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Status of Salinity, pH and Dissolved Oxygen in the Coasts and Tsunami Impounded Water Bodies of the South Andaman

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The Boxing Day *tsunami* on 26th December 2004 killed 16,000 people in India and inundated vast tract of Andaman and Nicobar Islands with saline water. The present study measured the surface water quality of some of those inundated land and beaches, six years after the *tsunami* event in the pre-monsoon season when the evaporation prevail precipitation. The study reveals that not only the salinity of the enclosed water remains high (33 to 47 ppt), but the DO (4.6 to 8.48 mgL^{-1}) and pH level (7.33 to 8.42) also varied. The enclosed water quality destroyed the agricultural crop of the area, as well as, vast tract of mangroves by the hyper salinity and anoxia. The disparity between the salinity statuses of the enclosed water in different station was regulated by their degree of enclosure from the seawater and evaporation process. The variation of the DO and pH has been explained by various level of anthropogenic contribution in the water bodies.

(***Key words:*** *South Andaman, Coasts, Tsunami, Tsunami impounded water bodies, Salinity, pH, Dissolved oxygen)*

The disastrous earth quake generated in the west coast of Sumatra, has stroked in different countries in the form of *tsunami* in 26th December, 2004. In India the *tsunami* severely affected Tamil Nadu, Andhra Pradesh and Andaman & Nicobar Islands. The south Andaman is the major inhabited island among the Andaman group of Islands, with a major part of the Island covered by agricultural lands, and has been rigorously affected by the *tsunami* (Velmurugan *et al.*, 2006). The direct environmental impact of the *tsunami* varied according to different factors, notably bathymetry and geomorphology of the coastline (Navalgund, 2005). In the middle and North Andaman, the problem aroused due to rising of the land from the mean sea level (2.40 m), where as in the South Andaman due to seduction of the land by about 1.25 m (0.8 m in case of Port Blair), the level of submergence due to tidal influence has also increased (Roy and Krishnan, 2005).

The low lying areas adjoining the creeks enables the intrusion of *tsunami* waters to a great extent, making these regions extremely vulnerable. In stations like Wandoor and Chidiyatopu landward inundation of upto 215 and 130 m was observed, whereas in Sippighat due to its low lying slope a maximum intrusion of 2 km was noticed (Ramanamurthy *et al.*, 2005). The water that entered the landmass during the *tsunami* carried huge amount of chemicals from the lower level of the sea and deposited in the land mass during its entry and recession. Immediately after *tsunami*, there was a visual appearance of reddish-brown-colored alluvium accumulations on the soil surface leading to speculation of iron toxicity problems due to *tsunami* (Nayak *et al.*, 2009). It has been reported that, 0.5°C increase in sea surface temperature (SST) was associated with a decrease in salinity from 33.5 to 32 psu, between 90°E and 92°E along 10°N, in the vicinity of the Andaman and Nicobor Islands (Luis *et al.*, 2007). On the other hand, analysis of the soil characteristics, revealed a significant increase in soluble salt concentration in the South Andaman markedly post-*tsunami* (2005), causing the soil highly saline/ saline sodic (Raja *et al.*, 2009). The tide surge not only influenced the agricultural land of the South Andaman, but the mangroves and mangrove associates are similarly affected (Roy and Krishnan, 2005).

It is evident that the tsunami driven water is still impounded in several low lying terrains of South Andaman which are posing adverse effects on the environment especially degrading the agricultural soil. The aim of the present study was to evaluate the current status of three basic physicochemical parameters of surface water, viz. salinity, pH and dissolved oxygen of the coastal water and the water bodies which came into existence by the *tsunami* event in the South Andaman.

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MATERIALS AND METHODS

The Andaman group of Islands comprises about 349 Islands and is located in the Bay of Bengal between peninsular India and Myanmar. Recently the entire Andaman group of Islands are divided into three districts, namely, the North Andaman, Middle Andaman, South Andaman and Nicobar district. South Andaman is the third largest Island of this archipelago. It is located immediately south of Middle Andaman Island, from which it is separated by a narrow channel of few hundred meters width. The Island is 93 km long and 31 km in width. Its area is 1348 km^2. It had a population of 181,949 as per the 2001 census.

Fourteen samples from the different beaches of the South Andaman were analyzed, including two and three beaches from the Havlock and Neil islands, respectively. Five samples were estimated from the water bodies, logged by *tsunami* event (Fig. 1). pH, salinity and water surface temperature were measured with the help of a Multikit (WTW Multi 340 i Set, Germany) using the probe WTW Tetracon 325 (for water surface temperature & conductivity) and WTW Sentix 41-3 (for pH). Salinity was further determined argent metrically by Mohr-Knudsen titration in the laboratory. The dissolved oxygen (D.O.) content of the water samples were measured using Winkler's titrimetric method as soon as the samples were collected.

RESULTS AND DISCUSSION

Salinity of the surface water in the coasts ranged between 30 to 34 ppt, pH between 7.42 to 8.28 and DO between 5.1 to 6.7 mgL^{-1} (Table 1). The same parameters were estimated from the tsunami formed water bodies of Therur, Sippi Ghat, Wandoor, Ugrabraj and Mithakari villages. In these sites the salinity was ranged between 33 to 47 ppt, pH between 7.33 to 8.42 and DO between 4.6 to 8.5 mgL^{-1}. The temperature of the surface water ranged between 29.1 to 35.8 oC during the study period (Table 2). The mean with standard deviation of the above mentioned parameters were compared between the two types of water bodies (Fig. 2). It revealed a substantially increased level of salinity and decreased level of pH and dissolved oxygen in the tsunami impounded water bodies as compared to the coastal waters.

Tsunami logged water showed two types of physicochemical condition, irrespective of their higher salinity status due to water logging and higher rate of evaporation in the pre-monsoon

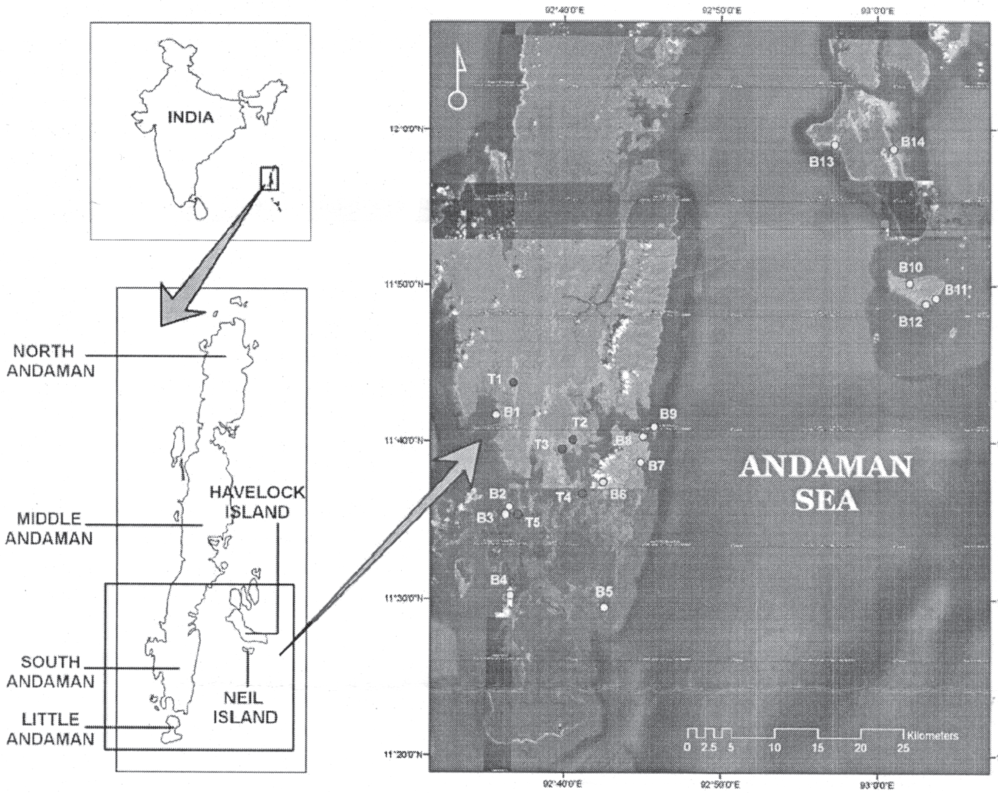

Fig. 1. The study site showing the sampling locations

Table 1. *Salinity, pH and DO in different beaches of the south Andaman during pre-monsoon*

Place		Lat/Long	Salinity (psu)	DO (mgL^{-1})	pH	Temperature (°C)
Collinpur (B1)		11° 41′ 40.7″ 92° 35′ 37.8″	30	6.2	7.98	34.2
Wandoor (B2)		11°35′ 50″ 92° 36′ 30.8″	32	6.3	8.10	32.4
Wandoor Jetty (B3)		11° 35′ 20.9″ 92° 36′ 15.8″	32.5	6.1	8.1	29.1
Jolly Buoy Island (B4)		11° 30′ 13.6″ 92° 36′ 35.2″	32	5.1	7.96	32.7
Chidiyatopu (B5)		11° 29′ 29.0″ 92° 42′ 33.0″	32.1	6.2	8.14	32.1
Dollygaunge (B6)		11° 37′ 25.6″ 92° 42′ 28.3″	32.8	5.3	7.42	32.8
Corbyn's Cove (B7)		11° 38′ 40.1″ 92° 44′ 52.4″	34	6.1	8.19	29.2
Jetty for Ross Island (B8)		11° 40′ 19.3″ 92° 45′ 00.8″	31	6.3	8.12	30.3
Ferari Beach (Ross Island) (B9)		11° 40′ 56.2″ 92° 45′ 42.8″	32	6.4	8.19	30.3
Neil Island	Bharatpur Beach (B10)	11° 50′ 9.9″ 93° 2′ 3.4″	33.5	6.7	8.28	30.2
	Sitapur Beach (B11)	11° 49′ 11.2″ 93° 03′ 44.7″	31	6.7	8.18	28.6
	Ramnagar Beach (B12)	11° 48′ 50.5″ 93° 03′ 07.0″	34	6.8	8.21	31.2
Havlock Island	Radhanagar Beach (B13)	11° 59′ 2.5″ 92° 57′ 13.4″	33	6.3	8.18	28.9
	Kalapathar (B14)	11° 58′ 46.6″ 93° 00′ 59.7″	32.5	6.6	8.08	29.8

period. First one is the less polluted condition where high pH prevails along with high DO, as in Therur, which indicates much less pollution and anthropogenic activity in this area. On the other hand, the rest of the logged water bodies showed less pH and DO value than the mean value coast, which is due to anthropogenic pollution load. On the other hand, the salinity of the Therur and Mithakari village showed much higher salinity (42 ppt and 47 ppt respectively) than the mean salinity of coasts. Other places showed a little higher salinity than the mean concentration of the coast. The variation in the salinity status was mainly directed by the extent of connection of the tsunami created water bodies from its source of sea water inundation. It can be clearly depicted from the satellite imagery that the water bodies of Therur and Mithakary villages have minute connections with the sea, which enabled evaporation to play a crucial role to increase salinity, even higher than the red sea. Correlation was calculated between the parameters measured.

The temperature showed significant negative correlation with DO ($r = -0.529$, $p=0.020$) and pH ($r = -0.569$, $p = 0.011$), as increase in the temperature reduces the solubility of the gases and raise acidity in the water. The DO showed positive correlation with pH ($r = 0.702$, $p = 0.001$) indicating probable organic contamination which produce organic acids and their oxidation reduce the DO value in the coast and *tsunami* flats. Regular monitoring of the water

Table 2. *Salinity, pH and DO in different tsunami impounded water bodies of the south Andaman during pre-monsoon*

Place	Lat/Long	Salinity (psu)	DO (mgL^{-1})	pH	Temperature (ºC)
Therur (T1)	11º 43′ 44.9″ 92º 36′ 44.8″	42	8.48	8.42	31.4
Mithakari Village (T2)	11º 40′ 07.6″ 92º 40′ 32.4″	47	4.6	7.77	35.3
Ugrabraj (T3)	11º 39′ 29.8″ 92º 39′ 52.5″	36	5.4	7.97	35.8
Sippi Ghat (T4)	11º 36′ 41.0″ 92º 41′ 09.9″	33	5.6	7.33	34.1
Wandoor (T5)	11º 35′ 20.5″ 92º 37′ 03.1″	34	5.8	7.92	31.9

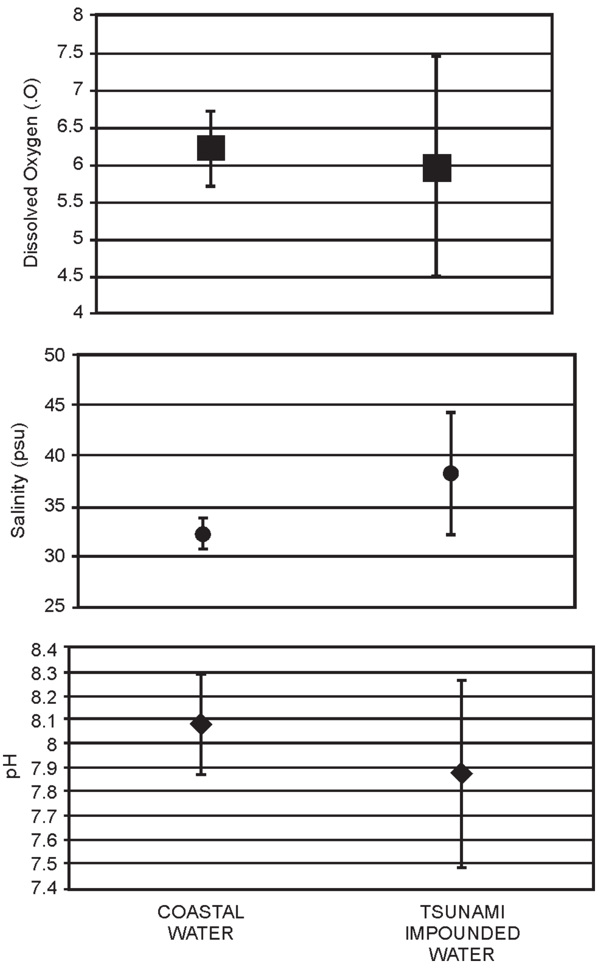

Fig. 2. Comparison of mean D.O., Salinity and pH in the coastal water and the Tsunami impounded water (error bars showing the standard deviation) Geomorphology and location of profile sites in a part

quality parameters of these *tsunami* created water bodies is essential because such a higher rate of salinity, even after six years of the *tsunami* event could be critically dangerous for the health of the surrounding soil and agriculture.

REFERENCES

Luis, A. J., Pednekar, S. M. and Sudhakar, M. (2007). Post-tsunami impact study on thermohaline structure in the Bay of Bengal. *Current Science* **93**(5): 699-703.

Navalgund, R. R. (2005). Sumatra *tsunami* of December 26, 2004. *Journal of Indian Society of Remote Sensing* **33**: 1–6.

Nayak, A. K., Damodaran, T., Singh, C. S., Jha, S. K., Raja, D., Mishra, V. K., Sharma, D. K. and Singh, G. (2010). Post *tsunami* changes in soil properties of Andaman Islands, India. *Environmental Monitoring and Assessment* **170**: 185-193.

Raja, R., Ghoshal Chaudhuri, S., Ravisankar, N., Swarnam, T. P., Jayakumar, V. and Srivastava, R. C. (2009). Salinity status of *tsunami*-affected soil and water resources of South Andaman, India. *Current Science* **96**(1): 152-156.

Ramanamurthy, M.V., Sundaramoorthy, S., Pari, Y., Ranga Rao, V., Mishra, P., Bhat, M., Usha, T., Venkatesan, R. and Subramanian, B. R. (2005). Inundation of sea water in Andaman and Nicobar Islands and parts of Tamil Nadu coast during 2004 Sumatra *tsunami*. *Current Science* **88** (11): 1736-1740.

Roy, S. D. and Krishnan, P. (2005). Mangrove stands of Andamans vis-à-vis *tsunami*. *Current Science* **89**(11): 1800-1804.

Velmurugan, A., Swarnam, T. P. and Ravisankar, N. (2006). Assessment of *tsunami* impact in South Andaman using Remote Sensing and GIS. *Journal of the Indian Society of Remote Sensing* **35**(2): 193-202.

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Standardisation of Critical Nutrient Concentration of Sulphur and Boron in Sesame (*Sesamum indicum* L.) Grown in an Entisol

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Sesame is the choice crop in Onattukara sandy soil of Kerala. To ensure a good produce from this crop, timely application of nutrients including secondary and micronutrients in correct quantity should be ensured. For this it is absolutely essential to standardize the critical nutrient concentration. Sulphur and boron are the key nutrients for ensuring sustained production of oil seed crops. Hence the present study was undertaken involving two field experiments with the application of graded levels of S (0, 7.5, 15 and 30 kg S ha^{-1}) and B (0, 2.5, 5 and 7.5 kg ha^{-1}). By using the scatter diagram technique, the critical level of S and B in plant was fixed as 0.088% and 22 mg kg^{-1} respectively. In the case of soil the levels were fixed at 23 kg ha^{-1} and 1.4 ppm for S and B, respectively.

(***Key words:*** *Sulphur, Boron, Critical nutrient concentration)*

Sesame is one of the oldest among the cultivated crops by man. Because of its medicinal properties, superior qualities of oil and its adaptability to be grown in fallow lands, this crop has immense scope to be cultivated by the small and marginal farmers. Sulphur and boron are the two essential nutrients which are considered to be of immense importance in oil seed production. It is the master nutrient in oil production ranked as the fourth major nutrient next to N, P and K. Boron plays a vital role in oilseed production. It is needed for carbohydrate transport as well as cellular differentiation and development. Often the farmers are not applying these two nutrients in any form to the crops with the result that they are not able to exploit the full production potential. Hence it is very important to standardize the critical concentration of these two nutrients which will enable the farmers to apply them in precise quantities and in a timely manner. Foliar analysis can reveal deficiencies before growth and yields are adversely affected, thereby permitting timely application of nutrients. Critical nutrient concentration range is that range below which deficiency of the particular nutrient will be exhibited by the crop and the level above which toxicity symptoms will appear in the crop plant. It can also be defined as the concentration of the nutrient in a particular soil or plant fraction at 95% of the maximum yield. The present study was undertaken to standardize the critical concentration of sulphur and boron in sesame grown in Onattukara sandy soil of Kerala.

MATERIALS AND METHODS

The experiment has been conducted in Oxyaquic Quartzi Psamment soil at Onattukara Regional Agricultural Research Station, Kayamkulam during two consecutive summers of the year 2008-2010. The area is located at 90 30′ N latitude and 76°20′ East longitude at an altitude of 3.05m above mean sea level. The soil belongs to the Oxyaquic Quartzi Psamment subgroup with low available nutrients and poor water and nutrient holding capacity. The variety chosen for the study was Thilarani, a high yielding variety of sesame widely popular in Onattukara as third crop in summer rice fallows. Two field experiments were laid out in factorial RBD design with four levels each of sulphur and boron. The levels of sulphur tried were 0, 7.5, 15 and 30 kg ha^{-1} and that for boron the levels were 0, 2.5, 5 and 7.5 kg ha^{-1}. Hence there were 16 treatment combinations. For standardizing the critical nutrient concentration in soil and plant, samples were taken at four stages viz., 4-5 leaf stage, flowering stage, branching stage and pod formation stage which were 20 DAS, 30 DAS, 40 DAS and 50 DAS, respectively. The plant and soil samples during these sampling stages were analyzed for their S and B content. Later the coefficient of correlation was worked out to standardize the index part and stage of sampling for both of these nutrients. The critical nutrient levels for maximum yield were fixed using the scatter diagram technique of Cate and Nelson (1965). The important physico chemical properties of the soil at the experiment site include pH -5.1, EC-0.3 dSm^{-1}, organic carbon- 0.31 per cent, available phosphorus- 6.5 kg ha^{-1}, available potassium- 62 kg ha^{-1}, exchangeable calcium - 0.48 cmol kg^{-1}, exchangeable magnesium - 0.034 cmol kg^{-1}, available sulphur - 10.20 kg ha^{-1}, available boron - 0.18 ppm.

RESULTS AND DISCUSSION

Effect of sulphur and boron on the yield of sesame

The average yield obtained in two years is presented in Table 1. Sulphur and B plays a significant role on enhancing the yield of sesame. Analysis of the yield data pertaining to the crop cultivated in two consecutive summer season has shown the significant influence of these nutrients in enhancing the seed yield of sesame. Considering the interaction effect of S and B it has been observed that the highest seed yield was recovered by the application of both nutrients at the highest level i.e., T16 (S_3B_3). This treatment recorded the yield of 1460.94 kg ha^{-1} in the first cropping season. This was followed by T_{14} (S_3B_1) and they were on par with each other. In the second crop also the same trend was repeated. T_{16} (S_3B3) recorded yield of 1407.30 kg ha^{-1}. This was followed by T_{14} (S_3B_1) which registered yield of 1172.94 kg ha^{-1}. The lowest yields in both the seasons were produced in the treatment which received neither sulphur nor boron (S0B0). The pooled analysis of the data also confirmed the trend.

Effect of S and B on the content of these nutrients in various plant parts

The data on the S content of the different parts of the plant such as lamina, petiole, midrib and internode sampled at 20 DAS, 30 DAS, 40 DAS and 50 DAS are presented in table 4 to Table 13. Statistical analysis of the data reveals that application of treatments had a significant effect upon the S content of these parts at different growth stages. In all the parts at all the sampling stages, the S content was found to be increasing with increasing level of nutrient application from 0 to 30 kg ha^{-1}. At all stages, T_{16} (S_3B_3) was the superior treatment followed by T_{15} (S_3B_2) and T_{14}(S_3B_1). The effect of different levels of S and B and the different combination of these nutrients were significant for the B content in plant parts taken at all the sampling stages as shown in Table 3. The highest value at all the four sampling stages were shown by the treatment which received S and B at the highest level followed by the treatment combinations with the highest level of B and the next level of S. This indeed shows the synergistic interaction between S and B on nutrient availability. By studying the correlation between yield and the nutrient composition it was observed that petiole recorded the highest correlation coefficient value for both the nutrients (0.479 for S and 0.581 for B) showing the maximum relationship with yield and it was selected as the best index for foliar sampling for S and B in sesame. Prevel *et al.* (1986) and Lanenegger and Du Plesser (1977) also observed that conducting tissues of plants especially petiole were useful indicators

Table 1. *Effect of treatments on the seed yield of sesame grown in Onattukara sandy soil*

Treatments	Seed yield (kg ha^{-1})		
	I crop	II Crop	Pooled data
S_0 B_0	585.94	537.50	561.72
S_0 B_1	1104.17	1113.17	1108.67
S_0 B_2	1057.29	1055.73	1056.51
S_0 B_3	940.11	1020.56	980.33
S_1 B_0	734.38	732.81	733.59
S_1 B_1	1010.38	1041.40	1025.89
S_1 B_2	968.75	938.54	953.65
S_1 B_3	1091.15	1084.38	1087.76
S_2 B_0	953.12	1063.54	1008.33
S_2 B_1	979.17	1055.72	1017.44
S_2 B_2	1127.61	1128.65	1128.13
S_2 B_3	1028.65	1034.89	1031.77
S_3 B_0	953.12	948.95	951.04
S_3 B_1	1377.61	1172.94	1275.27
S_3 B_2	895.83	894.27	895.05
S_3 B_3	1460.94	1407.30	1434.12
F-SXB	13.77**	28.31**	25.66 **
CD(SXB)	156.255	91.938	30.52

Table 4. *S content of plant parts at 20DAS (%)*

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	0.0603	0.0141	0.0660	0.0398
S_0 B_1	0.108	0.0423	0.0715	0.0440
S_0 B_2	0.126	0.0609	0.0945	0.0476
S_0 B_3	0.156	0.0548	0.1460	0.0485
S_1 B_0	0.166	0.0593	0.1700	0.0558
S_1 B_1	0.188	0.0630	0.1640	0.0571
S_1 B_2	0.170	0.1280	0.1710	0.0640
S_1 B_3	0.208	0.1630	0.1800	0.0582
S_2 B_0	0.250	0.1630	0.2030	0.0842
S_2 B_1	0.230	0.1530	0.2050	0.0636
S_2 B_2	0.226	0.1950	0.2340	0.0821
S_2 B_3	0.267	0.1740	0.2560	0.0831
S_3 B_0	0.263	0.1750	0.2520	0.0986
S_3 B_1	0.294	0.0930	0.2470	0.0985
S_3 B_2	0.308	0.1310	0.2470	0.0960
S_3 B_3	0.327	0.2660	0.2870	0.1070
F-S.B	3.19*	40.20**	3.58*	2.36^{NS}
CD - S.B	0.0506	0.02260	0.03340	–

Table 5. *S content of plant parts at 30 DAS (%)*

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	0.125	0.0460	0.0133	0.0716
S_0 B_1	0.122	0.0789	0.0163	0.0123
S_0 B_2	0.130	0.0890	0.0241	0.0139
S_0 B_3	0.152	0.0416	0.0258	0.0149
S_1 B_0	0.151	0.0693	0.0277	0.01872
S_1 B_1	0.155	0.0642	0.0283	0.0233
S_1 B_2	0.166	0.0792	0.0284	0.0297
S_1 B_3	0.164	0.0772	0.0292	0.0336
S_2 B_0	0.174	0.0884	0.0432	0.0360
S_2 B_1	0.194	0.0971	0.0402	0.0425
S_2 B_2	0.220	0.1090	0.0437	0.0644
S_2 B_3	0.213	0.1040	0.0414	0.0814
S_3 B_0	0.259	0.1030	0.0516	0.0884
S_3 B_1	0.211	0.1230	0.0525	0.1170
S_3 B_2	0.273	0.1510	0.0965	0.1040
S_3 B_3	0.292	0.1590	0.0575	0.1510
F-S.B	2.32^{NS}	2.89*	2.65*	12.72**
CD - S.B	–	0.0500	0.0462	0.0106

Table 6. *S content of plant parts at 40 DAS (%)*

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	0.0211	0.0355	0.0510	0.0460
S_0 B_1	0.0745	0.0380	0.0655	0.0481
S_0 B_2	0.1020	0.0411	0.0704	0.0595
S_0 B_3	0.1040	0.0545	0.0847	0.0699
S_1 B_0	0.1180	0.0465	0.0875	0.0702
S_1 B_1	0.1260	0.0826	0.0909	0.0717
S_1 B_2	0.1340	0.1070	0.1030	0.0819
S_1 B_3	0.1400	0.1180	0.1130	0.0700
S_2 B_0	0.1510	0.1170	0.1360	0.0972
S_2 B_1	0.1610	0.1210	0.1370	0.1040
S_2 B_2	0.1610	0.1270	0.1470	0.1000
S_2 B_3	0.1640	0.1320	0.1540	0.1020
S_3 B_0	0.2020	0.1330	0.1710	0.1110
S_3 B_1	0.2230	0.1380	0.1810	0.1030
S_3 B_2	0.2630	0.1430	0.1830	0.1200
S_3 B_3	0.2650	0.1510	0.1850	0.1580
F-S.B	9.10**	2.48^{NS}	4.12**	5.45**
CD - S.B	0.0168	–	0.0675	0.0156

of tissue nutrients and suggested the choice of the plant as it is easier to define and locate a petiole sample than any other leaf part. Petiole as index part for foliar diagnosis has been reported for clover, soybean, banana, mango and papaya (Tandon, 1993).

Among the different growth stages of the crop the stage at which the selected index part (petiole) showed maximum correlation with yield as evidenced by the magnitude of value of coefficient of correlation was adjudged as the best stage of sampling for that particular nutrient. On this basis,

Table 7. *S content of plant parts at 50 DAS (%)*

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	0.214	0.151	0.212	0.201
S_0 B_1	0.323	0.193	0.230	0.211
S_0 B_2	0.324	0.216	0.241	0.241
S_0 B_3	0.306	0.245	0.253	0.254
S_1 B_0	0.325	0.270	0.273	0.258
S_1 B_1	0.341	0.278	0.337	0.263
S_1 B_2	0.382	0.296	0.343	0.270
S_1 B_3	0.396	0.299	0.347	0.286
S_2 B_0	0.407	0.308	0.360	0.312
S_2 B_1	0.426	0.308	0.365	0.315
S_2 B_2	0.425	0.321	0.369	0.330
S_2 B_3	0.434	0.351	0.381	0.345
S_3 B_0	0.457	0.373	0.384	0.362
S_3 B_1	0.420	0.402	0.394	0.370
S_3 B_2	0.439	0.460	0.410	0.380
S_3 B_3	0.448	0.466	0.422	0.395
F-S.B	2.12^{NS}	2.10^{NS}	11.69**	3.51*
CD - S.B	–	–	0.215	0.265

Table 8. *B content of plant parts at 20 DAS (mg kg^{-1})*

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	17.72	20.13	14.73	11.11
S_0 B_1	22.55	24.38	15.23	12.23
S_0 B_2	24.10	26.68	24.13	15.73
S_0 B_3	36.23	28.10	28.20	18.63
S_1 B_0	18.93	26.05	20.73	16.22
S_1 B_1	28.30	28.78	25.63	21.23
S_1 B_2	31.10	30.73	28.47	24.41
S_1 B_3	33.00	32.00	29.55	28.83
S_2 B_0	19.41	24.21	20.51	17.24
S_2 B_1	33.12	26.63	21.08	19.14
S_2 B_2	32.30	29.62	27.41	28.24
S_2 B_3	35.40	32.15	31.71	29.61
S_3 B_0	29.01	28.61	22.05	20.32
S_3 B_1	35.20	32.20	22.02	24.14
S_3 B_2	37.41	36.72	30.73	29.75
S_3 B_3	40.44	40.05	38.60	30.01
F-S.B	4.18**	16.01**	9.28**	38.76**
CD - S.B	3.899	2.14	2.24	0.394

the branching stage of sampling (30 DAS) was selected as the best stage of sampling for foliar diagnosis in sesame for S and 4-5 leaf stage (20 DAS) for B. This is of practical significance as both these stages coincide with the early vegetative phase of the crop when fertiliser application is feasible.

