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Effect of foliar application of micronutrients and potassium humate on growth and flower yield of African marigold (*Tagetes erecta* L.)

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ABSTRACT

A field experiment was conducted in the Department of Horticulture, Faculty of Agriculture, Annamalai University, Tamil Nadu during 2016 to study the effect of foliar application of micronutrients and potassium humate on growth and flower yield of African marigold (Tagetes erecta L.). The experiment was laid out in the randomized block design with three replications and 13 treatments. The micronutrient viz., 0.5% $ZnSO_4$, 0.5 % $FeSO_4$, 0.5% $MgSO_4$ and 1% potassium humate in 12 different combinations were sprayed as foliar spray on 25 DAT and 50 DAT along with water spray as control. The F1 hybrid Maxima Yellow was used for this study. Foliar application of all the treatments significantly influenced the growth, flowering and yield parameters of African marigold when compared with control. Among the thirteen treatments, the highest plant height (64.32cm), plant spread (53.04cm), number of branches (22.49), number of leaves (202.15), leaf area (50.85cm), dry matter production (116.23 g plant^{-1}), number of flowers plant^{-1} (43.8), flower diameter (11.0cm), single flower weight (11.45g), flower yield per plant (468.4g) and xanthophylls content (6.02 mg g^{-1}) were observed in treatment which received foliar application of 0.5% $ZnSO_4$ + 0.5%$FeSO_4$ +0.5% $MgSO_4$ and 1%potassium humate on 25 DAT and 50 DAT. Foliar application of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ +1% Potassium humate was found to be the next best treatment with respect to all yield attributes and xanthophylls content (5.67 mg g^{-1}).

Keywords: Foliar nutrition, micronutrients, potassium humate, African marigold.

INTRODUCTION

African marigold (*Tagetes erecta* L.) is one of the most popular flowering annuals cultivated commercially in various parts of India including Tamil Nadu. African marigold is known for its clump forming habit. It is not only grown as ornamental flower and landscape plant but also as a source of natural carotenoid pigment, which is used in poultry feed supplements, pharmaceuticals, cosmetics, textile industries etc. In recent years, availability of newly developed F1 hybrids and demand for its lutein content has resulted in increasing trend of area under marigold cultivation. Further, this crop is becoming a cash crop both in traditional and non-traditional flower growing areas of Tamilnadu. Hence, different aspects of Marigold cultivation such as production technologies, post-harvest technologies and marketing linkages are to be improved to further bring this crop in limelight (Bharathi and Jawaharlal, 2014). As quality of the marigold is decided by the colourful bold flowers and xanthophylls content, the improved production technologies are aimed to improve these characters of the flowers. Quality of chrysanthemum flowers is influenced by the application of micronutrients, although required in smaller quantities, they are essential for crop growth and development. In recent past, micronutrients are gradually gaining momentum among the flower growers because of their beneficial nutritional support as well as their potential to ensure high yield with better quality. Studies have revealed the beneficial effect of $FeSO_4$ and $ZnSO_4$ on marigold with maximum growth, flowering, yield and quality parameters, like plant height, plant spread, number of branches, early flowering, number of flowers per plant, flower weight, flower yield, flower diameter and leaf chlorophyll content (Balakrishnan *et al.*,2007). The direct effect of humic acid on plant growth has been attributed to the increase in chlorophyll content, the acceleration of the respiration process, hormonal growth responses, increasing penetration in plant membranes or a combination of these processes. Considering the potential of HA in agriculture, various commercial humic acid based products were

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developed and these are widely marketed in the form of inexpensive soluble salts, referred to as potassium humate. Foliar application of fertilizer is particularly useful technique which can be designed to meet plants specific need for one or more micro or macro nutrients especially trace minerals and enable to correct deficiencies, strengthen weak or damaged crops, speed growth and grow better (Said-Al Ahl and Mahmoud, 2010). In light of the above facts this study was carried out to find the influence of foliar application of micronutrients and potassium humate on growth and development of African marigold and to standardize an ideal foliar nutrient combination for maximizing the flower yield and xanthophylls content.

