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Micro-nutrient content and uptake of direct sown rice as influenced by combined application of humic acid and inorganic nitrogen

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Abstract
A field experiment was carried out to study the influence of different levels of humic acid (10, 20, 30 kg ha^{-1}) and inorganic N fertilizer *viz.*, 100% of recommended dose and 75% of recommended dose on nutrient content and uptake of direct sown rice at Agricultural college farm, Bapatla during 2019. The experiment was laid out in RBD with ten treatments replicated thrice with BPT-5204 variety of rice as test crop. Plant samples collected at tillering, panicle initiation and harvest stages of crop were analyzed for contents of micro-nutrients (Fe, Mn, Zn, Cu) and their uptakes were calculated using drymatter production at different stages. Results indicated that plant contents of micro-nutrients (Fe, Mn, Zn, Cu) were not significantly influenced by the imposed treatments whereas, significantly highest uptake of micro-nutrients (Fe, Mn, Zn, Cu) at tillering, panicle initiation and harvest (straw and grain) stages were observed with the treatment T_6 that received 100% RDN and HA @ 30 kg ha^{-1}.

Keywords: Humic acid, direct sown rice, nutrient content and uptake

Introduction
Humic acids form complexes with mineral nitrogen fertilizers and they serve as slow release N sources. Humates possess extremely high ion-exchange capacities, which allow them to hold cations in a way that makes them more easily available to plant roots and thus improve micronutrient transfer to the plants circulation system. Remarkable response of cereals, pulses, cash crops, vegetables to humic acid application is observed by various scientists. Improved uptake of N, P, K, Ca, Mg, Fe, Mn and Zn by rice was observed by humic acid addition to soil (Govindasamy and Chandrasekharan, 2002) [4]. The present study was carried out in a view to observe the influence of humic acid and inorganic nitrogen on content and uptake of macro (N, P, K & S) and micro-nutrients (Fe, Mg, Zn, Cu) by direct sown rice.

Materials and Methods
A field experiment was conducted at the Agricultural College Farm, Bapatla of Acharya N.G. Ranga Agricultural University during 2019. The experiment was laid out in a randomized block design with three replications and ten treatments *viz.*, T_1- (control for N), T_2 - 100% Recommended Dose of Nitrogen (RDN), T_3 - 100% RDN + FYM @ 10 t ha^{-1}, T_4 - 100% RDN + Soil application of humic acid @ 10 kg ha^{-1}, T_5 - 100% RDN + Soil application of humic acid @ 20 kg ha^{-1}, T_6 -100% RDN + Soil application of humic acid @ 30 kg ha^{-1}, T_7 - 75% RDN + FYM @ 10 t ha^{-1}, T_8 -75% RDN + Soil application of humic acid @ 10 kg ha^{-1}, T_9 - 75% RDN + Soil application of humic acid @ 20 kg ha^{-1}, T_{10} -75% RDN + Soil application of humic acid @ 30 kg ha^{-1} (Note: RDF: 120:60:40 N-P_2O_5 and K_2O (kg ha^{-1}) through Urea, SSP and MOP. Recommended dose of P & K was applied from T_1 to T_{10}). Well decomposed farmyard manure @ 10 t ha^{-1} was applied to the field as per recommended treatments one week before sowing. Nitrogen @120 kg ha^{-1} (100% RDN) and @ 90 kg ha^{-1} (75% RDN) was applied as per the treatments in the form of urea in three equal splits i.e., 1/3rd as basal, 1/3rd at active tillering stage and 1/3rd at panicle initiation stage. A common dose of phosphorus @ 60 kg P_2O_5 ha^{-1} in the form of single super phosphate was applied as basal just before sowing. A common dose of 40 kg K_2O ha^{-1} was applied as muriate of potash, in two equal splits as half at basal and half at panicle initiation stage by taking the plot size into consideration. Humic acid @ 10, 20, 30 kg ha^{-1} was applied to the soil directly in granular form as basal just before sowing. Plant samples collected at initial, tillering, panicle initiation

and harvest stages of rice were analysed for contents of Fe, Mn, Zn, Cu using standard procedures and uptakes were calculated using drymatter production at different stages.