Table 9. *B content of plant parts at 30 DAS (mg kg^{-1})*

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	10.72	13.25	13.13	11.03
S_0 B_1	16.10	28.10	15.13	14.72
S_0 B_2	23.75	31.50	19.12	18.31
S_0 B_3	26.25	35.50	25.63	21.08
S_1 B_0	13.76	18.27	12.34	14.13
S_1 B_1	30.01	36.00	17.63	18.32
S_1 B_2	30.61	36.00	23.41	21.58
S_1 B_3	33.07	39.00	29.13	22.32
S_2 B_0	20.60	22.75	13.61	16.63
S_2 B_1	27.82	31.50	21.31	16.28
S_2 B_2	28.60	34.75	21.56	19.10
S_2 B_3	32.20	35.21	25.30	24.90
S_3 B_0	33.60	32.50	15.12	20.08
S_3 B_1	34.11	34.00	23.34	22.63
S_3 B_2	36.00	35.00	28.13	28.34
S_3 B_3	39.52	37.11	31.07	28.33
F-S.B	4.02**	24.53**	14.12**	10.26**
CD - S.B	4.46	2.43	1.54	1.33

Table 10. *B content of plant parts at 40 DAS (mg kg^{-1})*

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	18.10	19.75	11.09	9.29
S_0 B_1	18.97	24.50	15.54	12.25
S_0 B_2	23.58	33.50	22.5	14.00
S_0 B_3	27.28	34.00	29.07	20.60
S_1 B_0	22.02	20.75	15.46	11.33
S_1 B_1	24.61	26.00	16.13	20.16
S_1 B_2	28.33	27.00	24.90	24.07
S_1 B_3	30.14	33.00	30.11	25.70
S_2 B_0	24.13	23.00	16.58	14.65
S_2 B_1	26.81	31.50	18.72	17.23
S_2 B_2	28.82	34.75	27.00	21.64
S_2 B_3	30.13	37.00	25.23	21.30
S_3 B_0	26.28	25.00	18.38	21.49
S_3 B_1	29.12	32.00	22.42	23.83
S_3 B_2	31.08	36.75	31.49	24.50
S_3 B_3	35.63	39.00	33.86	25.96
F-S.B	117.11**	11.92**	1.57^{NS}	18.16**
CD - S.B	1.71	3.65	–	1.67

Table 11. *B content of plant parts at 50 DAS (mg kg-^{1})*

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	12.25	22.50	11.75	12.31
S_0 B_1	28.02	23.80	12.28	18.47
S_0 B_2	28.59	26.55	13.18	26.13
S_0 B_3	31.07	29.25	21.44	26.05
S_1 B_0	12.44	23.50	12.75	12.91
S_1 B_1	23.50	25.21	27.23	25.31
S_1 B_2	23.50	26.50	29.00	26.73
S_1 B_3	24.10	28.50	29.50	27.08
S_2 B_0	13.05	25.25	26.33	15.41
S_2 B_1	20.89	28.25	26.61	25.63
S_2 B_2	25.78	30.22	28.00	28.15
S_2 B_3	27.25	30.50	31.50	28.31
S_3 B_0	14.29	28.00	21.00	21.75
S_3 B_1	31.91	30.00	24.20	20.42
S_3 B_2	33.11	31.50	26.75	30.50
S_3 B_3	34.04	35.43	31.50	31.61
F-S.B	19.39**	1.21^{NS}	4.32**	19.69**
CD - S.B	4.090	–	5.44	2.21

Table 12. *Available S of the soil at different sampling stages (kg ha^{-1})*

Treatments	20DAS	30DAS	40DAS	50DAS
S_0 B_0	13.94	4.33	15.2	9.73
S_0 B_1	11.73	10.58	6.60	14.40
S_0 B_2	16.25	14.91	20.50	21.67
S_0 B_3	18.13	21.13	22.22	23.17
S_1 B_0	36.25	19.46	30.00	25.09
S_1 B_1	34.00	35.77	33.50	27.39
S_1 B_2	42.50	28.93	37.27	26.50
S_1 B_3	22.24	20.73	37.50	28.50
S_2 B_0	26.68	41.64	37.00	30.06
S_2 B_1	46.25	39.14	32.10	32.50
S_2 B_2	48.25	42.02	32.25	32.69
S_2 B_3	55.25	16.27	34.25	37.41
S_3 B_0	41.64	48.85	38.00	37.38
S_3 B_1	32.21	43.50	39.35	38.00
S_3 B_2	34.00	29.74	40.16	38.39
S_3 B_3	34.00	39.09	45.94	45.44
F-S.B	5.81**	3.60*	3.05 *	1.57^{NS}
CD - S.B	10.807	24.531	6.43761	–

On the basis of critical levels of these nutrients which have been worked out, the application schedule of these nutrients can be programmed so as to ensure the production of maximum number of primary and secondary branches which in turn will result in more number of pods and finally grain yield. As assured components of the plant composition at early stage of the crop, these nutrients can play their biochemical roles in oil synthesis also contributing to better oil yield quantitatively and qualitatively.

Critical S and B levels in petiole for maximum yield in sesame

The critical levels of S and B in the index part (petiole) at the stages identified as the best stage for sampling for each nutrient (30 DAS for S and 20 DAS for B) were determined adopting the scatter diagram technique of Cate and Nelson (1965). At each stage, graphs were plotted relating relative percentage yield values(Y axis) against the petiole S or B concentration (X axis) respectively. Using a plastic overlay the values were grouped into two populations constructing quadrants by drawing parallels, maximizing the number of points in the first and third quadrants. While drawing parallels, the concept of definition for critical level that it is the lowest nutrient levels accompanying the highest yield was taken as the guiding principle.

It can be observed from Fig.1 that the critical petiole S content of sesame at 30 DAS for maximum yield is 0.088 per cent and from Fig. 2 that the critical petiole B content at 20 DAS for maximum yield is 28 mg kg^{-1}.

Critical S and B levels in soil for maximum yield in sesame (Fig. 3 and 4)

For determining the critical levels of S and B in soil for maximum yield the stages of crop growth considered were the same as that for the foliar diagnosis of these nutrients. The procedure adopted was also the same as that for the plant (Cate and Nelson, 1965). For deriving the soil critical S level relative percentage yields were plotted against soil available S contents at 30 DAS. For the soil critical

Table 13. *Available (Hot Water Extractable) B of soil at the different sampling stages (ppm)*

Treatments	20DAS	30DAS	40DAS	50DAS
$S_0 B_0$	0.208	0.355	0.196	0.161
$S_0 B_1$	0.511	0.693	0.227	0.560
$S_0 B_2$	1.060	0.881	0.214	0.577
$S_0 B_3$	2.140	1.44	0.330	1.350
$S_1 B_0$	0.566	0.950	0.244	0.761
$S_1 B_1$	0.713	1.180	0.449	1.26
$S_1 B_2$	1.540	1.210	0.445	1.370
$S_1 B_3$	2.190	2.220	0.409	1.570
$S_2 B_0$	1.150	1.510	0.643	0.870
$S_2 B_1$	1.050	1.640	0.725	1.210
$S_2 B_2$	1.530	1.340	0.94	1.760
$S_2 B_3$	1.610	2.450	1.360	2.030
$S_3 B_0$	1.340	1.730	0.992	0.795
$S_3 B_1$	1.470	1.640	1.060	2.260
$S_3 B_2$	1.800	1.910	1.010	2.110
$S_3 B_3$	1.810	2.040	1.600	2.140
F-S.B	9.71**	1.66^{NS}	2.60 *	5.53**
CD - S.B	0.3317	0.5328	0.3023	0.3463

Table 14. *Coefficient of correlation with S content in petiole at the different growth stages in sesame*

Plant Part	20 DAS	30 DAS	40 DAS	50 DAS
Lamina	0.359	0.264	0.459	0.436
Petiole	0.390	0.479	0.297	0.261
Midrib	0.276	0.366	0.195	0.384
Internode	0.302	0.427	0.367	0.472

Table 15. *Coefficient of correlation with B content in petiole at the different growth stages in sesame*

Plant Part	20 DAS	30DAS	40DAS	50DAS
Lamina	0.446	0.496	0.319	0.136
Petiole	0.581	0.556	0.532	0.442
Midrib	0.391	0.436	0.455	0.324
Internode	0.368	0.439	0.409	0.333

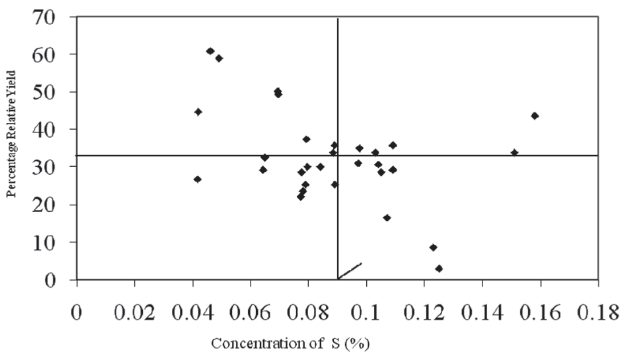

Fig. 1. Critical S level in petiole at 30 DAS

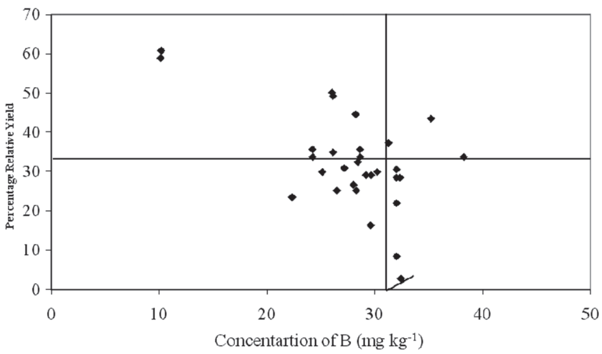

Fig. 2. Critical B level in petiole at 20 DAS

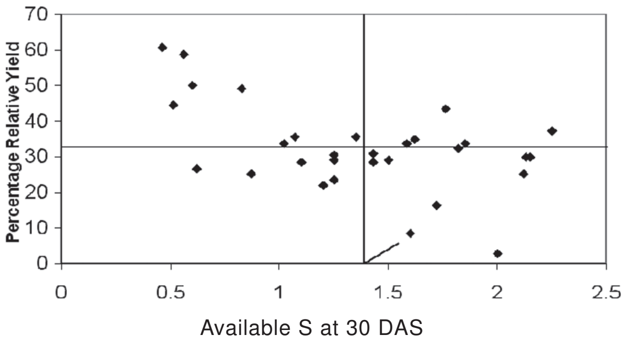

Fig. 3. Critical soil S at 30 DAS

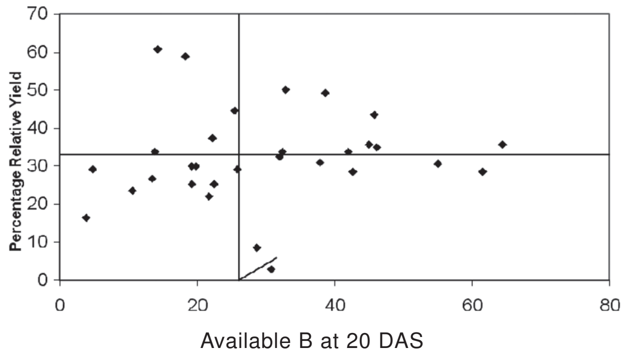

Fig. 4. Critical soil B at 20 DAS

B level, the relative percentage yields and the soil available B contents at 20 DAS were graphically related. From the figures, it can be conclusively stated that for the maximum yield of sesame, in Onattukara sandy loam soil, the critical soil S level is 23 kg ha^{-1} at 30 DAS and the critical soil B level at 20 DAS is 1.4 ppm. Basic analysis of the experimental soil shows a value of 10.2 kg ha^{-1} for available S and 0.18 ppm for available B which are below the critical levels. The results of the study highlight the scope of increasing the productivity of sesame in sandy soil through S and B fertilization.

REFERENCES

Cate, R. B. and Nelsen, L. A. (1965). A rapid method for correlation of soil test analysis with plant response data. *International Soil testing Series Technical Bullettin.* I. North Carolina State Univ. Agric. Expt. Station, Raleigh.

Lanenegger, W. and Duplessis, S. F. (1977). The determination of the nutritional status of the dwarf Cavendish banana in S. Africa. *Fruits* **32**(12): 711-724.

Prevel, M., Gagnard, J. and Gautier, P. (1986). Banana. In: *Plant Analysis as a guide to the nutrient requirements of temperate and tropical crops.* SBA Publications, Calcutta. pp 637-670.

Tandon, H. L. S. (1993). *Methods of Analysis of Soils, Plants, Fertilizers and Water.* Dr. H.L.S. Tandon (ed.). Fertilizer Department and Consultation Organisation, New Delhi. p 122.

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Effect of Lime and Organic Matter Applied under Different Moisture Regimes on Forms of Zn and DTPA Extractable Zn, Cu, Fe, and Mn in Alfisols of West Bengal

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A laboratory investigation was carried out to study the effect of lime, organic matter and lime + organic matter on the changes in different forms of Zn and DTPA extractable Zn, Cu, Fe and Mn in two Alfisols of West Bengal after incubating the soil samples in two moisture regimes viz. field capacity and continuous submergence. In both the moisture regimes, DTPA extractable Zn, Cu, Fe and Mn increased with application of organic matter and decreased with application of lime and lime + organic matter. Water soluble + exchangeable Zn increased with application of organic matter and decreased with application of lime and lime + organic matter in both the moisture regimes. Organically complexed Zn and amorphous sesquioxide bound Zn increased in all the three treatments in both the moisture regimes. The lime, organic matter and lime + organic matter treated soils, after being incubated at field capacity, were submerged for 21 days and then, the DTPA extractable Zn, Cu, Fe and Mn were determined. There was increase in DTPA extractable Zn, Fe and Mn in the pre-treated soils with lime, whereas there was decrease in DTPA extractable Zn, Cu and increase in DTPA extractable Fe and Mn in the pre-treated soils with organic matter after submergence. Submergence of the soils pre-treated with lime + organic matter increased DTPA extractable Zn, Fe, and Mn but decreased DTPA extractable Cu.

(***Key words :*** *Lime, Organic matter, Submergence, Field capacity, Forms of Zn, DTPA extractable Zn, Cu, Fe, Mn)*

A significant portion of the cultivated area in West Bengal is occupied by lateritic soils, belonging to Alfisols. These soils are acidic and light textured with low organic matter content and are low in Zn and Cu but high in Fe and Mn. Soil acidity is a major constraint for crop production in these soils. To neutralize the soil acidity lime is added, whereas organic matter is added to improve the physical condition of the soils.

Application of lime and organic matter change the soil properties depending on the moisture regimes in which these are applied. Transformations of micronutrients are, therefore influenced accordingly. Information in this respect is meagre for the red and lateritic soils of West Bengal. The present investigation has been undertaken to study the changes in different forms of Zn and DTPA extractable Zn, Cu, Fe and Mn after incubating the soil samples in two different moisture regimes viz. continuous submergence and field capacity with application of lime and organic matter in two Alfisols of West Bengal.

MATERIALS AND METHODS

Surface soil samples (0-15 cm) were collected from two typical medium lands of two representative lateritic zones of West Bengal viz. Kalikunda of Midanapur district and Santiniketan of Birbhum district. Both the soils belong to Alfisols. Rice is grown in *Kharif* in these soils, whereas pulses, oilseeds and vegetables are grown in *Rabi*. The soil samples were air-dried, ground and passed through a 0.5 mm nylon sieve and were preserved in polythene bottles for necessary analysis. Mechanical composition of the soil was determined by Bouyoucos hydrometer method (Piper, 1966). Soil pH was determined in 1:2.5 soil and water ratio by a glass electrode pH meter. Organic carbon was determined by Walkley-Black method (Jackson, 1973). Cation exchange capacities of the soils were determined by leaching the soils with neutral N NH_4OAc solution (Black, 1965). Free Fe_2O_3 content in the soils were determined in the Na-citrate-bicarbonate-dithionite extract of soil (Jackson, 1956). Available micronutrients like Zn, Cu, Fe and Mn were determined in the DTPA extract of the soils (Lindsay and Norvell, 1978) by atomic absorption spectrophotometer. Different forms of Zn in the soils were fractionated as described by Hazra *et al.*, (1987).

A portion of the soil sample was treated with lime, organic matter and lime + organic matter. Lime

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was added as pure $CaCO_3$ @ 1.0 LR determined by Woodruff buffer method and organic matter was added as 1% starch in soil. Both the original and treated soil samples were incubated under continuous submergence and at field capacity for 35 days. The soil samples, after incubation, were air-dried, ground to pass through a 0.5 mm nylon sieve and analyzed for various soil properties including free and amorphous Fe_2O_3 contents. Amorphous Fe_2O_3 content was determined in 0.2 M NH4 oxalate + 0.2 M oxalic acid (adjusted to pH 3.0) extracts of soil (Shuman, 1982) with destruction of oxalate ions. Crystalline Fe_2O_3 was determined from the difference between free Fe_2O_3 and amorphous Fe_2O_3. The incubated soil samples were also analysed for various forms of Zn and DTPA extractable Zn, Cu, Fe and Mn. Thirty gram of the original and treated soil samples, incubated at field capacity, were water logged for 21 days after which the soils were air- dried and ground to pass through a 0.5 mm nylon sieve. The soils were then analysed for DTPA extractable Zn, Cu, Fe and Mn.

RESULTS AND DISCUSSION

Some of the important physical and chemical properties of the soils are presented in Table 1. The soils were strongly acidic with low organic carbon content and low CEC. Different forms of Zn and DTPA extractable Zn, Cu, Fe and Mn in the soils are presented in Table 2. Crystalline and amorphous sesquioxide bound Zn was higher than the soluble + exchangeable Zn as well as organically complexed Zn in both the soils. DTPA extractable Fe and Mn were much higher than the DTPA extractable Zn and Cu in both the soils. Effects of lime and organic matter, applied under different moisture regimes, on the changes in various soil properties are presented in Table 3.

Change in soil pH

There was slight increase in pH of the original soils of Kalikunda and Santiniketan after submergence which might be due to the reduction condition occurring under submergence. Application of lime increased the soil pH in both the moisture regimes. There was slight reduction in pH in the organic matter treated soils over the controls after submergence. This might be due to release of organic acids during anaerobic decomposition of organic matter. However, a slight increase in pH was observed in the organic matter treated soils over the controls at field capacity. Application of lime along with organic matter increased the soil pH in both the moisture regimes. The extent of increase was, however, less than that due to application of lime only. Release of organic acids and CO_2 during decomposition of organic matter might have lowered down the magnitude of increase.

Table 1. *Some important properties of the soils*

Properties	Kalikunda Soil	Santiniketan soil
% Clay	18.2	13.6
pHw (1:2.5)	5.1	5.3
pH 0.01 M $CaCl_2$	4.1	4.1
% Organic carbon	0.40	0.35
CEC [cmol(p^+) kg^{-1}]	9.2	7.3
Free Fe_2O_3 (%)	0.75	1.37

Table 2. *DTPA extractable micronutrients and forms of Zn in the soils*

DTPA extractable micronutrients	Kalikunda soil ($\mu g\ g^{-1}$)	Santiniketan soil ($\mu g\ g^{-1}$)
Zn	1.04	1.56
Cu	1.73	1.63
Fe	61.0	92.1
Mn	24.0	158.2
Forms of Zn		
Water soluble + exchangeable	0.65	0.85
Organically complexed	0.70	1.05
Amorphous sesquioxide bound	5.80	7.70
Crystalline sesquioxide bound	5.07	11.83

Change in organic carbon content

There was significant decrease in organic carbon content of the original soil of Kalikunda after submergence, whereas no such change was observed for the Santiniketan soil. There was increase in organic carbon content with application of organic matter in both the moisture regimes over the controls. The increase was higher when the moisture content was at field capacity than at continuous submergence. This might be due to greater decomposition of organic matter in case of the latter. There was also increase in organic carbon content in lime + organic matter treated soils over the controls in both the moisture regimes. The extent of increase was, less than that due to application of organic matter only. This might be due to increase in the rate of decomposition of organic matter with application of lime which accelerates the microbial activities.

Table 3. *Changes in the physicochemical properties of the soils as influenced by moisture regimes and application of lime and organic matter*

Soils	Moisture regimes	Treatments	pH	% Org.C	CEC [cmol (p+)kg^{-1}]	Fe_2O_3%	
						Crystalline	Amorphous
Kalikunda	Countinuous submergence	Control	5.5	0.29	10.0	0.60	0.124
		Lime	8.3	0.26	16.2	0.50	0.139
		Organic matter	5.0	0.39	11.4	0.55	0.157
		Lime + Organic matter	7.8	0.35	12.8	0.61	0.126
	Field capacity	Control	5.1	0.41	9.0	0.67	0.157
		Lime	8.2	0.38	11.7	0.75	0.174
		Organic matter	5.6	1.03	10.5	0.62	0.181
		Lime + Organic matter	7.9	0.81	10.8	0.61	0.163
Santiniketan	Countinuous submergence	Control	5.7	0.33	8.4	1.24	0.224
		Lime	7.9	0.32	12.9	1.11	0.269
		Organic matter	5.5	0.47	9.9	0.97	0.244
		Lime + Organic matter	7.3	0.38	10.7	1.03	0.242
	Field capacity	Control	5.3	0.34	7.4	1.00	0.280
		Lime	8.0	0.33	13.2	1.13	0.302
		Organic matter	5.5	0.94	9.2	1.10	0.303
		Lime + Organic matter	7.5	0.86	10.7	1.19	0.289

Change in CEC

There was slight increase in CEC of the original soils after incubation under submergence which might be due to increase in soil pH. Liming the soils caused a significant increase in the CEC of the soils under both the moisture regimes. This might be due to increase in pH-dependent negative charges with increase in pH. Addition of organic matter increased the CEC of the soils under both the moisture regimes but the values were less than that due to liming. The increase in CEC after adding organic matter might be due to generation of more of the functional groups like COOH and OH during decomposition of organic matter. The COOH groups contribute to pH-dependent negative charges at the soil pH is >3.0 (Bolan *et al.*, 1999). Addition of lime + organic matter also increased the CEC in both the moisture regimes but the extent of increase was less than that due to application of lime only. This might be due to less pH in lime + organic matter treated soils than the lime treated soils. Increase in CEC due to application of lime + organic matter was higher than that due to application of organic matter.

Change in crystalline and amorphous Fe_2O_3 contents

Effect of lime

Application of lime caused a slight reduction in crystalline Fe_2O_3 but increase in amorphous Fe_2O_3 over control under continuous submergence (Table 3). Both crystalline and amorphous Fe_2O_3 contents increased with application of lime at the moisture level of field capacity. Increase in amorphous Fe_2O_3 content with application of lime at the moisture content of field capacity has also been reported by Das *et al.*, 2006. Because of the increase in pH after liming, the Fe^{3+} ions are precipitated as Fe $(OH)_3$ causing an increase in the amorphous forms of Fe. Some of the amorphous Fe $(OH)_3$ may slowly organize to crystalline forms thus increasing the crystalline form of Fe (Table 3).

Effect of organic matter

Crystalline Fe_2O_3 content decreased over control with application of organic matter under submergence. However, application of organic matter increased the amorphous Fe_2O_3 content in both the moisture regimes. Application of undecomposed organic matter increases the intensity of reduction in submerged soils. Therefore, more of the Fe^{3+} in crystalline forms might be reduced to Fe^{2+} which were reoxidized and precipitated as Fe_2O_3 or $Fe(OH)_3$ after submergence. The freshly precipitated Fe_2O_3 or Fe $(OH)_3$ exists in amorphous forms. Increase in amorphous Fe_2O_3 content with application of organic matter at the moisture level of field capacity might be due to formation of Fe-organic matter complexes which are also in amorphous form.

Effect of lime + organic matter

The change in crystalline Fe_2O_3 with application of lime + organic matter was inconsistent in both the moisture regimes, whereas there was slight increase in amorphous Fe_2O_3 over control in both the moisture regimes due to application of lime + organic matter.

Changes in DTPA extractable Zn, Cu, Fe and Mn

These were decrease in DTPA extractable Zn and Cu in the original soils from their initial values after submergence which might be due to increase in pH causing precipitation of Zn and Cu as their hydroxides (Table 4). There was also decrease in DTPA extractable Zn and Cu in the original soils after being incubated at field capacity. DTPA extractable Fe and Mn in the original soils increased after submergence which might be due to reduction of the insoluble Fe^{3+} and Mn^{4+} to soluble Fe2+ and Mn^{2+} forms. These Fe^{2+} and Mn2+, after submergence, are reoxidized and precipitated as there oxides or hydroxides which are in amorphous forms. The Fe and Mn in amorphous forms may be more subjected to extraction by DTPA than their crystalline forms. Application of lime reduced the DTPA extractable Zn, Cu, Fe and Mn over control in both the moisture regimes which might be due to increase in pH causing precipitation of these elements as their hydroxides. Decrease in DTPA extractable Zn, Cu, Fe with liming has been reported by different authors (Juo and Uzu, 1977; Haldar and Mandol, 1982; Bandyopadhyaya *et al.*, 1983). Decrease in DTPA extractable Mn after liming, as observed in the present investigation, is in contrary to the findings of Shuman, 1986 who reported an increase in DTPA extractable Mn with liming. Application of organic matter increased the DTPA extractable Zn, Cu and Fe over control in both the moisture regimes and increased the DTPA extractable Mn at the moisture regime of field capacity. This might be due to formation of complexes of these elements, from their insoluble forms, with the organic acids and other compounds released during decomposition of organic matter. Srivastava and Sethi, (1981) also observed an increase in DTPA extractable Zn in soil due to organic matter addition. Application of lime + organic matter reduced the DTPA extractable Zn, Fe and Mn over control in both the moisture regimes. This might be due to the dominating effect of lime over organic matter. Organic matter increases the DTPA extractable micronutrients, whereas lime decreases them. Application of lime+ organic matter increased the DTPA extractable Cu over control under continuous submergence but decreased the same over control at field capacity. The increase in DTPA extractable Cu over control under continuous submergence is difficult to be explained.

Changes in different forms of Zn

Changes in water soluble + exchangeable Zn

Application of lime reduced the water soluble + exchangeable Zn over control in both the moisture regimes which might be due to rise in pH causing precipitation of Zn (Table 5). Application of organic matter increased the water soluble + exchangeable Zn over control irrespective of the moisture regimes. During decomposition of organic matter, organic acids and other organic compounds are released which might have solubilised and chelated the insoluble Zn. Some of the soluble Zn^{2+} might be adsorbed by the soil increasing the exchangeable Zn. The increase in soluble + exchangeable Zn with

***Table 4.** Effect of moisture regimes, lime and organic matter on DTPA extractable Zn, Cu, Fe and Mn in the soils*

DTPA extractable micronutrients ($\mu g\ g^{-1}$)

Moisture regimes	Treatments	Kalikunda soil				Santiniketan soil			
		Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn
Continuous submergence	Control	0.84	1.33	82.1	59.8	0.96	1.30	113.5	266.0
	Lime	0.78	1.02	25.1	10.1	0.66	0.97	57.9	63.20
	Organic matter	1.20	1.76	131.6	43.3	1.54	1.52	134.9	255.3
	Lime +organic matter	0.61	1.41	50.7	12.0	0.62	1.50	51.0	56.6
Field capacity	Control	0.82	1.56	55.9	23.4	1.18	1.32	83.2	163.3
	Lime	0.61	1.42	18.9	6.3	0.90	1.13	27.5	25.3
	Organic matter	1.08	1.76	63.6	35.2	1.34	1.45	86.3	187.3
	Lime + organic matter	0.63	1.35	19.6	9.0	0.72	1.08	27.1	32.7

Table 5. *Changes in different forms of Zn as influenced by moisture regimes and application of lime and organic matter*

Soils	Moisture regimes	Treatments	Forms of Zn ($\mu g\ g^{-1}$)			
			Water soluble + exch.	Organically complexed	Amorphous sesquioxide bound	Crystalline sesquioxide bound
Kalikunda	Continuous submergence	Control	0.75	1.49	4.93	4.75
		Lime	0.53	1.54	5.25	4.50
		Organic matter	1.68	1.64	5.39	4.50
		Lime + Organic matter	0.63	1.67	5.09	5.05
	Field capacity	Control	0.75	1.06	5.37	5.75
		Lime	0.25	1.15	6.12	7.00
		Organic matter	0.87	1.26	6.70	5.05
		Lime + Organic matter	0.45	1.37	6.33	5.00
Shantiniketan	Continuous submergence	Control	0.40	0.80	7.00	13.62
		Lime	0.21	0.85	8.00	13.25
		Organic matter	1.10	0.90	7.30	10.00
		Lime + Organic matter	0.30	1.25	7.25	11.75
	Field capacity	Control	0.43	1.33	7.79	9.75
		Lime	0.18	1.51	8.56	13.20
		Organic matter	0.80	1.51	8.50	13.60
		Lime + Organic matter	0.27	1.67	8.10	12.00

addition of organic matter was more under submergence which might be due to release of occluded Zn due to reduction of Fe^{3+} and Mn^{4+}.The intensity of this reduction increases with addition of organic matter. Application of lime and organic matter together reduced the water soluble + exchangeable Zn over control in both the moisture regimes. This might be due to higher pH causing precipitation of Zn. However, the extent of decrease was less than that due to application of lime only. This might be due to less pH in lime+ organic matter treated soils than in the lime treated soils. Besides, organic matter tends to form soluble complexes with Zn^{2+}.

Changes in organically complexed Zn

Organically complexed Zn increased over control in both the moisture regimes with application of lime, organic matter and lime + organic matter. The increase due to application of lime might be due to an accelerated decomposition of organic matter with release of various organic compounds that chelate Zn^{2+}. Shuman (1986) also observed a similar increase in this form of Zn with application of lime in some Georgia soils. Application of organic matter increased the organically complexed Zn possibly by providing various chelating agents during decomposition. Combined application of lime and organic matter recorded the maximum increase in organically complexed Zn over control in both the moisture regimes. This might be due to a greater rate of decomposition of organic matter with release of more of the chelating agents to complex Zn^{2+}.

Changes in amorphous sesquioxide bound Zn

There was increase in amorphous sesquioxide bound Zn with application of lime, organic matter and lime + organic matter in both the moisture regimes over control. With liming, Fe, Al and Mn are precipitated as their hydroxides. Zn may be co-precipitated with Fe, Al and Mn or occluded by the amorphous oxides or hydroxides of these elements. Organic matter forms complex with Fe, Al and Mn. These complexes are also in amorphous forms and may occlude Zn also. Increase in amorphous sesquioxide bound Zn with application of organic matter has been reported by Mandal and Mandal, 1987.Increase in amorphous sesquioxide bound Zn with application of lime + organic matter is due to the positive effect of both the components on this forms of Zn.

Changes in crystalline sesquioxide bound Zn

There was slight reduction in crystalline sesquioxide bound Zn in the lime treated soils over control after submergence. This might be due to reduction of Fe^{3+} and Mn^{4+} from crystalline forms to soluble Fe^{2+} and Mn^{2+} with release of the occluded Zn. Liming reduces the intensity of reduction of Fe^{3+} and Mn^{4+} which might be the cause of a slight reduction in crystalline sesquioxiode bound Zn in the lime treated soils after submergence. However, there was an increase in crystalline sesquioxide bound Zn with application of lime at the moisture content of field capacity. With liming, the active Fe, Al and Mn are precipitated as their hydroxides. Zn may be co-precipitated with these elements or occluded by the hydroxides of Fe, Al and Mn. These precipitated Fe, Al, Mn, Zn or the precipitated Fe, Al and Mn occluding Zn may be gradually organized into crystalline forms to increase the crystalline sesquioxide bound Zn. There was slight decrease in crystalline sesquioxide bound Zn with application of lime at continuous submergence. Addition of organic matter also brought a reduction in crystalline sesquioxide bound Zn under submergence which might be due to increase in the intensity of reduction with addition of organic matter. Therefore, more of the Fe^{3+} and Mn^{4+} in crystalline forms might have been reduced to Fe^{2+} and Mn^{2+} with release of the occluded Zn.

Effect of submergence on DTPA extractable Zn, Cu, Fe and Mn in the pre-treated soils of lime, organic matter and lime + organic matter at the moisture level of field capacity

Effect on Zn and Cu

There was slight increase in DTPA extractable Zn after submergence of the untreated soils of Kalikunda and Santiniketan (Table 6). This might be due to release of the sesquioxide bound Zn due to reduction of Fe and Mn. There was increase in DTPA extractable Zn and Cu after submergence of the soils pre-treated with lime. The pH of the limed soil of Kalikunda was 8.3 and that of Santiniketan was 8.0 which might have been decreased after submergence with consequent increase in the solubility of the precipitated $Zn(OH)_2$ and $Cu(OH)_2$. There was decrease in DTPA extractable Zn and Cu after submergence of the soils pre-treated with organic matter. This might be due to increase in the intensity of reduction causing an increase in soil pH and precipitation of Zn and Cu as their hydroxides. DTPA extractable Zn increased in the pre-treated soils of lime + organic matter after submergence which might be due to decrease in pH after submergence. There was decrease in DTPA extractable Cu in the soils pre-treated with lime + organic matter after submergence. The pH of the lime+ organic matter treated soils were greater than 7.5 which might be reduced after submergence increasing the solubility of $Cu(OH)_2$. The soluble Cu++ forms strong complex with organic matter which might be the reason of the decrease in DTPA extractable Cu after submergence.

Effect on Fe and Mn

There was slight increase in DTPA extractable Fe and Mn in the untreated soils of Kalikunda and Santiniketana after submergence which might be due to reduction of insoluble Fe^{3+} and Mn^{4+} to soluble Fe^{2+} and Mn^{2+}. There was a significant increase in DTPA extractable Fe and Mn after submergence of the soils pre-treated with lime which might be due to decrease in pH with consequent increase in the solubility of $Fe(OH)_3$ and $Mn(OH)_4$. There was remarkable increase in DTPA extractable

Table 6. *Effect of submergence on the changes in DTPA extractable Zn, Cu, Fe and Mn in the soils pre-treated with lime, organic matter and lime + organic matter at field capacity*

DTPA extractable micronutrients (μg g^{-1} soil)

Treatments	Kalikunda soil				Santiniketan soil			
	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn
Control	0.88	1.56	58.9	25.2	1.42	1.36	86.2	178.8
Lime	1.13	2.18	103.4	38.8	1.01	1.64	43.6	173.3
Organic matter	0.43	0.78	408.2	44.5	0.69	0.11	416.6	261.0
Lime + Organic matter	1.17	1.26	449.9	34.4	1.17	0.38	386.7	119.5

Fe and increase in DTPA extractable Mn after submergence of the soils pre-treated with organic matter. This might be due to increase in the intensity of reduction of Fe^{3+} and Mn^{4+} since organic matter serves as an electron donor. There was also a significant increase in the DTPA extractable Fe and Mn after submergence of the soils pre treated with lime + organic matter which might be due to decrease in pH and increase in the solubility of $Fe(OH)_3$ and $Mn(OH)_4$.

