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CHANGES IN NUTRIENT AVAILABILITY AND UPTAKE IN TRANSPLANTED RICE UNDER SHALLOW AND DEEP SUBMERGENCE

K. Anilakumar, I. Johnkutty, P. K. G. Menon and C. Sivakumar
Regional Agricultural Research Station, Pattambi 679 306, India

Abstract: Field experiments were conducted to study the changes in electro-chemical properties and nutrient availability in soil and soil solution in transplanted rice during kharif and rabi season under deep (20 cm) and shallow (10 cm) submergence, respectively. The pH of soil and soil solution increased up to 30 days after transplanting (DAT), then decreased and again increased slightly at 50% flowering stage. Redox potential of soil decreased rapidly during kharif season while during rabi season, the values increased up to 30 DAT and thereafter stable values were recorded. Concentration of nutrients in soil and soil solution decreased with crop growth except in the case of soil P during kharif season and soil solution Ca during both the seasons. Availability of nutrients in soil and soil solution except for P and Mg was more during kharif season, while the nutrient uptake was higher during rabi season. Application of P and K during rabi season was effective in areas where P and K were applied once in two seasons. Significant difference in yield was obtained only during rabi season.

Key words: Depth of submergence, nutrient changes in soil, nutrient uptake, transplanted rice.

INTRODUCTION

Physico-chemical and biological changes brought about by waterlogging are important to the nutrition of rice crop. The availability of native and applied nutrients during the crop growth period is markedly influenced by these changes. Rice is mainly cultivated in Kerala during the south-west monsoon season under uncontrolled water situation of greater depth of submergence, whereas during north-east monsoon season, due to low rainfall, rice is grown under controlled water situation of shallow submergence. Since the efficient utilization of added nutrients has greater impact in this area, an attempt was made to study the changes of electro-chemical properties and nutrient availability in relation to crop growth during the major rice growing seasons of Kerala.

MATERIALS AND METHODS

Field experiments were conducted during kharif and rabi seasons at the Regional Agricultural Research Station, Pattambi on a sandy loam laterite (Fluventic Dystropepts). Some of the initial soil characteristics are given in Table 1. The experiment comprised of the following five treatments.

Treat No.	Treatments, kg ha^{-1}		
	N	P_2O_5	K_2O
Kharif			
1	0	0	0
2	40	0	0
3	80	0	0
4	40	20	20
5	80	40	40
Rabi			
1	0	0	0
2	60	0	0
3	120	0	0
4	60	20	20
5	120	40	40

The experiments were laid out in randomized block design with four replications, using IR 42 and Bharathi rice varieties as the test crops for kharif and rabi seasons, respectively. Entire amount of P, K and 50% N as single superphosphate, muriate of potash and prilled urea, respectively were incorporated into the soil just before transplanting; 25% N was top-dressed at three weeks after transplanting and the rest 25% was top-dressed at one week before panicle initiation. The depth of submergence was maintained at 20 and 10 cm up to 50% flowering stage during kharif and rabi seasons, respectively. Wet soil samples were collected using a metallic soil sampler (Pradhan and Patnaik, 1979). Soil solution

Table 1. Some characteristics of the initial soil

Soil characteristic	Kharif	Rabi
pH (1:1)	5.3	6.8
EC (1:1) dS m^{-1}	0.02	0.02
Ammoniacal N, ppm	18.3	20.8
Available P, ppm	7.9	17.1
Available K, ppm	52.9	21.1
Available Ca, ppm	213.5	106.3
Available Mg, ppm	19.9	30.6
Available Si, ppm	95.2	114.7

was collected in piezometers installed at 15 cm depth from soil surface. Soil samples and soil solution were collected at 10 days interval up to 50% flowering accounting to eight and five times collection during kharif and rabi seasoas, respectively. Wet soil samples were extracted with 10% NaCl solution, pH adjusted to 2.5 (Mohanty and Patnaik, 1975 & 1977) for determination of ammoniacal N, available K, Ca and Mg. Available P was extracted with Bray-I reagent and available Si was extracted by normal sodium acetate solution, pH adjusted to 4.0 (Jackson, 1958; Imaizumi and Yoshida, 1958). The redox potential (Eh), pH *and* electrical conductivity (EC) of soil and soil solution were measured *in situ*. Ammoniacal N, P, K, Ca and Mg in soil and soil solution were estimated as per the standard chemical procedures (Jackson, 1958); and Si by method suggested by Imaizumi and Yoshida (1958). Plant samples were also collected at the same intervals and the nutrient contents were estimated. Total N in plant samples was estimated by micro-kjeldahl method after sulphuric acid digestion (Jackson, 1958). After the nitric-perchloric acid digestion of the plant samples total P, K, Ca and Mg were estimated using standard analytical methods (Jackson, 1958) and Si by triple acid digestion method described by Imaizumi and Yoshida (1958).

