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Micronutrients (Zn, B and Mn) Effects on Sesame (*Sesamum indicum* L.)

Meer Muhammad Khan[*1], **Abdul Manaf**[1], **Fayyaz-ul-Hassan**[1],
Muhammad Sheeraz Ahmed[2]

[1]*Department of Agronomy, PMAS Arid Agriculture University, Rawalpindi, Pakistan*

[2]*Department of Biochemistry, PMAS Arid Agriculture University, Rawalpindi, Pakistan*

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Abstract

Micronutrients deficiencies may affect fundamental physiological and biochemical processes causing hormonal imbalance hence reduction in yield. Application of microelement fertilizers increase crop yield and can enhance plants resistance to environmental stresses. To assess the role of micronutrients, field experiments were conducted at NARC Islamabad, Pakistan by using four sesame cultivars (SG-30, TS-3, TS-5 and TH-6) and four micronutrient treatments (control, Zn, B and Mn) during summer 2014 and 2015 in randomized complete block design with split plot arrangement having four replications. Results revealed significant variations for the main effects of all studied factors (cultivars, micronutrient and year). Micronutrients application significantly increased all yield attributes over control. Zn, B and Mn increased capsule length, capsule weight, capsules plant^{-1}, seeds capsule^{-1}, 1000 seed weight, seed yield and oil yield of sesame. Maximum mean values of capsules plant^{-1}, seed yield and oil yield were observed for cv. SG-30, while the cv. TH-6 was lowest for these parameters. It may be concluded that micronutrient fertilizers application @ 10kg $ZnSO_4$ ha^{-1}, 10kg Borax ha^{-1} and 5kg $MnSO_4$ ha^{-1} would enhance yield and yield related traits provided proper cultivar is selected.

* **Corresponding Author:** Meer Muhammad Khan ✉ meermuhammad@yahoo.com

Introduction

Pakistan is deficient in oil seed production. Annual edible oil requirement of Pakistan is 3.523 million tones. Local production contributed 0.556 million tones (15.8%) of the requirement and 2.967 million tones (84.2%) edible oil requirement is met by imports, spending Rs. 269.41 billion (GOP, 2016). Therefore, it is necessary to increase the oilseed production. The Pothwar plateau is categorized as sub-tropical, sub-humid climate. More than 70% of annual precipitation received in the summer months July to September (Shah *et al*., 2012). The climate of rain-fed region is suited to production of many kind of cereals, ground nut, pulses, legumes, grasses for range land and forests of different types. In order to bridge the gap of domestic needs and local production, conventional oilseed crops such as sesame have been grown for centuries.

Sesame (*Sesamum indicum* L.) is a conventional oilseed crop of the country. Sesame seed contains around 50% oil, up to 25% protein, 3.2% crude fiber, 16-18 % carbohydrate and 5.7% ash as well as rich source of calcium, phosphorus and vitamin-E (Suddhiyan *et al.,* 2009; Khan *et al.,* 2009). It is also called queen of oilseed crops due to its high poly unsaturated fatty acids i.e. oleic acid (29.3-41.4%) and linoleic acid (40.7-49.3%) (Uzun *et al.,* 2008). In Pakistan it is mainly grown by subsistence farmers on marginal lands with low inputs. Production potential and yield gap of sesame crop is about 62% in Pakistan. The low production is due to a number of reasons such as low inputs, poor management (e.g. low or non-fertilization etc.), micronutrients deficiencies in soil and occurrence of biotic and abiotic stresses.

Studies have indicated a wide range of variations between genotypes (Pham *et al.,* 2010). Sesame yield is not stable and varies in wide range of locations and variability in environment, seasonal fluctuations and their interaction influence the performance of genotypes in relation to yield potential (Kumar, *et al.,* 2013). Sesame is generally grown in dry areas with 300-600mm rainfall (Ahmed and Mahmod, 2010). Usually irrigation is not needed for sesame crop but it is very prone to drought at different physiological stages. It is highly drought tolerant but particularly susceptible to water logging and heavy rainfall (Sarkar *et al.,* 2016). Sesame is very sensitive to even short periods of water logging and heavy rainfall, which might be inhibiting the growth and yield of the crop. Therefore, well-drained soil with moderate fertility is best for sesame (Amend *et al*., 2009).

