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Integrated Zinc and Iron Management Practices for Enhancing Productivity and Flower Quality of Marigold

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted at the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore during 2021-2022 to evaluate the effect of zinc and iron on growth, quality, yield and biochemical trait of marigold cv. Local Orange. The experiment was laid out in completely randomized design (CRD) with eight treatments and three replications. The eight treatments included an untreated control (T_1) , 100% RDF (T_2) , along with RDF soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ @ 10 and 15 kg ha^{-1} respectively (T_3), along with RDF soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ @ 15 and 20 kg ha^{-1} respectively (T_4), along with RDF soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ @ 20 and 25 kg ha^{-1} respectively (T_5), along with RDF foliar spray of $ZnSO_4$ and $FeSO_4$ each @ 0.5% (T_6), along with RDF foliar spray of $ZnSO_4$ and $FeSO_4$ @ 0.5 and 1.0 % respectively (T_7) , along with RDF foliar spray of 1.0 % liquid multi micronutrient (T_8). The effect was assessed on growth, quality, yield and xanthophyll content in marigold flower. The results revealed that foliar application of $ZnSO_4$ and $FeSO_4$ each @ 0.5 % along with RDF at 20DAT and 35DAT recorded maximum plant growth, flower quality and flower yield. On xanthophyll content foliar application of 1.0 % liquid multi micronutrient along with RDF produced significant effect compared to control. The present study

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revealed that the integrated application of zinc and iron fertilizer significantly improved the growth, yield, quality of marigold crop. However both soil application and foliar spray of zinc and iron showing significant effect compared to control for better productivity and flower quality of marigold.

Keywords: Zinc; iron; multi micronutrient; enriched FYM; marigold; xanthophyll.

1. INTRODUCTION

Marigold (*Tagetes erecta*) belonging to the family Asteraceae is one of the important annual commercial flower crops cultivated around the world. It is widely cultivated owing to its ease of growing. It is grown for loose flower and cut flower, garland making and garden display. It stands in second place next to Chrysanthemum among the annual flowers. The crop is also known for its potential to control root knot nematodes. The flowers are an important source of carotenoids [1]. It covers an area of 66.13 thousand hectares with 603.18 thousand metric tonnes of production in 2015-16 [2]. In India Andhra Pradesh and Tamil Nadu are major producers of marigold flower. India's maximum producer and the main trading centre for marigold is Erode, a city of Tamil Nadu. It covers an area of 2761 ha with 72.389 thousand metric tonnes of production and 26.22 metric tonnes productivity per hectare [3].

In Indian agriculture, the relevance of micronutrients is well understood as their application has greatly enhanced the production of a variety of crops. Micronutrients are as important as macronutrients in terms of plant development, yield, and quality. In the past, there was no need to supplement micronutrients in soil because these were naturally present. However, in most soils, due to intensive farming, increased salinity, and soil pH, these nutrients are not available to plants [4]. Micronutrient application has not only contributed in enhancing the food grain production but also helped in sustaining soil health. In India, micronutrient status is normally low. It has been estimated that the deficiency levels of available nutrients *viz.,* Fe, Zn, Mn, Cu and B in Tamil Nadu are 12.62%, 63.30%, 7.37%, 12.01% and 20.65% respectively. Among all micronutrients, deficiency of zinc is commonly prevalent in many of the districts in Tamil Nadu [5].

Iron plays a significant role in various physiological and biochemical pathways in plants. It serves as an element of many vital enzymes such as cytochromes of the electron transport chain, and it is thus required for a wide range of biological functions. In plants, iron is involved in the synthesis of chlorophyll, and it is essential for the maintenance of chloroplast structure and function [6]. Fe is needed for the synthesis of enzymes that produce chlorophyll it is used for catalytic activity, other metabolic activities like biological oxidation reduction in plants, oxidative photophosphorylation during cell respiration. Iron plays major role in the metabolism of carbohydrates and for the protein synthesis [7].

