Original Research Article

AVAILABLE NUTRIENT STATUS OF SOIL 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 chemical properties of soil under 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. Soil samples collected at tillering, panicle initiation and harvest stages of crop were analyzed for chemical properties like available N, P_2O_5, K_2O, Sulphur and cationic micro-nutrients (Fe, Mn, Zn, Cu). Results indicated that increased availability of N, P_2O_5, K_2O, Sulphur and cationic micro-nutrients (Fe, Mn, Zn, Cu) were observed with the treatment T_6 involving 100% RDN and HA @ 30 kg ha^{-1}.

Keywords: Humic acid, Direct sown rice, Soil chemical properties

1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food crops in the world, and staple food for more than 50% of the global population. Being the major source of food after wheat, it meets 43 % of calorie requirement of more than two third of the Indian population. Globally, area under rice cultivation was 162.06 m ha of which 43.8 m ha was from India (Ministry of Agriculture & Farmers Welfare) and the total rice production was 496 m t and 297.5 m t respectively in the year 2019 (*https://www.statista.com/topics/1443/rice/*). Direct sown rice refers to the process of establishing a rice crop from seeds sown in the field rather than by transplanting seedlings from the nursery.

Due to intensive cultivation, tropical soils are low in organic matter and also due to increased use of chemical fertilizers enhanced the degradation of soil organic matter by micro-organisms which resulted in depletion of soil organic carbon. The sustainable soil productivity is the key to crop production in any crop or cropping system. For this, maintenance of soil organic matter at satisfactory levels is necessary under Indian conditions. Humic Substances are considered as the most important constituents of soils. They form the largest fraction of soil organic matter and play the most dominant role in soil conditioning and plant growth. Humic substances improve the crop productivity by improving physical, chemical and biological properties of soil. Physically, humic substances improve soil structure and water holding capacity. Chemically, they serve as adsorption and retention complexes for plant nutrients. Humic substances (HS) function as important ion exchange and metal complexing (chelating) molecules (Beiraghi *et al.,* 2014). Complexed elements remain more available to plant roots (Randhawa and Broadbent, 1965) because complexing shields them from immobilization. Biologically, they improve growth of useful soil micro-organisms by acting as source of nutrients and energy to soil biota. HS mainly affect nutrient bioavailability via their ability to form complexes with metallic ions, which enhances the availability of micronutrients (zinc, manganese, copper, and iron); and macronutrients (phosphorus), and particularly when these nutrients are scarce in the soil (García *et al.,* 2016b). The present study was carried out in a view to observe the influence of humic acid and inorganic nitrogen on chemical properties of soil under direct sown rice.

2. MATERIAL AND METHODS

A field experiment was conducted during 2019 at the Agricultural College Farm, Bapatla of Acharya N.G. Ranga Agricultural University situated in Krishna Zone of Andhra Pradesh (15^0 $55^{'}$ N latitude and 80^0 $30^{'}$ E longitude) at an altitude of 5 m above mean sea level and about 8 km away from Bay of Bengal. The experiment was laid out in a randomized block design (RBD) 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 + HA @ 10 kg ha^{-1}), T_5 (100 % RDN + HA @ 20 kg ha^{-1}), T_6 (100 % RDN + HA@ 30 kg ha^{-1}), T_7 (75 % RDN + FYM @ 10 t ha^{-1}), T_8 (75 % RDN + HA@ 10 kg ha^{-1}), T_9 (75 % RDN + HA@ 20 kg ha^{-1}), T_{10} (75 % RDN + HA@ 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}). The experimental soil was low in available nitrogen (226 kg ha^{-1}), medium in available phosphorus (51.88 kg P_2O_5 ha^{-1}), high in available potassium content (601 kg K_2O ha^{-1}) and sufficient in available sulphur (15 mg kg^{-1}) and available cationic micro-nutrients *viz.,* Fe (42.08 mg kg^{-1}), Mn (5.65 mg kg^{-1}), Zn (2.15 mg kg^{-1}), Cu (2.03 mg kg^{-1}). 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., $1/3^{rd}$ as basal, $1/3^{rd}$ at active tillering stage and $1/3^{rd}$ 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. Soil samples collected at different growth stages of rice were analysed for chemical properties *viz.,* available nitrogen by alkaline permanganate method (Subbiah and Asija, 1956) using macro-kjeldahl distillation unit, available phosphorus by ascorbic acid method (Olsen *et al.,* 1954) using spectrophotometer, available potassium with neutral normal ammonium acetate method (Jackson, 1973) using Flame photometer and available sulphur by turbidimetry method (Chesnin and Yein, 1950) using spectrophotometer and cationic micro-nutrients (Fe, Mn, Zn, Cu) by DTPA extractable test (Lindsay and Norvell, 1978) at initial, tillering, panicle initiation and harvest stages of direct sown rice using standard procedures. The statistical analysis of the data was done by the analysis of variance (ANOVA). The means were tested for significance at $p \le 0.05$.

