Environment and Ecology 36 (2A) : 583—592, April—June 2018
Website: environmentandecology.com ISSN 0970-0420

Effect of Mulching and Humic Acid on the Nutrient Availability and Nutrient Uptake of Tomato under Fertigation

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Received 25 January 2018; Accepted 18 February 2018; Published on 12 March 2018

Abstract A field experiment was conducted to study the effect of mulching and humic acid on the yield and quality of tomato under fertigation and fertility of soil with twelve treatments. The study revealed that the application of 100% recommended dose of nutrients + Black color mulching + Humic acid @ 20 kg ha^{-1} as basal had a greater potential for improved the availability of Nitrogen (N-330.9 kg ha^{-1}), Phosphorus (P-28.65 kg ha^{-1}), Potassium (K-383.6 kg ha^{-1}), Exchangeable Calcium (Ca-6.71 cmol (P^+) kg^{-1}), Exchangeable Magnesium (Mg-4.25 cmol (P^+) kg^{-1}), Iron (Fe-10.81 kg ha^{-1}) and Zinc (Zn-2.55 kg ha^{-1}) in soil. Total nutrient uptake of Nitrogen (105.3 kg ha^{-1}), Phosphorus (29.41 kg ha^{-1}), Potassium (141.7 kg ha^{-1}), Calcium (30.48 kg ha^{-1}), Magnesium (14.91 kg ha^{-1}), Iron (0.890 kg ha^{-1}) and Zinc (0.350 kg ha^{-1}). Application of 100% recommended dose of fertilizers + Black color mulching increased the nutrient availability and uptake of nutrients over rest of the treatments.

Keywords Fertigation, Humic acid, Mulching, Tomato.

Introduction

Tomato (*Solanum lycopersicom*) is one of the popular vegetables in the world, ranking second in importance next to potato. Tomato otherwise called as Love apple or Golden apple or Poor man's apple is one, which has attained world wide importance. It is a good source of vitamin A, C and potassium. Lycopene pigment imparts red color and is a potential anti-oxidant for minimizing the damage caused by free radicals (Agarwal and Rao 2000). It is popularly grown throughout India and the major tomato producing states are Maharashtra, Bihar, Karnataka, Tamil Nadu, Uttar Pradesh, Orissa, Andhra Pradesh, Madhya Pradesh and Assam. Our national production of tomato is 16826400 Mt from an area of about 864900 ha with an average productivity of 19.5 Mt ha^{-1}. In Tamil Nadu, production of tomato is 580600 Mt from an area of about 27200 ha with an average productivity of 21.4 Mt ha^{-1} (Indian horticulture database 2011). The advent of increasing water scarcity in this century will observe less increase in irrigated land avail-

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Table 1. Effect of fertigation, mulching and humic acid on the available N, P and K (kg ha^{-1}) content of soil. RDF - Recommended dose of fertilizer through fertigation, BM - Black mulching, GM - Grey mulching, HA - Humic acid @ 20 kg ha^{-1} as basal, HA* - Foliar application of humic acid @ 0.1% @ 30, 45 and 60 DAT.

Treatments	Available N				Available P				Available K			
	Vegetative stage	Flowering stage	Harvest stage	Mean	Vegetative stage	Flowering stage	Harvest stage	Mean	Vegetative stage	Flowering stage	Harvest stage	Mean
T_1 - Absolute control	258.7	241.6	238.0	246.1	31.64	20.08	10.90	20.87	392.7	336.0	193.3	307.3
T_2 - 100% RDF	260.9	250.9	240.0	250.6	33.66	22.34	13.00	23.00	396.7	340.0	197.3	311.3
T_3-100% RDF+BM+HA	342.0	330.7	320.0	330.9	40.66	27.66	17.64	28.65	455.3	407.3	248.0	383.6
T_4-100% RDF+GM+HA	337.0	295.3	298.0	310.1	38.00	26.44	17.00	27.15	446.7	405.0	240.0	363.9
T_5 - 75% RDF+BM+HA	329.1	293.3	288.0	303.5	37.80	25.34	16.34	26.49	444.0	401.9	225.0	360.0
T_6 - 75% RDF+GM+HA	320.6	293.3	284.0	299.3	37.00	25.34	14.66	25.67	444.0	397.1	224.7	355.3
T_7-100% RDF+BM+HA*	302.0	290.7	282.0	291.6	37.00	24.94	13.66	25.20	443.0	376.0	222.7	347.2
T_8-100% RDF+GM+HA*	302.0	282.5	278.0	287.5	36.90	24.54	13.26	24.90	442.8	374.0	222.0	346.3
T_9 - 75% RDF+BM+HA*	300.0	260.5	254.0	271.5	36.20	23.74	12.74	24.23	441.0	370.0	221.0	344.0
T_{10} - 75% RDF+GM+HA*	264.0	259.3	247.0	256.8	35.44	23.14	12.18	23.59	440.0	342.7	219.3	334.0
T_{11} - 100% RDF+BM	262.7	257.3	245.0	255.0	34.66	23.01	11.66	23.11	437.8	341.3	201.3	326.8
T_{12} - 75% RDF + GM	262.7	254.7	242.0	253.1	34.66	22.96	11.46	23.03	400.7	340.5	199.8	313.6
Mean	295.1	275.8	268.0		36.14	24.13	13.71		432.1	369.3	217.9	

