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Humic acid and fertilizers on nutrition of rice in an Alfisol and Inceptisol

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Abstract: To study the fertilizers and humic acid on nutrient uptake in Alfisol and Inceptisol, two field experiments were conducted during *rabi* 2001 with various levels of fertilizers and humic acid treatments. A large increase was recorded in the uptake of nutrients for the application of humic acid (HA) upto 40 kg ha^{-1}. The significant increase of N, P and K uptake were recorded upto 20 and 10 kg HA ha^{-1} respectively in both Alfisol and Inceptisol. In the presence of humic acid, the effect of 75 and 100% NPK fertilizers on nutrient uptake and grain yield was comparable with each other.

Key words : Rice, Humic acid, Nutrient uptake, Alfisol, Inceptisol.

Introduction

Humic acid application had a definite input on the protein synthesis and nucleic acid synthesis (Guminski, 1968). The different humic acids had significant effect on nitrogen and phosphorus uptake by oats. The efficiency indices of various humic acids ranged between 25 and 65 per cent (Mishra and Srivastava, 1988). The humate migrated from one part of the root system into another, contributing to a more intensive absorption of iron (Aso and Sakai, 1963).

Raina and Goswami (1988) reported a significant increase in the uptake of N,P, Cu, Zn and Fe upto 20-ppm carbon as humic acid over control. Saalbach (1956) stated that humic acid enhanced the uptake and content of nitrogen in rye. Jelanic *et al.* (1966) reported that HA from lignite increased the P content and uptake in maize plants. Application of 10kg HA ha^{-1} as potassium humate along with 75 per cent recommended dose of fertilizer found to increase the crude protein content and mineral nutrition (P, K, Ca, Mg, Zn, Cu, Fe and Mn) of amaranthus (Bama and Selvakumari, 2001). Govindasamy and Chandrasekaran (2002) reported that, addition of humic acid was found to increase the content and enhance the uptake of N, P, K, Ca, Mg, Fe, Mn and Zn by rice. Effect of humic acid may vary with the source, soil type and variety of rice and hence to study the effect of lignite humic acid on rice in an Alfisol and Inceptisol the study was undertaken.

Materials and Methods

To study the influence of humic acid and fertilizers on nutrient uptake in rice, two trials were carried out during *rabi* 2001 i.e. one in Alfisol at wet lands Tamil Nadu Agricultural University (ADT36), other one in Inceptisol at Agricultural Research Station, Bhavanisagar (ADT39). The experimental soil of the wetlands, Tamil Nadu agricultural University, Coimbatore was clay loam in texture with the pH and EC of 8.0 and 0.32 dSm^{-1} respectively. The taxonomy of the soil was *Typic Haplustalf*. The organic carbon content and CEC of the soil were 0.706 per cent and 26.7 cmol (p+) kg^{-1} respectively. The soil was low in $KMnO_4$-N (238 kg ha^{-1}), medium in Olsen-P (19 kg ha^{-1}) and high in NH_4OAc K (670 kg ha^{-1}). The soil (*Typic Ustropept*) of the experimental field at Agricultural Research Station, Bhavanisagar was sandy loam in texture with a pH and EC of 7.7 and 0.30 dSm^{-1} respectively. The soil organic carbon content was 0.58 per cent and the cation exchange capacity was 19.5 cmol (p+) kg^{-1}. The soil was low in $KMnO_4$-N (198 kg ha^{-1}), medium in Olsen-P (16 kg ha^{-1}) and medium in NH_4OAc-K (170 kg ha^{-1}). The recommended dose of NPK fertilizer