REFERENCES

Bandyopadhyay, K. Haldar, M. and Mandal L. N. (1983). Effect of $CaCO_3$ on the changes in availability of B, Mn and Fe in an acid soil in relation to nutrition of rice. *Agrochimica* **27**(4): 290-297.

Black, C. A. (1965). *Methods of Soil Analysis*. Part-2 American Society of Agronomy, Madison, Wisconsin, USA

Bolan, N. S., Naidu, R., Syers, J. K. and Tillman, R. W. (1999). Surface charge and solute interactions in soils. *Advances in Agronomy* **67**: 87-140.

Das, P. K., Sahu S. K. and Sarangi, D. (2006). Effect of pH and lime on sulphate adsorption in some Alfisols of Orissa. *Journal of Indian Society of Soil Science* **54**: 283-289.

Haldar, M. and Mandal L. N. (1982). Influence of moisture regime and organic matter applica Mandal tion on Zn and Cu nutrition of rice. *Indian Agriculture* **26**(1): 29-38.

Hazra, G. C., Mandal, B. and Mandal, L. N. (1987). Distribution of zinc fractions and their transformation in submerged rice soils. *Plant Soil* **104**: 175-181.

Jackson, M. L. (1956). *Soil Chemical Analysis-Advanced Course*. Department of Soil, University of Wisconsin, USA.

Jackson, M. L. (1973). *Soil Chemical analysis*, Prentice-Hall of India Private Limited, New Delhi.

Juo, A. S. R. and Uzu, F. O. (1977). Liming and nutrient interactions in Ultisols from Southern Nigeria. *Plant Soil* **47**: 419.

Lindsay, W. L. and Norvell, W. A. (1978). Development of a DTPA test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42**: 421-428.

Mandal, L. N. and Mandal B. (1987). Transformation of zinc fractions in rice soils. *Soil Science* **143**: 205-212.

Piper, C. S. (1966). *Soil and Plant Analysis*, Hans Publishers, Bombay.

Shuman, L. M (1982). Separating soil iron and manganese – oxide fractions for microelement analysis. *Soil Science Society of America Journal* **46**: 1099-1102.

Shuman, L. M., (1986). Effect of liming on the distribution of manganese, copper, iron and zinc among soil fractions. *Soil Science Society of America Journal* **50**: 1236-1240.

Srivastava, O. P. and Sethi, B. C. (1981). Contribution of farm yard manure on the build up of available zinc in an Aridisol. *Communication Soil Science and Plant Analysis* **12**: 356-361.

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Effect of Mulch, Plant Densities and Land Configurations on Yield, Quality and Uptake of Major Nutrients by *Rabi* Groundnut in Coastal Region of Maharashtra

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A field trial was conducted to study the effect of mulch, plant densities and land configurations on the yield, quality and nutrient uptake of groundnut during Rabi 2002-2003 at the Agronomy farm, College of Agriculture, Dapoli, Dist. Ratnagiri (M.S.). Groundnut grown under polythene mulch recorded significantly higher values of dry pod yield (54.17 q ha^{-1}), kernel yield (39.78 q ha^{-1}), shelling per cent (73.49%) as well as the quality parameters like oil content (48.73%) , protein content (25.19%) and oil yield (20.54 q ha^{-1}) as compared to without mulching. Wider spacing of 30 x 15 cm recorded higher values oil content (48.73%) and protein content (25.19%) but closer spacing of 15 x 10 cm produced significantly higher pod yield and kernel yield (57.23 and 42.29 q ha-1 respectively) over all other spacings mainly due to the higher plant population per unit area. Similarly, due to substantial increase in plant population in flat beds all the yield values (dry pods as well as kernel) were significantly higher as compared to raised beds. Quality parameters except protein yield were not affected due to land configuration. The uptake of NPK in pod and haulm as well as total uptake by groundnut was significantly higher under polyhthene mulch with closer spacing of 15 x 10 cm and flat bed method of planting. Poly mulched groundnut recorded maximum net returns with B:C ratio of 2.48. Closer spacing and flat bed method of sowing recorded more B:C ratio mainly due to higher plant population per unit area.

(***Key words:*** *Groundnut, Mulches, Plant densities, Land configuration, Yield, Quality and Uptake*)

Groundnut is the premier oilseed crop of India and ranks first among the oilseed group. Konkan region of Maharashtra has the potential for this crop where it can be grown in both the rainy and the post rainy seasons with the productivity range of 2.0 to 3.0 t ha^{-1} (Bandopadhay and Desai, 2000). However, low temperature during the post rainy season is a major constraint for growth and development of groundnut crop. Transparent polythene mulch in groundnut increased soil temperature, which improved the growth, yield attributes and yield of groundnut (Thorat, 2001). The optimum plant population for any crop varies considerably due to environment under which it is grown and it is directly related to achieve maximum yield. ICRISAT has recommended broad bed furrow (BBF) method for groundnut planting in semi arid region. The present investigation was conducted to study the performance of Rabi groundnut under polythene mulch, spacings and land configurations.

MATERIALS AND METHODS

A field trial was conducted to study the effect of mulch, plant densities and land configurations on the yield, quality and uptake of major nutrients by groundnut during rabi, 2002-03 at the Agronomy farm, College of Agriculture, Dapoli. The experiment was laid out in split-plot design with three replications. The soil of the experimental site was lateritic, sandy clay loam in and texture slightly acidic in reaction (pH 6.5). Available nitrogen, phosphorus and potassium content of the soil were 310.17, 17.28 and 189.46 kg ha^{-1}, respectively. The treatment consisted of two levels of mulching (no mulch and polythene mulch), four levels of spacing (15 x 10 cm, 20 x 10 cm, 20 x 15 and 30 x 10 cm) in main plots and two land configurations (BBF and flat bed) in sub-plots. The gross plot size was 3.6 m x 3.6 m. Board bed furrows of 60 cm width 10 - 12 cm height and flat beds were prepared as per the treatment. The distance between two broad beds was 30 cm. The numbers of rows on raised beds at the different spacing were 4, 3, 3 and 2 at 15 x 10, 20 x 10, 20 x 15 and 30 x 10 cm, respectively. Well decomposed FYM @ 10 t ha^{-1} was thoroughly mixed in the soil at the time of bed formation. Uniform dose of nitrogen @ 50 kg ha^{-1}, phosphorus @ 100 kg ha^{-1} and potash @ 50 kg ha^{-1} was applied as a basal dose. Pre-emergence herbicide oxadiargyl @ 100 g ha^{-1} was sprayed one day before sowing in

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non-mulched and mulched plots. Then low density transparent polythene film strips of 0.007 mm thickness having 90 cm width with holes as per the spacing levels was laid to cover a bed. The edges of the sheet were buried on either side of the bed. Groundnut variety TG-26 was used for sowing. Seeds were treated with thiram @ 3 g kg^{-1} seed before sowing. Dibbling was made at the hole on the polythene film and then two seeds were placed in each hole. Need based plant protection measures were followed. One pre-sowing and nine subsequent irritations were given in total life span of the crop. Observations on the yield attributes and yield of groundnut were recorded and subjected to statistical analysis. The procedure for statistical analysis was carried out as described by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Effect of mulches on yield and quality

Polythene mulching to groundnut has significant effect in enhancing the pod yield and kernel yield (Table 1). The polythene mulch contributed to higher sink resulting into significantly higher dry pod yield (57.17 q ha^{-1}) and kernel yield (39.78 q ha^{-1}) as compared to non-mulched groundnut. Polythene mulch recorded 35.28 and 40.96% higher dry pods and kernel yield, respectively over no mulched groundnut. It might be due to the beneficial effect of polythene mulch in terms of optimum soil temperature and moisture which in turn resulted into better root growth, microbial activities and nutrient availability thereby more uptake of nutrients and therefore better yield of groundnut crop under polythene mulch than no mulch. Similar results were also reported by Hu *et al.*, (1995), Mane (2002) and Kathmale (2002).

Similarly, the quality parameters like shelling percent (73.49%), oil content (48.73%), protein content (25.19%), oil yield (20.54 q ha^{-1}) and protein yield (9.91q ha^{-1}) of groundnut was significantly higher under polythene mulch. These results corroborate the findings of Chavan (1999).

Effect of plant densities on yield and quality

Closer spacing of 15 x 10 cm recorded significantly higher pod yield (57.23 q ha^{-1}) and kernel yield (42.29 q ha^{-1}) over all other levels of spacing (Table 1). Every increase in the level of plant population significantly increased the pod and kernel yield of groundnut and thus the yield values were highest at higher plant population. It was the effect of less interplant competition among the lower plant population than the higher plant population for the various treatments. Yield per plant was to a greater extent can not be recovered by the increased plant population on hectare basis. Similar finding were reported by Thorat and Patil (1987), Deshmukh and Bhoi (1999) and Patra *et al.*, (1999).

Different plant densities did not influenced significantly shelling percentage of groundnut crop. However the Wider spacing of 30 x 15cm (S_4) recorded significantly higher oil content (49.32%) than the closer spacing of 15 x 10 cm (S_1) and 20 x 10 (S_2). However, the treatment (S_4) was at par with 20 x 15 cm (S_3) spacing. Similarly, in case of protein content, the wider spacing of 30 x15 cm (S_4) and 20 x15 cm (S_3) were at par and significantly superior over the closer spacing of 15 x 10 cm (S_1). On the other hand, protein yield was significantly higher under the spacing 15 x 10 cm (9.07 q ha^{-1}) and 20 x 10 cm (9.00 q ha^{-1}) over rest of the treatment but at par with each other. Oil yield was not influenced significantly due to different spacing.

Effect of land configurations on yield and quality

The dry pod and kernel yield, was significantly less under BBF as compared to flat bed (Table 1). This was mainly because of the higher plant population per unit area under flat bed than BBF. Thus substantially higher plant population under flat bed has suppressed the advantage of the better yield attributes per plant observed under BBF. Therefore, due to substantial increase in the plant population on hectare basis, all the yield values were significantly higher under flat bed than BBF. Land configuration treatments did not influenced the shelling, oil, protein percent and oil yield significantly and therefore both the treatments do not have any statistical difference with each other. However protein yield was significantly higher under flat bed (9.92 q ha^{-1}) than the BBF.

Effect on uptake of nutrients

Data in relation with NPK uptake in pods and haulm as well as total NPK uptake by groundnut crop was presented in Table 2. Polythene mulch (P_1) recorded significantly higher uptake of NPK in pod haulm and total uptake of NPK by the crop than no mulch (P_0). This might be due to higher and optimum soil temperature and moisture under polythene mulch throughout the growth period that resulted in providing the congenial conditions for better root growth and uptake of nutrients under polythene mulch than under no mulch. Similar results were

Table 1. *Effect of mulch, spacing and land configurations on yield, quality and economics of rabbi groundnut*

Treatments	Pod yield (q ha^{-1})	Kernel yield (q ha^{-1})	Shelling percent (%)	Oil content (%)	Oil yield (q ha^{-1})	Protein content (%)	Protein yield (Rs.ha^{-1})	Gross returns (Rs.ha^{-1})	Input cost (Rs.ha^{-1})	Net Returns (Rs.ha^{-1})	B:C ratio
Mulching treatments											
P_0 - No polythene mulch	40.04	28.22	69.39	45.89	13.61	22.43	6.31	69470.06	34885.20	34584.86	1.99
P_1 - With polythene mulch	54.17	39.78	73.49	48.73	20.54	25.19	9.91	94394.00	38047.68	56346.32	2.48
SEm +	0.78	0.91	0.80	0.57	1.14	0.72	0.29	–	–	–	–
C.D. at 5%	2.37	2.76	2.43	1.74	3.47	1.18	0.90	–	–	–	–
Plant densities											
S_1 - 15 x 10 cm	57.23	42.29	73.77	45.91	19.91	21.18	9.07	99254.00	41875.67	57378.33	2.37
S_2 - 20 x 10 cm	52.28	37.90	72.50	46.46	18.22	23.67	9.00	90653.60	38754.61	51898.99	2.33
S_3 - 20 x 15 cm	42.27	30.29	70.18	47.57	18.63	24.61	7.47	73297.60	33014.05	40297.55	2.22
S_4 - 30 x 15 cm	36.62	25.53	69.30	49.32	14.66	25.79	6.90	63497.60	31021.57	32476.03	2.00
SEm +	1.10	1.28	1.13	0.81	1.62	1.01	0.42	–	–	–	–
C.D. at 5%	3.35	3.91	NS	2.46	NS	3.09	1.27	–	–	–	–
Land configurations											
M_1- Board bed and furrow	38.19	28.28	72.56	47.92	15.81	24.21	6.80	66229.20	31569.19	34660.01	2.09
M_2- Flat bed	56.02	39.73	70.32	46.70	18.35	23.41	9.42	97135.60	40763.75	56371.85	2.38
SEm +	0.50	0.66	1.97	0.99	0.65	1.48	0.32	–	–	–	–
C.D. at 5%	1.49	1.97	NS	NS	NS	NS	1.01	–	–	–	–

Table 2. *Effect of mulch, spacing and land configurations on uptake of NPK (kg ha*$^{-1}$*) of rabbi groundnut*

Treatments	Nutrient uptake (kg ha^{-1})								
	Nitrogen			Phosphorus			Potassium		
	Pod	Haulm	Total uptake	Pod	Haulm	Total uptake	Pod	Haulm	Total uptake
Mulching treatments									
P_0 - No polythene mulch	183.19	53.33	236.41	19.01	12.15	31.17	38.52	42.75	81.28
P_1 - With polythene mulch	282.66	91.26	373.94	27.93	16.95	44.89	53.52	59.57	112.23
SEm +	1.93	1.35	4.87	0.71	0.30	1.58	0.87	1.30	2.57
C.D. at 5%	5.84	4.09	14.77	2.15	0.92	4.81	2.65	3.96	7.79
Plant densities									
S_1 - 15 x 10 cm	259.66	82.41	342.52	27.44	15.35	42.79	53.47	59.17	112.67
S_2 - 20 x 10 cm	246.02	79.92	325.27	26.10	15.27	41.37	51.87	56.60	107.96
S_3 - 20 x 15 cm	219.73	66.56	286.33	21.32	15.01	36.33	41.46	47.17	88.58
S_4 - 30 x 15 cm	206.29	60.28	266.58	19.04	12.59	31.63	36.93	41.70	77.80
SEm +	2. 73	1.91	6.88	1.00	0.43	2.24	1.23	1.84	3.63
C.D. at 5%	8.29	5.79	20.89	3.04	1.41	6.80	3.75	5.60	11.02
Land configurations									
M_1 - Board bed and furrow	189.48	59.51	249.21	20.07	12.69	32.76	37.71	41.22	78.70
M2 - Flat bed	276.37	85.08	361.14	26.88	16.41	43.30	54.13	61.10	114.81
SEm +	2.06	1.44	4.26	0.33	0.39	1.51	1.36	1.44	1.74
C.D. at 5%	6.17	4.31	12.77	0.99	1.19	4.50	4.07	4.31	5.21

reported by Hu *et al.*, (1995) and Chavan (1999). Nitrogen accumulation in pods and haulm as well as total uptake by groundnut was significantly influenced due to the spacings 15 x 10 cm (S_1) than rest of the spacing, except 20 x10 cm (S_2) spacing which was at par with S_1. Phosphorus accumulation in pods and haulm (kg ha^{-1}) as well as total uptake was significantly more under spacing 15 x 10 cm (S_1) over 30 x15 cm (S4). However the former closer spacing of 15 x 10 cm (S1) was statistically at par with 20 x10 cm (S_2) and 20 x15 cm (S_3) spacing. Potassium accumulation in pod and haulm (kg ha^{-1}) as well as total uptake by groundnut was significantly higher under 15 x 10 cm (S_1) and 20 x 10 cm (S_2) spacing than the broader spacing of 20 x 15 cm (S_3) and 30 x 15 cm (S_4). The former two and later two treatments were at par with each other. This might be attributed due to the better root growth under more availability of moisture and nutrients due to less inter plant competition under the lower plant density than under the higher plant density. Similar results were reported by Patra *et al.*, (1998). The nitrogen uptake by the pod and haulm and total nitrogen uptake by the crop was significantly more under flat bed (M_2) than BBF (M_1). Similar trend was observed in case of phosphorus accumulation (kg ha^{-1}) and potassium accumulation of pod and haulm and total uptake by groundnut crop.

Economics

Polythene mulched groundnut recorded the maximum gross and net returns of Rs. 94394/- and Rs. 56346.32 ha^{-1}, respectively with the B: C ratio of 2.48 (Table 1). The closer spacing of 15 x 10 cm register the maximum net profit of Rs. 57378.33/- ha^{-1} with B:C ratio of 2.37. As regards the land configurations, flat beds attributed maximum net returns (Rs. 56371.85 ha^{-1}) mainly due to the higher plant population per unit area.

REFERENCES

Bandopdhyay, A. and Desai, S. (2000). Groundnut as a source of oil and food the facts and a national preservative, (I) Souvenir, National Seminar on *Oils-Research and development needs in the Millennium*. Feb. 2-4: 72-87.

Chavan, V. G. (1999). Effect of sowing time and cultural practices on growth, yield and quality of *Rabi* groundnut. *Unpublished M.Sc.Thesis*, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra.

Deshmukh, G. N. and Bhoi, P. G. (1999). Effect of plant densities and fertilizer levels on growth and yield of groundnut (TAG-24). *Journal of Maharashtra Agricultural Universities* **24**(3): 298-299.

Hu, Wenguang, Duan Shafen and Sui, Qung Wei. (1995). High yield technology for groundnut. *International Archis News Letter* **15** (Supplement): 1-11.

Kathmale, D. K. (2002). Role of different components of production technology of groundnut (*Arachis hypogaea* L.) under polythene mulch. *Unpublished Ph.D Thesis*, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra.

Mane, B. N. (2002). Effect of sowing time, variety and mulching on growth and productivity of *Kharif* groundnut. *Unpublished M.Sc Thesis*, Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, Maharashtra.

Panse, V. G. and Sukhatme, P. V. (1967). *Statistical Methods for Agricultural Workers*, I.C.A.R., New Delhi.

Patra, A. K., Tripathi, S. K., Samui, R. C.,Panda, P. K., and Nanda, M. K. (1998). Effect of sowing date, irrigation and spacing on nutrient content and uptake by groundnut. *Indian Journal of Agronomy* **43**(3): 459-463.

Patra, A.K., Tripathi, S.K. and Samui, R.C. (1999). Effect of sowing date, irrigation and spacing on nodulation, dry matter and yield of summer groundnut (*Arachis hypogaea*). *Indian Journal of Agronomy* **44**(4): 800-804.

Thorat, S.T. (2001). Effect of irrigation regimes, weed management and growth regulators on the performance of groundnut grown under polythene mulch. *Unpublished Ph.D. (Agri.). Thesis* submitted to Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri.

Thorat, S.T. and Patil, B.P. (1987). Effect of genotype and plant population on yield of irrigated groundnut. *Annals of Agriculture Research* **8**(1): 161-168.

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Effect of Micro-irrigation Systems and Fertilizer Levels on Growth and Yield of Chilli (*Capsicum annuum*) in Lateritic Soils of Konkan Region of Maharashtra

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An experiment was conducted at A.I.C.R.P. on Water Management Dapoli Centre in lateritic soils of Konkan region of Maharashtra during the year 2007 to 2010, to study the effect of micro-irrigation methods and fertilizer levels on growth and yield of Chilli. The experiment was laid out in factorial randomized block design with nine treatments and three replications. The results revealed that, the growth parameters showed non significant effect with imposed irrigation treatments. In case of yield, the micro sprinkler irrigation at 100 percent PE + 100% recommended dose of fertilizer (150:50:50 NPK)recorded maximum green Chilli yield of 118.23 q ha^{-1} as compared to all other treatments. The effect of irrigation levels was found to be significant and maximum yield (132.32 q ha^{-1}) of Chilli was reported in I_1 treatment, whereas minimum yield (90.6 q ha^{-1}) was reported in I_3 treatment. The fertilizer levels also showed significant results with maximum yield of 116.7 q ha^{-1} under F_1 treatment and minimum yield of 104.72 q ha^{-1} in F_3 treatment. The water use efficiency ranged between 62 kg hacm^{-1} to 272 kg hacm^{-1}. Higher water use efficiency (272 kg hacm^{-1}) was found with micro sprinkler at 100% PE with recommended dose of fertilizers. The B:C ratio was 3.06 in micro-sprinkler at 100 percent PE + 100 % recommended dose of fertilizers. This indicates that, micro-sprinkler irrigation is superior for growing Chilli in lateritic soils of Konkan region of Maharashtra.

(***Key words:*** *Chilli, Micro-irrigation methods, Growth and yield, Water use efficiency, Fertilizer use efficiency.)*

The total area under micro irrigation in Maharashtra state is only 18.5% and it is estimated that after full development of water resources the irrigated area in the state may not exceed 30% with the adoption of conventional surface irrigation methods. Bringing more area under irrigation will largely depend on the efficiency of water use. In this context, micro-irrigation has to play a very significant role to achieve not only higher productivity and water use efficiency but also have sustainability. The micro-irrigation system keeps the soil moisture near to field capacity and this system also increases fertilizer use efficiency after avoiding losses through leaching, volatilization and fixing of nutrient in the soil (Nakayama and Bucks, 1986). Micro-irrigation is the major component in adoption of precision agriculture. Maharashtra has largest area under micro-irrigation. The work carried out by Shinde *et al.*, (2004) on effect of micro-irrigation system and Nitrogen levels on growth and yield of Chilli under lateritic soils of Konkan region shows that, the micro jet irrigation supplemented with 100 kg N ha^{-1} could be used for nitrogen saving, higher water use eficiciency and higher green Chilli yield. Also the work carried out by Muralikrishnasamy *et al.*, (2008) on drip irrigation and fertigation in Chillies showed that, drip irrigation at 50 percent PE along with fertigation of recommended level of N and K resulted in higher yield and water saving compared with surface irrigation. A very meager work has been carried on micro-irrigation under lateritic soils of Konkan region of Maharashtra.

Chilli is an important vegetable cum condiment. It is called as red pepper/hot pepper. A number of verities are grown for vegetables, spices, condiments, sauce and pickles. Chilli is source of vitamins, especially in vitamins A and C. It has many medicinal properties. India produces about 1.3 million tones of Chillies from an area of 0.806 million hectares with an average productivity of 16.11 t ha^{-1}. India contributes one fourth of the total quantity of chilli exported in the world. Thus an attempt was made to study the effect of micro irrigation systems and fertilizer levels on growth and yield of chilli (*Capsicum annuum*) in lateritic soil of Konkan region of Maharashtra.

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MATERIALS AND METHODS

A field experiment was carried at All India Co-ordinated Research Project (AICRP) on Water Management, Dapoli centre, in lateritic soils of Konkan region of Maharashtra during rabi seasons during the years 2007 to 2010. The soil was sandy clay loam with pH 5.5, very high in organic carbon content (18.45 g kg^{-1}), low in available nitrogen content (232 kg ha^{-1}), very low in available phosphorous content (6.11 kg ha^{-1}) and very high in available potassium content (369.6 kg ha^{-1}). The experiment was laid in factorial randomized block design with nine treatments and three replications. Three irrigation methods viz. drip (S_1), micro-sprinkler (S_2) and ridges and furrows (S_3) as control and three irrigation levels 1.0 PE, 0.8 PE and 0.6 PE i.e. I_1, I_2 and I_3 respectively, were applied to the crop during the entire growing seasons. Three fertilizer levels viz.100%, 80%, and 60% i.e. F_1, F_2, F_3 respectively, of recommended dose (150:50:50, N:P:K)

Table 1. *Total depth of water applied for different irrigation levels*

Sr. No.	Irrigation level	Depth of water applied (ha-cm)				Saving in water (percent) over control
		2006-07	2007-08	2009-10	Mean	
1	I_1 = 1.0 PE	61	70.1	52.32	61.14	46.37
2	I_2 = 0.8 PE	48.8	56.1	41.85	48.91	57.10
3	I_3 = 0.6 PE	36.6	42.1	31.4	36.7	67.81
4	Control	126	114	102	114	–

Table 2. *Effect of irrigation methods, irrigation levels and fertilizer levels on yield of green Chilli (q ha^{-1}) from 2006-07 to 2009-10*

Treatments	Green Chili yield , q ha^{-1}			
	2006-07	2007-08	2009-10	Mean
A. Irrigation methods				
S_1 = Drip	104.7	104.6	98.3	102.53
S_2 =Micro-sprinkler	119.9	120.5	114.3	118.23
Control	80.0	79.6	79.10	79.57
SE +	2.66	2.51	1.83	0.43
CD at 5percent	7.59	7.17	5.22	2.62
B. Irrigation levels				
I_1 = PE x 1.0	135.1	131.7	130.16	132.32
I_2 = PE x 0.8	112.7	109.8	102.81	108.43
I_3 = PE x 0.6	90.2	96.03	85.86	90.69
SE +	3.25	3.07	2.24	0.54
CD at 5percent	9.3	8.79	6.4	3.26
C. Fertilizer levels				
F_1 =100percent RDF	118.8	117.0	114.31	116.70
F_2 =80percent RDF	110.5	115.3	103.14	109.64
F_3 =60percent RDF	107.5	105.3	101.38	104.72
SE +	3.25	3.07	2.24	0.54
CD at 5percent	9.3	8.79	6.4	3.29
D. Interaction effects				
Irrigation levels x Fertilizer levels				
SE +	5.63	5.32	3.88	
CD at 5percent	16.11	NS	NS	NS
Irrigation levels x Irrigation methods				
SE +	4.60	4.35	3.17	
CD at 5percent	NS	NS	9.05	NS
Fertilizer levels x Irrigation method				
SE +	4.60	4.35	3.17	
CD at 5percent	NS	NS	NS	NS

were applied to the crop. The net plot size was 4.8 m x 3.6 m. The chilli seedlings of variety Konkan kirti were transplanted in third week of December every year. The normal plant spacing 60 cm x 60 cm was followed in ridges–furrows and in micro-sprinkler irrigation. For drip irrigation system paired row planting pattern was used with spacing of 45 cm x 90 cm x 45 cm. The discharge of micro-sprinkler was 36 lph with spacing between two micro- sprinklers was 1.5 m. The discharge of dripper was 4 lph with spacing between two drippers was 60 cm. The pre-transplantation irrigation of 6 cm depth was applied to all plots irrespective of the treatments during each year. The treatment wise schedule was followed after 15 days of transplanting. Due care was taken while irrigating with micro-sprinkler to avoid the effect on pollination. The recommended plant protection measures were taken during the crop growth. The yield was recorded in six pickings and data was analyzed statistically.

RESULTS AND DISCUSSIONS

Irrigation requirement

The experiment on chilli crop was undertaken during rabi seasons of 2006-07 to 2009-10 to determine the irrigation requirement for maximizing the productivity. The irrigation water applied during each growing season, their means and percentage of water saving under each treatment of micro-irrigation over furrow irrigation method are presented in Table 1.

The amount of irrigation water applied to Chilli crop varied with the evaporation during each season. The average irrigation water applied under furrow irrigation system was 114 ha-cm, while the irrigation mean water applied through micro-irrigation ranged from 36.7 ha-cm to 61.14 ha-cm during crop seasons. Thus, water saving under micro-irrigation system ranging from 46.4% to 67.81% was observed over water applied though furrow irrigation method.

Yield of green chilli

The data pertaining to green chilli yield is recorded in each season under various treatment combinations and is presented in Table 2 and the results of pooled analysis are presented as below.

The individual effects of the irrigation methods and levels of irrigation and fertigation were found significant during all the three growing seasons of

Table 3. *Water use efficiency for various treatment combinations (Average of 2006-07, 2007-08 and 2009-10)*

Treatment	Yield (q ha^{-1})	Depth of water (cm)	Fertilizer used (q ha^{-1})	Water use efficiency (kg ha-cm^{-1}	Fertilizer use efficiency
$S_1I_1F_1$	127.87	61.14	2.5	209.0	51.15
$S_1I_1F_2$	114.03	61.14	2.0	187.0	57.02
$S_1I_1F_3$	119.4	61.14	1.5	195.0	79.60
$S_1I_2F_1$	104.13	48.91	2.5	213.0	41.65
$S_1I_2F_2$	101.0	48.91	2.0	206.0	50.50
$S_1I_2F_3$	96.37	48.91	1.5	197.0	64.25
$S_1I_3F_1$	85.17	36.70	2.5	232.0	34.07
$S_1I_3F_2$	88.9	36.70	2.0	242.0	44.45
$S_1I_3F_3$	85.73	36.70	1.5	234.0	57.15
$S_2I_1F_1$	166.37	61.14	2.5	272.0	66.55
$S_2I_1F_2$	144.73	61.14	2.0	237.0	72.37
$S_2I_1F_3$	121.7	61.14	1.5	199.0	81.13
$S_2I_2F_1$	118.27	48.91	2.5	242.0	47.31
$S_2I_2F_2$	119.07	48.91	2.0	243.0	59.54
$S_2I_2F_3$	108.97	48.91	1.5	223.0	72.65
$S_2I_3F_1$	98.4	36.70	2.5	268.0	39.36
$S_2I_3F_2$	90.33	36.70	2.0	246.0	45.17
$S_2I_3F_3$	96.03	36.70	1.5	262.0	64.02
S_3 F_1	85.1	114	2.5	75.0	34.04
S_3 F_2	82.83	114	2.0	73.0	41.42
S_3 F_3	70.77	114	1.5	62.0	47.18

Table 4 . *Cost economics for different treatment combinations for Chilli crop*

Sr.No.	Particulars	$S_2I_1F_1$	$S_2I_1F_2$	$S_2I_1F_3$	$S_2I_2F_1$	$S_2I_2F_2$	$S_2I_2F_3$	$S_2I_3F_1$	$S_2I_3F_2$	$S_2I_3F_3$	Control
1.	Seasonal fixed cost	17465	17465	17465	17465	17465	17465	17465	17465	17465	
2 a	Variable cost (Rs ha^{-1})	26800	26800	26800	26800	26800	26800	26800	26800	26800	28800
2b.	Fertilizer cost (Rs ha^{-1})	61501	51271	41037	61501	51271	41037	61501	51271	41037	51271
2c	Irrigation water (Rs ha^{-1})	864	864	864	1296	1296	1296	1556	1556	1556	2700
2d	Total variable cost	89165	78935	68701	89597	79367	69133	89857	79627	69393	82771
2e	Interest on working capital	2674.95	2368.05	2061.03	2687.91	2381.01	2073.99	2695.71	2388.81	2081.79	2483.13
2f	Rental value Rs. 1000 ha^{-1}	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
2g.	Total operating cost per season	92839.95	82303.05	71762.03	93284.91	82748.01	72206.99	93552.71	83015.81	72474.79	86254.13
3.	Cost of production (Rs ha^{-1})	110304.95	99768.05	89227.03	110749.9	100213.01	89671.99	111017.71	100480.81	89939.79	86254.13
4.	Yield (q ha^{-1})	168.8	133.6	126.2	114.8	110.3	103.1	94.1	86.8	90.7	79.03
5.	Selling price (Rs ha^{-1})	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
6.	Gross monetary returns	337600	267200	252400	229600	220600	206200	188200	173600	181400	158060
7.	Net income (Rs ha^{-1})	227295.05	167431.95	163173	118850.1	120386.99	116528.01	77182.29	73119.19	91460.21	71805.87
8.	B : C ratio	3.06	2.68	2.83	2.07	2.20	2.30	1.70	1.73	2.02	1.83

Sr. No.	Particulars	$S_1I_1F_1$	$S_1I_1F_2$	$S_1I_1F_3$	$S_1I_2F_1$	$S_1I_2F_2$	$S_1I_2F_3$	$S_1I_3F_1$	$S_1I_3F_2$	$S_1I_3F_3$
1.	Seasonal fixed cost	13615	13615	13615	13615	13615	13615	13615	13615	13615
2a.	Variable cost (Rs ha^{-1})	26800	26800	26800	26800	26800	26800	26800	26800	26800
2b.	Fertilizer cost (Rs ha^{-1})	61501	51271	41037	61501	51271	41037	61501	51271	41037
2c.	Irrigation water (Rs ha^{-1})	864	864	864	1296	1296	1296	1556	1556	1556
2d.	Total variable cost	89165	78935	68701	89597	79367	69133	89857	79627	69393
2e.	Interest on working capital	2674.95	2368.05	2061.03	2687.91	2381.01	2073.99	2695.71	2388.81	2081.79
2f.	Rental value Rs. 1000 ha^{-1}	1000	1000	1000	1000	1000	1000	1000	1000	1000
2g.	Total operating cost per season	92839.95	82303.05	71762.03	93284.91	82748.01	72206.99	93552.71	83015.81	72474.79
3.	Cost of production (Rs ha^{-1})	106454.95	95918.05	85377.03	106899.9	96363.01	85821.99	107167.71	96630.81	86089.79
4.	Yield (q ha^{-1})	125.8	109.2	117.3	97.8	97.4	93.5	84.5	81.6	77.5
5.	Selling price (Rs ha^{-1})	2000	2000	2000	2000	2000	2000	2000	2000	2000
6.	Gross monetary returns	251600	218400	234600	195600	194800	187000	169000	163200	155000
7.	Net income (Rs ha^{-1})	145145.05	122481.95	149223	88700.09	98436.99	101178.01	61832.29	66569.19	68910.21
8.	B: C ratio	2.36	2.28	2.75	1.83	2.02	2.18	1.58	1.69	1.80

year 2006-07 to 2009-10 (Table 2). Among the treatments of irrigation methods, irrigation and fertilizer levels, the irrigation levels were found to be most influencing treatment.

i) Effect of irrigation methods

The irrigation methods also significantly influenced the green chilli yield. From pooled mean of three years data it is observed that, the treatment S_2 (micro-sprinkler) has produced significantly higher green chilli yield of 118.23 q ha^{-1} as compared to S_1 and S_3. Increased yield indicates that the application of water to chilli crop through micro-sprinkler can be more effective in producing the micro-climate as well as meeting out the water requirement of crop, which might have helped the crop in keeping healthy throughout the crop season.

ii) Effect of fertilizer level on yield

The fertilizer levels significantly influenced the green chilli yield with the consistant and maximum yield 116.70 q ha^{-1} with 100% recommended doze of fertilizers (F_1) as compared to the rest of the treatments and is significantly superior over F_2 and F_3 treatments.

iii) Effect of irrigation levels on yield

The different levels of irrigation shown significant effect on yield of green Chilli. The treatment I_1 (1.0 PE) has produced highest and significant yield of 132.82 q ha^{-1} over the treatment I_2 and I_3.

iv) Interaction effect on yield

The average yield of Chilli showed non-significant effect due to interaction of irrigation and fertilizer levels, methods of irrigation and fertilizer levels, methods of irrigation and irrigation levels.

