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The Effects of Micronutrient and Organic Fertilizers on Yield and Growth Characteristics of Sunflower (*Helianthus annuus* L.)

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Abstract: To evaluate the effect of different micronutrients (Mn, Fe, Zn) and farmyard manure (FYM) on the vegetative, phenological, and achene yield components of sunflower a field experiment was conducted in Maragheh, North West of Iran during the growing season 2018–2019. The treatments were arranged in a split-plot design- with three replicates. The main plots assigned to two levels of FYM (0 and 20 t ha^{-1}) and sub plots assigned to the recommended dose of three micronutrients (Mn, Fe, Zn). The results revealed significant improvements in the growth and yield of sunflower due to the main and interaction effects of farmyard manure and inorganic fertilizer application. The highest number of leaves and the highest leaf area was observed in a plant grown by FYM + Zn. However, there was no significant difference between micronutrients under inorganic condition (without FYM application). The highest leaf relative water content (RWC), plant height, internode distance, and chlorophyll was recorded for plants grown by Fe or Zn under FYM applied condition. Application of FYM and micronutrients reduced the number of days to flowering. However, the application of FYM significantly delayed plant maturity. Achene number per head, 100-achene weight, achene length, achene width, achene oil percent, achene yield, and harvest index significantly increased with the application of FYM and the best performance was in a plant grown by FYM + Zn and FYM + Fe. The percentage of hollow and empty achene was

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significantly reduced by the application of FYM. Combined applications of FYM and micronutrients has become an increasingly common practice.

Keywords: farmyard manure, oil crop, phenological, semi-arid region, yield components, zinc

Introduction

Sunflower (*Helianthus annuus* L.) is an important oilseed crop which ranks 3rd after soybean and peanut along with other oil seed crops like (canola, and cotton) which contributes considerably to edible oil in the world (Thavaprakash *et al.*, 2003). It has been estimated that world production of sunflower seed exceeds 47.8 million tonnes from an area of 26.5 million ha of land (Faostat, 2017). Over the past years from 2013 to 2017, its cultivated area has increased by about 10.51 % and its production has increased by about 11.53 % (Faostat, 2013, 2017). The annual production of sunflower in Iran is close to 40,000 tones achieved from 40,000 ha (Faostat, 2017). Yield of sunflower in Iran is significantly low, and this status is also found in elsewhere with semi-arid climates. In North West of Iran, as representative of semi-arid regions, much of the rainfall occurs during the cold months of the year. This is when the spring crops are not yet cultivated, and winter crops have not active growth, and they are in a state of winter stagnation. However, the moisture stored in the soil cannot remain in the soil for a long time. The moisture supplied to the soil from rain is easily offset by evaporation; the latter is enhanced by low air humidity, high solar radiation and high air temperature (Lucke *et al.*, 2013; Pasandi *et al.*, 2014). The result is a limited dissolution of soluble primary minerals and the development of only a shallow, skeletal soil with a weak profile differentiation. Soils of these regions generally have free $CaCO_3$, high pH, and low organic matter, which reduce the availability of some essential elements and cause their deficiencies.

Iron (Fe), manganese (Mn) and zinc (Zn) are among the most important micronutrients which are essential for proper growth and reproduction of plants. Their phyto-available concentration is the most important factor, which determines the toxicity or deficiency of elements in the environment and governs soil fertility status (Shukla, 2018). With regards to inappropriate water and soil conditions of semi-arid regions, the widespread deficiencies of micronutrients are revealing, but among them, the main focus was on Zn, Fe, and Mn. It means that crops are grown in the semi-arid tropical regions not only face water shortages and deficiencies of major plant nutrients (nitrogen and phosphorus), but they also suffer from micronutrient deficiencies (Sahrawat *et al.*, 2007).

In recent decades, soil fertility has decreased due to the indiscriminate use of agrochemicals and continuous use of inorganic fertilizers (Panpatte and Jhala, 2019). On the other hand, the soil organic matter content (SOM) is low in this area, and it can significantly disrupt the nutritional balance. The nutrient imbalance is one of the major constrictions limiting the productivity of crop plant in the semi-arid region (Janmohammadi *et al.*, 2018). Therefore, it is important to ameliorate the soil physical environment. Maintenance of optimum soil physical conditions is a key component for soil fertility management (Zhang *et al.*, 2014). Organic fertilizers such as farmyard manure (FYM) can improve soil physical, chemical and biological properties (Janmohammadi *et al.*, 2016) Improvement in the soil structure due to FYM application leads to a better environment for root development.

However, the utilization of FYM alone as a substitute to inorganic fertilizer is not enough to maintain the present levels of crop productivity of high yielding varieties (Efthimiadou *et al.*, 2010; Yang *et al.*, 2016). Therefore, integrated nutrient management in which both organic manures and inorganic fertilizers are used simultaneously is the most effective method to maintain healthy and sustainably productive soil. Sustainable development is a fundamental keyword regarding current unfavorable soil conditions in the area, which aims to improve the productivity and preserve resource availability for future generations (Panpatte and Jhala, 2019). Due to climatic conditions, soil properties, and growing population of the area, it appears that the optimized fertilization strategies in here are becoming a need for sustainable crop productivity and efficient resources use. Although some studies have investigated the effects of the use of FYM and macro fertilizers, there is little information on the combined use of organic and micronutrient fertilizers. In this paper, we quantified the influence combined application of micronutrient and FYM on growth characterizes of sunflower.