Table 1. Humic acid and fertilizers on N uptake (kg ha^{-1}) by rice in Alfisol

Treatments	Tillering				Flowering				Grain				Straw			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	4.53	10.87	11.63	9.01	16.51	36.90	44.57	32.66	9.04	40.91	42.82	30.92	6.86	31.07	34.42	24.12
S_2	5.93	14.26	15.75	11.98	18.41	47.80	50.44	38.88	12.91	51.92	53.47	39.43	9.96	38.08	42.41	30.15
S_3	6.75	15.34	16.58	12.89	20.61	51.99	54.27	42.29	15.23	55.62	56.78	42.54	12.33	42.49	43.52	32.78
S_4	7.36	16.16	17.00	13.51	22.04	54.43	55.88	44.12	16.74	57.87	59.22	44.61	14.41	47.42	48.87	36.90
S_5	8.36	16.61	17.82	14.26	23.62	56.52	57.24	45.79	17.85	59.99	60.66	46.17	15.81	52.14	52.51	40.15
S_6	6.50	14.95	16.27	12.57	21.96	53.01	53.63	42.87	14.90	56.28	56.96	42.71	11.78	45.52	45.65	34.32
S_7	6.37	14.51	15.98	12.29	19.84	53.91	55.26	43.00	14.44	53.34	54.61	40.80	11.36	41.73	42.99	32.03
S_8	6.86	15.63	16.91	13.13	23.51	54.08	56.29	44.63	16.84	57.28	58.27	44.13	13.63	47.23	48.48	36.45
Mean	6.58	14.79	15.99	12.46	20.81	51.08	53.45	41.78	14.74	54.15	55.35	41.41	12.02	43.21	44.86	33.36
CD (P=0.05)																
M		1.17				1.41				1.59				9.54		
S		0.83				2.62				2.24				7.53		
M at S		1.05				3.80				4.50				15.32		
S at M		1.20				3.50				4.20				13.04		

Table 2. Humic acid and fertilizers on N uptake (kg ha^{-1}) by rice in Inceptisol

Treatments	Tillering				Flowering				Grain				Straw			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	10.8	21.5	25.0	19.1	26.8	64.7	67.6	53.0	22.0	57.1	62.7	47.3	15.7	48.9	51.8	38.8
S_2	11.7	23.1	26.3	20.4	28.6	69.0	70.5	56.0	24.0	62.5	67.9	51.5	19.0	55.5	60.0	44.8
S_3	12.4	24.4	27.6	21.5	29.8	73.5	73.7	59.0	25.9	67.3	71.7	54.9	21.6	62.2	62.6	48.8
S_4	13.0	25.3	28.5	22.3	30.9	76.1	76.3	61.1	27.7	71.5	74.0	57.7	23.9	68.2	70.2	54.1
S_5	13.4	26.1	29.4	23.0	32.1	78.7	79.0	63.3	29.0	73.9	77.3	60.1	25.8	73.9	73.5	57.7
S_6	12.2	24.2	27.4	21.3	30.0	73.4	74.3	59.2	26.3	67.6	72.3	55.4	22.4	62.7	65.3	50.1
S_7	12.3	23.8	26.8	21.0	29.1	70.8	72.9	57.6	26.6	64.4	69.2	53.4	21.4	60.5	62.1	48.0
S_8	12.5	24.7	27.9	21.7	30.7	75.5	75.7	60.7	27.5	69.0	73.4	56.6	23.1	65.7	68.6	52.5
Mean	12.3	24.1	27.4	21.3	29.8	72.7	73.8	58.7	26.1	66.7	71.1	54.6	21.6	62.2	64.3	49.4
CD (P=0.05)																
M		1.2				1.0				3.0				3.28		
S		0.9				2.8				2.1				2.88		
M at S		1.9				4.6				3.4				4.42		
S at M		1.7				5.4				2.9				3.26		

Table 3. Humic acid and fertilizers on P uptake (kg ha^{-1}) by rice in Alfisol

Treatments	Tillering				Flowering				Grain				Straw			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	1.34	2.73	2.96	2.34	5.31	11.21	11.74	9.42	2.18	9.07	9.41	6.89	1.52	7.58	7.88	7.66
S_2	1.45	2.90	3.09	2.48	5.67	11.73	12.32	9.90	2.52	9.60	9.86	7.33	2.03	8.19	8.25	6.16
S_3	1.53	3.05	3.19	2.59	6.01	12.15	12.75	10.30	2.74	10.02	10.13	7.63	2.31	8.67	8.71	6.56
S_4	1.61	3.16	3.25	2.67	6.26	12.47	13.05	10.60	2.94	10.26	10.44	7.88	2.52	9.13	9.37	7.01
S_5	1.66	3.19	3.27	2.70	6.55	12.86	13.31	10.91	3.06	10.47	10.67	8.07	2.70	9.67	9.57	7.31
S_6	1.48	2.98	3.14	2.53	6.02	12.17	12.76	10.31	2.62	9.81	10.02	7.49	2.14	8.79	8.82	6.58
S_7	1.43	2.99	3.10	2.51	6.20	12.29	12.86	10.45	2.74	9.77	9.97	7.49	2.22	8.72	8.61	6.52
S_8	1.54	3.00	3.20	2.58	6.30	12.57	13.12	10.67	2.97	10.05	10.15	7.72	2.46	9.08	9.01	6.85
Mean	1.50	3.00	3.15	2.55	6.04	12.18	12.74	10.32	2.72	9.88	10.08	7.56	2.24	8.73	8.78	6.58
CD (P=0.05)																
M		0.05				0.24				0.18				0.36		
S		0.11				0.44				0.40				0.45		
M at S		0.19				NS				NS				NS		
S at M		0.20														

