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EFFECT OF MICRONUTRIENT (ZINC) ON GROWTH AND YIELD OF MUSTARD VARIETIES

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ABSTRACT

Two varieties (Early Mustard and S-9) were evaluated against six Zn levels (0, 2, 4, 6, 8 and 10 kg Zn ha^{-1}). Significant improvements in the plant growth, seed yield and oil contents increased with increasing Zn levels. The results revealed that there was a significant improvement in the growth, seed yield and oil content with increasing Zn levels, irrespectively. The highest Zn level of 10 kg ha^{-1} resulted 216 cm plant height, 10.86 branches $plant^{-1}$, took 55.66 days to initiate flowering, 574.50 pods $plant^{-1}$, 17.61 g weight of seeds $plant^{-1}$, 3.63 g seed index, 2037.20 seed yield kg ha^{-1} and 36.80 percent oil as the highest output. In case of varieties, S-9 ranked 1st with 216.50 cm plant height, 10.84 branches $plant^{-1}$, took 56.33 days to initiate flowering, 581.11 pods $plant^{-1}$, 17.82 g weight of seeds $plant^{-1}$, 3.66 g seed index, 1960.30 seed yield kg ha^{-1} and 36.80 percent oil content; while variety Early Mustard resulted 186.56 cm plant height, 9.25 branches $plant^{-1}$, took 52.72 days to initiate flowering, 484.67 pods $plant^{-1}$, 14.50 g weight of seeds $plant^{-1}$, 2.90 g seed index, 1677.90 seed yield kg ha^{-1} and 35.13 percent oil content. It is suggested that for achieving economically higher seed yields in mustard, the Zn application to mustard may be done at the rate of 8 kg ha^{-1}. Moreover, variety S-9 may preferably grow for obtaining higher seed and oil contact yields.

Keywords: Zinc; growth; yield and mustard

INTRODUCTION

Mustard, *Brassica juncea* L., is an important member of family Brassicaceae (Bayer, 2010). Oilseeds contribute the second highest share in the economy of Pakistan after grain crops. There are number of species producing edible oil mainly the species and sub-species in the Brassicaceae family. The most popular species are *B. juncea, B. napus, B. oleracea* and *B. rapa* (*B. campestris*). The scientists have sequenced the entire genome of rapeseed/canola (*B. napus*) and its constituent genomes present in *Brassica rapa* and *Brassica oleracea* in 2009. This also represents the A genome component of the amphidiploid crop species *B. napus* and *B. juncea* (Bayer, 2010). Mustard has primary center of its origin in central Asia (northwest India), with secondary centers in central and western China, eastern India, Burma and through Iran to Near East cultivated for centuries in many parts of Eurasia. However, the principal growing countries are Bangladesh, Central Africa, China, India, Japan, Nepal, and Pakistan, as well as southern Russia in north of the Caspian Sea (Perry, 1999).

The total availability of edible oil in 2009-10 was 2.9 million tons. Local production of edible oil was 662 thousand tons which accounted for 23 percent of total availability in the country, while the remaining 77 percent availability was ensured through imports. During the year 2010-11 (July-March), a quantity of 1.7 million tons edible oil/oilseeds worth US$ 1.65 billion has been imported. The local production in 2010-11 is provisionally estimated at 696 thousand tons. Total availability from all sources is thus reduced to 2.35 million tons so far. The area under rapeseed and mustard during 2009-10 was 178,000 hectares with production of 151,000 tons, while during 2010-11 the area increased to 194,000 hectares and production to 168,000 tons showing an increase of 11.3 percent. During 2010-11, the oil from the rapeseed and mustard was 50,000 tons (GoP, 2011). Similarly, the area under mustard cultivation in Sindh province during the year 2008-2009 was 45,412 hectares with production of 48,478 tons, showing seed yield of 1.067 tons ha^{-1}. Mustard is often used at the table as a condiment on meat (Sawyer, 1990). Due to continuous cropping and non-practice of green manuring

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or non-use of farm yard manure, the soils have become deficient in various macro and micronutrients. Therefore, the major soil fertility problems in our soils are deficiencies of macro and some micronutrients (Rashid *et al.,* 1993).