RESULTS AND DISCUSSION

Electro-chemical properties

Changes in pH of soil and soil solution showed similar trend in both the seasons (Table 2). The pH of the soil increased up to 30 DAT, followed by a decrease up to 60 DAT and 40 DAT during kharif and rabi season, respectively; thereafter slightly increased at 50% flowering stage. On the other hand, pH of soil solution did not exhibit any definite trend in both the seasons. Increase in soil pH during the crop growth up to active tillering stage was due to reduction of iron (Ponnamperuma, 1972). The production of CO_2 by the respiration of aerobic bacteria might have resulted in the carbonation and decrease in pH in later period (Mohanty and Patnaik, 1975).

Table 2. Changes in electro-chemical properties of soil and soil solution during kharif and rabi seasons

Days after transp-lanting	pH		Redox potential (mV)		EC (dS m^{-1})	
	Soil	SS	Soil	SS	Soil	SS
Kharif						
10	6.80	6.76	14	67	0.27	0.46
20	6.76	6.70	-19	42	0.21	0.99
30	6.82	6.70	-39	55	0.26	0.75
40	6.42	6.92	-72	26	0.28	0.64
50	6.24	6.52	-60	03	0.59	1.13
60	5.88	6.72	-43	01	0.55	0.86
70	6.08	6.44	-48	21	0.52	0.86
80	6.18	6.48	-39	11	0.65	1.04
Rabi						
10	6.62	6.52	-42	16	0.44	0.55
20	6.63	6.58	-14	55	0.37	0.52
30	6.77	6.41	-06	54	0.28	0.51
40	6.39	6.48	-05	29	0.22	0.64
50	6.67	6.25	-8	59	0.31	0.50

SS=Soil **Solution**

The Eh of soil was negative except at 10 DAT during kharif seasons whereas the Eh of soil solution was positive at all periods of observation. During kharif season, Eh of soil decreased rapidly up to 40 DAT and then increased slightly thereafter. On the other hand, during rabi season, the Eh of soil increased initially up to 30 DAT and then stable values were recorded. Almost similar trend of variation was recorded in the case of Eh soil solution also. Ponnamperuma (1972) had reported that when an aerobic soil (before the onset of monsoon during the kharif season as in the present study) is submerged, its Eh decreased and reached a minimum (40 DAT during kharif season), then it increased and attained a maximum (30 DAT during rabi season) and decreased again to a value characteristic of the soil. The presence of oxidising conditions in the rhizosphere of the rice plant might be the reason for the positive Eh of soil solution.

The EC of soil solution recorded higher values man that of soil, owing to the migration of soluble salts to the soil solution. In both the seasons, the EC of soil decreased up to the active tillering stage and then increased thereafter, might be due to the top dressing effect of fertilizers. The initial higher EC of soil might be due to the increased accumulation of organic and inorganic ions. In the present study also higher values of nutrient concentrations were observed in the initial period, which decreased in the subsequent periods. The EC of soil solution recorded a late peak at 50 DAT and an early peak at 20 DAT during kharif and rabi seasons respectively owing to the differences in the time of top dressing of fertilizer N.