3. RESULTS AND DISCUSSION

3.1 Nitrogen

Data pertaining to available nitrogen content in soil at different growth stages were furnished in Table 1. Perusal of data revealed that application of HA showed a significant increase in available nitrogen content at all the stages of crop growth.

The maximum available nitrogen content (297, 275, 261 kg ha^{-1}) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}), while the lowest available nitrogen content (234, 227, 226 kg ha^{-1}) was recorded with T_1 (control) at maximum tillering, panicle initiation and harvest stages respectively. The treatments T_5, T_3 and T_{10} were on par with the treatment T_6.

Among the humic acid treatments, increase in available nitrogen content was upto a dose of 30 kg ha^{-1}. However, the significant increase was observed only upto 20 kg ha^{-1} when it is combined with 100% RDN. Similar significant increase in available nitrogen was observed with increase in N dose in the presence of humic acid or FYM.

The application of humic acid increases CEC of soil and hence ammonia loss becomes reduced. The negative sites due to ionization of carboxylic (COOH) and phenolic (OH) might have improved NH_4^+ retention, hence reduction in N loss (Stevenson, 1994) and thereby increased the availability of N in soils. Increase in available nitrogen content may also be due to the newly formed quinines from humic acid that inhibited nitrification process and consequently decreased the leaching losses (Flaig, 1964). Usually, urea gets rapidly hydrolysed. On application of humic acid combined with urea, it allows the controlled release of urea and provides a continuity in supply of nitrogen (Dong and Yuan, 2009).
The increase in availability of nitrogen might be due to N contributed by native nitrogen by the increased microbial activities induced by HA. Independent application of urea could also suffer severe volatilization losses as ammonia not engaged by plants is quickly oxidized. This chemolithoautotrophic oxidation of ammonia to NO_2 is restricted by NH_3 availability (Laanbroek and Woldendorp, 1995). The increased N availability might be due to decreased no. of nitrifying micro-organisms (Quraishi and Cornfield, 1973).

Table 1. Effect of different levels of Humic acid and inorganic nitrogen on Available Nitrogen (kg ha^{-1}) in soil at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage
T1 : Control (0N-P-K)	234	227	226
T2 : 100% RDN	251	233	229
T3 : 100% RDN + FYM @ 10 t ha^{-1}	281	261	249
T4 : 100% RDN + HA @ 10 kg ha^{-1}	267	246	236
T5 : 100% RDN + HA @ 20 kg ha^{-1}	294	262	257
T6 : 100% RDN + HA @ 30 kg ha^{-1}	297	275	261
T7 : 75% RDN + FYM @ 10 t ha^{-1}	255	231	230
T8 : 75% RDN + HA @ 10 kg ha^{-1}	247	232	224
T9 : 75% RDN + HA @ 20 kg ha^{-1}	258	236	235
T10:75% RDN + HA @ 30 kg ha^{-1}	278	259	240

SEm (±)	8.13	9.10	8.23
CD (P=0.05 %)	24	27	24
CV (%)	5.3	6.4	6.0

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

3.2 Phosphorus

The data pertaining to available Phosphorus content in soil at different growth stages of rice were furnished in Table 2. Perusal of data indicated that available phosphorus was not significantly influenced by different treatments at any growth stage of rice. However, an increase in available phosphorus content was observed in humic acid applied plots at all three stages of crop growth. The available Phosphorus content ranged from 67.33 to 82.78, 64.64 to 80.09 and 63.40 to 78.24 kg P_2O_5 ha^{-1} at tillering, panicle initiation and harvest stages of the crop respectively.