Water use efficiency

The water use efficiency is the ratio of yield obtained in a particular treatment to the depth of water applied. From Table 3, it was observed that the maximum water use efficiency was in treatment $S_2I_1F_1$ (272 kg hacm^{-1}) followed by $S_2I_3F_1$ (268 kg ha-cm^{-1}). The minimum water use efficiency of 62 kg ha-cm-1was found in control (furrow irrigation). This indicates that the irrigation frequency also plays important role in improving the yield. The results also revealed that the water use efficiency in micro-sprinkler was more than 3.5 folds as in the furrow irrigation.

From Table 3, the maximum fertilizer use efficiency (81.13) was observed in treatment $S_2I_1F_3$ followed by treatment $S_1I_1F_3$ (79.60). The fertilizer use efficiency for S_3F_1 treatment was 34.04.

Economics

The details of economics of chilli crop was worked out. The benefit cost ratio under various treatment combinations is reported in Table 4. The maximum benefit cost ratio of 3.06 was observed under micro-sprinkler irrigation at 1.0 PE with 100 percent recommended dose of fertilizer ($S_2I_1F_1$ treatment). The maximum net monetary returns of Rs 2.27 lakhs ha^{-1} was observed in $S_2I_1F_1$ treatment and minimum net monetary returns of Rs. 61832/- was observed in drip irrigation at 0.6 PE under recommended dose of fertilizer ($S_1I_3F_1$ treatment).

CONCLUSIONS

1. Total water requirement for growing chilli in Konkan region was found to be 61.14 ha-cm using micro-sprinkler.
2. To achieve the average maximum yield of green chilli in Konkan region, the water should be delivered through micro-sprinkler irrigation at 1.0 PE with 100 % recommended fertilizer dose.
3. If fertilizer is the main constraint, one should go for growing the chilli with the use of drip irrigation, water delivered at 1.0 PE and fertilizer application at 60% RDF. However, the yield may reduce to about 27% of the maximum achievable yield.
4. The maximum benefit cost ratio of 3.06 was observed under micro-sprinkler irrigation at 1.0 PE with 100 % recommended dose of fertilizer ($S_2I_1F_1$ treatment).

REFERENCES

Muralikrishnasamy, S., Veerabadran,V., Krishnasamy Kumar, V. and Sakthivel, S. (2008). Drip irrigation and fertigation in Chillies, *7th International Micro-irrigation* Congress organized by International Commission on Irrigation and Drainage held during September 13-15, 2006 at Kuala Lumpur, Malaysia. pp 1-7.

Nakayama, F. S. and Bucks, D. A. (1986). Trickle Irrigation for crop production: Design, Operation and Management. *Elsevier Science Publication*. Netherland. pp 176-187.

Shinde, P. P., Chavan, M. G., More, V. G. and Mane, M. J. (2004). Effect of micro-irrigation system and Nitrogen levels on growth and yield of Chilli under lateritic soils of Konkan region. *Journal of Maharashtra Agriculture Universities* **29**(1): 25-26.

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Influence of Nutrients on Growth of Water hyacinth, *Eichhornia crassipes* (Mart.) Solms.

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The present study was conducted both in natural environment and ex-situ conditions to ascertain the influence of nutrients on growth of *Eichhornia crassipes*. Quadrate method was followed in fields to collect biomass of *E. crassipes*. In the conditions of maximum growth, biomass of *E. crassipes* ranged in between 20.8-23.3 kg m^{-2} $month^{-1}$ and its Relative Growth Rate (RGR) in the range of -0.003 to + 0.045. The range of nutrients in soil as; nitrogen (8.8-10.4 mg $100g^{-1}$), phosphorus (0.25-0.46 mg $100g^{-1}$), organic carbon (0.68-0.72%) were analyzed from the quadrate of maximum growth zones. Ammonium nitrogen and orthophosphate recorded in the water was in the range of 0.12-0.15 ppm and 0.044-0.077 ppm, respectively. The recorded value of nutrients reveals that increased amount of nutrients was found influential for increasing growth of *E. crassipes* and vis-à-vis. Regression analysis ($Y=0.852 - 0.034N^{**} + 0.325P^{**} + 0.024^{O}C^{**}$, $R^2=0.53$ and SE=0.021) from the data of field samples indicates that phosphorus is a major influential factor, in promoting the luxuriant growth of *E. crassipes*, though the role of organic carbon is also found important for growth of the same. On the other hand, nitrogen initially influenced the growth, but was not constant factor to be growth promoting element. Canonical Discriminant Function Coefficients analysis highlights that the months following after July and August favour the growth of *E. crassipes* when nutrients availability remain in greater amount to influence its growth.

(***Key words:*** *Water hyacinth, Growth, Nutrients*)

Water hyacinth, *Eichhornia crassipes* (Mart.) Solms., proliferates so rapidly that it forms dense mono-specific stand covering the entire water body. Even, its dense population does not allow other aquatic plant communities to grow and develop. The species survives in diverse freshwater habitats from marshy place to deep water reservoir, can withstand all the seasons and establish luxuriantly almost in all conditions of freshwater environment (Gopal and Sharma, 1981; Mathur *et al.*, 2005; Mandal, *et al.*, 2011). The role of water hyacinth to accumulate nutrients and heavy metals from environment has been documented by Trivedi and Thomas (2005). However, attempts to compare the role of different nutrients in support to the growth of *E. crassipes* (water hyacinth) have been few (Atkinson & Smith, 1984; Duarte, 1992). Therefore, the present study has been carried out in field conditions to ascertain the role of specific nutrients in relation to the growth of *E. crassipes* in diverse habitats. Besides, microcosm experiment (*ex situ*) has been conducted so as to confirm the observation drawn in field studies. Eventually, the present study aims to know which nutrient among others is responsible for influencing the growth of *E. crassipes*.

MATERIAL AND METHODS

Surveys were conducted in adjoining low land areas of Regional Research Centre, Central Institute of Freshwater Aquaculture (CIFA), Rahara, Kolkata and in adjacent areas of CIFA, Kausalyaganga, Bhubaneswar. Quadrat method was followed to collect biomass (g m^{-2}) of *E. crassipes* through random survey. Monthly samplings were carried out at 20 places for two years from May to January during 2007-2009. For nutrients study soil and water samples were collected from respective quadrat, labeled and brought to the laboratory for analysis. Organic carbon, available nitrogen and Phosphorus were analyzed from soil samples following Jackson (1973), while ammonium nitrogen and orthophosphate were analyzed from water samples following APHA (2002).

Relative Growth Rate (RGR) was calculated, following the formula as mentioned by Bock (1969) and Gopal and Sharma (1981) as; RGR = $l_nX_t - l_nX_o/t$ [Where X_o is initial weight and X_t is weight increased after time t.] = Total amount of biomass increased in particular month/number of days i.e. growth increment/day in particular month.

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Role of nitrogen, phosphorus and organic carbon was studied separately. For each nutrient experiment, 3 replicates were set up. Total 12 cisterns each with 336L water capacity were set up for three nutrients and one control was taken. nitrogen, phosphorus and organic carbon each @ 50mg l^{-1} was added separately to each cistern in form of urea, single super phosphate and cow dung. One kg of wet weight of *E. crassipes* was put in each cistern and experiment was allowed for one month. Data on biomass of *E. crassipes* of different places of survey was randomly segregated into the range under two groups as maximum biomass and minimum biomass in respective month and accordingly RGR value was obtained. Soil and water samples of respective quadrat in month wise were labeled. Data on nutrients such as nitrogen (mg $100g^{-1}$), phosphorus (mg $100g^{-1}$), organic carbon (%) from soil and ammonium nitrogen (ppm), orthophosphate (ppm) from water after analysis were obtained. In microcosm experiment (*ex situ*), final weight on biomass of *E. crassipes* was recorded from different cisterns. Canonical Discriminant Function Coefficients was used to obtain the role of particular nutrient in response to growth of *E. crassipes* in different months. Further, Stepwise regression analysis was used to calculate the growth of *E. crassipes* in relation with specific nutrients role.

RESULTS AND DISCUSSIONS

Result showed that maximum biomass was obtained during the months from July to September in all the studied areas, followed by October to November (Table 1). This growth performance is an indicative of general growth trend of all aquatic plants when rainy season favours the growth (Gopal and Sharma, 1981). In maximum growth zones, the biomass ranged in between 20.8-23.3 kg m^{-2} $month^{-1}$ and accordingly RGR value was obtained from 0.67 to 0.79. This range of growth increment (g m^{-2} day^{-1}) exhibited the optimal growth trend of *E. crassipes* in all the studied areas of RRC, CIFA, West Bengal and of CIFA, Orissa. This is the reflection of miximum growth trend of *E. crassipes* in general. In fact, there are limited references on the growth aspect of *E. crassipes*. However, the recorded value of RGR is found quite low as compared to the value ranging from 1.012 to 1.077 as mentioned by Bock (1969), though his studies on *E. crassipes* was conducted in different climatic and environmental conditions. The data of nutrients value was correlated with that of RGR value in accordance with respective maximum and minimum growth zones (Fig. 1 to 5).

Higher value of nutrients (mg $100g^{-1}$) in soil in the range as nitrogen (8.8-10.4), phosphorus (0.25-0.46) and organic carbon (0.68-0.72%) were responsible for the higher growth of water hyacinth (*E. crassipes*) as reflected in biomass values. Similar trend was revealed when ammonium nitrogen (0.12-0.15ppm) and orthophosphate (0.14-0.18ppm) analyzed from water samples responded to maximum biomass value. On the other hand lower value of nutrients (mg $100g^{-1}$) in soil in the range as nitrogen (7.2-8.4), phosphorus (0.1-0.22), organic carbon (0.54-0.66%), and ammonium nitrogen (0.044-0.077ppm), orthophosphate (0.04-0.07ppm) in water was related to the lower value of RGR in the range from 0.45 to 0.54 which is reflected in poor growth of *E. crassipes*. Scarsbrook and Davis (1970) and later Boyd and Scarsbrook (1975) observed that good growth of *E. crassipes* was

Table 1. *Showing comparative biomass status and RGR value of E. crassipes at different months (n=20)*

Diff. months	Biomass (kg)		Relative Growth Rate (RGR)	
	Max. (mean + SD)	Min. (mean + SD)	Max. (Average)	Min. (Average)
May	21.6 + 1.28	14.0 + 2.4	+0.0032	+0.0064
June	21.8 + 1.44	14.6 + 2.08	+0.006	+0.02
July	23.2 + 1.12	15.0 + 1.62	+0.045	+0.012
August	23.3 + 1.08	15.3 + 1.6	+0.0032	+0.0096
September	23.0 + 1.2	16.25 + 2.32	-0.01	+0.031
October	22.8 + 1.36	16.25 + 2.32	-0.006	+0
November	22.7 + 1.24	14.8 + 2.24	-0.003	-0.048
December	21.6 + 1.14	14 + 2.12	-0.035	-0.025
January	20.8 + 0.83	13.4 + 2.4	-0.025	-0.019

(Initial maximum and minimum biomass were 21.5kg and 13.8kg respectively) influenced by substantial amounts of nutrients. The present study supports the above view that higher amounts of nutrients are influential for increased growth of water hyacinth (*E. crassipes*) in terms of biomass increment.

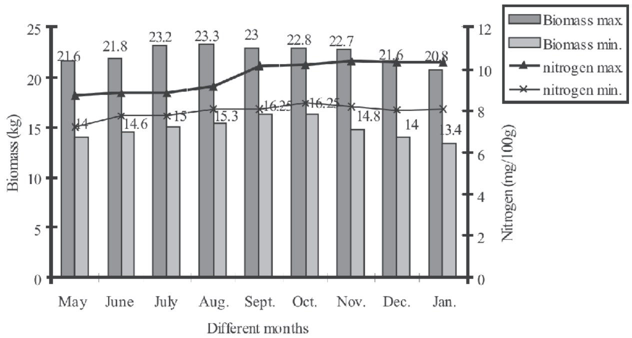

Fig. 1. Biomass value with nitrogen in soil

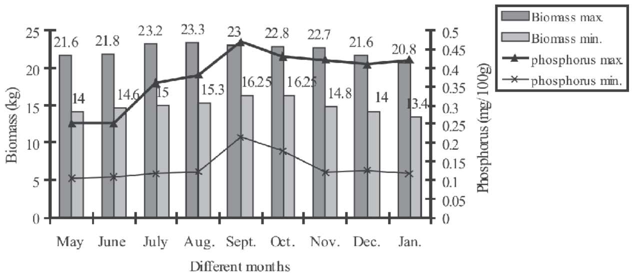

Fig. 2. Biomass value with phosphorus in soil

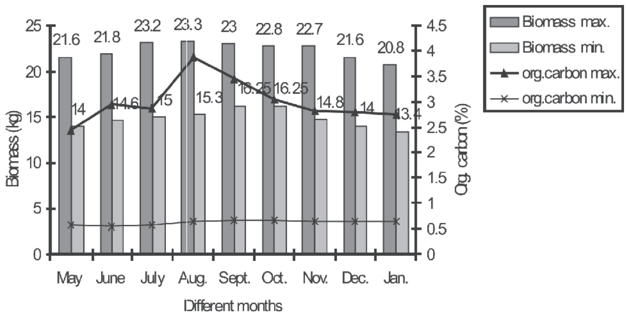

Fig. 3. Biomass value with organic carbon in soil

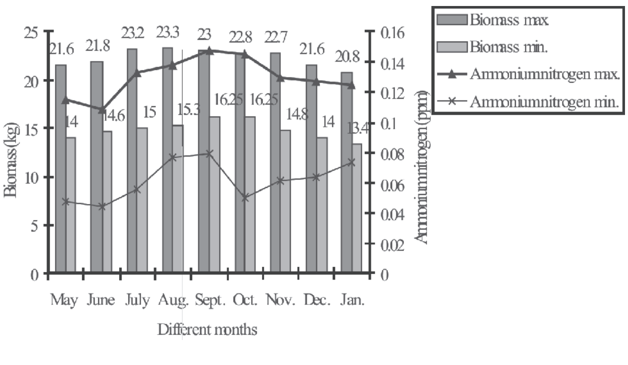

Fig. 4. Biomass value with ammonium nitrogen in water

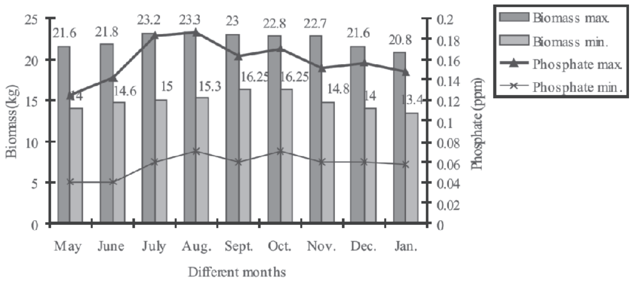

Fig. 5. Biomass value with orthophosphate in soil

Microcosm experiment (Table 2) reveals that phosphorus and organic carbon influenced *E. crassipes* to achieve three folds more growth in terms of biomass amount than that of the initial growth. Haller *et al.*, (1970) opined that higher concentration of phosphorus influenced luxuriant growth of water hyacinth.

Importantly, it is evident from the present study that phosphorus played a major role to influence the growth of *E. crassipes*. However, the role of organic carbon is also found very important to influence the growth of this species. Chadwick and Obeid (1966); Haller and Sutton (1973) advocated that mainly nitrogen and phosphorus responded to the optimal growth of plants. However, in the growth perspective of water hyacinth (*E. crassipes*) Reddy *et al.*, (1990) did not support the above view and rather highlighted that nutrient like phosphorus is major responsible for its growth. The present study also finds similarity with this view that Phosphorus plays a major role to the luxuriant growth of *E. crassipes*. This is supported by both field data and microcosm experiment in laboratory (*ex situ*). Regression analysis (Y=0.852 – 0.034N**+ 0.325P**+0.024OC**, R^2=0.53 and SE=0.021) from the data of field samples indicates that phosphorus was found major responsible, followed by organic carbon, for the maximum growth of *E. crassipes*. Importantly, both the elements promote consistently to the growth of *E. crassipes*, even though limited

Table 2. *Showing microcosm experiment by applying different nutrients (n=3)*

Cistern Expt. (336L water in each)	Nutrient (50mg/L)	Weed biomass	
		Initial wt.(kg)	Final wt.(kg) (mean + SD)
Set-1	Nitrogen	1.0	1.177 + 0.039
Set-2	Phosphorus	1.0	3.15 + 0.104
Set-3	Organic carbon	1.0	3.286 + 0.043
Set-4	Control	1.0	0.89 + 0.046

Table 3. *Unstandardized Canonical Discriminant Function Coefficients of RGR of E. crassipes*

Variable in maximum growth zone	Function				
	1	2	3	4	5
Nitrogen in soil	11.92	-5.70	3.90	1.11	2.19
Phosphorus in soil	29.09	55.33	-38.74	-14.14	-24.50
Organic carbon soil	0.09	1.84	0.59	4.10	-0.63
P2O5 in water	7.79	34.09	-25.04	2.73	56.70
RGR value	3.785	52.055	66.439	-35.50	6.89
(Constant)	-130.30	-14.22	-68.66	7.45	-23.99
Eigenvalue	115.32	22.95	1.98	1.24	0.23
% of Variance	81.40	16.20	1.40	0.90	0.20
Cumulative %	81.40	97.60	99.00	99.80	100.00
Canonical Correlation	1.00	0.98	0.82	0.74	0.44

Functions at Group Centroids

MONTH	Function				
	1	2	3	4	5
5 (May)	-14.88	-5.57	-0.14	-0.53	-0.63
6 (June)	-13.94	-3.05	1.90	0.71	0.39
7 (July)	-9.72	5.20	-1.81	-1.81	0.31
8 (August)	-5.65	7.19	-0.31	2.01	0.03
9 (September)	8.77	5.23	1.19	-0.33	-0.87
10 (October)	8.26	0.96	0.35	-0.29	0.54
11 (November)	9.74	-1.52	1.66	-0.98	0.18
12 (December)	8.89	-3.62	-0.81	0.43	0.34
13 (January)	8.54	-4.82	-2.02	0.80	-0.28

(Unstandardized canonical discriminant functions evaluated at group means)

amount of organic carbon was recorded in habitats. On the other hand, nitrogen initially influenced the growth, but not found as constant a factor in respect of growth promoting element. Canonical Discriminant Function Coefficients (Table 3) showed that 81.4% increase of biomass occurred out of total weight gain during the months from September to January, followed by 16.20% in the rest months including July to October, when several factors like monthwise growth, nutrient responsibility and biomass increment altogether were correlated.

This analysis indicates that though growth was initiated at the month of July but consistent growth continued afterwards. That is why months following after July-August are found suitable for *E. crassipes* achieving luxuriant growth; though, apparently July to September seem to be favourable.

The study concludes the following: (i) Mainly, phosphorus plays a major role to influence consistently to the luxuriant growth of *E. crassipes*, though organic carbon is also important to promote the growth of the same, (ii) Months following after July and August favour the luxuriant growth of E. crassipes when nutrients availability remain in greater amount to influence its growth.

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REFERENCES

APHA (2002). *Standard methods for examination of water and wastewater*, 20th ed. American Public Health Association, Washington, DC.

Atkinson, M. J. and Smith, S. V. (1984). C:N:P ratios of benthic marine plants. *Limnol. Oceanogr* **28**: 568-574.

Bock, J. H. (1969). Productivity of the water hyacinth, *Eichhornia crassipes* (Mart.) solms. *Ecology* **50**: 460-464.

Boyd, C. E. and Scarsbrook, E. (1975). Influence of nutrients addition and initial density of plants on production of water hyacinth, *Eichhornia crassipes. Aquatic Botany* **1**: 253-261.

Chadwick, M. J. and Obeid, M. (1966). A comparative study of the growth of *Eichhornia crassipes* Solms and *Pistia strateotes* in water culture. *Journal of Ecology* **54**: 563-575.

Duarte, M. C. (1992). Nutrients concentrations of aquatic plants: Patterns across species, Limnol. *Oceanogr* **37**: 882-889.

Gopal, B. and Sharma, K. P. (1981). Water hyacinth (*Eichhornia crassipes*). Hindusia, Delhi-110 007.

Haller, W. T. and Sutton, D. L. (1973). Effects of pH and high Phosphorus concentration on growth of water hyacinth. *Hyacinth control* Journal **11**: 59-61.

Haller, W. T., Knipling, E. B. and West, S. H. (1970). Phosphorus adsorption by and distribution in water hyacinth. *Soil & Crop soil Science Florida, Proceedings* **30**: 64-68.

Jackson, M. L. (1973). *Soil chemical analysis.* Prentice Hall of India Pvt. Ltd., New Delhi.

Mandal, R. N., Bar, R., Chattopadhyay, D. N. and Datta, A. K. (2011). Assessment of Impact of water hyacinth (*Eichhornia crassipes*) on ecology and socio-economy. In: *Evaluation and Impact Assessment of Technologies and Development Activities in Agricultures, Fisheries and Allied Fields*, Ray, A. K. (ed.), New India Publishing Agency, New Delhi. pp 291-312.

Mathur, S. M., Mathur, A. N. and Bhatt, Y. C. (2005). Water hyacinth – Threat to Environment or boon in disguise. In: *Aquatic weeds, problems, control and Management*, Mathur *et al.* (ed.). Himanshu Publications, Delhi.

Reddy, K. R., Agami, M. and Tucker, J. C. (1990). Influence of phosphorus on growth and nutrient storage by water hyacinth (*Eichhornia crassipes* (Mart.) Solms. Plants. *Aquatic Botany* **37**: 355-365.

Scarsbrook, E. and Davis, D. E. (1970). The effect of sewage effluent on growth of five aquatic species. *Hyacinth control* Journal **9**(1): 26-30.

Trivedi, R. K. and Thomas, S. (2005). Water hyacinth for pollution control and resource recovery. In: *Aquatic weeds, problems, control and Management*, Mathur *et al.* (ed.), Himanshu Publications, Delhi.

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Studies on the Non-Symbiotic Diazotrophs and Dinitrogen Fixation in Coastal Saline Soils from Sagar Island

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Surface and subsurface soils from Ishwaripur, Mouriganga and Companichar areas of Sagar Island, 24 Parganas (South), West Bengal, India, collected during April 2012 were studied. Out of the three locations, Ishwaripur was mudflat and other two were agricultural fields. The pH, ECe, organic carbon and total nitrogen, diazotrophic bacterial population and dinitrogen fixation of the surface soils were higher than the subsurface soils. Organic carbon content of the agricultural fields was higher than the mudflat soil. Out of eight pure diazotrophic bacteria isolated from the above soils, five were Gram (+ve). The isolates could use glucose, sucrose, lactose and mannitol, with acid production in almost all cases. The isolates could hydrolyze starch and were catalase positive. Dinitrogen fixation of the isolates ranged from 4.09-1.02 mg nitrogen 50 mL^{-1}.

(***Key words:*** *Coastal saline soil, Sagar island, Diazotrophic bacterial population, Dinitrogen fixation*)

Salinity is a serious threat to agriculture world wide. In India about 8.1 million hectares of land are salt affected, of which 3.1 million hectares are in the coastal regions (Yadav *et al.*, 1983). In West Bengal 0.82 million hectares of land is salt affected occurring in the coastal region. Sagar Island is one of the most important islands of the Sundarbans delta. This island is located in extreme south of eastern coastal plain forming a part of the Sundarbans (Maji *et al.*, 1998).

It is known that the soil properties vary depth wise (Gul *et al.*, 2011). The effect is much prominent in saline soil as the accumulation of salt during summer month occurs in the surface soil (Bandyopadhyay *et al.*, 2003).

Saline habitats are nitrogen poor (Sprent and Sprent, 1990) and have their own microbial population adapted to their environment (Zahran, 1997). Therefore, supply of nitrogen input can dramatically improve the crop production in this region. One of the sources of N-input in saline habitats is biological nitrogen fixation (Whiting and Morris, 1986). This is non-polluting source of nitrogen and curtails the consumption of fertilizers (Cocking, 2003).

Reports on the effect of salinity on soil physical and chemical properties are available (Bandyopadhyay *et al.*, 2003; Sardinha *et al.*, 2003). Microbiological properties in general (Zahran, 1997; Rietz and Haynes, 2003; Tripathi *et al.*, 2006) and diazotrophic population and dinitrogen fixation of coastal saline soils have been studied scantily (Barua *et al.*, 2011). Information regarding bacterial diazotrophs and nitrogen fixation of soils from Sagar Island is yet to be gathered. With those backgrounds this work has been undertaken with the following aspects:

1. Enumeration of non-symbiotic diazotrophic bacterial population and nitrogen fixation in soils both from surface and subsurface region of three different parts of Sagar Island.
2. Characterization of pure diazotrophic bacteria from the above soils and their dinitrogen fixation.

MATERIALS AND METHODS

Study site and Soil Sampling

Four replicated soil samples from surface (0-15 cm) and sub-surface (15-30 cm) regions were collected from three different locations viz., Ishwaripur (88º09′41.1″ E & 21°49′25.3″ N), Mouriganga (88º10′01.6″ E & 21º49′03.8″ N) and Companichar (88º09′18.1″ E & 21°49′28.7″ N) of Sagar Island, 24 Parganas (South), West Bengal, India during April 2012. The field moist soil samples

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were preserved at 4°C before microbial analysis and the physico-chemical properties of soil were carried out with air dried soils.

Determination of Physico-chemical properties of soil

Soil pH (1:2.5 soil-water), soil ECe (USDA, 1954), organic carbon (Nelson and Sommers, 1982) and total nitrogen (Black, 1965) of soils were determined by standard methods.

Microbiological analyses of soil

Enumeration of Culturable Aerobic Non-symbiotic Diazotrophic Bacterial Count of Soil

Enumeration was conducted by soil-dilution plate technique using nitrogen free LG-agar medium and the data were recorded after three days of incubation at 28–30°C. The composition of the media in gl-1of water was as follows: Sucrose 20 g, K_2HPO_4 0.05 g, KH_2PO_4 0.15 g, $CaCl_2$ 0.01 g, $MgSO_4$,$7H_2O$ 0.2 g, Na_2MoO_4, $2H_2O$ 0.002 g, $FeSO_4$ 0.01 g, Bromo thymol blue (5 % solution in ethanol) – 2 mL, $CaCO_3$ – 1g, Agar – 18 g, pH adjusted at 7.2.

Determination of Nitrogen Fixation

One gram of each soil sample was added to duplicate flasks containing 50 mL LG broth and then sterilized. These served as blanks. To another duplicate set of flasks containing 50 mL sterile broth 1 g of each soil sample was added aseptically. The flasks were incubated at 28-30° C for 7 days. Total nitrogen in the broth was determined by macro-Kjeldahl method (Allen, 1957). Nitrogen fixation in soil, per 50 ml^{-1} culture media was determined by subtracting the value of nitrogen in the blank from the nitrogen in the sample.

Isolation and Purification of Non-Symbiotic Diazotrophic Bacteria

The individual colonies developed on soil dilution plate were streaked on fresh LG media till pure culture was obtained. In this way 8 pure cultures were obtained and were maintained in LG agar slants.

Phenotypic and biochemical characterization of the Isolates

Colony characteristics of the isolates on nitrogen free LG agar slants and cellular morphology by negative staining, Gram reactions and biochemical character of the isolates were determined according to Holtz (1993).

Determination of Nitrogen Fixing Power of the Isolates:

Nitrogen fixing efficacy of the isolates were estimated by growing the isolates in nitrogen free LG broth for seven days at 28-30°C, followed by determination of nitrogen in the cultures media as well as blanks by macro-Kjeldahl method (Allen, 1957). Nitrogen fixing efficacy was expressed as mg N fixed 50 mL^{-1} culture media.

Statistical Analysis

Assigning the soil as treatment factor, analysis of variance (ANOVA) was carried out by Completely Randomized Design (CRD) using SPSS 11.0 statistical package. The factor soil had six levels and the replicate had four levels. The least significant difference (LSD) test was applied to evaluate the significance of differences between individual treatment factors. The treatment means were compared by Duncan's multiple range tests at 0.05 P.

RESULTS AND DISCUSSION

Physico-chemical properties of soils

The pH of the soils varied significantly among themselves. Surface soil of Ishwaripur (8.25) recorded the highest value and the lowest value was observed in surface soil of Mouriganga (5.70) (Table 1). The pH of the surface soils of agricultural

Table 1. *Physico-chemical properties of the soils under study*

Location	Soil depth	PH (1:2.5)	ECe (dSm^{-1})	Organic carbon ($g\ kg^{-1}$)	Total nitrogen ($g\ kg^{-1}$)
Ishwaripur	Surface	8.25a*	12.22^a	3.50^f	0.225^f
	Sub-surface	8.10^b	9.55^b	3.70^e	0.280^e
Mouriganga	Surface	5.70^f	6.32^c	7.80^b	0.810^a
	Sub-surface	7.01^e	4.65^e	4.90^d	0.482^c
Companichar	Surface	6.10^d	5.20^d	8.75^a	0.612^b
	Sub-surface	7.25^c	3.80^f	5.40^c	0.375^d

*Figures denoted by same alphabets are statistically similar at 5 % probability level by DMRT lands was lower than that of subsurface. The lowering of pH in the surface soils of agricultural lands may be due to the effect of cultivation. Accumulation of root biomass in the surface soil was probably responsible for this lowering of pH. In case of subsurface soils these effect was not so prominent and soils recorded the neutral pH.