Zinc is one of the first micronutrients recognized as essential for plants that transported to plant root surface through diffusion (Maqsood *et al.*, 2009). Zn is a micronutrient and in case of its severe deficiency the symptoms may last throughout the entire crop season (Asad and Rafique, 2000). Zn deficient plant also appears to be stunted (Torun *et al.,* 2001) as a result approximately 2 billion people suffer from Zn deficiency all over the world (Asad and Rafique, 2002). The grain yield can be improved by addition of Zn fertilization (Maqsood *et al.*, 2009). Bora and Hazarika, (1997) reported highest stover yield (2770 kg ha^{-1}) with Zn and almost the same trend of seed yield. The seed yield can be improved by addition of Zn fertilization. Chen and Aviad, (1990) found that application of Zn alongwith other micronutrients improved soil organic matter and resulted in increasing mustard yields. Kutuk *et al.,* (2000) also suggested that the application of Zn has become necessary for improved crop yields. Mandal and Sinha, (2004) recommended application of $ZnSO_4$ at the rate of 20 kg ha-1 for oilseeds including mustard. Moniruzzaman *et al.,* (2008) applied zinc at the concentrations of 0, 2.5, 5.0 and 7.5 kg ha^{-1} and suggested 8 kg Zn ha^{-1} for brassica species. In view of the significance of zinc in crop production process, the experiment was conducted to investigate the effect of micronutrient (zinc) on growth and yield of mustard varieties at Tandojam.

MATERIALS AND METHODS

The study was carried out to investigate the effect of micronutrient (zinc) on growth and yield of mustard varieties at the experimental fields of physiology Section, Agriculture Research Institute, Tandojam in a three replicated Randomized Complete Block Design (Factorial) having plot size of 3 x 5m ($15m^2$). The land was prepared by giving two dry plowings, followed by land leveling. After soaking dose and when land came in condition, the land was plowed with crosswise cultivator, followed rotavator and planking for a good seed bed preparation. The sowing of the seed was done by hand drilling method. The treatments details are as under:

Treatments: A Zinc levels = 6

Z_1=0 kg ha^{-1}, Z_2=2 kg ha^{-1}, Z_3=4 kg ha^{-1}, Z_4=6 kg ha^{-1}, Z_5=8 kg ha^{-1}, Z_6=10 kg ha^{-1}

Treatments: B Varieties = 2

V1= Early Mustard and V2= S-9.

The zinc was applied in the form of $ZnSO_4$ after sowing at first irrigation with the use of N (@ 100 kg ha^{-1}) and P (@ 50 kg ha^{-1}). All P along with $1/3^{rd}$ of N was applied at the time of sowing and remaining two N splits were applied at flowering and pod formation stages, respectively. For recording observations on various agronomical traits, five plants in each plot were selected at random and labeled. After completion of observations on growth parameters, and when crop matured, the labeled plants were harvested manually and tied in small bundles, and were shifted to threshing yard. Threshing was performed manually to record observations on the following traits:

Observations recorded

1. Soil analysis (pH, EC, Organic Matter), **2.** Plant height (cm), **3.** Number of branches $plant^{-1}$, **3.** Days to flowering, **4.** Number of pods $plant^{-1}$, **5.** Weight of seeds $plant^{-1}$ (g), **6.** Seed index (1000 seed weight, g), **7.** Seed yield (kg ha^{-1}) and **8.** Oil content (%).

Methodology for recording observations

Electrical conductivity: 1:5 soil water extract by using conductivity digital meter model Hi-8333 as dSm^{-1}.

Soil reaction (pH): 1:5 soil water extract by using Suntex pH meter (Model SP-34).

Organic matter: By Walkely-Black method "Soil and Chemical Analysis" By M.L. Jackson (1959).

Plant height (cm): The plant height (cm) was measured at maturity of the crop by measuring tape from bottom to tip of plant in labelled plants in each treatment.