	N SEd	N CD (0.05)	P SEd	P CD (0.05)	K SEd	K CD (0.05)
T	4.393	8.763	0.354	0.706	4.760	9.493
S	8.787	17.53	0.708	1.411	9.519	18.99
T × S	15.22	NS	1.225	NS	16.488	NS

ability for food production than in the past. Novel irrigation technologies need to be tested under local environments and particularly in agricultural production systems of developing countries. Drip irrigation helps in maintaining optimum soil moisture in the root zone with increased yield and water use efficiency. A significant goal in soil fertility research is to develop practices by which crop nutrient requirements are satisfied through maximum uptake of nutrients from minimum quantity of applied fertilizers (Shedeed et al. 2009). India is the third fertilizer producing and consuming country in the world. The nutrient consumption per hectare and fertilizer use efficiency is very low in India. The main reasons for low efficiency are the type of fertilizer used and its method of application adopted by Indian farmers. Fertigation is the process of application of water soluble solid fertilizers of liquid fertilizers through drip irrigation system. Through fertigation, nutrients are applied directly into the wetted volume of soil immediately below the emitter, where root activity is concentrated. Fertigation is possible only in drip irrigation (Jaya Kumar et al. 2014). Drip fertigation in combination with mulch is one of the best management option, which can improve the water management practice significantly. Surface mulches have been used to improve soil water retention, reduce soil temperature, soil erosion and reduce wind velocity at the soil surface and arid lands. Surface mulches can also improve water penetration by impeding runoff and protecting the soil from rain drop splash and reducing soil crusting. Plastic mulches are commonly used in the production of vegetables. Black plastic mulch, the predominant color used in crop production, is an opaque black body absorber and radiator (Aniekwe et al. 2004). Keeping these in view the present study is contemplated to study the effect of fertigation, mulching and humic acid on the soil available nutrients viz., N, P, K, Ca, Mg, Fe and Zn and total nutrient uptake viz., N, P, K, Ca, Mg, Fe and Zn.

Materials and Methods

Experimental sites

A field experiment was conducted at irrigation cafete-

Table 2. Effect of fertigation, mulching and humic acid on the exchangeable Ca and Mg (c mol (p+) kg^{-1}) content of soil. RDF - Recommended dose of fertilizer through fertigation, BM - Black mulching, GM - Grey mulching, HA - Humic acid @ 20 kg ha^{-1} as basal, HA* - Foliar application of humic acid @ 0.1% @ 30, 45 and 60 DAT.

Treatments	Exchangeable Ca				Exchangeable Mg			
	Vegetable stage	Flowering stage	Harvest stage	Mean	Vegetable stage	Flowering stage	Harvest stage	Mean
T_1–Absolute control	6.46	5.12	4.2	5.26	3.08	3.12	2.86	3.02
T_2–100% RDF	6.66	5.54	4.88	5.69	3.66	3.26	3.06	3.33
T_3–100% RDF + BM + HA	8.26	6.14	5.74	6.71	4.68	4.14	3.94	4.25
T_4–100% RDF + GM + HA	7.66	6.14	5.74	6.51	4.54	3.94	3.74	4.07
T_5–75% RDF + BM + HA	7.46	6.14	5.60	6.40	4.28	3.94	3.74	3.99
T_6–75% RDF + GM + HA	7.46	6.02	5.60	6.36	4.26	3.90	3.70	3.95
T_7–100% RDF + BM + HA*	7.46	5.98	5.54	6.33	4.22	3.74	3.56	3.84
T_8–100% RDF + GM + HA*	7.12	5.96	5.34	6.14	4.20	3.66	3.54	3.80
T_9–75% RDF + BM + HA*	6.96	5.94	5.34	6.08	4.18	3.56	3.46	3.73
T_{10}–75% RDF + GM + HA*	6.86	5.94	5.34	6.05	4.14	3.46	3.36	3.65
T_{11}–100% RDF + BM	6.66	5.74	5.14	5.85	4.14	3.46	3.26	3.62
T_{12}–75% RDF + GM	6.66	5.74	4.92	5.77	3.66	3.36	3.00	3.34
Mean	7.14	5.87	5.28		4.09	3.63	3.44	

