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Full Length Research Paper

Effects of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomilla* L.)

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In order to evaluate the effects of foliar application of micronutrients (iron and zinc) on yield and essential oil of chamomile, two field experiments were carried out in 2008 and 2009 at the Research Station of Faculty of Agriculture, University of Tabriz, Iran. Both experiments were arranged as factorial on the basis of randomized complete block design (RCBD) with four replications. Treatments were foliar application of micronutrients (Fe, Zn and Fe + Zn through ferrous sulphate and zinc sulphate at the concentration of 0.35%) and time of application (at stem elongation, flowering and both stages) with control (without foliar application). The results showed that flower yield, essential oil percentage, and essential oil yield increased by foliar application of Fe and Zn compared with control (untreated). The highest flower yield (1963.0 kgha^{-1}), essential oil percentage (1.062%), and essential oil yield (20.835 kgha^{-1}) were obtained for Fe + Zn spray treatment with about 46.4, 24.64, and 81.77% improvements in comparison with control, respectively. The time of foliar application had significant effect on flower dry yield, essential oil percentage and essential oil yield. The foliar application at both stages of stem elongation and flowering had more beneficial effects on these characters as compared with spray at only one stage. It seems that foliar application of iron and zinc can considerably improve flower yield and essential oil content of chamomile especially in calcareous soils.

Key words: Chamomile, essential oil, foliar application, iron, yield, zinc.

INTRODUCTION

During the recent decades, medicinal plants gained a substantial importance in agricultural production, pharmacy and exportation because of their use as a raw material for the pharmaceutical industry (Abou-Arab and Abou, 2000). Chamomile [*Matricaria chamomilla* L., syn.*Chamomilla recutita* L.] (*Asteraceae*) belongs to a major group of cultivated medicinal plants. Chamomile anthodia (*Matricariae flos* drug) are used therapeutically, mainly due to their anti-inflammatory and spasmolytic effects (Schilcher, 1987). It is an important medicinal and aromatic plant of both traditional and modern systems of medicine. The blue essential oil of flowers of this plant has a wide application in medicine, cosmetics, and foodstuffs, in the flavouring of alcoholic and non-alcoholic beverages (Sashidhara et al., 2005).

A balanced fertilization program with macro and micronutrients in plant nutrition is very important in the production of high yield with high quality products (Sawan et al., 2001). For adequate plant growth and production, micronutrients are needed in small quantities; however, their deficiencies cause a great disturbance in the physiological and metabolic processes in the plant (Bacha et al., 1997). Plants normally take up nutrients from soils through their roots although nutrients can be supplied to plants as fertilizers by foliar sprays. Foliar feeding is a relatively new and controversial technique of feeding plants by applying

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Abbreviations: RCBD, Randomized complete block design; **Cu,** copper; **Zn,** zinc; **Fe,** iron; **Mn,** Manganese.

Table 1. Monthly temperature and precipitation during the growing season in 2008 and 2009.

	Average temperature (°C)						Total precipitation (mm)	
	Minimum		Maximum		Mean			
Month	2008	2009	2008	2009	2008	2009	2008	2009
May	6.7	7.7	22.6	23.7	14.65	15.7	0	6
June	12.6	11.6	28.7	27.3	20.65	19.45	7	64
July	16.3	15.9	32.5	31.1	24.4	23.5	20	1.8
August	16.7	15.5	33.7	37.9	25.2	26.7	0	0

liquid fertilizer directly to their leaves (Bernal et al., 2007; Baloch et al., 2008). Throughout the world microelements as Fe, Zn, Mn and Cu are added to foliar fertilizers, in order to compensate their deficiency especially in arid and semi arid regions (Kaya et al., 2005). Micronutrients, especially Fe and Zn, act either as metal components of various enzymes or as functional, structural, or regulatory cofactors. Thus, they are associated with saccharide metabolism, photo-synthesis, and protein synthesis (Marschner, 1995). Iron is mainly present in the form of insoluble Fe (III), therefore, unavailable to higher plants, particularly in neutral and alkaline soils (Shao et al., 2007).

Essential oil of *Mentha piperita* increased by 28.2% by foliar application of 3 ppm zinc chloride foliar application compared with the control (Akhtar et al., 2009). Essential oil biosynthesis in basil *(Ocimum sanctum* L.) is strongly influenced by Fe and Zn (Misra et al., 2006). Misra and Sharma (1991) reported that zinc application stimulated the fresh and dry matter production, essential oil and menthol concentration of Japanese mint. Foliar spraying with zinc (100 ppm) in blue sage (*Salvia farinacea* L.) enhanced the length of peduncle, length of main inflorescence, number of inflorescence and florets, and fresh and dry weight of inflorescences/ plant (Nahed and Balbaa, 2007). Influence of microelements especially iron and zinc on the yield and essential oil of chamomile plants is not well documented. Therefore, the purpose of this research is to investigate the effect of foliar application of iron and zinc at different stages of growth on flower yield and essential oil of *M. chamomilla* in a calcareous soil.