Number of branches $plant^{-1}$: The number of branches $plant^{-1}$ was counted at maturity of the crop in labelled plants in each treatment and mean was worked out.

Days to flowering: The number of days from sowing to initiation of flowering was counted in each treatment and mean was worked out.

Number of pods plant^{-1}: The number of pods plant^{-1} was counted at maturity of the crop in labelled plants in each treatment.

Weight of seed plant^{-1}: The total seeds of labelled plants were weighed and divided with total number of plants examined to obtain weight of seeds plant^{-1} in each treatment.

Seed index (1000 seeds, g): Seed index value was observed on the basis of 100 seeds manually separated by counting in each treatment and was weighed to record seed index in grams.

Seed yield (kg ha^{-1}): The seed yield (kg ha^{-1}) was worked out by using the following formula:

$$\text{Seed yield (kgha}^{-1}\text{)} = \frac{\text{Yield plot}^{-1}\text{ of given treatment (kg)}}{\text{Plot area (m}^2\text{)}} \times 10000$$

Oil content (%): The extracted oil was weighed from a certain quantity of seed and percentage of the total weight was calculated.

STATISTICAL ANALYSIS

The collected data were subjected to analysis of variance using the statistical software Statix-8.1. The difference among the treatment means were compared by the least significant difference (LSD) test at P=0.05 level (Steel and Torrie, 1984).

RESULTS

Soil analysis

The soil analysis (Table-1) indicates that before sowing of mustard the soil pH was 7.8 which decreased to 7.2 when soil samples were determined after harvesting of the crop. The EC before sowing of mustard was 4.52 dSm^{-1} which slightly decreased to 4.34 dSm^{-1} while, the soil organic matter before sowing of the experimental crop was 0.63 percent which increased to 0.84 percent and soil samples were determined after harvest of the crop. This indicates that the application of Zn reduced soil pH and soil EC, while considerably improved the soil organic matter.

Table 1. Soil analysis before sowing and after harvesting

Soil properties	Before sowing	After harvest
pH	7.8	7.2
EC (dSm^{-1})	4.52	4.34
Organic matter (%)	0.63	0.84

Plant height (cm)

The results presented in Table- 2 about the analysis of variance indicated that the plant height of mustard was significantly (P<0.05) affected by Zn levels and varieties, while the effect of their interaction on plant height was non-significant (P>0.05). The application of Zn at the rate of 10 kg ha^{-1} resulted in maximum plant height of 216 cm, followed by Zn application at the rates of 8 kg and 6 kg ha^{-1}, resulting average plant height of 212.50 cm and 206.33 cm, respectively. The plant height was significantly declined to 197.33 and 191.50 cm when the Zn levels were reduced to 4 kg and 2 kg ha^{-1}, respectively. The lowest plant height (185.50 cm) was recorded in control plots (without Zn). This indicates that application of Zn had marked effect on plant height of mustard. However, the increase in plant height was not statistically positive when Zn was applied beyond 6 kg ha^{-1}, because the differences in plant height under Zn levels of 6, 8 and 10 kg ha^{-1} were non-significant (P>0.05). In case of varieties, the plants of S-9 were found to be genetically tall growing (216.50 cm) more than those for variety Early Mustard (186.56 cm). The interactive effect of Zn levels and varieties indicates that mustard variety S-9 when given 10 kg Zn ha^{-1} resulted in significantly maximum plant height (232 cm), while the variety Early Mustard resulted in minimum plant height (171.67 cm) when given no Zn (control). Both the mustard varieties were found to be responsive to Zn levels, but S-9 showed more promising results than Early Mustard for plant height.

