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EXOGENOUSLY FOLIAGE APPLIED MICRONUTRIENTS EFFICACIOUS IMPACT ON ACHENE YIELD OF SUNFLOWER UNDER TEMPERATE CONDITIONS

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Abstract

Climate change, rapidly increasing population and decreasing fertile lands demand boosting the productivity of oil seed crops. In hilly areas, micronutrients losses are high owing to leaching and runoff which negatively effects crops yield. A field trial was executed to evaluate the impact of foliage applied micronutrients (zinc 0.5%, boron 0.7% and manganese 0.7%) solely and in co-application, on agro-morphological traits and achene yield of sunflower. The relationship among yield attributes and achene yield of sunflower was also determined through correlation analysis. Solo applied boron (0.7%) remained unmatched by recording the maximum yield attributes such as plant height, stem girth, number of leaves, head diameter and weight, number of achene per head and 100-achene weight which led to the highest achene yield (0.96 t ha^{-1}). The co-application of zinc and boron followed solely applied boron, while manganese applied solely or in conjunction with zinc and boron remained inferior to rest of the micronutrients. The correlation analysis revealed direct interrelationships among yield attributes (plant height, stem girth, head diameter and weight) and achene yield of sunflower and thus indicating the need to exogenously supply micronutrients especially boron for improving the agro-botanical traits and economic yield of sunflower under temperate conditions of rainfed regions. However, there is a dire need to conduct further studies to comparatively evaluate and optimize the doses of micronutrients including silicon and copper which may impart drought tolerance to rainfed sunflower under varying pedo-climatic conditions.

Key words: Achene yield, Boron and manganese, Edible oil, Foliar spray, Zinc.

Introduction

Climate change and decreasing agricultural lands due to expanding human settlements are putting pressure to boost crops productivity for ensuring the food security of skyrocketing population. Like many other developing countries, Pakistan is deficient in vegetable oil production with oilseed production of 0.696 million tons (Iqbal, 2015a; Abbas *et al.*, 2015), which fulfills only 23% of domestic cooking oil requirement (Iqbal*,* 2015b). Presently, Pakistan is the third largest importer of edible oil (Iqbal *et al.*, 2015), which jeopardizes food security of rapidly increasing population. Thus domestically, more concrete efforts are needed to increase oilseed production.

Sunflower (*Helianthus annuus* L.) belongs to compositae or asteraceae family, helianthus genus (Ullah *et al.*, 2018) and has obtained a prominent place among oilseed crops globally (Vital *et al.*, 2017; Cechen *et al.*, 2015; Andrew *et al.*, 2013; Ahmad & Jabeen, 2009). Sunflower contains significantly higher oil content (40-47%) which is rich in protein (20-27%), calcium and vitamins (A, D and E) (Diovisalvi *et al.*, 2018; Primo *et al.,* 2018; Li *et al.,* 2017; Iqbal *et al.,* 2015a; Jabeen & Ahmad, 2011; Skoric *et al.*, 2008). It is being grown in all habitat-able continents and can potentially fit in the prevalent cropping systems (rainfed and irrigated) of Pakistan. However, sunflower yield continues to remain far abject compared to genetic potential of the crop varieties in Pakistan. Inadequate fertilizers application, lack of high yielding cultivars and lack of modern production technologies are the major constraints for low productivity (Ma *et al.*, 2017; Scapinelli *et al.*, 2017; Anjum *et al.*, 2015; Iqbal *et al.,* 2015b). Foliar application of micronutrients such as zinc, boron and manganese can be a biological and economically viable strategy to increase sunflower productivity, but a serious research gap exists regarding their use.