Materials and methods

The field trials were performed in 2017 and 2018 growing season at the field of plant genetics and production department of agriculture faculty of university of Maragheh (latitude 37°23′ N, longitude 46°16′ E and altitude 1485 m). The field is located in a semi-arid area (according to the Köppen climate classification) with moderate and dry summer. In Maragheh, the average annual temperature is 11.2 °C. The average amount of annual precipitation is 353 mm. Between the driest and the most humid months, the difference in precipitation is close to

64 mm. The variation in annual temperature is around 25.2 °C. Rainfall from June to October is relatively light, and the highest rate of evapotranspiration then occurs. The soil was sampled 20 days before the beginning of the experiment. Composite soil sampling was performed from the top 30 cm depth, and the physical and chemical characteristics were determined in the laboratory. The total nitrogen, available phosphorus, and available potassium were measured based on the Kjeldahl method, the Olsen method (Olsen *et al.*, 1954), and ammonium acetate extraction protocol (Tandon, 2005), respectively. The soil texture of the experimental site is clay loam, comprising of 26 % sand, 33 % silt, and 41 % clay. The site was covered by a poor fine mixed, mesic, typical cacixerepts soil, exhibited xeric moisture regime (Salehi *et al.*, 2003). It contains 0.36 % organic matter (OM) with a pH of 7.35, with electrical conductivity (EC) = 1.13 ds m^{-1}, total volatile nitrogen (TNV) = 43.8 %, 0.12 % nitrogen (N), 21.61 available phosphorus (mg kg^{-1}), and 247 mg kg^{-1} available potassium (K). The previous crop was Barley (*Hordeum vulgare* L.) (The crop rotation in site was winter barley- sunflower- fallow- winter wheat). The experimental design was Split block with control in randomized complete block design with four replications. Main plot size was set to 18 m × 5 m and Sub-plots size was set to 5 m × 4 m. Each experimental plot consisted of 8 rows, 4 m in length, with inter-row and inter-plant distances of 60 and 20 cm, respectively. Achenes of sunflower (*Helianthus annuus* L., cv. Azargol) were hand sown on the 19th of March. To prevent interference of fertilizers, one-meter margin between subplots were considered. Main plot treatments consisted of two farmyard manure rates: 0 and 20 t ha^{-1}. Sub plot treatments were four levels of micronutrient (C-control, Zn, Fe, and Mn; 2 kg ha^{-1}). After tillage operations, decayed farmyard manure at rates of 0 and 20 t ha^{-1} were uniformly applied on the surface and mixed to 15 cm depth by the spade. Then, the field was ridged or transformed into the row and inter-row. Thus, greater manure along with the soil was accumulated on the row. The subplot treatments were randomly assigned independently within each main plot. Control or check plot received no treatments. Micronutrients fertilizers (containing 18.0 % 13.0 % and 14 % water-soluble iron, zinc and manganese) was divided into three equal parts; the first part of the micronutrients was applied at planting time, second and third parts used at the stage of stem elongation (BBCH = 32) and were repeated at the flowering stage (BBCH = 63). The micronutrient fertilizers were used as fertigation by the incorporation of fertilizers into the irrigation water. By adopting this approach, readily soluble nutrients can be supplied directly to the root volume, thereby maximizing nutrient efficiency and minimizing over fertilization and leakage to underground water with possible damage to the environment. Chemical properties of FYM included CEC = 33.51 meq/100 g, 0.75 % of total N, 0.54 % of available P and

1.23 % of available K, 480 mg kg^{-1} Fe, 231 mg kg^{-1} Zn, 207 mg kg^{-1} Mn, pH 6.78. Also recommended a dose of macronutrients chemical fertilizers (100:50:50, that is 200 kg ha^{-1} N + 100 kg ha^{-1} P + 100 kg ha^{-1} K) was applied. Macronutrient fertilizers were added after layout preparation in the form of urea, triple superphosphate, and potassium sulphate. To prevent urea fertilizer leaching, it was used as split in three phases with micronutrients. All cultural practices (e. g. hoeing, weed management, irrigation, plant protection measures, etc.) were kept normal for the crop during the growing season. Furrow irrigation applied in 7-day intervals. Chlorophyll content (SPAD) values were recorded with a SPAD-502 meter (Konica-Minolta, Japan) using fully expanded upper leaves at the flowering stage. Relative water content (RWC) was measured in leaves adjusted to head at the seed filling stage according to the following equation [((FW-DW)/(TW-DW))*100], where FW, TW, and DW are fresh weight (g), turgid weight (g), and dry weight (g), respectively. The influence of different micronutrient treatments on phenological development of the plants was evaluated through regular monitoring of the field and by recording the days to 50 % flowering and days to maturity. Plants were harvested at the stage of physiological maturity when the back of the head had turned from green to yellow, and the bracts were turning brown. At harvest, ten plants from each replicate for each treatment were sampled randomly and quantified for yield and yield components. The following data were recorded: plant height; stem diameter; head diameter; husk percentage; the number of seeds per head; the weight of 100 achenes; achene length; achene width; straw yield; and harvest index. The Oil content was determined gravimetrically by extraction with technical grade hexane (Sigma-Aldrich) in a Soxhlet apparatus (Cole-Parmer, Germany) for 10 h at 40 °C (AOCS, 1993). Analyses of variance were performed using the SAS statistical program (SAS V8.2, SAS Institute, Inc., Cary, NC). Analysis of variance technique was employed with the least significance difference (LSD) test at 5 % level to compare treatments means.