Zn is an important element for growth of plant as well as for other metabolic functions namely enzymatic activities, protein synthesis (regulatory cofactor), photosynthesis, synthesis of auxin, cell division, construction of membrane and sexual fertilization. Next to iron (Fe), zinc (Zn) is the second most abundant microelement in organisms, and it plays a vital role in a variety of biological activities [6]. Plants require zinc as a critical micronutrient because it is a component of many enzymes and proteins in organisms; it is an influential metal for appropriate growth and development in plants [8,9].

This study aimed to investigate the effect of varying quantities of iron and zinc in combination, when applied as soil with dissolved irrigation water and applied as a foliar spray, affecting the growth, blooming, and chemical composition of marigold under shade net house condition.

2. MATERIALS AND METHODS

The experiment was conducted during 2021-2022 at the Radioisotope (Tracer) Laboratory, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore. Coimbatore located in the North Western agro climatic zone of Tamil Nadu at (11 ^{0}N latitude, 77 ^{0}E longitudes and at an altitude of 426 meters above MSL). The mean annual maximum and minimum temperature are 31.5˚C and 21.2 ˚C, respectively. The mean annual rainfall is 657mm.

Shade net house was constructed with 50% green shade net. It provided a partially controlled climate and environment for the marigold crop by decreasing light intensity and effective heat during the day.

The pot experiment was conducted with marigold cv. Local Orange. The pot soil was clay loam in texture, slightly alkaline in reaction (pH of 7.52), medium in organic carbon (0.54 %) with low in available nitrogen (191.0 kg ha^{-1}), medium in available phosphorous (19.0 kg ha^{-1}) and high in available potassium (297.0 kg ha^{-1}), sufficient in both DTPA Mn (2.08ppm) and DTPA Cu (2.20ppm) but deficient in DTPA Zn (0.74ppm) and DTPA Fe (1.32ppm). The investigation included eight treatment combinations (listed out in Table) replicated three times, was laid out in completely randomized design.

2.1 Zinc and Iron Enriched FYM

Farmyard Manure (FYM) was collected from the farm at the Tamil Nadu Agricultural University, Coimbatore and used for application. $ZnSO_4$ and $FeSO_4$ were mixed with FYM in 1:10 ratio as per the treatments. The mixture was kept in polythene bags for incubation under anaerobic condition for 21 days. The mixture was turned over periodically and the moisture content was checked twice in a week.

2.2 Crop Husbandry

Earthen pots of height 25cm with inner diameter of 25cm were used for the experiment. Each pot was filled with 10kg of processed soil and the soil was watered and made to a fine tilth. Before transplanting, the soil was fertilized as per the blanket recommendation *viz*., 90:90:75 kg N: P_2O_5: K_2O $ha^{-1.}$ Full dose of the recommended phosphorus and potassium were applied as basal using single super phosphate and muriate of potash respectively as source of fertilizers. Half of the recommended dose of nitrogen was applied basally and the remaining half was applied as top dressing after transplanting. Enriched FYM was mixed with RDF and applied before transplanting. At the time of transplanting, a thin film of water was maintained in the pot. Twenty one days old seedlings were transplanted in the pot with three seedlings in each pot.

2.3 Preparation of Micronutrients Solution

Fresh stock solution of micronutrients with a known concentration was prepared. The micronutrients were first dissolved in a small amount of water, and then combined with water to create a stock solution. The needed concentrations of solution were then generated by dilution from the stock solution.

Liquid multi micronutrient developed by the Department of Soil Science and Agricultural Chemistry, TNAU, Coimbatore was used. It contains Zn (0.3567%), Fe (0.9651%), Mn (0.1456%) and Cu (1.1345%).$ZnSO_4$, $FeSO_4$ and multi micronutrient mixture were applied as foliar spray at two stages namely (20 DAT and 35 DAT).

The observations recorded included vegetative growth parameters namely plant height, number of branches, fresh weight of plant, dry weight of plant, flower yield and quality parameters namely diameter of flower, individual flower weight, shelf life of flower and xanthophyll content in the flowers.

2.4 Biochemical Traits

Total Xanthophyll content was estimated by AOAC method [10].

2.5 Statistical Analysis

The data obtained from the experiment were subjected to statistical analysis using AGRESS software version 7.01. The level of significance used was $p < 0.05$. Critical difference (CD) values were calculated for the $p < 0.05$ whenever "F" test was found significant [11].