Among the treatments, available phosphorus content (105.96, 98.63, 96.78 kg P_2O_5 ha^{-1}) was recorded highest in T_6 (100% RDN + HA @ 30 kg ha^{-1}) and the lowest available phosphorus content (90.51, 83.18, 80.09 kg P_2O_5 ha^{-1}) was recorded in T_1 (control) at maximum tillering, panicle initiation and harvest stages respectively.

Table 2. Effect of different levels of Humic acid and inorganic nitrogen on Available Phosphorus (kg P_2O_5 ha^{-1}) in soil at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage
T1 : Control (0N-P-K)	67.33	64.64	63.40
T2 : 100% RDN	70.42	67.17	65.87
T3 : 100% RDN + FYM @ 10 t ha^{-1}	75.52	75.15	75.15
T4 : 100% RDN + HA @ 10 kg ha^{-1}	71.97	72.30	72.05
T5 : 100% RDN + HA @ 20 kg ha^{-1}	76.60	78.24	77.00
T6 : 100% RDN + HA @ 30 kg ha^{-1}	82.78	80.09	78.24
T7 : 75% RDN + FYM @ 10 t ha^{-1}	71.97	67.73	67.73
T8 : 75% RDN + HA @ 10 kg ha^{-1}	68.88	65.87	64.02
T9 : 75% RDN + HA @ 20 kg ha^{-1}	71.97	71.44	70.82
T10:75% RDN + HA @ 30 kg ha^{-1}	73.51	73.29	73.91
SEm (±)	4.30	4.08	3.47

CD (P=0.05 %)	NS	NS	NS
CV (%)	10.2	9.9	8.5

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

Humic acid has the ability to reduce P fixation and solubilize insoluble P compounds and hence increases the P concentration in soil (Sibanda and Young, 1986). Application of humic acid increases the phosphatase activity in soil. Phosphatase enzyme which is responsible for hydrolysis of phosphate esters into inorganic phosphorus might have contributed to increased P availability in the soil (Malcolm and Vaughan, 1979). Humic acid causes slow and continuous dissolution of phosphate minerals in soil which might have accounted for its increased availability throughout the crop growth (Wang *et al.*, 1995).

3.3 Potassium

Perusal of data presented in the Table 3 indicated that soil available potassium did not differ significantly among the treatments at any stage of crop growth. However, available potassium content in soil increased on application of humic acid along with inorganic nitrogen at all the stages of crop growth. The available Potassium content in soil ranged from 700 to 763, 637 to 754 and 610 to 709 kg ha^{-1} at tillering, panicle initiation and harvest stages of the crop respectively.

Maximum available potassium content (763, 754, 709 kg K_2O ha^{-1}) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}), while the lowest available potassium content (700, 637, 610 kg K_2O ha^{-1}) was recorded in T_1 (control) at maximum tillering, panicle initiation and harvest stages respectively.

Table 3. Effect of different levels of Humic acid and inorganic nitrogen on Available Potassium (kg K_2O ha^{-1}) in soil at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage
T1 : Control (0N-P-K)	700	637	610
T2 : 100% RDN	709	655	628
T3 : 100% RDN + FYM @ 10 t ha^{-1}	745	718	691
T4 : 100% RDN + HA @ 10 kg ha^{-1}	718	691	655
T5 : 100% RDN + HA @ 20 kg ha^{-1}	754	745	700
T6 : 100% RDN + HA @ 30 kg ha^{-1}	763	754	709
T7 : 75% RDN + FYM @ 10 t ha^{-1}	709	682	637
T8 : 75% RDN + HA @ 10 kg ha^{-1}	709	646	628
T9 : 75% RDN + HA @ 20 kg ha^{-1}	718	691	637