The ECe of the soils varied considerably ranging from 3.80 (sub-surface soil of Companichar) to 12.22 dSm^{-1} (surface soil of Ishwaripur). ECe of the surface soils were higher than the subsurface soils. The mudflat soil of Ishwaripur recorded higher ECe value than agricultural soils. Among the agricultural soils sub-surface soil of Companichar was non saline. According to USDA (1954), a soil is said to be saline when the electrical conductivity of the saturation water extract of soil (ECe) is >4dSm^{-1} at 25°C. Accordingly, the soils were mostly saline. Accumulation of salt in the surface soils particularly during summer month is a natural phenomenon in coastal zone. The capillary movement of brackish water from subsurface to surface soil caused higher salinity in surface soil (Bandyopadhyay *et al.*, 2003). The lowering of ECe value in the subsurface soils might be due to the above reason as the soil samples were collected during summer month i.e., April 2012.

The organic carbon content of soils varied from 8.75 to 3.50 g kg^{-1}. Variation in organic carbon content in mudflat and agricultural soil was prominent in the present study. Organic carbon content of the surface soils was mostly higher than the sub-surface soils. Total nitrogen content of the soils followed the trend of soil organic carbon. The range of total nitrogen content of the soils varied from 0.810 to 0.225 g kg^{-1}. Agricultural soils recorded higher total nitrogen than the mudflat soils. Higher organic carbon and total nitrogen in the agricultural soils seem to be related to input of organic matter through cultivation practices.

Diazotrophic microbial population (log colony forming unit) and dinitrogen fixation (mg nitrogen fixed 50 mL^{-1} culture media) of soils under study

The soils varied with respect to their aerobic diazotrophic bacterial populations (Table 2), with the highest value recorded in surface soil of Mouriganga (6.87) and the lowest in sub-surface soil of Companichar (4.99). Surface soils always recorded higher diazotrophic population than sub-surface soils. The variations in diazotrophic population seem to be related to the physico-chemical characteristics of soils, and the inherent type and diversity of microorganisms occurring in

Table 2. *Diazotrophic microbial population and nitrogen fixing power of the soils under study*

Location	Soil depth	Diazotrophic microbial population (log colony forming unit)	Nitrogen fixation (mg nitrogen fixed 50 ml^{-1} culture media)
Ishwaripur	Surface	6.18^{b}	4.318^{c}
	Sub-surface	5.28^{e}	2.500^{f}
Mouriganga	Surface	6.87^{a}	5.187^{a}
	Sub-surface	5.63^{d}	2.965^{d}
Companichar	Surface	6.09^{c}	4.915^{b}
	Sub-surface	4.99^{f}	2.565^{e}

*Figures denoted by same alphabets are statistically similar at 5 % probability level by DMRT

Table 3. *Phenotypic characteristics of the pure isolates*

Strain code	Colony characteristics on nitrogen free LG agar slant	Morphology of cells by negative staining	Gram character
Sagar1	Appear single moist colony, small, rounded, convex, opaque	Small, thin, rod shaped	Gram Positive
Sagar2	Appear single moist colony, small, rounded, convex, opaque	Small, thin, rod shaped	Gram Negative
Sagar3	Appear single moist colony, small, rounded, convex, opaque	Small, thin, rod shaped	Gram Positive
Sagar4	Appear single moist colony, small, rounded, convex, opaque	Small, thin, rod shaped	Gram Positive
Sagar5	Appear single dry colony, small, rounded, convex, opaque	Small, thin, rod shaped	Gram Negative
Sagar6	Appear single moist colony, small, rounded, convex, opaque	Small, thin, rod shaped	Gram Positive
Sagar7	Appear single moist colony, small, rounded, convex, opaque	Small, thin, rod shaped	Gram Positive
Sagar8	Appear single moist colony, small, rounded, convex, opaque	Small, thin, rod shaped	Gram Negative

Table 4. *Biochemical characteristics of the isolates from the studied soils*

Strain code	Starch utilization	Glucose		Sucrose		Mannitol		Lactose utilization	Catalase activity
		Utilization	Acid production	Utilization	Acid production	Utilization	Acid production		
Sagar1	+	+	+	+	+	+	-	+	+
Sagar2	+	+	+	+	+	+	+	+	+
Sagar3	+	+	+	+	+	+	+	+	+
Sagar4	+	+	+	+	+	+	+	+	+
Sagar5	+	+	+	+	+	+	+	+	+
Sagar6	+	+	+	+	+	+	+	+	+
Sagar7	+	+	+	+	+	+	+	+	+
Sagar8	+	+	+	+	+	+	+	+	+

[+ = Positive activity and - = Negative activity]

Table 5. *Nitrogen fixing power of the pure isolates*

Strain code	Isolated from soil	Nitrogen fixation (mg nitrogen fixed 50 ml^{-1} culture media)
Sagar1	1A	1.90
Sagar2	1B	2.42
Sagar3	1B	1.02
Sagar4	1B	1.25
Sagar5	2A	2.54
Sagar6	2B	4.09
Sagar7	3A	2.01
Sagar8	3B	2.79

these soils (Broadbent and Nakashima, 1971; Laura, 1974; El-Shinnawi and Seifert, 1975). The total count of bacteria is usually negatively correlated with the total soluble salts of saline soils (Ragab, 1993), but positively correlated with organic carbon contents (Zahran *et al.*, 1992; Ragab, 1993). Present study did not corroborate with previous results. These soils may have their own diazotrophic bacterial communities, which have adapted to their respective environments (Zahran, 1997).

The highest nitrogen fixation was recorded in Mouriganga surface soil (5.187) which was related to its diazotrophic population. The lowest nitrogen fixation was recorded in sub-surface soil of Ishwaripur (2.5). In this case nitrogen fixation did not correspond to its diazotrophic population. Subsurface soils recorded lower nitrogen fixation than their surface counterparts. This variation might be related to the variation in aerobic and anaerobic population in two depth of soils and also to their population.

Phenotypic and biochemical characteristics of the diazotrophic isolates

All the isolates produced moist colonies except the Sagar 5 isolate, whose colony was dry (Table 3). The colonies of all isolates were small, round convex and opaque. The cellular morphology of the isolates was small rods (Fig. 1). Five isolates were Gram (+ve) and three were Gram (-ve).

All the isolates could utilize glucose, sucrose and mannitol with acid production in most cases (Table 4). They could hydrolyze starch and lactose and were catalase positive.

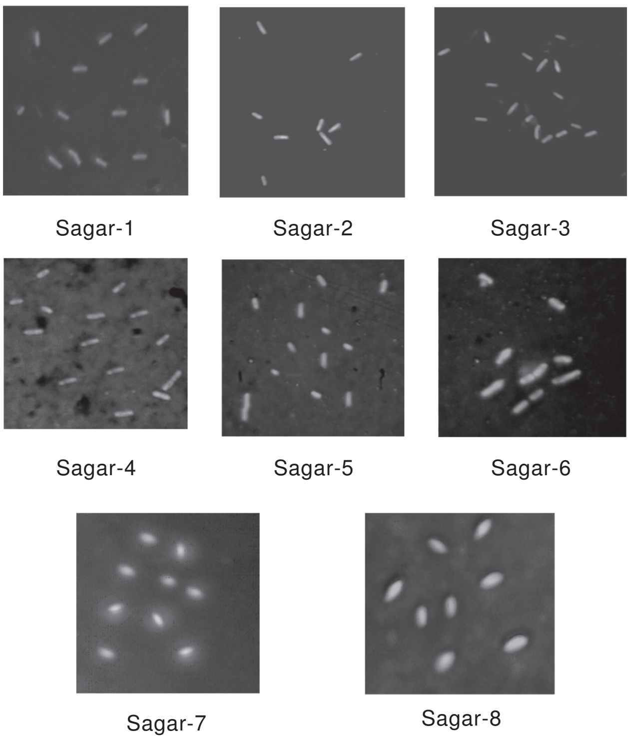

Fig. 1. Picture of negative staining (1000X) of eight pure bacterial isolates

Nitrogen fixation (mg nitrogen fixed 50 mL^{-1} culture media) by the isolates

Out of eight isolates the range of nitrogen fixation by seven isolates varied from 2.54 to 1.02 (Table 5). The isolate Sagar 6 recorded a value of 4.09. The nitrogen fixing power of the present isolates were within the range as reported by Barua *et al.*, (2011) from other part of Sundarbans

Sagar soils have their own aerobic heterotrophic diazotrophic bacteria adapted to the physico-chemical properties of the soils. Diazotrophic population and dinitrogen fixation in surface soils were higher than subsurface soils. Among the studied bacterial strains, the strain Sagar-6 was found to be the best nitrogen fixer.

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REFERENCE

Allen, O. N. (1957). Experiments in soil bacteriology. Burgess Publishing Co., Minneapolis, Minnesota. pp 83-86.

Bandyopadhyay, B. K., Maji, B., Sen, H. S. and Tyagi, N. K. (2003). *Coastal soils of West Bengal – their nature, distribution and characteristics.* Bulletin no. 1/2003. Central Soil Salinity Research Institute, Regional Research Station, Canning Town, West Bengal, India. pp 1- 62.

Barua, S., Tripathi, S., Ghosh, S., Chakraborty, A. and Chakrabarti, K. (2011). Studies on non-symbiotic diazotrophic bacterial populations of coastal arable saline soils of India. *Indian Journal of Microbiology.* **51**(3): 369-376.

Black, C. A. (1965). *Methods of soil analysis.* American Society of Agronomy, Wisconsin, USA.

Broadbent, F. .E., Nakashima, T. (1971). Effect of added salt on nitrogen mineralization in the California soils. *Soil Science Society of America Proceedings* **35**: 457–4603

Cocking, E. C. (2003). Endophytic colonization of plant roots by nitrogen-fixing bacteria. *Plant and Soil* **252**: 169-175.

El-Shinnawi, M. M. and Seifert, J. (1995). Influence of salt concentration and moisture on the microbial activities in alluvial soil. *Acta. University Corol. Biology* **4**: 45-49

Gul, H., Khattak, R. A., Muhammad, D. and Shah, Z. (2011). Physical properties of soils under sub-surface drainage system. *Sarhad Journal Agriculture* **27**(2): 225-232.

Holtz, J. D. (1993). *Bergey's manual of determinative bacteriology*, 9th edition, Williams and Wikins, Baltimore.

Laura, R. O. (1974). Effects of neutral salts on carbon and nitrogen mineralisation of organic matter in soil. *Plant Soil* **4**: 113–127

Maji, B., Bandyopadhyay, B. K., Sarkar, D. and Chatterji, S. (1998). Morphological and chemical characterization of soils of Sagar Island of the Sundarbans, West Bengal. *Journal of the Indian Society of Soil Science* **46**(1): 99-103.

Nelson, D. W. and Sommers, L. E. (1982). Total carbon, Organic carbon and organic matter. In: *Methods of soil analysis. Part 2.* Sparks, D. L., Page, A.L., Helmke, R.A., Loeppert, R.H., Sottanpor, P.N., Tabatabai, M.A., Johnson, C. T. and Sumner, M.E. (eds.). *America Society Agronomy and Soil Science Society of America*, Madison, Wisconsin. pp 539-579.

Ragab, M. (1993). Distribution pattern of soil microbial population in salt-affected soil. In: *Towards rational use of higher salinity tolerant plants, deliberations about high salinity tolerant plants and ecosystems*, Lieth, H. and Al-Masoon, A.A. (eds.)., Vol.1. Kluwer Academic, Dordrecht, The Netherlands. pp 467- 472.

Rietz, D. N. and Haynes, R. J. (2003). Effects of irrigation-induced salinity and sodicity on soil microbial activity. *Soil Biology and Biochemistry* **35**: 845-854.

Sardinha, M., Muller, T., Schmeisky, H. and Joergensen, R. G. (2003). Microbial performance in soils along a salinity gradient under acidic conditions. *Appication of Soil Ecology* **23**: 237-244.

Sprent, J. I. and Sprent, P. (1990). Nitrogen-fixing organisms: Pure and applied aspects. Chapman and Hall, London, UK.

Tripathi, S., Kumari, S., Chakraborty, A., Gupta, A., Chakrabarti, K. and Bandyopadhyay, B. K. (2006). Microbial biomass and its activities in salt-affected coastal soils. *Biological Fertilizer Soil* **42**: 273 - 277.

United States Department of Agriculture (1954). Diagnosis and improvement of saline and alkali soils. In: *Agriculture Hand Book no 60*, Richards, L.A. (ed.), Oxford & IBH Publishing Company. New Delhi, India. pp 1-160.

Whiting, G. J. and Morris, J. T. (1986). Nitrogen fixation (C_2H_2 reduction) in a salt marsh: its relationship to temperature and an evolution of an in situ chamber technique. *Soil Biological Biochemistry* **18**: 169-175.

Yadav, J. S. P., Bandyopadhyay, A. K. and Bandyopadhyay, B. K. (1983). Extent of coastal saline soils of India. *Journal of Indian Society of Coastal Agriculture Research* **1**: 1-6.

Zahran, H. H. (1992). Characterization of root-nodule bacteria indigenous in the salt-affected soils of Egypt by lipopolysaccharide, protein and plasmid profiles. *Journal of Basic Microbioogy* **32**: 279–287.

Zahran, H. H. (1997). Diversity, adaptation and activity of the bacterial flora in saline environments. *Biological Fertilizer Soils*. **25**: 211-223.

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Nutrient Management in Rice-lentil-sesame Cropping System for Sustainable Productivity in Coastal Agroclimatic Zone of West Bengal

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The effects due to partial substitution of chemical fertilizers with different organic sources on rice-lentil-sesame cropping sequence were studied and evaluated in coastal saline belts of West Bengal during 2007-2008 and 2008-2009. The maximum values were occurred in the growth parameters, yield components and productivity of all the crops in sequence when the organic manure was applied along with inorganic fertilizer at 75% of the recommended dose. The effect of well decomposed fishmeal (WDFM) on rice and its residual effect on succeeding crops of lentil and sesame were as good as farm yard manure (FYM). At the time of application of 75% recommended dose of NPK + 2t well decomposed fish meal ha^{-1}, the highest rice equivalent yield (8458.7 kg ha^{-1}), net returns (Rs.42356.58 ha^{-1}) and 2t net production value (1.48) were recorded.

(***Key Words:*** *Fishmeal, FYM, Residual effect, Rice-lentil-sesame, Coastal saline zone, Nutrient management)*

Intensive/multiple cropping except in the extremely saline zones is favourable to the climatic condition of the coastal zone of West Bengal. It is feasible to take two crops under rainfed and three crops under irrigated conditions in rice based cropping sequence. Inclusion of low water requiring crops like oilseeds and pulses in the cropping sequence improves the cropping intensity as well as promotes optimal utilization of land, water and nutrient resources. Moreover, it may bring down the deficit in the demand of oilseeds and pulses in West Bengal. It can also augment the soil health as a whole. Integrated use of organic and inorganic sources of plant nutrients helps in maintaining stability in crop production under intensive cropping by improving the physico-chemical properties of soil. Organic matters like farmyard manure (FYM) compost, crop residues. Vermicompost as well as animal manures like fish manure/fishmeal, green manures etc. are environmentally sound and supplying nutrients to the current crop, it often leaves substantial residual effect to the succeeding crops. Farmers usually apply raw fishmeal, amply available in the coastal zone of West Bengal, in the vegetables and some other crops. But it creates some problems of diseases and insect occurrence. However, application of well decomposed fishmeal increases the yield of crops without causing any pest problem (Brahmachari *et al.*, 2009). Thus the low cost locally available resources may be used in a proper manner. In this context, the present study was undertaken with the objective of utilizing the locally available organic resources for substituting the chemical fertilizer partly and augmenting the soil health for sustaining crop productivity and increasing the cropping intensity of the coastal saline zone (CSZ) of West Bengal.

MATERIALS AND METHODS

The experiment was carried out at Regional Research Station of Coastal Saline Zone, Bidhan Chandra Krishi Viswavidyalaya during rainy season (*Kharif*), winter season (*Rabi*) and summer season (pre-*kharif*) of 2007-08 and 2008-09 under coastal saline soil of Kakdwip, 24 Parganas (South), West Bengal. The experiment was laid out in Randomized Block Design (RBD) with 9 different nutritional treatments each replicated four times. The different nutritional treatments of rice were 100% recommended dose (RD) of NPK to all the crops in sequence (T_1), 75% RD of NPK to all the crops in sequence (T_2), 50% RD of NPK to all the crops in sequence (T_3), 75% of RD of NPK to all the crops in sequence + 10 t FYM ha^{-1} 0nly to rice (T_4), 50% RD

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of NPK to all the crops in sequence + 10t FYM ha^{-1} only to rice (T_5), 75% RD of NPK to all the crops in sequence + 2t well decomposed fish meal (WDFM) ha^{-1} only to rice (T_6), 50 % RD of NPK to all the crops in sequence + 2t WDFM ha^{-1} to rice (T_7), 75% RD of NPK to all the crops in sequence + 5t paddy straw ha^{-1} only to rice (T_8) and 50% RD of NPK to all the crops in sequence + 5t paddy straw ha^{-1} only to rice (T_9).

The experiment was conducted for six consecutive seasons in the same piece of land without any change in the layout. Starting with Kharif rice (cv. *Khitish* i.e. IET-4094) in 2006, the staple cereal grain of West Bengal, was transplanted in the end of July in every year with recommended dose of fertilizers (60:30:30 kg NPK ha^{-1}), the second crop, lentil (B-77 i.e. Asha) as a Winter crop, was sown in mid November with RD of fertilizers of 80:40:40 kg and the third crop sesame (B-67 i.e. Tillottma) sown in the mid March with RD of fertilizers of 20:40:15) kg of NPK ha^{-1}. The sources of NPK were urea, single super phosphate (SSP) and muriate of potash (MOP). Organic manure like FYM, vermicompost and WDFM (Dried fish, amply available in this zone, but erratically used in raw condition causing various insect and diseases problems in crops, was decomposed properly in "heap method") were incorporated into the soil at the time of final land preparation. The well decomposed fishmeal containing 6.9% N, 5.1% P_2O_5 and 1.5% K_2O whereas vermicompost containing 1.4% N, 0.6% P_2O_5 and 1.1% K_2O and FYM containing 0.6% N, 0.3% P_2O_5 and 0.8% K_2O. Total nitrogen, available phosphorus and available potassium were estimated by modified Macro - Kjeldahl's method, Olsen's method and flame photometric method (Jackson, 1967). Net production value was calculated by dividing net profit with total cost of cultivation.

RESULTS AND DISCUSSION

The growth parameters of rice i.e. dry matter accumulation (DMA), crop growth rate (CGR), and plant height differed significantly with different treatments at different stages (Table 1).The maximum DMA (653.9 and 862.8 gm^{-2} at 60 and 90 days after transplanting respectively). were obtained at the treatment 75% RD of NPK along with 2t WDFM ha^{-1} only to rice but it was at par with 75% RD of NPK to all the crops in sequence + 10t FYM ha^{-1} only to rice. Maximum value of CGR (7.16 gm^{-2} day^{-1}) at 60-90 days after transplanting was recorded with

Table 1. *Effect of different nutritional management treatments on growth parameters, yield components, yield and harvest index of rice (Mean of two years)*

Treatments	Growth parameters				Yield components				Yield		Harvest index (%)
	DMA		CGR 60-90 DAT	Plant height (cm)	No. of panicles m^{-2}	No. of filled grains $panicle^{-1}$	% filled grain	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	
	60 DAT	90 DAT									
T_1	567.7	742.9	6.04	88.75	340.4	83.20	85.53	20.43	3938	4587	44.38
T_2	511.7	658.3	5.09	78.39	309.8	77.23	80.17	20.70	3514	4245	43.10
T_3	448.2	573.5	4.38	73.04	290.7	71.47	79.30	19.77	3043	3779	41.97
T_4	637.8	840.3	6.95	85.40	363.5	87.57	90.33	21.37	4191	4745	45.28
T_5	575.0	733.5	6.04	80.74	338.0	81.60	84.00	20.60	3905	4477	44.76
T_6	653.9	862.8	7.16	87.98	369.1	87.87	89.07	20.73	3015	4872	45.19
T_7	571.4	750.3	6.16	84.57	345.9	80.40	85.50	21.43	3012	4643	45.60
T_8	597.5	780.3	6.29	82.97	343.6	84.89	86.33	21.06	4278	4550	44.35
T_9	533.3	694.2	5.56	79.14	327.5	78.88	82.03	20.50	3711	4299	44.38
SEm(+)	3.92	5.49	0.074	1.030	2.71	0.727	1.48	0.26	38.90	36.2	0.399
CD (P=0.05)	11.15	15.61	0.210	3.09	7.71	2.07	4.22	NS	110.6	103.2	1.13

DMA- Dry Matter Accumulation (g m^{-2}), CGR- Crop Growth Rate (g m^{-2} day^{-1}) **DAT- Days After Transplanting
***NS- Non Significant ****Treatment details: 100% recommended dose (RD) of NPK to all the crops in sequence (T_1),75% RD of NPK to all the crops in sequence (T_2), 50% RD of NPK to all the crops in sequence (T_3), 75% of RD of NPK to all the crops in sequence + 10 t FYM ha^{-1} 0nly to rice (T_4), 50% RD of NPK to all the crops in sequence + 10t FYM ha^{-1} only to rice (T_5), 75% RD of NPK to all the crops in sequence + 2t well decomposed fish meal (WDFM) ha^{-1} only to rice (T_6), 50 % RD of NPK to all the crops in sequence + 2t WDFM ha^{-1} to rice (T_7), 75% RD of NPK to all the crops in sequence + 5t paddy straw ha-1 only to rice (T_8) and 50% RD of NPK to all the crops in sequence + 5t paddy straw ha^{-1} only to rice (T_9)

75% Rd of NPK along with 2t WDFM only to rice. At the harvest, the maximum plant height (88.75 cm) was recorded in the treatment with 100% RD of NPK to all the crop sequence. The yield component of rice i.e. number of panicles m^{-2}, number of filled grains panicle-1 and percentage of filled grain varied significantly (Table 1). The highest number of panicles m^{-2} (369.1 m^{-2}) was recorded with75 % RD of NPK along with 2t WDFM ha^{-1} only to rice and it was at par with 75% RD of NPK + 10t FYM ha^{-1} only to rice. The maximum number of filled grains $panicle^{-1}$ (87.87) and maximum grain filling percentage (89.07%) were also obtained in the same treatment. However, the 1000 grain weight of rice did not differ significantly with different treatments. The highest grain yield of rice (4278 kg ha^{-1}) was recorded in 75% of NPK along with 2t WDFM ha^{-1} and it was at par with 75% RD of NPK +10 t FYM ha^{-1} only to rice. However, the highest straw yield (4872 kg ha^{-1}) was obtained with 75% Rd of NPK along with 2t WDFM ha^{-1} the harvest index of the rice was maximum in the plots where crop received 75% RD of NPK along with 2t WDFM ha^{-1}. However, Patil *et al.*, (2000) reported 50% RD of NPK along with it WDFM ha^{-1}. Bandopadhyay and Puste (2002) reported higher yield and yield attributes when 25% of chemical fertilizer replaced either with FYM or rice straw.

The growth parameters of lentil viz. dry matter accumulation (DMA), crop growth rate (CGR) and number of branches $plant^{-1}$ differed significantly with different treatments (Table 2). The maximum DMA (220.3g m^{-2} and 278.5 g m^{-2} at 60 and 90 days after sowing respectively) was recorded with the plots treated with 75% of RD of NPK along with 2t WDFM ha^{-1} to rice only. The CGR at 60 and 90 DAS in rapeseed crop showed the similar trend. The treatments did not show any significant influence on the plant height at harvest; however it was highest (35.9 cm) in 100 % RD of NPK to all the crops in sequence. The number of branches $plant^{-1}$ was highest (7.56) in 75% of RD of NPK to all the crops in sequence along with 2t WDFM ha^{-1} to rice only. The number of pods per plant ranged from 44.7-72.9 and the treatment differences were significant (Table 2). However, the number of seeds pod^{-1} and 1000 seed weight of rapeseed crop did not differ with the treatments. The highest seed yield (897 kg ha^{-1}) and straw yield (1900 kg ha^{-1}) was due to application of 75% of NPK to all the crops in sequence along with 2t of WDFM ha^{-1} only to rice. However, the harvest index was highest (33.34%)

Table 2. *Effect of different nutritional management treatments on growth parameters, yield components, yield and harvest index of lentil (Mean of two years)*

Treatments	Growth parameters					Yield components			Yield		Harvest
	DMA		75-90 DAS CGR (gm^{-2} d^{-1})	Plant height (cm)	Number of branches $plant^{-1}$	Number of pods $plant^{-1}$	Number of seeds pod^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	index (%)
	60 DAS	90 DAS									
T_1	208.4	265.7	1.42	35.9	6.87	68.4	1.92	18.51	872	1814	32.46
T_2	177.8	229.5	1.28	34.9	5.72	56.2	1.86	19.20	695	1560	30.82
T_3	146.2	189.5	0.95	30.4	4.12	44.7	1.62	18.16	532	1286	29.26
T_4	213.9	270.4	1.39	35.6	7.42	71.6	1.98	18.95	885	1815	32.78
T_5	177.7	230.2	1.16	34.2	6.02	58.3	1.87	18.75	719	1572	31.39
T_6	220.3	278.5	1.45	35.5	7.56	72.9	1.98	17.95	897	1900	30.14
T_7	185.1	238.5	1.20	34.9	6.15	59.2	1.89	18.72	730	1544	32.10
T_8	201.2	255.2	1.30	34.9	7.15	67.1	1.90	18.56	832	1793	33.34
T_9	169.7	216.3	1.01	32.6	5.78	53.3	1.82	18.42	659	1527	30.14
SEm(+)	12.12	15.92	0.095	2.02	1.054	4.16	0.242	1.459	42.1	108.1	2.66
CD(P=0.05)	36.34	47.73	0.285	NS	NS	12.47	NS	NS	126.3	324.1	NS

*DMA- Dry Matter Accumulation (g m^{-2}), CGR- Crop Growth Rate (g m^{-2} day^{-1}) **DAT- Days After Transplanting
***NS- Non Significant ****Treatment details: 100% recommended dose(RD) of NPK to all the crops in sequence (T_1),75% RD of NPK to all the crops in sequence (T_2), 50% RD of NPK to all the crops in sequence (T_3), 75% of RD of NPK to all the crops in sequence + 10 t FYM ha^{-1} 0nly to rice (T_4), 50% RD of NPK to all the crops in sequence + 10t FYM ha^{-1} only to rice (T_5), 75% RD of NPK to all the crops in sequence + 2t well decomposed fish meal (WDFM) ha^{-1} only to rice (T_6), 50 % RD of NPK to all the crops in sequence + 2t WDFM ha^{-1} to rice (T_7), 75% RD of NPK to all the crops in sequence + 5t paddy straw ha-1 only to rice (T_8) and 50% RD of NPK to all the crops in sequence + 5t paddy straw ha^{-1} only to rice (T_9)

in 75% RD of NPK to all the crops in sequence at all the crops in sequence + 10 t FYM ha^{-1} only to rice. Similar type of result was reported by Pal (2006).

Significantly variations were also obesrved in case of dry natter accumulation (DMA), plant height and number of branches per plant of sésame. The highest DMA (232.4 and 344.5 g m^{-2} at 60 and 90 DAS, respectively) was recorded with 100% RD of NPK to all the crops in sequence. But the CGR at 60 and 90 DAS did not vary with the nutritional management treatments. Plant height of green gram at harvest significantly differed and maximum plant height (98.45cm) was observed in the crop fertilized with 100% RD of NPK to all the crops in sequence. The number of branches per plant varied significantly from 2.82 in the treatment 50% RD of NPK to all the crops in sequence to 3.41 in the treatment where 100% of NPK applied to all the crops in sequence. The yield component of green gram i.e. number of capsules $plant^{-1}$ and number of seeds $capsule^{-1}$ also varied significantly with the different treatments (Table 3). The highest number of capsule $plant^{-1}$ (59.26) was observed in the crop fertilized with 100% RD of NPK to all the crops in sequence. The maximum number of seeds $capsule^{-1}$ (54.71) was observed in 75% RD of NPK to all the crops in sequence + 2 t WDFM ha^{-1} only to rice. However, there was no significant effect on 1000 seed weight of sesame. The highest seed (971 kg ha^{-1}) and stover yield (2704 kg ha^{-1}) of sesame was recorded with 100% RD of NPK applied to all the crops in sequence. In the case of harvest index, the highest value (28.51%) was obtained with 75% RD of NPK applied to all the crops in sequence + 2t WDFM ha^{-1} only to rice. Similar results were reported by Brahmachari *et al.*, (2009) that application of fish meal at 2t ha^{-1} in the rice based cropping sequence produced higher grain and straw yield of rice. Thus there is a positive residual effect of well decomposed fishmeal on the subsequent crops in terms of increasing yield component and yield.

The highest rice equivalent yield (8458.7 kg ha^{-1}) was obtained in the treatment where the rice crop received 75% RD of NPK applied to all the crops in sequence along with 2 t WDFM ha^{-1} only to rice followed by the treatment 50% RD of NPK along with 10t FYM ha^{-1} only to rice (8304.7 kg ha^{-1}). This result is corroborated with the findings of several workers (Pal *et al.*, 2005). It is apparent that the application of organic manure only to wet season rice could

Table 3. *Effect of different nutritional management treatments on growth parameters, yield components, yield and harvest index of sesame (Mean of two years)*

Treatments	Growth Components					Yield components			Yield		Harvest
	DMA		75-90 DAS CGR	Plant height (cm)	Number of branches $plant^{-1}$	Number of capsule $plant^{-1}$	Number of seeds $capsule^{-1}$	1000 seed weight (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	index (%)
	60 DAS	90 DAS									
T_1	224.5	341.6	2.57	98.45	3.41	57.59	53.65	3.14	971	2704	26.42
T_2	213.5	321.5	2.40	91.21	3.11	54.16	48.89	3.12	896	2530	26.15
T_3	173.4	281.6	2.36	84.41	2.82	48.24	42.62	2.95	775	2293	25.26
T_4	217.5	336.7	2.45	97.26	3.32	57.14	53.81	2.74	923	2234	28.34
T_5	185.4	306.3	2.38	89.46	2.98	51.87	47.11	2.92	812	2150	27.41
T_6	232.4	344.5	2.49	98.21	3.39	59.26	54.71	3.09	939	2355	28.51
T_7	198.6	311.2	2.40	90.24	3.05	52.91	46.42	3.15	830	2155	27.65
T_8	214.7	327.4	2.45	96.11	3.24	55.14	51.16	2.68	906	2352	27.81
T_9	177.5	288.7	2.36	88.42	2.91	49.98	43.45	2.72	792	2161	26.82
SEm(+)	10.41	14.51	0.254	3.051	0.170	2.261	2.242	0.119	30.7	85.1	0.850
CD (P=0.05)	31.21	43.50	NS	9.147	0.509	6.779	6.722	NS	92.1	255.1	NS

*DMA- Dry Matter Accumulation (g m^{-2}), CGR- Crop Growth Rate (g m^{-2} day^{-1}) **DAT- Days After Transplanting
***NS- Non Significant ****Treatment details: 100% recommended dose (RD) of NPK to all the crops in sequence (T_1),75% RD of NPK to all the crops in sequence (T_2), 50% RD of NPK to all the crops in sequence(T_3), 75% of RD of NPK to all the crops in sequence + 10 t FYM ha^{-1} 0nly to rice (T_4), 50% RD of NPK to all the crops in sequence + 10t FYM ha^{-1} only to rice (T_5), 75% RD of NPK to all the crops in sequence + 2t well decomposed fish meal (WDFM) ha^{-1} only to rice (T_6), 50 % RD of NPK to all the crops in sequence + 2t WDFM ha^{-1} to rice (T_7), 75% RD of NPK to all the crops in sequence + 5t paddy straw ha-1 only to rice (T_8) and 50% RD of NPK to all the crops in sequence + 5t paddy straw ha^{-1} only to rice (T_9)

Table 4. *Effect of different nutritional management treatments on rice equivalent yield and net production value in rice- lentil–sesame crop sequence (Mean of two years)*

Treatments	Rice equivalent yield (kg ha^{-1})	Net Returns (Rs. ha^{-1})	Net Production Value (NPV)
T_1	8178.3	39049.98	1.37
T_2	8161.9	34499.81	1.22
T_3	5991.9	27413.16	0.94
T_4	8304.7	41176.58	1.46
T_5	7430.7	36376.07	1.31
T_6	8458.7	42356.58	1.48
T_7	7608.4	37076.91	1.31
T_8	7992.3	40064.28	1.40
T_9	7018.2	33316.73	1.15

Treatment details: 100% recommended dose (RD) of NPK to all the crops in sequence (T_1), 75% RD of NPK to all the crops in sequence (T_2), 50% RD of NPK to all the crops in sequence (T_3), 75% of RD of NPK to all the crops in sequence + 10 t FYM ha^{-1} 0nly to rice (T_4),50% RD of NPK to all the crops in sequence + 10t FYM ha^{-1} only to rice (T_5), 75% RD of NPK to all the crops in sequence + 2t well decomposed fish meal (WDFM) ha^{-1} only to rice (T_6),50 % RD of NPK to all the crops in sequence + 2t WDFM ha^{-1} to rice (T_7), 75% RD of NPK to all the crops in sequence + 5t paddy straw ha^{-1} only to rice (T_8) and 50% RD of NPK to all the crops in sequence + 5t paddy straw ha^{-1} only to rice (T_9).

substitute NPK dose of the crops in the sequence of the tune of 25% of the RD as it was observed that rice equivalent yield obtained from & 5% RD of NPK to all the crops along with organic manure (WDFM and FYM) was more than that obtained with 100% RD of NPK to all the crops in sequence (Table 4). The maximum net production value (1.48) was obtained in the treatments of 75% RD of NPK applied to all the crops in sequence along with 2t WDFM ha^{-1} only to rice and it was followed by the treatment 75% RD of NPK applied to all the crops in sequence + 10t FYM ha^{-1} only to rice. Observed that the net production value was highest when 75% RD of NPK applied to all the crops in sequence along with 2 t WDFM ha^{-1} applied to the rice crop in the rice based cropping sequence. Application of the fishmeal at 2t ha-1 was along with 75% RD of NPK in rice showed the best result under coastal saline zone of West Bengal (Brahmachari *et al.*, 2009).

