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COMBINED FOLIAGE APPLICATION OF ZINC AND BORON IMPROVES ACHENE YIELD, OIL QUALITY AND NET RETURNS IN SUNFLOWER HYBRIDS UNDER AN ARID CLIMATE

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ABSTRACT

The deficiency of micronutrients is one of the main reason for low seed yield in oilseed crops in many developing countries including Pakistan. Therefore, this two-year field study was conducted to assess the influence of foliage applied micronutrients (individual/or in combination) on the yield and quality of sunflower hybrids. For this study, we hypothesized that foliage application of micronutrients will improve achene yield, oil quality and net returns in sunflower hybrids. The results indicated that sunflower hybrid 'Parsun' produced the higher head diameter, and had more 1000-achene weight, achene yield, oil content, stearic acid, palmitic acid and linolenic acid as compared to 'FMC-1'. Likewise the tallest plants, greater number of leaves, maximum seed weight, the highest achene yield, and oil content were noted with the combined application of Zn+B. Highest achene yield with combined application of Zn+B also resulted in highest net income. The application of micronutrient also improved the oil content and oil quality. In conclusion, the hybrid 'Parsun' should be grown with the application of Zn+B (10 and 2 kg ha^{-1} respectively) to achieve higher achene yield, better seed quality and to earn higher net benefits in sunflower hybrids under arid climate of Layyah Punjab, Pakistan.

Keywords: Achene yield, fatty acid profile, micronutrients, oil content, sunflower hybrids

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is regarded as the most important source of edible oil across the globe after soybean (*Glycine max* L.). However its average production is very low in developing countries including Pakistan owing to deficiency of micronutrients.

Micronutrients [including zinc (Zn), boron (B) and molybdenum (Mo)] play in important role in the growth cascades of oil seed crops. For examples, the role of micronutrients in improving the photosynthates translocation, seed formation, pollen grain germination, protein and amino acid synthesis, stigma receptivity are well documented (Arabhanvi et al., 2015), which ultimately result in higher seed and oil yield. In a recent study, application of Zn and B improved leaf area, head/stem diameter, achene yield and oil yield in sunflower (Kawade et al., 2018). In another study, the foliage application of a mixture of micronutrients [Zn 3%, B 0.3%, iron (Fe) 3% and manganese (Mn) 3%] improved the seed and oil yield in sunflower under salt stress (El-Nasharty et al., 2017). Kumbhar et al. (2017) also reported that the application of combined Zn, B and Fe improved the availability of these micronutrients to sunflower plant.

Likewise, different sunflower hybrids differ for achene yield, oil content and oil quality (Sher et al., 2018). Various studies have reported that the yield of sunflower is affected by choice of sunflower genotypes (Al-Doori, 2012; Hassan et al., 2012).

There are several ways of application of micronutrients in field crops. In most regions of the world, the micronutrients are soil applied. However, the availability of a micronutrient from soil to plants depends on many factors including soil pH, soil organic matter and type of fertilizer. The most of the arid and semi-arid regions of the world including Pakistan are characterized by high pH and low soil organic matter which decreases the availability of soil applied micronutrients (Madani, 2013; Ullah et al., 2020).

Although there are several studies which depicts the individual role of Zn (Khurana and Chatterjee, 2001; Mirzapour and Khoshgoftar, 2006; Al-Doori and Al-Dulaimy, 2012), B (Al-Amery et al., 2011; Shaker, 2011;

Zahoor et al., 2011; Tahir et al., 2014; Mekki, 2015; da Silva et al., 2016; Khalid et al., 2018), Mo (Škarpa et al., 2013; Steiner and Zoz, 2015), Zn+B (Patil et al., 2006), B+Mn (Jabeen and Ahmad, 2011), Zn+B (Siddiqui et al., 2009), Zn+B+Fe (Nagesh and Shanwad, 2010; Kumbhar et al., 2017), B+Mo (Hirpara et al., 2017), B+sulphur (Karthikeyan et al., 2008; Zafar et al., 2014), B+nitrogen (Parameswari et al., 2012), Zn+phosphorous (Gobarah et al., 2006), Zn+Fe+Mn with manures (Nouraein et al., 2019), Zn+B+Mo+nitrogen (Hlisnikovský et al., 2016), Zn and B with synthetic fertilizer and manures (Dhury et al., 2010), in improving the performance of sunflower under optimal and sub-optimal conditions. Nonetheless no study has been conducted to check the combined influence of foliage applied Zn, B and Mo in improving the achene yield, oil yield, oil quality and economic returns of sunflower under arid climates.