T10:75% RDN + HA @ 30 kg ha^{-1}	745	700	682
SEm (±)	24.81	40.26	40.70
CD (P=0.05 %)	NS	NS	NS
CV (%)	5.9	10.1	10.7

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

The addition of compost-HA is suspected that HA-$NH_4{}^{+}$ and -K^{+} exchanged to soil -Na^{+} and soil-Ca^{+2} caused reduced soil salinity. This reduction of Na was because of K+ replaced them on the surface of adsorption colloid so the proportion of K was increased. Because the three ions have a similar valence, their exchangeability is determined by the affinity of the cations (Tan, 2003). Increase in soil available potassium may be contributed due to the reduced K fixation as well as release of fixed K by humic acid. The humic compounds are capable of penetrating the inter-micellar spaces of clays and reaches the specific sorption sites for K^{+} ions where they might compete for sites with K and increase in K availability in soil (Bharath *et al.,* 2015).

3.4 Sulphur

Data presented in the Table 4, revealed that available sulphur in soil was not significantly influenced by different treatments at any stage of crop growth. The available Sulphur content in soil ranged from 15.10 to 16.39, 14.96 to 16.11 and 14.16 to 15.37 mg kg^{-1} at tillering, panicle initiation and harvest stages of the crop respectively. Application of humic acid combined with inorganic nitrogen increased available sulphur content in soil at all the stages of the crop growth.

Table 4. Effect of different levels of Humic acid and inorganic nitrogen on Available Sulphur (mg kg^{-1}) in soil at different growth stages of direct sown rice

Treatment	**Maximum Tillering stage**	**Panicle Initiation stage**	**Harvest stage**
T1 : Control (0N-P-K)	15.10	14.96	14.16
T2 : 100% RDN	15.10	15.03	14.22
T3 : 100% RDN + FYM @ 10 t ha^{-1}	15.91	15.37	14.76
T4 : 100% RDN + HA @ 10 kg ha^{-1}	16.11	15.84	15.03
T5 : 100% RDN + HA @ 20 kg ha^{-1}	16.38	16.04	15.10
T6 : 100% RDN + HA @ 30 kg ha^{-1}	16.39	16.11	15.37
T7 : 75% RDN + FYM @ 10 t ha^{-1}	15.44	15.30	14.49
T8 : 75% RDN + HA @ 10 kg ha^{-1}	15.23	15.17	14.43
T9 : 75% RDN + HA @ 20 kg ha^{-1}	15.50	15.30	14.49

T10:75% RDN + HA @ 30 kg ha^{-1}	16.24	15.97	15.03
SEm (±)	0.54	0.67	0.50
CD (P=0.05 %)	NS	NS	NS
CV (%)	5.9	7.4	5.8

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

Highest available sulphur content (16.39, 16.11, 15.37 mg kg^{-1} at maximum tillering, panicle initiation and harvest stages respectively) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}) and the lowest available sulphur content (15.10, 14.96, 14.16 mg kg^{-1} at maximum tillering, panicle initiation and harvest stages respectively) was recorded in T_1 (control). The increase in available sulphur might be due to mineralization of sulphur containing amino acids during decomposition of organics.

3.5 Iron

Data pertaining to the effect of humic acid and inorganic nitrogen on available iron content were presented in the Table 5. It was observed that application of HA did not significantly influence available iron content in soil at any growth stage of rice. The available iron content in soil ranged from 42.45 to 48.68, 41.20 to 46.41 and 35.68 to 43.57 mg kg^{-1} at tillering, panicle initiation and harvest stages of the crop respectively. Application of humic acid in combination with either 100% or 75% N (inorganic) increased the available iron content in soil over control and 100% RDN alone.

