**Determining the Effect of Potassium and Zinc on the Growth and Yield of Mustard (*Brassica juncea* L*.*) from Dehradun, Uttarakhand, India**

*.*

**Abstract**

 A field experiment was conducted during the Rabiseason of 2023-2024 to assess the influence of potassium and zinc on the growth, yield, and quality of mustard (*Brassica juncea* L.) var. ‘Pant Shweta’ at the Agricultural Research Farm, Graphic Era Hill University, Dehradun, Uttarakhand. The treatments comprised T1 – Control, T2 – NP+30kg K/ha, T3 – NP+ 30kg K/ha + 10 kg Zn/ha, T4 – NP+30kg K/ha+ 15kg Zn/ha, T5 – NP+ 40kg K/ha + 10 kg Zn/ha, T6 – NP+ 40kg K/ha + 15 kg Zn/ha, T7 –NP+ 50kg K/ha + 10 kg Zn/ha and T8- 5NP+ 50kg K/ha + 15 kg Zn/ha. Application of NP+ 50kg K/ha + 15 kg Zn/ha recorded a maximum plant height (60.77cm), (85.63cm) and (138.83cm) and maximum plant dry weight (5.56gm), (19.42gm) and (30.60gm)at 30DAS, 60DAS and 90DAS. Maximum test weight (3.12 g), number of siliqua/plant (201.68), number of seeds/siliqua (28.82), seed yield (26.00q/ha), stover yield (34.13 q/ha), Oil content (40.00%) ,monetary benefits like gross return (146900.00 Rs./ha), net return (91575.00 Rs./ha) and benefit: cost ratio (1.66).

**Keywords:** Potassium, Zinc, agriculture economy, Oilseed crop.

1. **INTRODUCTION**

“Oilseed crops play an important role in agriculture economy of India which constitutes the second largest agriculture product next to food grains in the country” **(Mathal *et.al.,* 2011)**. Mustard (*Brassica juncea* L*.*) is considered to be one of the most valuable oil-seed crops. It belongs to *Brassicaceae* (*Cruciferae*) family. Indian mustard is known as Raya, and is considered a vital oil-producing crop among *Brassica* in India *(***Meena *et.al.,* 2018).** “Mustard production has increased by 40% from 91.24 to 128.18 lakh tonnes during last 3 years. The productivity saw an 11% increase from 1331 to 1447 kg/ha. The area under rapeseed and mustard was increased by 29% from 68.56 lakh ha in 2019-20 to 88.58 lakh ha in 2022-23. Timely action by central and state government made this remarkable achievement possible” **(PIB 2023)**. “Rajasthan, Madhya Pradesh, Uttar Pradesh, Uttarakhand, Haryana, Gujarat, Andra Pradesh, Karnataka, Haryana, Orissa, Punjab and West Bengal are majorly growing of mustard in India” **(Sharma *et.al.,* 2020).**

Among the mineral cations that the plant needs, potassium is one of the key nutrients in the soil. 2.4% of the earth's crust is potassium. Potassium is mostly found in complex silicate components, while some of it is also found in soil's organic matter and clay fraction. The amount of potassium in soil can range from 0.1% to 3.0% or even higher. In instances of insufficient soil moisture, potash is also necessary for the root system to absorb water **(Umar *et.al.,* 2006).** The lack of potassium is responsible for low yields and poor crop quality because, apart from other major physiological and biochemical requirements in growth, K is a key nutrient element in the biosynthesis of oil in oilseeds and protein (**Sinha *et.al.,* 2022, Solanki *et.al.,* 2016).**

“Zinc (Zn) being one of the essential micronutrient, plays significant role in various enzymatic and physiological activities of the plant system. It is also essential for photosynthesis and N metabolism. It is important for stability of cytoplasmic ribosomes, cell division, dehydrogenase, proteinase and peptidase enzymes; and also helps in the synthesis of protein and carotene” **(Kumawat *et.al.,*2023). “**In India, Zn is now considered as fourth most important yield limiting nutrient in agricultural crops. Zinc deficiency in Indian soils is expected to increase from 42% in 1970 to 63% by 2025 due to continuous depletion of soil fertility” **(Bhatt *et.al.*, 2020).** Zinc is vital for vigorous growth and natural resistance to disease, pest and stress. Mustard plants absorb zinc in larger amounts than any other micronutrient” **(Bartaria *et.al.,* 2002).**