Chart 1. Treatment details

Notation	Treatment details
T_1	Absolute Control
T_2	100% RDF (90:90:75 NPK kg ha^{-1})
T_3	RDF + soil application of FYM enriched $ZnSO_4$ @10 kg ha^{-1} and $FeSO_4$ @15 kg ha^{-1}
T_4	RDF +soil application of FYM enriched $ZnSO_4$ @15 kg ha^{-1} and $FeSO_4$ @20 kg ha^{-1}
T_5	RDF +soil application of FYM enriched $ZnSO_4$ @20 kg ha^{-1} and $FeSO_4$ @25 kg ha^{-1}
T_6	RDF + 0.5% $ZnSO_4$(foliar spray) + 0.5% $FeSO_4$(foliar spray)
T_7	RDF + 0.5%$ZnSO_4$(foliar spray) + 1.0%$FeSO_4$(foliar spray)
T_8	RDF + 1.0% liquid multi micronutrient (foliar spray)

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

The treatment T_6 (RDF + 0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS) recorded the maximum plant height (53.49 cm at 60 DAT) which was followed by T_8 (53.29 cm), where RDF was applied along with FS of 1.0% liquid multi micronutrient. The greater plant height in T_6 can be attributed to the foliar application of Zn and Fe which might have increased the cell division, cell elongation and other growth promoting hormones which was ultimately reflected as taller plants in the said treatment. Similar results were obtained earlier [12,15].

The highest number of branches (18.33 at 60 DAT) was recorded in T_6 (RDF + 0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS) followed by T_8 (17.00), whereas control showed minimum number of branches (9.67). Such a significant increased in number of branches is due to foliar application of zinc and iron which might have increased vegetative growth parameters of plant by involving in tryptophan and chlorophyll synthesis, which in turn helps to maintain polarity and apical dominance of plant. Similar results were obtained by earlier workers [6,16].

The treatment T_6 (RDF + 0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS) recorded the maximum fresh weight of plant (359.86g) which was followed by T8 (350.05g) whereas T_1 (control) recorded minimum (250.11g). The treatment T_6 recorded the maximum dry weight of plant (78.08g) which was followed by T8 (77.20g) while T_1 (control) recorded minimum (50.11g).This is due to application of zinc and iron which play major role in production of vegetative growth and ultimately encourage the biomass of plant, resulting in increased fresh and dry weight of plants [16-18].

3.2 Quality Parameters

Flowering, quality attributes namely individual flower weight, flower diameter, shelf life of flower were significantly influenced by Zn and Fe (Table 2).

The treatment T_6 (RDF + 0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS) recorded the maximum individual diameter of flower (6.76cm) which was followed by T_8 (6.62cm), where RDF was applied along with FS of 1.0% liquid multi micronutrient. The treatment T_1 (control) recorded the minimum (5.62cm) diameter of flower. This could be due to the fact that iron and zinc work together to regulate semi-permeability of cell walls that allowed enormous water to enter into flowers and also help for increasing iron synthesis, which promotes cell expansion in turn resulting in increased flower diameter [19,20].

The treatment T_6 (RDF + 0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS) recorded the maximum fresh flower weight (4.69g) which was followed by T_8 (4.65g), where RDF was applied along with FS of 1.0% liquid multi micronutrient. The treatment T_1 (control) recorded the minimum fresh flower weight (3.67g).Both zinc and iron enhance biomass of the plant which ultimately resulted in maximum fresh and dry weight of flower [21-23].

The treatment T_6 (RDF + 0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS) recorded the maximum dry weight of flower (1.05g) which was followed by T_8 (1.03g), where RDF was applied along with FS of 1.0% liquid multi micronutrient. The treatment T_1 (control) recorded the minimum dry weight of flower (0.75g).The results revealed application of zinc and iron might have accumulate dry matter alongside with increased availability and uptake of micronutrients which ultimately increased dry flower weight [24,25].