Table 2. Effect of zinc (Zn) on the plant height (cm) on different varieties of mustard

Treatments (Zinc levels)	Varieties		Mean for Zn levels
	Early Mustard	S-9	
Zn @ 0 kg ha^{-1} (control)	171.67	199.33	185.50 c
Zn @ 2 kg ha^{-1}	177.33	205.67	191.50 b
Zn @ 4 kg ha^{-1}	182.67	212.00	197.33 b
Zn @ 6 kg ha^{-1}	191.00	221.67	206.33 a
Zn @ 8 kg ha^{-1}	196.67	228.33	212.50 a
Zn @ 10 kg ha^{-1}	200.00	232.00	216.00 a
Mean for varieties	186.56 b	216.50 a	-

Number of branches plant^{-1}

The data in relation to the number of branches plant^{-1} of two mustard varieties as affected by different Zinc (Zn) levels are shown in Table-3. The analysis of variance suggested that the number of branches plant^{-1} of mustard was significantly ($P<0.05$) influenced by Zn levels and varieties, while the effect of their interaction was non-significant ($P>0.05$). The results indicated that the application of Zn at the rate of 10 kg ha^{-1} resulted in maximum number of branches (10.86) plant^{-1}, followed by Zn application at the rates of 8 kg and 6 kg ha^{-1}, resulting 10.62 and 10.31 average number of branches plant^{-1}, respectively. The number of branches diminished to 9.86 and 9.62 plant^{-1} when Zn was applied at the lower rates of 4 kg and 2 kg ha^{-1}, respectively. However, the minimum number of branches (9.00) plant^{-1} was observed in control plots, where Zn was not applied. Among varieties, the number of branches plant^{-1} was significantly higher (10.84) in variety S-9 as compared to variety Early Mustard (9.25). The interactive effect of Zn levels and varieties showed that mustard variety S-9 when fertilized with 10 kg Zn ha^{-1} resulted in significantly maximum branches (11.60) plant^{-1}, while the variety Early Mustard resulted in minimum number of branches (8.04) plant^{-1} under control (no Zn). The application of Zn had positive impact on the number of branches plant^{-1} of mustard; but Zn application beyond 6 kg ha^{-1} did not show economical impact on the number of branches plant^{-1}, because the differences in the number of branches under 6, 8 and 10 kg ha^{-1} Zn levels were non-significant ($P>0.05$).

Table- 3. Effect of zinc (Zn) on the number of branches plant^{-1}

Treatments (Zinc levels)	Varieties		Mean for Zn levels
	Early Mustard	S-9	
Zn @ 0 kg ha^{-1} (control)	8.04	9.95	9.00 c
Zn @ 2 kg ha^{-1}	8.86	10.98	9.62 b
Zn @ 4 kg ha^{-1}	9.13	10.59	9.86 b
Zn @ 6 kg ha^{-1}	9.55	11.07	10.31 a
Zn @ 8 kg ha^{-1}	9.83	11.40	10.62 a
Zn @ 10 kg ha^{-1}	10.11	11.60	10.86 a
Mean for varieties	9.25 b	10.84 a	-

Days to flowering

The results pertaining to days to flowering of mustard varieties as influenced by different Zinc (Zn) levels are presented in Table- 4. The analysis of variance suggested that the days to flowering of mustard was significantly ($P<0.05$) influenced by Zn levels and varieties, while the effect of their interaction was non-significant ($P>0.05$) on this parameter. It is evident from the results that the crop supplied with Zn at the rates of 10 kg ha^{-1} and 8 kg ha^{-1} took equally 55.66 days to flowering, followed by Zn application at the rates of 6 kg and 6 kg ha^{-1}, where the crop took 55.50 days to flowering. The mustard crop initiated flowering little earlier i.e. in 54.16 and 53.50 days when the crop supplied with Zn at the lower rates of 4 kg and 2 kg ha^{-1}, respectively. However, the minimum number of days (52.66) to flowering was noted in plots given no Zn application (control). In varieties, variety S-9 took significantly greater number of days (56.33) to flowering as compared to variety Early Mustard (52.72 days). The interactive effect of Zn levels and varieties showed that mustard variety S-9 given 10 kg or 8 kg Zn ha^{-1} initiated flowering equally in maximum number of days (57.33), while the variety Early Mustard initiated flowering earliest in 51 days when sown without Zn application. This indicates that irrespective of varieties, the application of Zn delayed the flowering, but this delay in flowering was Zn dose specific. The LSD test suggested that the differences in the days to flowering of mustard was non-significant (P>0.05) between Zn levels of 6, 8 and 10 kg ha^{-1}. However, Early Mustard was found to be genetically early flowering initiation when compared with variety S-9.

