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Nutrient uptake by African marigold (*Tagetes Erecta* L.) as influenced by fertigation, irrigation and mulching

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Abstract
A field experiment was conducted at ICAR-Indian Institute of Horticultural Research, Bengaluru during *kharif* and *rabi* seasons of 2016-17 to study the effect of fertigation, irrigation and mulching on nutrient uptake in African marigold. The results revealed that highest nitrogen, phosphorus and potassium uptake by African marigold in plots treated with irrigation at 1.0 Evapo-replenishment and fertigation with 100% recommended dose of fertilisers (RDF) and polyethylene mulching during both the seasons followed by 0.8 Evapo-replenishment and fertigation with 100% RDF and polyethylene mulching. Similar trend was observed in the uptake of micronutrients (iron, manganese, zinc and copper) as well. There was a decrease in uptake pattern of nutrients in case of *rabi* than *kharif* season. Among the treatments, the minimum nutrient uptake was recorded in 0.6 ER and soil application of normal fertilizers @ 100% RDF without Mulching.

Keywords: Fertigation, irrigation, mulching, evapo-replenishment

Introduction
The African marigold (*Tagetes erecta* L.) is hardy flower crop grown throughout the India. It is extensively used in various religious and social functions. It has got considerable choice among the gardeners and flower growers on account of its ease in cultivation, wide adaptability in varying soil and climatic conditions. Flowers are used for making garlands and 'veni'. Sustainable flower production requires optimal fertilizer management to attain a high value of produce and to reduce production costs (Zhang *et al.* 2012) [15]. Fertigation is the technique of applying nutrients along with irrigation water directly at the site of active root zone resulting in quality production. Nutrient status of the plants can be a pointer to the response of plant to the fertilization and internal content of the nutrients determine the fertilizer requirements. Nitrogen applied as fertilizer was used to meet the N requirements of plant growth (Konnerup and Brix 2010) [8]. When used properly, at the correct application rates and at the right time, N contributes to optimal growth. Excessive N fertilization has an adverse effect on plants may become darker green and flowering may be delayed (Gadagi *et al.* 2004) [5]. Phosphorus is also important elements for plant growth and yield. Lack of P nutrition resulted in a low basal root fresh weight and a shorter stem length (Filippelli 2008 and Joshi *et al.* 2012) [4].

Materials and methods
The experiment was conducted during *kharif* season of 2016-17, at the experimental farm of ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru. The experiment was laid out in split plot design withIrrigationlevels*viz.*,1.0, 0.8 and 0.6 ER as main plot treatments and fertigation and mulching as sub plot treatments *viz.*, fertigation of WSF @ 100% RDF with polyethylene mulching, fertigation of WSF @ 75% RDF with polyethylene mulching, fertigation of WSF @ 100% RDF without polyethylene mulching, fertigation of WSF @ 75% RDF without polyethylene mulching, soil application of normal fertilizers @ 100% RDF with polyethylene mulching and soil application of normal fertilizers @ 100% RDF without polyethylene mulching. Soil samples were collected before transplanting the plants from five randomly selected locations at a depth of 0-15 cm from the experimental plot and composite sample was analyzed for its chemical properties. The composite soil of the experimental plot was slightly alkaline (pH 7.35) in soil reaction and non-saline (0.26 d Sm^{-1}) in nature. The soil was low in organic carbon (0.41%) content. Low in available N (148.8 kg ha^{-1}), high in available P (72.8 kg ha^{-1}) and medium in available K(272.4 kg ha^{-1}) contents. Among the available micronutrients, except DTPA-Zn (0.46 mg kg^{-1}), other three available micronutrient such as Fe, Mn and Cu contents were adequate.