	Ca SEd `	Ca CD (0.05)	Mg SEd	Mg CD (0.05)
T	0.09	0.17	0.05	0.11
S	0.17	0.34	0.11	0.22
T × S	0.30	NS	0.19	NS

ria, Water Technology Center, Tamil Nadu Agricultural University, Coimbatore to study the effect of fertigation, mulching and humic acid on the soil available nutrients which in turn effect on total nutrient uptake by tomato. The soil was sandy clay loam belonging to *Isohyperthermic vertic ustropept*. The field is located at 11°N latitude and 77°E longitude with mean altitude of 426 m above the mean sea level. Topography of the experimental plot was uniform and leveled. The soil was having pH 7.54, EC 0.72 dS m^{-1}, oxidized organic carbon 0.65%, CEC 18.1 cmol (P^+) kg^{-1}, available N 228 kg ha^{-1}, available P 18 kg ha^{-1}, available K 525 kg ha^{-1}, exchangeable Ca 4.3 cmol (P^+) kg^{-1} and exchangeable Mg 1.8 cmol (P^+) kg^{-1}.

Experimental design, treatments
and crop managements

The field experiment was laid out in a randomized block design with three replications for tomato crop under fertigation. The experiments consisted of twelve treatments viz., absolute control (T_1), 100% Recommended dose of fertilizer (RDF) through fertigation (T_2), 100% Recommended dose of fertilizer (RDF) through fertigation + Black color polythene sheet mulching + Humic acid @ 20 kg ha^{-1} as basal (T_3), 100% Recommended dose of fertilizer (RDF) through fertigation + Grey color polythene sheet mulching + Humic acid @ 20 kg ha^{-1} as basal (T_4), 75% Recommended dose of fertilizer (RDF) through fertigation + Black color polythene sheet mulching + Humic acid @ 20 kg ha^{-1} as basal (T_5), 75% Recommended dose of fertilizer (RDF) through fertigation + Grey color polythene sheet mulching + Humic acid @ 20 kg ha^{-1} as basal (T_6), 100% Recommended dose of fertilizer (RDF) through fertigation + Black color polythene sheet mulching + Humic acid * (T_7), 100% Recommended dose of fertilizer (RDF) through fertigation + Grey color polythene sheet mulching + Humic acid * (T_8), 75% Recommended dose of fertilizer (RDF) through fertigation + Black color polythene sheet mul ching + Humic acid * (T_9), 75% Recommended dose of fertilizer (RDF) through fertigation + Grey color polythene sheet mulching + Humic acid * (T_{10}), 100% Recommended dose of fertilizer (RDF) through fertigation + Black color polythene sheet mulching (T_{11}) and 75% Recommended dose of fertilizer (RDF) through fertigation + Grey color polythene sheet

Table 3. Effect of fertigation, mulching and humic acid on the available Fe and Zn (kg ha^{-1}) content of soil. RDF - Recommended dose of fertilizer through fertigation, BM - Black mulching, GM - Grey mulching, HA - Humic acid @ 20 kg ha^{-1} as basal, HA* - Foliar application of humic acid @ 0.1% @ 30, 45 and 60 DAT.

	Available Fe				Available Zn			
Treatments	Vegetative stage	Flowering stage	Harvest stage	Mean	Vegetative stage	Flowering stage	Harvest stage	Mean
T_1–Absolute control	10.10	10.06	10.02	10.06	1.92	1.88	1.84	1.88
T_2–100% RDF	10.18	10.12	10.08	10.13	1.96	1.92	1.88	1.92
T_3–100% RDF + BM + HA	10.86	10.8	10.76	10.81	2.58	2.56	2.52	2.55
T_4–100% RDF + GM + HA	10.86	10.78	10.74	10.79	2.58	2.56	2.52	2.55
T_5–75% RDF + BM + HA	10.68	10.64	10.6	10.64	2.28	2.24	2.20	2.24
T_6–75% RDF + GM + HA	10.68	10.64	10.58	10.63	2.28	2.24	2.20	2.24
T_7–100% RDF + BM + HA*	10.64	10.6	10.56	10.60	2.26	2.22	2.00	2.16
T_8–100% RDF + GM + HA*	10.64	10.6	10.56	10.60	2.26	2.22	2.00	2.16
T_9–75% RDF + BM + HA*	10.62	10.56	10.5	10.56	2.24	2.00	1.96	2.07
T_{10}–75% RDF + GM + HA*	10.62	10.54	10.46	10.54	2.24	2.00	1.96	2.07
T_{11}–100% RDF + BM	10.22	10.2	10.16	10.19	2.02	1.96	1.94	1.97
T_{12}–75% RDF + GM	10.18	10.14	10.12	10.15	1.98	1.92	1.92	1.94
Mean	10.52	10.47	10.43		2.22	2.14	2.08	
	SEd `		CD (0.05)			SEd	CD (0.05)	
T	0.078		NS			0.04	0.08	
S	0.156		0.311			0.08	0.15	
T × S	0.270		NS			0.13	NS	

mulching (T_{12}). Foliar spraying (HA*) of 0.1% humic acid was employed thrice, first at 30 days after transplanting and the remaining two sprays at 15 days interval.

