85 per cent. Similar results were reported by Xue *et al.* (1992) in direct sown rice. Pre-emergence thiobencarb fb HW recorded higher WCE (74.9%) next to pretilachlor fb HW. Application of bentazon fb HW recorded the maximum dominant weed populations and total weed dry weight resulting in the minimum WCE of 56.6% which might be due to early dominance of weed and delayed weeding. Tosh and Jena (1984) also reported that bentazon was not effective for controlling weeds in dry seeded rice.

Growth and yield of rice

Application of pretilachlor fb HW suppressed the weeds at the time of emergence itself which in tunr increased the vigour and growth of rice seedlings recording maximum shoot length (15.8 cm), root length (7.1 cm) and seedling stand establishment (368 No. m^{-2}). Pretilachlor plus also recorded 0 visual rating indicating the absence of crop injury. Pretilachlor fb HW recorded the maximum dry matter production (DMP) of 6.6 t/ha, number of panicles (319 m^{-2}) and filled grains (133 $panicle^{-1}$) leading to significantly increased grain yield (5.5 t ha^{-1}) and B:C (3.12). Similar results were reported by Singh and Bhan (1986) due to better weed control in dry sown rice. Delayed weeding by the post emergence bentazon very much reduced the seedling growth and grain yield (2.9 t ha^{-1}) and B:C (1.67).

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(Received : June 1998 Revised : July 1999)

Madras Agric. J., 86(1-3): 118 - 124 January - March 1999
https://doi.org/10.29321/MAJ.10.A00568

IMPACT OF PAPER MILL EFFLUENT IRRIGATION ON THE YIELD, NUTRIENT CONTENT AND THEIR UPTAKE IN RICE

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ABSTRACT

The impact of paper mill effluent irrigation along with soil amendments (FYM, composted coir waste, pressmud and lime + FYM) on the yield, nutrient content and their uptake in rice was studied in an acid and a neutral soil of Thambirabarani river tract. Effluent irrigation resulted in an increase in the Ca and Na contents and a decrease in the K content of rice grain and straw in both the soils. The N content of the grain and straw showed an increase for the effluent irrigation in neutral soils and a decrease in acid soil. A marked reduction in the total N and K uptake as well as the grain and straw yield of rice under the effluent irrigation treatments was recorded in both the soils. Effluent irrigation decreased the Ca uptake of rice in neutral soil and increased the Na uptake in acid soil. The soil amendments had a favourable effecton the P and K uptake of rice in acid soil. The use of 50% diluted clarified effluent was found superior to raw effluent irrigation more particularly in neutral soil. The adverse effect of raw effluent irrigation was more in neutral soil compared to acid soil. Application of composted coir waste improved the grain yield of rice when raw effluent was used for irrigation in neutral soil.

KEY WORDS : Paper mill effluent, Utilisation of effluent, Rice, nutrient content, Nutrients uptake

The pulp and paper industry is the one which ranks high both in terms of water usage and pollution loads. In India, at present, there are about 215 paper mills in operation with an installed capacity of 2.04 x 10^6 tonnes of paper per annum. It is estimated that 215 - 350 m^3 of water is required per ton of paper made (Gove, 1982) and practically the entire quantity of water used reappers as effluents which is let out into the agricultural lands either treated or untreated and used for irrigation. The usefulness of such a large volume of recycled wastewaters is not fully understood, especially method of treating the water and increasing the yield of crops. The high levels of alkalinity and hazarduous salts, more particularly that of sodium, may cause severe set back in the growth and physiology of crops irrigated with such effluent and the magnitude of such problems varied with different soils and crops (Prasad *et al.*, 1977 ; Kannan and Oblisami, 1992). Hence, a study was undertaken with a view to elucidate the information on the impact of paper mill effluent irrigation on the yield, nutrient content and uptake in rice in two different soils.

MATERIALS AND METHODS

Characterisation of the paper mill effluent

Bulk samples of the raw paper mill effluent were collected from the combined effluents discharge point of M/s Sun paper mills, Thiru nelveli, Tamil Nadu. Six samples were collected during July-October 1993, and characterised for various physico-chemical parameters. The details of the anlytical results are furnished in Table 1.