1. **MATERIAL AND METHOD**

A field experiment was conducted during the rabi season of 2023, at Agricultural Research Farm, Graphic Era Hill University, Dehradun, Uttarakhand.It is situated geographically at 30.34°N latitude and 78.02°E longitude and 64°m above sea level. It falls under Western Himalayan Region of agro climatic zone of Uttarakhand. To assess the effect of potassium and zinc on growth and yield of Mustard *[Brassica juncea (L.).* The investigational plot’s soil had a sandy loam texture, a (6.00 pH ) with Electric Conductivity -(0.21d S/m), low in organic carbon (0.55%), available N(125kg/ha),available P(54.82 kg/ha), available K(89.8kg/ha) and Zn(0.76ppm).  *“*The experiment was laid out in Randomized Block Design comprising of 8 treatments which are replicated thrice. Each treatment net plot size is3.5 m x 4.5 m. The treatment are categorized as with recommended dose of nitrogen through urea and phosphorus through SSP, in addition with Potassium and zinc when applied in combinations as follows,T1 – Control, T2 – NP+30kg K/ha, T3 – NP+ 30kg K/ha + 10 kg Zn/ha, T4 – NP+30kg K/ha+ 15kg Zn/ha, T5 – NP+ 40kg K/ha + 10 kg Zn/ha, T6 – NP+ 40kg K/ha + 15 kg Zn/ha, T7 –NP+ 50kg K/ha + 10 kg Zn/ha and T8- 5NP+ 50kg K/ha + 15 kg Zn/ha. “The mustard crop was harvested treatment wise at harvesting maturity stage. Growth parameters viz. plant height (cm), dry matter accumulation g/m2 were recorded manually on five randomly selected representative plants from each plot of each replication separately and after harvesting, seeds were separated from each net plot and were dried under sun for five days. Later winnowed, cleaned and seed yield per ha was computed and expressed in kilogram per hectare. After complete drying under sun for 10 days stover yield from each net plot was recorded and expressed in kilogram per hectare. The data was computed and analyzed by using the F-test as per the procedure” given by **Gomez and Gomez (1984)**. CD values at P=0.05 were used to determine the significance of different treatment means. For testing the hypothesis, the ANOVA table was used.

1. **RESULTS AND DISSCUSION**

**A. Pre-harvest observations**

**a. Emergence Count/m2**

Data regarding mean number of plants emerged / m2 at 20 DAS are presented in Table 1.

Table 1: Mean number of plants emerged per m2 at 20 DAS

|  |  |
| --- | --- |
| Treatment | Emergence/m2 |
|
| T1 Control | 30.67 |
| T2 NP+30kg K/ha | 43.33 |
| T3 NP+ 30kg K/ha + 10 kg Zn/ha | 52.67 |
| T4 NP+30kg K/ha+ 15 kgZn/ha | 56.67 |
| T5 NP+ 40kg K/ha + 10 kg Zn/ha | 60.00 |
| T6 NP+ 40kg K/ha + 15 kg Zn/ha | 65.00 |
| T7 NP+ 50kg K/ha + 10 kg Zn/ha | 57.67 |
| T8 NP+ 50kg K/ha + 15 kg Zn/ha | 69.00 |
| SEm± | 1.63 |
| CD(5%) | 4.85 |

The result showed that maximum emergence count / m2 (69.00) is obtained with the application of NP+ 50kg K/ha + 15 kg Zn/ha (T8). Which was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha(T6) and significantly higher than the rest of the treatments. The results showed that NP+ 50kg K/ha + 15 kg Zn/ha (T8) increased by 31.00% and 124% over NP+ 30kg K/ha and control respectively.

**b. Plant height (cm)**

At 30DAS which was statistically at par with NP+30kg K/ha+ 15 kg Zn/ha(T4), NP+ 40kg K/ha + 10 kg Zn/ha(T5), NP+ 40kg K/ha + 15 kg Zn/ha(T6), and NP+ 50kg K/ha + 10 kg Zn/ha (T7) and significantly higher than the rest of the treatments. At 60DAS and 90DAS it was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha(T6), and NP+ 50kg K/ha + 10 kg Zn/ha (T7) over NP+30kg K/ha and control. Application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) increased plant height by 41% over control and 30% over NP+30kg K/ha. The results are in conformity with **Farhad *et. al*., (2010)** the application of 50kg K/ha significantly increased plant height compared to lower potassium levels. Increase in plant height due to adequate availability of zinc might be attributed to profuse root system which increases the plant growth by the enhancement in cell division because it influenced the formation of several growth hormones like IAA in plants. Similar results were also reported by **(Husain and Kumar2006).**