Results

Analysis of variance and means comparison for leaf number indicated that the main effect of FYM and micronutrients was significant. FYM application increased leaf number by about 33 % compared to inorganic conditions (from 7). Application of Zn fertilizer and FYM caused the highest number of leaves. The main effect of micronutrient and FYM was significant on leaf number. Between the micronutrient the effects of Zn and Fe was more prominent. Also plants grown under FYM applied condition had more leaves than inorganic condition. This tends also were observable for leaf area where the application of Fe and Zn in combination with FYM caused the highest leaf area. Interestingly, no significant differences were observed between micronutrients under inorganic condition (Table 1).

Evaluation of plant height analysis showed that application of iron and zinc at both levels of FYM improved this trait and the tallest plants were observed in the treatment of Zn with FYM (171.66 cm), which were 41 % taller than control plants (the treatment with zero FYM). Application of FYM significantly increased the stem diameter (by 35 %) when compared with the inorganic condition. The effect of micronutrients application on stem diameter was not significant under inorganic condition. The thickest stems were observed in plants grown by application of Zn and FYM. Evaluation of RWC showed that FYM application increased this trait by 22 %. Application of micronutrients under inorganic conditions had no significant effect on RWC (Figure 1). The highest RWC was recorded for a plant grown by application of Zn and Fe along with FYM. Effectiveness of micronutrient fertilizers was quite evident under FYM application conditions. A similar trend also was recorded for chlorophyll content, and application of FYM increased the SPAD unit BY 27 %. The highest amount of SPADE unit was recorded for plants grown by iron and zinc application under application FYM. Application of Zn and Fe increased SPAD unit by 17 % and 15 % compared with conditions without the application of micronutrient, respectively (Table 1).

Phenological stages of sunflower were significantly affected by FYM and micronutrients. On average, the use of FYM accelerated initiation of flowering up to eight days. The highest number of days to flowering was observed in plants grown without application of micronutrient fertilizer (control) and plants grown with Mn under inorganic condition. Application of Fe and Zn accelerated flowering on average for ten days. The reverse trend was observed for the number of days to the physiological maturity (Table 1). It means that the application of FYM delayed maturity stage up to 9 days. Zn application had the greatest effect on the number of days to maturity compared to other elements.

The diameter of the main head is one of the most important components of achene yield in sunflower, and evaluation of this trait showed the effect of Zn fertilizer in both FYM level was significantly higher than Mn and Fe fertilizers. Application of FYM increased the main diameter by 13 %. The number of the achene per head (NAH) affected by FYM application so that the application of FYM could increase this component of yield by about 25 %. Application of Mn, Fe, and Zn increased NAH by 10.42 %, 10.69 %, and 14.29 % over control,

Table 1: Morphphysiological and phenological traits of sunflower (*Helianthus annuus* L.), as affected by fertilizer treatments.