The bulk effluent sample collected from the factory was clarified using alum and the clarified effluent was adjusted for SAR value (<4.00) with calcium and used for irrigating the experimental crop as undiluted/diluted as per the treatment schedule given under irrigation sources. The characteristics of the irrigation sources used in the experiment are furnished in Table 2.

Pot culture experiment

A pot culture experiment to assess the impact of paper mill effluent irrigation on the growth and yield of rice was conducted at Agricultural College Research Institute, Killikulam. Two types of soil viz., an acid soil (pH = 5.8) and a neutral soil (pH = 7.8) predominantly occurring in the paper mill locality were collected and used in the pot culture study. The neutral and acid soils used in the pot culture experiment were sandy clay loam and clay loam in texture respectively. The neutral soil was medium in organic carbon and available N and high in available P and K, whereas the acid soil was medium in organic carbon, low in available N and high in available P and K.

Table 1. Characteristics of paper mill raw effluent

Characteristics		Value
1.	Colour	Dark brown
2.	Odour	Phenolic
3.	Total solids (mg l^{-1})	1330
4.	Suspended solids (mg l^{-1})	547
5.	Dissolved solids (mg l^{-1})	783
6.	pH	7.6
7.	EC (dSm^{-1})	2.10
8.	BOD (mg l^{-1})	557
9.	COD (mg l^{-1})	1553
10.	Nitrates (m.eq l^{-1})	0.02
11.	Phosphorus (m.eq l^{-1})	0.29
12.	Potassium (m.eq l^{-1})	0.59
13.	Calcium (m.eq l^{-1})	9.0
14.	Magnesium (m.eq l^{-1})	1.2
15.	Sodium (m.eq l^{-1})	14.3
16.	Carbonate (m.eq l^{-1})	Traces
17.	Bicarbonate (m.eq l^{-1})	10.2
18.	Sulphate (m.eq l^{-1})	2.22
19.	Chloride (m.eq l^{-1})	14.4
20.	Zinc (ppm)	0.52

Treatments comprising of different irrigation sources and soil amendments as detailed below were imposed to both the soils grown under rice.

I. Irrigation sources

I_0 = Irrigation with good quality well water

I_1 = Irrigation with raw effluent

I_2 = Irrigation with clarified effluent

I_3 = Irrigation with clarified effluent - SAR adjusted to <4.00

I_4 = Irrigation with 50% diluted clarified effluent

Table 2. Analytical results of irrigation sources used in the experiment

Irrigation sources	pH	EC (dSm^{-1})	Na	Ca	Mg	SAR
			(m eq l^{-1})			
1. Well water (I_0)	7.40	0.70	1.5	2.6	2.7	0.95
2. Raw effluent (I_1)	7.60	2.10	14.4	9.0	1.1	6.42
3. Clarified effluent (I_2)	6.76	2.20	14.4	9.5	1.2	6.23
4. SAR adjusted clarified effluent (I_3)	6.91	3.00	14.4	25.9	2.8	3.81
5. 50% diluted clarified effluent (I_4)	7.12	1.35	7.8	5.3	2.7	3 .92

II. Soil amendments

A_0 = Control

A_1 = FYM @ 12.5 t ha^{-1}

A_2 = Composted coirpith @ 12.5 t ha^{-1}

A_3 = Pressmud @ 12.5 t ha^{-1}

A_4 = Lime stone @ 10 t ha^{-1} + FYM @ 12.5 t ha^{-1}

The soil amendments as per the schedule were added and thoroughly mixed to the weighed quantities of air dried, powdered and 2 mm sieved soils and put into mud pots of uniform size. In all, there were 25 treatment combinations for each soil type adopting a factorial randomised design with three replications. Rice crop variety ADT 36 (105 days duration) was planted at 3 hills per pot and grown in the experiment with normal recommended fertiliser schedule of 150 : 50 : 50 kg N, P_2O_5, K_2O

Table 3. Effect of paper mill effluent irrigation and soil amendments on nutrient content (per cent) of rice grain

