg ha^{-1})

Treatment	Treatment Combination	Total seed yield (kg ha^{-1})
T_0	100 % NPK as per RDF	958.73
T_1	½ of RDN + (2 water spray + 0.0 kg B)	1009.52
T_2	½ of RDN + (I^{st} nano-urea spray + 2^{nd} water spray + 0.0 kg B)	1066.67
T_3	½ of RDN + (I^{st} nano-urea spray + 2^{nd} nano-urea spray + 0.0 kg B)	1155.55
T_4	½ of RDN + (2 water spray + 0.5 kg B)	1117.46
T_5	½ of RDN + (I^{st} nano-urea spray + 2^{nd} water spray + 0.5 kg B)	1212.70
T_6	½ of RDN + (I^{st} nano-urea spray + 2^{nd} nano-urea spray + 0.5 kg B)	1346.03
T_7	½ of RDN + (2 water spray + 1.0 kg B)	1295.24
T_8	½ of RDN + (I^{st} nano-urea spray + 2^{nd} water spray + 1.0 kg B)	1422.22
T_9	½ of RDN + (I^{st} nano-urea spray + 2^{nd} nano-urea spray + 1.0 kg B)	1485.71
T_{10}	½ of RDN + (2 water spray + 1.25 kg B)	1384.13
T_{11}	½ of RDN + (I^{st} nano-urea spray + 2^{nd} water spray + 1.25 kg B)	1453.97
T_{12}	½ of RDN + (I^{st} nano-urea spray + 2^{nd} nano-urea spray + 1.25 kg B)	1523.81
SEm ±		**3.64**
C.D. (P=0.05)		**10.75**

Table 2. Effect of different treatment combination on oil content and oil yield

Treatment	Treatment Combination	Oil content (%)	Oil yield (kg ha^{-1})
T_0	100 % NPK as per RDF	31.1	298.17
T_1	½ of RDN + (2 water spray + 0.0 kg B)	32.2	325.07
T_2	½ of RDN + (Ist nano-urea spray + 2nd water spray + 0.0 kg B)	32.6	347.73
T_3	½ of RDN + (Ist nano-urea spray + 2nd nano-urea spray + 0.0 kg B)	33.2	383.64
T_4	½ of RDN + (2 water spray + 0.5 kg B)	32.9	367.64
T_5	½ of RDN + (Ist nano-urea spray + 2nd water spray + 0.5 kg B)	33.5	406.25
T_6	½ of RDN + (Ist nano-urea spray + 2nd nano-urea spray + 0.5 kg B)	34.1	459.00
T_7	½ of RDN + (2 water spray + 1.0 kg B)	33.8	437.79
T_8	½ of RDN + (Ist nano-urea spray + 2nd water spray + 1.0 kg B)	34.8	494.93
T_9	½ of RDN + (Ist nano-urea spray + 2nd nano-urea spray + 1.0 kg B)	35.0	520.00
T_{10}	½ of RDN + (2 water spray + 1.25 kg B)	34.5	477.52
T_{11}	½ of RDN + (Ist nano-urea spray + 2nd water spray + 1.25 kg B)	13.1	190.47
T_{12}	½ of RDN + (Ist nano-urea spray + 2nd nano-urea spray + 1.25 kg B)	35.6	542.48
SEm ±		**0.12**	**2.06**
C.D. (P=0.05)		**0.35**	**6.06**

4. CONCLUSION

The study highlights the beneficial effects of combining nano-urea and boron applications on mustard crop yield and oil quality in the Chitrakoot region. The treatment combination T_{12} (½ RDN + two nano-urea sprays + 1.25 kg B) proved to be the most effective, significantly enhancing seed yield (1523.81 kg/ha) and oil yield (542.48 kg/ha) compared to the control treatment with 100 % NPK as per RDF. Results indicate that the combined application of boron and nano-urea not only boosts seed yield but also improves oil content, with T_{12} achieving the highest oil percentage at 35.6 %. This study suggests that using nano-urea and boron synergistically can optimize nutrient efficiency, enhance mustard crop productivity, and improve oil quality, making it a promising nutrient management strategy for similar semi-arid regions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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