Fertilizer treatments	PH	LA	LN	DF	SD	AL	AW	IL	BY	HI	DM	EA	MHD	HAW	CC
FYM_0-C	120.00^{d}	838.00^{c}	7.66^{d}	70.08^{a}	15.88^{d}	10.67^{e}	4.14^{c}	5.26^{cd}	6836.2^{b}	28.80^{e}	110.33^{d}	8.66^{a}	11.99^{d}	4.60^{c}	39.25^{d}
FYM_0-Mn	128.00^{d}	828.67^{c}	8.16^{cd}	71.06^{a}	18.02^{cd}	11.06^{de}	4.60^{b}	4.83^{d}	7410.2^{b}	29.56^{de}	111.66^{d}	8.98^{a}	12.96^{c}	4.66^{c}	41.45^{d}
FYM_0-Fe	145.00^{c}	902.00^{c}	8.53^{cd}	63.04^{bc}	18.17^{cd}	11.97^{bcd}	4.53^{b}	4.93^{cd}	7545.8^{b}	29.51^{de}	114.33^{bcd}	7.33^{b}	13.19^{c}	4.68^{c}	46.73^{c}
FYM_0-Zn	148.66^{c}	900.33^{c}	8.73^{c}	67.20^{ab}	18.96^{cd}	11.24^{de}	4.58^{b}	4.96^{cd}	8879.6^{a}	30.31^{cd}	117.33^{b}	9.33^{a}	13.94^{b}	4.90^{bc}	45.85^{c}
FYM_{20}-C	145.66^{c}	1099.33^{b}	11.66^{b}	64.32^{b}	21.22^{bc}	11.81^{cd}	4.77^{ab}	6.24^{b}	8936.1^{a}	31.09^{bc}	126.66^{a}	5.99^{c}	14.02^{b}	5.20^{ab}	51.99^{b}
FYM_{20}-Mn	155.66^{bc}	1091.67^{b}	11.63^{b}	63.68^{bc}	22.96^{b}	12.94^{ab}	4.92^{a}	5.79^{cb}	9482.3^{a}	30.51^{cd}	116.00^{bc}	5.59^{c}	14.47^{b}	5.05^{ab}	51.40^{b}
FYM_{20}-Fe	165.00^{ab}	1156.00^{ab}	12.10^{b}	58.56^{cd}	23.17^{b}	13.36^{a}	5.04^{a}	7.30^{a}	9771.6^{a}	32.40^{a}	118.66^{b}	5.81^{c}	14.63^{b}	5.16^{ab}	59.29^{a}
FYM_{20}-Zn	171.66^{a}	1200.00^{a}	13.26^{a}	54.72^{d}	24.27^{a}	12.83^{abc}	5.06^{a}	7.37^{a}	9693.0^{a}	32.21^{ab}	127.00^{a}	5.11^{c}	15.81^{a}	5.26^{a}	57.73^{a}
FYM	**	**	*	**	*	**	*	*	**	**	**	**	**	*	**
MN	**	**	*	*	*	*	ns	*	*	*	**	ns	**	ns	**
FYM × MN	ns	ns	ns	ns	**	*	ns	ns	ns	*	**	*	ns	ns	*

PH = plant height (cm), LA = leaf area (cm^2), LN = number of leaves during the flowering, DF = number of day to flowering, SD = stem diameter (mm), AL = achene length (mm), AW = achene width (mm), IL = internode length (mm), BY = biological yield (Kg ha^{-1}), HI = harvest index (%), DM = number of day to maturity, EA = percent of empty achene (%), MHD = mean head diameter (mm), HAW = 100-achene weight (g), CC = chlorophyll content (SPAD unit). FYM0 = without farm yard application, FYM20 = application farmyard manure at rate of 20 t $ha^{-1.}$ In a column figures with the same letter (s) or without a letter (s) do not differ significantly whereas figures with the dissimilar letter are statistically different based on least significant differences (LSD). ns = not significant, * = Significant at 5 % level of probability, ** = Significant at 1 % level of probability.

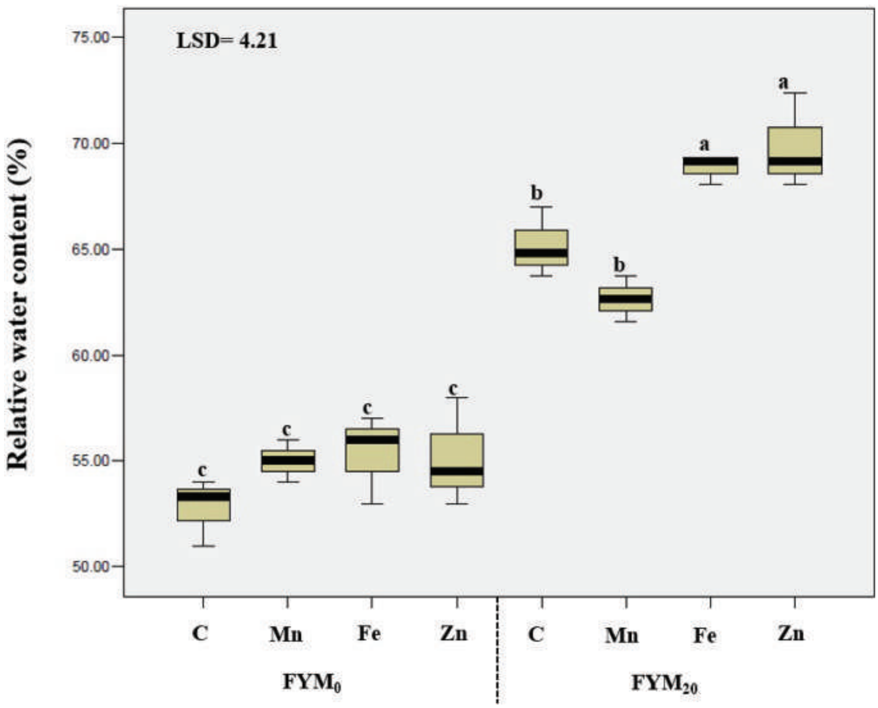

Figure 1: Effect of farmyard manure (FYM) and micronutrient (Fe, Zn, Mn) on the relative water content of leaves in sunflower plants grown in Northwest of Iran. Values with different superscripts are significantly different (p < 0.05). All values are mean ± SEM.

respectively (Figure 2). The percentage of empty achene significantly decreased with the application of FYM (by 2.95 %). In inorganic fertilizers the lowest percentage of empty achene was observed in a plant grown by application of Fe. 100-achene weight significantly increased by FYM (by 10 %). The heaviest achene at both levels of FYM was obtained by Zn application (Table 1). Also, micronutrient application considerably increased achene size (length and width). However, their application with the use of FYM was much more effective, and this trend was more evident for achene length.