Thus, this study 2-years was aimed to evaluate the individual and combined influence of foliage applied Zn, B and Mo in improving the achene yield, oil yield, oil quality and economic returns of sunflower under an arid climate.

MATERIALS AND METHODS

Experimental Site

This two-year (2017 and 2018) field trail was conducted at Hafizabad Research Farm, College of Agriculture, BZU, Bahadur Campus Layyah, Pakistan (30°57'N; 70°56'E; 151m above sea level). Physical and chemical properties of soil of experimental site are given in Table 1. The monthly average minimum and maximum temperature (°C) and rainfall (mm) for both years were recorded during the whole experiment as shown in Table 2.

Table 1. Physicochemical properties of experimental site

Depth	**0-15 cm**	**15-30 cm**
Texture	sandy loam	sandy loam
Soil pH	8.2	8.4
EC (dS m^{-1})	0.65	0.70
Total nitrogen (%)	0.04	0.05
Available phosphorous (mg kg^{-1})	2	3
Available potassium (mg kg^{-1})	164	168

Table 2. Meteorological data throughout the experimental periods

Months/ Years	**Mean maximum temperature (°C)**		**Mean minimum temperature (°C)**		**Total rainfall (mm)**	
	2017	**2018**	**2017**	**2018**	**2017**	**2018**
February	24.0	23.5	11.2	9.1	14.7	0.0
March	26.2	29.4	14.7	15.2	119.9	11
April	33.9	35.2	19.4	19.4	16	0.0
May	40.7	42.3	25.3	25.9	1.0	0.0
June	41.6	44.5	28.8	26.5	36	20.5

Source: Adaptive Research Farm, Karor Layyah, Punjab-Pakistan

Treatment variables

The experiment consisted of eight micronutrient treatments *viz.* i) control, ii) Zinc (Zn; 10 kg ha^{-1}), iii) boron (B; 2 kg ha^{-1}), iv) molybdenum (Mo; 0.25 kg ha^{-1}), v) Zn+B, vi) Zn+Mo, vii) Mo+B and viii) Zn+B+Mo, which were soil applied in two sunflower hybrids (FMC-1 and Parsun) at the time of sowing. Zinc, B and Mo were applied as zinc sulphate (21% Zn), boric acid (11%) and molybdic acid (59% Mo), respectively. The experiment was executed according to randomized complete block design (RCBD) under factorial arrangement, with three replications. The net plot size was 1.35 × 5.0 m.

Crop husbandry

Seeds of both sunflower hybrids were sown on ridges with the help of dibbler in 45 cm spaced rows. The ridges were made with tractor mounted ridger after cultivating the field with two ploughings and one planking. Crop was sown on February 16 and 22 in 2017 and 2018, respectively. Nitrogen (N) and phosphorus (P) fertilizers were applied at the rate of 90 and 60 kg ha^{-1}, at sowing using diammonium phosphate (18% N, 46% P_2O_5,) and urea (46% N) as source, respectively. Weeds were removed from the plots by hand pulling. The plots were irrigated when needed to maintain the required moisture level. In total, five irrigations (each of 75 mm depth) were applied from sowing to harvesting. There was no attack of insect pests during bot years, thus no pesticide was used. Mature crop was harvested on June 05 and 10 in 2017 and 2018, respectively.

Data recording

Twenty plants were randomly selected from each plot to record average plant height, number of leaves, stem diameter and head meter as detailed in Sher et al. (2018). Three samples of 1000 achenes were taken from each seed lot to record 1000-achene weight. In each plot, achene yield was recorded after sun drying the harvested crop, followed by its manual threshing, which was later converted into hectare basis.

Seed quality parameters, agronomic efficiency and economic analysis

Achene oil content and fatty acid profile were assayed through Near-Infrared Reflectance (NIR) Spectroscopy system (NIRS) (Sato et al. 2008) by using A NIR Systems Model 6500 spectrophotometer (Foss-NIR Systems, Inc., Silver Spring, MD, USA) as detailed in Pérez-Vich et al. (1998).