Table- 4. Effect of zinc (Zn) on the number of days to flowering

Treatments (Zinc levels)	Varieties		Mean for Zn levels
	Early Mustard	S-9	
Zn @ 0 kg ha^{-1} (control)	51.00	54.33	52.66 c
Zn @ 2 kg ha^{-1}	51.66	55.33	53.50 b
Zn @ 4 kg ha^{-1}	52.33	56.00	54.16 b
Zn @ 6 kg ha^{-1}	53.33	57.66	55.50 a
Zn @ 8 kg ha^{-1}	54.00	57.33	55.66 a
Zn @ 10 kg ha^{-1}	54.00	57.33	55.66 a
Mean for varieties	52.42 b	56.33 a	-

Number of pods plant^{-1}

The data in regards to number of pods $plant^{-1}$ of mustard varieties as affected by different Zinc (Zn) levels are given in Table-5. The analysis of variance demonstrated that the number of pods $plant^{-1}$ of mustard was significantly (P<0.05) affected by Zn levels and varieties, while the effect of their interaction was non-significant (P>0.05). It is apparent from the data (Table-5) that the application of Zn at the rate of 10 kg ha^{-1} produced maximum number of pods (574.50) $plant^{-1}$, followed by Zn application at the rates of 8 kg and 6 kg ha^{-1}, producing 569.67 and 548.67 average number of pods $plant^{-1}$, respectively. The number of pods reduced to 516.67 and 510.67 $plant^{-1}$ when Zn was applied at the lower rates of 4 kg and 2 kg ha^{-1}, respectively. However, the lowest number of pods (477.17) $plant^{-1}$ was noted in control, where no Zn was applied. Among varieties, the number of pods $plant^{-1}$ was significantly higher (581.11) in variety S-9 as compared to variety Early Mustard (484.67). The interactive effect of Zn levels and varieties indicated that highest number of pods (621.33) $plant^{-1}$ was recorded under interaction of S-9 x 10 kg Zn ha^{-1}, while the lowest number of pods (419.33) $plant^{-1}$ under interaction of Early Mustard x 0 kg Zn ha^{-1}. The application of Zn had positive impact on the number of pods $plant^{-1}$; but Zn application beyond 6 kg ha^{-1} did not show economical impact on this trait, because the differences in pods under 6, 8 and 10 kg ha^{-1} Zn levels were non-significant (P>0.05). The pod bearing capacity was found to be genetically higher in variety S-9 as compared to variety Early Mustard.

Table- 5. Effect of zinc (Zn) on the number of pods plant^{-1}

Treatments (Zinc levels)	Varieties		Mean for Zn levels
	Early Mustard	S-9	
Zn @ 0 kg ha^{-1} (control)	419.33	535.00	477.17 c
Zn @ 2 kg ha^{-1}	454.00	567.33	510.67 b
Zn @ 4 kg ha^{-1}	470.33	563.00	516.67 b
Zn @ 6 kg ha^{-1}	503.33	594.00	548.67 a
Zn @ 8 kg ha^{-1}	533.33	606.00	569.67 a
Zn @ 10 kg ha^{-1}	527.67	621.33	574.50 a
Mean for varieties	484.67 b	581.11 a	-