The treatment receiving 100% recommended dose of fertilizer were supplied through fertigation system with calculated quantities of fertilizer containing NPK to supply 150:300:150 kg ha^{-1} various growth stages after transplanting of tomato crops. Similarly fertilizers containing 150:225:150 kg ha^{-1} of N, P_2O_5 and K_2O were applied through fertigation system to treatments receiving 75% recommended dose of NPK fertilizers. Soil application of humic acid @ 20 kg ha^{-1} was also applied the basal soil application. Foliar spraying of humic acid @ 0.1% was done on 30, 45 and 60 days after transplanting.

During vegetative stage the fertilizers was applied at weekly intervals. During flowering stages the fertilizer was applied at three days intervals and at fruiting stage it was applied again at weekly intervals. Tomato cultivar TNAU tomato hybrid CO_3 was selected for the experiment. Humic acid was obtained from SP Agro farm in the form of potassium humate which was 60% humic acid 9.21% potassium. According to American classification it falls into the group of ignite B and is ideally suited for extraction of humic acid. Humic acid is prepared by treating ignite with alkali and neutralizing with mineral acid. The precipitated humic acid is washed free of electrolytes, pressed made into cakes and dried. Then it is dissolved in caustic potash and used as potassium humate. Black and grey color polythene sheets were obtained from reny marketing. Polythene sheet thickness is 30 micron.

The total quantity of fertilizer required to fertigation were 177, 660 and 400 kg ha^{-1} respectively for urea, DAP and MOP. Inter cultivation operations as and when required were taken up during the entire crop growth period.

Data collection and analysis

Composite surface (0—15 cm) soil samples were collected from the site before the experiment and analyzed for their physical, physico-chemical and chemi-

Table 4. Effect of fertigation, mulching and humic acid on the total uptake of N, P and K (kg ha^{-1}) content of soil.

Treatments	Total uptake of N Vegetative stage	Flowering stage	Harvest stage	Mean	Total uptake of P Vegetative stage	Flowering stage	Harvest stage	Mean	Total uptake of K Vegetative stage	Flowering stage	Harvest stage	Mean
T_1 - Absolute control	5.740	23.18	199.9	76.26	0.150	3.860	23.12	9.040	4.750	34.78	228.2	89.25
T_2 - 100% RDF	6.970	29.17	220.4	85.50	0.190	5.950	30.54	12.23	5.750	47.80	239.3	97.60
T_3-100% RDF+BM+HA	13.42	74.94	227.7	105.3	0.800	12.80	74.64	29.41	21.62	108.1	295.4	141.7
T_4-100% RDF+GM+HA	12.03	72.28	221.4	101.9	0.680	12.58	70.47	27.91	19.11	101.8	294.5	138.5
T_5 - 75% RDF+BM+HA	8.780	64.68	197.4	90.29	0.490	10.89	63.08	24.82	15.16	98.48	283.1	132.3
T_6 - 75% RDF+GM+HA	7.720	61.76	196.8	88.74	0.490	10.70	60.69	23.96	14.63	90.45	274.0	126.4
T_7-100% RDF+BM+HA*	6.680	54.52	197.9	83.06	0.380	9.910	52.00	20.76	12.05	80.08	252.4	114.9
T_8-100% RDF+GM+HA*	5.550	52.68	198.4	85.54	0.380	9.680	48.94	19.67	12.01	78.80	249.1	113.3
T_9 - 75% RDF+BM+HA*	5.430	46.54	191.6	81.21	0.240	8.740	46.00	18.33	10.56	71.46	234.3	105.4
T_{10} - 75% RDF+GM+HA*	4.760	43.83	187.9	78.83	0.220	8.320	44.78	17.77	10.04	67.96	228.1	102.0
T_{11} - 100% RDF+BM	3.080	40.54	170.3	71.32	0.210	7.740	41.22	16.39	9.700	59.30	212.0	93.65
T_{12} - 75% RDF + GM	3.230	35.50	160.6	66.45	0.180	6.980	39.68	15.61	9.660	54.84	207.9	90.81
Mean	6.950	49.97	196.7		0.370	9.010	49.60		12.09	74.49	249.9	