Thus, it may be concluded that the direct effect of well decomposed fishmeal (WDFM) on rice and residual effect on succeeding lentil and sesame crops were as good as farm yard manure. The maximum rice equivalent yield and net returns in rice- lentil-sesame sequence was obtained from the crop treated with well decomposed fishmeal @ 2 t ha^{-1} only to rice along with 75% RD of NPK applied to all the crops in sequence. Thus the application of well decomposed fishmeal to rice and its residual effect on succeeding crop under saline coastal soil of West Bengal may be a low cost, locally suited technology for the poor farming community.

REFERENCES

Bandopadhyay, S., and Puste, A. M. (2002). Effect of integrated nutrient management on productivity and residual soil fertility status under different rice (Oryza sativa) pulse cropping systems in rainfed lateritic belt of West Bengal. *Indian Journal of Agronomy* **47**(1): 33-40.

Brahmachari, K., Pal, S., Kundu, R., Roy, T. K., Roychoudhury, S., and Das, A. (2009). Effect of nutrient management in rice-lentil (*paira*)-sesame cropping system under coastal saline zone of West Bengal. (In) Abstracts of the 4th World Congress on Conservation Agriculture “Innovations for improving Efficiency, Equity and Environment” New Delhi, India, 3-7 Feb., 2009. pp 218-219.

Jackson, M. L. (1967). Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi. pp 183-347 and 387-408.

Pal, S. (2006). Integrated nutrient management of different rice-based cropping systems in coastal saline zone of West Bengal. *Ph.D. Thesis*, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal.

Pal, S., and Brahmachari, K. (2005). Effect of organic and inorganic sources of nutrients on rice-*lathyrus*-greengram crop sequence under coastal saline zone of West Bengal. (In) Abstract Of the National Seminar on “Coastal Resource and their Sustainable Management : Issues and Strategies” Kalyani, 24-27th Nov. 2005. p 134.

Pal. S., Brahmachari, K., and Mondal, N. N. (2003). Effect of different sources of nutrients along with inorganic sources on rice-rapeseed-blackgram cropping sequence in coastal saline zone of West Bengal. *Journal of the Indian Society of Coastal Agricultural Research* **21**(2): 24-26.

Pal, S., Brahmachari. K., and Roy, T. K. (2005). Effect of different organic sources of nutrients along with inorganic sources on rice-lentil-sesame cropping sequences in coastal saline zone of West Bengal. (In) Abstracts of the 8th National Seminar on "Strategies for improved Farming and Ecological security of Coastal Region" CTCRI, Thiruvanathapuram, Kerala, 21-24th Dec., 2005, pp 35-36.

Patil, S. H., Talasilkar, S. C., and Mehta, V. B. (2000). Integrated nutrient management using fishmeal and fertilizers for rice (*Oryza sativa*). *Indian Journal of Agricultural, Sciences* **70**(1): 31-33.

Patra, A. K., Nayak, B. C., and Mishra, M. M., (2000). Integrated nutrient management in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. *Indian journal of Agronomy* **45**(3): 453-457.

Raju, R. A., and Reddy, M. N. (2000). Integrated management of green leaf, compost, crop residues and inorganic fertilizers in rice (*Oryza sativa*)-rice system. *Indian Journal of Agronomy* **45**(4):629-635.

J. Indian Soc. Coastal agric. Res. 30(1): 45-53 (2012)

Exploration, Evaluation and Conservation of Salt Tolerant Rice Genetic Resources from *Sundarbans* Region of West Bengal

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Traditional landraces represent important reservoir of potentially useful traits to be conserved for further varietal development programme. A germplasm collection mission was undertaken to collect known rice landraces for salt tolerance from *Sundarbans* region, West Bengal during December, 2011. The area surveyed includes coastal saline region of West Bengal, sub categorized into lower alluvial plain, deltaic flood plains, marshy/inundated area, coastal sand dunes and coastal plains with wide variation in soil types, salinity level and irrigation water quality. In all, 63 accessions of traditional rice landraces were collected from 48 collection sites in four blocks comprising Gosaba (35), Basanti (07), Sandeshkhalli (09), Canning (12) of South and North 24-Parganas districts of West Bengal. This includes a number of trait specific landraces including salt tolerant, lowland and scented rice genotypes, which may be utilized in rice breeding programmes of the country. Wide range of on-farm variability was recorded among collected rice landraces for various morpho-agronomic traits. *Dudheswar*, *Talmugur* and *Nonabokra* has been identified as salt tolerant doner for breeding salt tolerant varieities for lowland conditions.

*(**Keywords:** Collection, evaluation, landrace, Oryza sativa, salt tolerant, variability)*

Traditional landraces are important reservoirs of potential traits. Plant breeders utilize these landraces in varietal improvement programme for developing high yielding varieties. These landraces or farmer varieties are primitive cultivars that were grown by ancient farmers and their successors (Biodiversity Act, 2002). With rich source of genetic variation, these landraces are nurtured and cultivated through traditional method of selection. Furthermore, farmers prefer cultivating these landraces, as these were the only option under unfavorable areas where modern crop varieties are not well adopted. However, now a days cultivation of traditional landraces being fast depleted due to adoption of high yielding modern varieties. Considering the ever changing climatic condition, development of stress tolerant varieties is being emphasized for enhancing production and productivity of any crop for which collection, characterization and conservation of traditional landraces is essential.

Rice is the staple food for most Asian people, but problem soils and unfavorable agro-climatic conditions pose a threat on rice production and productivity. Soil salinity has become the single largest factor limiting rice production in coastal regions of the country. Globally it affects about 1000 million hectares of cultivable land, where it is quite challenging in enhancing rice productivity. In India, about 6.73 million ha is salt affected posing limitation in enhancing rice productivity. Millions of hectares in the coastal regions of India are left uncultivated or are grown with very limited yields because of non availability or less availability of suitable rice varieties for this ecosystem. Rice is one of the few crops that can grow on most of the coastal saline soils despite being sensitive to salt stress. Developing salt tolerant rice cultivars is the most efficient way to stabilize rice production and alleviate food insecurity and poverty in coastal region. The vast genetic variability in tolerance to salinity in rice makes it suitable for further improvement through breeding. Few traditional salt tolerant rice landraces such as *Pokkali* and *Nonabokra* have been used in conventional breeding programmes to develop high yielding salt tolerant varieties. For further development of high yielding salt tolerant rice varieties, it is required to enrich the salt tolerant rice genetic resources. Buu *et al.*, 2002 reported that characterization and evaluation of traditional landraces provides information necessary in the identification of initial materials for hybridization to produce varieties with improved productivity and quality. Though the development

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of rice varieties to improve productivity in salt affected areas is continuing for the last two decades, progress in this respect is very slow probably due to narrow genetic base. It is felt that the success of the development of a variety lies primarily with the availability of salt tolerant landraces. Coastal region in the eastern parts of the country, characterized by a wide variation in soil types, soil salinity, quality of irrigation water and land uses is extremely dynamic with apparent long term and seasonal changes. The major part of the coastal region falls within the boundary of the districts like South 24 Parganas and North 24 Parganas, popularly known as 'the *Sundarbans*'.

The *Sundarbans* region falls within the geographical boundary of both India and Bangladesh with an area of 2.50 million ha (Hazra *et al.*, 2002). The Indian part of *Sundarbans* (Bengal Basin) comprises of coastal region of the districts of North and South 24-Parganas between 21° 30′N & 22° 40′48″ N latitude & 88° 1′48″ E & 89° 04′48″ E longitudes. It is bounded by the river Hoogli on the West, Bay of Bengal on the South, Ichhamati, Kalindi, Raimangal rivers on the east and "Dampier Hodges line" on the north. In India, the geographical area of this region is about 0.963 million ha out of which 0.449 million ha is inhabited and 0.426 million ha is under wetland mangrove forest (Bandyopadhayay *et al.*, 2003). A number of distributaries, channels and tidal creeks dissect the region forming 102 deltaic Islands out of which 54 Islands are under habitation. These inhabited areas are protected from ingression of saline water from rivers by earthen embankments thus making the soil cultivable. This region is having a flat topography with an elevation of about 3-8 meter from MSL (Hazra *et al.*, 2002). In view of providing salt tolerant rice genetic resources for breeding programmes, augmentation of rice germplasm from salt prone areas in *Sundarbans* was planned under National Initiative on Climate Resilient Agriculture (NICRA) project being in operation at NBPGR, New Delhi. The available published information has helped the exploration team for proper planning and executing the programme to collect the germplasm of known landraces of rice for salinity tolerance.

MATERIALS AND METHODS

Exploration and germplasm collection

National Bureau of Plant Genetic Resources (NBPGR), New Delhi has planned the exploration programme for collection of salt tolerant rice landraces from *Sundarbans* and was executed by its Exploration Base Centre, Cuttack, Odisha during December, 2011. Keeping in view the higher level of soil salinity in the region due to the occurrence of cyclonic storm 'AILA' during May, 2009 with saline ingression in the cultivated lands in *Sundarbans* region, the exploration was undertaken in Gosaba, Basanti, Canning and Sandeshkalli blocks under North and South 24-Parganas districts of West Bengal (Fig. 1). The period of collection was selected (December) as per the maturity / harvesting time of rice landraces. Biased, random and bulk sampling methods were followed for sample collection (Fig.2).

Panicles and freshly harvested seeds were collected from each ecological region (macro-niche) the farmer's field, threshing yards and farm stores. Due attention was given to collect variable disease / pest free seeds with sufficient quantity (100-200 grams per sample). Comprehensive data for morphological traits viz. 1000 grain weight, seed size (length and breadth), lemma palea colour, kernel colour, scent, awning, basal leaf colour, blade colour, blade pubescence, ligule colour, ligule shape, collar colour and auricle colour was recorded. The

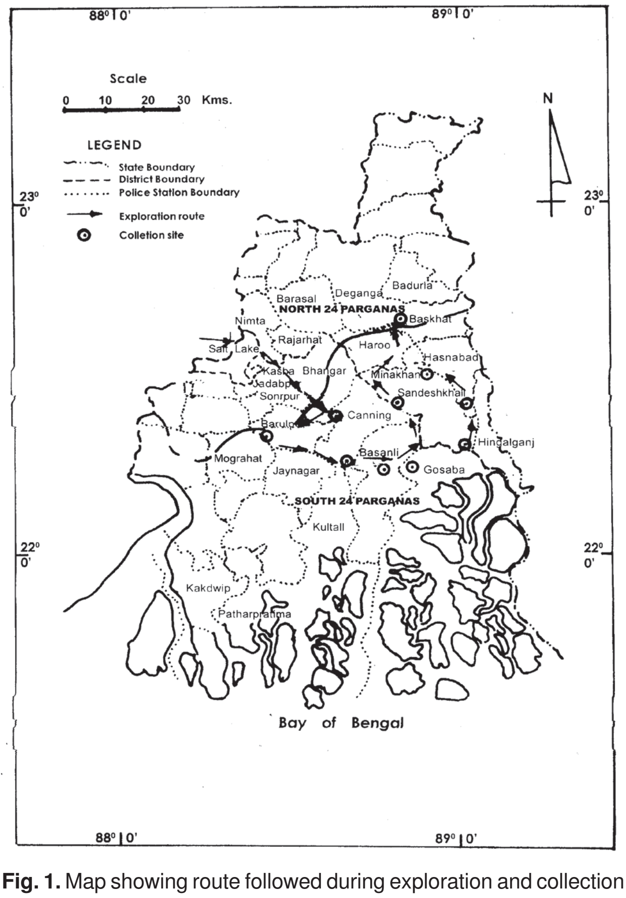

Fig. 1. Map showing route followed during exploration and collection of rice germplasm from Sundarbans region, West Bengal

collected seeds were cleaned and dried to optimum moisture level and one set was deposited for conservation in National Gene Bank for long-term storage and national accessioning. The other set was retained for seed multiplication and characterization for agro-morphological traits in collaboration with CRRI. Information of detailed passport and GPS data, route map, range of variability among the landraces, duration and other desirable traits were recorded as per the passport data book published by NBPGR, New Delhi for documentation and future use.

Fig. 2. Germplasm sampling from farmer's field at Gosaba

Climate and physiographic condition

The explored area represented variable agro climatic niche with wide range of edaphic and environmental conditions. It experiences a subtropical monsoon climate, classified as hot humid with three distinct seasons (summer, winter and monsoon). The average minimum and maximum temperature varies between 13.6ºC to 38.3ºC and average annual precipitation is about 1,600 to 1,800 mm (Gopal and Chauhan, 2005). The area belongs to the broad geographic unit i.e. alluvial and deltaic plains of West Bengal that can be sub-categorized into lower alluvial plain, deltaic flood plains, marshy / inundated area, coastal sand dunes and coastal plains. The soils of the region varies from Loamy in texture with pH neutral to slight alkaline in upper deltaic area to fine textured soil with pH acidic to alkaline (pH 5.0-8.0) in lower deltaic areas. Soils of marshy area may be categorized as fine texture with acidic to neutral in reaction. Brownish yellow to dark reddish brown mottles are noticeable in the area. As regards the fertility status of soils, these soils are in general low in available nitrogen, medium in available phosphorus and high in available potassium (Bandyopadhyay *et al.*, 2003). Mangrove is the natural vegetation in the tidal water marshes while salt tolerant, fruit trees, common agroforestry plants, common species of natural vegetation and common trees found in the coastal region of the state. Among cultivated field crops rice, maize, jute, mesta, sugarbeet, cotton, sunflower, chilli and watermelon are commonly grown in the region. A good number of published literature exists on vegetation of Sundarbans (Naskar and Guha Bakshi, 1987; Chakrabarti; 1995; Guha Bakshi *et al.*, 1999). Rice is the predominant crop during Kharif season followed by brinjal, tomato, chilli etc. Crop cultivation followed by pisciculture is the major land use pattern and source of economy in Sundarban region. Almost the entire cropped area of the region is mono cropped growing rainfed tall indica rice varieties in monsoon season, where sowing and transplanting was done during June and July respectively. The medium duration crop is usually harvested during November-December and late duration rice is harvested during December-January. Cultivation of late duration rice is preferred than short and medium duration rice varieties due to the prevalence of waterlogging for a long period. It was observed that good quality irrigation facility is not available in this region. The underground water (up to 250 m.) is usually saline and unsuitable for irrigation. The most practical way of irrigation resources is through surface collection of excess rainwater as dugout farm ponds of approximately three meter depth.

RESULTS AND DISCUSSION

The present study of exploration and collection of rice germplasm showed that *Sundarbans* region holds rich genetic variability in traditional landraces adapted to higher levels of soil salinity. The landraces are also varying in adaptation to rainfed upland, medium land and low land ecosystem. A total of 63 accessions were collected from 48 collection sites spread over four blocks in two districts of West Bengal (Table 1).

The district wise collection of the rice germplasm includes 54 accessions from three blocks viz. Gosaba, Basanti, Canning of South 24 Parganas and nine accessions from one block Sandeshkhalli of North 24 Parganas (Table 2).

Both the districts (North & South 24 Parganas) are traversed by a number of spill channels of Hoogli river. The Bay of Bengal through the network of rivers spreads its long arms, which are the chief sources of brackish water in this region. Most of

Table 1. *List of rice germplasm collections from Sundarbans region*

Sl. No.	IC. No.	Vernacular name	Site of collection	
			Mandal	District
1	593980	Sabita patnai	Canning-I	24 Pgs (S)
2	593981	Gitanjali patnai	Canning-I	24 Pgs (S)
3	593982	Malapoti patnai	Canning-I	24 Pgs (S)
4	593983	Lathi patnai	Canning-I	24 Pgs (S)
5	593984	Hanseswari	Canning-I	24 Pgs (S)
6	593985	Dudheswar	Canning-I	24 Pgs (S)
7	593986	Benimadhav	Canning-I	24 Pgs (S)
8	593987	Desipatnai	Sandeshkhali	24 Pgs (N)
9	593988	Gopalbhog	Basanti	24 Pgs (S)
10	593989	Auspachali	Sandeshkhali	24 Pgs (N)
11	593990	Odasal	Sandeshkhali	24 Pgs (N)
12	593991	Darsal	Sandeshkhali	24 Pgs (N)
13	593992	Heuse	Sandeshkhali	24 Pgs (N)
14	593993	Darsal	Sandeshkhali	24 Pgs (N)
15	593994	Phuterdhan	Sandeshkhali	24 Pgs (N)
16	593995	Kamini	Sandeshkhali	24 Pgs (N)
17	593996	Ranidhan	Sandeshkhali	24 Pgs (N)
18	593997	Niko	Basanti	24 Pgs (S)
19	593998	Dudheswar	Basanti	24 Pgs (S)
20	593999	Marisal	Basanti	24 Pgs (S)
21	594000	Malabati	Gosaba	24 Pgs (S)
22	594001	Rajlaxmi	Gosaba	24 Pgs (S)
23	594002	Kanak chur	Basanti	24 Pgs (S)
24	594003	Talmugur	Basanti	24 Pgs (S)
25	594004	Getu	Basanti	24 Pgs (S)
26	-	Gobindabhog	Gosaba	24 Pgs (S)
27	594005	Rupsal	Gosaba	24 Pgs (S)
28	594006	Narasinghajatta	Gosaba	24 Pgs (S)
29	594007	Kaminibasa	Gosaba	24 Pgs (S)
30	-	Gheuse	Gosaba	24 Pgs (S)
31	594008	Jarava	Gosaba	24 Pgs (S)
32	594009	Kalomota	Gosaba	24 Pgs (S)
33	594010	Khejurchhodi	Gosaba	24 Pgs (S)
34	594011	Katrangi	Gosaba	24 Pgs (S)
35	594012	Sitabhog	Gosaba	24 Pgs (S)
36	594013	Kumrogoor	Gosaba	24 Pgs (S)
37	594014	Dudheswar	Gosaba	24 Pgs (S)
38	594015	Marisal	Gosaba	24 Pgs (S)
39	594016	Sada patnai	Gosaba	24 Pgs (S)
40	594017	Tulaipanji	Gosaba	24 Pgs (S)
41	594018	Malabati	Gosaba	24 Pgs (S)
42	-	Boyarbot	Gosaba	24 Pgs (S)
43	-	Gobindabhog	Gosaba	24 Pgs (S)
44	594019	Nonabokra	Gosaba	24 Pgs (S)
45	594020	Talmugur	Gosaba	24 Pgs (S)
46	-	Dudheswar	Gosaba	24 Pgs (S)
47	-	Dadsal	Gosaba	24 Pgs (S)
48	594021	Sada getu	Gosaba	24 Pgs (S)
49	-	Kalonunia	Gosaba	24 Pgs (S)
50	-	Dudhkamal	Gosaba	24 Pgs (S)
51	594022	Marisal	Gosaba	24 Pgs (S)
52	594023	Haldibatola	Gosaba	24 Pgs (S)
53	594024	Hoogla	Gosaba	24 Pgs (S)
54	594025	Malabati	Gosaba	24 Pgs (S)
55	594026	Asfalmota	Gosaba	24 Pgs (S)
56	594027	Nonabokra	Gosaba	24 Pgs (S)
57	-	Darsal	Gosaba	24 Pgs (S)
58	594028	Kanta rangi	Gosaba	24 Pgs (S)
59	594029	Marisal	Canning-I	24 Pgs (S)
60	594030	Kamini	Canning-I	24 Pgs (S)
61	594031	Kumarmani	Canning-I	24 Pgs (S)
62	594032	Palbeda	Canning-I	24 Pgs (S)
63	594033	Laxmi patnai	Canning-I	24 Pgs (S)

the areas have very low elevations (average being 4-6m above MSL). Major parts of the coastal area occur in the form of low laying marshy lands prone to high salinity level. The lower elevated areas are usually under water during most of the period of the year which is exposed for few months during dry season and used for cultivation of crops.

Selective varieties of rice such as Nonabokra, Getu, Kalonunia, Talmugur are commonly grown in high salinity area. Due to problematic soil conditions and agro climatic constraints the entire area is almost mono-cropped with rainfed rice during monsoon period. The land remains fallow during the rest of the period due to lack of good quality irrigation water. Rice varieties suitable for higher

Table 2. *Distribution of rice landraces in Sundarbans*

Sl. No.	Collection site		No. of sites	No. of accessions
	Block	District		
1.	Gosaba	24 Pgs (S)	26	35
2.	Basanti	24 Pgs (S)	05	07
3.	Canning	24 Pgs (S)	10	12
4.	Sandeshkhalli	24 Pgs (N)	07	09
Total	04	02	48	63

Table 3. *In-situ variability among salt tolerant rice genetic resources collected fron Sundarbans*

Sl #	IC. No.	Vernacular name	Grain length	Grain width	Spikelet colour	Kernel colour	100 grain Wt.	Basal leaf colour	Blade colour	Blade pubescence	Ligule colour	Collar colour	Auricle colour
1	593980	Sabita patnai	6.45	2.91	S	LB	2.80	Green	Green	Intermediate	White	Pale green	Pale green
2	593981	Gitanjali patnai	7.10	2.10	S	W	2.48	Green	Green	Intermediate	White	Pale green	Pale green
3	593982	Malabati patnai	5.66	2.10	Br. Fu.	R	2.48	Green	Green	Intermediate	White	Pale green	Pale green
4	593983	Lathi patnai	6.90	2.10	S	W	2.86	Green	Green	Intermediate	White	Pale green	Pale green
5	593984	Hanseswari	6.15	2.25	S	W	3.24	Light Purple	Green	Intermediate	White	Pale green	Pale green
6	593985	Dudheswar	6.15	1.75	S	W	1.66	Green	Green	Intermediate	White	Green	Pale green
7	593986	Benimadhav	6.15	2.25	S	R	2.63	Green	Green	Intermediate	White	Green	Pale green
8	593987	Desipatnai	6.85	2.00	S	R	2.39	Green	Green	Intermediate	White	Green	Pale green
9	593988	Gopalbhog	5.35	2.40	Br. Sp.	LB	2.87	Green	Green	Intermediate	White	Green	Pale green
10	593989	Auspachali	7.10	2.35	S	R	2.68	Light Purple	Green	Intermediate	White	Green	Pale green
11	593990	Odasal	6.30	2.05	Br. Fu.	R	2.41	Green	Green	Intermediate	White	Green	Pale green
12	593991	Darsal	5.10	2.00	S	W	1.46	Green	Green	Intermediate	White	Green	Pale green
13	593992	Heuse	5.85	2.35	G	W	2.83	Green	Green	Intermediate	White	Pale green	Pale green
14	593993	Darsal	5.30	2.00	S	W	1.57	Green	Green	Intermediate	White	Green	Pale green
15	593994	Phuterdhan	6.00	2.70	S	W	2.74	Green	Green	Intermediate	White	Pale green	Pale green
16	593995	Kamini	4.95	2.00	S	W	1.45	Green	Green	Intermediate	White	Green	Pale green
17	593996	Ranidhan	6.25	2.00	B	LB	1.76	Green	Green	Intermediate	White	Green	Pale green
18	593997	Niko	6.10	2.50	S	W	2.81	Green	Green	Intermediate	White	Green	Pale green
19	593998	Dudheswar	6.10	2.00	S	W	1.44	Green	Green	Intermediate	White	Green	Pale green
20	593999	Marisal	4.50	2.40	S	W	2.07	Green	Green	Intermediate	White	Green	Pale green
21	594000	Malabati	6.55	2.55	Br.sp.	R	2.64	Light Purple	Green	Intermediate	White	Purple	Pale green
22	594001	Rajlaxmi	6.94	2.00	S	W	2.36	Green	Dark green	Intermediate	White	Green	Pale green
23	594002	Kanakchur	6.10	2.10	S	W	1.53	Green	Dark green	Intermediate	White	Green	Pale green
24	594003	Talmugur	6.20	2.35	Br.fu	R	2.57	Green	Green	Intermediate	White	Green	Pale green
25	594004	Getu	5.95	2.30	S	W	2.12	Green	Green	Intermediate	White	Green	Pale green
26	-	Gobindabhog	4.85	1.70	S	W	0.93	Green	Green	Intermediate	White	Pale green	Pale green
27	594005	Rupsal	6.20	1.80	S	W	1.59	Green	Green	Intermediate	White	Green	Pale green
28	594006	Narasinghajatta	5.15	2.00	S	W	1.65	Green	Green	Intermediate	White	Green	Pale green
29	594007	Kaminibasa	5.15	1.75	S	W	1.03	Green	Green	Intermediate	White	Green	Pale green
30	-	Gheuse	6.15	2.35	G	W	2.72	Green	Green	Intermediate	White	Green	Pale green
31	594008	Jarava	6.75	2.15	S	W	2.44	Green	Dark green	Intermediate	White	Green	Pale green
32	594009	Kalomota	5.30	2.25	Br.fu	R	2.72	PPlines	Green	Intermediate	White	Purple	Purple
33	594010	Khejurchhodi	5.60	2.40	P.P. sp.	W	2.99	Green	Green	Intermediate	White	Green	Pale green
34	594011	Katrangi	6.20	2.15	Br.fu.	R	2.38	Green	Green	Intermediate	White	Green	Pale green

Contd.

Sl #	IC. No.	Vernacular name	Grain length	Grain width	Spikelet colour	Kernel colour	100 grain Wt.	Basal leaf colour	Blade colour	Blade pubescence	Ligule colour	Collar colour	Auricle colour
35	594012	Sitabhog	4.75	2.15	S	W	1.50	Green	Green	Intermediate	White	Green	Pale green
36	594013	Kumrogoor	6.00	2.55	S	W	2.92	Green	Green	Intermediate	White	Green	Pale green
37	594014	Dudheswar	5.85	2.00	S	W	1.72	Green	Green	Intermediate	White	Green	Pale green
38	594015	Marisal	5.10	2.20	S	W	2.02	Green	Green	Intermediate	White	Green	Pale green
39	594016	Sada patnai	7.55	2.00	S	LB	2.90	Green	Green	Intermediate	White	Green	Pale green
40	594017	Tulaipanji	6.25	2.00	S	W	1.35	Green	Green	Intermediate	White	Green	Pale green
41	594018	Malabati	5.90	2.05	Br.fu.	R	2.53	PPlines	Green	Intermediate	White	Purple	Purple
42	-	Boyarbot	5.60	2.44	Br.fu.	W	2.80	Green	Green	Intermediate	White	Green	Pale green
43	-	Gobindabhog	4.25	2.22	S	W	1.02	Green	Green	Intermediate	White	Green	Pale green
44	594019	Nonabokra	6.25	2.60	S	R	2.87	Green	Green	Intermediate	White	Green	Pale green
45	594020	Talmugur	6.55	2.30	Br.fu.	R	2.73	Green	Green	Intermediate	White	Green	Pale green
46	-	Dudheswar	6.15	1.90	S	W	1.75	Green	Green	Intermediate	White	Green	Pale green
47	-	Dadsal	5.35	2.00	S	W	1.18	Green	Green	Intermediate	White	Green	Pale green
48	594021	Sada getu	5.65	2.40	S	LB	2.42	Green	Green	Intermediate	White	Pale green	Pale green
49	-	Kalonunia	5.85	1.95	Bl.	W	1.34	Green	Green	Intermediate	White	Pale green	Pale green
50	-	Dudhkamal	4.80	2.60	S	SB	2.88	Green	Green	Intermediate	White	Green	Pale green
51	594022	Marisal	4.95	2.20	S	W	2.05	Green	Green	Intermediate	White	Pale green	Pale green
52	594023	Haldibatola	5.88	2.45	G	W	2.66	Green	Green	Intermediate	White	Green	Pale green
53	594024	Hoogla	6.20	2.50	G	W	2.93	Green	Green	Intermediate	White	Green	Pale green
54	594025	Malabati	6.20	2.30	Br. Fu.	SB	2.61	PPlines	Green	Intermediate	White	Purple	Purple
55	594026	Asfalmota	6.95	2.50	S	W	3.30	PPlines	Green	Intermediate	P.P. lines	Green	Pale green
56	594027	Nonabokra	6.10	2.35	Br.	R	2.87	Green	Green	Intermediate	White	Pale green	Pale green
57	-	Darsal	6.05	2.20	Br.fu.	R	2.63	Green	Green	Intermediate	White	Pale green	Pale green
58	594028	Kanta rangi	5.90	2.10	Br.	R	2.67	Green	Green	Intermediate	White	Green	Pale green
59	594029	Marisal	4.50	2.25	S	W	2.00	Green	Green	Intermediate	White	Green	Pale green
60	594030	Kamini	7.05	2.00	S	R	2.89	Green	Green	Intermediate	White	Green	Pale green
61	594031	Kumarmani	6.10	2.00	Br.	W	1.65	Green	Green	Intermediate	White	Pale green	Pale green
62	594032	Palbeda	7.31	2.20	S	W	2.78	Green	Green	Pubescent (hairy)	White	Pale green	Pale green
63	594033	Laxmi patnai	4.90	2.00	S	W	0.99	Green	Green	Intermediate	White	Pale green	Pale green

Spikelet color- S- Straw, Br. Fu.- Br. furrows, Br.Sp.- Br. Spot on straw, G- Gold/gold furrow, P.P. sp.- P.P. spots on straw, Bl.- Black, Br.- Brown

Kernel color- LB- Light brown, W- White, SB- Seckled brown, R- Red salinity level along with other traits like fine grain quality, scented rice, and good for popped / puffed / beaten rice are preferred by the farmers.

On-farm variability among collected germplasm

The diversity collected includes landraces of very tall, tall, intermediate in height with crop maturity of 100-160 days duration. Variability recorded among the landraces were foliage colour (green, light purple, purple lines), blade pubescence (intermediate, hairy, partial pubescent), colour of auricle (purple, pale green), ligule (white, purple lines) and collar (green, pale green, purple), grain density (partial/full filled), kernel colour (white, brown, red, golden) and lemma palea colour (golden, brown, red, black) (Table 3).