Organic manure *i.e.,* farmyard manure (20 t ha^{-1}) was applied in the pre marked rows as per the treatments five days earlier to transplanting. The recommended dose of fertilizers (NPK @ 100:75:75 kg ha^{-1}) was applied based on treatments (through fertigation) in the form of water soluble fertilizers (Urea, 19:19:19). The fertigation schedule was started from twenty days after transplanting up to 70 days given at weekly intervals. For direct soil application treatments, normal fertilizers like Urea, DAP and MOP (585, 1265 and 337 g, respectively) were applied at the time of bed preparation.
The estimation of nitrogen was carried out by microkjeldahl's method (Piper, 1996) [9]. Phosphorus content in plant sample was determined by Vandomolybdate method (Jackson, 1973) [6]. Potash content of plant was estimated by Flame photometer (Jackson, 1973) [6]. The content of micronutrients (Fe, Mn, Zn and Cu) was determined by using Atomic Absorption Spectrophotometry (AAS), (Sarma *et al*. 1987) [11].
The uptake of N, P, K Fe, Mn, Zn and Cuby the plant was computed by multiplying flower yieldwith respective percentage composition of nutrients.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Percent nutrient content X flower yield (t ha}^{-1}\text{)}}{100}$$

Results

There was a significant decrease in nutrient uptake of N, P, K, Fe, Mn, Zn and Cu in *rabi* season than *kharif* season by marigold flower in proportion to the supply of respective levels of Irrigation, Fertigation and Mulching (Table 1& 2).

Nitrogen uptake

The uptake of nitrogen showed significant effect on irrigation, fertigation and interaction levels. The data from Table 1 revealed that during the kharif and rabi seasons, irrigation with 1.0 ER found to be significantly effected nitrogen uptake by plant (200.06 and 175.66 kg ha^{-1}) followed by 0.8 ER. The treatment 0.6 ER recorded minimum nitrogen uptake.
The effect of fertigation and mulching on nitrogen uptake during both seasons found to be significant. The maximum nitrogen uptake was recorded (233.98 and 209.39 kg ha^{-1}) in the treatment of fertigation of WSF @ 100% RDF with polyethylene mulching followed by fertigation of WSF @ 75% RDF with polyethylene mulching. However minimum uptake was recorded in case of direct soil application of fertilizers. The interaction study revealed that the irrigation treatment 1.0 ER with fertigation of WSF @ 100% RDF with polyethylene mulching recorded highest nitrogen uptake (279.19 and 250.59 kg ha^{-1}) in both seasons.

Phosphorus uptake

Phosphorus uptake was significantly affected by irrigation, fertigation and interactions. The data from Table 1 revealed that irrigation with 1.0 ER found to be significantly maximum in respect of phosphorus uptake by plant (57.93 and 50.72 kg ha^{-1}) followed by 0.8 ER during the *kharif* and *rabi* seasons. The treatment 0.6 ER recorded minimum phosphorus uptake.
The effect of fertigation and mulching on phosphorus uptake during both seasons found to be significant. Greater phosphorus uptake was recorded (65.47 and 58.81 kg ha^{-1}) in the treatment of fertigation of WSF @ 100% RDF with polyethylene mulching followed by fertigation of WSF @ 75% RDF with polyethylene mulching. However minimum uptake was recorded in case of direct soil application of fertilizers. The interaction study revealed that the irrigation treatment 1.0 ER with fertigation of WSF @ 100% RDF with polyethylene mulching recorded highest phosphorus uptake (79.30 and 71.17 kg ha^{-1}) in both seasons.

Potassium uptake

The uptake of potassium showed significant effect on irrigation, fertigation and interaction levels. The data from Table 1 revealed that irrigation with 1.0 ER showed potassium uptake by plant (283.25 and 247.16 kg ha^{-1}) followed by 0.8 ER during the *kharif* and *rabi* seasons. The treatment 0.6 ER recorded minimum potassium uptake.
The effect of fertigation and mulching on potassium uptake during both seasons found to be significant. The potassium uptake was maximum (336.54 and 302.31 kg ha^{-1}) in the treatment of fertigation of WSF @ 100% RDF with polyethylene mulching followed by fertigation of WSF @ 75% RDF with polyethylene mulching. However minimum uptake was recorded in case of direct soil application of fertilizers. The interaction study revealed that the irrigation treatment 1.0 ER with fertigation of WSF @ 100% RDF with polyethylene mulching recorded highest potassium uptake (396.48 and 355.86 kg ha^{-1}) in both seasons.