Table 4. Humic acid and fertilizers on P uptake (kg ha^{-1}) by rice in Inceptisol

Treatments	Tillering				Flowering				Grain				Straw			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	1.58	3.12	3.64	2.78	5.40	12.98	13.69	10.69	5.03	12.94	13.43	10.46	3.05	8.86	9.34	7.08
S_2	1.70	3.31	3.80	2.94	5.68	13.43	14.19	11.10	5.32	13.74	14.04	11.03	3.36	9.71	10.24	7.77
S_3	1.79	3.46	3.92	3.06	5.87	13.90	14.56	11.44	5.57	14.22	14.51	11.43	3.72	10.37	10.86	8.32
S_4	1.87	3.58	4.05	3.17	6.05	14.23	14.87	11.72	5.77	14.54	14.91	11.74	4.06	11.05	11.47	8.86
S_5	1.92	3.68	4.19	3.26	6.17	14.46	15.18	11.94	5.94	14.81	15.14	11.96	4.34	11.72	11.83	9.30
S_6	1.71	3.35	3.81	2.96	5.90	13.78	14.63	11.43	5.49	14.02	14.27	11.26	3.64	10.02	10.85	8.17
S_7	1.76	3.40	3.84	3.00	5.81	13.67	14.40	11.29	5.75	14.00	14.20	11.32	3.62	9.99	10.63	8.08
S_8	1.78	3.44	3.89	3.04	5.94	13.98	14.83	11.58	5.70	14.31	14.61	11.54	3.88	10.56	11.20	8.55
Mean	1.76	3.42	3.89	3.03	5.85	13.80	14.54	11.40	5.57	14.07	14.39	11.34	3.71	10.28	10.80	8.27
CD (P=0.05)																
M		0.49				0.11				0.71				0.54		
S		0.14				0.51				0.32				0.36		
M at S		0.47				0.60				0.73				0.59		
S at M		0.29				0.63				0.40				0.48		

ir short duration variety 120:38:38 kg N, land K per hectare and for medium duration riety 150:50:50 kg N, P and K per hectare. he treatments comprised of three main plot eatments *viz.* 0 (M_1), 75 (M_2) and 100 (M_3) er cent NPK fertilizer and eight sub plot eatments *viz.* 0 (S_1), 10 (S_2), 20 (S_3), 30 S_4) and 40 (S_5) kg HA ha^{-1} and 10 kg HA a^{-1} combined with foliar spray of 0.1% HA S_6), 10 kg HA ha^{-1} combined root dipping 0.3% HA (S_7) and 10 kg HA ha^{-1} combined ith foliar spray of HA and root dipping of HA (S_8). The foliar spray was given during llering stage of rice and the root dipping ne by dipping the roots of rice seedlings the 0.3% HA solution for 30 minutes. The nt samples were drawn at tillering and flowering ge of rice. The grain and straw samples re drawn during harvest stage and the N, nd K uptake were calculated by multiplying trient content with respective dry matter oduction.

lesults and Discussion

The nutrient uptake of rice as influenced the application of NPK fertilizers and HA as estimated at tillering, flowering and at arvest stages of the rice crop and the uptake N, P and K nutrients were determined in oth Alfisol and Inceptisol.

itrogen uptake

The data pertaining to the N uptake at fferent growth stages in Alfisol by short duration ariety are given in Table 1. At tillering stage, e N uptake was increased significantly due NPK fertilizer treatment. The M_3, M_2 and M_1 recorded 15.99, 14.79 and 6.58 kg $a^{-1}$of N uptake and the per cent increase recorded y M_2 and M_3 over M_1 were 58.8 and 55.5. HA treatments, the S_5 recorded 14.26 kg a^{-1} of N uptake, which was on par with S_4 3.51 kg ha^{-1}). The treatments S_6 and S_8 recorded 2.57 and 13.13 kg ha^{-1} of N uptake and was followed by S_7 (12.29 kg ha^{-1}). Again he S_8 and S_4 were comparable. The range f N uptake (10.87 to 11.63 kg ha^{-1}) recorded by NPK fertilizer treatment was less than that recorded by NPK fertiliser with HA (14.26 to 17.82 kg ha^{-1}).