Treatments	Nitrogen		Phosphorus		Potassium		Calcium		Sodium	
	Neutral soil	Acid soil	Neutral soil	Acid soil	Neutral soil	Acid soil	Neutral soil	Acid soil	Neutral soil	Acid soil
A. Irrigation treatments										
I_0 Good quality water	1.59	1.69	0.12	0.09	1.58	2.05	0.60	0.53	0.08	0.06
I_1 Raw effluent	2.18	1.43	0.17	0.12	1.39	1.42	0.69	0.68	0.14	0.11
I_2 Clarified effluent	2.18	1.25	0.12	0.13	1.33	1.61	0.67	0.65	0.15	0.10
I_3 SAR adjusted clarified effluent	2.15	1.28	0.13	0.09	1.50	1.39	0.66	0.65	0.12	0.10
I_4 50% diluted clarified effluent	1.76	1.32	0.12	0.10	1.43	1.46	0.65	0.64	0.13	0.09
Mean	**1.97**	**1.39**	**0.13**	**0.11**	**01.44**	**1.58**	**0.65**	**0.63**	**0.12**	**0.09**
CD (5%)	**0.17**	**0.09**	**NS**	**0.03**	**0.09**	**0.08**	**0.04**	**0.05**	**0.02**	**0.02**
B. Soil amendments										
A_0 Control	1.97	1.53	0.13	0.07	1.36	1.51	0.67	0.62	0.08	0.09
A_1 FYM @ 12.5 t ha^{-1}1.97 /	1.44	0.12	0.9	1.46	1.62	6.7	0.64	0.14	0.10	
A_2 Composted coirpith @ 12.5 t ha^{-1}	1.92	1.33	0.14	0.14	1.42	1.63	0.66	0.62	0.15	0.09
A_3 Pressmud @ 12.5 t ha^{-1}	1.96	1.36	0.15	0.13	1.47	1.65	0.61	0.63	0.12	0.08
A_4 Lime stone @ 10 t ha^{-1} + FYM @ 12.5 t ha^{-1}	2.05	1.31	0.13	0.10	1.52	0.52	0.53	0.64	0.13	0.10
Mean	**1.97**	**1.39**	**1.13**	**0.11**	**1.44**	**1.58**	**0.65**	**0.63**	**0.12**	**0.09**
CD (5%)	**NS**	**0.09**	**NS**	**0.03**	**0.09**	**0.08**	**0.04**	**NS**	**0.02**	**NS**

per ha. The crop was regularly irrigated with the various irrigation sources as per the treatment schedule upto harvest. The plants were harvested at maturity, the grain and straw samples were powdered and analysed for nitrogen by kjeldhal digestion and distillation (Humphries, 1956). The triple acid extract of the grain and straw samples were used for analysing P by colorimetry (Piper, 1966), K and Na by flame photometr (Piper, 1966), and Ca by Versanate titration (Jackson, 1967). Using the nutrient content and the yield of grain and straw, the total uptake values of N, P, K , Ca and Na were computed and presented in Table 6.

RESULTS AND DISCUSSION

Nutrient content of rice

The mean values of nutrient contents of grain and straw of rice under the various treatments are presented in Tables 3 and 4.

The nitrogen content of rice grain was 1.18-2.43 per cent with a mean value of 1.97 and 1.39 per cent; and in the straw, it was 1.08-2.32 per cent with a mean value of 1.84 and 1.26 per cent for the neutral and acid soil respectively. Effluent irrigation treatments in general registered an increase in the N content of grain as well as straw in neutral soil while in acid soil the trend was the reverse. The effect of various soil amendments used in the study was negligible on the N content of plant parts in neutral soil while they had an adverse effect in acid soil. The increase N content of plant parts under the effluent irrigation treatments in neutral soil could be attributed to the relatively higher reduction in the grian and straw yield of rice under effluent irrigation in neutral soil compared to that of the acid soil, leading to an accumulation of N in plant parts.

The phosphorus content of rice grain was 0.07-0.22 per cent with a mean value of 0.13 and 0.11 per cent; and in straw it was 0.04-0.23 per cent with a mean value of 0.11 an d0.08 per cent for the neutral and acid soil respectively. Though the impact of effluent irrigation treatments on the P content of rice grain was not much, their favourable effect in increasing the P content of straw could be seen in

Table 4. Effect of paper mill effluent irrigation, soil amendments and their interaction on rice yield