Among micronutrients, boron (B) is known to play an important role in achene setting and yield of sunflower. It influenced the photosynthesis and respiration processes along with activating a number of enzymatic systems for protein, carbohydrates, fats and nucleic acid metabolism (Iqbal *et al.,* 2019; Tahir *et al.*, 2014). It stimulated germination of pollen tubes which resulted in better fertilization and higher seed set in sunflower (Sher *et al.*, 2015). The maintenance of water relations, translocation of sugars and longer viability of pollen along with balancing cation-anion absorption are some other prominent functions of B (Asad *et al.*, 2003). Debbarma *et al.*, (2017) reported that foliar application of B increased seed yield of sunflower (1.4 t ha^{-1}) owing to better vegetative growth and increased partitioning of assimilates towards head which led to significant increase in head weight and diameter (Anjum *et al.*, 2015). Similarly, zinc (Zn) application improved vegetative growth (Brunetto *et al.*, 2018) and also influenced achene yield and oil content (Babaeian *et al.,* 2011). Farzanian *et al.*, (2010) reported that Zn application significantly increased leaf area index of sunflower hybrids through improved photosynthesis.

Manganese (Mn) has been reported to have pivotal role in Hill reaction of photosynthesis during which splitting of water occurs and oxygen evolves. Photosystem II contains a Mangano-protein which catalysis the early stages of O_2 evolution. Foliar applied manganese triggered the photosynthesis rate which led to increased growth rate of barley on saline soil (Cramer & Nowak, 1992). In addition, Babaeian *et al*., (2011) reported that Mn application assisted sunflower to cope with water stress and resulted in higher chlorophyll content which resulted in increased photosynthesis rate. In hilly areas leaching and run-off losses are high and thus, crops have responded positively to applied micronutrients (Baraich *et al*., 2016; Shehzad & Maqsood, 2015; Machikowa *et al*., 2013). However, reliable experimental evidences are scarce regarding the impact of foliar applied micronutrients on sunflower under pedo-climatic conditions of Rawalakot (Azad Jammu & Kashmir), Pakistan which necessitates further in-depth studies. In addition, correlation analysis of yield attributes and achene yield could be pertinent to plant breeders for trait selection and to breed new genotypes having higher yield potential. Furthermore, interrelationship quantification of yield components and yield of sunflower through path coefficient analysis was reported to assist in developing models for predicting yield under changing climate (Saleem *et al.*, 2002).

Thus, it was hypothesized that foliar applied micronutrients may positively influence the agronomic attributes leading to higher achene yield of rainfed sunflower. The prime objectives of this field investigation were to examine the comparative impact of foliar application of different micronutrients on yield attributes of sunflower and to optimize the foliar dose of micronutrients for boosting sunflower yield. The study has also attempted to sort out interrelationships between achene yield of sunflower and its components while determining the linear or indirect impact of each yield attribute under rainfed conditions.

Materials and Methods

Experimental site description: The research was carried out at the Research Area of the Department of Agronomy, Faculty of Agriculture, University of the Poonch Rawalakot, Azad Kashmir (33°51'32.18"N, 73° 45'34.93"E) which is situated at an altitude of 1638 meters (Zafar *et al.*, 2013). The research trial was executed during spring season of 2017. The soil of the experimental area is classified as Thermic Lithic Eutrudepts, while it has temperate climate as per Koppen classification scheme. The experimental area receives an annual precipitation of about 700-800 mm, while mean temperature remains 5-28°C (Khaliq & Abbasi, 2015). A pre-sowing physico-chemical analysis was performed from representative soil samples collected from corners and middle of the experimental block up to a depth of 15 cm. The analysis revealed that soil of the experimental block was of silt-loam type, while it was slightly of alkaline nature with pH of around 8. It was also found to be rich in organic matter (8%) (Table 1).

Table 1. Physico-chemical analysis of experimental site (Rawalakot, Poonch, Azad Jammu and Kashmir, Pakistan).