At flowering stage, the fertilizer treatment M_3 recorded significantly the highest N uptake of 53.45 kg ha^{-1} than M_2 (51.08 kg ha^{-1}) and M_1 (20.81 kg ha^{-1}). Among the HA treatments, the highest N uptake of 45.79 kg ha^{-1} was recorded in S_5 and it was followed by S_4 (44.12 kg ha^{-1}) and S_3 (42.29 kg ha^{-1}). Among S_6, S_7 and S_8, the treatment S_8 recorded the highest N uptake of 44.63 kg ha^{-1} and it was followed by S_7 (43.00 kg ha^{-1}) and S_6 (42.87 kg ha^{-1}). In interaction, the application of NPK fertilizer recorded 36.90 to 44.57 kg ha^{-1} of N uptake than NPK fertilizer with HA (47.8 to 57.24 kg ha^{-1}).

At harvest, the N uptake was calculated both in grain and straw samples. In the grain, the per cent increase recorded by M_3 and M_2 over M_1 were 73.4 and 72.8. Among the HA treatments, S_2 recorded 46.17 kg ha^{-1} of N uptake. This was on par with S_4 (44.61 kg ha^{-1}), which was followed by S_3 (42.54 kg ha^{-1}). The treaments S_5, S_8 and S_4 were comparable. The per cent increase recorded by S_5 over S_8, S_4 and S_3 were 4.4, 3.4 and 7.9. The interaction of NPK fertilizer and HA on N uptake in grain was significant. The NPK fertilizer combined with HA recorded higher range of N uptake (51.92 to 60.66 kg ha^{-1}) than NPK fertilizer (40.91 to 42.82 kg ha^{-1}). In straw samples, the N uptake performed similar to that of grain samples.

The data regarding the N uptake in Inceptisol are given in Table 2. At tillering stage, N uptake was found to be higher in NPK fertilizer applied treatment than no fertilizer. The treatment M_3 recorded significantly higher N uptake of 27.4 kg ha^{-1} than M_2 (24.1 kg ha^{-1}) and M_1 (12.3 kg ha^{-1}). In HA treatments, the N uptake recorded in S_5 (23.0 kg ha^{-1}) and S_4 (22.3 kg ha^{-1}) were statistically on par with each other and followed by S_3 (21.5 kg ha^{-1}) and

Table 5. Humic acid and fertilizers on K uptake (kg ha^{-1}) by rice in Alfisol

Treatments	Tillering				Flowering				Grain				Straw			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	6.20	12.08	12.99	10.42	17.24	35.88	37.07	30.06	2.13	8.24	8.67	6.35	16.40	62.26	64.38	47.68
S_2	6.60	12.60	13.35	10.85	17.95	37.04	37.81	30.93	2.47	8.70	9.13	6.77	18.35	63.91	65.95	49.40
S_3	6.85	13.07	13.65	11.19	18.63	37.98	38.75	31.79	2.70	9.15	9.49	7.11	19.94	65.37	66.88	50.73
S_4	7.14	13.40	13.74	11.43	19.27	38.86	39.46	32.53	2.93	9.54	9.80	7.42	20.85	66.98	68.09	51.97
S_5	7.27	13.48	14.01	11.59	19.81	39.50	40.11	33.14	3.03	9.80	10.02	7.62	21.69	68.70	68.33	52.91
S_6	6.59	12.70	13.30	10.86	18.67	37.89	38.72	31.76	2.64	9.21	9.47	7.11	18.88	66.13	67.45	50.82
S_7	6.55	12.93	13.49	10.99	19.07	38.38	39.07	32.17	2.71	9.06	9.31	7.02	19.82	66.18	67.34	51.11
S_8	6.84	13.02	13.58	11.15	19.48	39.00	39.58	32.68	3.03	9.36	9.48	7.29	21.44	67.72	68.54	52.56
Mean	6.75	12.91	13.51	11.06	18.76	38.07	38.82	31.88	2.71	9.13	9.42	7.09	19.67	65.91	67.12	50.90
CD (P=0.05)																
M		0.12				0.13				0.19				1.43		
S		0.46				1.42				0.36				2.45		
M at S		NS				NS				NS				NS		
S at M																