Results and Discussion

Drymatter Production

The data pertaining to drymatter production were furnished in the Table 1. In general, the drymatter production increases as the crop growth progresses. From the table, it is evident that application of humic acid showed a significant influence on drymatter production at all the three growth stages of rice.

Significantly higher drymatter production (5089, 8178, 13179 kg ha^{-1}) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}) and the lowest (2600, 5333, 9385 kg ha^{-1}) was recorded in T_1 (control) at tillering, panicle initiation and at harvest stages respectively. The treatments T_5, T_3 and T_{10} were statistically on par with treatment T_6 at all the three stages of crop growth.

There is an increase in drymatter production on increase of humic acid dose from 10 kg ha^{-1} to 30 kg ha^{-1} throughout the crop growth. It was also observed that increase in inorganic nitrogen dose from 75% to 100% also increased the drymatter production in combination with different levels of HA and FYM @ 10 t ha^{-1}. There is a significant increase in drymatter production up to a humic acid dose of 20 kg ha^{-1} combined with 100% N and at a fertilizer level of 75% N, the increase was significant upto a humic acid dose of 30 kg ha^{-1} at all the three stages of the crop growth. Compared to FYM treated plots, the plots supplied with humic acid @ 20 and 30 kg ha^{-1} recorded more drymatter production at same level of inorganic N fertilizer.

Table 1: Effect of different levels of Humic acid and inorganic nitrogen on Drymatter production (kg ha^{-1}) at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage
T1 : Control (0N-P-K)	2600	5333	9385
T2 : 100% RDN	3222	6733	11117
T3 : 100% RDN + FYM @ 10 t ha^{-1}	4911	7867	12672
T4 : 100% RDN + HA @ 10 kg ha^{-1}	4400	7444	11796
T5 : 100% RDN + HA @ 20 kg ha^{-1}	4956	8022	12944
T6 : 100% RDN + HA @ 30 kg ha^{-1}	5089	8178	13179
T7 : 75% RDN + FYM @ 10 t ha^{-1}	4111	7111	11523
T8 : 75% RDN + HA @ 10 kg ha^{-1}	3600	6778	11266
T9 : 75% RDN + HA @ 20 kg ha^{-1}	4333	7178	11760
T10:75% RDN + HA @ 30 kg ha^{-1}	4756	7622	12379
SEm (±)	195.41	236.52	352.52
CD (P=0.05%)	581	703	1047
CV (%)	8.1	5.7	5.2

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Yield

Grain yield

The data presented in Table 2, revealed a significant increase in grain yield with different levels of inorganic N fertilizer and its integration with FYM or humic acid.

The highest grain yield (4291 kg ha^{-1}) was recorded in T_6 (100% N + HA @ 30 kg ha^{-1}) and the lowest grain yield (3036 kg ha^{-1}) was recorded in T_1 (control) where humic acid and inorganic nitrogen were not applied. The treatments receiving 100% N + HA @ 20 kg ha^{-1} (T_5), 100% N + FYM @ 10 t ha^{-1} (T_3) and 75% N + HA @ 30 kg ha^{-1} (T_{10}) were statistically on par with 100% N + HA @ 30 kg ha^{-1} (T_6).

There is a significant increase in grain yield up to a HA dose of 20 kg ha^{-1} combined with 100% N and at a fertilizer level of 75% N, the increase was significant upto a humic acid dose of 30 kg ha^{-1}. However, increase in grain yield was observed with an increase in humic acid dose upto 30 kg ha^{-1} at a specified level of inorganic N fertilizer. Application of humic acid @ 30 kg ha^{-1} combined with 100% RDN recorded 41.3% more grain yield compared to control (N_0PK).

Straw yield

On perusal of the data presented in the Table 2, it was revealed that there is a significant difference in straw yield among different treatments of humic acid levels combined with inorganic nitrogen.