**Figure 1. Effect of Potassium and Zinc on Plant height of Mustard.**

**c. Dry Matter Accumulation/m2**

The results showed that maximum dry matter accumulation g/m2 (7.17gm, 89.90gm, 223.3gm) respectively at 30, 60 & 90 DAS) was obtained with the application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) at all the crop growth stages. At 30 and 90 DAS, it was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha (T6) and significantly higher than the rest of the treatments. At 60 DAS, it was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha(T6), NP+ 50kg K/ha + 10 kg Zn/ha(T7) over NP+30kg K/ha and control. Application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) increased plant height by 226% over control and 85% over NP+30kg K/ha.

This might be due to Potassium. It influences the transport and assimilation of nutrients and water within the plant. Which was involved in maintaining osmotic balance and cell turgor, which are necessary for cell expansion and overall plant growth. This nutrient helps in the movement of sugars and other carbohydrates from leaves to storage organs, promoting the accumulation of biomass​ confirmed by **Hasanuzzaman *et.al.,* (2018).** This might be due to higher branches and more height. Similar result is also reported by **Kaur *et al.* (2017)** wherein they reported significant increase in mustard dry matter due to 5 kg Zn/ha.

**Table 2. Effect of Potassium and Zinc on Dry Matter Accumulation accumulation/m2**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Treatments | 30 DAS | 60 DAS | 90 DAS |
| T1 | Control | 3.33 | 42.03 | 68.33 |
| T2 | NP+30kg K/ha | 4.10 | 55.37 | 120.17 |
| T3 | NP+ 30kg K/ha + 10 kg Zn/ha | 3.86 | 67.07 | 141.67 |
| T4 | NP+30kg K/ha+ 15 kgZn/ha | 4.78 | 62.73 | 148.00 |
| T5 | NP+ 40kg K/ha + 10 kg Zn/ha | 5.02 | 70.87 | 168.39 |
| T6 | NP+ 40kg K/ha + 15 kg Zn/ha | 6.33 | 79.63 | 210.67 |
| T7 | NP+ 50kg K/ha + 10 kg Zn/ha | 5.97 | 75.63 | 161.63 |
| T8 | NP+ 50kg K/ha + 15 kg Zn/ha | 7.17 | 89.90 | 223.33 |
| SEm± | 0.37 | 5.41 | 8.59 |
| CD 5 % | 1.12 | 16.57 | 26.30 |

**d. Crop Growth Rate (CGR)**

The results showed that maximum Crop Growth Rate (1.00, 11.67 & 16.9 gm/m2/day, respectively at 30, 60 & 90 DAS) was obtained with the application NP+ 50kg K/ha + 15 kg Zn/ha (T8) at all the crop growth stages. However, it was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha (T6) and NP+ 50kg K/ha + 10 kg Zn/ha (T7) and significantly higher than the rest of the treatments. Application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) resulted in increased crop growth rate by 78% and 195 % over NP+30kg K/ha and control, respectively at 90 DAS. Minimum CGR (0.47, 5.19 & 5.47 ) gm/m2/day at 30, 60 & 90 DAS) was recorded under control at all the crop growth stages.

**Figure 2. Effect potassium and zinc on crop growth rate**

**E.Relative Growth Rate**

At 60 DAS it was statistically at par with NP+ 40kg K/ha + 10 kg Zn/ha(T5), NP+ 40kg K/ha + 15 kg Zn/ha(T6) and NP+ 50kg K/ha + 10 kg Zn/ha (T7). At 90DAS it was statistically at par with NP+ 40kg K/ha + 10 kg Zn/ha(T5) and NP+ 40kg K/ha + 15 kg Zn/ha(T6). RGR increased by 2.7% and 24% with application NP+30kg K/ha (T2) and control (T1), respectively. Minimum relative growth rate (0.087, 0.169, and 0.170 mg/g/day at 30, 60, & 90 DAS) was recorded under control at all the crop growth stages.