Table 3. Changes in nutrient availability (ppm) in soil and soil solution during kharif and rabi seasons

DAT	NH_4-N		P		K		Ca		Mg		Si	
	Soil	SS	Soil	SS	Soil	SS	Soil	SS	Soil	SS	Soil	SS
Kharif												
10	22.0	7.18	10.6	0.09	52.5	4.56	161	22.4	19.7	12.1	157	5.2
20	20.1	8.59	10.3	0.08	52.0	3.52	139	22.4	37.6	12.4	167	4.0
30	15.7	6.71	10.4	0.06	50.3	2.71	133	22.8	35.0	13.2	180	4.0
40	5.5	0.81	11.7	0.05	48.5	0.46	150	25.0	29.7	11.9	148	4.0
50	4.5	0.74	13.3	0.04	38.9	0.21	146	26.2	18.2	12.7	126	1.7
60	3.6	0.38	12.7	0.02	15.7	0.21	146	26.0	19.0	11.1	140	1.8
70	3.0	0.46	13.9	0.02	16.8	0.23	85	27.2	22.4	10.8	85	1.2
80	3.5	0.48	12.4	0.01	15.0	0.32	87	28.0	18.6	10.9	106	1.3
Rabi												
10	18.4	3.64	27.1	0.33	27.0	3.87	161	19.7	59.4	9.5	123	3.0
20	10.8	1.60	16.8	0.37	21.7	1.91	143	18.0	60.0	9.6	132	2.5
30	7.3	0.28	15.9	0.36	14.8	0.71	121	20.5	45.0	11.3	116	3.2
40	5.7	0.32	17.8	0.34	13.7	0.57	114	20.0	42.7	11.4	97	1.8
50	4.8	0.25	17.1	0.35	12.9	0.54	127	20.7	43.0	12.1	84	2.0

SS = Soil solution

Table 4. Uptake of nutrients (kg ha^{-1}) at different periods of crop growth during kharif and rabi seasons

DAT	N	P	K	Ca	Mg	Si
Kharif						
10	2.61	0.25	2.76	0.23	0.17	3.5
20	7.88	1.11	10.07	1.09	0.74	14.9
30	18.54	2.60	26.90	2.80	2.42	37.3
40	48.43	5.84	41.45	5.50	6.38	126.8
50	53.98	8.61	43.75	11.11	8.86	209.6
60	69.47	11.30	56.06	14.35	10.89	280.9
70	69.40	13.30	57.98	14.50	9.84	429.7
80	83.84	12.89	62.03	12.69	12.00	590.6
Rabi						
10	16.30	1.79	16.90	1.22	0.52	19.8
20	45.20	5.94	44.30	3.33	1.78	67.1
30	61.55	8.18	68.77	6.55	4.92	103.0
40	120.00	9.26	65.26	11.11	5.57	187.1
50	111.20	14.00	70.00	12.49	9.28	272.1

Nutrient availability

Statistical analysis did not show any significant treatment differences in nutrient availability in soil and soil solution at any period of observation in both the seasons. The mean values are presented in Table 3. The concentration of ammoniacal N and K in soil decreased continuously with the progress of crop growth. Concentration of Ca in soil decreased during 30 to 40 days and thereafter increased. However, during kharif season, the increased concentration of Ca in soil at 60 DAT decreased sharply at 70 DAT. On the other hand, concentration of Mg and Si in soil increased slightly up to 20 to 30 DAT and again decreased and increased alternately. In the case of P, during kharif season the values increased gradually with the progress of crop growth which might be due to the increased availability of soil P due to submergence; whereas during rabi season, the values decreased up to 30 DAT, followed by a slight increase during 40 DAT, and DAT and decreased again. The concentration of ammoniacal N, K, Ca and Si in soil was more during kharif season than that of rabi season, whereas the concentration of P and Mg in soil was more during rabi season.

In the case of soil solution, the concentration of animmoniacal N, K and Si decreased sharply with the progress of crop growth while the concentration of Ca increased with plant growth. This increase was not expected and could not be explained. There was no change in the concentration of P and Mg. Submergence of soil under laboratory condition effected an increased availability of N, P, K, Ca, Mg and Si (Ponnamperuma, 1972; Mohanty and Patnaik, 1975 and 1977). However, in this study concentration of nutrients in soil either decreased continuously or decreased up to active tillering stage of crop growth which could be attributed to vigorous absorption and efficient assimilation of nutrients by the rice plant. Similar results were also obtained by Pande *et al.* (1990 & 1993).