Nutrients fertilization aims not only for a high economic return of the investment through optimized crop yield and quality, but also for minimum environmental hazards. The basic concept of integrated plant nutrition systems is the maintenance and possible increase of soil fertility for sustaining crop productivity through optimal use of all sources of plant nutrients, particularly inorganic fertilizer, in an integrated manner and as appropriate to each specific ecological, social and economic situation (Etukudo, *et al.,* 2015; Zainab, *et al.,* 2016). The incidence of micronutrient deficiencies in crops has increased due to intensive cropping, loss of top soil by erosion, losses of micronutrients through leaching and use of marginal lands for crop production (Fageria *et al.,* 2012). Zinc and boron deficiency is reported in soils of Pothwar region while manganese is also found deficient in some areas (Shaheen *et al.,* 2008).

Micronutrients have a vital role for proper growth and functions of plants. Even crop plants require micronutrients in very minute quantities but their deficiencies may affect vital physiological and biochemical processes and causing hormonal imbalance, hence reduction in yield of oil crops (Sadeghzadeh, 2013). Application of micronutrients increases the crop yield and can enhance plants resistance to environmental stresses (Cakmak, 2008).

Yield related traits of oilseed crops such as rapeseed, soybean, sunflower and maize were significantly amplified by micronutrients applications i.e. zinc, manganese and boron (Baloch, *et al.,* 2015: Ghasemian *et al.,* 2010; Gurpreet & Nelson, 2015; Baraich, *et al.,* 2016: Sahito, *et al*., 2014).

Similarly, significant affirmative effects of micronutrients application have been reported on sesame. Application of zinc, boron and manganese significantly increased number of seeds per capsules, 1000 seed weight, number of capsules and seed yield of sesame (Shirazy, *et al.,* 2015; Parkash, 2010).

However, very little informations are available related to sesame grown under rain fed conditions and its response to micronutrients. Therefore, present study was planned to investigate the performance of sesame cultivars and the role of zinc, boron and manganese on yield and yield related traits of sesame.

Materials and methods

Soil analysis

The composite soil samples were collected at 0-15cm and 15-30cm depth from the experimental field before sowing and after harvest and were analyzed for physio-chemical characteristics (Table 2).

Soil pH was determined through soil to 1N potassium chloride (KCl) ratio of 1:2.5 suspensions (McLean, 1982). Organic matter (O.M) was determined by wet digestion in 1N potassium dichromate ($K_2Cr_2O_7$) titrated against 0.5N ferrous ammonium sulphate ($Fe(NH_4)_2(SO_4)_2$) solution (Nelson and Sommers, 1982). Electrical Conductivity (EC) of water or 1:5 suspensions in case of solid waste and soil was recorded by a conductivity meter (Rhoades, 1982). Bulk density was measured by core method (Blake, G.R., 1965). While soil total porosity was determined by using following formula:

$$\text{Soil total porosity (\%)} = \frac{\text{Bulk density}}{\text{Particle density (2.65 mg m}^{-3})} \times 100$$

Zinc and manganese were determined by DTPA extraction method (Lindsay and Norvell, 1978). Whereas Boron was extracted by hot water (Berger and Truog, 1944) and measured colorimetrically using azomethine-H (Bingham, 1982).

Table 1. Weather data of experimental site during 2014 and 2015.

	Minimum Temp. (˚C)		Maximum Temp. (˚C)		Humidity (%)			Rainfall (mm)	
Months	2014	2015	2014	2015	2014	2015		2014	2015
July	24.9	24.2	34.9	33	84	90		309	380.2
August	23.2	23.9	33.9	33.6	91	93		208.4	198.5
September	21.1	19.8	31.6	33.4	91	87		444.8	134.8
October	15.9	14.9	28.7	28.7	92	91		23	190.2
November	7.1	8.7	25	23.6	93	92		9	18.7
Mean	18.4	18.3	30.8	30.5	90.2	90.6	Total	994.2	922.4

Meteorological data during the course of study for both years were collected from Pakistan Meteorological Department Islamabad, Pakistan.

Table 2. Physio-chemical soil analysis of experimental site during 2014 and 2015.