Table 5. Effect of different levels of Humic acid and inorganic nitrogen on Available Iron (mg kg^{-1}) in soil at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage
T1 : Control (0N-P-K)	42.45	41.20	35.68
T2 : 100% RDN	42.89	41.64	38.54
T3 : 100% RDN + FYM @ 10 t ha^{-1}	43.89	43.13	39.35
T4 : 100% RDN + HA @ 10 kg ha^{-1}	44.79	43.39	39.62
T5 : 100% RDN + HA @ 20 kg ha^{-1}	45.79	44.37	41.32
T6 : 100% RDN + HA @ 30 kg ha^{-1}	48.68	46.41	43.57
T7 : 75% RDN + FYM @ 10 t ha^{-1}	43.46	42.54	38.70
T8 : 75% RDN + HA @ 10 kg ha^{-1}	43.21	42.08	38.62
T9 : 75% RDN + HA @ 20 kg ha^{-1}	44.19	42.77	39.20
T10:75% RDN + HA @ 30 kg ha^{-1}	45.39	43.87	40.71

SEm (±)	2.06	1.80	1.61
CD (P=0.05 %)	NS	NS	NS
CV (%)	8.0	7.2	7.1

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

Among various treatments, highest available iron content (48.68, 46.41, 43.57 mg kg^{-1}) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}) and the lowest available iron content (42.45, 41.20, 35.68 mg kg^{-1}) was recorded in T_1 (control) at maximum tillering, panicle initiation and harvest stages respectively.

3.6 Manganese

Data pertaining to the effect of humic acid and inorganic nitrogen on available manganese content were presented in the Table 6. It is evident that there is no significant effect of treatments on available manganese content in soil at any of the three stages of crop growth. However, an increase in available manganese content in soil was observed on application of humic acid combined with inorganic nitrogen. The available manganese content in soil ranged from 5.96 to 6.72, 5.80 to 6.64 and 5.54 to 6.35 mg kg^{-1} at tillering, panicle initiation and harvest stages of the crop respectively.

Highest available manganese content (6.72, 6.64, 6.35 mg kg^{-1}) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}) and the lowest available manganese content (5.96, 5.80, 5.54 mg kg^{-1}) was recorded in T_1 (control) at maximum tillering, panicle initiation and harvest stages respectively.

Table 6. Effect of different levels of Humic acid and inorganic nitrogen on Available Manganese (mg kg^{-1}) in soil at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage
T1 : Control (0N-P-K)	5.96	5.80	5.54
T2 : 100% RDN	6.14	5.95	5.86
T3 : 100% RDN + FYM @ 10 t ha^{-1}	6.65	6.44	6.22
T4 : 100% RDN + HA @ 10 kg ha^{-1}	6.67	6.53	6.26
T5 : 100% RDN + HA @ 20 kg ha^{-1}	6.72	6.63	6.28
T6 : 100% RDN + HA @ 30 kg ha^{-1}	6.72	6.64	6.35
T7 : 75% RDN + FYM @ 10 t ha^{-1}	6.24	6.16	6.09
T8 : 75% RDN + HA @ 10 kg ha^{-1}	6.16	6.08	6.03
T9 : 75% RDN + HA @ 20 kg ha^{-1}	6.27	6.19	6.10

T10:75% RDN + HA @ 30 kg ha^{-1}	6.70	6.59	6.28
SEm (±)	0.20	0.28	0.20
CD (P=0.05 %)	NS	NS	NS
CV (%)	5.5	7.7	5.5

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

3.7 Zinc

Data pertaining to the effect of humic acid and inorganic nitrogen on available zinc content were presented in the Table 7. It was observed that available zinc in soil did not differ significantly among the treatments at any stage of crop growth. It was observed that there is a non-significant increase in available zinc on application of humic acid combined with inorganic N. The available zinc content in soil ranged from 4.30 to 5.81, 3.76 to 5.23 and 3.34 to 4.21 mg kg^{-1} at tillering, panicle initiation and harvest stages of the crop respectively.

Highest available zinc content (5.81, 5.23, 4.21 mg kg^{-1}) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}) and the lowest available zinc content (4.30, 3.76, 3.34 mg kg^{-1}) was recorded in T_1 (control) at maximum tillering, panicle initiation and harvest stages respectively. Increased zinc availability might be attributed due to prevention of formation of immobile and insoluble hydroxides of zinc by humic acid (Stumm and Morgan, 1970).