MATERIALS AND METHODS

The field experiment was conducted in the Department of Horticulture, Faculty of Agriculture, Annamalai University, Tamil Nadu during 2016 in African marigold (*Tagetes erecta* L.). Seedlings of F1 hybrid Maxima yellow were grown in pro trays and transplanted at a spacing of 30 cm x 45 cm in flat beds of 2.7 m x 1.5 m dimension. The experiment was laid out in the Randomized block design with three replications. The 13 treatments include, T_1-0.5%$ZnSO_4$ + 1%potassium humate,T_2-0.5%$FeSO_4$ + 1%potassium humate, T_3-0.5 % $MgSO_4$ +1% potassium humate, T_4-0.5% $ZnSO_4$ + 0.5% $FeSO_4$,T_5-0.5%Fe SO_4 + 0.5% $MgSO_4$, T_6- 0.5% $ZnSO_4$ + 0.5% $MgSO_4$, T_7-0.5% $ZnSO_4$ + 0.5%$FeSO_4$+ 0.5 %$MgSO_4$, T_8-0.5%$ZnSO_4$ + 0.5% $FeSO_4$ + 1% potassium humate, T_9-0.5% Fe SO_4 + 0.5%$MgSO_4$ +1% potassium humate, T_{10}-0.5% $ZnSO_4$ + 0.5 % $MgSO_4$ + 1% potassium humate, T_{11}-0.5% $ZnSO_4$ + 0.5%$FeSO_4$ + 0.5%$MgSO_4$+ 1% potassium humate, T_{12}-1% potassium humate and T_{13}-Control. The micronutrient *viz.,* 0.5% $ZnSO_4$, 0.5 % $FeSO_4$, 0.5% $MgSO_4$ and 1% Potassium humate in 12 different combinations were sprayed as foliar spray on 25 DAT and 50 DAT along with water spray as control. Solutions of micronutrients *viz.,* Zn, Fe and Mg were prepared by using chelated forms of $ZnSO_4$, $FeSO_4$ and $MgSO_4$**.** Respective amount of $ZnSO_4$, $FeSO_4$ and $MgSO_4$ were dissolved in distilled water to make up 0.5% concentrations. Potassium humate solution was prepared by using Humisol® consisting 80 % humic acid and 12 % potassium. The growth, flowering and yield character were recorded at 30, 60 and 90 days after planting. The total chlorophyll content was determined by the Spectrophotometry method of Yoshida *et al.* (1971) and expressed in mg g^{-1} of fresh weight. Xanthophyll content was extracted and estimated from the flowers by the method of Neogy *et al.* (2001). The data recorded were subjected to statistical analysis by adopting the standard procedure of Panse and Sukhatme (1978).

RESULTS AND DISCUSSION

The results of the present investigation showed that foliar application of zinc sulphate, ferrous sulphate, magnesium sulphate and potassium humate markedly influenced the growth characters of marigold. The foliar application of micronutrient treatments exerted significant effect over control in different levels (Table 1). The treatment T_{11} (0.5% $ZnSO_4$ + 0.5% $FeSO_4$ +0.5% $MgSO_4$ + 1% potassium humate) envisaged the highest plant height (64.90 cm) than all other treatments followed by T_8 (0.5% $ZnSO_4$ + 0.5% $FeSO_4$ +1% potassium humate) with 63.44 cm. The least plant height was recorded in the T_{13} (control). The increase in the plant height might be due to increased synthesis of auxin, protein and utilization of carbohydrate in improving plant height. Zinc is required for the synthesis of Auxin IAA and for carbohydrate metabolism, protein synthesis and internode elongation for stem growth (Shukla *et al.*, 2009). In addition to that increase in plant height might be due to the action of iron as an important catalyst in the enzymatic reactions of the metabolism and would have helped in larger biosynthesis of photoassimilates thereby enhancing growth of the plants. Addition of humic acid along with micronutrients has played an additive effect in enhancing plant height in the current study.