Iron uptake

Uptake of iron showed significant effect on irrigation, fertigation and interaction levels. The data from Table 2 revealed that irrigation with 1.0 ER found to be significantly maximum in respect of iron uptake by plant (2.90 and 2.51 kg ha^{-1}) followed by 0.8 ER during the *kharif* and *rabi* seasons. The treatment 0.6 ER recorded minimum iron uptake.
The effect of fertigation and mulching on iron uptake during both seasons found to be significant. The iron uptake was maximum (3.25 and 2.92 kg ha^{-1}) in the treatment of fertigation of WSF @ 100% RDF with polyethylene mulching followed by fertigation of WSF @ 75% RDF with polyethylene mulching. However minimum uptake was recorded in case of direct soil application of fertilizers. The interaction study revealed that the irrigation treatment 1.0 ER with fertigation of WSF @ 100% RDF with polyethylene mulching recorded highest iron uptake (3.83 and 3.44 ha^{-1}) in both seasons.

Manganese uptake

Manganese uptake was significantly affected by irrigation, fertigation and interactions. The data from Table 2 revealed that irrigation with 1.0 ER found to be significantly maximum in respect of manganese uptake by plant (0.54 and 0.40 kg ha^{-1}) followed by 0.8 ER during the *kharif* and *rabi* seasons. The treatment 0.6 ER recorded minimum manganese uptake.
The effect of fertigation and mulching on manganese uptake during both seasons found to be significant. Greater manganese uptake was recorded (0.63 and 0.53 kg ha^{-1}) in the treatment of fertigation of WSF @ 100% RDF with polyethylene mulching followed by fertigation of WSF @ 75% RDF with polyethylene mulching. However minimum uptake was recorded in case of direct soil application of fertilizers. The interaction study revealed that the irrigation treatment 1.0 ER with fertigation of WSF @ 100% RDF with polyethylene mulching recorded highest manganese uptake (0.62 and 0.62 kg ha^{-1}) in both seasons.

Zinc uptake

The uptake of zinc showed significant effect on irrigation, fertigation and interaction levels. The data from Table 2 revealed that irrigation with 1.0 ER found to be significantly maximum in respect of zinc uptake by plant (0.43 and 0.37 kg ha^{-1}) followed by 0.8 ER during the *kharif* and *rabi* seasons. The treatment 0.6 ER recorded minimum zinc uptake.

The effect of fertigation and mulching on zinc uptake during both seasons found to be significant. The zinc uptake was maximum (0.52 and 0.46 kg ha^{-1}) in the treatment of fertigation of WSF @ 100% RDF with polyethylene mulching followed by fertigation of WSF @ 75% RDF with polyethylene mulching. However minimum uptake was recorded in case of direct soil application of fertilizers. The interaction study revealed that the irrigation treatment 1.0 ER with fertigation of WSF @ 100% RDF with polyethylene mulching recorded highest zinc uptake (0.62 and 0.53 kg ha^{-1}) in both seasons.

Copper uptake

Copper uptake was significantly affected by irrigation, fertigation and interactions. The data from Table 2 revealed that irrigation with 1.0 ER found to be significantly maximum in respect of copper uptake by plant (0.23 and 0.21 kg ha^{-1}) followed by 0.8 ER during the *kharif* and *rabi* seasons. The treatment 0.6 ER recorded minimum copper uptake.

The effect of fertigation and mulching on copper uptake during both seasons found to be significant. Greater copper uptake was recorded (0.25 and 0.22 kg ha^{-1}) in the treatment of fertigation of WSF @ 100% RDF with polyethylene mulching followed by fertigation of WSF @ 75% RDF with polyethylene mulching. However, minimum uptake was recorded in case of direct soil application of fertilizers. The interaction study revealed that the irrigation treatment 1.0 ER with fertigation of WSF @ 100% RDF with polyethylene mulching recorded highest copper uptake (0.31 and 0.27 kg ha^{-1}) in both seasons.

Discussion

The high uptake of nutrients under fertigation may be due to increased uptake, owing to precise, frequent and direct application of water soluble fertilizers in the root zone which led to minimum leaching losses. This could also be attributed to rapid absorption of these elements by the plant surface, especially the leaves and their translocation within the plant. Higher nutrient uptake is attributed to an increase in the availability of N, P, K in the soil and thereby increase in dry matter content of the plant as compared to the soil application of normal recommended dose of fertilizers. The increase in nutrient uptake could also be attributed to the conductive environment of the growing media created by maintaining high moisture level, which might have increased the solubility of these nutrients. Similar results were revealed by the findings of Das *et al.* (2012) [2] and Singh *et al.* (2015) [12].