Table 6. Humic acid and fertilizers on K uptake (kg ha^{-1}) by rice in Inceptisol

Treatments	Tillering				Flowering				Grain				Straw			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	8.91	16.52	18.93	14.79	19.84	45.94	46.76	37.51	4.73	12.32	12.81	9.95	31.49	77.02	78.41	62.31
S_2	9.40	17.19	19.47	15.36	20.51	47.01	47.82	38.45	5.02	13.07	13.50	10.53	32.34	79.91	81.35	64.53
S_3	9.75	17.72	19.85	15.77	20.95	47.93	48.49	39.12	5.26	13.46	13.84	10.85	33.27	81.29	82.59	65.72
S_4	10.01	18.10	20.26	16.12	21.26	48.45	49.03	39.58	5.48	13.77	14.17	11.14	34.31	82.86	84.40	67.19
S_5	10.22	18.40	20.54	16.39	21.59	48.95	49.19	39.91	5.59	14.06	14.45	11.37	34.91	84.81	85.25	68.32
S_6	9.48	17.34	9.58	15.47	20.79	47.85	48.38	39.01	5.21	13.47	13.78	10.82	33.52	80.74	83.32	65.86
S_7	9.73	17.64	19.68	15.68	20.80	47.96	48.21	38.99	5.27	13.45	13.63	10.78	34.10	81.36	82.58	66.01
S_8	9.80	17.73	19.80	15.78	21.06	48.44	48.62	39.37	5.44	13.67	13.93	11.01	34.46	83.14	84.44	67.35
Mean	9.66	17.58	19.76	15.67	20.85	47.82	48.31	38.99	5.25	13.41	13.76	10.81	33.55	81.39	82.79	65.91
CD (P=0.05)																
M		0.86				0.46				0.72				1.52		
S		0.66				0.68				0.38				0.98		
M at S		0.75				0.70				0.74				1.60		
S at M		0.78				0.78				0.38				0.90		

(20.4 kg ha^{-1}). The treatments S_8 (21.7 kg a^{-1}), S_6 (21.3 kg ha^{-1}) and S_7 21.0 kg a^{-1}) were comparable.

At flowering stage, the NPK fertilizer eatment M_3 recorded significantly the highest uptake of 73.8 kg ha^{-1} and it was follwoed y M_2 and M_1 that recorded 72.7 and 29.8 g ha^{-1} respectively. In HA treatments, the S_5 corded the highest N uptake of 63.3 kg a^{-1} and it was on par with S_4 (61.1 kg a^{-1}) and followed by S_3 (59.0 kg ha^{-1}).

At harvest stage, the N uptake of grain d straw samples were determined. In the ain, M_3 recorded 71.1 kg ha^{-1} of N uptake d that was significantly higher than that obtained M_2 (66.7 kg ha^{-1}) and M_1 (26.1 kg ha^{-1}). HA treatments, S_5 recorded the highest N ptake (60.1 kg ha^{-1}) and it was followed by (57.7 kg ha^{-1}). The S_8 recorded the highest uptake of 56.6 kg ha^{-1}, which was followed y S_6 (55.4 kg ha^{-1}) and S_7 (53.4 kg ha^{-1}). he application of NPK fertilizer with HA corded higher N uptake in grain (62.5 to 7.3 kg ha^{-1}) than NPK fertilizer treatments 57.1 to 62.7 kg ha^{-1}).

In the straw, the fertilizer treatments M_3 nd M_2 recorded 64.3 and 62.2 kg ha^{-1} of N uptake, and they were on par with each ther. The HA treatments S_5 recorded the higher N uptake of 57.7 kg ha^{-1} and it was followed y S_4 (54.1 kg ha^{-1}). Among S_6, S_7 and S_8, he S_8 recorded 52.5 kg ha^{-1} of N uptake and t was on par with S_6 (50.1 kg ha^{-1}).

The N uptake was increased by HA pplication. Significant increase was observed pto 20 kg ha^{-1} for all stages in Alfisol. For nceptisol, the N uptake was found to increase vith increase in HA dose at each critical stage f the rice growth. The highest uptake of nitrogen n grain and straw was found up to 40 kg IA ha^{-1}. The increased N uptake by the rice rop for HA application was attributed to better se efficiency of applied nitrogen fertilisers n the presence of HA (Guminski, 1968). HA pplication would have sustained the flow of ammonical nitrogen for longer period of time. When such N availabiity was coupled with enhanced activation of roots, it would have led to the better utilization of N by rice. This is in agreement with the findings of Govindasamy *et al.* (1989). According to Guminski (1968), HA application had a definite impact on the protein and nucleic acid synthesis, which indirectly indicated the increased uptake of various nutrient elements essentially N, K and Ca.