The plant spread, number of branches and number of leaves were significantly influenced by the varying levels of the treatments. The treatment T_{11} (0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.5% $MgSO_4$ + 1% potassium humate) recorded significantly higher plant spread (53.04 cm), number of branches (22.49) and number of leaves (211.26) when compared to other treatments. Increase in plant spread due to the $ZnSO_4$ could be attributed to improved

Table 1: Effect of foliar application of micronutrients and potassium humate on growth parameters of African marigold (*Tagetes erecta* L.)

Foliar Treatments	Plant height (cm)	Plant spread (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Leaf area (cm^2)	Dry matter production (g plant^{-1})	Chlorophyll content (mg g^{-1})
T_1 0.5% $ZnSO_4$ + 1% Potassium humate	56.03	44.29	20.50	200.88	45.36	102.29	1.60
T_2 0.5 $FeSO_4$ + 1% Potassium humate	55.39	43.23	19.78	198.17	42.14	100.66	1.40
T_3 0.5 % $MgSO_4$ +1% Potassium humate	54.11	42.24	18.34	194.17	40.30	98.77	1.30
T_4 0.5% $ZnSO_4$ + 0.5% $FeSO_4$	56.01	44.25	20.49	200.83	44.17	102.18	1.59
T_5 0.5% Fe SO_4 + 0.5% $MgSO_4$	55.11	43.43	19.18	198.12	42.02	100.13	1.39
T_6 0.5% $ZnSO_4$ + 0.5 % $MgSO_4$	54.07	42.20	18.30	194.13	40.22	98.14	1.25
T_7 0.5% $ZnSO_4$ + 0.5% $FeSO_4$+ 0.5 % $MgSO_4$	56.36	44.80	20.15	201.56	44.03	103.77	1.58
T_8 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 1% Potassium humate	63.44	50.80	21.47	208.97	50.59	110.45	2.03
T_9 0.5% Fe SO_4 + 0.5% $MgSO_4$ +1% Potassium humate	58.02	48.54	21.10	204.72	48.49	108.23	1.90
T_{10} 0.5% $ZnSO_4$ + 0.5 % $MgSO_4$ + 1% Potassium humate	62.32	46.10	20.78	202.15	46.88	104.43	1.77
T_{11} 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.5 % $MgSO_4$ + 1% Potassium humate	64.90	53.04	22.49	211.26	50.85	116.23	2.15
T_{12} 1% Potassium humate	48.97	39.12	16.86	187.88	35.90	94.76	1.10
T_{13} Control	46.60	38.09	16.16	185.27	33.80	92.73	1.01
S. Ed	0.30	0.35	0.11	0.46	0.62	0.56	0.01
CD (P=0.05)	0.62	0.73	0.24	0.95	1.29	1.16	0.02

root system of plants resulting in absorption of more water and nutrients and its utilization. Ferrous sulphate is an essential component of several dehydrogenase, proteinase, peptidase and promotes growth hormones and closely associated with growth, all these factors contributed to cell multiplication, cell division and cell differentiation resulting in increased photosynthesis and translocation of food material which enhanced the plant spread. Moreover, micronutrients activate several enzymes and involved themselves in chlorophyll synthesis and various physiological activities. This could be attributed to better flow of various micronutrients, which might have favoured production of auxillary buds resulting in formation of more number of branches. These results observed in present study are in line with the reports by Kakade *et al.* (2009) in China aster and Kumar *et al.* (2010) in marigold. Enhanced growth observed in treatments with potassium humate in present study may be due to the role of potassium in plant metabolism and increased mineral uptake by plants. Hossain *et al.*,(2009) found that increasing potassium fertilizer levels increased shoot height, number of leaves per plant and shoot fresh weight.