Investigation of achene oil content (OC) showed that application of FYM increased the OC by 8 % over the inorganic condition. A brief comparison of micronutrients indicated that these elements had no significant effect on OC under inorganic condition. However, the study of micronutrients under FYM applied condition indicated that there is a significant difference between them, so that the highest OC was recorded for plants grown with Fe and Zn (Figure 3).

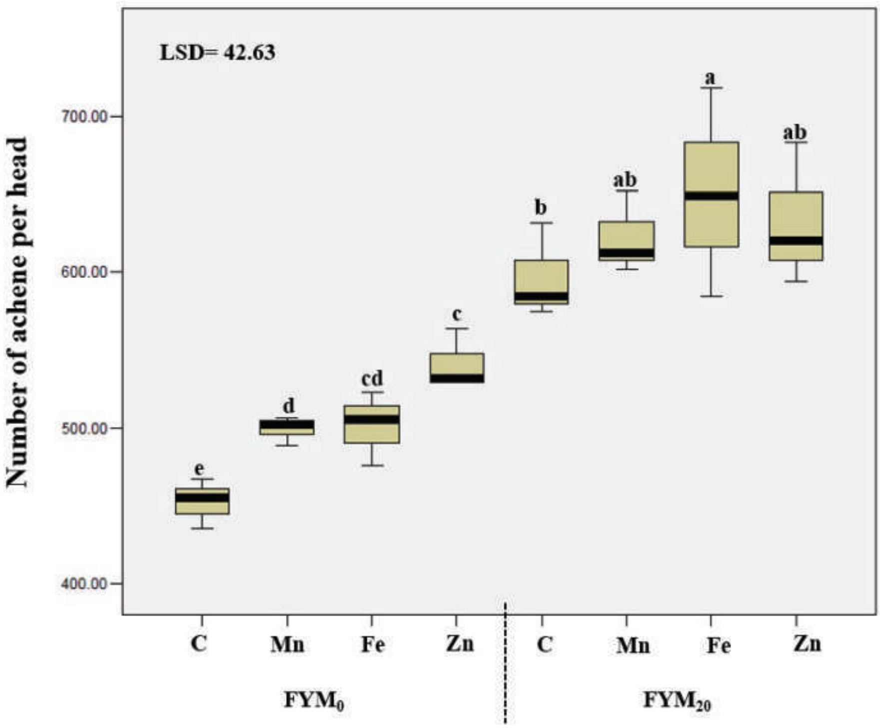

Figure 2: Effect of farmyard manure (FYM) and micronutrient (Fe, Zn, Mn) on the number of achene per head sunflower plants grown in Northwest of Iran. Values with different superscripts are significantly different (p < 0.05). All values are mean ± SEM.

Evaluation of achene yield showed that application of FYM increased grain yield by 30 %. The highest yield was obtained by application of Fe and Zn under FYM utilized condition. The effectiveness of micronutrient fertilizers was more evident under FYM utilized condition than inorganic conditions. However, the application of Zn under inorganic condition significantly increased achene yield. The interesting thing was that there was not a significant difference between control, Mn, and Fe under inorganic condition. However, the difference between micronutrients was evident under the FYM utilized condition (Figure 4).

Correlations between achene yield and leaf number, plant height, leaf area, main head diameter, number of the achene per head, achene width, chlorophyll concentration, relative water content (RWC), and 1,00-seed weight were positive and significant (Table 2). It was recognized by small angels between the mentioned traits. These traits showed the best performance by application of FYM_{20}-Zn (Figure 5).