Amendments	Neutral soil						Acid soil					
Irrigation	A_0	A_1	A_2	A_3	A_4	Mean	A_0	A_1	A_2	A_3	A_4	Mean
					Grain yield (g pot^{-1})							
I_0	26.7	23.1	28.0	26.5	25.8	**28.0**	33.9	32.6	33.1	35.3	34.5	**33.9**
I_1	10.9	16.2	18.9	13.1	11.9	**14.2**	32.2	28.2	23.9	31.0	25.4	**28.3**
I_2	14.3	14.7	13.8	13.6	12.7	**13.8**	26.7	25.1	25.2	22.3	20.4	**24.0**
I_3	19.3	15.1	18.9	12.5	15.2	**16.2**	26.9	23.9	24.6	26.4	23.7	**25.1**
I_4	23.1	18.3	14.5	22.2	21.5	**19.9**	25.0	32.3	33.4	28.7	28.1	**29.5**
Mean	**18.9**	**19.5**	**18.8**	**17.6**	**17.4**	**18.4**	**29.0**	**28.6**	**28.0**	**28.8**	**26.4**	**28.1**
					Straw yield (g pot^{-1})							
I_0	14.7	12.5	16.5	14.9	16.2	**15.0**	24.2	22.9	20.9	22.7	24.3	**23.0**
I_1	9.5	7.7	8.8	10.9	9.3	**9.3**	18.2	15.4	15.1	14.9	18.4	**16.4**
I_2	10.9	7.8	8.1	9.7	8.3	**9.0**	15.7	14.7	15.9	15.6	18.0	**16.0**
I_3	7.9	9.2	8.7	10.2	7.4	**8.7**	15.1	14.9	13.5	14.9	16.7	**15.0**
I_4	11.4	9.0	10.9	9.6	12.3	**10.5**	17.5	18.9	18.9	17.2	16.7	**17.8**
Mean	**10.9**	**9.2**	**10.6**	**11.0**	**10.7**	**10.5**	**18.1**	**17.4**	**16.9**	**17.1**	**18.8**	**17.6**

C.D. (5%)	Grain	Straw	Grain	Straw
Irrigation	2.7	1.1	3.0	1.6
Amendments	NS	1.1	NS	NS
Interaction	6.1	2.5	NS	NS

both the soils. Considerable quantities of P present in the effluent (0.29 m eq.l[-1]) might have contributed for the increased P content of plant parts in addition to the concentration effect due to the stunted plant growth as reflected from lower grain and straw yield. The P contents of grain and straw were almost unaffected by the amendments used both in the neutral and acid soils except in the case of pressmud favourably increasing the P content of grain and straw and that of composted coir waste registering higher P content in grain.

The K content of rice grain was 1.27-2.24 per cent with a mean value of 1.44 and 1.58 per cent, and in straw it was 1.11-2.05 with a mean value of 1.35 and 1.48 per cent for the neutral and acid soil respectively. Effluent irrigation treatments in general, except that of the SAR adjusted clarified effluent, markedly decreased the K content of grain and straw in both the soils. This could be attributed to the antagonistic effect of sodium present in the effluent waters in larger quantities upon the absorption of K by rice. The comparable levels of plant K content observed under SAR adjusted clarified effluent with that of good quality water might be due to the reduction in the sodium hazard of the effluent water with low SAR. The soil amendments in general had favourably increased the K content of the grain and straw more particularly in neutral soil. The favourable effect of farm yard manure on K content of plant parts in acid soil was slashed down by the applied lime.

A marked increase in the Ca and Na contents of the grain as well as straw for the effluent irrigation was observed in both the soils which might be due to the presenc of moderate quantities of Ca and relative higher quantities of Na in the effluent. The various soil amendments did not influence the Ca and Na contents of grainas well as straw in acid soil. In neutral soil, application of pressmud as well as lime + FYM resulted in a decrease in the Ca content of grain and straw. With regard to the Na content, it increased in rice grain by the soil amendments. In straw, none of the soil amendments except pressmud influenced the Na content, while the applicationof pressmud markedly decreased the straw Na content compared to control.