The treatment T_6 (RDF + 0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS) showed the maximum shelf life of flower (5.20 days) which was followed by T_8 (5.05 days), where RDF was applied along with FS of 1.0% liquid multi micronutrient. The treatment T_1 (control) recorded the minimum (2.50 days).The longest shelf life of flower in days observed in T_6 due to the foliar application of Zn and Fe because they play an important role in physiology *viz.,* carbohydrate metabolism, plant growth regulation and enzyme synthesis which results in good flower quality. Further this creates favourable condition inside the stem and gives strength against adverse condition after harvest.Similar results were reported by earlier [20,26,27].

3.3 Yield Attributes

The flower yield attributes namely number of flowers per plant, number of flowers per pot and flower yield were also significantly influenced by application of zinc and iron (Table 2).

The treatment T_6 (RDF + 0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS) recorded the maximum number of flowers plant^{-1} (15.67) which was followed by T_8 (14.67), where RDF was applied along with FS of

Table 1. Effect of Zn and Fe on growth parameters of marigold cv. Local Orange

Treatment	Plant height (cm)			No. of primary branches per plant			Fresh weight of plants (g)			Dry weight of plants (g)		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
T_1	25.80	32.94	42.92	5.00	8.00	9.67	170.05	210.06	250.11	26.10	38.11	50.11
T_2	26.32	33.44	43.42	7.00	10.00	11.67	189.79	240.87	272.71	41.06	53.07	65.07
T_3	28.55	35.64	47.64	8.00	11.00	13.67	205.82	256.89	315.81	46.04	58.05	70.05
T_4	29.22	36.32	48.32	10.00	13.00	15.33	210.68	261.75	327.67	48.06	60.07	72.07
T_5	29.98	37.08	49.07	11.00	14.00	16.67	216.18	267.25	340.11	50.53	62.54	74.54
T_6	34.39	41.50	53.49	13.00	16.00	18.33	247.95	299.00	359.86	54.07	66.08	78.08
T_7	31.37	38.56	50.64	11.00	14.00	15.67	226.15	277.22	343.15	51.65	63.66	75.66
T_8	34.10	41.24	53.25	12.00	15.00	17.00	245.89	296.94	350.05	53.19	65.20	77.20
SEd	0.12	0.09	0.07	0.82	0.04	0.53	0.83	0.78	0.08	1.16	0.57	0.57
CD (0.05)	0.25	0.19	0.14	0.09	1.12	1.12	1.76	1.65	0.16	2.46	1.21	1.21

Table 2. Effect of Zn and Fe on quality, yield and biochemical parameter of marigold cv. Local orange

Treatment	Diameter of flower (cm)	Fresh weight of flower (g)	Dry weight of flower (g)	No. of flowers per plant	No. of flowers per pot	Yield of flowers per plant (g/plant)	Yield of flowers per pot (g/pot)	Shelf life of flowers (days)	Xanthophyll content (mg/g)
T_1	5.62	3.67	0.78	6.33	19.33	23.24	70.95	3.50	1.30
T_2	5.82	3.80	0.83	8.67	25.67	32.93	97.53	3.90	1.36
T_3	5.90	4.34	0.90	11.00	32.67	47.74	141.77	4.30	1.45
T_4	5.95	4.40	0.95	11.33	34.00	49.87	149.60	4.51	1.49
T_5	6.01	4.50	0.97	12.67	38.33	57.00	172.50	4.49	1.55
T_6	6.76	4.69	1.05	15.67	46.33	73.48	217.30	5.20	1.67
T_7	6.21	4.62	0.98	13.67	41.00	63.14	189.42	4.53	1.65
T_8	6.62	4.65	1.03	14.67	44.00	68.20	204.60	5.06	1.73
SEd	0.51	0.10	0.01	0.53	1.28	2.39	6.79	0.09	0.03
CD (0.05)	1.08	0.22	0.02	1.12	2.71	4.90	14.40	0.20	0.06