The highest straw yield (8888 kg ha^{-1}) was recorded with T_6 (100% RDN + HA @ 30 kg ha^{-1}). The lowest straw yield (6349 kg ha^{-1}) was recorded with T_1 (control) where, neither humic acid nor inorganic nitrogen was applied. The treatments receiving 100% N + HA @ 20 kg ha^{-1} (T_5), 100% N + FYM @ 10 t ha^{-1} (T_3) and 75% N + HA @ 30 kg ha^{-1} (T_{10}) were statistically on par with 100% N + HA @ 30 kg ha^{-1} (T_6).

There is a significant increase in straw yield up to a HA dose of 20 kg ha^{-1} combined with 100% N and at a fertilizer level of 75% N, the increase was significant upto a humic acid dose of 30 kg ha^{-1}. However, increase in straw yield was observed with an increase in humic acid dose upto 30 kg ha^{-1} at a specified level of inorganic N fertilizer. Application of humic acid @ 30 kg ha^{-1} combined with 100% RDN recorded 40% more straw yield compared to control. Experimental plots treated with FYM combined with a specified level of inorganic fertilizer recorded lower straw yield compared to the plots supplied with HA @ 20 kg ha^{-1} or more.

Nardi *et al.* (1988) [5] reported that humic substances exhibited auxin-, gibberellin- and cytokinin-like activities. The positive effect of humic acid on yield could be mainly due to hormone-like activities through their association in photosynthesis, cell respiration, protein synthesis, oxidative phosphorylation and various enzymatic reactions (Vaughan and Ord, 1985; Chen and Aviad, 1990) [7, 2].

Table 2: Effect of different levels of Humic acid and inorganic nitrogen on Grain yield and Straw yield (kg ha^{-1}) of direct sown rice

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T1 : Control (0N-P-K)	3036	6349
T2 : 100% RDN	3815	7301
T3 : 100% RDN + FYM @ 10 t ha^{-1}	4132	8539
T4 : 100% RDN + HA @ 10 kg ha^{-1}	3940	7856
T5 : 100% RDN + HA @ 20 kg ha^{-1}	4135	8809
T6 : 100% RDN + HA @ 30 kg ha^{-1}	4291	8888
T7 : 75% RDN + FYM @ 10 t ha^{-1}	3904	7619
T8 : 75% RDN + HA @ 10 kg ha^{-1}	3886	7380
T9 : 75% RDN + HA @ 20 kg ha^{-1}	3935	7825
T10:75% RDN + HA @ 30 kg ha^{-1}	4126	8254
SEm (±)	118.12	342.48
CD (P=0.05%)	350	1018
CV (%)	5.2	7.5

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Micro-nutrient content

Iron

Iron content in direct seeded rice at different stages was furnished in the Table 3. Perusal of data revealed that application of humic acid combined with inorganic nitrogen had no significant influence on iron content at any stage of the crop. However, an increase in iron content in treatments receiving humic acid doses along with inorganic nitrogen compared to treatments T_1 (control) and T_2 (100% RDN). Highest iron content (481, 479, 444, 223 ppm) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}) whereas the lowest (446, 397, 376, 189 ppm) was recorded in T_1 (control) at tillering, panicle initiation, harvest stages (straw and in grain) respectively.

Table 3: Effect of different levels of Humic acid and inorganic nitrogen on Iron content (ppm) at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage	
			Straw	Grain
T1 : Control (0N-P-K)	446	397	376	189
T2 : 100% RDN	448	419	391	196
T3 : 100% RDN + FYM @ 10 t ha^{-1}	471	447	437	219
T4 : 100% RDN + HA @ 10 kg ha^{-1}	453	438	413	207
T5 : 100% RDN + HA @ 20 kg ha^{-1}	472	450	437	220
T6 : 100% RDN + HA @ 30 kg ha^{-1}	481	479	444	223
T7 : 75% RDN + FYM @ 10 t ha^{-1}	452	422	404	203
T8 : 75% RDN + HA @ 10 kg ha^{-1}	449	411	397	199
T9 : 75% RDN + HA @ 20 kg ha^{-1}	452	431	412	207
T10:75% RDN + HA @ 30 kg ha^{-1}	460	447	426	214
SEm (±)	14.61	15.21	15.40	7.70
CD (P=0.05%)	NS	NS	NS	NS
CV (%)	5.5	6.1	6.4	6.4