Phosphorus uptake

In Alfisol at tillering stage, M_3 recorded significantly increased P uptake of 3.15 kg ha^{-1} as compared to M_2 (3.00 kg ha^{-1}) and M_1 (1.5 kg ha^{-1}) (Table 3). In HA treatments, the P uptake recorded in S_5 (2.70 kg ha^{-1}), S_4 (2.67 kg ha^{-1}) and S_3 (2.59 kg ha^{-1}) were statistically on par with each other. The treatments S_6 (2.53 kg ha^{-1}), S_7 (2.51 kg ha^{-1}) and S_8 (2.58 kg ha^{-1}) were comparable. The treatments S_5, S_4, S_3 and S_8 were also on par with each other. At flowering stage, M_3 recorded significantly the higher P uptake of 12.74 kg ha^{-1} whereas M_2 and M_1 registered 12.18 and 6.04 kg ha^{-1} of P uptake. In HA treatments, S_5 recorded the highest P uptake of 10.91 kg ha^{-1} and it was on par with S_4 (10.60 kg ha^{-1}), The application of NPK fertilizer with HA recorded the higher range of P uptake (11.37 to 13.31 kg ha^{-1}) than NPK fertilizer treatments, which registered only 11.21 to 11.74 kg ha^{-1}.

At harvest the P uptake of grain and straw samples were calculated. In grain among the fertilizer treatments, M_3 recorded the highest P uptake of 10.08 kg ha^{-1} and it was followed by M_2 (9.88 kg ha^{-1}) and M_1 (2.72 kg ha^{-1}). The application of NPK fertilizer with HA recorded higher range of P uptake (9.60 to 10.67 kg ha^{-1}) than NPK fertilizer (9.07 to 9.41 kg ha^{-1}). The interaction was found to be significant. In straw, per cent increase recorded by M_3 and M_2 over M_1 were 74.5 and 74.3. Among the HA treatments, the S_5 recorded highest P uptake (7.31 kg ha^{-1}). Combination of NPK fertilizer and HA recorded higher range of P uptake of 8.19 to 9.57 kg ha^{-1} than NPK fertilizer alone (7.58 to 7.88 kg ha^{-1}).

The statistical scrutiny of the data showed that the uptake of P increased from tillering to flowering stage (Table 4) in Inceptisol. At tillering stage, P uptake was significantly increased by addition of fertilizer. The treatments M_3 and M_2 registered 3.89 and 3.42 kg ha^{-1} of P uptake and they were on par with each other, while the M_1 recorded only 76 kg ha^{-1} of P uptake. In the HA treatments, the S_5 recorded 3.26 kg ha^{-1} of P uptake which was on par with S_4 (3.17 kg ha^{-1}). The treatment S_8 (3.04 kg ha^{-1}), S_7 (3.00 kg ha^{-1}), S_6 (2.96 kg ha^{-1}) and S_2 (2.94 kg ha^{-1}) were comparable. The NPK fertilizer with HA recorded higher P uptake (3.31 to 4.19 kg ha^{-1}) than NPK fertilizer treatments alone (3.12 to 3.64 kg ha^{-1}).

At flowering stage, the higher P uptake of 14.54 kg ha^{-1} was recorded in M_3 than M_2 (13.80 kg ha^{-1}) and M_1 (5.85 kg ha^{-1}). In the HA treatments, the S_5, S_4, S_3, S_6 and S_8 were found to be comparable. At harvest stage, the P uptake of grain and straw samples were determined. The P uptake was higher in grain than straw. In grain, the M_3 and M_2 recorded 14.39 and 14.07 kg ha^{-1} of P uptake and they were statistically on par with each other. Among the HA treatments, the S_5 recorded 11.96 kg ha^{-1} of P uptake and it was on par with S_4 (11.74 kg ha^{-1}) and followed by S_3 (11.43 kg ha^{-1}). The treatments S_8 (11.54 kg ha^{-1}), S_7 - (11.32 kg ha^{-1}) and S_6 (11.26 kg ha^{-1}) were on par with each other. The application of NPK integrated with HA recorded higher P uptake of 13.74 to 15.14 kg ha^{-1} than NPK fertilizer treatments (12.94 to 13.43 kg ha^{-1}). In the straw, between the fertilizer treatments, the M_3 and M_2 recorded 10.80 and 10.28 kg ha^{-1} of P uptake, which were comparable. In the HA treatments, S_5 recorded higher P uptake of 9.30 kg ha^{-1} and it was followed by S_4 (8.86 kg ha^{-1}) and S_3 (8.32 kg ha^{-1}). The NPK fertilizer integrated with HA recorded higher P uptake of 9.71 to 11.83 kg ha^{-1} than NPK fertilizer (8.86 to 9.34 kg ha^{-1}).