Agronomic efficiency in terms of seed nutrient ratio (SNR) was calculated as given below.

Agronomic efficiency (SNR) = Increase in yield / Nutrient applied

The economic analysis was carried out to check the economic feasibility of applied micronutrients after estimation of cost of all inputs and sale price of output.

Statistical analysis

Collected data were analyzed using Fisher's two-way ANOVA technique to check overall significance of data and least significant difference (LSD) test, at 5% probability level, was used to compare the treatments means (micronutrients and sunflower hybrids) (Steel et al., 1997). The year effect was non-significant for all traits except 1000-achene weight and achene yield, thus data was pooled and analyzed.

RESULTS

Morphological traits

This experiment indicated that plant height, number of leaves and stem diameter were remained non-significant; while the head diameter was significantly different among sunflower hybrids. Likewise, various micronutrients application significantly affected plant height, number of leaves, and head diameter (Table 3). The interaction of micronutrient application with sunflower hybrids was non-significant for all morphological traits.

Table 3. Influence of foliage applied zinc, boron and molybdenum on morphological traits of sunflower hybrids (average of two years)

Treatments	Plant height (cm)	Number of leaves/plant	Stem diameter (cm)	Head diameter (mm)
Sunflower hybrids				
FMC-1	67.40	16.35	0.24	104.3 B
Parsun	69.90	17.42	0.31	134.4 A
LSD ($p \leq 0.05$)	NS	NS	NS	8.79
Micronutrients application				
Control	65.86 B	17.6 AB	0.30	127.3 AB
Zinc (Zn)	64.83 B	15.8 AB	0.18	117.3 AB
Boron (B)	63.80 B	16.9 AB	0.20	132.3 A
Molybdenum	66.00 B	16.1 AB	0.20	121.5 AB
Zn + B	79.56 A	21.4 A	0.42	131.1 A
Zn + Mo	71.00 AB	15.9 AB	0.35	121.7 AB
Mo + B	71.33 AB	14.3 B	0.35	106.0 AB
Zn+ Mo +B	66.80 AB	16.9 AB	0.18	99.7 B
LSD ($p \leq 0.05$)	12.97	5.75	NS	28.06
Significance				
Micronutrients (M)	NS	NS	NS	*
Sunflower hybrids (SH)	*	*	NS	*
M × SH	NS	NS	NS	*

Means sharing the same case letter do not differ significantly at $p \leq 0.05$; Mo= Molybdenum;
*= significant at $p \leq 0.05$; NS= non-significant

Among micronutrients, the highest plant height and number of leaves were recorded with sole application of Zn+B. Among sunflower hybrids, the highest head diameter was recorded in sunflower hybrid 'Parsun'. Among micronutrients, the highest head diameter was recorded with sole application of Zn+B.

Yield traits

Results indicated that micronutrient application significantly affected the 1000-achene weight, achene yield of different sunflower hybrids (Table 4). Among sunflower hybrids, the highest 1000-achene weight was recorded in sunflower hybrid 'Parsun' in both years. Among micronutrients, the highest 1000-achene weight was recorded with sole application of Zn+B in both years. The interaction of micronutrient application with sunflower hybrids was significant only for 1000-achene weight.

The achene yield remained non-significant between both sunflower hybrids in both years. Among micronutrients, the highest achene yield was recorded with sole application of Zn+B.

Table 4. Influence of foliage applied zinc, boron and molybdenum on yield traits of sunflower hybrids under an arid climate during 2017 and 2018

Treatments	**1000- achene weight (g)**		**Achene yield (kg ha^{-1})**	
	2017	**2018**	**2017**	**2018**
Sunflower hybrids				
FMC-1	65.2 B	59.9 B	2275	2207
Parsun	69.3 A	64.0 A	2481	2378
LSD (p≤0.05)	2.45	2.35	NS	NS
Micronutrients application				
Control	52.5 E	47.5 E	1683 E	1599 C
Zinc (Zn)	67.5 CD	62.2 C	2212 CDE	2126 ABC
Boron (B)	67.0 CD	61.8 C	2500 ABC	2398 ABC
Molybdenum	75.2 B	70.2 B	2342 BCD	2240 ABC
Zn + B	86.2 A	80.5 A	2992 A	2880 A
Zn + Mo	56.7 E	51.3 DE	2812 AB	2707 AB
Mo + B	63.0 D	58.0 CD	1895 DE	1840 BC
Zn+ Mo +B	70.0 C	64.2 BC	2590 ABC	2550 AB
LSD (p≤0.05)	7.81	7.51	931	904
Significance				
Micronutrients (M)	*	*	NS	NS
Sunflower hybrids (SH)	*	*	*	*
M × SH	*	*	NS	*