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Manganese

Manganese content in direct seeded rice at different stages was furnished in the Table 4. Perusal of data revealed a non-significant influence of various treatments on manganese content at any stage of crop growth. However, an increase in manganese content in treatments receiving humic acid doses along with inorganic nitrogen was noticed compared to treatments T_1 (control) and T_2 (100% RDN). Highest manganese content (144, 134, 113, 57 ppm) was recorded in T_6 (100% N + HA @ 30 kg ha^{-1}) whereas the lowest (131, 117, 97, 49 ppm) was recorded in T_1 (control) at tillering, panicle initiation, harvest stages (straw and in grain) respectively.

Table 4: Effect of different levels of Humic acid and inorganic nitrogen on Manganese content (ppm) at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage	
			Straw	Grain
T1 : Control (0N-P-K)	131	117	97	49
T2 : 100% RDN	132	117	98	50
T3 : 100% RDN + FYM @ 10 t ha^{-1}	139	130	108	55
T4 : 100% RDN + HA @ 10 kg ha^{-1}	136	121	99	50
T5 : 100% RDN + HA @ 20 kg ha^{-1}	141	131	112	57
T6 : 100% RDN + HA @ 30 kg ha^{-1}	144	134	113	57
T7 : 75% RDN + FYM @ 10 t ha^{-1}	134	119	105	54
T8 : 75% RDN + HA @ 10 kg ha^{-1}	132	117	98	50
T9 : 75% RDN + HA @ 20 kg ha^{-1}	134	120	102	52
T10:75% RDN + HA @ 30 kg ha^{-1}	139	130	108	55
SEm (±)	4.94	4.45	4.46	2.23

CD (P=0.05%)	NS	NS	NS	NS
CV (%)	6.3	6.2	7.4	7.3

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Zinc

Zinc content in direct seeded rice at different stages was furnished in the Table 5. Perusal of data revealed that application of humic acid combined with inorganic nitrogen showed no significant influence on zinc content at any stage of crop growth. Moreover, a non-significant increase in zinc content in treatments receiving humic acid doses along with inorganic nitrogen compared to treatments T_1 (control) and T_2 (100% RDN) was observed.

Highest zinc content (78.15, 76.73, 48.67, 44.18 ppm) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}) whereas the lowest (70.43, 57.93, 39.47, 34.06 ppm) was recorded in T_1 (control) at tillering, panicle initiation, harvest stages (straw and in grain) respectively.

The treatments that received 100% N + HA @ 20 kg ha^{-1} (T_5), 100% N + FYM @ 10 t ha^{-1} (T_3) and 75% N + HA @ 30 kg ha^{-1} (T_{10}) were in decreasing order of zinc content followed by 100% N + HA @ 30 kg ha^{-1} (T_6) at all the growth stages and also in grain.

Copper

Copper content in direct seeded rice at different stages was furnished in the Table 6. Perusal of data indicated that application of humic acid combined with inorganic nitrogen had no significant influence on copper content at any stage of crop growth. However, a non-significant increase was observed in copper content in treatments receiving humic acid doses along with inorganic nitrogen compared to treatments T_1 (control) and T_2 (100% RDN).

Highest copper content (25.60, 23.18, 16.94, 11.47 ppm) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}) whereas the lowest (22.10, 20.10, 13.70, 9.85 ppm) was recorded in T_1 (control) at tillering, panicle initiation, harvest stages (straw and in grain) respectively.