Soil Characteristics	Recordings
pH	7.67
Soil organic matter (g kg^{-1})	7.43
Sand (g kg^{-1})	245
Silt (g kg^{-1})	545
Clay (g kg^{-1})	210
Textural Class	Silt loam
Total N (mg kg^{-1})	0.35
Available phosphorus (g kg^{-1})	6.91
Extractable potassium (g kg^{-1})	79.8

Details of experiment: Treatments included solo foliar sprays of zinc (0.5%), boron (0.5%) and manganese (0.5%), while there were also three combined applications of zinc (0.5%) + boron (0.7%), zinc (0.5%) + manganese (0.7%) and boron (0.7%) + manganese (0.7%). The experiment was laid out in the regular arrangement of randomized complete block design (RCBD) and was replicated thrice. The net plot size was maintained at 4 m^2. The foliar application of solo and co-application of micronutrients was done twice at 35 and 55 days after sowing (DAS).

Stock solutions preparation: To obtain the required concentrations of boron (0.7%), manganese (0.7%) and zinc (0.5%), stock solutions were prepared. For preparing stock solutions, 2.19 g of anhydrous zinc sulphate (ZnSo4.7H2O) was used, while 1.92 g of manganous sulphate ($MnSO_4.H_2O$) was added for making 0.7% solution of manganese and 4.00 g of boric acid (H_3BO_3) added for making 0.7% solution of boron. All the micronutrients were applied through foliage sprays using manual sprayer machine.

Crop management: In order to prepare a fine seed bed, the experimental block was ploughed three times using tractor mounted plough. Each ploughing was followed by planking using wooden plank to pulverize the soil. The plant-plant and row-row spacing was maintained at 30 cm and 70 cm respectively. An approved sunflower cultivar (S-278) was used as a planting material. The crop was sown by dibbling method, using the seed rate of 10 kg ha^{-1}. After calculations 4 g seed was used for each plot. The recommended dose of mineral nitrogen (60 kg ha^{-1} elemental N), phosphorous (25 kg ha^{-1} elemental P) and potash (50 kg ha^{-1} elemental K) were applied in the form of urea, single super phosphate and sulphate of potash respectively. All the fertilizers were applied as basal dose. Weeds were uprooted manually through hoeing done at 18 and 34 days after sowing. The non-experimental area was maintained around the experimental block where sunflower was broadcasted.

Data recordings: Plant population at complete emergence was counted using randomly thrown quadrant in each experimental plot at 17 DAS. For measuring all agronomic yield attributes, ten randomly selected plants from inner rows of each experimental plot were used. Plant height (from base to tip of the highest head) was recorded using measuring tape, while stem (base, middle and top) and head diameters were measured and vernier caliper and measuring tape respectively. Digital electrical balance was used to record head and 100-achene weights. Heads were separated from plants and threshed manually by rubbing sunflower heads against a metal piece and thereafter hitting to earth for counting their number as described by Mirzabe *et al.*, (2016). In order to record achene yield, all heads in each plot were manually threshed, weighted and converted into tons per hectare.

Statistical analysis: The recorded data were subjected to analysis of variance technique using statistical software package "Statistix 8.1 version", while significance of the treatments means was determined by putting into practice the orthogonal contrasts at 5% level of probability (Steel *et al.,* 1997).

Results and Discussion

The foliar application of micronutrients such as zinc (Zn), boron (B) and manganese (Mn) applied solely or in combination with each other remained non-significant for plant population of sunflower was (Table 2). It was probably owing to uniform germination and it has been previously described that plant population was a genetically controlled trait and it got affected by factors such as seed vigor and soil conditions only, while foliar application of micro-nutrients remained in-effective as far as plant population of sunflower was concerned (Ahmed & Quresh, 2000).