Table 7. Effect of different levels of Humic acid and inorganic nitrogen on Available Zinc (mg kg^{-1}) in soil at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage
T1 : Control (0N-P-K)	4.30	3.76	3.34
T2 : 100% RDN	4.70	3.92	3.43
T3 : 100% RDN + FYM @ 10 t ha^{-1}	5.74	4.99	4.05
T4 : 100% RDN + HA @ 10 kg ha^{-1}	5.75	5.04	4.06
T5 : 100% RDN + HA @ 20 kg ha^{-1}	5.81	5.21	4.17
T6 : 100% RDN + HA @ 30 kg ha^{-1}	5.81	5.23	4.21
T7 : 75% RDN + FYM @ 10 t ha^{-1}	5.20	4.91	4.04
T8 : 75% RDN + HA @ 10 kg ha^{-1}	4.82	4.47	3.75
T9 : 75% RDN + HA @ 20 kg ha^{-1}	5.50	4.94	4.04
T10:75% RDN + HA @ 30 kg ha^{-1}	5.78	5.11	4.17
SEm (±)	0.36	0.35	0.21

CD (P=0.05 %)	NS	NS	NS
CV (%)	11.5	12.7	9.4

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

3.8 Copper

On perusal of data furnished in the Table 8, it is evident that application of HA had no significant effect on available copper content in soil at any of the three stages of crop growth. However, application of humic acid combined with inorganic nitrogen increased the copper content in soil over control (T_1) and 100% RDF alone (T_2). The available copper content in soil ranged from 2.69 to 3.04, 2.60 to 2.96 and 2.44 to 2.82 mg kg^{-1} at tillering, panicle initiation and harvest stages of the crop respectively.

Among different treatments imposed, highest available copper content (3.04, 2.96, 2.82 mg kg^{-1}) was recorded in T_6 (100% RDN + HA @ 30 kg ha^{-1}) and the lowest available copper content (2.69, 2.60, 2.44 mg kg^{-1}) was recorded in T_1 (control) at maximum tillering, panicle initiation and harvest stages respectively.

Humic acid attracts positive ions and forms chelate with micronutrients serving as a reservoir of essential plant nutrients. Humic acid being polyvalent molecule (Schnitzer and Khan, 1972; Spostio, 1989) attracts micronutrient cations and release them to the plants. Humic acid might have enhanced the nutrient availability by breakdown of minerals in two ways. 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).

Table 8. Effect of different levels of Humic acid and inorganic nitrogen on Available Copper (mg kg^{-1}) in soil at different growth stages of direct sown rice

Treatment	Maximum Tillering stage	Panicle Initiation stage	Harvest stage
T1 : Control (0N-P-K)	2.69	2.60	2.44
T2 : 100% RDN	2.73	2.66	2.50
T3 : 100% RDN + FYM @ 10 t ha^{-1}	2.97	2.87	2.68
T4 : 100% RDN + HA @ 10 kg ha^{-1}	2.97	2.88	2.70
T5 : 100% RDN + HA @ 20 kg ha^{-1}	3.02	2.94	2.81
T6 : 100% RDN + HA @ 30 kg ha^{-1}	3.04	2.96	2.82
T7 : 75% RDN + FYM @ 10 t ha^{-1}	2.84	2.71	2.61
T8 : 75% RDN + HA @ 10 kg ha^{-1}	2.78	2.68	2.55
T9 : 75% RDN + HA @ 20 kg ha^{-1}	2.89	2.81	2.63

T10:75% RDN + HA @ 30 kg ha^{-1}	3.00	2.89	2.73
SEm (±)	0.11	0.17	0.18
CD (P=0.05 %)	NS	NS	NS
CV (%)	6.8	10.7	12.1

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

4. CONCLUSION

The treatment involving application of humic acid @ 30 kg ha^{-1} combined with 100% RDN (T_6) recorded significantly highest available nitrogen content in soil. Available P_2O_5, K_2O, Sulphur and cationic micro-nutrients (Fe, Mn, Zn, Cu) were also recorded highest with treatment T_6. However, except available nitrogen, rest of the available nutrients were not significantly influenced at any stage of crop growth with the imposed treatments.

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