Means sharing the same case letter do not differ significantly at p≤0.05; Mo= Molybdenum;
*= significant at p≤0.05; NS= non-significant

Quality variables

The study indicated that oil content, stearic acid, palmitic acid, linolenic acid and oleic acids were significantly different in both sunflower hybrids. Similarly, application of various micronutrients both discretely and in combinations significantly affected oil content, stearic acid, palmitic acid, linolenic acid and oleic acid (Table 5). The interaction of micronutrient application with sunflower hybrids was significant for stearic acid.

Table 5. Influence of foliage applied zinc, boron and molybdenum on oil quality of sunflower hybrids (average of two years)

Treatments	**Oil content (%)**	**Stearic acid (%)**	**Palmitic acid (%)**	**Linolenic acid (%)**	**Oleic acid (%)**
Sunflower hybrids					
FMC-1	39.7 B	5.4 B	5.01 B	71.9 B	14.9 A
Parsun	40.9 A	5.8 A	5.05 A	73.8 A	11.9 B
LSD (p≤0.05)	0.99	0.09	0.03	0.21	0.09
Micronutrients Application					
Control	38.0 D	5.7 AB	4.52 E	68.5 G	8.9 H
Zinc (Zn)	39.6 CD	5.4 D	4.58 E	77.7 A	18.5 A
Boron (B)	40.5 BC	5.8 A	5.14 C	72.8 D	13.2 E
Molybdenum (Mo)	42.1 AB	5.8 A	5.26 B	71.6 E	12.3 F
Zn + B	42.5 A	5.5 CD	5.32 A	73.4 C	13.7 D
Zn + Mo	40.9 ABC	5.6 BC	4.91 D	73.7 C	14.3 C
Mo + B	38.1 D	5.3 D	5.18 C	70.7 F	11.3 G
Zn + Mo +B	40.6 ABC	5.9 A	5.36 A	74.7 B	15.4 B
LSD (p≤0.05)	1.99	0.18	0.06	0.43	0.19
Significance					
Micronutrients (M)	*	*	*	*	*
Sunflower hybrids (SH)	*	*	*	*	*
M × SH	NS	*	NS	NS	NS

Means sharing the same case letter do not differ significantly at p≤0.05; *= significant at p≤0.05; NS= non-significant

Among sunflower hybrids, the highest oil content was observed in sunflower hybrid 'Parsun'. Among micronutrients, the highest oil content was recorded with sole application of Zn+B. The highest stearic acid was recorded in sunflower hybrid 'Parsun'. Among micronutrients, the highest stearic acid was recorded with sole application of Zn+Mo+B that was statistically similar to the sole application of with B and Mo, respectively. The highest palmitic acid was observed in sunflower hybrid 'Parsun'. Among micronutrients, the highest palmitic acid was recorded with sole application of Zn+B.

The highest linoleic acid was recorded in sunflower hybrid 'Parsun'. Among micronutrients, the highest linoleic acid was recorded with sole application of Zinc. The highest oleic acid was recorded in sunflower hybrid'FMC-1. Among micronutrients, the highest oleic acid was recorded with sole application of Zn.

Agronomic efficiency of Zn, B and Mo application

Agronomic efficiency of Zn, B and Mo application showed that the highest seed nutrient ratio (SNR) was recorded when Mo was applied at 0.25 kg ha^{-1}. The lowest SNR was obtained where 10 kg Zn was applied (Table 6).