The treatments that received 100% N + HA @ 20 kg ha^{-1} (T_5), 100% N + FYM @ 10 t ha^{-1} (T_3) and 75% N + HA @ 30 kg ha^{-1} (T_{10}) were in decreasing order of copper content followed by 100% N + HA @ 30 kg ha^{-1} (T_6) at all the three growth stages and also in grain.

Table 5: Effect of different levels of Humic acid and inorganic nitrogen on Zinc content (ppm) at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage	
			Straw	Grain
T1 : control (0N-P-K)	70.43	57.93	39.47	34.06
T2 : 100% RDN	70.52	58.87	40.17	34.83
T3 : 100% RDN + FYM @ 10 t ha^{-1}	77.70	73.87	44.30	39.38
T4 : 100% RDN + HA @ 10 kg ha^{-1}	74.72	63.33	42.83	37.77
T5 : 100% RDN + HA @ 20 kg ha^{-1}	78.05	74.07	44.63	39.75
T6 : 100% RDN + HA @ 30 kg ha^{-1}	78.15	76.73	48.67	44.18
T7 : 75% RDN + FYM @ 10 t ha^{-1}	72.78	59.47	42.63	37.55
T8 : 75% RDN + HA @ 10 kg ha^{-1}	71.68	58.93	40.87	35.60
T9 : 75% RDN + HA @ 20 kg ha^{-1}	73.33	61.20	42.67	37.58
T10:75% RDN + HA @ 30 kg ha^{-1}	76.35	69.20	44.03	39.09
SEm (±)	2.37	4.87	2.27	2.49
CD (P=0.05%)	NS	NS	NS	NS
CV (%)	5.5	12.9	9.1	11.4

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Table 6: Effect of different levels of Humic acid and inorganic nitrogen on Copper content (ppm) at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage	
			Straw	Grain
T1 : Control (0N-P-K)	22.10	20.10	13.70	9.85
T2 : 100% RDN	22.70	20.40	13.80	9.90
T3 : 100% RDN + FYM @ 10 t ha^{-1}	25.20	22.30	16.62	11.31
T4 : 100% RDN + HA @ 10 kg ha^{-1}	24.50	21.00	14.02	10.01
T5 : 100% RDN + HA @ 20 kg ha^{-1}	25.56	22.70	16.64	11.32
T6 : 100% RDN + HA @ 30 kg ha^{-1}	25.60	23.18	16.94	11.47
T7 : 75% RDN + FYM @ 10 t ha^{-1}	23.60	20.70	13.92	9.96
T8 : 75% RDN + HA @ 10 kg ha^{-1}	23.00	20.60	13.84	9.92
T9 : 75% RDN + HA @ 20 kg ha^{-1}	24.02	20.90	14.02	10.01
T10:75% RDN + HA @ 30 kg ha^{-1}	25.00	21.56	16.07	11.04
SEm (±)	1.10	0.72	0.96	0.48
CD (P=0.05%)	NS	NS	NS	NS
CV (%)	7.9	5.8	11.1	7.9

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Uptake of micro-nutrients

Iron

Iron uptake in direct seeded rice at different stages was furnished in the Table 7. On perusal of data, it was revealed that iron uptake was significantly influenced by various treatments at all the stages of crop growth. There was a significant increase in iron uptake in treatments receiving humic acid doses along with inorganic nitrogen compared to treatments T_1 (control) and T_2 (100% RDN).

Highest iron uptake (2.45, 3.92, 3.94, 0.96 kg ha^{-1}) was recorded in T_6 (100% N + HA @ 30 kg ha^{-1}) whereas the lowest (1.16, 2.12, 2.39, 0.57 kg ha^{-1}) was recorded in T_1

(control) at tillering, panicle initiation, harvest stages (Straw and in grain) respectively. The treatments that received 100% N + HA @ 20 kg ha^{-1} (T_5), 100% N + FYM @ 10 t ha^{-1} (T_3) and 75% N + HA @ 30 kg ha^{-1} (T_{10}) were statistically at par with (T_6) at maximum tillering, harvest stages (straw and grain) of crop growth. At panicle initiation stage, only the treatments T_5 and T_3 were at par with T_6.