	2014				2015			
	Before sowing		After harvest		Before sowing		After harvest	
Depth (cm)	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Soil texture	SCL	SCL	SCL	SCL	SCL	SCL	SCL	SCL
pH	7.61	7.59	7.67	7.63	7.69	7.65	7.7	7.69
O.M (%)	1.07	1.02	1.00	0.95	1.1	0.98	1.05	1.01
EC (dS m^{-1})	0.81	0.79	0.78	0.74	0.8	0.79	0.81	0.77
BD (g cm^{-3})	1.39	1.4	1.37	1.39	1.38	1.39	1.4	1.41
Porosity (%)	47.5	47.2	48.3	47.5	47.9	47.5	47.2	46.8
NO_3. N (mg kg^{-1})	7.3	7.29	7.25	7.23	7.36	7.32	7.51	7.43
P (mg kg^{-1})	4.13	4.09	4.22	4.15	4.19	3.98	4.08	4.01
K (mg kg^{-1})	118	117	124	117	130	124	128	119
Zn (mg kg^{-1})	0.26	0.25	0.34	0.31	0.32	0.29	0.36	0.35
Mn (mg kg^{-1})	1.16	1.11	1.07	1.04	1.02	0.97	1.01	0.98
B (mg kg^{-1})	0.36	0.33	0.39	0.36	0.35	0.31	0.34	0.32

SCL= Sandy clay loam, OM = Organic Matter, EC = Electric Conductivity, BD = Bulk Density.

Experimentation

To document the response of sesame cultivars as influenced by micronutrients, field experiments were conducted at National Agriculture Research Center (NARC) Islamabad, Pakistan (latitude of 33.40°N and 44.30°E, 499 meters elevation above the sea level with annual rainfall of 1000-200mm). Experiments were conducted under rainfed conditions by using four sesame cultivars viz. SG-30, TS-3, TS-5, TH-6 and four micronutrient treatments, viz. control (no micronutrients applied), zinc (Zn), boron (B) and manganese (Mn).

Experiments were laid out in split plot randomized complete block design (RCBD) with four replications. Cultivars were kept in main plots and micronutrients in subplots. All plots were assigned randomly with in each replication. Crop was seeded on 25th July 2014 and 21st July 2015 with single row hand drill at the seed rate of 5kg ha^{-1}. Crop was sown in net plot size of 2.7m x 5m and there were six rows in each plot 45cm apart. Recommended doses of fertilizers i.e. 90kg N ha^{-1}, and 60 kg $P_2O_5ha^{-1}$ in the form of urea and DAP were applied at the time of last ploughing.

Zinc was applied in the form of $ZnSO_4$ @ 10kg ha^{-1}, boron in the form of Borax @ 10kg ha^{-1} and manganese in the form of $MnSO_4$ @ 5kg ha^{-1}. Micronutrients were applied as a side banding along with rows at the time of sowing. After complete emergence crop was thinned manually to maintain plant to plant distance of 10cm. Weeds were manually controlled as and when needed.

Crop data

Number of capsules $plant^{-1}$ was counted from ten randomly selected plants of each treatment at maturity and average was worked out. Twenty capsules were randomly taken from each plot at maturity to record length and weight of capsules, thereafter per plant average was calculated. One hundred capsules were randomly taken from each plot at maturity. Number of seeds in each capsule was counted and average number of seeds per capsule was worked out.

For 1000 seed weight (SW), three lots of thousand seeds were taken from bulk seed sample of each treatment after threshing and seeds were counted by using seed counter. Wight of each 1000 seed sample was recorded by using electrical balance and average was calculated for each treatment. Plants of two meter row length of two central rows were harvested on 16th November 2014 and 5th November 2015 from each treatment at maturity and plants were sun dried for few days. Dried samples were threshed manually and obtained seed samples were weighed thereafter seed yield was worked out in kg ha^{-1}. Oil yield was calculated by using the following formula:

$$\text{Oil yield (kg ha}^{-1}\text{)} = \frac{\text{seed oil content (\%) x seed yield (kg ha}^{-1}\text{)}}{100}$$

Statistical analysis

The collected data was analyzed for analysis of variance by using Statistics 8.1 software to conclude the significance of tested factors (cultivar, micronutrients & years) and their interactions. LSD test ($P<0.05$) was adopted to identify the means of statistically significant sources.

Results

Statistically significant variation ($p<0.01$) for yield attributes were revealed by sesame cultivars, micronutrient treatments and years (Table 3). But significance was at $p<0.05$ among years for capsule length and among micronutrient treatments for seeds $capsule^{-1}$ and 1000 SW. Non-significant variation among micronutrient treatments was observed for capsule weight. Cultivar x year interaction was highly significant ($p<0.01$) for all studied traits and significant ($p<0.05$) for seeds $capsule^{-1}$, while non-significant for capsule length. Two and three way interactions of micronutrient treatments with years and cultivars were found non-significant for all traits except capsule length, which is significant ($P<0.05$) for year x micronutrient and highly significant ($P<0.01$) for cultivar x micronutrient and year x cultivar x micronutrient.