All micronutrients performed better in comparison to control for plant height, stem girth and number of leaves per plant of sunflower. However, solo application of B remained superior by recording the tallest plants with greatest stem girth, while solo Zn followed it for plant height and it remained statistically at par to B for stem girth and number of leaves per plant of sunflower (Table 2). It was probably due to improved enzymatic activity and metabolism along with stimulating influence on photosynthetic pigments by exogenously applied B which increased vegetative growth of sunflower. These results coincide with the findings of Baraich *et al.*, (2016) and Marchetti *et al*., (2001), as they reported that micronutrients including B and Zn caused significant variation in plant height of sunflower, whereas foliar application of B remained superior and gave the highest plant height. These results also corroborate with the finding of O'Neill *et al.*, (2004), Silva *et al.*, (2011) and Tahir *et al.*, (2014), who reported that the maximum stem diameter (2.21 cm) of sunflower was obtained when boron was soil applied (4 kg ha^{-1}). The significantly higher cell elongation owing to B application was attributed as the major reason behind improved stem diameter of sunflower cultivars. It was also concluded that co-application of B and Mn at vegetative stage imparted drought resistance to oil seed crops including sunflower and canola which led to significantly higher number of leaves per plant as well as stem girth. However, these results are in contrast with those of Kumar *et al.*, (2010), who demonstrated that foliar application of Zn was instrumental in increasing the number of leaves and leaf area per plant and overall higher vegetative growth was recorded. It was also suggested that Zn application resulted in providing more balanced nutrients to sunflower and ultimately higher biomass production was recorded.

Table 2. Yield attributes of sunflower as influenced by foliar application of micronutrients under rainfed conditions of Rawalakot, Poonch (Azad Jammu and Kashmir), Pakistan.

Treatments	Plant population (m^2)	Plant height (cm)	Stem diameter (cm)	Number of leaves $plant^{-1}$
Control	4.66	102.67e	3.96c	14.33c
Solo application of zinc (0.5%)	4.33	124.47b	4.11b	21.63ab
Solo application of boron (0.7%)	5.00	138.93a	4.22a	23.33a
Solo application of manganese (0.7%)	5.00	116.67cd	4.05bc	20.80ab
Co-application of zinc (0.5%) + (0.7%) boron	4.00	128.77b	4.11b	20.13ab
Co-application of zinc (0.5%) + manganese (0.7%)	4.66	111.00d	4.10b	19.43b
Co-application of boron (0.7%) + manganese (0.7%)	4.33	122.07bc	4.04bc	17.80bc

Table 3. Yield attributes and achene yield of sunflower as influenced by foliar application of micronutrients under rainfed conditions of Rawalakot, Poonch (Azad Jammu and Kashmir), Pakistan.

Treatments	Head diameter (cm)	Head weight (g)	Number of achene $head^{-1}$	100-achene weight (g)	Achene yield (t ha^{-1})
Control	7.70d	55.067c	48.00bc	4.47d	0.79f
Solo application of zinc (0.5%)	11.40abc	58.86c	463.33c	5.30bc	0.90c
Solo application of boron (0.7%)	13.40a	97.00a	550.33a	6.11a	0.96a
Solo application of manganese (0.7%)	12.73ab	60.36c	506.00abc	5.80ab	0.83e
Co-application of zinc (0.5%) + (0.7%) boron	11.06bc	81.80ab	475.00bc	5.32bc	0.94b
Co-application of zinc (0.5%) + manganese (0.7%)	11.60abc	66.03bc	478.00bc	5.07c	0.87d
Co-application of boron (0.7%) + manganese (0.7%)	10.13c	91.46a	522.33ab	5.38bc	0.924bc

