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Full Research Article

Effect of Iron Application on Yield of Turmeric (*Curcuma longa*) in Maharashtra, India

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Abstract

The field experiments were conducted during 2006-12 at Agricultural Research Station, Kasabe Digraj, Dist-Sangli, Maharashtra, India to study the effect of iron application on growth, soil fertility, yield and curcumin of turmeric cv. Phule Swarupa. The experiment was laid out in a randomized block design with seven treatments and four replications. The treatments consisted of control, general recommended dose of fertilizer (GRDF) i.e. 200: 100:100 N:P_2O_5:K_2O kg ha^{-1}+25 t FYM ha^{-1}, GRDF+10 kg $FeSO_4$ ha^{-1} , GRDF+20 kg $FeSO_4$ ha^{-1} soil application (50% at the time of planting and 50% at the time of earthing-up), GRDF+1% $FeSO_4$ foliar spray after planting at monthly interval, GRDF+1% $FeSO_4$ foliar spray after planting at bimonthly interval and GRDF with FYM 50 t ha^{-1}. The results revealed that the significantly highest fresh rhizome yield (337.9 q ha^{-1}), dry yield (70.3 q ha^{-1}), height of plant (95.6 cm), number of leaves plant^{-1} (10.6) and number of tillers^{-1} (4.4) was recorded in GRDF+20 kg $FeSO_4$ ha^{-1} soil application as compared to control. The significantly highest soil pH and electrical conductivity were recorded in control at harvest. The significantly maximum available N and DTPA Fe in soil were noticed in GRDF+FYM 50 t ha^{-1}. The significantly highest DTPA Zn and Cu were recorded in GRDF+20 kg $FeSO_4$ ha^{-1} soil application as compared to control. The soil application of 20 kg $FeSO_4$ ha^{-1} or four sprays of 1% $FeSO_4$ along with GRDF to turmeric can be recommended for getting the highest yield, monetary benefits and maintaining soil fertility.

1. Introduction

Turmeric is considered as a major and scared spice of India and is exploited for its manifold uses. India is the leading producer, consumer and exporter of turmeric in the world (Tyagi, 2012). Curcumin is the major principle responsible for the yellow colour and it is present normally in a range of 3-4% in the rhizomes. It is shown to pharmaceutical attributes with its antioxidant, antiarthritic, antimutagenic, antithrombotic, antivenomous, antimicrobial properties and acts against Alzheimer's disease (Anil Kumar et al., 2011). In India, this crop is cultivated on 1.94 mha with an annual production of 9.71 mt and productivity 5.0 t ha^{-1} during the year 2012-13 (Tiwari, 2014). Maharashtra is one of the important turmeric growing states. Considering the ecological situations of the state, this crop can be taken in all districts of Maharashtra where good irrigation facility is available and area covered under irrigation in 2006-07 was 39.57 mha. A total of 17.5% of land under cultivation is irrigated (Anonymous, 2015). The international demand of turmeric is increasing (Tyagi, 2012). Hence, there is good scope to increase the area and production of this crop which will be better for development of economical status of cultivators and the state.

Turmeric is considered as a nutrient exhaustive crop. Among micronutrients, iron plays vital role in synthesis of chlorophyll, carbohydrate production, cell respiration. Iron deficiency is quite commonly observed in calcareous soils in all the important field crops. Deficiency of Fe manifest into yellowish inter-veinal paling of younger leaves (commonly referred as iron chlorosis). In general, the plants are prone to iron deficiency in alkaline, calcareous, coarse textured and low organic matter containing soils. Recent research has shown that application of Fe significantly increased in yield of crops. Chhibba et al., (2007) reported that the foliar application of Fe increased yield and Fe concentration in fenugreek. Abbas et al., (2009) applied 0, 4, 8 and 12 kg ha^{-1} in the form of iron sulfate to the soil increased Fe and protein contents of the wheat grain. Zeidan et al., (2010) reported that the foliar Fe fertilizer (1.0% $FeSO_4$) application increased protein and Fe contents of wheat grain. Meena et al., (2013) reported that