Other variability encountered during the exploration was plant type (very tall, tall, intermediate and semi-dwarf), internode length (short, long), stiffness of straw (stiff, moderate, weak), panicle type (open, intermediate), awn (+/-), scent (+/-), number of grains per panicle (high, medium), grain density (partial/full filled). Variability was also pronounced for grain type ranging from short, medium, long sized with bold and slender shape (Fig. 3).

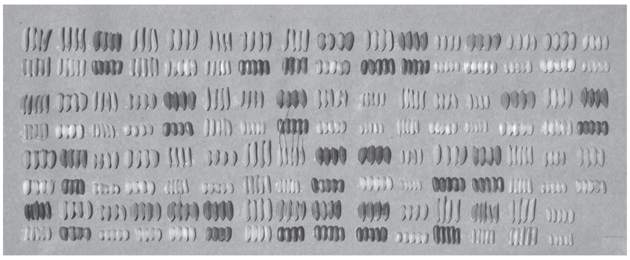

Fig. 3. Grain diversity among collected rice landraces

The germplasm from high saline area represented collections from the farmers fields that was completely inundated by saline water ingression due to the occurrence of cyclonic storm (AILA) during May, 2009. Farmers informed that their cultivated lands were inundated for 20-25 days with 10-15 feet of standing saline water making the soils highly saline. Therefore there was no crop cultivation (even weeds/ grasses could not grow) during 2010. Majority of traditional rice varieties grown by the farmers are known to tolerate salinity stress to some extent. The landraces like *Getu* and *Nonabokra* has been widely used in salt tolerant rice breeding programme by CSSRI, Karnal and its Regional Station, Canning, West Bengal. During 2011, selective rice varieties such as *Talmugur, Kalonunia, Getu, Nonabokra, Marisal, Darsal, Gheuse, Boyarbot, Kumarmani, Dadsal* and *Asfalmota* were grown in higher saline soils. During the survey and from farmer's information the landraces viz. *Odasal (IC.No. 593990), Getu (IC.No. 594004), Nonabokra (IC.No. 594027), Marisal (IC.No. 593999) Darsal (IC.No. 593991), Talmugur (IC.No. 594003), Dadsal* and *Kalonunia* were identified as salt tolerant. Field evaluation of some of the salt tolerant rice germplasm at CSSRI, RRS, Canning Town revealed that the grain yield varied from 2.68 to 3.81 tha^{-1} in case of *Gavir Saru* and *Patnai* 23 respectively for semi-deep water situation and 1.97 to 3.61 tha^{-1} in case of *Pokkali* and *Dudheswar* respectively for low land conditions (Table 4). Out of these *Dudheswar* (IC No. 593998), *Talmugur* (IC No. (594003) and *Nonabokra* (IC No. 594027) has been identified as salt tolerant doner for breeding salt tolerant rice varieties for lowland conditions.

***Table 4.** Performance of salt tolerant rice germplasm at CSSRI, RRS, Canning Town*

Germplasm	Height (cm)	EBT	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Salinity Score
Semi-deep water					
Gavir Saru	133.7	9	2.68	5.81	3.0
NC 678	170.3	6	2.69	4.87	3.0
Asfal	159.0	5	3.18	4.77	2.5
Sada Mota	166.0	6	2.99	4.49	2.5
Najani	166.3	5	3.04	5.30	2.5
Tilak Kanchari	168.0	10	3.18	6.28	2.5
Patnai 23	143.7	7	3.81	5.85	2.0
Low land					
Dudheswar (IC No. 593998)	135.3	10	3.61	6.02	1.5
Baktulsi	136.3	6	2.80	3.65	2.0
Talmugur (IC No. 594003)	137.3	5	2.04	2.89	2.5
Velki	136.7	12	2.14	5.25	2.5
Nona bokra (IC No. 594027)	129.3	9	3.35	6.41	1.5
Pokkali (check)	128.0	5	1.97	3.16	3.0

*EBT : Ear bearing tillers

The farmers prefer to grow vegetable crops such as tomato, beans, brinjal in the bunds of the rice field to get some return as insurance in case of the failure of rice crop. Besides rice, the farmers also cultivating other crops like maize, chilli, cabbage, cauliflower, turmeric, ginger and taro in the uplands and backyards in the region. Farmers are growing fine quality rice varieties with salt tolerance ability among which *Dudheswar* ranks first followed by

Kanakchur and *Laxmi patnai*. *Kanakchur* is used for preparation of a local favorite called '*Moa*'. These varieties are giving 2-3 times more economic return to the farmer. Few other trait specific landraces viz. *Kamini, Gobinda bhog, Sita bhog, Tulaipanji* (Scented); *Phuterdhan (IC.No.593994) Gheuse, Katrangi (IC.No.594011)* and *Hoogla (IC.No.594024)* with popping and puffing quality were collected during the exploration.

CONCLUSION

Rice is one of the most suitable crops for saline soils although it is usually considered moderately sensitive to salinity (Akbar *et al.*, 1972, Korkor and Abdel-Aal 1974, Maas and Hoffman 1977, Mori *et a1.* 1987). Inspite of rich indigenous diversity of stress tolerant rice genetic resources, the research workers are utilizing very limited and specific genotypes from other sources. The Indian diverse agroclimatic conditions helped not only in natural screening and selection of the germplasm against biotic and abiotic stresses, but also provides genotypes with wide genetic base. During the exploration it was observed that local landraces of salt tolerant rice germplasm such as *Getu, Nonabokra, Talmugur, Kalonunia, Darsal* and *Marisal* are very much confined to small pockets with higher soil salinity. Some potential salt tolerant landraces like *Matla* and *Hamilton* has completely vanished from the surveyed area. The intervention of various co-operative societies and adoption of pisciculture are playing important role in discouraging the cultivation of local landraces. Though earlier exploration for collection of salt tolerant rice germplasm was undertaken by crop based institutes, a systematic attempt in this regard with objectives for augmentation, characterization and evaluation of salt tolerant landraces is required for further research. For getting higher yield potential farmers are looking for modern varieties and researchers have already engaged in developing high yielding salt tolerant rices. However, there is a need for further exploration in coastal saline area of the country as well as detailed characterization and evaluation for further improvement. Hence, the present effort for exploration and collection of salt tolerant rice germplasm from coastal saline region of West Bengal is an important initiative for enriching the specific group of rice genetic resources. *Sundarbans* with vast coastal saline area extends further scope for intensive study, survey and collection of salt tolerant plant genetic resources.

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REFERENCES

Akbar, M., Yabuno, Y., Nakao, S. (1972). Breeding for saline resistant varieties of rice. I. Variability for salt tolerance among some rice varieties. *Japanese Journal of Breeding* **22**:277-284.

Bandyopadhyay, B. K., Maji, B., Sen, H. S. and Tyagi, N. K. (2003). *Coastal Soils of West Bengal-Their Nature, Distribution and Characteristics*, Bulletin No. 1/2003 Central Soil Salinity Research Institute, Regional station, Canning Town, W.B, India p.62.

Biological Diversity Act (2002) and Biological Diversity Rules (2004), *National Biodiversity Authority*, 2004, 57 pp.

Buu, B. C.,Tai, N. V., Luy, T. T. and Lang, N. T. (2002). Rice germplasm conservation in Mekong Delta. *In*: Plant Genetic Resources Conservation in Agriculture. MARD (ed.) Nong Nghiep Publishing House, Hanoi. pp 38-56.

Chakrabarti, P. (1995). Evolutionary history of the coastal quaternaries of the Bengal Plain, India. *Proceedings of the Indian National Science Academy* **61A**: 343–354.

Gopal, B. and Chauhan, M. (2006). Biodiversity and its conservation in the Sundarban Mangrove Ecosystem. *Aquatic Sciences* **68**: 338–354.

Guhabakshi, D. N., Sanyal, P. and Naskar, K. R. (eds.), (1999). *Sundarbans Mangal*. Naya Prokash, Calcutta, 771 pp.

Hazra, S., Ghosh, S., Dasgupta, R. and Sen, G. (2002). Sea Level and associated changes in the Sundarbans. *Science and Culture* **68**: 309-332.

Korkor, S. A., Abdel-Aal, R. M. (1974). Effect of total salinity and type of salts on rice crop. *Agricultural Research Review* **52**(5):73-78.

Maas, E. V., Hoffman, G. J. (1977). Crop salt tolerance: current assessment. *ASCE Journal of Irrigation and Drainage Division* **103**: 1 15-1 34.

Mori, I. K., Kinoshita, T. (1987). Salt tolerance of rice callus clones. *Rice Genetic Newsletter* **4**: 112-I 13.

Naskar, K. R. and Guhabakshi, D.N. (1987). *Mangrove Swamps of the Sundarbans – An Ecological Perspective.* Naya Prokash,Calcutta, 263 pp.

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Effect of Drainage Systems on Crop Production and Sustainable Agriculture in Waterlogged Saline Lands

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This research study was started in the year 2005 at Pathareddypalem village and during 2006 at Kovelamudi village respectively, in the Guntur district of Andhra Pradesh, India. The experiment was conducted in the Krishna Western Delta canal command area. Data on soil salinity, crop yield, cropping pattern and intensity were collected and analyzed. The research study for four years in open sub surface drainage system indicated that the soil salinity decreased from an average 21.7 to 11.2 dS m^{-1} and the crop yield increased from an average of 2.2 to 4.9 t ha^{-1}. Cropping intensity also increased by 153%. The study at Kovelamudi on closed sub surface drainage system indicated that the average soil salinity decreased from 7.55 to 5.68 dS m^{-1}, average crop yield increased from 4.4 to 5.5 t ha^{-1} and cropping intensity by 160%. At both the pilot areas, only one crop (Rice) used to be grown during irrigation season (*Kharif*) and land used to be kept fallow during the remaining part of the year due to salinity and waterlogged problems. After the installation of drainage systems at both the pilot areas, the soils were reclaimed and therefore the farmers could grow green manure crop Dhaincha before Paddy and crops of *Sunhemp, Pillipesara* and *Jowar* for fodder as second crop after Paddy just after one year. After second year, the farmers are cultivating income generating crops like Maize, Blackgram and Greengram. Through there was an increase in the yield from 4.4 t ha^{-1} during 2005-06 to 5.4 t ha^{-1} during 2008-09 under Closed Sub Surface Drainage (CSSD), the huge escalation in total cost of cultivation owing to the increased labor wages resulted in decrease in net Benefit Cost Ratio from 0.20 during 2005-06 to 0.16 during 2008-09. However, the same has been increased from -0.39 during 2004-05 to -0.02 during 2008-09 under Opened Sub Surface Drainage (OSSD).

(***Key words:*** *Open sub surface drainage, Closed sub surface drainage, Soil salinity and Waterlogged saline lands)*

The rapid development of irrigation has brought irrigation water to farm holding and it is the major factor for enhancing food production in irrigated areas. Introduction of canal irrigation without provision for adequate drainage to take out excess seepage and irrigation water is bound to result in ground water rise and associated problem of salinity. This has caused millions of hectares of land gradually going out of production or experiencing reduced yields. It is estimated that an area of 8.4 million ha is affected by soil salinity and alkalinity in India of which about 5.5 million ha waterlogged saline area is distributed in the irrigation canal commands. In addition to this, about 2.5 million ha area is estimated to suffer from coastal salinity problems in different states of India. Water logging and salinity can be reduced to a considerable extent by lowering the water table to a designed level by constructing surface and sub surface drainage. The rapid development of irrigation has brought irrigation water to farm holding and it is the major factor for enhancing food production in irrigated areas. Introduction of canal irrigation without provision for adequate drainage to take out excess seepage and irrigation water is bound to result in ground water rise and associated problem of salinity. This has caused millions of hectares of land gradually going out of production or experiencing reduced yields. It is estimated that an area of 8.4 million ha is affected by soil salinity and alkalinity in India of which about 5.5 million ha waterlogged saline area is distributed in the irrigation canal commands. In addition to this, about 2.5 million ha area is estimated to suffer from coastal salinity problems in different states of India. Water logging and salinity can be reduced to a considerable extent by lowering the water table to a designed level by constructing surface and sub surface drainage.

The yields of major food grains have stagnated or declined since 2000. One of the ways to improve the food grain production is, restoring degraded or problematic soils and improving quality of surface and ground water (Lal, 2008). The total salt-affected area in the state of Andhra Pradesh is estimated as

8.18 lakh ha. The irrigation induced water logging and salinity were estimated to be 2.72 and 1.15 lakh ha respectively and these are the two major causes which lead to reduction in crop yields in most of the irrigated commands (Anonymous, 2006). It is also observed that continuous irrigation over the years without proper drainage also results in raising the ground water table to the root zone, thus leading to reduction in crop yields. From the results of the reconnaissance survey, an area of 35000 ha was identified as salt affected in the Krishna Western Delta (KWD) irrigated commands where the average grain yield of rice was as low as 1.5-2.5 t ha^{-1}.

The problem of increasing salinity caused by the rise of water table due to lack of proper drainage is considered as a major environmental problem that threatens the capital investment in irrigated agriculture and its sustainability. Drainage has not been given importance as much as irrigation by the farmers as well as the Government agencies. So there is a great demand for the concerned research and developmental efforts to reclaim all the salt affected and water logged soils and bring them back to profitable farming with increased agricultural production as well as cropping intensity. The only means to overcome the salinity and water logging permanently is selection and adoption of suitable sub surface drainage systems. To test and demonstrate the drainage need for control of soil salinity and water logging, a collaborative project of Acharya N.G.Agricultural University with Alterra, ILRI, The Netherlands, was approved by the Government of Andhra Pradesh, Bapatla as the main center. The Bapatla center is entrusted with the responsibility of solving the water logging and salinity problems by installation of open subsurface drainage (OSSD) and closed sub surface drainage system (CSSD) systems in the canal commands of Andhra Pradesh.

MATERIALS AND METHODS

A pilot area of 21.67 and 15.67 ha was selected at Pathareddy palem and Kovelamudi villages under Mutluru channel command of KWD in Guntur district to study the performance of open and closed sub surface drainage systems respectively, to overcome the severe problem of salinity and water logging.

The soil samples collected from 62 grid points at OSSD (Fig.1) and 64 grid points at CSSD of the pilot areas fixed at spacing of 60 m (OSSD), 50 m (CSSD) apart were analyzed for pH, ECe, water-soluble cations and anions, ESP, and available macro and micronutrients following the standard procedures described by Black (1965) and Richards (1954).

The soils of the both the pilot areas are deep and clayey in texture, with ECe ranging from 1.6 to 61.3 dS m^{-1} and pH from 6.7 to 8.4. Sodium is the dominant water soluble cation followed by Mg and Ca, while chlorides are the dominant water soluble anions followed by sulphates and bicarbonates. The ESP varies from 10.12 to 14.10 indicating that the soils are saline and not sodic in nature. The available nitrogen is low to medium, while the phosphorous and potassium are medium to high. The average values of ECe of ground water is highly saline and not suitable for agriculture. The soils are highly affected by water logging and salinity due to insufficient capacity of main drain to evacuate excess rainfall. The principal crop grown in both the pilot areas is rice during Kharif season which suffers badly due to patchy growth, poor tillering and ultimately result in less yields.

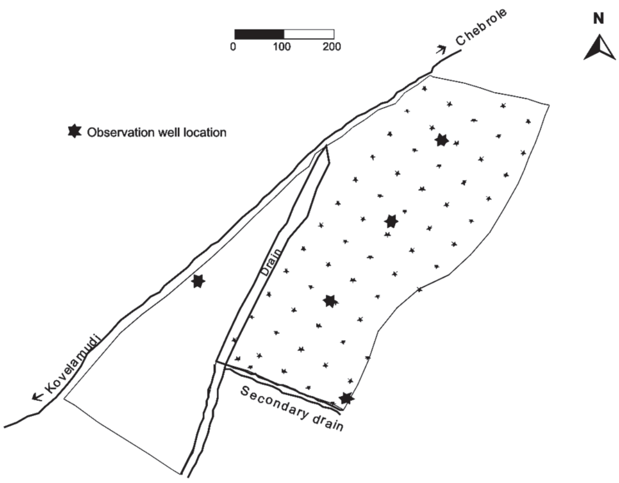

Fig. 1. Map showing the grid soil sample locations in Open sub surface drainage system at Pathareddy Palem drainage pilot area

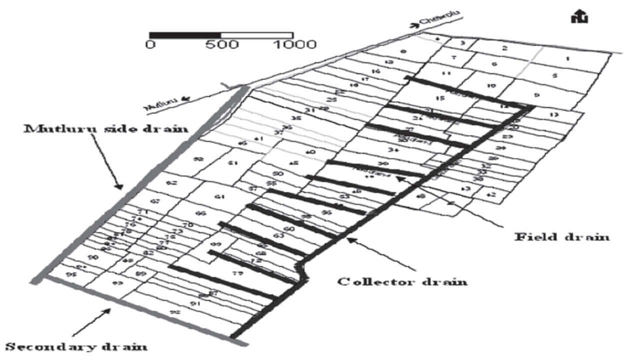

Fig. 2. Map showing open sub surface drainage system at Pathereddy Palem drainage Pilot area under Mutluru Channel Command of Krishna Western Delta

The open sub surface drainage system (Fig. 2) consists of 10 laterals covering a length of 1250 m and bottom width of 0.75 m with slope of 0.01% gradient, being properly dugged out with hydraulic excavator. The laterals were first connected to a collector drain. The collector drain was connected to a secondary drain and then to the Mutluru side drain to convey drain water offsite. The drainage coefficient was 1mm day^{-1}. Eight observation wells were installed up to 3.4 m depth in Mutluru channel command and four out of eight falls in the experimental site to monitor water table fluctuations and for sampling ground water for water quality determinations.

The closed sub surface drainage system (Fig. 3) consists of 10 laterals connected to a collector pipe which is passed through a sump and then to an existing Mutluru side drain. Corrugated perforated flexible PVC pipes of 80 mm diameter were used for ten laterals at a slope of 0.01% to a total length of 2145 m and these laterals are wrapped with nylon 60 mesh envelop material to avoid clogging and allow free flow of drained water through soil column. To these laterals by closing one end with end plug the other end was fixed to the 225 mm diameter collector pipe with pre-fabricated (225/80) T- joint or reducer. The collector drain was laid out perpendicularly to the laterals at a slope of 0.012% to a length of 480 m and at the end the collector outlet is made to pass through a sump and then to an existing drain (Mutluru side drain) in order to let out the collected drained out water either through gravity or pumped

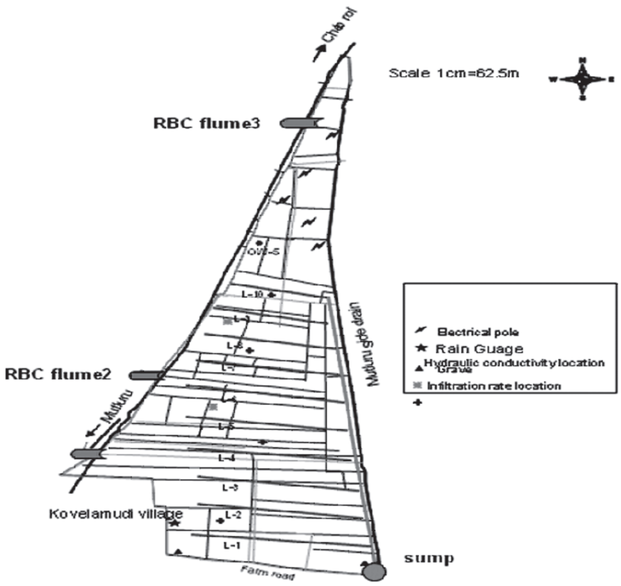

Fig. 3. Layout of closed subsurface drainage system at Kovelamudi pilot area

outlet arranged near the sump. The drainage coefficient was 1mm day^{-1}. Design parameters of closed subsurface drainage system were mentioned in Table 1. Five observation wells were installed up to 3.4 m depth in Mutluru channel command and four out of eight falls in the experimental site to monitor water table fluctuations and for sampling ground water for water quality determinations.

RESULTS AND DISCUSSION

Monitoring of the open subsurface drainage system during *Kharif* 2005-2009 clearly indicated that the system effectively controlled the ground water table in the root zone at a relatively shallow depth of 0.5-1.5m. The shallow water table also avoids excessive drainage while at the same time harmful salts that are brought in by the irrigation water were also reduced to a level ranging from 1.2 to 35.4 dS m^{-1}. Further the data on soil salinity at 62 grid locations showed a relative decrease in soil salinity during post drainage conditions with an

Table 1. *Design Parameters of CSSD*

Sl. No.	Design Parameters	Specifications
1.	Area covered	15.67 ha
2.	Hydraulic conductivity	0.45 m d^{-1}
3	Rainfall	900-1300mm
4	Drainage coefficient	1mm d^{-1}
5	Hydraulic head above the drains	0.4m
6	Depth of water table (May 2006)	2.35m
7	Drain depth	0.56-1m
8	Depth to impervious layer from drain level	5 m
9	Equivalent depth	5-6 m
10	Drain spacing	50 m
11	Lateral pipe line	Depth: 0.56-1m Diameter: 80 mm Slope: 0.01% Total length: 2145 m
12	Type of envelope material	Nylon 60 mesh
13	Collector pipe line	Depth: 0.58-0.95 mm Diameter: 225mm Slope: 0.012% Total length: 480m
14	Installation method	combination of mechanical and manual installation using a hydraulic excavator

average mean value of 11.6, 14.2, 12.9 and 11.8 dS m^{-1} (Table 1 & Fig. 4 and 5) during first, second, third and fourth year after installation respectively, which helped in increasing the grain yield.

After installation of drainage systems, there was a significant reduction in salinity at the pilot area (Table 2 & Fig. 6 and 7). In general, the soils with less than 2 dS m^{-1} salinity are considered as safe for almost all the crops and most of the crops can tolerate salinity up to 4 dS m^{-1}. At Kovelamudi, before installation of drainage systems, only 41% of the lands had ECe less than 4 dS m^{-1}. Four years after installation of drainage systems, this has increased to 51% i.e there is drastic change in improving saline area into non-saline area from 41% to 51%. Prasad *et al.*, (2007) also reported positive results with open sub surface drainage system in reducing the salinity of problematic soils.

The grain yield (Table 1, Fig. 5) data collected from 62 grid points indicated a steady increase from 2005 to 2009. The average grain yield obtained during *Kharif* 2006, 2007, 2008 and 2009 were 2.9 t ha^{-1}, 3.8 t ha^{-1}, 4.5 t ha^{-1} and 4.9 t ha^{-1} respectively, as against 2.2 t ha^{-1} (2005) before installation of the system. Further, an overall increase of 123 per cent in grain yield was observed by the end of four years after installation of the OSSD drainage system. The study at Kovelamudi on CSSD indicated that the average grain yield obtained during *Kharif* 2007, 2008 and 2009 were 4.6 t ha^{-1}, 5.3 t ha^{-1} and 5.5 t ha^{-1} respectively, as against 4.4 t ha^{-1} (2006) before installation of the system (Table 2 & Fig. 7). After 3 years of installation with an average 25% of the grain yield was increased in the CSSD system. Similar positive results were reported by Konanki and Uppugundur drainage pilot areas of Indo-Dutch net work project. (IDNP Comprehensive Report, 1995)

The cropping intensity was 100% with *kharif* rice only without any second crop before installation of the system where as the cropping intensity was also increased to 153 % by the end of four year after installation of the system allowing the farmers to raise Fodder Jowar, sunhemp and black gram as second crop during *Rabi* season in 53% of the drainage pilot area. The significant increase in crop yield and cropping intensity can be attributed to the direct effects of the introduction of open subsurface drainage system which in turn lowered the water table and decreased the soil salinity by leaching out the soluble salts from the root zone, there

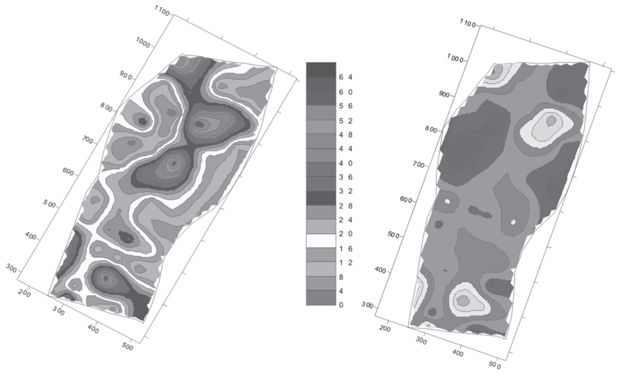

Fig.4. Impact of open sub-surface drainage system on summer soil salinity of Pathareddy Palem pilot area

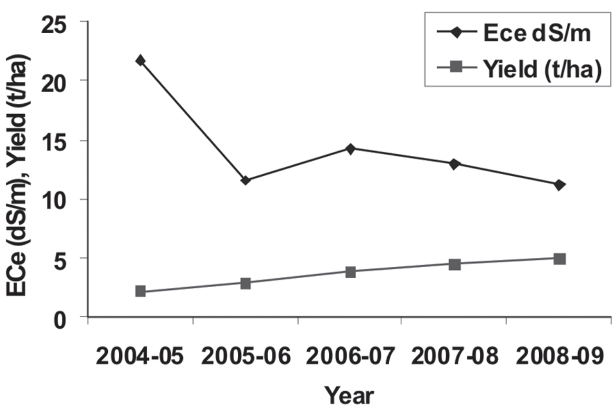

Fig. 5. Relationship between EC_e and Grain yield ($t\ ha^{-1}$) during 2005-2008

Table 2. *Effect of open sub-surface drainage system on soil salinity, grain yield and cropping intensity during 2005-2008*

Year	EC_e dS m^{-1}	Grain Yield ($t\ ha^{-1}$)	Cropping intensity (%)
2004 (before installation)	21.7	2.2	100
2005	11.6	2.9	125
2006	14.2	3.8	146
2007	12.9	4.5	153
2008	11.8	4.9	158

Table 3. *Effect of open sub-surface drainage system on soil salinity, grain yield and cropping intensity during 2006-2008*

Year	EC_e dS m^{-1}	Grain Yield ($t\ ha^{-1}$)	Cropping intensity (%)
2005-06 (Before installation)	7.55	4.4	100
2006-07	6.32	4.6	125
2007-08	5.95	5.3	146
2008-09	5.68	5.5	160

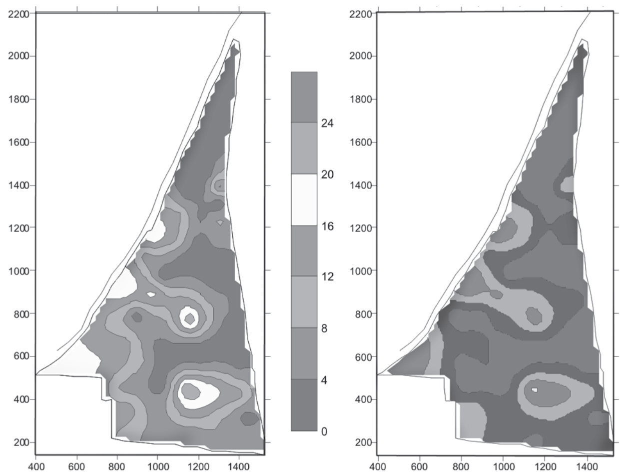

Fig. 6. Impact of closed sub-surface drainage system on summer soil salinity of Kovelamudi pilot area

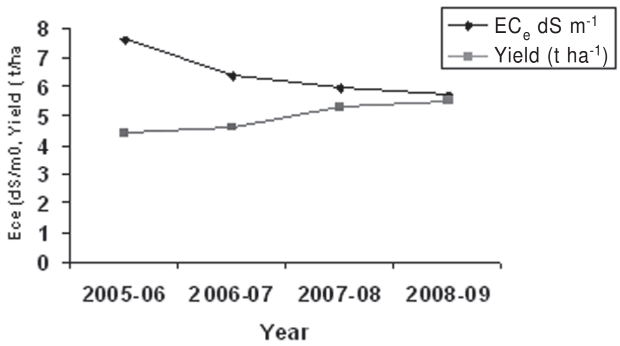

Fig. 7. Relationship between EC_e and Grain yield (t ha^{-1}) during 2006-2009

by not only creating the favorable conditions in root zone but also making the nutrients available to the plants resulting in optimum plant growth and yield.

Further, the shallow water table helped to overcome the excessive drainage and also remove the harmful salts that are brought in by the irrigation water there by creating favorable conditions in the soil root zone to establish fodder crops successfully in the second season after harvest of *Kharif* rice.

CONCLUSIONS

At both the pilot areas after introduction of drainage systems :

- The non saline area has been gradually increasing year after year and concentration of the salinity also gradually decreasing.
- The yield of the rice crop has been increasing right from the installation of the drainage systems.
- The farmers are used to grow second crop as income generating crops like black gram, maize and fodder Jowar.

REFERENCES

Annual Reports (2006). All India Co-Ordinated Project on *Management of salt affected soils and use of saline water in Agriculture.*

Black, C. A. (1965). *Methods of Soil Analysis*, Part-1 & II American Society of Agronomy Madison, Wisconsin, USA.

Comprehensive Report on Research Achievements of Indo-Dutch Net Work Project, Bapatla (1.4.96 to 31.3.2002) on "*Drainage and Water Management for Salinity Control in Canal Commands*".

Lal, R. (2008). Soils and India's food security, *Journal of Indian Society of Soil Science* **56**(2): 129-138.

Prasad, P. R. K., Srinivas D, Satyanarayana, T. V., Ramesh Chandra, S., Subba Rao, G., Mukunda Rao, B. and Srinivasulu, A. (2007). Reclamation saline and waterlogged soils in Mutluru channel command of Krishna Western Delta, Andhra Pradesh, India. Paper presented during *58th ICID meeting and The USCID 4th International conference on Irrigation and drainage*, organized from 30.09.2007 to 06.10.2007 at Sacramento Convention Center, California-USA.

Richards, L. A. (1954). *Diagnosis and Improvement of Saline and Alkali Soils.* USDA Handbook 60, US Department of Agriculture and Oxford & IBH Pub. Co. Pvt. Ltd., New Delhi.

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Effect of Age, Number of Seedlings hill^{-1} and Levels of Nitrogen on Yield of Hybrid Rice in Coastal Region of Maharashtra

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A field experiment was conducted at Agricultural Research Station, Phondaghat during the year 2001-2003 to study the effect of age of seedling, number of seedlings hill^{-1} and graded levels of nitrogen on yield of hybrid rice Cv. Sahyadri in lateratic soils of Konkan region of Maharashtra. The pooled results indicated that the transplanting of 20 days old seedling (D_1) produced significantly higher grain yield (56.21 q ha^{-1}) over 30 (D_2) and 40 (D_3) days old seedlings. Similarly one seedling hill^{-1} (S_1) produced significantly higher grain yield (54.34 q ha^{-1}) over two seedlings hill^{-1}(S_2). The higher dose of nitrogen application i.e. 150 kg N ha^{-1} (N_3) significantly increased the grain yield (65.92 q ha^{-1}) over rest of the levels of nitrogen and the per cent increase in grain yield was to the tune of 45.87, 39.13 and 13.33 over N_0, N_1 and N_2 treatments respectively. The highest B:C ratio (1.36) was observed in the treatment combination $S_1D_1N_3$.

(***Key words:*** *Hybrid rice, Seedling age and number hill^{-1}, Nitrogen levels, Yield)*

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world. Introduction of hybrid rice is an important step towards augmentation of rice yield. Hybrid rice yields about 15-20% more than the promising high-yielding commercial varieties. Rice production and productivity trends in India are suggestive of the fact that future increase in rice production will have to be achieved by exploiting the full heterotic potential of recently released hybrid rice varieties with development of suitable production technology package for hybrid rice through nursery management, seedling number, planting time and optimum fertilizers in conjunction with water management.