 **Figure 3. Effect potassium and zinc on Relative Growth Rate**

**B. Post-harvest observations**

Table 3 Relative Growth Rate in different treatment varieties

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S.No | Treatment | **No. of** **siliqua/Plant (No.)** | **No. of****seeds/siliqua (No.)** | **Test weight****(g)** |
| T1 | Control | 70.93 | 22.33 | 2.30 |
| T2 | NP+30kg K/ha | 83.10 | 23.40 | 2.95 |
| T3 | NP+ 30kg K/ha + 10 kg Zn/ha | 87.90 | 24.67 | 2.23 |
| T4 | NP+30kg K/ha+15 kgZn/ha | 170.53 | 25.67 | 2.83 |
| T5 | NP+ 40kg K/ha + 10 kg Zn/ha | 145.03 | 25.00 | 2.93 |
| T6 | NP+ 40kg K/ha + 15 kg Zn/ha | 190.50 | 27.00 | 3.05 |
| T7 | NP+ 50kg K/ha + 10 kg Zn/ha | 149.87 | 26.00 | 2.73 |
| T8 | NP+ 50kg K/ha + 15 kg Zn/ha | 201.68 | 28.82 | 3.12 |
| SEm± | 9.20 | 1.52 | 0.21 |
| CD 5 % | 28.16 | 4.60 | 0.64 |

**a. Siliqua/plant (No.)**

The result showed that maximum number of Siliqua/plant (No.) (201.68) was obtained with the application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) and it was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha (T6) and significantly higher than the rest of the treatments.Number of siliqua/plant have increased due to higher dose of potassium and zinc. Potassium is reported to enhance the absorption of native as well as added major nutrients and there by improves number of siliqua/plant. Potassium application enhances the development of strong cell walls and improves germination of pollen in the florets which leads to high fertility and Siliqua formation. The results were in accordance with **Cheema *et.al*., (2012).** This might be due to optimum availability of Zn which might/have resulted in balanced nutrition. Similar findings were also reported by **Kaur *et.al*.,(2017).**

**b. Seed/Siliqua (No.)**

The result showed that maximum number of seed/siliqua (28.82 No.) was obtained with the application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) and it was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha (T6) and significantly higher than the rest of the treatments. The results showed that NP+ 50kg K/ha + 15 kg Zn/ha (T8) increased by 23% and 29% over NP+30kg K/ha (T2) and control (T1), respectively.

Potassium might be attributed to better filling of grains and thus, an increase in different yield attributing characters. The results were found to be similar with **Singh *et.al*., (2017).** This might be due to higher growth attributes in same treatments **Kaur *et al*. (2017)** also found similar results which support present findings.

**c. Test weight (g)**

The result showed that the maximum test weight (3.12g) was obtained with the application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) and it was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha (T6) and significantly higher than the rest of the treatments, the results showed that NP+ 50kg K/ha + 15 kg Zn/ha (T8) increased by 5% and 35% over NP+30kg K/ha (T2) and control (T1), respectively.

**C. Yield**

**Table 4: Yield and harvest index**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S.No | Treatment | **Seed yield** **(q/ha)** | **Stover yield****(q/ha)** | **Harvest** **index (%)** | **Oil content****(%)** |
| T1 | Control | 18.08 | 22.75 | 43.84 | 36.00 |
| T2 | NP+30kg K/ha | 20.83 | 23.33 | 44.89 | 36.67 |
| T3 | NP+ 30kg K/ha + 10 kg Zn/ha | 21.00 | 25.45 | 45.58 | 37.67 |
| T4 | NP+30kg K/ha+15 kgZn/ha | 22.73 | 24.07 | 49.57 | 37.82 |
| T5 | NP+ 40kg K/ha + 10 kg Zn/ha | 23.01 | 25.66 | 47.82 | 38.75 |
| T6 | NP+ 40kg K/ha + 15 kg Zn/ha | 25.44 | 32.06 | 44.23 | 39.33 |
| T7 | NP+ 50kg K/ha + 10 kg Zn/ha | 24.08 | 26.08 | 48.86 | 39.00 |
| T8 | NP+ 50kg K/ha + 15 kg Zn/ha | 26.00 | 34.13 | 44.17 | 40.00 |
|  SEm± | 0.44 | 1.76 | 1.94 | 0.64 |
|  CD 5 % | 1.33 | 5.34 | NS | 1.95 |

1. **Seed yield**

The table showed that the maximum seed yield (26 q/ha) was obtained with the application of NP+ 50kg K/ha + 15 kg Zn/ha (T8). It was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha (T6) and NP+ 50kg K/ha + 10 kg Zn/ha (T7) but significantly higher than the rest of the treatments. Application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) resulted in an increased seed yield 43% & 24% over control (T1) and NP+30kg K/ha (T2), respectively. Minimum seed yield (18.08 q/ha) was recorded under control (T1).