	N SEd	N CD (0.05)	P SEd	P CD (0.05)	K SEd	K CD (0.05)
T	1.661	3.314	0.435	0.868	2.431	4.848
S	3.323	6.628	0.871	1.737	4.861	9.695
T × S	5.756	11.48	1.508	3.008	8.420	16.79

cal properties. Soil samples were also collected from each plots at vegetative (30 DAT-days after transplanting), 50% flowering (45 DAT) and harvesting stage of crop for analysis of several parameters. The collected samples were air – dried and passed through 2 mm sieve prior to analysis. The pH and EC of soil samples was determined in 1:2.5 (soil:water) suspension using digital pH meter. Organic carbon (OC) content of soil was determined by chromic acid wet oxidation method (Walkely and Black 1934). Available Nitrogen content in soil was determined by Alkaline permanganate method (Subbiah and Asija 1956). Available phosphorus content in soil was estimated using olsen's extraction method (Olsen et al. 1954). Available potassium in soil was analyzed neutral normal ammonium acetate method (Stanford and English 1949), exchangeable calcium and magnesium in soil was determined by Versenate titration - neutral normal ammonium acetate extract (Jackson 1973) and available micronutrient (Fe and Zn) in soil was estimated by atomic absorbtion spectro photometer (AAS) after extracting soil samples with DTPA (Diethelene Triamine Penta Acetic Acid) extractant (Lindsoy and Norvell 1978).

After recording dry weight, the plant samples collected at vegetative, flowering and harvest stages were ground to a fine powder in a willey mill. Total N in plant was determined by diacid extract – microkjeldahl distillation (Piper 1966), total P in plant was estimated using triacid extract – vanadomolybdate colorimetric method (Jackson 1973), total K in plant determined by triacid extract – neutralized with ammonia and estimated using flame photometer (Jackson 1973, Ca and Mg by triacid extract – versenate method (Jackson 1973) and micronutrient by triacid extract – Atomic Absorption Spectro Photometer (Jackson 1973). Tomato yield in each plot was weighed and expressed in t ha^{-1}. Data were statistically analyzed using ANOVA package method (Panse and Sukhatme 1978) and least significant difference (LSD) at 5% probability level was computed to compare the treatments.

Results and Discussion

Available N

Humic acid and fertilizer increased the availability of

N in soil. Use of 100% RDF increased availability of N. In all the treatment, available N increased up to flowering and then followed a decreasing trend accounting for the crop removal. Soil application of humic acid @ 20 kg ha^{-1} along with 100% RDF had highest available N status at vegetative, flowering and harvest stages of crop growth (Table 1). The treatment 100% RDF, black color mulching and humic acid increased the availability of N to a greater extent and was 34.45% increased over control. The very high ion exchange capacity of humates may bring about better utilization of applied N by making the N available to the root zone (Suntari et al. 2013). Humic acid produces ligands, capable of complexing with nutrient elements and the complexed elements remain more available to plant roots as complexation shields them against immobilization in soil. Inhibition of urease activity by humic acid led to reduced losses of N by volatilization and this contributed to increased availability of N. The possible reasons for inhibition of urease activity by humic acid are as follows: (i) catechol group of humic acid inhibited urease activity, (ii) phenolic substances present in humic acid inhibited the activity of urease, (iii) metal complexes of Cu (II), Hg (II) and Ag formed by humic acid had an inhibitory effect on soil urease activity (Marzadori et al. 2000).

Available P

The data on the available P also supported on use of fertigation, mulching and humic acid had resulted in an increased available P status in soil. Soil application of humic acid @ 20 kg ha^{-1} along with 100% RDF increased the available P content of soil at all the stages in Table 1. The treatment 100% RDF with black color mulching and humic acid application increased the availability of P which was 61.83% increased over the control. Humic substances had increased P availability by preventing their fixation in soil. The slow and continuous dissolution of raw phosphate in soil by humic acid may account for its increased availability. Soil phosphatase activity improved by humic acid may be resulted in increased P availability as phosphatase hydrolyzed the phosphate esters to inorganic P. Another possible reason humic acid dissolved the P fixed in the form of tricalcium phosphate and fluorapatite (Cimrin and Yilmaz 2005).

Available K

The changes in available K content of soil with the effect of fertigation, mulching and humic acid application increased the available K content of soil. Soil application of humic acid @ 20 kg ha^{-1} along with 100% RDF had highest available K content of soil. The 100% RDF with black color mulching and humic acid to a great extent increased the availability of K and was 28.30% increased over control in Table 1. The release of fixed K by humic acid increased availability and also fertigation resulted in lesser leaching of K to deeper layer of soil (Husein et al. 2015).

