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Effect of Iron and Zinc Fertilization on Growth and Yield of Mustard (*Brassica juncea* L.) in Loamy Sand

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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 during *rabi* 2022-23 at Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The soil of the experimental field was loamy sand in texture, neutral to alkaline in reaction, normal with respect to salt content, low in available nitrogen and sulphur, medium in available phosphorus, potash, zinc and iron and high in manganese and copper. Nine treatment combinations comprising three levels of iron 0.0 kg Fe ha^{-1} (Fe_0), Soil application of 20.0 kg $FeSO_4$.

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$7H_2O$ ha^{-1} (Fe_1) and 0.5 % $FeSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS (Days after sowing) (Fe_2) and three levels of zinc 0.0 kg Zn ha^{-1} (Zn_0), Soil application of 10.0 kg $ZnSO_4$. $7H_2O$ ha^{-1} (Zn_1) and 0.5 % $ZnSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS (Zn_2) were evaluated in randomized block design with factorial concept with four replication. Mustard variety GDM 4 was used as a test crop.

Significantly higher number of secondary branches $plant^{-1}$ (16.59), number of siliquae $plant^{-1}$ (341.4), test weight (5.18 g), seed yield (2061 kg ha^{-1}) and stover yield (4976 kg ha^{-1}) were recorded with soil application of 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Fe_1) but it was at par with 0.5 % $FeSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS. Stover yield of mustard remained at par with 0.5 % $FeSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS.

Significantly higher number of secondary branches $plant^{-1}$ (16.37), number of siliquae $plant^{-1}$ (340.1), seed (2001 kg ha^{-1}) and stover yield (4961 kg ha^{-1}) were recorded with soil application of 10.0 kg $ZnSO_4$. $7H_2O$ ha^{-1} (Zn_1) but it was at par with foliar spray of 0.5 % $ZnSO_4$. $7H_2O$ at 30 and 45 DAS except seed yield of mustard.

Keywords: Iron; zinc; mustard; yield; loamy sand.

1. INTRODUCTION

"Indian mustard (*Brassica juncea* L.) belongs to family "Cruciferae" is one of the most important oilseed crop in India. The rapeseed-mustard is an important group of oilseed crops in India. Broadly, the rapeseed-mustard group includes Indian mustard, brown sarsson, yellow sarson, raya and toria crops. Indian mustard (*Brassica juncea* L.) is the oldest cultivated amphidiploid and is believed to be originated from *Brassica rapa* and *Brassica nigra* in Asia Minor and Southern Iran. The crop can be raised well Under, both irrigated and rainfed conditions. Mustard (*Brassica juncea* L.) belongs to the family cruciferease popularly known as rai" [1].

"Rapeseed-mustard is the third most important edible oilseed crop in India. Mustard is one of the major sources of oil in India. Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is the most important winter season oilseed crop, which thrives best in light to heavy loam soil in areas having 25 to 40 cm rainfall. Rapeseed- mustard is the major source of income especially to the marginal and small farmers in rainfed areas. Since these crops are cultivated mainly in the rainfed and resource scarce regions of the country, their contribution to livelihood security of the small and marginal farmers in these regions is also very important. By increasing the domestic production of oilseeds, substantial import substitution can be achieved" [1].

"Among the nine edible oilseeds cultivated in India, rapeseed-mustard (*Brassica spp*.) contributes 28.6% in the total production of oilseeds. European Union is the leading producer of mustard seed in the world accounting for 35% of the world production followed by Canada (21%), China (22%) and India (11%)" (GOI, 2018). "In India, it is the second most important edible oilseed after groundnut sharing 27.8% in the India's oilseed economy. In India, mustard is mainly grown in North West parts of the country. Gujarat ranks sixth in the production of mustard after Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and West Bengal. In Gujarat, rapeseed-mustard is grown in 0.21 Mha of area with 0.42 million tonnes of total production and productivity of 1976 kg ha^{-1}" [2].

"Micronutrient (Fe, Zn) fertilization has led to the improvement of growth, seed yield and nutritional quality of Indian mustard. Various methods including soil, foliar and seed treatment of Fe and Zn application to crops have been reported for alleviating their deficiency" [3] "Foliar feeding of micronutrients is usually cheap, more effective with greater nutrient use efficiency and considerably reduce environmental pollution via a decline in the quantity of fertilizers added. In addition, foliar fertilization has been evidenced to promote root growth, leading to an increased uptake of nutrients by crops" [1]. Recent research has shown that a small amount of nutrients, particularly Fe and Zn supplied through soil application and foliar spray, have resulted in significant increases in the yield of crops. It is well-known that oilseed crops require high N and an optimum number of micronutrients (Fe, Zn) for the production of a sustainable yield. Thus, the supply of mineral Fe and Zn fertilizers in adequate amounts is essential for getting higher yield and quality of oilseed crops.

2. MATERIALS AND METHODS

The field experiment was carried out on Plot No. A-9 at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha (Gujarat).