Table 3. Main and interactive effects of cultivars, micronutrients and years for yield attributes of sesame.

	Capsules plant⁻¹	Capsule Length (cm)	Capsule Weight (g)	Seeds Capsule⁻¹	1000 SW (g)	Seed Yield (kg ha⁻¹)	Oil Yield (kg ha⁻¹)
Cultivar (C)	**	**	**	**	**	**	**
SG-30	69.5a	2.58c	0.258b	53.0c	2.24bc	731.9a	268.0a
TS-3	55.6b	2.60c	0.257b	54.1c	2.28b	652.9b	241.4b
TS-5	47.7c	2.71b	0.257b	61.3b	2.19c	617.6b	227.3b
TH-6	29.8d	3.45a	0.315a	66.6a	2.40a	388.2c	137.0c
SE±	1.781	0.036	0.0066	0.802	0.036	25.31	10.31
Micronutrients (MN)	**	**	NS	*	*	**	**
Control	46.0c	2.72c	0.261	57.2b	2.21b	541.8c	191.9c
Zinc	52.6ab	2.89a	0.277	59.2a	2.31a	628.1a	231.9a
Boron	53.7a	2.93a	0.279	60.0a	2.32a	632.6a	237.4a
Manganese	50.3b	2.80b	0.269	58.5ab	2.29a	588.2b	212.5b
SE±	1.301	0.04		0.868	0.035	18.98	7.13
Year (Y)	**	*	**	**	**	**	**
2014	62.1a	2.92a	0.308a	59.4a	2.43a	672.5a	238.2a
2015	39.2b	2.75b	0.236b	58.0b	2.14b	522.8b	198.6b
SE±	0.753	0.047	0.0031	0.196	0.006	15.2	5.03
Y x C	**	NS	**	*	**	**	**
Y x MN	NS	*	NS	NS	NS	NS	NS
C x MN	NS	**	NS	NS	NS	NS	NS
Y x C x MN	NS	**	NS	NS	NS	NS	NS

**=Significant (P≤0.01), *=Significant (P≤0.05), NS=Non-significant, SW= Seed Weight.

Maximum capsules plant⁻¹ (69.5), seed yield (731.9kg ha⁻¹) and oil yield (268kg ha⁻¹) were observed for cv. SG-30 but capsule length (2.58cm), capsule weight (0.258g) and seeds capsule⁻¹ (53) was found lowest for this cultivar (Table 3). On the other hand, cv. TH-6 recorded maximum capsule length (3.45cm), capsule weight (0.315 g), seeds capsule⁻¹ (66.6) and 1000 SW (2.40g) however lowest for capsules plant⁻¹ (29.8), seed yield (388.2kg ha⁻¹) and oil yield (137kg ha⁻¹). TS-5 was statistically at par with cv. SG-30 for seed yield and oil yield while TS-3 was statistically at par with SG-30 for capsule length, capsule weight, seeds capsule⁻¹ and 1000 SW.

All the studied yield characters significantly decreased (P<0.01) during second year (2015) but decrease was significant at P<0.05 for capsule length (Table 3). Cultivar x year interaction was highly significant (P<0.01) for yield attributes and significant (P<0.05) for seeds capsule⁻¹ but non-significant for capsule length. Drastic reduction in capsules plant⁻¹, capsule length, capsule weight, 1000 seed weight, seed yield and oil yield was observed for cv. TS-3 and TS-5 during second year of study (Table 4).

Maximum capsules plant⁻¹ were noted for cv. SG-30 (78.4) closely followed by TS-3 (77.8) during first year while the cv. TH-6 produced minimum capsules plant⁻¹ (27.6) during second year. Maximum capsule weight (0.335 g) was observed for cv. TH-6 during first year. TH-6 during second year and rest of the cultivars during first year were statistically at par with each other. Minimum capsule weight (0.209g) was noted for cv. TS-3 during second year which is statistically same with SG-30 and TS-5 during same year. TH-6 produced maximum seeds capsule⁻¹ (67.4) during first year followed by the same cultivar (65.7) during second year, while minimum seeds capsule⁻¹ (53.6) was observed for SG-30 during second year. SG-30 and TS-3 were statistically at par with each other during both years. For 1000 seed weight, cv. SG-30 attained maximum value of 2.52g during 2014 followed by TS-3 during 2014 and TH-6 during 2015 which acquired same value of 2.45g.