Table 6. Agronomic efficiency of Zn, B and Mo application in seed yield of sunflower

Sr. No.	Micronutrients rates (Mg ha^{-1}) Zn	B	Mo	SY	YI	%	SNR
1	0	0	0	1683	-	-	-
2	10	0	0	2212	529	31	52.9
3	0	2	0	2500	817	39	408.5
4	0	0	0.25	2342	659	39	2636.0
5	10	2	0	2992	1309	78	109.1
6	10	0	0.25	2812	1129	67	110.1
7	0	2	0.25	1895	212	13	94.2
8	10	2	0.25	2590	907	54	74.0

SY: seed yield; **YI:** yield increase over control; **SNR:** seed nutrient ratio

Economic analysis

The economic analysis showed that the highest net benefits were recorded with the combined application of Zn+B, whereas the lowest net benefits were recorded in control treatment which was treated with distilled water only instead of Zn, B or Mo (Table 7).

Table 7. Economic of micronutrient application in sunflower (average of two years)

Treatments	Achene yield (kg ha^{-1})	Total income (Rs. ha^{-1})	Total fixed cost (Rs. ha^{-1})	Total variable cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Net income (Rs. ha^{-1})
Control	1683	92565	30000	0	30000	62565
Zinc (Zn)	2212	121660	30000	1750	31750	89910
Boron (B)	2500	137500	30000	700	30700	106800
Molybdenum (Mo)	2342	128810	30000	15000	45000	83810
Zn + B	2992	164560	30000	2450	32450	132110
Zn + Mo	2812	154660	30000	16750	46750	107910
Mo + B	1895	104225	30000	15700	45700	58525
Zn + Mo +B	2590	142450	30000	17450	47450	95000

DISCUSSION

Micronutrients play an important role in improving the productivity of field crops. This study indicated that application of different micronutrients (B, Zn, Mo) alone, significantly improved the morphological traits (plant height, number of leaves per plant, stem and head diameter), yield related traits (1000-achene weight, achene yield) and quality traits (oil content, stearic acid, palmitic acid, linolenic acid and oleic acid) in both sunflower hybrids (Table 3, 4 and 5).

Indeed, Zn, Mo and B are vital for the growth and development of field crops including oilseeds as they perform specific function in plant tissues. For example, B is involved in metabolism of carbohydrates, development of cell wall, translocation and metabolism of RNA, synthesis of nucleic acid, elongation of roots and lignification and differentiation of tissues in plants (Manaf et al., 2019 a, b). Likewise, Zn triggers the root growth, improves leaf development, assimilate translocation, and is involved in the metabolism of nitrogen and other macromolecules (lipids and proteins) and is activator of several enzymes (Haider et al., 2019; Rehman et al., 2019). On the other hand, Mo is component of several enzymes (involved in oxidation-reduction reaction) including nitrogenase, nitrate reductase, xanthine dehydrogenase, and sulfite oxidase (Steiner and Zoz, 2015). Thus, the involvement of these micronutrients in different physiological and biochemical processes resulted in improved achene yield in this study. Several other studies have reported that individual or combined application of micronutrients improved the performance of sunflower under optimal and sub-optimal conditions (Al-Doori and Al-Dulaimy, 2012; da Silva et al., 2016; Steiner and Zoz, 2015; Hlisnikovský et al., 2016; Kumbhar et al., 2017; Khalid et al., 2018) as observed in this study.

The highest achene yield was recorded with the combined application of Zn+B which was the result of improved morphological and yield parameters (especially 1000 achene weight) in this treatment. The highest achene yield contributed to receive highest economic returns in this treatment. The net returns were poor in the treatments involving Mo application which was attributed to high cost of Mo fertilizer source.

Besides improvement in achene yield, there was an improvement in oil content and fatty acid profile of sunflower. Indeed, oleic acid and linoleic acid are important fatty acids whose concentration in seeds depicts shelf life of seeds and their suitability for human health (Manaf et al., 2019 a, b; Manaf et al., 2020). Sunflower hybrid 'Parsun' attained significantly higher yield, oil content than FMC-1, which might be due to varying genetic potential of these hybrids. Differences in morphological, achene yield and oil quality among sunflower hybrids has already been reported (Sher et al., 2017).

CONCLUSIONS

In conclusion, the hybrid 'Parsun' should be grown with the application of Zn+B (10 and 2 kg ha^{-1} respectively) to achieve higher achene yield, better seed quality and earn high net benefits in sunflower hybrids under arid climate of Layyah Punjab, Pakistan.

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