100 ppm NAA and 0.4% $FeSO_4$ was significantly increased the fruit weight (18.35 and 22.95%), fruit length (23.11 and 27.95%) and fruit width (20.15 and 17.9%) respectively over the control. Highest seed (17.72 q ha^{-1}), oil (7.08 q ha^{-1}) and stover yields (59.12 q ha^{-1}) in mustard were recorded in 20 kg $FeSO_4$ ha^{-1} as compared to control (Kumar et al., 2006). In view of the above, the present investigation was undertaken to study the effect of iron application on growth parameters, soil available nutrient status and yield of turmeric.

2. Materials and Methods

The field experiments were conducted during 2006-12 at Agricultural Research Station, Kasabe Digraj, Dist-Sangli, Maharashtra, India to study the effect of iron application on growth parameters, soil available nutrient status and yield of turmeric cv. Phule Swarupa. The experiment was laid down in a randomized block design with seven treatments and four replications. The experimental site had soil pH 7.98, EC 0.42 dS m^{-1}, N 203 kg ha^{-1}, P 9.78 kg ha^{-1}, K 408 kg ha^{-1}, $CaCO_3$ 7.85%, Fe 2.07 ppm, Mn 2.44 ppm, Zn 0.43 ppm and Cu 1.29 ppm. The treatments T_{1-} control,T_{2-} recommended dose of fertilizer (RDF) (200: 100:100 N:P_2O_5:K_2O kg ha^{-1}), T_3- RDF+FYM 50 t ha^{-1} at the time of planting , T_4-general recommended dose of fertilizer (RDF+25 t FYM $ha^{-1'}$)+10 kg $FeSO_4$ ha^{-1} soil application (50% at the time of planting and 50% at the time of earthing-up), T_{5-} GRDF+20 kg $FeSO_4$ ha^{-1} soil application (50% at the time of planting and 50% at the time of earthing-up), T_6- GRDF+1% $FeSO_4$ foliar spray after planting at the monthly interval starting from 2nd , 3rd, 4th, 5th and 6th month and T_7- GRDF+1% $FeSO_4$ foliar spray after planting at bimonthly interval starting from 2nd, 4 th and 6th month. The FYM was applied and incorporated to the experimental field before planting of crops as per treatments. The turmeric was planted with ridge and furrow method with spacing of 37.5×30 cm^2. The basal dose of inorganic fertilizers phosphorus and potassium @ 60 and 60 kg ha^{-1} respectively and ferrous sulphate at the time of planting while nitrogen through urea was top dressed @ 100 kg ha^{-1} after 45 and 75 days of planting as per treatments. All recommended agronomical practices were carried out. The biometric observations on growth and yield were recorded at harvesting. The soil samples were collected at the time of harvest and analysed for available N (Subbiah and Asija, 1956), phosphorus (Watanabe and Olsen, 1965), potassium (Knudsen et al., 1982) and DTPA extractable micronutrients (Lindsay and Norvell, 1978). The statistical analysis of the data was carried out by following ANOVA technique (Panse and Sukhatme, 1985).