Table 5. Effect of paper mill effluent irrigation, soil amendments and their interaction on rice yield

Amendments	Neutral soil						Acid soil					
Irrigation	A_0	A_1	A_2	A_3	A_4	Mean	A_0	A_1	A_2	A_3	A_4	Mean
					Grain yield (g pot[-1])							
I_0	26.7	23.1	28.0	26.5	25.8	28.0	33.9	32.6	33.1	35.3	34.5	33.9
I_1	10.9	16.2	18.9	13.1	11.9	14.2	32.2	28.2	23.9	31.0	25.4	28.3
I_2	14.3	14.7	13.8	13.6	12.7	13.8	26.7	25.1	25.2	22.3	20.4	24.0
I_3	19.3	15.1	18.9	12.5	15.2	16.2	26.9	23.9	24.6	26.4	23.7	25.1
I_4	23.1	18.3	14.5	22.2	21.5	19.9	25.0	32.3	33.4	28.7	28.1	29.5
Mean	**18.9**	**19.5**	**18.8**	**17.6**	**17.4**	**18.4**	**29.0**	**28.6**	**28.0**	**28.8**	**26.4**	**28.1**
					Straw yield (g pot[-1])							
I_0	14.7	12.5	16.5	14.9	16.2	15.0	24.2	22.9	20.9	22.7	24.3	23.0
I_1	9.5	7.7	8.8	10.9	9.3	9.3	18.2	15.4	15.1	14.9	18.4	16.4
I_2	10.9	7.8	8.1	9.7	8.3	9.0	15.7	14.7	15.9	15.6	18.0	16.0
I_3	7.9	9.2	8.7	10.2	7.4	8.7	15.1	14.9	13.5	14.9	16.7	15.0
I_4	11.4	9.0	10.9	9.6	12.3	10.5	17.5	18.9	18.9	17.2	16.7	17.8
Mean	**10.9**	**9.2**	**10.6**	**11.0**	**10.7**	**10.5**	**18.1**	**17.4**	**16.9**	**17.1**	**18.8**	**17.6**

C.D. (5%)	Grain	Straw	Grain	Straw
Irrigation	2.7	1.1	3.0	1.6
Amendments	NS	1.1	NS	NS
Interaction	6.1	2.5	NS	NS

Yield of rice

The grain yield of rice (Table 5) varied between 11.9 - 25.9 g pot^{-1} in neutral soil and 20.4 - 35.2 g pot^{-1} in acid soil with overall mean values of 18.4 and 28.1 g pot^{-1} respectively. Irrigation with good quality water (I_0) recorded the highest grain yield of rice over the rest of the irrigation treatments in both the soils. This was followed by 50% diluted clarified effluent which was again found superior to the rest of the irrigation treatments in neutral soil while it was found comparable with raw effluent in acid soil. This is in line with the reports of Kannan and Oblisami (1992) who reported a reduction in dry matter production and yield of field crops under paper mill effluent irrigation. Clarification of the effluent or the SAR adjustment of the clarified effluent did not improve the yield of rice over raw effluent irrigation in both the soils.

Though the direct effect of the soil amendments used in the present investigation failed to produce appreciable increase in the grain yield of rice in both the soils, their interaction with irrigation treatments had thrown some light on the usefulness of the soil amendments in reducing the adverse effect of effluent irrigation on rice, more particularly in neutral soil. When the main effects of the effluent irrigation treatments were considered, the use of raw effluent recorded the lowest grain yield, but it was also found comparable with that of 50% diluted clarified effluent in the presence of farm yard manure as well as composted coir waste ; and that of SAR adjusted clarified effluent in the presence of pressmud as well as lime + FYM, indicating the role of the amendments in reducing the adverse effect of raw effluent irrigation particularly in neutral soil. The usefulness of the organic amendments in improving the sugarcane yield under paper mill effluent irrigation has been reported by Jeyamani (1992). The straw yield of rice almost followed the same trend of results as that of the grain yield under the various irrigation sources.

Uptake of nutrients in rice

The N uptake of the crop has been significantly influenced by the irrigation treatments. In both the soils, effluent irrigation registered a marked decline in the total N uptake in

Table 6. Effect of paper mill effluent irrigation, soil amendment on nutrient uptake (mg pot^{-1}) in rice