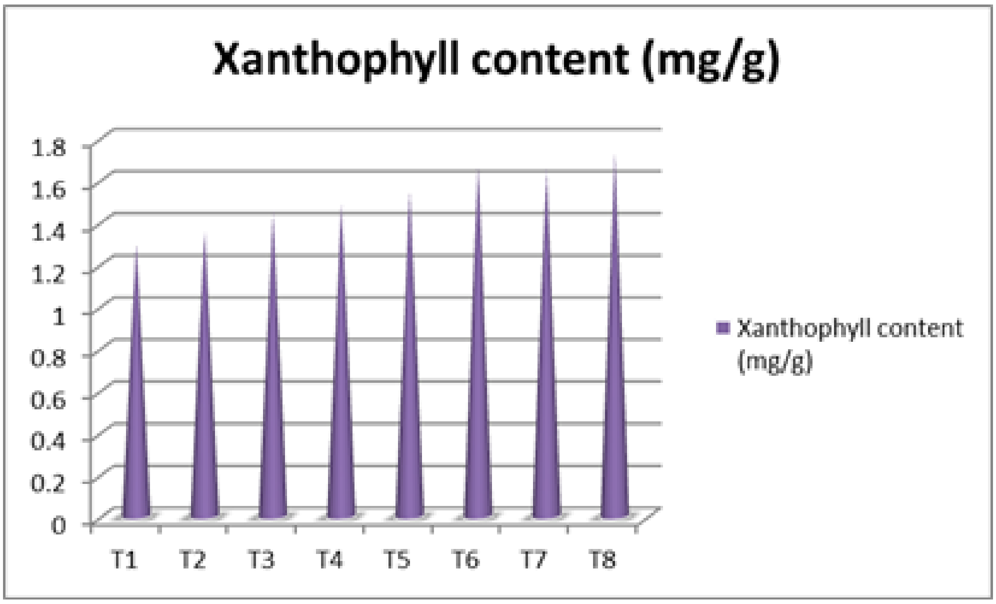

Fig. 1. Effect of zinc and iron on xanthophyll content of marigold cv. Local Orange

1.0% liquid multi micronutrient. The treatment T_1 (control) recorded the minimum number of flowers plant^{-1} (6.33). Application of iron and zinc either through foliar spray or soil application might have increased vegetative growth and this in turn might have led to production of more food material resulting in better development enabled by enhanced RNA metabolism, formation of DNA, synthesis of proteins, formation of pollen [9,18,28] ultimately leading and increase in number of flowers per plant.

The treatment T_6 (RDF + 0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS) recorded the maximum flower yield plant^{-1} (73.48g) which was followed by T_8 (68.20g), where RDF was applied along with FS of 1.0% liquid multi micronutrient whereas the treatment T_1 (control) recorded the minimum flower yield plant^{-1} (23.24g).This results showed that application of zinc and iron increased the synthesis of chlorophyll, growth promoting substances and mobility of minerals, water, photosynthesis and amino acids from source to sink which might have increased the flower production and ultimately flower yield. Similar results were also obtained by earlier workers [9,25,28].

3.4 Biochemical Parameter

The treatment T_8 (RDF + 1.0% liquid multi micronutrient) recorded the maximum xanthophyll content in flower (1.73mg/g) which was followed by T_6 (1.67mg), where (RDF+0.5% $ZnSO_4$ FS + 0.5% $FeSO_4$ FS). The treatment T_1 (control) recorded the minimum xanthophyll content (1.30mg/g). This could be due to fact that iron plays a vital role in chlorophyll biosynthesis and zinc is favourable for influencing photosynthetic pigments, application of Zn and Fe might have helped in improving the photosynthetic electron transfer and photosynthesis rates leading to increased xanthophyll content in flowers. Similar results were reported earlier [3,15,17,25].

4. CONCLUSION

The importance of Zn and Fe in the cultivation of marigold could be well demonstrated in the present experiment. The foliar method of application of nutrients makes it to absorb and translocate quickly within the plants and its timely application results its accumulation in flower parts. The study indicated that enriched FYM, foliar application zinc and iron significantly affect the plant growth, flower quality and flower yield. The results revealed that marigold cv. Local Orange responded better to foliar application of $ZnSO_4$ and $FeSO_4$ each @ 0.5% at two stages *viz.* 20 and 35 days after transplanting. These micronutrients improved the vegetative growth attributes, flower yield and quality. Application of 1.0% liquid multi micronutrient which contains zinc and iron significantly enhanced the biochemical trait *viz*. xanthophyll content (mg/g) of flowers [29].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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