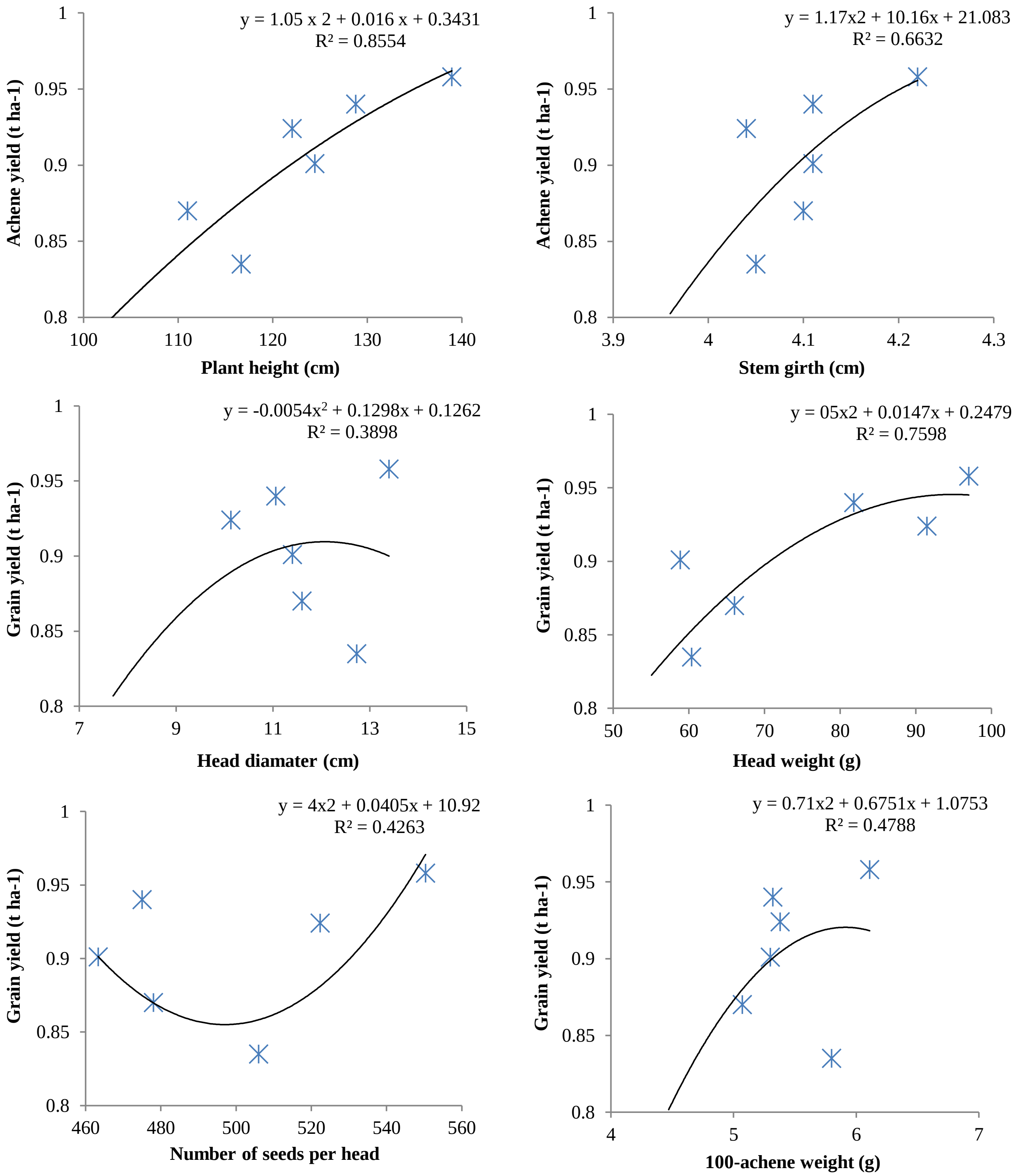

Fig. 1. Correlation among yield attributes and achene yield of sunflower as influenced by foliage applied micronutrients under rainfed conditions of Rawalakot, Poonch (Azad Jammu and Kashmir), Pakistan.