Due to mulching, water is conserved within the soil. Optimum moisture in the soil might have facilitated more uptakes of nutrients by crop. These observations are in consonance with the findings of Bhanu and Mahavishan (2008) [1] on bhendi and Tumbare *et al.* (2004) [14] on capsicum, Deepadevi and Shanth (2013) [3] in tomato, Tipu *et al.* (2014) [13] in chilli, Polara *et al.* (2014) [10] in marigold.

Table 1: Effect of fertigation, irrigation and mulching on nitrogen, phosphorus and potassium uptake by African marigold flower during *kharif* and *rabi* seasons.

Treatment	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})	
	kharif	***rabi***	***kharif***	***rabi***	***kharif***	***rabi***
Irrigation						
I_1(1.0 ER)	200.03	175.66	57.93	50.72	283.25	247.16
I_2(0.8 ER)	186.20	162.99	53.77	46.73	265.50	231.81
I_3(0.6 ER)	118.84	108.82	32.14	30.00	157.52	143.12
^{CD}0.05	13.60	11.54	4.33	3.23	21.30	19.63
Fertigation and Muching						
S_1	233.98	209.39	65.47	58.81	336.54	302.31
S_2	194.71	174.00	58.57	51.28	286.70	246.70
S_3	173.41	154.01	51.54	45.73	244.65	216.93
S_4	149.37	135.82	42.64	39.41	218.39	198.53
S_5	143.63	117.84	39.88	32.72	185.63	152.37
S_6	115.04	103.85	29.57	26.94	140.62	127.35
^{CD}0.05	5.82	4.32	1.81	1.00	9.73	7.43
Interactions						
I_1 X S_1	279.19	250.59	79.30	71.17	396.48	355.86
I_1 X S_2	227.92	207.05	69.30	60.98	338.80	288.00
I_1 X S_3	200.74	173.89	60.35	52.28	301.76	261.41
I_1 X S_4	174.98	154.23	52.12	45.94	260.61	229.71
I_1 X S_5	174.59	147.44	49.10	41.47	231.88	195.82
I_1 X S_6	142.76	120.73	37.39	32.47	169.95	152.18
I_2 X S_1	270.75	243.90	75.03	67.59	407.75	367.32
I_2 X S_2	230.80	190.44	71.25	57.16	340.78	283.86
I_2 X S_3	187.20	165.45	57.41	50.74	262.08	231.64
I_2 X S_4	156.51	145.51	44.40	41.28	233.10	216.72
I_2 X S_5	154.38	122.87	43.23	34.40	197.60	157.27
I_2 X S_6	117.55	109.74	31.28	29.20	151.68	134.06
I_3 X S_1	152.00	133.68	42.11	37.67	205.40	183.76
I_3 X S_2	125.40	124.52	35.15	35.69	180.50	168.24
I_3 X S_3	132.30	122.68	36.86	34.18	170.10	157.73
I_3 X S_4	116.61	107.73	31.40	31.00	161.46	149.16
I_3 X S_5	101.92	83.22	27.30	22.29	127.40	104.03
I_3 X S_6	84.81	81.07	20.05	19.16	100.23	95.81
^{CD}0.05	12.18	11.43	3.79	2.98	20.13	18.35

S_1: Fertigation of WSF@ 100% RDF with Mulching S_2: Fertigation of WSF @ 75% RDF with Mulching
S_3: Fertigation of WSF @ 100% RDF without Mulching S_4: Fertigation of WSF @ 75% RDF without Mulching
S_5: Soil application of normal fertilizers @ 100% RDF with Mulching S_6: Soil application of normal fertilizers @ 100% RDF without Mulching

Table 2: Effect of fertigation, irrigation and mulching on iron, manganese, zinc and copper uptake by African marigold flower during *kharif* and *rabi* seasons.