MATERIALS AND METHODS

Two field experiments were carried out in 2008 and 2009 at the Research Farm of the Faculty of Agriculture, University of Tabriz, Tabriz (37º, 5´ N, 46º, 17´ E and 1360 m mean sea level), Iran. The meteorological data recorded during the trial period both years are shown in Table 1. The physicochemical properties of soil and irrigation water characteristics are given in Table 2 (Page et al., 1982). The treatments were foliar application (Fe, Zn and Fe + Zn by using ferrous sulphate and zinc sulphate at the concentration of 0.35% for the both micronutrients) and time of foliar application (at stem elongation, flowering and both stages) with control (without foliar application). These treatments were arranged in a factorial experiment on the basis of randomized complete block design with four replications.

Seeds of chamomile (*M. chamomilla* L.) obtained from Hungary and planted on prepared plots in May 2008 and 2009. The plots were 4 x 2 m with 6 rows, 0.30 m row distance and 0.10 m seed distance. Required fertilizers except iron and zinc were added to the plots according to soil test results (Table 2). Soil moisture was kept at adequate levels to prevent water deficit and wilting. Weed control was done by hand as required. Foliar spray was done according to experimental treatments. Flowers were harvested four times from three central rows (1 m^2) in 7 - 10 days intervals. Flowers were dried in a shady place and prepared for essential oil extraction. 15 g dry flowers of chamomile were hydro-distilled in a modified Clevenger apparatus in 1000 mL round bottomed flaks with 500 mL distilled water for 4 h (Hoelz and Demuth, 1975; Letchamo, 1993). Data were analyzed using MSTATC statistical package. The least significant difference (LSD) at 5% level was used to compare the means of treatments.

RESULTS AND DISCUSSION

Foliar application of iron, zinc and iron + zinc and time of application had significant effects on flower yield, essential oil percentage and essential oil yield ($p<0.01$). Flower yield and percentage of essential oil were also significantly affected by year ($p<0.05$). However, the interactions of these treatments were not significant ($p\geq0.05$) for any of the parameters. The highest mean flower yield was obtained by the foliar application of Fe + Zn, 46.4% improvement in comparison with the control (Table 3). A similar effect of Zn supply on this parameter was also reported on *M. chamomilla* (Grejtovský et al., 2006), *S. farinacea* (Nahed and Balbaa, 2007), *Coriandrum sativum* (Said-Al Ahl and Omer, 2009) and *Ocimum basilicum* (Said-Al Ahl and Mahmoud, 2010). Zinc is one of the eight essential trace elements which is necessary for the normal healthy growth and reproduction of crop plants (Parker and Thomason, 1992).

The positive effects of Fe and Zn on plant may be due to their effects as a metal component of some enzymes or regulatory for the others. Moreover, they have essential roles in plant metabolism (Abd El-Hady, 2007). Essential oil percentage of chamomile flowers was significantly increased by foliar application of Fe + Zn. It was improved by 10.16, 7.48 and 24.64% in

Table 2. Physico-chemical properties of the soil and irrigation water characteristics.

Soil properties	Values	Water characteristics	Values
EC (dS m^{-1})	0.195	EC (dSm^{-1})	0.646
pH	7.96	pH	7.28
Saturation Percentage	29	Ca^{2+} ($meqL^{-1}$)	3.00
Organic carbon (%)	0.9	Mg^{2+} ($meqL^{-1}$)	2.00
Total N (%)	0.09	Na^{+} ($meqL^{-1}$)	2.25
Available P ($mgkg^{-1}$)	10.8	Cl^{-} ($meqL^{-1}$)	1.50
Available K ($mgkg^{-1}$)	294	HCO_3^{-} ($meqL^{-1}$)	4.60
Mn (mg kg^{-1})	4.88	CO_3^{-2} ($meqL^{-1}$)	Nil
Zn (mg kg^{-1})	0.22		
Fe (mg kg^{-1})	1.88		
Cu (mg kg^{-1})	1.02		
Calcium Carbonate equivalent (gkg^{-1})	110		
Soil texture	Sandy loam		

Table 3. The influence of iron and zinc foliar application on flower yield, essential oil percentage and essential oil yield of *M. chamomilla* L. (Means of the two years).