In this filed investigation, foliar applied micronutrients had also varying impact on other morphological traits which contribute to economic yield of sunflower. Foliar application of B remained superior for recording the highest head diameter (13.40 cm) and weight (97.00), number of achene per head (550.33) and 100-achene weight (6.11 g) (Table 3). It was followed by solo application of Zn for head diameter and weight, while Mn applied solely as foliar spray followed it for number of achene per head and 100-achene weight. The superior performance of exogenously applied B might be attributed to its role in effectively trans-locating the carbohydrates to sunflower head which favored significant increment in head diameter and weight. These results are in conformity with those of Renukadevi *et al*., (2003), Kapila and Shivay (2008), Somroo *et al*., (2007), Oyinlola (2007) and Reddy *et al*., (2003). Similarly, significantly higher head diameter (18.77 cm) was observed by Tahir *et al*., (2014), when B was used at the rate of 4 kg ha^{-1}. These results are also coincide with the findings of Kumar *et al*., (2010), who demonstrated that foliar application of boron (0.3%) enhanced the head weight of sunflower. It was also concluded that foliage applied boron increased head weight of spring planted sunflower by reducing achene sterility and increasing achene size. These results are in line with the findings of Oyinlola (2007) and Bilen *et al*., (2011), who reported that exogenously, applied B increased achene weight owing to better photosynthesis rate. Similar results were also reported by Chowdhury *et al*., (2010), who concluded that the increase in 100-achene weight of sunflower was probably due to gradual increment in translocation of photosynthates from sources towards the head as a result of boron application. It was also reported that boron assisted in enhancing the activity of dehydrogenase and the phosphatase enzymes which resulted in significantly higher seed weight.

As foliage applied B was effective in improving yield attributes such as plant height, stem girth, number of leaves, head diameter and weight as well as number of achene per head and 100-achene weight which led to significantly higher achene yield (0.958 t ha^{-1}) of sunflower. The co-application of Zn and B followed it, while it was closely followed by combined application of Zn and Mn, as far as achene yield of sunflower was concerned. The foliar application of B enhanced the achene yield because it has been reported to maintain a good balance between photosynthesis and respiration. It has also been reported that foliar applied B remained effective in enhancing pollen viability which contributed significantly to achene yield of spring planted sunflower. Mekki (2015) reported that achene yield of sunflower was increased by 36% when the concentration of foliage applied B was increased from 300 to 600 ppm. In addition, the role of B in pollen tube development was reported as one of the major reasons behind higher achene yield of rainfed sunflower. In contrast, it has also been reported that co-application of Zn and B remained more effective in increasing achene yield compared to their solo application (Gitte *et al.*, 2005). There was found significantly positive relationship among yield attributes and achene yield of sunflower (Fig. 1). Similar results were also reported by Oyinlola (2007) and Patil *et al.*, (2006) who reported that foliar applied micronutrients improved yield attributes especially head diameter and weight which led to higher yield of sunflower. Increased yield by B application was also reported by Al-Amery *et al*., (2011) and Sumathi *et al.*, (2005) owing to improved yield attributes (stem girth, 100-achene weight and number of achene per head) which were directly co-related to achene yield of sunflower. In addition to zinc, boron and manganese, copper has also been reported to influence vegetative growth positively (Hippler *et al.*, 2017) and it also needs to be tested for dose optimization.

Conclusions

It was hypothesized that foliar application of micronutrients (zinc 0.5%, boron 0.7% and manganese 0.7%) applied solely or in conjunction with each other have the potential to impart growth triggering influence on yield attributes leading to higher achene yield of sunflower. The research findings proved to be in line with the postulated hypothesis, although micronutrients differed in their influence as far as achene yield of sunflower was concerned. Solo applied boron (0.7%) remained superior to zinc and manganese applied either solely or in conjunction with each other. However, there is a dire need to conduct further in-depth studies to evaluate and optimize the doses of micronutrients including silicon and copper which may impart drought tolerance to rainfed sunflower under varying pedo-climatic conditions. Moreover, it is also suggested to optimize the time of micronutrients exogenous application and the findings of this field study encourage testing their application at the initiation of flowering stage. Lastly, these findings may serve as reference to develop and integrate micronutrients application in the production technology peckage of rainfed sunflower under temperate climate.

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