Weight of seeds plant^{-1}

The results in relation to weight of seeds plant^{-1} of mustard varieties as affected by different Zinc (Zn) levels are presented in Table-6. The analysis of variance suggested that the weight of seeds plant^{-1} of mustard was significantly ($P<0.05$) affected by Zn levels and varieties, while the effect of their interaction was non-significant ($P>0.05$). The application of Zn at the highest rate of 10 kg ha^{-1} produced maximum weight of seeds (17.61 g) plant^{-1}, closely followed by Zn application at the rates of 8 kg and 6 kg ha^{-1}, producing average seed weight of 17.46 g and 16.84 g plant^{-1}, respectively. The weight of seeds decreased markedly to 15.70 g and 15.52 g plant^{-1} when Zn was applied at the lower rates of 4 kg and 2 kg ha^{-1}, respectively. However, the minimum weight of seeds (13.82 g) plant^{-1} was obtained in control, where no Zn was applied. Among varieties, the weight of seeds plant^{-1} was significantly higher (17.82 g) in variety S-9 as compared to variety Early Mustard (14.50 g). The interactive effect of Zn levels and varieties showed that highest weight of seeds (19.02 g) plant^{-1} was recorded under interaction of S-9 x 10 kg Zn ha^{-1} while the lowest weight of seeds (11.38 g) plant^{-1} under interaction of Early Mustard x 0 kg Zn ha^{-1}. The increasing Zn application resulted in a positive effect on the weight of seeds plant^{-1}; but Zn application beyond 6 kg ha^{-1} did not show economical impact on this parameter, because the differences in weight of seeds plant^{-1} in plots supplied with 6, 8 and 10 kg ha^{-1} Zn were non-significant ($P>0.05$). Moreover, the seeds were found to be heavier in variety S-9 as compared to Early Mustard, because regardless the Zn levels, S-9 showed its superiority in seed weight plant^{-1}.

Table- 6. Effect of (Zn) on the weight of seeds (g) plant^{-1}

Treatments (Zinc levels)	Varieties		Mean for Zn levels
	Early Mustard	S-9	
Zn @ 0 kg ha^{-1} (control)	11.38	16.26	13.82 c
Zn @ 2 kg ha^{-1}	13.80	17.25	15.52 b
Zn @ 4 kg ha^{-1}	14.28	17.11	15.70 b
Zn @ 6 kg ha^{-1}	15.30	19.39	16.84 a
Zn @ 8 kg ha^{-1}	16.03	18.89	17.46 a
Zn @ 10 kg ha^{-1}	16.21	19.02	17.61 a
Mean for varieties	14.50 b	17.82 a	-

Seed index

The data regarding the seed index (1000 seeds weight) of mustard varieties as affected by various Zinc (Zn) levels are shown in Table-7. The analysis of variance indicated that the seed index of mustard was significantly ($P<0.05$) influenced by Zn levels and varieties, while the influence of their interaction was non-significant ($P>0.05$) on seed index. The data indicates that the application of highest Zn level of 10 kg ha^{-1} resulted in maximum seed index (3.63 g), closely followed by Zn levels of 8 kg and 6 kg ha^{-1}, resulting average seed index of 3.56 g and 3.49 g, respectively. The seed index value declined to 3.14 g and 3.10 g when Zn was applied at the lower rates of 4 kg and 2 kg ha^{-1}, respectively. However, the lowest seed index value (2.76 g) was noted in control, where no Zn was applied. Among varieties, the seed index was significantly higher (3.66 g) in variety S-9 as compared to variety Early Mustard (2.90 g). The interactive effect of Zn levels and varieties indicated that highest seed index value (4.02 g) was recorded under interaction of S-9 x 10 kg Zn ha^{-1} while the lowest seed index (2.28 g) under interaction of Early Mustard x 0 kg Zn ha^{-1}. The increasing Zn application resulted in an increased seed index in mustard; but Zn application beyond 6 kg ha^{-1} remained uneconomical for this trait, because the differences in seed index in plots supplied with 6, 8 and 10 kg ha^{-1} Zn were non-significant (P>0.05) statistically. Moreover, the seed index represents the seed quality; thus variety S-9 supposed to have better quality seed as compared to Early Mustard on the basis of their seed index values.