There is a significant increase in iron uptake up to a HA dose of 20 kg ha^{-1} combined with 100% N and at a fertilizer level of 75% N, the increase was significant upto a humic acid dose of 30 kg ha^{-1} at all the stages of crop growth (except PI stage) and also in grain. At panicle initiation stage, significant increase in iron uptake was pronounced only when humic acid is combined with 100% N but not with 75% N.

According to Patil *et al.* (2011) [6] the humic substances act as chelating agents there by prevents formation of precipitation, fixation, leaching and oxidation of micronutrients in soil.

Table 7: Effect of different levels of Humic acid and inorganic nitrogen on Iron uptake (kg ha^{-1}) at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage	
			Straw	Grain
T1 : control (0N-P-K)	1.16	2.12	2.39	0.57
T2 : 100% RDN	1.45	2.83	2.87	0.75
T3 : 100% RDN + FYM @ 10 t ha^{-1}	2.31	3.53	3.73	0.91
T4 : 100% RDN + HA @ 10 kg ha^{-1}	1.99	3.26	3.26	0.82
T5 : 100% RDN + HA @ 20 kg ha^{-1}	2.34	3.61	3.86	0.91
T6 : 100% RDN + HA @ 30 kg ha^{-1}	2.45	3.92	3.94	0.96
T7 : 75% RDN + FYM @ 10 t ha^{-1}	1.86	2.99	3.08	0.80
T8 : 75% RDN + HA @ 10 kg ha^{-1}	1.61	2.79	2.93	0.77
T9 : 75% RDN + HA @ 20 kg ha^{-1}	1.96	3.10	3.22	0.81
T10:75% RDN + HA @ 30 kg ha^{-1}	2.19	3.40	3.52	0.88
SEm (±)	0.11	0.17	0.22	0.04
CD (P=0.05%)	0.32	0.49	0.64	0.12
CV (%)	9.7	9.1	11.5	8.8

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Manganese

Manganese uptake in direct seeded rice at different stages was furnished in the Table 8. Perusal of data revealed that application of humic acid combined with inorganic nitrogen significantly influenced the manganese uptake at all the stages of crop growth. There was a significant increase in manganese uptake in treatments receiving humic acid doses along with inorganic nitrogen compared to treatments T_1 (control) and T_2 (100% RDN).

Significantly highest manganese uptake (0.73, 1.09, 1.00, 0.25 kg ha^{-1}) was recorded in T_6 (100% N + HA @ 30 kg ha^{-1}) whereas the lowest (0.34, 0.62, 0.61, 0.15 kg ha^{-1}) was recorded in T_1 (control) at tillering, panicle initiation, harvest stages (straw and in grain) respectively. The treatments receiving 100% N + HA @ 20 kg ha^{-1} (T_5), 100% N + FYM @ 10 t ha^{-1} (T_3) and 75% N + HA @ 30 kg ha^{-1} (T_{10}) were statistically at par with (T_6) at maximum tillering, harvest stages (straw and in grain) of crop growth. At panicle initiation stage, only the treatments T_5 and T_3 were at par with T_6.

There is a significant increase in manganese uptake up to a HA dose of 20 kg ha^{-1} combined with 100% N and at a fertilizer level of 75% N, the increase was significant upto a humic acid dose of 30 kg ha^{-1} at maximum tillering and harvest stages of crop growth. At panicle initiation stage, significant increase in manganese uptake is pronounced only when humic acid is combined with 100% N but not with 75% N.