The fact that K is crucial for processes including photosynthesis, water interactions, protein synthesis, and at least 60 distinct enzyme systems inside the plant explains why there is an increase in seed production after K treatment. Similar findings are in agreement with **Rohit and Jitendra (2020).** The increase in seed of mustard under higher zinc supply might be ascribed mainly due to combined effect of higher number of siliqua/plant and number of seeds/siliqua, which was the result of better translocation of photosynthesis from source to sink. Similar results were also reported **Chandra and Khandelwal (2009)** and **Meena *etal.*(2006).**

**c. Stover yield (q/ha)**

The results showed that maximum Stover yield (34.13 q/ha) was obtained with the application of NP+ 50kg K/ha + 15 kg Zn/ha (T8). It was statistically at par with NP+ 40kg K/ha + 15 kg Zn/ha (T6) but significantly higher than the rest of the treatments. Application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) resulted in increased seed yield 50% & 46% over control (T1) and NP+30kg K/ha (T2), respectively. The fact that K is the primary plant nutrient limiting yield in K deficient soils may be the cause of the rise in Stover yields brought on by K treatment. According to reports, “applied K increases the plant's general growth and development as well as the uptake of important nutrients, leading to increased Stover output. Additionally, the role of K in numerous enzymatic reactions, growth processes, hormone production, protein synthesis, and the translocation of photosynthates to reproductive parts may be responsible for the beneficial effect of K application on the yield of mustard” (**Yadav *et.al*., 2013). “**Applied Zn is reported to enhance the absorption of native as well as added major nutrients and thereby improves overall growth and development of plant and ultimately the seed and Stover yield. In addition the beneficial influence of Zn application on the yield of mustard may be attributed to its role in various enzymatic reactions, growth processes, hormone production and protein synthesis and also the translocation of photosynthates to reproductive parts thereby leading to higher yield of crop” (**Upadhyay 2012 and Singh *et.al.,* 2013).**

**d. Harvest index (q/ha)**

The table showed that the highest harvest index was evident with NP+ 30kg K/ha + 15 kg Zn/ha (T4) (49.57%) and the lowest value was found with control (T1) (43.84%) though the effect is non-significant among the treatments but it is clearly visible with the application of balance dose of potash and zinc lead to achieve the proper growth and development throughout the crop span. “The trend in the projected study under potash applied plants might be due to decrease in the transpiration rate which ultimately maximize the water retention and utilization” (**Syrovy *et.al.,* 2015**). “The performance of potash in the plant growth and development might be due to trigger out the bio-chemical, morphological and physiological processes as a catalyst in the mustard crop plants” **Trivedi *et.al.,* (2014)**

**e. Oil content**

The results showed that maximum oil content (%) (40.00%) was obtained with the application of NP+ 50kg K/ha + 15 kg Zn/ha (T8). It was statistically at par with NP+ 40kg K/ha + 10 kg Zn/ha (T5), NP+ 40kg K/ha + 15 kg Zn/ha (T6) and NP+ 50kg K/ha + 10 kg Zn/ha (T7) but significantly higher than the rest of the treatments. Application of NP+ 50kg K/ha + 15 kg Zn/ha (T8) resulted in increased oil content 11% & 9% over control (T1) and NP+30kg K/ha (T2), respectively. “Potassium might have activated the enzymes responsible for producing oil and caused higher oil content. Beneficial effect of K on oil content” was also reported by **Singh *et.al.,* (2017).**

1. **Economic Analysis**

Significantly higher gross return (146900 INR/ha) was recorded in 50 kg K/ha + 15 kg Zn/ha. However, 50 kg K/ha + 10 kg Zn/ha was found to be statistically at par with 40 kg K/ha + 15 kg Zn/ha. Highest net return and benefit cost ratio (91575 INR/ha and 1.66 respectively) was recorded under treatments 50 kg K/ha + 15 kg Zn/ha. However, for net return and benefit cost ratio 50 kg K/ha + 10 kg Zn/ha was found to be statistically at par with 40 kg K/ha + 15 kg Zn/ha.