Exchangeable Ca and Mg

Soil application of humic acid @ 20 kg ha^{-1} along with 100% RDF recorded the highest exchangeable Ca and Mg content of soil. The treatment receiving 100% RDF, black color mulching and humic acid recorded to the greater extent in exchangeable Ca and Mg, which was 36.67 and 37.76% increase respectively, over control in Table 2. Chelating and complex, formation property of humic acid increased exchangeable Ca and Mg content of soil (Tufenkci et al. 2006).

Availability of Fe

Addition of fertigation, mulching and humic acid had a promising effect on the availability of Fe. The difference between treatments 100% RDF and 75% RDF was not statistically observable in Table 3. Soil application of humic acid @ 20 kg ha^{-1} enhanced the availability of Fe in all the stages. The treatment 100% RDF, black color mulching and humic acid greatly improved the availability of Fe and the per cent increase was higher (7.39%) over control. The enhanced solubilization and increased extractability of iron by reduction of non-available higher oxide forms to available forms by humic acid may account for its increased availability (Tufenkci et al. 2006).

Availability of Zn

Addition of fertigation, mulching and humic acid increased the availability of Zn. Soil application of humic acid @ 20 kg ha^{-1} increased the zinc availability. The treatment 100% RDF with black color mulching

Table 5. Effect of fertigation, mulching and humic acid on the total uptake of Ca and Mg (kg ha^{-1}) by tomato plant. RDF – Recommended dose of fertilizer through fertigation, BM – Black mulching, GM - Grey mulching, HA –Humic acid @ 20 kg ha^{-1} as basal, HA* - Foliar application of humic acid @ 0.1% @ 30, 45 and 60 DAT.

Treatments	Total uptake of Ca Vegetative stage	Flowering stage	Harvest stage	Mean	Total uptake of Mg Vegetative stage	Flowering stage	Harvest stage	Mean
T_1–Absolute control	0.550	9.56	43.89	18.00	0.080	4.250	21.95	8.760
T_2–100% RDF	0.660	11.22	49.11	20.33	0.090	5.390	23.61	9.700
T_3–100% RDF + BM + HA	2.590	24.42	64.44	30.48	0.380	12.12	32.22	14.91
T_4–100% RDF + GM + HA	2.460	23.31	63.11	29.63	0.320	11.57	31.55	14.48
T_5–75% RDF + BM + HA	1.710	21.61	62.60	28.64	0.270	10.73	29.85	13.62
T_6–75% RDF + GM + HA	1.650	20.91	61.16	27.91	0.260	10.37	29.39	13.34
T_7–100% RDF + BM + HA*	1.360	19.05	57.33	25.91	0.190	9.290	28.44	12.64
T_8–100% RDF + GM + HA*	1.330	17.97	56.37	25.22	0.190	8.910	27.97	12.26
T_9–75% RDF + BM + HA*	0.940	16.18	54.94	24.02	0.140	7.880	27.68	11.90
T_{10}–75% RDF + GM + HA*	0.910	14.70	54.41	23.34	0.140	7.210	26.78	11.38
T_{11}–100% RDF + BM	0.790	13.51	52.50	22.27	0.120	6.820	25.28	10.74
T_{12}–75% RDF + GM	0.760	12.48	51.12	21.45	0.120	6.240	24.42	10.26
Mean	1.310	17.08	55.92		0.190	8.400	27.43	

	Ca SEd `	Ca CD (0.05)	Mg SEd	Mg CD (0.05)
T	0.504	1.006	0.237	0.473
S	1.009	1.012	0.474	0.946
T × S	1.748	3.486	0.822	1.639

and humic acid improved the availability of Zn which was 36.96% increased over control in Table 3. The possible reasosns for increased availability of zinc upon humic acid addition are (i) increased solubility of Zn by humic acid as concluded by and (ii) ability of humic acid to form stable complezes with Zn (Tufenkci et al. 2006.

Total uptake of N

Application of 100% RDF increased the total uptake of N to a significant level, which was 13.93% increased over control. The black color polythene sheet mulching increased the dry matter production to a greater extent, which was 13.93% increased over control in Table 4. Black color mulching showed the highest N uptake than grey color mulching.

The rate of N uptake in tomato was much higher to sustain its rapid growth and higher rate of biomass accumulation. Soil application of humic acid @ 20 kg ha^{-1} along with 100% RDF enhanced the uptake of N at vegetative, flowering and harvest stages. The increased uptake of N was supposed to be due to the better use efficiency of applied N fertilizer in the presence of humic acid coupled with the retarded nitrification process enabling the slow availability of applied N. The primary physiological function of humic acid may be that they reduced the oxygen deficiency in plants which resulted in the uptake of larger amount of N. Reactions of ammonium ion with humic acid yielding covalent compounds maintaining the mobility of ammonium in solution and aids in the increased uptake of ammonium by plants. The acidic functionality of humic acid simulated the nitrate uptake by plants. Nitrate reductase is the key enzyme for N assimilation by most of the plants. Humic substances induced the activities of enzymes such as invertase and nitrate reductase and there by helped in increased assimilation of N by plants (Ferretti et al. 1991). Higher uptake of N by shoot could be due to the fact that N is the mobile element and it is utilized more in shoot than root.