3. Results and Discussion

3.1. Growth attributing characters

The pooled data on growth attributing characters viz; plant height, number of leaves $plant^{-1}$ and number of $tillers^{-1}$ plant were significantly influenced by soil application and foliar sprays of ferrous sulphate (Table 1). The treatment T_5 (GRDF+20 kg $FeSO_4$ ha^{-1} soil application i.e. 50% at the time of planting and 50% at time of earthing-up) was recorded significantly highest height of plant (95.6 cm), number of leaves $plant^{-1}$ (10.6) and numbers of tillers $plant^{-1}$ (4.4). The treatment T_5 was at par with treatments T_4 (GRDF+50 t FYM $ha^{-1'}$)+10 kg $FeSO_4$ ha^{-1} soil application, T_6 (GRDF+1% $FeSO_4$ foliar spray at monthly interval 2nd , 3rd, 4th, 5th and 6th month), T_7 (GRDF+1% $FeSO_4$ foliar spray bimonthly interval 2nd ,4 and 6th month) for plant height of turmeric and treatments T_4 (GRDF+50 t FYM ha^{-1}+10 kg $FeSO_4$ ha^{-1} soil application) and T_7 (GRDF+1% $FeSO_4$ foliar spray bimonthly at 2nd , 3rd, 4th, 5th and 6th month) for number of leaves per plant and number of tillers per plant. Application of $FeSO_4$ either through foliar spray or soil was increased plant height, number of leaves per plant and number of tillers per plant as compared to control. This is obvious because of the greater role of Fe in chlorophyll synthesis and other metabolic activities of the plant thereby increased vegetative growth leading to more number of tillers and leaves. Similar results were close in conformity with Rajamani and Shanmugasundaram, (2014) stated that Soil application of ferrous sulphate @ 50 kg ha^{-1} (+Fe) resulted

Table 1: Effects of soil application and foliar sprays of ferrous sulphate on plant height , number of leaves and tillers per plant of the turmeric at 135 days after planting (Pooled mean of five years)

Treatments	Plant height (cm)	Number of leaves $plant^{-1}$	Number of tillers $plant^{-1}$
T_1	64.1	7.3	2.0
T_2	78.0	8.3	2.6
T_3	87.1	9.2	3.1
T_4	91.3	9.9	3.6
T_5	95.6	10.6	4.0
T_6	91.6	10.2	3.6
T_7	89.4	9.3	3.4
SEm±	2.5	0.3	0.15
CD (p=0.05)	7.4	0.9	0.43

T_1: control; T_2: recommended dose of fertilizer (RDF) (200: 100:100 N:P_2O_5:K_2O kg ha^{-1}); T_3: RDF+FYM 50 t ha^{-1} at the time of planting; T_4: general recommended dose of fertilizer (RDF+25 t FYM ha^{-1}')+10 kg $FeSO_4$ ha^{-1} soil application (50% at the time of planting and 50% at the time of earthing-up), T_5: GRDF+20 kg $FeSO_4$ ha^{-1} soil application (50% at the time of planting and 50% at the time of earthing-up); T_6: GRDF+1% $FeSO_4$ foliar spray after planting at the monthly interval starting from 2nd , 3rd, 4th, 5th and 6th month; T_7: GRDF+1% FeSO4 in higher plant growth and yield in all the genotypes of black gram as compared to control (-Fe). The lowest plant height, numbers of leaves per plant and number of tillers per plant were recorded under treatment T_1 (control). This might be due to low soil available macro and micronutrient status (Table 3 and 4) ultimately less uptake of nutrients and affected the growth parameters. Similar observations were recorded by Rajamani and Shanmugasundaram, (2014)