Data concerning to cultivar x year interaction for seed yield and oil yield of sesame revealed that cv. SG-30 produced maximum seed yield (828.1kg ha⁻¹) and oil yield (293.7kg ha⁻¹) during first year which are statistically at par with TS-3 (785.4kg ha⁻¹ and 282kg ha⁻¹ for seed yield and oil yield respectively) during the same year.

Minimum seed yield and oil yield was recorded for TH-6 (385.7kg ha^{-1} and 141.2kg ha^{-1} respectively) during second year (2015) which is statistically not different from the same cultivar during first year. TS-5 during first year and SG-30 during second year were statistically at par for seed yield and oil yield. Similarly, TS-3 and TS-5 were also found statistically parallel during second year for these traits.

Table 4. Interactive effect between cultivars and years for yield traits of sesame.

Cultivar	Year	Capsules plant^{-1}	Capsule Weight (g)	Seeds Capsule^{-1}	1000 Seed Weight (g)	Seed Yield (kg ha^{-1})	Oil Yield (kg ha^{-1})
SG-30	2014	78.4^{a}	0.295^{b}	52.5^{d}	2.52^{a}	828.1^{a}	293.7^{a}
	2015	60.6^{b}	0.221^{c}	53.6^{d}	1.97^{e}	635.7^{b}	242.2^{b}
TS-3	2014	77.8^{a}	0.306^{b}	54.3^{d}	2.45^{abc}	785.4^{a}	282.0^{a}
	2015	33.4^{c}	0.209^{c}	53.9^{d}	2.12^{d}	520.4^{c}	200.7^{c}
TS-5	2014	60.1^{b}	0.295^{b}	63.5^{b}	2.39^{bc}	685.7^{b}	244.4^{b}
	2015	35.2^{c}	0.218^{c}	59.0^{c}	2.00^{e}	549.4^{c}	210.1^{c}
TH-6	2014	32.0^{c}	0.335^{a}	67.4^{a}	2.35^{c}	390.7^{d}	132.8^{d}
	2015	27.6^{d}	0.294^{b}	65.7^{ab}	2.45^{ab}	385.7^{d}	141.2^{d}
$LSD_{0.05}$		3.93	0.019	2.37	0.098	57.40	22.04

Micronutrients (Zn, B and Mn) application significantly increased the yield and its associated traits of sesame cultivars during two successive years (Table 3). Zn, B and Mn increased capsules plant^{-1} 14.3%, 16.7%, 9.3%; capsule length 6.3%, 7.7%, 2.9%; capsule weight 6.1%, 6.9%, 3.1%; seeds capsule^{-1} 3.5%, 4.9%, 2.3%; 1000 SW 4.5%, 5.0%, 2.3%; seed yield 15.9%, 16.8%, 8.6% and oil yield 20.8%, 23.7%, 10.7% respectively.

Results revealed that micronutrients treatments significantly increased capsule length over control during first year (2014) as compare to second year (2015) (Table 5).

Maximum capsule length (3.04 cm) was noted for boron application during 2014 which is statistically same for Zn application during same year (3.02cm). Minimum capsule length was recorded for control treatment during 2014 and 2015 (2.67cm and 2.68cm respectively) which were statistically parallel. Moreover, the cv. TH-6 obtained maximum capsule length (3.65cm) by boron application closely followed by Zn application for the same cultivar (3.62cm). Minimum capsule length (2.44cm) was observed for control treatment of cv. SG-30. Non-significant variations were observed among the means of micronutrient x cultivar interaction in case of SG-30, TS-3 and TS-5.

Table 5. Two way interaction of micronutrients with years and sesame cultivars for capsule length (cm).