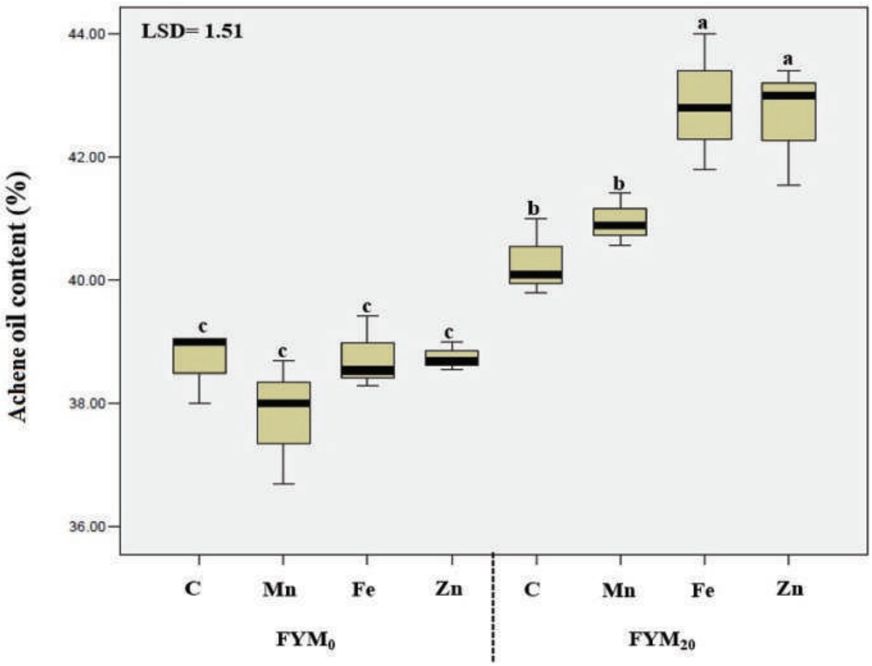

Figure 3: Effect of farmyard manure (FYM) and micronutrient (Fe, Zn, Mn) on the achene oil content of sunflower plants grown in Northwest of Iran. Values with different superscripts are significantly different (p < 0.05). All values are mean ± SEM.

Also, cluster analysis of combined treatments regarding the effect of treatments on yield component as well as phenological and physiological traits divided the treatments into three clusters based on Wilk's Lambada of multivariate analysis of variance. Cluster I included FYM0-C, FYM0-Mn, and FYM0-Fe, which had no prominent effects or showed the lowest performance. Cluster II included FYM0-Zn and FYM20-C, which slightly improved plant growth and affected the phenological developments. Cluster III included FYM20-Mn, FYM20-Fe, and FYM20-Zn, through which approximately the best performance was achieved (Figure 6).

Discussion

Soil nutrients similar to all agricultural inputs necessitate being managed appropriately to meet the fertility requirements of sunflower without adversely affecting the environmental aspects. Our result showed that the combined application of

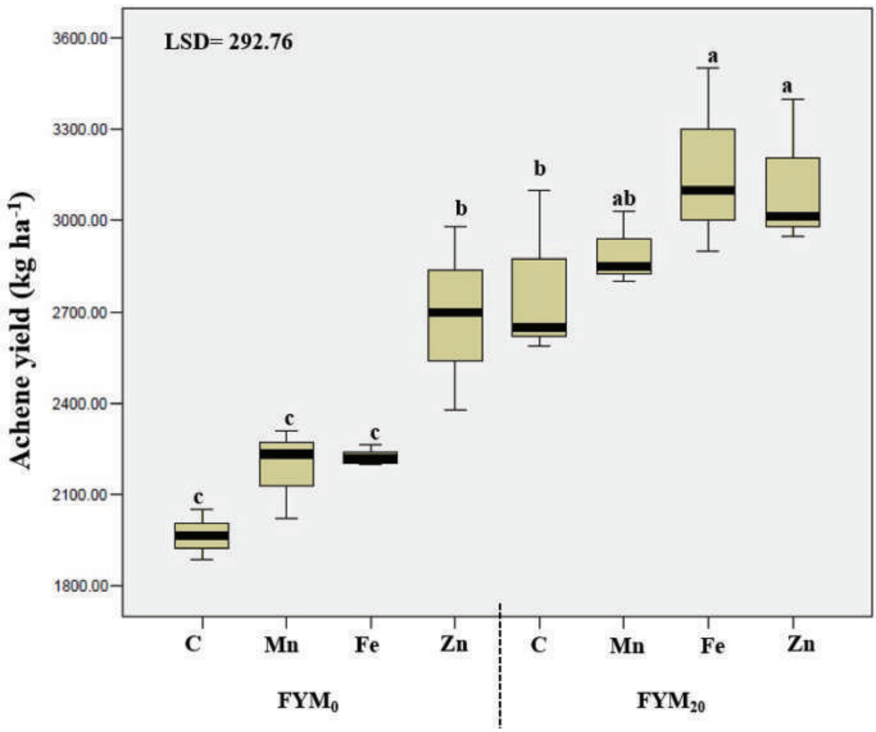

Figure 4: Effect of farmyard manure (FYM) and micronutrient (Fe, Zn, Mn) on achene yield of sunflower plants grown in Northwest of Iran. Values with different superscripts are significantly different ($p < 0.05$). All values are mean ± SEM.

FYM and micronutrient considerably increased the number of leaves, leaf area, and plant height. The increase in these components is all linked to an increase in the level of photosynthesis and access to more light. The plant can be divided into source and sink, sources being the parts where net fixation of carbon dioxide occurs, and sinks being the sites where assimilates are stored or used. Allocation of assimilates between plant parts occurs via transport in the phloem (Engels *et al.*, 2012). However, the source-sink relationship for yield in crops is not static and is strictly influenced by external environmental factors. Here, the results show that the application of FYM is necessary to improve the source size. Growth of source organs are definitely under the control of phytohormones, so it seems that the FYM and micronutrients indirectly affect source size by modulating the ratio of hormones or enhancing the phytohormones involved in growth such as auxin and cytokinin increases the leaf number and leaf area (Hänsch and Mendel, 2009; Marschner, 2012). This also accords with our earlier observations, which showed

Table 2: Pearson's correlation coefficients among morpho-physiological traits of sunflower (*Helianthus annuus* L.) under application of two levels of farm yard manure and micronutrients (Mn, Fe, Zn) in Maragheh region in North West of Iran.