Application of zinc was found to increase the green pigments of necrotic leaf of plants. Iron application increased the levels of all leaf pigments. The chlorophyll content is a major factor that determines the rate of photosynthesis which always combined as an index of metabolic efficiency of the plant to utilize the absorbed nutrients. In the present study, the highest chlorophyll content of 2.15 mg g^{-1} was recorded in the treatment T_{11} followed by treatment T_8 (2.03 mg g^{-1}). The least amount of chlorophyll content was observed in the control treatment T_{13} (1.88 mg g^{-1}) in control. Higher chlorophyll might be due to the better utilization of nitrogen for protein synthesis, which would have indirectly influenced the photosynthetic activity resulting in better production of assimilation. Magnesium and nitrogen as constituents of chlorophyll molecules and iron as catalyst in the process of chlorophyll synthesis might have increased the photosynthesis leading to enhanced growth. This might accelerate the synthesis of amino acids which are associated with major photosynthetic process of plants (Gouda *et al.,* 2001). Increase in total chlorophyll content observed in *Tagetes erecta* with addition of potassium humate in foliar solution might be attributed to the fact that Potassium has been reported to be involved in increased nutrient uptake by virtue of more chlorophyll formation with an increased leaf area. The total dry matter production was recorded the highest (116.23g $plant^{-1}$) in treatment T_{11} (0.5% $ZnSO_4$ + 0.5% $FeSO_4$ +0.5% $MgSO_4$ + 1% potassium humate). Enhanced dry matter production observed in the treatments which received potassium humate might be due to the fact that humic acid could sustain photosynthetic tissues and thus total dry weight would increase (Torkaman *et al.,* 2005).

Flowering and yield parameters of African marigold

Among the various treatments, application of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ +0.5% $MgSO_4$ + 1% potassium humate (T_{11}) was considered as the best treatment in terms of all flowering and yield parameters. The treatments with both micronutrients and potassium humate as components excelled well when compared with control and other treatments. The early flower bud initiation (28.3 days) and maximum duration of flowering (94.5 days) was observed in T_{11} followed by T_8 (Table 2). Extended flowering duration observed due to these treatments is a positive result as the availability of flowers are gradually stretched throughout the cropping season rather than synchronizing within a shorter duration. This will help the farmers getting a higher price and staggered harvest. In the present study, among the various micronutrient treatment T_{11} (0.5% $ZnSO_4$ + 0.5% $FeSO_4$ +0.5% $MgSO_4$ + 1% potassium humate) recorded the highest number of flowers $plant^{-1}$ (43.83), flower diameter (11.0cm), single flower weight (11.45g) and flower yield per plant (468.44g). T_8 (0.5% $ZnSO_4$ + 0.5% $FeSO_4$ +1% potassium humate) was considered as next best treatment in terms of these parameters. Increase in fresh weight of flowers might be attributed to increased fresh weight of complete stem due to good growth of plants. These findings are in accordance with the results of Khalifa *et al.* (2011), who noted fresh weight increase in Iris flowers due to foliar application of $ZnSO_4$. In present study, enhanced yield parameters observed due to combination of three micronutrients with potassium humate might have been due to the complementary effect of

Table 2: Effect of foliar application of micronutrients and potassium humate on yield and quality parameters of African marigold (*Tagetes erecta* L.)