**Table 5. Effect of Potassium and Zinc on economics of production of Mustard**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S.No | Treatment | **Cost of cultivation (INR/ha)** | **Gross return****(INR/ha)** | **Net Returns****(INR/ha)** | **Benefit:Cost** |
| T1 | Control | 45156 | 102171 | 57015 | 1.18 |
| T2 | NP+30kg K/ha | 52790 | 117708 | 64918 | 1.23 |
| T3 | NP+ 30kg K/ha + 10 kg Zn/ha | 53930 | 118669 | 64739 | 1.20 |
| T4 | NP+30kg K/ha +15 kgZn/ha | 54500 | 128443 | 73943 | 1.36 |
| T5 | NP+ 40kg K/ha + 10 kg Zn/ha | 54180 | 129999 | 75819 | 1.40 |
| T6 | NP+ 40kg K/ha + 15 kg Zn/ha | 54750 | 143717 | 88967 | 1.62 |
| T7 | NP+ 50kg K/ha + 10 kg Zn/ha | 54755 | 136071 | 81316 | 1.49 |
| T8 | NP+ 50kg K/ha + 15 kg Zn/ha | 55325 | 146900 | 91575 | 1.66 |
| SEm± | - | 2477.73 | 2443.24 | 0.06 |
| CD 5 % | - | 7515.02 | 7410.42 | 0.17 |

1. **CONCLUSION**

 The result obtained from the current study led to the conclusion that the application of NP+ 50kg K/ha + 15 kg Zn/ha (T8), resulted in enhance plant growth, increase yield, and highest benefit cost ratio (B:C ratio). This outcome may be due to potassium that helps in the regulation of stomatal opening and closing. By managing water loss and maintaining turgor pressure, potassium ensures that plants are less stressed and more capable of resisting infections. Proper stomatal function can also prevent the entry of pathogens through leaf openings. Potassium ensures a balanced nutrient status within the plant, which is crucial for maintaining robust plant health. Healthy plants are better equipped to resist diseases compared to nutrient-deficient plants. Adequate zinc availability can enhance flowering, fruit set, and seed production, thus improving the overall yield and quality of mustard crops.

**Disclaimer (Artificial intelligence)**

Option 1:

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 the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

2.

3.

**REFERENCES**

Mathal. P, Punetha .H, Tewari, A.K & Agarwal, S 2011, ‘Biochemical defence mechanism in rapeseed- mustard genotypes against Alternaria blight disease’, Journal of oilseed brassica,vol-2, no.22, pp.87-94 .

Meena1, D.S. Meena1, K.C. Meena2 and C.B. Meena.Enhanced Mustard Productivity and Profitability through Frontline Demonstrations in South-Eastern Rajasthan, India.Int.J.Curr.Microbiol.App.S

Umar S. Alleviating adverse effects of water stress on yield of Sorghum, mustard and groundnut by potassium application. Pakistan Journal of Botany. 2006;38:1373- 1380.

Kumar A, Singh S, Singh K. Effect of micronutrients on yield, quality and nutrient uptake by mustard in alluvial soil.Annuals of Plant and Soil Research.2012;14:68-70.ci (2018) 7(7): 800-805

Bartaria AM, Shukla AK, Kaushik CD, Kumar PR, Singh NB. Major diseases of rapeseed mustard and their management. In: Proc. Nation. Sem. Biopesticide Indian Agricultural Research Institute, New Delhi; c2002. p. 24.

Gomez KA, Gomez AA. Statistical Procedure for Agricultural Research. 2nd Edition, Willey, Hoboken. 1984;28-192.

Farhad ISM, Islam MN, Hoque S, Bhuiyan MSI.Role of potassium and sulphur on the growth,yield and oil content of soybean (*Glycine max*).Academic Journal of Plant Science.2010;3(2):99-103.

Hussain MF, Kumar R. Influence of sowing dates and application of zinc on the performance of mustard in south-west semi arid zone of Uttar Pradesh. International Journal of Agricultural Science. 2006;2(2):601-604.

Kaur S, Gupta M, Bharat R, Sharma V. Effect of zinc and boron on yield, nutrient uptake and economics of mustard (*Brassica junceae* L.) in mustard-maize cropping sequence.Bangladesh J. Bot. 2017;46(2):817-821.

Rohit and Singh, J., (2020). Effect of potassium application on seed yield of mustard in Agra. *International Journal of Ecology and Environmental Sciences.*2(3): 253-254.

Chandra D, Khandelwal RB. Effect of zinc and phosphorus on yield, nutrient uptake on oil content of mustard grown on the gypsum treated sodic soil. Journal of Indian Society Soil Scienc. 2009;57(1): 194-197.