Treatments		Nitrogen		Phosphorus		Potassium		Calcium		Sodium	
		Neutral soil	Acid soil	Neutral soil	Acid soil	Neutral soil	Acid soil	Neutral soil	Acid soil	Neutral soil	Acid soil
A.	Irrigation treatments										
I_0	Good quality water	672	890	42.4	-40.4	675	1088	255	276	33.4	29.2
I_1	Raw effluent	562	616	40.3	47.2	322	616	170	291	33.3	46.6
I_2	Clarified effluent	511	488	27.1	47.7	309	625	159	247	34.2	37.2
I_3	SAR adjusted Clarified effluent	515	491	30.2	34.5	398	562	159	247	34.2	37.2
I_4	50% diluted clarified effluent	488	583	34.2	54.9	433	685	198	290	38.9	402
	Mean	**550**	**614**	**34.9**	**45.0**	**431**	**715**	**195**	**270**	**34.5**	**38.0**
	CD (5%)	**94**	**89**	**10.6**	**8.9**	**72**	**60**	**32**	**36**	**NS**	**90.2**
B.	**Soil amendments**										
A_0	Control	570	699	33.8	33.7	423	696	211	276	40.1	39.3
A_1	FYM @ 12.5 t ha^{-1}	560	652	36.5	40.9	442	734	208	280	37.5	42.2
A_2	Composted coirpith @ 12.5 t ha^{-1}	518	581	38.2	58.5	419	729	187	263	35.6	35.9
A_3	Pressmud @ 12.5 t ha^{-1}	522	560	37.3	50.4	432	757	179	260	29.1	32.6
A_4	Lime stone @ 10 t ha^{-1} + FYM @ 12.5 t ha^{-1}	579	577	28.7	41.2	442	660	177	270	30.3	39.8
	Mean	**550**	**614**	**34.9**	**45.0**	**431**	**715**	**195**	**270**	**34.5**	**38.0**
	C.D. (5%)	**NS**	**89**	**NS**	**8.9**	**NS**	**60**	**32**	**NS**	**6.9**	**NS**

rice compared to that of the good quality water. Eventhough the N content in the plant parts were found to be higher in the case of effluent irrigation treatments especially in the neutral soil, it has not been reflected on the total N uptake by the crop which could be attirbuted to the lower yield of grain and straw under the effluent irrigation treatments compared to that of good quality water, thereby resulting in lower N uptake in rice. In acid soil., the N content of plant parts as well as the yield were markedly lower under effluent irrigation treatments and hence a very marked reduction could be seen in the uptake of N by the crop under these treatments. The various soil amendments tried did not show any favourable influence on the N uptake of rice in both the soils, rather they suppressed the N uptake in acid soil. However, the favourable effects of farm yard manure in reducing the ill effects of raw effluent irrigation upon the crop N uptake was clearly exhibited under the interaction effect of the soil amendments with that of irrigation treatments (data not given).

The P uptake of the crop under the raw effluent irrigation was comparable with that of good quality water in both the soils. While the use of clarified effluent and SAR adjusted clarified effluent registered a marked decline in the P uptake in neutral soil, the use of 50 per cent diluted clarified effluent favoured an increased P uptake in rice in acid soil. The use of composted coir waste as well as pressmud resulted in the higher P uptake in rice in acid soil.

As in the case of N, the K uptake of the crop was markedly reduced by the effluent irrigation treatments in both the soils. The reduced K content of the plant parts coupled with lower grain and straw yield of rice resulted in a reduction in the K uptake in rice under the effluent irrigation treatments. Use of clarified effluent rather registered the lowest K uptake (so also the P uptake) in neutral soil. The use of alum for effluent clarification, leading to an increase in the Al^{3+} content in the irrigation source might have adversely affected the P and K uptake of the crop by precipitation and antagonistic action respectively. All the soil amendments were almost comparable with control in respect of the K uptake of the crop in both the soils. However, a favourable effect of the application of pressmud and an adverse effect of the lime + farm yard manure on the K uptake was observed in acid soil.

A marked reduction in the Ca uptake of rice was observed for the effluent irrigation treatments in the neutral soil while in the acid soil the various effluent irrigation treatments were found almost comparable with that of good quality water. Though an increase in the Ca content of the plant parts was observed for the effluent irrigation in both the soils, due to a larger reduction in the yield of grain and straw, more particularly in the neutral soil, had resulted in decreased Ca uptake in rice. The soil amendments did not favour the Ca uptake in rice. The Na uptake of rice showed an increase for the raw effluent irrigation over that of good quality water onlyin acid soil. Among the soil amendments, the use of pressmud as well as lime + FYM in neutral soil had significantly reduced the Na uptake of rice while the rest were comparable with control, and their impact on the Na uptake in acid soil was insignificant.

Acknowledgements

The authors thank the authorities of M/s. Sun paper mills, Cheranmadevi, Tamil Nadu for providing facilities during this study.

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(Received : May 1998 Revised : August 1999).