3.2. Fresh rhizome and dry yield

Soil application and foliar sprays of ferrous sulphate significantly influenced the fresh and dry rhizome yield and curcumin content in turmeric (Table 2). The significantly highest fresh rhizome yield (337.9 q ha^{-1}), dry rhizome yield (70.3 q ha^{-1}), curcumin content (5.07%) and B: C ratio (1.52) were recorded in treatment T_5 as compared to control and RDF. The treatment T_5 (GRDF+20 kg $FeSO_4$ ha^{-1} soil application) was at par with treatments T_4 (RDF'+50 t FYM $ha^{-1'}$)+10 kg $FeSO_4$ ha^{-1} soil application), T_6 (GRDF+1% $FeSO_4$ foliar spray at 2nd , 3rd, 4th, 5th and 6th month) for fresh rhizome and dry yield and treatments T_4 (GRDF+50 t FYM $ha^{-1'}$+10 kg $FeSO_4$ ha^{-1} soil application), T_6 (GRDF+1% $FeSO_4$ foliar spray after planting at the monthly 2nd , 3rd, 4th, 5th and 6th month) and T_7 (GRDF+1% $FeSO_4$ foliar spray at 2nd ,4 and 6th month) for curcumin content. The increase in rhizome yield with soil applied Fe might have been the result of increase in the content of available Fe in the soil and foliar application of Fe could be attributed to the direct absorption of the element by the foliage sprayed with Fe solution and enhanced photosynthetic activity and increased vegetative growth leading to more number of tillers and leaves, ultimately increased rhizome yield. Similar results were close in conformity with Chhibba et al., (2007) reported that the foliar and soil application of Fe significantly increased yield of fenugreek. Durgude et al., (2014) reported that the cotton yield and B:C ratio was significantly increased in treatment of RD as per STCR equation+soil application of $FeSO_4$ @ 25+$ZnSO_4$ @ 20 kg ha^{-1}. The lowest fresh rhizome yield, dry yield and curcumin content were observed in treatment T_1 (control) and followed by T_2 (RDF) over the rest of the treatments. This might be due to low DTPA Fe status in soil ultimately less uptake of Fe nutrient and affected the yield. Similar observations were noticed by Rajamani and Shanmugasundaram, (2014)

Table 2: Effects of soil application and foliar sprays of ferrous sulphate on yield curcumin and B:C ratio of the turmeric (Pooled mean of five years)

Treatments	Fresh rhizome Yield (q ha^{-1})	Dry rhizome Yield (q ha^{-1})	Curcumin (%)	B:C Ratio
T_1	201.9	39.8	4.82 (12.69)	0.92
T_2	245.1	50.3	4.89 (12.78)	1.19
T_3	300.2	61.4	5.09 (13.04)	1.04
T_4	315.9	64.5	5.00 (12.92)	1.29
T_5	337.9	70.3	5.07 (13.00)	1.52
T_6	324.8	66.3	5.00 (12.92)	1.32
T_7	309.0	62.5	4.99 (12.91)	1.20
SEm±	9.4	2.1	0.03	0.10
CD (p=0.05)	27.3	6.2	0.10	0.31

Figures in parenthesis indicates arcsine values

3.3. Soil properties and available nutrient status after harvest

The data pertaining to soil pH, EC and available nutrient status after harvest of turmeric as influenced by ferrous sulphate application is presented in Table 3. The soil application and spraying of ferrous sulphate significantly influenced soil pH, EC, available N, available P, whereas, did not differ available K. The lowest soil pH was recorded in treatment T_3 (RDF+FYM 50 t ha^{-1} at the time of planting) due to more amount FYM application. Decomposition of FYM releases the organic acid and reduces the soil pH. The addition of FYM along with chemical fertilizers helped in reducing the soil pH (Jagtap et al., 2007). The treatment T_3 (RDF+FYM 50 t ha^{-1} at the time of planting) was at par with treatments T_4 to T_6. The highest soil pH (8.06) and EC (0.39 dS m^{-1}) were recorded in treatments T_1 (absolute control). The treatments T_2 to T_7 were at par with each other for electrical conductivity of soil. The highest available N and K were recorded in T_3 (RDF+FYM 50 t ha^{-1} at the time of planting) and available P in treatment T_5 (GRDF+20 kg $FeSO_4$ ha^{-1} soil application) over the rest of treatments. The treatments T_2 to T_7 were at par with each other for available N and the treatments T_2 to T_5 were at par with each other for available P. The increase in available nutrients status in FYM treated soil might be due to the decomposition and mineralization of nutrients present in the organic material and releases of some organic acids as a result of organic decomposition, which

Table 3: Effects of soil application and foliar sprays of ferrous sulphate on soil properties and available nutrient status after harvest of turmeric (Pooled mean of five years)