Humic substances extracted from soil stimulated ion uptake by roots. Humic acid is known to be surface active and increases the permeability of root membranes and so enhances the nutrient uptake

Table 6. Effect of fertigation, mulching and humic acid on the total uptake of Fe and Zn (kg ha^{-1}) by tomato plant. RDF – Recommended dose of fertilizer through fertigation, BM – Black mulching, GM – Grey mulching, HA – Humic acid @ 20 kg ha^{-1} as basal, HA^* - Foliar application of humic acid @ 0.1% @ 30, 45 and 60 DAT.

Treatments	Total uptake of Fe				Total uptake of Zn			
	Vegetative stage	Flowering stage	Harvest stage	Mean	Vegetative stage	Flowering stage	Harvest stage	Mean
T_1–Absolute control	0.004	0.013	0.951	0.320	0.001	0.047	0.319	0.120
T_2–100% RDF	0.005	0.027	1.039	0.360	0.002	0.056	0.349	0.140
T_3–100% RDF + BM + HA	0.014	0.051	2.599	0.890	0.007	0.127	0.924	0.350
T_4–100% RDF + GM + HA	0.013	0.050	2.545	0.870	0.007	0.126	0.905	0.350
T_5–75% RDF + BM + HA	0.010	0.047	2.090	0.720	0.005	0.111	0.742	0.290
T_6–75% RDF + GM + HA	0.010	0.047	2.067	0.710	0.005	0.110	0.725	0.280
T_7–100% RDF + BM + HA^*	0.008	0.043	1.875	0.640	0.004	0.101	0.609	0.240
T_8–100% RDF + GM + HA^*	0.008	0.043	1.844	0.630	0.004	0.100	0.599	0.230
T_9–75% RDF + BM + HA^*	0.006	0.039	1.623	0.560	0.003	0.087	0.554	0.210
T_{10}–75% RDF + GM + HA^*	0.006	0.037	1.590	0.540	0.003	0.085	0.511	0.200
T_{11}–100% RDF + BM	0.005	0.035	1.451	0.500	0.002	0.075	0.467	0.180
T_{12}–75% RDF + GM	0.005	0.020	1.293	0.440	0.002	0.065	0.431	0.170
Mean	0.010	0.040	1.750		0.004	0.091	0.594	

	Fe SEd `	Fe CD (0.05)	Zn SEd	Zn CD (0.05)
T	0.015	0.029	0.004	0.008
S	0.029	0.058	0.008	0.016
T × S	0.051	0.101	0.014	0.028

(Hussein and Fawy 2011).

Total uptake of P

Application of 100% RDF enhanced the total uptake of P at vegetative, flowering and harvest stages than 75% RDF. This may be due to frequent application of water which led to the more solubility of P which was applied in soil and its higher availability near root zone. The black color mulching increased the total uptake of P over control in Table 4. P concentration in tomato leaves was significantly higher in plants grown on clear plastic mulch due to better soil temperature than plants grown on bare soil (Choudhary et al. 2013).

100% RDF increase the total uptake of P over control. Soil application of humic acid @ 20 kg ha^{-1} along with 100% RDF profoundly enhanced the P uptake in all the stages. Addition of humic acid increased the root growth by 58% and this could help in better assimilation of P by plants (Khaled and Fawy 2011). The increase in P uptake may be due to the prevention of P fixation in the soil and also by forming humophospho complexes which were easily assimilate by the plants. The increase in P accumulation in tomato shoot suggested that humic acid may enhance the uptake of P indirectly by complexing with iron. Addition of humic acid maintained higher levels of acid phosphatase activity and this increased phosphatase activity holds key enzyme for increased P uptake by plants. Organic phosphorus in soil comprises of 30—70% of the total P content. Hydrolysis of organic P compounds was essential for uptake by plants and humic acid brought out this hydrolysis.

Total uptake of K

100% RDF increased the total uptake of K to a significant level, which was 29.33% increased over the control. Increasing the K levels in fertigation increased the K uptake in tomato. The treatment receiving black color mulching increased the uptake of K to a greater extent, thus the percent increase was 29.33% than the control in Table 4.