Table 5. Mean grain and straw yield during kharif and rabi seasons

Treatment	Yield, kg ha-1	
	Grain	Straw
Kharif		
N_0 P_0 K_0	5208	3831
N_{40} P_0 K_0	5465	4519
N_{80} P_0 K_0	5559	4595
N« P_0 K_0	5682	4380
N_{80} P_{20} K_{20}	5691	5123
CD (0.05)	NS	NS
Rahi		
N_0 P_0 K_0	3582	3338
N_{60} P_0 K_0	4406	4766
N_{120} P_0 K_0	4565	5590
N_{60} P_{20} K_{20}	4569	5033
N_{120} P_{40} K_{40}	4543	5876
CD (0.05)	388	491

Nutrient uptake

The uptake of nutrients increased progressively at all stages of the crop growth except at panicle initiation to 50% flowering stage (Table 4). However, in the case of Si, uptake was linear even at 50% flowering stage. The rate of nutrient uptake was slow for the long duration variety IR 42 during the initial periods. On the other hand, the uptake rate was more for the medium duration variety Bharathi for the same periods. The increased availability of most of the nutrients during the kharif season was not reflected on the rate of nutrient uptake by rice grown during this season. Comparatively higher uptake of nutrients was recorded during rabi season which can be attributed to the differences in varietal characters, the favourable climatic factors prevailing in the season and also to the higher rate of fertilizer N application during rabi season.

The results of nutrient availability and uptake also showed mat application of P and K during rabi season was effective in areas where P and K were applied once in two seasons due to lower soil availability and higher uptake rate of these nutrients.

Grain and straw yield

Grain and straw yield showed that each of the treatments gave significantly higher grain and straw yields over the control, only during the rabi season (Table 5). Application of N alone at lower level of 60 kg ha^{-1} increased the grain yield over control. However, application of P and K in conjunction with N had no beneficial effect on grain yield. Similarly, application of P and K up to 40 kg ha^{-1} each in conjunction with N at 120 kg ha^{-1} showed some what depressing effect on the grain yield. On the other hand, maximum straw yield was recorded for the treatment receiving 120 kg N ha^{-1} together with P and K up to 40 kg ha^{-1}. However, this treatment was on par with the application of 120 kg N ha ' alone. Earlier studies also confirmed the response of applied N, while P and K had no effect (Pande *et al.*,1985 and 1990) which might be due to higher availability of P and K from soil during the crop growth.

REFERENCES

Imaizumi, K.and Yoshida, S. 1985. Edaphological studies on silicon supplying power of paddy fields. *Bull. nat. Inst. agric. Sci. Ser.* B. 8 : 262-304

Jackson, M.L., 1958. *Soil Chemical Analysis.* Prentice-Hall of India Ltd., New Delhi, p. 498

Mohanty, S.K. and Patnaik, S. 1975. Effect of submergence of the physico-chemical and chemical changes in different rice soils : I. Kinetics of pH, Eh, C and N. *Ada Agronomica Acad. Sci. Hung.* 24 : 446-451

Mohanty, S.K. and Patnaik, S. 1977. Effect of submergence on the chemical changes in different rice soils: III. Kinetics of K, Ca and Mg. *Acta Agronomica Acad Sci. Hung.* 26 : 187-191

Pande, N.C., Samantaray, R.N. and Mohanty, S.K. 1985. Nutrient changes in direct seeded submerged rice soils with varying nutrio-environments. *Pl. Soil* 88 : 299-306

Pande, N.C., Samantaray, R.N. and Mohanty, S.K. 1990. Nutrient changes in rice soil and soil solution under shallow submergence with varying nutrio-environment. *Oryza* 27 : 170-176

Pande, N.C., Samantaray, R.N., Mahapatra, P. and Mohanty, S.K., 1993. Effect of optimal and sub-optimal nutrient management on nutrient changes, yield and nutrient uptake by rice in submerged soil. *J. Indian Soc. Soil Sci.* 41 : 90-95

Patnaik, S. and Mandal, L.N. 1982. Chemistry of submerged rice soils. Review of soil research in India. *Indian Soc. Soil Sci.* 39 : 181-198

Ponnamperuma, F.N. 1972. The chemistry of submerged soils. *Adv. Agron.* 24 : 29-96

Pradhan, S.K. and Patnaik, S. 1979. Soil samples for collection of wet soil samples from different depths of flooded soils. *J. Indian Soc. Soil Sci.* 27 : 314-344