Treatments	pH	EC (dS m^{-1})	Available nutrient status (kg ha^{-1})		
			N	P	K
T_1	8.06	0.39	213.70	8.98	471.20
T_2	7.99	0.31	238.78	11.43	510.40
T_3	7.79	0.32	247.37	10.21	548.27
T_4	7.90	0.29	227.26	11.48	521.60
T_5	7.86	0.32	244.49	12.23	515.47
T_6	7.84	0.31	240.96	11.15	492.80
T_7	7.87	0.33	239.86	10.45	516.53
SEm±	0.03	0.02	7.24	0.44	24.58
CD (p=0.05)	0.09	0.05	20.90	1.28	NS

reduces the soil pH and improving nutrient availability. The integration of urea, SSP, $FeS0_4$ +$ZnS0_4$, biofertilizers and FYM was found to be beneficial for release of phosphorus, DTPA-extractable zinc and iron (Jagtap et al., 2007).

3.4. *DTPA extractable micronutrient status after harvest*

The DTPA extractable micronutrients Zn , Fe, Cu, and Mn status after harvest of turmeric as influenced by various treatments is presented in Table 4. The DTPA extractable micronutrients were significantly influenced by the soil application and foliar spray of ferrous sulphate. The highest available Zn, Fe, Cu and Mn were observed in treatment T_4. Increase in DTPA-extractable Zn, Fe, Cu and Mn content with $FeSO_4$ soil application might be due to formation of different stable complexes with organic ligands. This has decreased their susceptibility for adsorption or fixation or precipitation reaction in soil, which has helped in keeping micronutrient elements soluble and consequently more available to plants for longer period. Mimmo et al., (2014) reported that an enhanced release of inorganic (such as protons) and organic (organic acids, carbohydrates, amino acids, phytosiderophores, siderophores, phenolics and enzymes) compounds to increase the solubility of poorly available Fe pools. The DTPA-Fe and Zn in soil was significantly increased (6.60 and 0.77 ppm, respectively) in treatment of RD as per STCR equation+soil application of $FeSO_4$ @ 25+$ZnSO_4$ @ 20 kg ha^{-1} (Durgude et al., 2014). The treatment T_5 (GRDF+20 kg $FeSO_4$ ha^{-1} soil application) was at par with T_6(GRDF+1% $FeSO_4$ foliar spray at 2nd , 3rd, 4th, 5th and 6th month) for available Zn, the treatment T_3 (RDF+FYM 50 t ha^{-1} at the time of planting) for available Fe, the treatment T_5 for available Cu and treatments T_4 (GRDF+50 t FYM ha^{-1})+10 kg $FeSO_4$ ha^{-1} soil application),T_6 (GRDF+1% $FeSO_4$ foliar spray at 2nd , 3rd, 4th, 5th and 6th month) and T_7 (GRDF+1% $FeSO_4$ foliar at 2nd ,4 and 6th month) for available Mn. The lowest available micro nutrients were recorded in treatment T_1 (control).

Table 4: Effects of soil application and foliar sprays of ferrous sulphate on DTPA soil available micronutrient status after harvest of turmeric (Pooled mean of five years)

Treatments	DTPA soil available micronutrient (ppm)			
	Zn	Fe	Cu	Mn
T_1	0.34	2.48	0.99	4.13
T_2	0.39	2.56	1.08	4.18
T_3	0.43	3.38	1.18	4.31
T_4	0.42	2.77	1.20	4.82
T_5	0.48	3.29	1.41	5.02
T_6	0.45	2.75	1.39	4.81
T_7	0.42	2.88	1.21	4.72
SEm±	0.01	0.10	0.03	0.11
CD (p=0.05)	0.04	0.30	0.09	0.32

4. Conclusion

The soil application of 20 kg $FeSO_4$ ha^{-1} (50% at the time of planting and 50% at the time of earthing-up) or four sprays of 1% $FeSO_4$ (2nd , 3,4,5 and 6th month) along with GRDF to turmeric can be recommended for getting the higher dry rhizome yield, monetary benefits and maintaining soil fertility.

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