	LN	PH	LA	SD	RWC	IL	MHD	CC	DF	DM	NAH	EA	HAW	AL	AW	OC	AY	BY
PH	0.87																	
LA	0.99	0.88																
SD	0.96	0.91	0.94															
RWC	0.98	0.85	0.98	0.93														
IL	0.91	0.78	0.93	0.86	0.95													
MHD	0.91	0.96	0.89	0.97	0.88	0.79												
CC	0.94	0.94	0.96	0.90	0.96	0.91	0.90											
DF	−0.85	−0.93	−0.88	−0.88	−0.86	−0.86	−0.86	−0.92										
DM	0.83	0.71	0.81	0.78	0.81	0.73	0.80	0.76	−0.72									
NAH	0.95	0.90	0.95	0.91	0.94	0.84	0.92	0.95	−0.79	0.73								
EA	−0.93	−0.77	−0.94	−0.85	−0.90	−0.83	−0.76	−0.87	0.84	−0.70	−0.84							
HAW	0.96	0.85	0.96	0.90	0.94	0.86	0.91	0.91	−0.78	0.90	0.95	−0.82						
AL	0.85	0.89	0.88	0.84	0.85	0.78	0.81	0.92	−0.86	0.50	0.90	−0.88	0.75					
AW	0.91	0.91	0.89	0.92	0.91	0.78	0.93	0.92	−0.79	0.69	0.96	−0.80	0.87	0.90				
OC	0.93	0.87	0.96	0.90	0.95	0.97	0.84	0.95	−0.90	0.67	0.90	−0.88	0.87	0.90	0.84			
AY	0.92	0.93	0.93	0.90	0.91	0.83	0.94	0.94	−0.81	0.76	0.98	−0.76	0.95	0.85	0.93	0.89		
BY	0.90	0.92	0.90	0.88	0.87	0.77	0.93	0.91	−0.77	0.73	0.97	−0.74	0.94	0.84	0.92	0.85	0.99	
HI	0.92	0.90	0.92	0.90	0.95	0.92	0.91	0.96	−0.85	0.79	0.93	−0.76	0.93	0.82	0.91	0.92	0.95	0.91

Critical values of correlation $p < 0.05$ and $p < 0.01$ are 0.75 and 0.90, respectively. Abbreviations: PH = plant height, LA = leaf area, SD = stem diameter, RWC = relative water content, IL = internode length, MHD = mean head diameter, CC = chlorophyll content (SPAD unit), DF = number of day to flowering, DM = number of day to maturity, NAH = number of achene per head, EA = percent of empty achene, HAW = 100-achene weight, AL = achene length, AW = achene width, OC = oil percentage of achene, AY = achene yield, BY = biological yield, HI = harvest index.

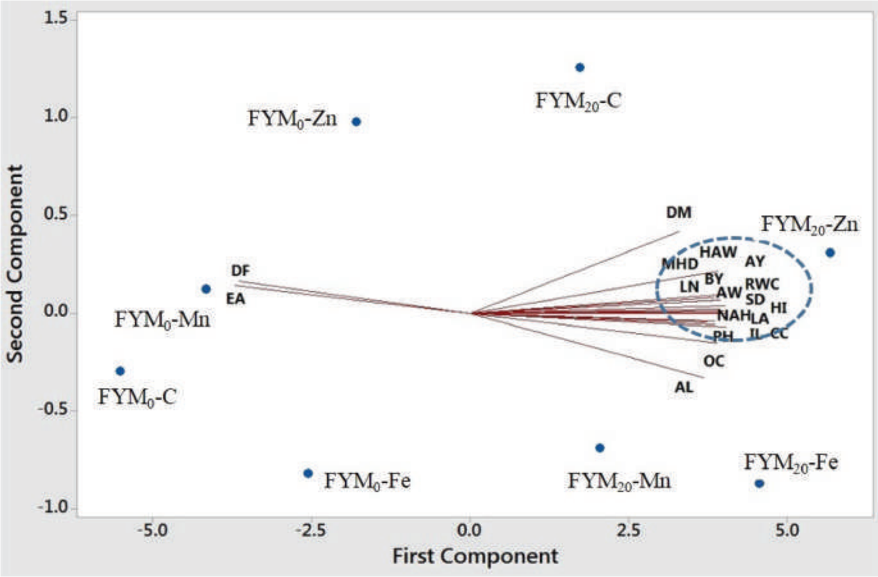

Figure 5: Biplots for the first and second principal components used for mean agronomic traits in sunflower plants grown by different level of farm yard manure (FYM) and micronutrients. FYM0 = without farm yard manure, FYM20 = application of FYM 20 t ha^{-1}, PH = plant height, LA = leaf area, SD = stem diameter, RWC = relative water content, IL = internode length, MHD = mean head diameter, CC = chlorophyll content (SPAD unit), DF = number of day to flowering, DM = number of day to maturity, NAH = number of achene per head, EA = percent of empty achene, HAW = 100-achene weight, AL = achene length, AW = achene width, OC = oil percentage of seed, AY = achene yield, BY = biological yield, HI = harvest index.

that application of FYM in the semi-arid region is essential to improve plant growth and extension of photosynthetic organs (Janmohammadi *et al.*, 2014). Examination of leaf chlorophyll content also confirmed this assumption. Results showed that a combination of FYM and micronutrients, especially Fe and Zn, was also needed to improve source strength. The observed increased magnitude of chlorophyll due to application of fertilizers is verifies earlier findings in this field. Improving physical and chemical properties of soil as well as suitable fertilizer application had good influence on crop yield mainly through affecting source capacity via the net photosynthetic rate, total leaf area and leaf life span (Li *et al.*, 2016).