Humic acid application favourably influenced the P uptake of rice. The significant increase in P uptake was observed at 10 kg ha^{-1} in all the growth stages of rice in Alfisol. But in Inceptisol, the trend was different. Significant increase in P uptake occurred at lower level of HA (10 kg HA ha^{-1}) at tillering and as the growth of rice advanced, the P uptake was significant at higher levels of HA. In Alfisol, 10 kg of HA ha^{-1} itself would have mobilised enough of P to meet the crop need throughout its growth. Probably the rich native P would have contributed to P nutrition in the presence of 10 kg HA ha^{-1}. In contrast in Inceptisol, more than 10 kg HA ha^{-1} would have needed to meet the P requirement of rice. The variations in the levels of HA to bring about the significant effect on P nutrition of rice might be attributed to the chemistry of soil towards P release. The results have clearly showed that, the dose of HA would differ in different soil types to produce marked effect on nutrition of crops. The increased P uptake was ascribed to the action of forming humo phospho complexes, which could be easily assimilable by plants (Szymanski, 1962) and this explains the more of P uptake by rice in the present study. Vaughan and Ord (1985) reported that, the higher P uptake by rice could be due to development of uptake capacity in plants through the stimulating effect of HA. In the presence of humates, the plants could use phosphate fertilizers fully at the humic molecules and the phosphate anion compete on an almost equal basis. Anion exchange phenomenon could be another reason for increasing P availability and higher P uptake by rice (Deb and Datta, 1967).

Potassium uptake

The data pertaining to K uptake in Alfisol are given in Table 5. At tillering stage, among the fertilizer treatments, the highest K uptake was recorded in M_3 (13.51 kg ha^{-1}). The M_2 and M_1 recorded 12.91 and 6.75 kg ha^{-1} of K uptake. In the HA treatments, S_5 (11.59 kg ha^{-1}), S_4 (11.43 kg ha^{-1}) and S_3 (11.19 kg ha^{-1}) recorded comparable K. The per cent increase recorded by S_5 over S_3, S_4, S_6, S_7 and S_8 were 3.5, 1.4, 6.3, 5.2 and 3.8. The NPK fertilizer with HA recorded higher

uptake (12.6 to 14.01 kg ha^{-1}) than NPK rtilizer alone (12.08 to 12.99 kg ha^{-1}).

At flowering stage, the per cent increase corded by M_3 and M_2 over M_1 were 51.7 d 50.7. In HA treatments, S_5 recorded 33.14 ha^{-1} of K uptake and it was followed by (32.53 kg ha^{-1}) and S_3 (31.79 kg ha^{-1}). he treatment S_8 (32.68 kg ha^{-1}), S_7 (32.17 ha^{-1}) and S_6 (31.76 kg ha^{-1}) were on par th each other. The per cent increase recorded S_5 over S_3, S_4, S_6, S_7 and S_8 were 4.1, 8, 4.2, 2.9 and 1.4. The NPK fertilizer recorded .88 to 37.07 kg ha^{-1} of K uptake, whereas e NPK fertilizer with HA recorded 37.04 40.11 kg ha^{-1}. At harvest, the K uptake s estimated both in grain and straw. In the in the NPK fertilizer treatment M_3 recorded 2 kg ha^{-1} of K uptake and it was significantly gher than that obtained in M_2 (9.13 kg ha and M_1 (2.71 kg ha^{-1}). In HA treatments, S_4 and S_3 recorded 7.62, 7.42 and 7.11 ha^{-1} of K uptake respectively and they were par with each other. Per cent increase recorded S_5 over S_4 and S_8 were 2.6 and 4.3. In aw, the per cent yield increased by M_3 and $_2$ over M_1 were 70.7 and 70.1. In the HA eatments, the S_5 (52.91 kg ha^{-1}), S_4 (51.97 ha^{-1}), and S_3 (50.73 kg ha^{-1}) were on par ith each other.