	Years		Cultivars			
	2014	2015	SG-30	TS-3	TS-5	TH-6
Control	2.67^{d}	2.68^{d}	2.44^{f}	2.56^{ef}	2.66^{de}	3.04^{c}
Zn	3.02^{a}	2.77^{cd}	2.62^{de}	2.62^{de}	2.72^{de}	3.62^{ab}
B	3.04^{a}	2.83^{bc}	2.67^{de}	2.65^{de}	2.76^{d}	3.65^{a}
Mn	2.93^{ab}	2.74^{cd}	2.58^{ef}	2.56^{ef}	2.71^{de}	3.49^{b}
$LSD_{0.05}$	0.11		0.16			

Maximum number of capsules (83) were observed for cv. TS-3 during first year (2014) by boron application and followed by zinc application (81.7) (Fig. 1). Minimum capsules plant^{-1} were recorded for TH-6 during 2015 and 2014 (25.8 and 30 respectively) where no micronutrients applied. In case of capsule length, maximum same value of 3.87cm was recorded for TH-6 during first year of experimentation by boron and zinc application followed by manganese (3.65cm) (Fig 2). While control treatment obtained minimum values of capsule length for SG-30 during 2014 and 2015 (2.46cm and 2.43cm respectively). Maximum 1000 seed weight (2.56g) was recorded for SG-30 during 2014 where manganese was applied and followed by zinc application (2.52g), while minimum value of 1.87g 1000 seed weight was recorded for control treatment of TS-5 during first year (Fig. 3).

Similar trend of seed yield and oil yield were exhibited for three way interactions of sesame cultivars, micronutrient treatments and years (Fig. 4 & 5). Maximum seed yield and oil yield (870.9kg ha^{-1} and 322.1kg ha^{-1} respectively) were noted by boron application followed by zinc application (858.8 kg ha^{-1}seed yield) for cv. SG-30 during first year but 306.2kg ha^{-1} oil yield was recorded by boron application for TS-3 during first year. Minimum values of 373.5 kg ha^{-1} and 374.2 kg ha^{-1} for seed yield; 120.1 kg ha^{-1} and 130.4 kg ha^{-1} for oil yield were observed in control treatments of cv. TH-6 during 2014 and 2015 respectively.

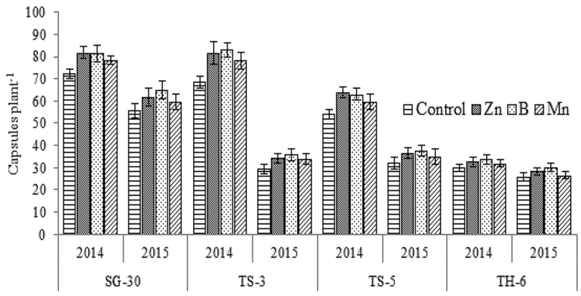

Fig. 1. Capsules plant^{-1} of sesame cultivars as influenced by micronutrients during 2014 and 2015.

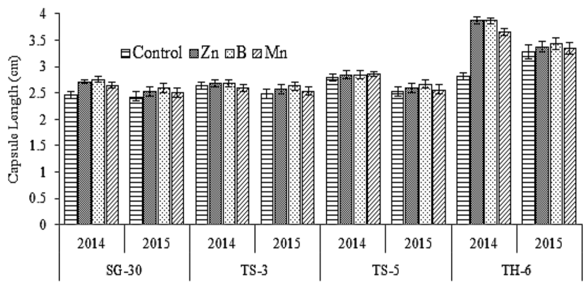

Fig. 2. Capsule length (cm) of sesame cultivars as influenced by micronutrients during 2014 and 2015.

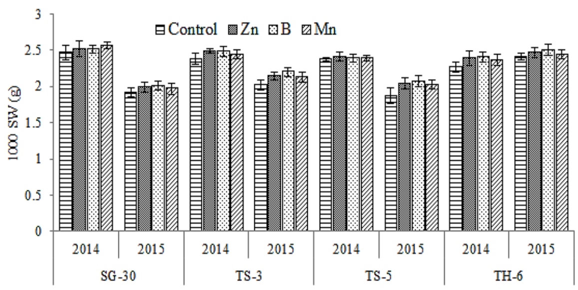

Fig. 3. 1000 seed weight (g) of sesame cultivars as influenced by micronutrients during 2014 and 2015.

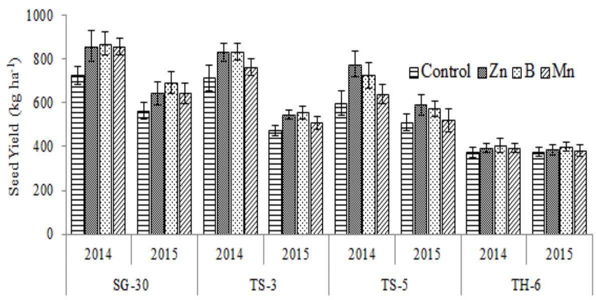

Fig. 4. Seed yield (kg ha^{-1}) of sesame cultivars as influenced by micronutrients during 2014 and 2015.