Meena MC, Patel KP, Rathod DD. Effect of Zn and Fe enriched FYM on mustard yield and micronutrient availability in loamy sand soil of Anand. J. Indian Soc. Sci.

2006;54(4):495-499.

Yadav SS, Tikoo A, Singh JP,. Potassium response in Indian mustard (*Brassica juncea*)as influenced by irrigation and nutrient levels. Indian J. Agron. 2013; 55(1):56-59.

Singh, S., and Singh, V. (2017). Effect of rate and source of zinc on yield, quality and uptake of nutrients in Indian mustard (*Brassica juncea*) and soil fertility. *Indian Journal of Agricultural Sciences* 87 (12): 1701–5.

Singh, C.H., and Pandey, G., (2017). Effect of sulphur and zinc on growth and yield of mustard (*Brassica juncea* L.). *Advance Research Journal of improvement* 8(2);199-202.

Sharma, A., Meena, B.S., Meena, R.K., Yadav, R.K., Patidar, B.K., and Kumar,R., (2020). Effect of Different Levels of Nitrogen, Phosphorous and Potassium on Growth, Yield Attributes and Yield of Indian Mustard. *International Journal of Current Microbiology and Applied Sciences.9*(9): 2216-2221.

Sultana, R., Kumar, S.P., Sarkar, A.R., Sarkar, S.K., (2020). Response of sulphur and zinc nutrition to the seed yield and oil content of mustard (CV. BARI SARISHA-14). *Tropical Agrobiodiversity (TRAB).*1(2): 52-56.

Pandey, B.K., Pathak, S.O., Kumar, A., and Singh, A.K., (2020). Effect of Zinc and FYM on growth and yield of mustard (Brassica juncea L.). *International Journal of Chemical Studies.*8(3): 2323-2325.

Pandey, S. B., Sachan, R., Patel, V., and Bhawan, R., (2022). Effect of Sulphur, Potassium and PSB on Growth Parameters, Root Architecture and Quality of Mustard (Brassica juncea L.). *International Journal of Plant & Soil Science.*34(24): 122-127.

Pant, C., Pachauri, S., Srivastava, A., Singh, V. and Shukla, A., 2022. Residual effect of varying levels of sulphur, zinc and boron on yield, yield attributing characters, nutrient uptake and quality in mustard (*Brassica juncea* L.) grown after cluster bean in a Mollisol. *Annals of Plant and Soil Research,* 24(4):636-645.

Rana, P., Sirothia, P. and Yadav, B.S. (2018). Effect of sulphur and zinc on yield and uptake of nutrients by mustard (*Brassica spp.* L.) under rainfed condition. *International Journal of Chemical Studies.* 6(6): 871-874.

Amanullah and Khan, M.H., (2015). Difference in dry matter accumulation with variable rates of sulphur and potassium application under calcareous soils in *Brassica napus* vs. *B. juncea*. *Journal of Oilseed Brassica.* 6(2): 241-248.

Atkari, B.K., Pagar, P.C., Jamdade, R.N., Yelane, A.J., and Kothikar, R.B., (2022). Effect of potassium and sulphur on growth, yield and economics of mustard (*Brassica juncea* L.) under irrigated conditions. *The Pharma Innovation Journal.*11(6): 1000-1003.

Gajghane, P.G., Toncher, S.S., and Raut, M.M, (2015). Effect of Potassium and Sulphur Levels on Soil Fertility Status After Harvest of Mustard. *Plant Archives* 15 (1): 347-351.

Gautam, S., Pandey, H.P., Pathak, R. K., Sharma, S., and Pandey, S., (2020). Effect of Nitrogen, Phosphorus, Potassium, Sulphur and Zinc on Yield and their Attributing Characterstics of Mustard Crop. *International Journal of Plant & Soil Science* 32(12): 12-20.

Jackson, M.L., (1967). Soil chemical analysis. Prentis Hall of India. Pvt. Ltd. New Delhi, 498. Jukanti, A.K., Pooran., Gaur, M., Gowda, C.C.L., Ravindra., & Chibbar, N. (2012).

Janaki, B., Singh, R., and Tripathi, P., (2022). Effect of Biofertilizers and Potassium on Yield and Economics of Yellow Mustard (*Brassica campestris* L.). *International Journal of Environment and Climate Change* 12(11): 1282-1287.