Plants try to ensure their survival under adverse conditions by changing the length of their developmental periods and accelerating them. Our finding in the current study showed that combined application of FYM and Zn and Fe tended to decrease the number of days to initiation of the flowering. That means that under combined application of FYM and micronutrients plants spend much of

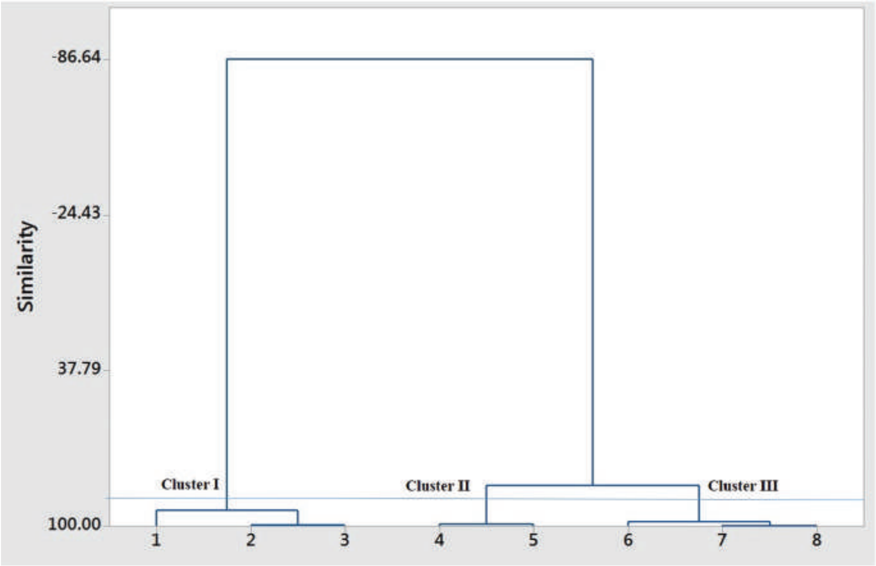

Figure 6: Grouping of different combined treatments of FYM and micronutrient fertilizer in terms of similarities in influencing the growth and yield of sunflower. 1 = FYM_0 + C, 2 = FYM_0 + Mn, 3 = FYM_0 + Fe, 4 = FYM_0 + Zn, 5 = FYM_{20} + C, 6 = FYM_0 + Mn, 7 = FYM_0 + Fe, 8 = FYM_0 + Zn.

their growing time for flowering and growth of economic yields (achene) and this will have a significant effect on improving the harvest index. It was while that plants grown by combined application of FYM and Zn had a longer maturity period and this confirms the above. So that they will be able to make more use of environmental resources such as light and ultimately, this could lead to greater performance. Zinc plays a critical role as a cofactor in all enzymatic groups and, therefore, can regulate the actions of several genes (Hänsch and Mendel, 2009). Due to zinc deficiency in the soils of semiarid regions and its wide range of functions, its superiority over other micronutrients is justifiable.

Application of FYM significantly improved the RWC. According to semi-arid climatic conditions, this trait is very important. It seems that the application of FYM improved the moisture status of the plant by improving soil moisture-holding capacity. A high correlation between seed yield and RWC re-emphasize the importance of water status in studied site.

Reduced the number of empty achene and increased yield components (head diameter, number of achene per head, 100-achene weight, achene length, achene width) due to the combined application of FYM and micronutrients can be due to the direct effect of fertilizers on the sink strength through phytohormonal changes, or it can be indirectly caused by the improved ability of the source for supply of photoassimilates. The present findings seem to be consistent with our previous research which, found that oil content can be improved by the application of Zn and Fe (Pasandi *et al.*, 2018).

Conclusions

Based on findings, following conclusions can be made that includes; the soil of studied site is facing a severe shortage of organic matter and micronutrients, and application of organic fertilizers such as farm yard manure are necessary for this area. The efficiency of micronutrient fertilizers is extremely low under FYM free condition. Increase of achene yield due to the application of FYM and micronutrient fertilizers can be attributed to phenological changes and improvement of yield components and physiological. However, the efficiency and effectiveness of micro fertilizers are strongly influenced by soil conditions and presence of buffers such as organic matter. From this study, it can be accomplished that integrated application of FYM, Zn, and Fe should be considered to achieve higher achene yield as well as oil contents under agro-climatic conditions of Maragheh-Iran.

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