The soil of experimental field was loamy sand in texture with slightly alkaline in reaction, electrical conductivity within safe limit. The soil was low in organic carbon, available N, S, Fe and Zn, medium in available P_2O_5, available K_2O and high in available Mn and Cu.

The experiment was laid out in Randomized Block Design with Factorial Concept (FRBD) with four replications. The details of experiment on " Effect of iron and zinc fertilization on growth, yield and quality of mustard (*Brassica juncea* L.) in loamy sand." had three levels of iron Fe_0: 0.0 kg Fe ha^{-1}, Fe_1: 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Soil application) and Fe_2: 0.5% $FeSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS) and three levels of zinc Zn_0 : 0.0 kg Zn ha^{-1}, Zn_1 : 10.0 kg $ZnSO_4.7H_2O$ ha^{-1} (Soil application) and Zn_2 : 0.5% $ZnSO_4.7H_2O$ foliar spray at 30 and 45 DAS. Mustard variety Gujarat Dantiwada Mustard 4 (GDM 4) was sown with recommended seed rate of 3.5 kg ha^{-1} by maintaining 45 cm distance between two rows at a depth of 3 cm in previously opened furrows and covered properly with soil and irrigated immediately.

3. RESULTS AND DISCUSSION

3.1 Effect of Iron on Growth and Yield

Different levels of iron did not exert any significant effect on plant height of mustard at harvest (Table 1).

Significantly higher number of secondary branches $plant^{-1}$ (16.59) was observed under the soil application of 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Fe_1) but it was at par with treatment Fe_2 (0.5 % $ZnSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS) (Table 1).Significantly increased in number of branches per plant attributed to increase in absorption and translocation of assimilation and stimulation graphical and lateral meristems to grow. These results are in accordance with the results of [4] in mustard and [5] in groundnut.

The result presented in Table 2 revealed that significantly higher number of siliquae per plant (341.4) observed with soil application of 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Fe_1). The increase in number of siliquae per plant might be due to iron are involved in photosynthesis which resulted higher growth and development. Similar result was also reported by [4] in mustard and [5] in groundnut. The test weight was found significant with different levels of iron. The significantly higher value of test weight was noted (5.18 g) with soil application of 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Fe_1) but it was remained at par with 0.5 % $FeSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS (Fe_2).Increase of seed weight by iron can be due to increase of carbohydrate synthesis. Similar result was found by [6] and [7] in groundnut.

The data furnished in the Table 3 revealed that seed yield, stover yield and harvest index of mustard significantly influenced due to iron application. Soil application of 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Fe_1) gave significantly higher seed yield (2061 kg ha^{-1}). Iron is a structural component of porphyrin molecules cytochromes, haematin, ferrichrome and leg hemoglobin. These substances are involved in oxidation reductions in respiration and photosynthesis. It performs an essential role in nucleic acid metabolism which helps in increase in the yield. The present result is in close agreement with the result obtained by [8] and [4] in mustard and [9] in soybean. Different levels of iron significantly influenced on stover yield of mustard. Soil application of @ 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Fe_1) recorded significantly higher stover yield (4976 kg ha^{-1}) but it was at par with 0.5 % $FeSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS (Fe_2). These significant differences were observed because of iron plays an important role in synthesis of chlorophyl and plant growth regulators. Iron improves photosynthesis and assimilates transportation to sinks and finally increase stover yield. The finding were confirmed to those reported by [8] and [4] in mustard. Soil application of 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Fe_1) recorded significantly higher harvest index (29.30 %) but it was remained at par with foliar spray of 0.5 % $FeSO_4$. $7H_2O$ at 30 and 45 DAS (Fe_2). The higher harvest index might be due to higher seed yield of mustard with iron fertilization. Similar result was found by [6] in groundnut.

3.2 Effect of Zinc on Growth and Yield

Data presented in Table 1 indicated that significantly higher number of secondary branches recorded with soil application of 10.0 kg $ZnSO_4$. $7H_2O$ ha^{-1} (Zn_1) which was at par with treatment Zn_2 (0.5 % $ZnSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS).The positive effect of micronutrients on number of branches per plant

Table 1. Effect of iron and zinc fertilization on plant height, number of primary and secondary branches per plant of mustard

Treatments	Plant height at harvest (cm)	Number of primary branches plant^{-1}	Number of secondary branches plant^{-1}
Levels of iron			
Fe_0: 0.0 kg Fe ha^{-1}	178.4	5.23	15.27
Fe_1: 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Soil application)	184.5	5.56	16.59
Fe_2: 0.5 % $FeSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS	180.9	5.36	15.74
S.Em.±	2.92	0.15	0.23
C.D. at 5 %	NS	NS	0.68
Levels of zinc			
Zn_0: 0.0 kg Zn ha^{-1}	179.6	5.35	15.54
Zn_1: 10.0 kg $ZnSO_4$. $7H_2O$ ha^{-1} (Soil application)	183.1	5.37	16.37
Zn_2: 0.5 % $ZnSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS	181.0	5.44	15.70
S.Em.±	2.92	0.15	0.23
C.D. at 5 %	NS	NS	0.68
Interaction: Fe × Zn			
S.Em.±	5.05	0.26	0.41
C.D. at 5 %	NS	NS	NS
C.V. %	5.58	9.50	5.12