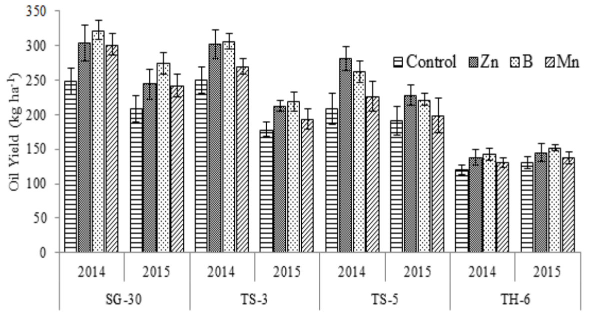

Fig. 5. Oil yield (kg ha^{-1}) of sesame cultivars as influenced by micronutrients during 2014 and 2015.

Discussion

Micronutrients play vital role for appropriate growth and functions of plants. Application of micronutrient fertilizers enhance the crop yield as well as improve plant resistance to environmental stresses. In present research, maximum increase was observed for boron application followed by zinc application for yield related characters and seed yield as well.

Zn and boron were found deficient in soil of experimental field during both yeas, hence added Zn and B would have fulfilled deficiency thus higher yield recorded (Table 2). Boron is essential element for the growth and development of reproductive parts of the plant (Mathew and George, 2011); therefore, maximum increase for number of capsules, capsule length, capsule weight and 1000 SW might have been due to boron application. Increase in studied traits was recorded by Zn fertilizer application due to its important role in plant growth hormones and enzyme systems as well as increasing plant resistance against biotic and abiotic stresses which lead to maximize the plant growth and yield (Cakmak, 2008).

A slight increase of Zn and B content was observed in soils taken from two depths (0-15cm and 15-30cm) after harvest of the crop during first year of study.
It indicated that after uptake of applied Zn and B by sesame plants, residuals of these micronutrients was remained in soil (Table 2). Manganese is essentially required for plant metabolism and development (Hansch and Mendel, 2009), further it aids in chlorophyll synthesis and increases the availability of macronutrients i.e. Phosphorus (P) and Calcium (Ca). Moreover, manganese content in the soil of experimental site was found on marginal level (Table 2). Due to these reasons manganese application slightly increased the sesame yield characters over control. Mn content in soil slightly decreased after crop harvest of first year. Non-significant variations were observed for Mn and B content in soils taken before sowing and after harvest of the crop during second year.

Due to Irregular rainfall pattern and varying genotypic make up, sesame cultivars responded differently to the particular environmental conditions of two seasons (2014 and 2015). The cv. TH-6 was quite different from rest of the cultivars. It is a single stem early maturing cultivar produced lowest number of capsules and seed yield, but other yield characters were significantly higher for this cultivar.

It was also observed that cv. TH-6 was highly sensitive to water logging, excess humidity and moderately tolerant to insect pests, phyllody disease and charcoal rot (Anwar *et al.,* 2013). Short period of water logging due to heavy rainfall resulted significant reduction in number of plants and seed yield (Sarkar *et al.* 2013). In present study, second year received less average monthly rainfall during crop growing period (Table 1).

Therefore, yield attributes including capsules plant^{-1} and seed yield were lower during second year where comparatively low average rainfall recorded. High rainfall during the month of September 2014 (444.8mm) was useful for crop growth due to its particular growth stage. But low rainfall (134.8mm) during the same month of second year suppressed the growth and yield of sesame. Further very low rainfall occurred during October 2014 (23mm) but it was high (190mm) during the same month of second year. Water logging during many days of heavy rainfall adversely influenced the growth and yield of sesame. Similar explanations were also carried by Sarkar *et al.* (2016) that sesame is highly sensitive to heavy constant rains. Rainfall late in season prolonged the growth and increased the shattering losses. Moreover, heavy rainfall may cause leaching down of nutrients subject to low productivity of crop.

Conclusion

This study concludes that application of zinc as $ZnSO_4$ @ 10kg ha^{-1}, boron as borax @ 10kg ha^{-1} and manganese as $MnSO_4$ @ 5kg ha^{-1} along with recommended dose of macronutrients significantly enhanced the sesame production by using sesame cv. SG-30.

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