Table 8: Effect of different levels of Humic acid and inorganic nitrogen on Manganese uptake (kg ha^{-1}) at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage	
			Straw	Grain
T1 : Control (0N-P-K)	0.34	0.62	0.61	0.15
T2 : 100% RDN	0.43	0.78	0.71	0.19
T3 : 100% RDN + FYM @ 10 t ha^{-1}	0.68	1.02	0.92	0.23
T4 : 100% RDN + HA @ 10 kg ha^{-1}	0.60	0.90	0.78	0.20
T5 : 100% RDN + HA @ 20 kg ha^{-1}	0.70	1.05	0.99	0.24
T6 : 100% RDN + HA @ 30 kg ha^{-1}	0.73	1.09	1.00	0.25
T7 : 75% RDN + FYM @ 10 t ha^{-1}	0.55	0.85	0.80	0.21
T8 : 75% RDN + HA @ 10 kg ha^{-1}	0.48	0.79	0.72	0.19
T9 : 75% RDN + HA @ 20 kg ha^{-1}	0.58	0.86	0.79	0.20
T10:75% RDN + HA @ 30 kg ha^{-1}	0.66	0.99	0.89	0.23
SEm (±)	0.03	0.03	0.05	0.01
CD (P=0.05%)	0.08	0.10	0.15	0.04
CV (%)	7.9	6.2	10.9	9.9

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Zinc

Zinc uptake in direct seeded rice at different stages was furnished in the Table 9. The perusal of data revealed a significant influence of imposed treatments on zinc uptake by direct sown rice at all the stages of crop growth. There was a significant increase in zinc uptake in treatments receiving humic acid doses along with inorganic nitrogen compared to treatments T_1 (control) and T_2 (100% RDN).

Highest zinc uptake (0.40, 0.63, 0.43, 0.19 kg ha^{-1}) was recorded in T_6 (100% N + HA @ 30 kg ha^{-1}) whereas the

lowest (0.18, 0.31, 0.25, 0.10 kg ha^{-1}) was recorded in T_1 (control) at tillering, panicle initiation, harvest stages (straw and in grain) respectively. The treatments that received 100% N + HA @ 20 kg ha^{-1} (T_5), 100% N + FYM @ 10 t ha^{-1} (T_3) and 75% N + HA @ 30 kg ha^{-1} (T_{10}) were statistically at par with (T_6) at maximum tillering, panicle initiation stages and also in grain. At harvest stage, only the treatments T_5 and T_3 were at par with T_6.

There is a significant increase in zinc uptake up to a HA dose of 20 kg ha^{-1} combined with 100% N and at a fertilizer level of 75% N, the increase was significant upto a humic acid dose of 30 kg ha^{-1} at maximum tillering, panicle initiation stages and also in grain . At harvest stage (straw), significant increase in zinc uptake is pronounced only when humic acid is combined with 100% N but not with 75% N.

Table 9: Effect of different levels of Humic acid and inorganic nitrogen on Zinc uptake (kg ha^{-1}) at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage	
			Straw	Grain
T1 : Control (0N-P-K)	0.18	0.31	0.25	0.10
T2 : 100% RDN	0.23	0.40	0.29	0.13
T3 : 100% RDN + FYM @ 10 t ha^{-1}	0.38	0.58	0.38	0.16
T4 : 100% RDN + HA @ 10 kg ha^{-1}	0.33	0.47	0.34	0.15
T5 : 100% RDN + HA @ 20 kg ha^{-1}	0.39	0.60	0.39	0.16
T6 : 100% RDN + HA @ 30 kg ha^{-1}	0.40	0.63	0.43	0.19
T7 : 75% RDN + FYM @ 10 t ha^{-1}	0.30	0.42	0.33	0.15
T8 : 75% RDN + HA @ 10 kg ha^{-1}	0.26	0.40	0.30	0.14
T9 : 75% RDN + HA @ 20 kg ha^{-1}	0.32	0.44	0.33	0.15
T10:75% RDN + HA @ 30 kg ha^{-1}	0.36	0.53	0.36	0.16
SEm (±)	0.02	0.04	0.02	0.01
CD (P=0.05%)	0.05	0.12	0.05	0.03
CV (%)	9.6	14.4	9.2	12.1

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Copper

Copper uptake in direct seeded rice at different stages was furnished in the Table 10. Perusal of data revealed that application of humic acid combined with inorganic nitrogen significantly affected the copper uptake at all the stages of crop growth. There was a significant increase in copper uptake in treatments receiving humic acid doses along with inorganic nitrogen compared to treatments T_1 (control) and T_2 (100% RDN).