Table- 7. Effect of zinc (Zn) on the seed index (1000 seeds weight g)

Treatments (Zinc levels)	**Varieties**		**Mean for Zn levels**
	Early Mustard	S-9	
Zn @ 0 kg ha^{-1} (control)	2.28	3.25	2.76 c
Zn @ 2 kg ha^{-1}	2.76	3.45	3.10 b
Zn @ 4 kg ha^{-1}	2.86	3.42	3.14 b
Zn @ 6 kg ha^{-1}	3.06	3.93	3.49 a
Zn @ 8 kg ha^{-1}	3.20	3.92	3.56 a
Zn @ 10 kg ha^{-1}	3.24	4.02	3.63 a
Mean for varieties	2.90 b	3.66 a	-

Seed yield (kg ha^{-1})

The results pertaining to seed yield kg ha^{-1} of mustard varieties as affected by different Zinc (Zn) levels are reported in Table-8. The analysis of variance indicated that the seed yield kg ha^{-1} of mustard was significantly (P<0.05) affected by Zn levels and varieties, while the effect of their interaction was non-significant (P>0.05) on seed yield kg ha^{-1}. It can be seen from the results (Table-8) that Zn application at the highest level of 10 kg ha^{-1} produced maximum seed yield (2037.20 kg ha^{-1}), closely followed by Zn levels of 8 kg and 6 kg ha^{-1}, producing average seed yields of 1936.50 kg and 1883.70 kg ha^{-1}, respectively. The seed yield declined to 1746 kg and 1701.30 kg ha^{-1} when Zn was applied at the lower rates of 4 kg and 2 kg ha^{-1}, respectively. However, the lowest seed yield kg (1610.20 kg ha^{-1}) was recorded in control, where no Zn was applied. In case of varieties, the seed yield kg ha^{-1} was significantly higher (1960.30 kg) in variety S-9 as compared to variety Early Mustard (1677.90 kg ha^{-1}). The interactive effect of Zn levels and varieties indicated that highest seed yield (2092.30 kg ha^{-1}) was achieved under interaction of S-9 x 10 kg Zn ha^{-1} while the lowest seed yield (1431.70 kg ha^{-1}) under interaction of Early Mustard x 0 kg Zn ha^{-1}. There was a simultaneous increase in seed yield ha^{-1} with increasing Zn levels, but the seed yield did not improve significantly when Zn was applied beyond 8 kg ha^{-1}, because the differences in seed yield ha^{-1} were statistically non-significant (P>0.05) when Zn levels of 8 kg and 10 kg ha^{-1} were compared. It was also observed that genetically, variety S-9 showed its superiority over Early Mustard irrespective of the Zn levels.

Table- 8. Effect of zinc (Zn) on the seed yield (kg ha^{-1})

Treatments (Zinc levels)	**Varieties**		**Mean for Zn levels**
	Early Mustard	S-9	
Zn @ 0 kg ha^{-1} (control)	1431.70	1788.70	1610.20 d
Zn @ 2 kg ha^{-1}	1505.30	1897.30	1701.30 c
Zn @ 4 kg ha^{-1}	1609.30	1882.70	1746.00 c
Zn @ 6 kg ha^{-1}	1744.30	2023.00	1883.70 b
Zn @ 8 kg ha^{-1}	1795.00	2078.00	1936.50 a`
Zn @ 10 kg ha^{-1}	1982.00	2092.30	2037.20 a
Mean for varieties	1677.90 b	1960.30 a	-

Oil content (%)

The data in regards to oil content of mustard varieties as influenced by different Zinc (Zn) levels are shown in Table-9. The analysis of variance suggested that the oil content of mustard was significantly ($P<0.05$) affected by Zn levels and varieties, while the effect of interaction between Zn levels and mustard varieties was non-significant ($P>0.05$) on oil content. It is evident from the results (Table-9) that maximum oil content (36.80%) in mustard was achieved from the plots supplied with highest Zn level of 10 kg ha^{-1}, followed by Zn levels of 8 kg and 6 kg ha^{-1} where the average oil content was 35.74 and 35.85 percent, respectively. The oil content was 35.31 and 35.44 percent when the mustard was supplied with Zn levels of 4 kg and 2 kg ha^{-1}, respectively. The lowest oil content (34.97%) was recorded in control plots (without Zn). This indicates that application of Zn had positive impact on oil content of mustard. In case of varieties, the oil content was significantly higher (36.24%) in seeds of mustard variety S-9 as compared to variety Early Mustard (35.13 %). The interactive effect of Zn levels and varieties indicates that mustard variety S-9 when given 10 kg Zn ha^{-1} resulted in significantly maximum oil content (37.48%), while the variety Early Mustard receiving zero Zn (control) resulted in minimum oil content (34.45 %). Both the mustard varieties were found to be responsive to Zn levels for oil content, but S-9 showed more promising results than Early Mustard for this character.