Foliar Treatments	Days to flower bud initiation	Duration of flowering (Days)	No. of flowers $plant^{-1}$	Flower diameter (cm)	Single flower weight (g)	Flower yield $plant^{-1}$ (g)	Flower yield $plot^{-1}$ (kg)	Flower yield t ha^{-1}	Xanthophylls content (mg g^{-1})
T_1 0.5% $ZnSO_4$ + 1% Potassium humate	30.4	86.2	39.5	7.05	10.87	429.3	11.59	28.62	4.10
T_2 0.5 $FeSO_4$ + 1% Potassium humate	31.8	85.1	38.7	6.85	9.69	375.9	10.15	25.06	3.76
T_3 0.5 % $MgSO_4$ +1% Potassium humate	32.5	84.3	37.6	5.98	9.24	348.3	9.41	23.22	3.13
T_4 0.5% $ZnSO_4$ + 0.5% $FeSO_4$	30.5	86.5	39.3	7.03	10.79	424.6	11.47	28.31	4.08
T_5 0.5% Fe SO_4 + 0.5% $MgSO_4$	31.9	85.5	38.7	6.69	9.88	383.0	10.34	25.53	3.70
T_6 0.5% $ZnSO_4$ + 0.5 % $MgSO_4$	32.6	84.6	37.3	5.97	9.05	338.1	9.13	22.54	3.11
T_7 0.5% $ZnSO_4$ + 0.5% $FeSO_4$+ 0.5 % $MgSO_4$	30.1	86.1	39.9	7.13	10.74	428.4	11.57	28.56	3.82
T_8 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 1% Potassium humate	28.9	92.3	42.4	9.46	12.07	511.7	13.82	34.11	5.67
T_9 0.5% Fe SO_4 + 0.5% $MgSO_4$ +1% Potassium humate	29.0	90.1	41.2	8.15	11.64	480.2	12.97	32.01	5.01
T_{10} 0.5% $ZnSO_4$ + 0.5 % $MgSO_4$ + 1% Potassium humate	29.6	88.5	40.9	7.67	11.45	468.44	12.65	31.22	4.54
T_{11} 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.5 % $MgSO_4$ + 1% Potassium humate	28.3	94.5	43.8	11.0	12.61	552.9	14.93	36.86	6.02
T_{12} 1% Potassium humate	33.9	80.1	36.2	4.74	7.38	267.7	7.23	17.84	2.07
T_{13} Control	34.3	78.9	34.7	4.12	7.01	243.4	6.57	16.23	1.56
S. Ed	0.05	0.22	0.25	0.10	0.16	5.78	0.14	0. 54	0.08
CD (P=0.05)	0.10	0.44	0.52	0.20	0.32	11.93	0.29	0.11	0.18

these nutrients with each other as stated by Lahije (2012) in gladiolus. The highest flower yield of 18.78 kg plot $^{-1}$ and 36.86 kg ha^{-1} were recorded in treatment T_{11} (0.5% $ZnSO_4$ + 0.5% $FeSO_4$ +0.5% $MgSO_4$ + 1% Potassium humate). This enhancement in yield might be due to improved yield parameters like number of flowers plant^{-1}, flower diameter and single flower weight recorded in this treatment. The increase in flowering attributes might be due to the beneficial role of zinc and iron in enhancing the translocation of carbohydrates, minerals, water and aminoacids from the site of synthesis to the storage tissue especially on flowers which in turn increase the number, size and weight of flowers. These results are in conformity to the reports by Balakrishnan *et al.* (2007) in African marigold and Naveenkumar *et al.* (2009) in chrysanthemum.The treatment T_8 (0.5% $ZnSO_4$ + 0.5% $FeSO_4$ +1% Potassium humate) was found to be the next best to T_{11} with respect to all yield attributes. The treatment T_8 was considered better in all yield parameters when compared with T_7 (0.5% $ZnSO_4$ +0.5% $FeSO_4$+0.5% $MgSO_4$). This suggested that the application of potassium humate has greater effect than the $MgSO_4$ in the foliar nutrient combination. Application of zinc and iron not only relieved the chlorosis and produced healthy green plants with increased synthesis of chlorophyll. Further, mobility of minerals, water, photosynthates and aminoacids from the source to sink might have been augmented due to micronutrient in combination with potassium humate in foliar nutrients, which may intern increased the flower production and ultimately flower yield. The treatment T_{11} recorded the highest xanthophylls content of 6.02 mg g^{-1} followed by T_8 with 5.67 mg g^{-1} of Xanthophyll. The better quality of marigold flowers observed in these treatments might be due to assimilation of more essential nutrients and micro nutrients through foliar feeding and deposition of plant growth regulators and enzymes in flower cells by the physiological role zinc and iron. Enhancement in xanthophyll content of marigold flowers observed due to micronutrients is in line with Karuppaiah (2014) who observed increase in xanthophylls content of chrysanthemum flowers due to foliar application of Fe and Zn.

From the results, it can be concluded that foliar application of $ZnSO_4$ @ 0.5% + $FeSO_4$ @ 0.5% + $MgSO_4$ @ 0.5 % + Potassium humate @ 1% on 25 DAT and 50 DAT was found to have beneficial effect on growth, yield and quality parameters of marigold.

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