Treatment	Iron(kg ha^{-1})		Manganese(kg ha^{-1})		Zinc(kg ha^{-1})		Copper(kg ha^{-1})	
	kharif	***rabi***	***kharif***	***rabi***	***kharif***	***rabi***	***kharif***	***rabi***
Irrigation								
I_1(1.0 ER)	2.90	2.51	0.54	0.40	0.43	0.37	0.23	0.21
I_2(0.8 ER)	2.72	2.38	0.50	0.38	0.85	0.34	0.21	0.19
I_3(0.6 ER)	1.75	1.59	0.31	0.24	0.25	0.23	0.13	0.12
^{CD}0.05	0.19	0.11	0.04	0.02	0.09	0.06	0.01	0.01
Fertigation and Muching								
S_1	3.25	2.92	0.63	0.53	0.52	0.46	0.25	0.22
S_2	2.99	2.58	0.54	0.46	0.44	0.38	0.23	0.20
S_3	2.57	2.28	0.46	0.35	0.36	0.32	0.19	0.17
S_4	2.24	2.04	0.40	0.30	0.32	0.29	0.17	0.16
S_5	2.09	1.72	0.39	0.23	1.22	0.24	0.17	0.14
S_6	1.61	1.46	0.30	0.18	0.21	0.20	0.13	0.13
^{CD}0.05	0.08	0.05	0.01	0.01	0.08	0.06	0.01	0.01
Interactions								
I_1 X S_1	3.83	3.44	0.74	0.62	0.62	0.53	0.31	0.27
I_1 X S_2	3.45	2.93	0.65	0.54	0.51	0.43	0.28	0.24
I_1 X S_3	3.02	2.61	0.53	0.39	0.43	0.37	0.23	0.20
I_1 X S_4	2.61	2.30	0.47	0.35	0.39	0.34	0.21	0.19
I_1 X S_5	2.51	2.12	0.49	0.29	0.38	0.32	0.21	0.18
I_1 X S_6	1.98	1.68	0.39	0.20	0.25	0.23	0.17	0.15
I_2 X S_1	3.75	3.38	0.75	0.62	0.59	0.53	0.29	0.26
I_2 X S_2	3.50	2.92	0.62	0.52	0.52	0.43	0.27	0.22
I_2 X S_3	2.80	2.47	0.51	0.39	0.39	0.34	0.21	0.18
I_2 X S_4	2.31	2.15	0.42	0.33	0.33	0.31	0.18	0.17
I_2 X S_5	2.31	1.84	0.41	0.23	3.06	0.24	0.18	0.14
I_2 X S_6	1.67	1.56	0.28	0.18	0.22	0.21	0.13	0.13
I_3 X S_1	2.16	1.93	0.40	0.34	0.34	0.31	0.15	0.14
I_3 X S_2	2.01	1.88	0.34	0.31	0.29	0.27	0.14	0.13
I_3 X S_3	1.89	1.75	0.34	0.26	0.27	0.25	0.14	0.13
I_3 X S_4	1.80	1.67	0.31	0.21	0.24	0.22	0.13	0.12
I_3 X S_5	1.46	1.19	0.28	0.16	0.21	0.17	0.12	0.10
I_3 X S_6	1.18	1.13	0.22	0.16	0.17	0.16	0.09	0.09
^{CD}0.05	0.17	0.15	0.03	0.01	0.15	0.11	0.01	0.01

S_1: Fertigation of WSF@ 100% RDF with Mulching S_2: Fertigation of WSF @ 75% RDF with Mulching
S_3: Fertigation of WSF @ 100% RDF without Mulching S_4: Fertigation of WSF @ 75% RDF without Mulching
S_5: Soil application of normal fertilizers @ 100% RDF with Mulching S_6: Soil application of normal fertilizers @ 100% RDF without Mulching