The K uptake for different growth stages paddy in Inceptisol is given in Table 6. tillering stage, the M_3 registered significantly highest K uptake of 19.76 kg ha^{-1} and was followed by M_2 (17.58 kg ha^{-1}) and (9.66 kg ha^{-1}). In the HA treatments, the (16.39 kg ha^{-1}), S_4 (16.12 kg ha^{-1}) and (15.77 kg ha^{-1}) were on par with each ier and S_3 was followed by S_2 (15.36 kg ha^{-1}). The treatments S_3, S_4, S_5 and S_8 were und to be comparable. The application of PK fertilizer with HA recorded higher K otake of 17.19 to 20.54 kg ha^{-1} than NPK rtilizer treatments (16.52 to 18.93 kg ha^{-1}).

At flowering stage, the uptake of K registered M_3 was significantly highest (48.31 kg ha^{-1}) as against M_2 (47.82 kg ha^{-1}) and M_1 (20.85 kg ha^{-1}). In the HA treatments, the highest K uptake was recorded in S_5 (39.91 kg ha^{-1}), which was on par with S_4 (39.58 kg ha^{-1}) and followed by S_3 (39.12 kg ha^{-1}). The S_5, S_4 and S_8 were found to be comparable.

In the grain, uptake of K recorded in M_3 and M_2 were 13.76 and 13.41 kg ha^{-1} and they were on par with each other. The M_1 recorded only 5.25 kg ha^{-1} of K uptake. In the HA treatments, S_5 and S_4 recorded 11.37 and 11.14 kg ha^{-1} of K uptake and the S_4 was followed by S_3 (10.85 kg ha^{-1}) and S_2 (10.53 kg ha^{-1}). The S_4, S_5 and S_8 were comparable. The application of NPK fertilizer combined with HA recorded higher K uptake (13.07 to 14.45 kg ha^{-1}) than NPK fertilizer treatments (12.32 to 12.81 kg ha^{-1}). In the straw, the NPK fertilizer combined with HA registered higher K uptake of 79.91 to 85.25 kg ha^{-1} than NPK fertilizer (77.02 to 78.41 kg ha^{-1}).

Potassium uptake by rice was also marked due to HA application. The K uptake significantly increased upto 10 kg ha^{-1} in both Alfisol and Inceptisol. Rice being a monocot it could have taken up more of K by virtue of its high root CEC (Tisdale *et al.* 1997), which was increased due to HA. The mobile nature of K and increase in the root volume would also have resulted in higher K uptake. The increased K content of the soil due to HA application would have led to more K absorption by rice.

A large increase of nutrient uptake was recorded for the application of HA upto 40 kg ha^{-1}. The increased nutrient availability by HA as evident from the literature would have resulted in better absorption and higher uptake of nutrients by rice. Thus HA influenced the nutrition and growth of plants in an indirect manner. HA might also influence the plant growth directly either through its effects on ion uptake or by more direct effects on the growth regulation of the plant (Vaughan and Linehan, 1976). The increased nutrient uptake due to HA would be attributed to the enhanced microbial activity and reduced nutrient losses in the soil. With increasing dose of HA from

0 to 40 kg ha^{-1}, the uptake of N, P and K also increased.

At optimum level of HA, the roots were highly branched and this might have resulted an increase in surface area, which would have facilitated more efficient nutrient absorption (Mallikarjuna Rao *et al.* 1987). Tan and Nopamornbodi (1979) also reported similar results. Increased root volume, surface area and CEC together would have led to more nutrient uptake by providing better means for greater absorption. The mechanisms of root interception with soil nutrients is one of the ways in which crop could take nutrients. It was made possible when there was profuse root growth (Tisdale *et al.* 1997). The improved root growth of rice in the presenc of HA observed would have induced the large uptake of nutrients.

Conclusions

The results have highlighted that HA levels to bring out pronounced effect on rice nutrition would depend largely on soil type, rice variety and yield. In Alfisol, the significant effect on nutrient uptake by a short duration variety of rice was observed upto 20 kg ha^{-1}. However, in Inceptisol, the medium duration rice variety recorded significantly high amount of N, P and K uptake for the application of HA at a level higher than 20 kg ha^{-1} especially as growth advanced towards maturity.

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