Application treatments		Flower yield (kg .ha^{-1})**	Essential oil (%)**	Essential oil yield (kg .ha^{-1})**
Control(untreated)		1340.8	0.852	11.462
Iron		1725.9	0.964	16.602
Zinc		1674.4	0.988	16.495
Iron + Zinc		1963.0	1.062	20.835
$LSD_{0.05}$†	Control Versus Other	123.33	0.03	1.378
	Other	87.22	0.026	0.974
CV %		10.53	5.9	11.85

† Control: n = 8 and Other: n = 24. ** Significant at 1% levels.

comparison with the foliar application of Fe, Zn and control, respectively (Table 3). These results are in agreement with those reported for Japanese mint (Misra and Sharma, 1991), *O. sanctum* (Misra et al., 2006), peppermint (Akhtar et al., 2009) and sweet basil (Said-Al Ahl and Mahmoud, 2010). The highest essential oil yield (20.835 kg.ha^{-1}) was obtained by the foliar application of Fe and Zn followed by separate application of Fe and Zn. The difference in essential oil yield between the latter treatments was not significant, but essential oil yield of control was significantly lower than that of other treatments (Table 3). Zehtab-Salmasi et al. (2008) reported that essential oil yield of *M. piperita* increased by the application of these micronutrients. Said-Al Ahl and Mahmoud (2010) also obtained the highest values of essential oil yield by foliar spraying of a mixture of iron + zinc in sweet basil.

The highest flower yield (1894.6 kg.ha^{-1}) was observed in the plants that treated at both stages of stem elongation and flowering. There was no significant difference between foliar application at two stages of stem elongation and flowering (Table 4). The essential oil percentage for the foliar applications of Fe and Zn at different stages of chamomile development (stem elongation, flowering and both stages) was statistically similar, but it was significantly higher than that for control (Table 4). Foliar application of Fe and Zn at both stages (stem elongation + flowering) led to the highest production of essential oil yield, which was 67.68% more than that of control. Foliar application of the nutrients at the individual stages (stem elongation or flowering) was also significantly improved the essential oil yield of chamomile (Table 4).

Micronutrients, especially Fe and Zn act as metal components of various enzymes and also are associated with saccharide metabolism, photosynthesis, and protein synthesis and Iron has important functions in plant metabolism, such as activating catalase enzymes associated with superoxide dismutase, as well as in photorespiration, the glycolate pathway and chlorophyll content. Zinc is an essential micronutrient for synthesis of auxin, cell division and the maintenance of membrane structure and function. Zinc deficiency reduces plant growth, pollen viability, flowering, number of fruits and seed production (Sharma et al., 1990; Marschner, 1995). Therefore, sufficient amount of these nutrients in

Table 4. The influence of time of foliar application (iron and zinc) on flower yield, essential oil percentage and essential oil yield of *M. chamomilla* L. (Means of the two years).

Application treatments		Flower Yield (kg .ha^{-1})**	Essential Oil (%)**	Essential Oil Yield (kg .ha^{-1})**
Control (untreated)		1340.8	0.852	11.462
Stem elongation stage		1759.3	0.989	17.462
Flowering stage		1709.4	1.010	17.250
Both stages		1894.6	1.014	19.220
$LSD_{0.05}$†	Control Versus Other	123.33	0.03	1.378
	Other	87.22	0.026	0.974
CV %		10.53	5.9	11.85

† Control: n = 8 and Other: n = 24. ** Significant at 1% levels.

Table 5. The influence of year (2008 & 2009) on flower yield, essential oil percentage and essential oil yield of *M. chamomilla* L.

Year	Flower yield (kg .ha^{-1})*	Essential oil (%)*	Essential oil yield (kg .ha^{-1})^{ns}
2008	1846.8	0.963	17.846
2009	1641.3	1.016	16.805
$LSD_{0.05}$†	126.55	0.033	4.144
CV %	10.53	5.9	11.85

†n = 40, * significant at 5 % levels, ^{ns} non significant at 5% levels.

the plant is necessary for normal growth, in order to obtain satisfactory yield. Although, foliar application of various macro and micro nutrients has been proved beneficial, foliar feeding is a relatively new and controversial technique of feeding plants by applying liquid fertilizer directly to their leaves (Baloch et al., 2008; Yassen et al., 2010). Abd El- Wahab (2008) reported that micronutrients such as iron, manganese and zinc have important roles in plant growth and yield of aromatic and medicinal plants. The foliar application of mineral nutrients offers a method of supplying nutrients to higher plants that are more efficiently than methods involving root application when soil conditions are not suitable for nutrients availability (Erdal et al., 2004). Flower yield in the first year (2008) was greater than that in the second year (2009). In contrast, the highest essential oil percentage was obtained in the second year. Consequently, essential oil yield per unit area was statistically similar for both years (Table 5).

Conclusion

In general, it can be concluded that foliar application of Fe and Zn can considerably improve the flower and essential oil yields of chamomile, particularly if these micronutrients were applied together at both stages of stem elongation and flowering.

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