Table- 9. Effect of zinc (Zn) on the oil content (%)

Treatments (Zinc levels)	Varieties		Mean for Zn levels
	Early Mustard	S-9	
Zn @ 0 kg ha^{-1} (control)	34.45	35.49	34.94 c
Zn @ 2 kg ha^{-1}	34.91	35.97	35.44 b
Zn @ 4 kg ha^{-1}	34.81	35.84	35.31 b
Zn @ 6 kg ha^{-1}	35.32	36.38	35.85 b
Zn @ 8 kg ha^{-1}	35.21	36.27	35.74 b
Zn @ 10 kg ha^{-1}	36.12	37.48	36.80 a
Mean for varieties	35.13 b	36.24 a	-

DISCUSSION

The study showed that Zn level resulted to increase the plant height, branches per plant, that took less days to reach at flowering stage, pods per plant, weight of seeds per plant, seed index, seed yield and oil percent level. The results further are in agreed with the soils have become deficient of micronutrients, particularly Zinc deficiency has resulted significant reduction in crop yields (Rashid *et al.,* 1993; Grewal *et al.,* 1998). These results are partially supported by Maqsood *et al.,* (2009) who reported that the seed yield can be improved by addition of Zn fertilization; and Chen and Aviad (1990) found that application of Zn alongwith other micronutrients improved soil organic matter and resulted in increasing mustard yields. Kutuk *et al.,* (2000) also suggested that the application of Zn has become necessary for improved crop yields. Moniruzzaman *et al.,* (2008) applied zinc at the concentrations of 0, 2.5, 5.0 and 7.5 kg ha^{-1} and suggested 8 kg Zn ha^{-1} for brassica species. Mandal and Sinha, (2004) recommended application of $ZnSO_4$ at the rate of 20 kg ha-1 for oilseeds including mustard.

Moreover, the variety S-9 may preferably grow for obtaining higher seed and oil yields in mustard so far. These results are categorically supported by many researchers, who worked on the similar aspects of rape seed and mustard in different parts of the world. Chen and Aviad, (1990), Rashid *et al.,* (1994), Asad *et al.,* (1997) examined the effect of foliar applied Boron at concentrations from 0.04 to.0.3 percent on *B. napus* (L) found the higher seed and oil yield from mustard. Bora and Hazarika, (1997) carried out studies to investigate the effect of micronutrients on the growth, seed yield and stover yield of rape seed. The results showed that the highest stover yield (2770 kg ha^{-1}) was obtained with Zn + B + Mo and followed almost the same trend of seed yield. In a similar investigation, the study of Mandal and Sinha, (2004) examined the effect of Zn and B application in addition to NPK fertilizers on production and yield of Indian mustard. Plant height, number of branches per plant, number of siliqua per plant, number of seeds per siliquae, 1000-seed weight with 20 kg ha^{-1} $ZnSO_4$. Yang *et al.*, (2009) reported that the combined application of B with Zn resulted in higher seed yield than the application of B or Zn alone, and the seed yield of the B+Zn treatment was the highest in all treatments, 68.1% above the control. The above discussion on the comparative research results obtained in the present study and findings reviewed from various studies carried out in different parts of the world clearly suggested that addition of zinc along with recommended dose of NPK fertilizers have resulted improved mustard yields. The results indicated that the seed yield kg ha^{-1} was highest under 10 kg Zn ha^{-1}, but the differences in seed yield kg ha^{-1} were non-significant (P>0.05) when compared with those obtained under 8 kg Zn ha^{-1}. Hence, it was concluded that for achieving economically higher seed yields in mustard, the Zn application to mustard may be done at the rate of 8 kg ha^{-1}. Moreover, variety S-9 may preferably grow for obtaining higher seed and oil yields in mustard.

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