Table 2. Effect of iron and zinc fertilization on number of siliquae per plant, length of siliqua, number of seeds per siliqua and test weight of mustard

Treatments	Number of siliquae per plant	Length of siliqua (cm)	Number of seeds per siliqua	Test weight (g)
Levels of iron				
Fe_0: 0.0 kg Fe ha^{-1}	316.9	4.80	14.74	5.00
Fe_1: 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Soil application)	341.4	4.97	15.26	5.18
Fe_2: 0.5 % $FeSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS	329.8	4.87	14.94	5.10
S.Em.±	5.68	0.10	0.20	0.04
C.D. at 5 %	16.58	NS	NS	0.13
Levels of zinc				
Zn_0: 0.0 kg Zn ha^{-1}	318.9	4.84	14.77	5.05
Zn_1: 10.0 kg $ZnSO_4$. $7H_2O$ ha^{-1} (Soil application)	340.1	4.92	15.29	5.15
Zn_2: 0.5 % $ZnSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS	329.1	4.88	14.88	5.08
S.Em.±	5.68	0.10	0.20	0.04
C.D. at 5 %	16.58	NS	NS	NS
Interaction: Fe × Zn				
S.Em.±	9.84	0.17	0.35	0.08
C.D. at 5 %	NS	NS	NS	NS
C.V. %	5.97	6.88	4.65	3.04

as observed in present study could be attributed to the application of zinc through foliar spray as well as soil activate plant enzymes which are involved in carbohydrate metabolism and also require for the synthesis of growth hormone auxin leading to cell enlargement and increase in normal cell division. These results are in conformity with the findings of [10-14] and [15].

Table 3. Effect of iron and zinc fertilization on seed yield, stover yield and harvest index of mustard

Treatments	Seed (kg ha^{-1})	Stover (kg ha^{-1})	Harvest index (%)
Levels of iron			
Fe_0 : 0.0 kg Fe ha^{-1}	1769	4609	27.76
Fe_1 : 20.0 kg $FeSO_4$. $7H_2O$ ha^{-1} (Soil application)	2061	4976	29.30
Fe_2 : 0.5 % $FeSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS	1832	4703	28.05
S.Em.±	47.04	96.40	0.43
C.D. at 5 %	137	281	1.27
Levels of zinc			
Zn_0 : 0.0 kg Zn ha^{-1}	1843	4609	28.54
Zn_1 : 10.0 kg $ZnSO_4$. $7H_2O$ ha^{-1} (Soil application)	2001	4961	28.75
Zn_2 : 0.5 % $ZnSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS	1818	4714	27.83
S.Em.±	47.04	96.40	0.43
C.D. at 5 %	137	281	NS
Interaction: Fe × Zn			
S.Em.±	81.47	166.97	0.75
C.D. at 5 %	NS	NS	NS
C.V. %	7.81	7.01	5.30

An appraisal of data given in Table 2 showed that soil application of 10.0 kg $ZnSO_4$. $7H_2O$ ha^{-1} (Zn_1) gave significantly higher number of siliquae per plant (340.06) but it was remained at par with treatment Zn_2 (0.5 % $ZnSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS). Application of recommended dose of fertilizers along with application of Zn boosted the growth and yield components by enhancing cell division, cell elongation process and photosynthetic activity leading to production and accumulation of more carbohydrates and auxins which favours retention of more flowers ultimately leading to more number of reproductive parts per plant. The similar result were also found by [12,16,17,13,18] and [19].

Data tabulated in the Table 3 that indicated that significantly higher seed yield (2001 kg ha^{-1}) was recorded with application of 10.0 kg $ZnSO_4$. $7H_2O$ ha^{-1}. The increased in yield may be due to zinc application, various enzymatic reaction, growth, process, hormones production and protein synthesis and also the translocation of photosynthet to seed leading to higher yield of mustard. Similar result were found by [20-24] and [19]. Significantly higher stover yield (4961 kg ha^{-1}) was obtained with soil application of @ 10.0 kg $ZnSO_4$. $7H_2O$ ha^{-1} (Zn_1), but it was at par with Zn_2 (0.5 % $ZnSO_4$. $7H_2O$ foliar spray at 30 and 45 DAS). These significant differences were observed because of the application of $ZnSO_4$ as it increased availability of Zn in soil. So, plant can easily uptake these micronutrient from the soil and resulted into enhanced photosynthesis which resulted in higher growth and development. Similar result were found by [12,25,13,18] and [15]. The data revealed that different levels of zinc did not exert any significant effect on harvest index of mustard (Table 3).

4. CONCLUSION

This study has shown that applying micronutrient fertilizers to the soil helps mustard plants biofortify vital micronutrients (Zn and Fe), which are important for human nutrition. Mustard yield will be increased by using RDF and micronutrient fertilizer together, which is easily available to farmers. Therefore, farmers that grow mustard should be advised to apply micronutrient fertilizers to their soil along with other contemporary crop management techniques.

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 the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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