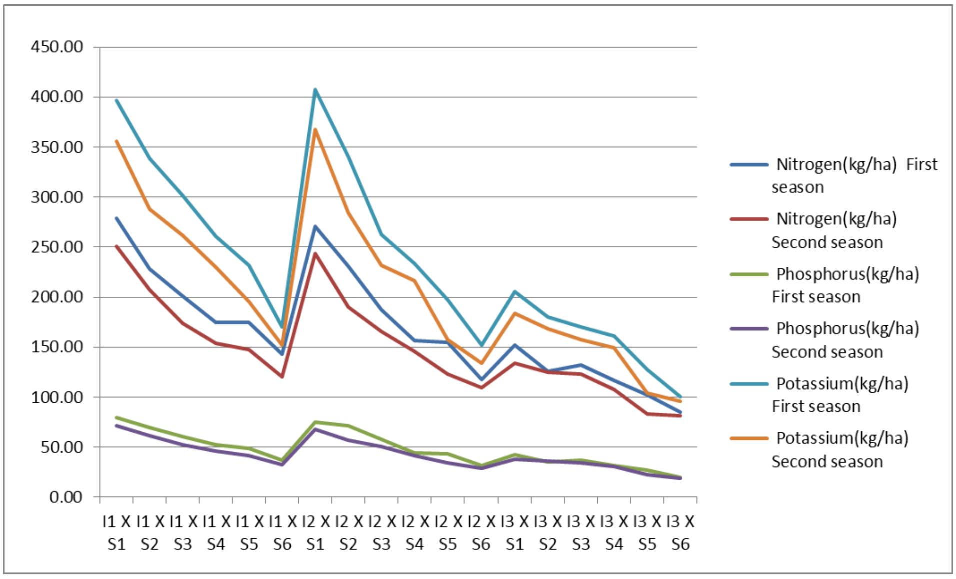

Fig 1: Effect of fertigation, irrigation and mulching on nitrogen, phosphorus and potassium uptake by African marigold flower during *kharif* and *rabi* seasons.

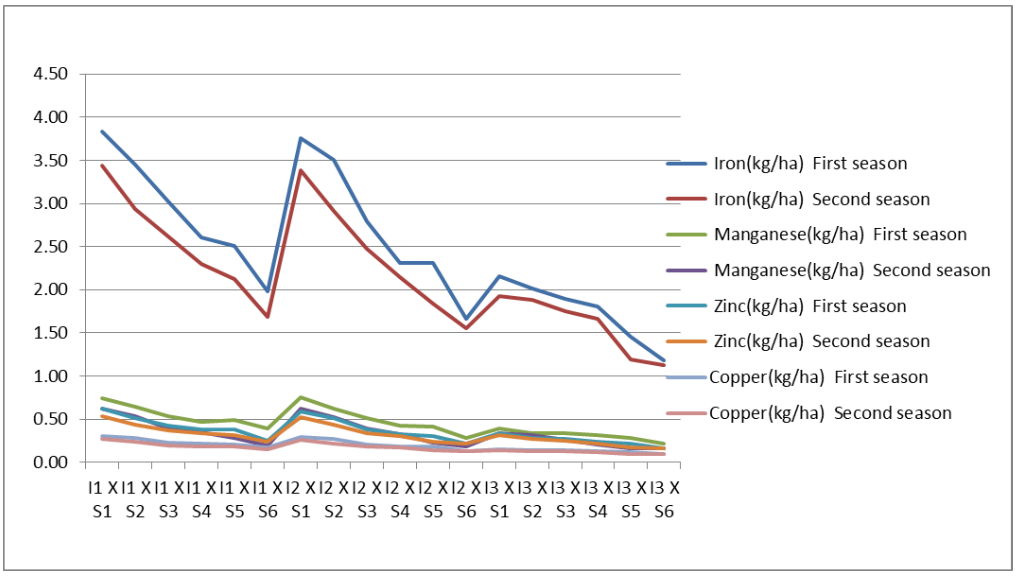

Fig 2: Effect of fertigation, irrigation and mulching on iron, manganese, zinc and copper uptake by African marigold flower during *kharif* and *rabi* seasons.

Conclusion

The findings of the present investigation revealed that the nutrient uptake by African Marigold flower was significantly influenced with fertigation, irrigation and mulching treatments. Irrigation at 1.0 Evaporation Replenishment (ER), Fertigation with water soluble fertilizers @100% RDF and polyethylene mulching was found superior in uptake of all nutrients by African marigold flower and it was at par with irrigation level of 0.8 evaporation replenishment and fertigation of WSF @ 100% RDF with polyethylene mulching.

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