The K uptake was higher in shoot with 100% RDF when compared to 75% RDF and control. Soil application of humic acid @ 20 kg ha^{-1} along with

100% RDF had highest K uptake by shoot and root. Humic acid induced increase in the permeability of bio membranes for electrolytes accounted for increased uptake of K. Humic substances modify membrane bound ATPase activity and the relation between membrane ATPase activity, H^+ extrusion and the ion uptake suggested that humic substances influence active uptake of potassium by interfering with specific ion carrier (Khaled and Fawy 2011).

The mobile nature of K might be significantly increased the K uptake due to the supply of nutrients by HA which contains 6.25% K. Apart from this, the humic acid creates favorable physical condition for better root proliferation facilitating higher K uptake by plants (Baskar 2003). The mobile nature of K and increase in the root volume would also have higher K uptake.

Total uptake of Ca

The total uptake of Ca was higher with 100% RDF than the 75% RDF. Soil application of humic acid @ 20 kg ha^{-1} along with 100% RDF increased the total uptake of Ca by shoot and root. 100% RDF, black color mulching and humic acid improved the total uptake of Ca and was 46.8% increased over control in Table 5. The improved total uptake of Ca by humic acid may be attributed to (i) complexation of Ca by various functional groups of humic acid, (ii) altered membrane permeability by humic acid which allows active nutrient uptake process, and (iii) enhanced cuticle and cell membrane penetration caused by humic acid (Khaled and Fawy 2011).

Total uptake of Mg

The applied organic and mineral fertilizers increased the total uptake of Mg by shoot and root. Addition of 100% RDF showed enhanced total uptake of Mg by all the plant parts over control. Soil application of humic acid @ 20 kg ha^{-1} along with 100% RDF increased the total uptake of Mg in Table 5. Foliar spraying of 0.1% humic acid was also impressive in increasing total uptake of Mg by tomato. The treatment receiving 100% RDF, black color mulching and humic acid improved the total uptake of Mg which was 46.79% increased over the control. Humic acid, by the formation of complex compounds with Mg plays a key role in the transport of Mg in tissues and plant parts (Khaled and Fawy 2011).

Total uptake of Fe

Fertigation, mulching and humic acid application significantly affected total uptake of Fe by plant. Soil application of humic acid @ kg ha^{-1} along with 100% RDF recorded the highest total uptake of Fe by both shoot and root in Table 6. Protonation reaction of humic acid caused a reduction of iron (Fe^{3+}) and made Fe chelates which are readily available to the plants (Khaled and Fawy 2011). Humic substances prevented precipitation of Fe in nutrient solution even in the presence of high phosphate content due to its chelating property and facilitated Fe translocation from the roots to the stalk and leaves.

Total uptake of Zn

Significant increase in total uptake of Zn, by both shoot and root, was evidenced in 100% RDF. Soil application of humic acid @ 20 kg ha^{-1} along with recommended dose of fertilizer increased the total uptake of Zn at vegetative, flowering and harvest stages in Table 6. 3×10^4 times increase in Zn solubility due to fulvic acid and this indicates that chelation of native Zn by chelating agents is an important mechanism where by added humic acid can alleviate Zn deficiency. The heneficial influence of humic acid in soil prevented the formation of insoluble complexes of Zn and facilitated their uptake by plants (Khaled and Fawy 2011).

The significant increase in the micronutrient uptake could be ascribed to the presence of chelated micronutrients (Zn, Fe, Cu and Mn) in the humic substances. Humic substances are well known as complexing agents for transition metal cations, thereby facilitating enhanced micronutrients uptake in crops (El-Dusuki 2004).

Conclusion

In conclusion, increased the availability of Nitrogen (N-330.9 +kg ha^{-1}), Phosphorus (P-28.65 kg ha^{-1}), Potassium (K-383.6 kg ha^{-1}), Exchangeable Calcium

(Ca-6.71 cmol (p^+ kg^{-1}), Exchangeable Magnesium (Mg-4.25 cmol (P^+) kg^{-1}), Iron (Fe-10.81 kg ha^{-1}) and Zinc (Zn-2.55 kg ha^{-1}) by the application of 100% recommended dose of fertilizer + Black color mulching + Humic acid @ 20 kg ha^{-1} as basal. In the light of uptake of nutrients, application of 100% recommended dose of fertilizer + Black color mulching + Humic acid @ 20 kg ha^{-1} as basal significantly favored the total uptake of Nitrogen (105.3 kg ha^{-1}), Phosphorus (29.41 kg ha^{-1}), Potassium (141.7 kg ha^{-1}), Calcium (30.48 kg ha^{-1}), Magnesium (14.91 kg ha^{-1}), Iron ((0.890 kg ha^{-1}) and Zinc (0.350 kg ha^{-1}) by tomato.

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