Highest copper uptake (0.13, 0.19, 0.15, 0.05 kg ha^{-1}) was recorded in T_6 (100% N + HA @ 30 kg ha^{-1}) whereas the lowest (0.06, 0.11, 0.09, 0.03 kg ha^{-1}) was recorded in T_1 (control) at tillering, panicle initiation, harvest stages (straw and in grain) respectively. The treatments that received 100% N + HA @ 20 kg ha^{-1} (T_5), 100% N + FYM @ 10 t ha^{-1} (T_3) and 75% N + HA @ 30 kg ha^{-1} (T_{10}) were statistically at par with (T_6) at all the stages of crop growth and also in grain.

There is a significant increase in copper uptake up to a HA dose of 20 kg ha^{-1} combined with 100% N and at a fertilizer level of 75% N, the increase was significant upto a humic acid dose of 30 kg ha^{-1} at all the stages of crop growth and also in grain.

The treatments supplied with 75% RDN recorded lower micro-nutrient uptake compared to the ones which received 100% RDN. The treatments involving FYM recorded lower micro-nutrient uptake compared to the treatments supplied with HA @ 20 or 30 kg ha^{-1} at a specified level of inorganic N fertilizer. However, the treatments with HA @ 10 kg ha^{-1} recorded a decreased uptake of micro-nutrients compared to FYM treated plots at same level of inorganic N fertilizer.

The increase in the content and uptake of micronutrients might be due to increased root activity. On addition of HA, the formation of soluble humus chelates in soil favoured increase in micronutrients uptake (Fortun and Polo, 1989) [3]. Humic acids might have attacked minerals and decomposed them thereby releasing them from molecular state to adsorbed state or the HA formed stable organo-mineral complexes of ions such as HA-Fe^{+2}, HA-Mn^{+2}, HA-Zn^{+2}, HA-Cu^{+2} which become easily available to the plant (Brady, 1996) [1]. The redox potential might also have increased the micro-nutrient uptake.

Table 10: Effect of different levels of Humic acid and inorganic nitrogen on Copper uptake (kg ha^{-1}) at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage	
			Straw	Grain
T1 : Control (0N-P-K)	0.06	0.11	0.09	0.03
T2 : 100% RDN	0.07	0.14	0.10	0.04
T3 : 100% RDN + FYM @ 10 t ha^{-1}	0.12	0.18	0.14	0.05
T4 : 100% RDN + HA @ 10 kg ha^{-1}	0.11	0.16	0.11	0.04
T5 : 100% RDN + HA @ 20 kg ha^{-1}	0.13	0.18	0.15	0.05
T6 : 100% RDN + HA @ 30 kg ha^{-1}	0.13	0.19	0.15	0.05
T7 : 75% RDN + FYM @ 10 t ha^{-1}	0.10	0.15	0.11	0.04
T8 : 75% RDN + HA @ 10 kg ha^{-1}	0.08	0.14	0.10	0.04
T9 : 75% RDN + HA @ 20 kg ha^{-1}	0.10	0.15	0.11	0.04
T10:75% RDN + HA @ 30 kg ha^{-1}	0.12	0.16	0.13	0.05
SEm (±)	0.01	0.01	0.01	0.002
CD (P=0.05%)	0.02	0.03	0.03	0.01
CV (%)	9.5	9.9	12.3	10.3

(**Note:** Recommended dose of P & K was applied from T_1 to T_{10})

Conclusions

The treatment that received humic acid @ 30 kg ha^{-1} combined with 100% RDN (T_6) recorded highest plant micro-nutrient (Fe, Mn, Zn, Cu) content and uptake. However, plant micro-nutrient (Fe, Mn, Zn, Cu) content and uptake were not significantly influenced by the applied treatments.

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