Konkan is major rice growing tract of Maharashtra having about 4.54 lakh hectares of land under rice with total annual production of about 11.2 lakh tones and productivity of 24.88 q ha^{-1}. Still there is wide scope to increase the yield potential of rice by using appropriate production technology. Farmers of this region are very often use 35 to 50 days old seedlings in place of recommended 25 to 30 days old seedlings. Use of appropriate aged seedlings for transplanting are important non cash inputs for realizing the higher productivity in rice (Pattar *et al.*, 2001). Similarly time of planting and number of seedlings hill^{-1} are also the important factors influencing yield of the rice crop. The available information on dates of planting, plant geometry and seedlings rate for inbred varieties may or may not be suitable for rice hybrids which are also to be revalidated with certain confirmations. Besides this earlier studies reveal that judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice. Given the importance of nitrogen fertilization on the yield, it is necessary to know the best dose for each variety as well as its influence on components of yield and other agronomic parameters such as the cycle, plant height, lodging and moisture content. An adequate supply of nitrogen to the crop plants during their early growth period is very important for the initiation of leaves and florets primordia (Tisdale and Nelson, 1984). With this in view, the field investigation was carried out with major objectives to find out suitable age of seedling, optimum number of seedlings hill^{-1} and optimum nitrogen levels for hybrid rice.

MATERIALS AND METHODS

A field investigation was carried out in split plot design with three replications during Kharif, 2001 to 2003 at the Agriculture Research Station Phondaghat. The main plot treatments comprised of number of seedlings hill^{-1} (One and two seedlings hill^{-1}) and age of seedlings (20, 30 and 40 days seedlings) while the sub-plot treatments comprised of four graded levels of nitrogen (0, 50, 100 and 150 N kg ha^{-1}). The soil of the experimental plot was lateratic having 221.56, 12.34 and 201.19

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available N, P_2O_5 and K_2O kg ha^{-1}, respectively. The soil was acidic in reaction (pH 6.28) and organic carbon content was 1.23%. The net and gross plot sizes were 4.20 x 3.00 m and 4.50 x 3.60 m, respectively. Sowing of the crop in nursery was done in the first week of June for every year and transplanting was done at 20 x 15cm spacing as per the treatments. Fertilizer nitrogen was applied as per the treatments with recommended splits. However, entire dose of phosphorus (single super phosphate) and potash (muriate of potash) were given at the time of transplanting as a basal dose. Need based weeding and plant protection measures were carried out.

RESULTS AND DISCUSSIONS

Effect of number of seedlings hill^{-1}

The number of seedlings hill^{-1} significantly influenced the grain yield of hybrid rice (Table 1). Transplanting with one seedling hill^{-1} significantly recorded higher grain yield (54.34 q ha^{-1}) over transplanting of two seedlings hill^{-1}. The yield increase due to one seedling hill^{-1} as compared to two seedlings hill^{-1} was 10.23%. Thus increasing seedling number from one to two seedlings hill^{-1} did not help in increasing yield of hybrid rice indicating one seedling to be adequate enough for high yield of hybrid rice if crop is sown timely. Also planting one seedling hill^{-1} might have provided better conditions for vigorous seedlings which create more congenial conditions in development of sink throughout the crop period in hybrid rice. These results are in agreement with the observations made by Channabasappa *et al.*, (1998) and Srinivasulu *et al.*, (1999).

Effect of age of seedlings at transplanting

The pooled results presented in Table 1 indicated that the age of seedling significantly influenced the grain yield of hybrid rice. Transplanting of 20 day old seedling produced significantly higher grain yield (56.51 q ha^{-1}) over 30 and 40 days old seedling. The percent yield increase due to 20 days old seedling over 30 and 40 days old seedling was 9.25 and 16.28%, respectively. Transplanting younger seedlings in producing higher number and more vigorous tilling which in turn helped in extracting nutrients from soil. These results are in agreement with the observations made by Balsubramanian *et al.*, (1977), Bali *et al.*, (1995) and Patel (1999).

Table 1. *Effect of age, number of seedlings hill^{-1} and nitrogen levels on yield of hybrid rice (q ha^{-1})*

Treatments	Yield of hybrid rice (q ha^{-1})			
	2001	2002	2003	Pooled mean
A. Main plot treatments:				
I) Number of seedlings hill^{-1}				
S_1- One seedling hill^{-1}	60.89	49.16	52.96	54.34
S_2- Two seedlings hill^{-1}	63.18	35.56	47.40	48.71
SE +	0.16	0.56	0.35	0.73
CD at 5%	0.52	1.75	1.11	2.20
II) Age of seedlings				
D_1- 20 days	63.63	53.37	52.53	56.51
D_1- 30 days	62.36	39.16	51.52	51.01
D_1- 40 days	60.11	34.57	46.50	47.06
SE +	0.20	0.68	0.43	0.94
CD at 5%	0.63	2.14	1.36	2.83
B. Sub plot treatments: Nitrogen levels (kg ha^{-1})				
N_0 - 0	40.93	28.25	37.87	35.68
N_1 - 50	56.13	37.75	48.26	47.38
N_2 - 100	69.08	47.35	54.95	57.13
N_3 - 150	82.00	56.13	59.64	65.92
SE +	0.22	0.80	0.56	2.25
CD at 5%	0.62	NS	1.59	6.76

Table 2a. *Interaction effects due to number of seedlings hill^{-1} and graded levels of 'N' on grain yield (q ha^{-1}) of hybrid rice*

Number of seedlings hill-1	Nitrogen levels (kg ha^{-1})				
	N_0	N_{50}	N_{100}	N_{150}	Mean
S_1 - One seedling	29.31	38.99	48.85	57.54	43.67
S_2 - Two seedlings	27.87	37.48	46.99	56.05	42.10
Mean	28.59	38.24	47.92	56.80	—
	Number of seedlings hill^{-1}	Nitrogen levels	Interaction		
SE +	1.13	0.77	0.05		
CD at 5%	NS	2.22	0.10		

Table 2a. *Interaction effects due to seedlings age and graded levels of 'N' on grain yield (q ha^{-1}) of hybrid rice*

Age of seedlings	Nitrogen levels (kg ha^{-1})				
	N_0	N_{50}	N_{100}	N_{150}	Mean
D_1 - 20 days	36.56	49.82	64.94	74.75	56.52
D_2 - 30 days	34.92	48.05	56.09	64.99	51.01
D_3 - 40 days	35.58	44.27	50.35	58.04	47.06
Mean	35.67	47.38	57.13	65.93	—
	Age of seedling	Nitrogen levels	Interaction		
SE +	0.43	2.25	2.76		
CD at 5%	NS	6.76	8.21		

Table 3. *Economics of the various treatments*

Treatment combination	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Cost of cultiva-tion (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net Returns (Rs. ha^{-1})	B:C ratio
$S_1D_1N_0$	38.38	38.57	25756	20841	(-) 4915	0.81
$S_1D_1N_1$	48.99	50.36	27578	27299	(-) 279	0.99
$S_1D_1N_2$	66.78	67.25	29899	37101	7202	1.24
$S_1D_1N_3$	76.34	81.37	31479	42771	11292	1.36
$S_1D_2N_0$	36.20	38.70	25665	20291	(-) 5374	0.79
$S_1D_2N_1$	48.29	50.36	27522	26967	(-) 555	0.98
$S_1D_2N_2$	57.34	61.73	29078	32175	3097	1.11
$S_1D_2N_3$	67.97	72.40	30697	38078	7381	1.24
$S_1D_3N_0$	35.52	36.62	25583	19802	(-) 5781	0.77
$S_1D_3N_1$	45.25	47.81	27248	25319	(-) 1929	0.93
$S_1D_3N_2$	50.19	53.11	28397	28089	(-) 308	0.99
$S_1D_3N_3$	58.00	62.11	29771	32519	2748	1.09
$S_2D_1N_0$	35.74	39.50	27969	20137	(-) 7832	0.72
$S_2D_1N_1$	50.64	53.76	30084	28355	(-) 1729	0.94
S_2D1N_2	63.09	68.51	31954	35449	3495	1.11
$S_2D_1N_3$	73.15	78.03	33512	40989	7477	1.22
$S_2D_2N_0$	33.63	35.00	27742	18775	(-) 8967	0.68
$S_2D_2N_1$	47.81	48.74	29793	26609	(-) 3184	0.89
$S_2D_2N_2$	54.84	55.48	31127	30487	(-) 640	0.98
$S_2D_2N_3$	62.01	65.07	32458	34660	2202	1.07
$S_2D_3N_0$	35.64	36.10	27916	19817	(-) 8099	0.71
$S_2D_3N_1$	43.29	44.93	29384	24157	(-) 5227	0.82
$S_2D_3N_2$	50.52	53.27	30756	28259	(-) 2417	0.92
$S_2D_3N_3$	58.07	61.80	32102	32527	425	1.01

Urea @ Rs.10.89 kg^{-1}, Paddy grain @ Rs.475 q^{-1}, Paddy straw @ Rs.80 q^{-1}

Effect of fertilizer levels

From the Table1 it is evident that maximum values of the grain yield was significantly increased up to 150 kg N ha^{-1}. The results pertaining to grain yield indicated that grain yield (65.92 q ha^{-1}) of hybrid rice increased in fertilizer level up to 150 kg N ha^{-1}. Percent increase in grain yield by fertilizer level 150 kg N ha^{-1} was to the tune of 45.87, 39.13 and 13.33 over N_0, N_1 and N_2, respectively. Thus the response of hybrid rice in developing better sink was evident up to 150 kg N ha^{-1}. It might be due to development of higher biomass at higher fertilizer level applied. These results corroborate the findings of Hari Om *et al.*, (1998) and Srivastav and Tripathi (1999).

Interaction effects among the treatments

The interaction effects due to age of seedling, number of seedling $hill^{-1}$ and fertilizer levels on yield of hybrid rice was found to be significant (Table 2.a and b). The treatment combination S_1N_3 i.e. one seedling $hill^{-1}$ along with application of 150 kg N ha^{-1} recorded significantly higher grain yield (57.34 q ha^{-1}) over rest of the treatment combinations while the treatment combination D_1N_3 i.e. transplanting of 20 days old seedling along with application of 150 kg N ha^{-1} recorded significantly higher grain yield (74.75 q ha^{-1}) over rest of the treatment combinations under study.

Economics of the treatments

The data pertaining to the economics of the treatments (Table 3) indicated that the gross returns were higher (Rs.42771 ha^{-1}) due to treatment combination $S_1D_1N_3$ (transplanting 20 days old seedling with one seedling $hill^{-1}$ and application of 150 kg N ha^{-1}). Similarly, the net returns (Rs.11292 ha^{-1}) and benefit: cost ratio (1.36) of hybrid rice was also enhanced substantially due to this treatment only. The results are in confirmation with the findings obtained by Shrivastav and Tripathi, 1999.

CONCLUSION

From the three years pooled results it can be concluded that transplanting one seedling $hill^{-1}$ of 20 days old and application of 150 kg N ha^{-1} along with basal dose of 50 kg P_2O_5 and 50 kg K_2O ha^{-1} for hybrid rice (Cv. Sahyadri) during Kharif season in lateratic soils of South Konkan region is useful for obtaining higher yields.

REFERENCES

Balasubramanian, A., Venkataraman, R. and Palaniappan, S. P. (1977). Studies on the time of planting and seedling age on the performance of rice. *Madras Journal of Agriculture* **64**: 49-51.

Bali, A. S., Singh, K. N., Balli, A. S., Ganai, B. A. and Hasan, B. (1995). Effect of transplanting date, number and age of seedlings on rice. *Indian Journal of Agronomy* **90**: 504-507.

Channabasappa, K. S., MasthanaReddy, B. G., Patil, S. G. and Dineshkumar, N. (1998). Response of late transplanted rice (*Oryza sativa*) to age, number of seedlings and fertilizer levels. *Indian Journal of Agronomy* **43**(4): 636-638.

Hari, Om, Dhiman, S. D., Nandal, D. P. and Verma, S. L. (1998). Effect of method of nursery raising and nitrogen on growth and yield of hybrid rice (*Oryza sativa*). *Indian Journal of Agronomy* **43**(1): 68-70.

Patel, J. R. (1999). Response of rice (*Oryza sativa*) to time of transplanting, spacing and age of seedlings. *Indian Journal of Agronomy* **44**(2): 344-346.

Pattar, P. S., Reddy, B. G. M. and Kuchanur, P. H. (2001). Yield and yield parameters of rice (*Oryza sativa* L.) as influenced by date of planting and age of seedlings. *Indian Journal of Agricultural Sciences* **71**: 521-522.

Srivastav, B. K. and Tripathi, R. S. (1999). Effect of nitrogen levels on hybrid and high yielding varieties of rice under lowland ecology of eastern Madhya Pradesh. *Indian Journal of Agronomy* **36**(4): 386-388.

Srinivasulu, K., Veeraraghavaiah, R. and Madhavi, K. (1999). Yield and nutrient uptake of rice hybrids as influenced by planting method and seedling rate. *Oryza* **36**(3): 288-289.

Tisdale, S. L. and Nelson, W. L. (1984). *Soil Fertility and Fertilizers*, Third edition. McMillan Publishing Company, New York. pp 68–73.

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A Green-Ampt Model for Computing Infiltration through Multi-Layered Salt Affected Soils

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The coastal alluvial soil is very fragile and vulnerable to ingress of saline water through numerous tidal rivers and rivulets. The salts in the soil vary spatially and temporally according to input and output by various processes, also influence the physical properties of soil. Usually, the concentration of salts in soil water increases towards the summer due to evaporation from the surface and decreases by leaching during the rainy season. Because of the deficit charges in clays, the electric double layer (EDL) is formed on the clay surface. Larger the EDL, slower is the hydraulic conductivity and vice versa. Here, based on the Green and Ampt approach, an infiltration model is developed for the multi-layered soil incorporating the EDL theory. By this model, the cumulative infiltration through a multi-layered soil can be computed at any time under changing hydraulic conductivity in each layer.

*(**Key words:** Infiltration, Soil, Soil water, Salts, Electric double layer)*

Water present in the soil and constituting its liquid phase is never chemically pure (Hillel, 1998). The ionic composition and concentration of ions in the soil solution affect soil physical properties (Keren, 2000). In case of the clay minerals, the lower valence cations isomorphically substitute the higher valence cations that take place during the formation of clay minerals. The deficit charges thus formed are compensated by adsorption of the cations (e.g., Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} etc.) on the exterior surface (Bolt, 1978; Grim, 1953; Rhodes, 1982). The electrostatic forces that exist between the charges on the clay surface and the cations present in the soil water form the electric double layer (EDL) on the clay surface. The thickness of EDL i.e. β is an important controlling factor for the structural development, hydraulic conductivity, and other physico-chemical and mechanical properties of soil (Fukue *et al.*, 1999 & 2001). β is governed by the concentrations of salts and types of cations in the soil water (Schofield, 1947; van Olphen, 1977). It is a known fact that the swelling in clayey soil increases with a rise in the percentage of monovalent exchangeable cations. The decrease in permeability at a concentration below the threshold value is due to the extensive development of diffuse double layer on the clay surface (Quirk, 1986; Bolt, 1978). The available experimental data on the hydraulic conductivity ($\tilde{K}$) (Acar *et al.*, 1985; Alther *et al.*, 1985; Mitchell and Madsen, 1987) of compacted clay exposed to chemicals indicate that the effects of chemicals on $\tilde{K}$ is consistent with the diffused double layer and the interparticle forces that control flocculation, dispersion, shrinkage, and swelling. The EDL approach works surprisingly well for the soil systems, although it suffers from the drawback that the calculations are complicated.

For efficient plant growth, there is a necessity for reclamation of salt affected soils. The reclamation of saline soils is accomplished through leaching with water of lower salinity and proper drainage. Infiltration of water into the soil is an important process for agriculture. Leaching with good quality and quantity of water is only effective if the saline soil or the applied water contains a certain amount of gypsum. In this case, during the process of leaching, the absorption of sodium ions by the soil particles from the applied water is hindered and the harmful salt content can be removed without the residual alkalinity in the soil. If no gypsum is available during leaching, the soil particles adsorb sodium ions from the applied water and the saline soil develops into sodic. The ponded gypsum solution infiltrates into the soil and facilitates leaching. Common infiltration types include: (a) ponded water infiltration into homogenous soil (Bodman and Coleman, 1943; Philip, 1957) or heterogeneous soil (Hanks and Bowers, 1962; Dagan and Bresler, 1979); (b) constant or variable (non-ponded) water infiltration into homogenous and heterogeneous soil (Whisler and Klute, 1965; Bresler *et al.*, 1969; Hanks *et al.*, 1969); and (c) infiltration

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into deforming soil material (Philip,1969; Narasimhan and Witherspoon, 1977). The depth of ponding varies with time because of infiltration. For reclaiming the sodic or saline-sodic soils, when higher valence ions such as Ca^{2+} ions (gypsum solution) are applied, less number of ions are required for compensating the same charge on the clay surface, which results in reduction of β and consequently increment in the hydraulic conductivity ($\tilde{K}$). At the same time, the Na ions which are present excessively inside the double layer, get replaced into the bulk solution and subsequently leached out.

MATERIALS AND METHODS

With passage of each pore volume of infiltrated water, Na ions and Ca ions reorient in each soil layer. Hence, β and consequently, $\tilde{K}$ in each layer through which the pore volume passes gets changed. Therefore, the infiltration during leaching process can be classified as variable ponded water infiltration into non-homogenous soil. Consider the root zone to be comprised of a series of reservoirs (Fig. 1). Thickness of each reservoir is D. Each reservoir is regarded as a separate control volume. Initially the soil is homogenous. The soil moisture content is at field capacity θ_f. The bulk concentrations of Na and Ca ions in soil moisture in all the reservoirs are identical. Once a pore-volume passes through a reservoir, the saturation hydraulic conductivity of the soil in the reservoir changes in accordance with the exchange of lower valence cations by the higher valence cations in the

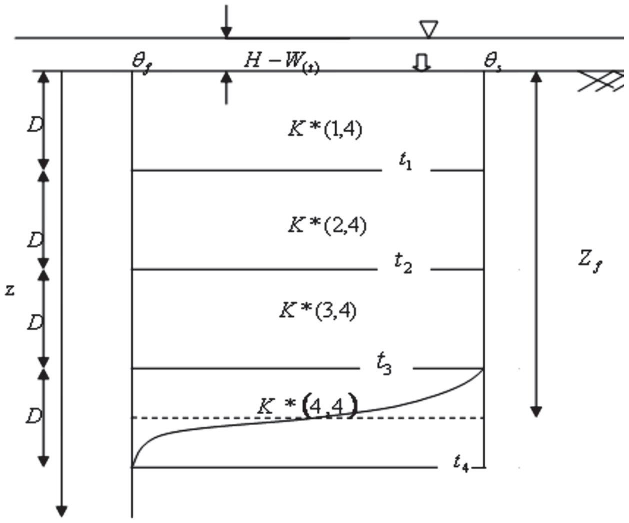

Fig. 1. Infiltration into layers of equal size; at t = 0, initial ponding depth = H; initial soil moisture content = θ_f; moisture content at saturation = θ_s

EDL and the hydraulic conductivity of the soil in the reservoir differs from those of others. A pore volume is a calculation of the equivalent amount of transmitted water in depth units (Jury *et al.*, 1991). Thus, one pore volume equals to $D(\theta_s - \theta_f)$. Applying Green and Ampt (1911) theory, infiltration rate through a layered soil system is computed and relation between cumulative infiltration, hence pore volumes with time is established.

RESULTS AND DISCUSSION

The ponded water infiltrate vertically into the soil. As the infiltration continues, the inflow mixes with the existing soil solution and the ions reorient inside the pore. The model development is described below.

a) Infiltration into the First Reservoir

The following procedures can be adopted to predict the saturated hydraulic conductivity in each reservoir when gypsum solution infiltrates:

1) The saturated hydraulic conductivity ($\tilde{K}$) of the salt affected soil can be determined from a laboratory test on a core sample either using a permeameter.

2) Measure the bulk concentrations of ions in the effluent of the permeameter at the time of test.

3) Using these bulk concentrations, calculate β as:

$$\beta = \sqrt{\frac{\varepsilon RT}{2F^2\left\{Z_1^{\,2}C_{bNa^+} + Z_2^{\,2}C_{bCa^{2+}}\right\}}} \tag{1}$$

where ε = permittivity of the medium ($C^2J^{-1}m^{-1}$); F = Faraday's number i.e. 96487 C/gm-equivalent; R = gas constant (8.314 J mol^{-1} K^{-1}); T = absolute temperature (K); Z_1 valence of the Na^+; Z_2 = valence of the Ca^{2+}; C_{bNa^+} = concentrations of Na^+ ions in the bulk solution (mol m^{-3}); $C_{bCa^{2+}}$ = concentrations of Ca^{2+} ions in the bulk solution (mol m^{-3}).

Knowing $\tilde{K}$, the effective pore space α_0 is estimated from the relation (Harr, 1962; Polubarinova-Kochina,1962):

$$a_0 = \sqrt{\frac{3\nu\tilde{K}}{g}} \tag{2}$$

where $\nu = \frac{\mu}{\rho_b}$ = kinematic viscosity of water (m^2 day^{-1}); g =acceleration due to gravity (m day^{-2}); μ = viscosity (Nday m^{-2}). The kinematic viscosity of water ν = 0.9025 x 24 x 60 x 60 x 10^{-6} m^2day^{-1} at 25°C.

4) The total pore space between two clay plates is determined adding α_0 and 2β.

5) Prior to prediction of time pore volume relation, the bulk concentrations C_{bNa^+} (I, J) and $C_{bCa^{2+}}$, (I, J), β(I, J) have already been predicted. Using the known β(I, J), K^* (I, J) are computed. It has been assumed that during the time J^{th} pore volume is passing through the I^{th} reservoir, the hydraulic conductivity is K^* (I, J).

Let the hydraulic conductivity of the first reservoir after passage of first pore volume be K^* (I, I). β_f be the initial volumetric soil moisture content (m^3 m^{-3}); θ_s be the volumetric soil moisture content at saturation (m^3 m^{-3}); H_f be the capillary pressure head at the wetting front (m); H be the depth of water applied at the surface in the beginning (m). Let, the saturation front be at a depth $Z_f(t)$ at time t. The cumulative infiltration up to time t is given by:

$$W(t) = (\theta_s - \theta_f)\, Z_f(t) \tag{3}$$

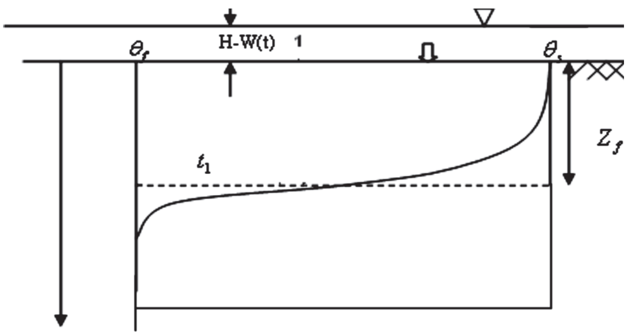

Fig. 2. The infiltration into the top reservoir under variable ponding depth

Let dW(t) be the increment in cumulative infiltration in a time interval dt at time t. The infiltration rate (i) is given by:

$$i = \frac{dW(t)}{dt} = \left(\theta_s - \theta_f\right)\frac{dZ_f(t)}{dt} \tag{4}$$

Up to any time t, the cumulative infiltration is given by: $\int_0^t i(\tau)\, d\tau = W(t)$ (5)

The hydraulic heads at points 1 and 2 (Fig. 2) are:

$h_1(t) = H - W(t)$, $h_2(t) = H_f - Z_f(t)$

Applying Darcy law to the wetted zone, the Green and Ampt equation can be written as:

$$\frac{K^*(1,1)\left(H - W(t) + H_f + Z_f(t)\right)}{Z_f(t)} = \left(\theta_s - \theta_f\right)\frac{dZ_f(t)}{dt} \tag{6}$$

Capillary pressure head, can be determined using Bower's relation:

$$H_f = \int_0^{h_{ci}} K_{rw}(\theta)\, dh_c \tag{7}$$

where $K_{rw}(\theta) = \frac{K(\theta)}{K^*(1,1)}$ relative hydraulic conductivity (dimensionless); h_c = suction head (m); and h_{ci} = suction head (m) at initial soil moisture content θ_f . Incorporating Eq. (2) in Eq. (4)

$$\frac{K^*(1,1)\left(H_f + Z_f(t) + H - W(t)\right)}{Z_f(t)} = \frac{dW(t)}{dt} \tag{8}$$

Multiplying and dividing the left hand term by (θ_s - θ_f),

$$\frac{K^*(1,1)\left\{\left(H_f + H\right)\left(\theta_s - \theta_f\right) + \left(\theta_s - \theta_f\right)Z_f(t) - \left(\theta_s - \theta_f\right)W(t)\right\}}{\left(\theta_s - \theta_f\right)Z_f(t)} = \frac{dW(t)}{dt} \tag{9}$$

Rearranging,

$$K^*(1,1)\, dt = \frac{W(t)\, dW(t)}{\left(H_f + H\right)\left(\theta_s - \theta_f\right) + \left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t)} \tag{10}$$

Multiplying both sides by the term {1 – (θ_s - θ_f)},

$$K^*(1,1)\left\{1 - \left(\theta_s - \theta_f\right)\right\}dt = \frac{\left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t)\, dW(t)}{\left(H_f + H\right)\left(\theta_s - \theta_f\right) + \left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t)} \tag{11}$$

Adding and subtracting term (H_f+ H) (θ_s - θ_f) in the numerator of the term on the right hand side,

$$K^*(1,1)\left\{1 - \left(\theta_s - \theta_f\right)\right\}dt = \frac{\left[\left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t) + \left(H_f + H\right)\left(\theta_s - \theta_f\right) - \left(H_f + H\right)\left(\theta_s - \theta_f\right)\right]dW(t)}{\left(H_f + H\right)\left(\theta_s - \theta_f\right) + \left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t)} \tag{12}$$

or

$$K^*(1,1)\left\{1 - \left(\theta_s - \theta_f\right)\right\}dt = dW(t) - \frac{\left[\left(H_f + H\right)\left(\theta_s - \theta_f\right)\right]dW(t)}{\left(H_f + H\right)\left(\theta_s - \theta_f\right) + \left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t)} \tag{13}$$

Integrating,

$$\int_0^t K^*(1,1)\left\{1 - \left(\theta_s - \theta_f\right)\right\}dt = \int_0^W dW(t) - \int_0^W \frac{\left[\left(H_f + H\right)\left(\theta_s - \theta_f\right)\right]dW(t)}{\left(H_f + H\right)\left(\theta_s - \theta_f\right) + \left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t)} \tag{14}$$

or

$$K^*(1,1)\left\{1 - \left(\theta_s - \theta_f\right)\right\}t = W(t) - \frac{\left[\left(H_f + H\right)\left(\theta_s - \theta_f\right)\right]}{\left\{1 - \left(\theta_s - \theta_f\right)\right\}}\ln\left[\left(H_f + H\right)\left(\theta_s - \theta_f\right) + \left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t)\right] + A \tag{15}$$

where A is an integration constant.

At time t = 0, cumulative infiltration, W (t) = 0.

Therefore,

$$A = \frac{\left[\left(H_f + H\right)\left(\theta_s - \theta_f\right)\right]}{\left\{1 - \left(\theta_s - \theta_f\right)\right\}}\ln\left[\left(H_f + H\right)\left(\theta_s - \theta_f\right)\right] \tag{16}$$

Substituting the value of A in Eq. (15) and rearranging,

$$K^*(1,1)\left\{1 - \left(\theta_s - \theta_f\right)\right\}t = W(t) - \frac{\left[\left(H_f + H\right)\left(\theta_s - \theta_f\right)\right]}{\left\{1 - \left(\theta_s - \theta_f\right)\right\}}\ln\frac{\left[\left(H_f + H\right)\left(\theta_s - \theta_f\right) + \left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t)\right]}{\left(H_f + H\right)\left(\theta_s - \theta_f\right)} \tag{17}$$

Dividing both sides by (θ_s – θ_f),

$$K^*(1,1)\frac{\left\{1 - \left(\theta_s - \theta_f\right)\right\}}{\left(\theta_s - \theta_f\right)}t = \frac{W(t)}{\left(\theta_s - \theta_f\right)} - \frac{\left[\left(H_f + H\right)\left(\theta_s - \theta_f\right)\right]}{\left(\theta_s - \theta_f\right)\left\{1 - \left(\theta_s - \theta_f\right)\right\}}\ln\left[1 + \frac{\left\{1 - \left(\theta_s - \theta_f\right)\right\}W(t)}{\left(H_f + H\right)\left(\theta_s - \theta_f\right)}\right] \tag{18a}$$

For W (t) = J (θ_s – θ_f)D, where J = number of pore volume, the corresponding time can be computed directly using Eq. (18). Substituting W (t) = J (θ_s – θ_f)D in (18a)

$$K^{*}(1,1)\frac{\{1-(\theta_s-\theta_f)\}}{(\theta_s-\theta_f)}t = JD - \frac{[(H_f+H)(\theta_s-\theta_f)]}{(\theta_s-\theta_f)\{1-(\theta_s-\theta_f)\}}\ln\left[1+\frac{\{1-(\theta_s-\theta_f)\}JD}{(H_f+H)}\right] \quad (18b)$$

Equation (18b) relates time and number of infiltrated pore volumes.

In terms of Z_f Eq. (18a) can be written as:

$$K^{*}(1,1)\frac{\{1-(\theta_s-\theta_f)\}}{(\theta_s-\theta_f)}t = Z_f(t) - \frac{(H_f+H)}{\{1-(\theta_s-\theta_f)\}}\ln\left[1+\frac{Z_f(t)\{1-(\theta_s-\theta_f)\}}{(H_f+H)}\right] \quad (19)$$

At any time t, the position of the saturation front Z_f (t) can be computed from Eq. (19) using an iteration procedure.

b) Infiltration into a Two Layered Soil System

Let the saturation front be located at depth Z_f at time t. At the time t, let the hydraulic heads at points 1 and 4 (Fig. 3) are:

$$h_1(t) = H - W(t) \quad (20)$$

$$h_4(t) = H_f - Z_f(t) \quad (21)$$

The hydraulic head at point 3, h_3 (t) at time t when the saturation front is at Z_f is unknown which can be evaluated as follows.

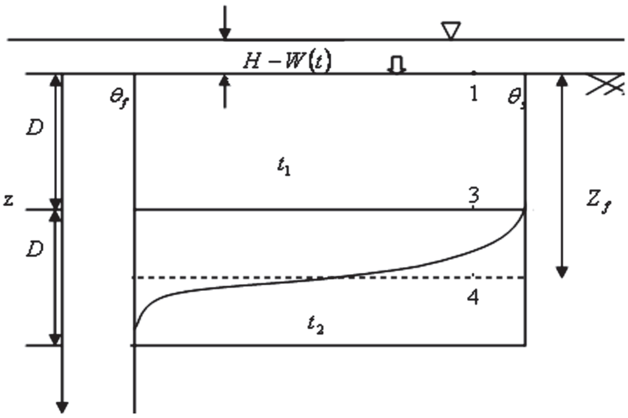

Fig. 3. Infiltration into a two layered soil system where the hydraulic conductivity of the first layer has changed due to infiltration of first pore volume of water under variable ponding depth at surface (initial soil moisture content θ_f = ; soil moisture content at saturation = θ_s; initial poding depth = H)

According to the assumption in the Green and Ampt theory, the velocity within the saturation front is same everywhere. Hence, applying Darcy's law:

$$-K^{*}(1,2)\left[\frac{h_3(t)-h_1(t)}{D}\right] = -K^{*}(2,2)\left[\frac{h_4(t)-h_3(t)}{Z_f(t)-D}\right] \quad (22)$$

where K* (1, 2) is the hydraulic conductivity in the first layer (m day[-1]) when second pore volume is passing through; and K* (2, 2) is the saturated hydraulic conductivity in the second reservoir when the first pore volume being displaced from the first reservoir to the second one.

Arranging Eq. (22),

$$\frac{K^{*}(1,2)}{K^{*}(2,2)}\left[\frac{h_3(t)-h_1(t)}{D}\right] = \frac{h_4(t)-h_3(t)}{Z_f(t)-D} \quad (23)$$

$$\frac{K^{*}(1,2)}{K^{*}(2,2)} = k_r \quad (24)$$

Substituting k_r in Eq. (23),

$$k_r\left[\frac{h_3(t)-h_1(t)}{D}\right] = \frac{h_4(t)-h_3(t)}{Z_f(t)-D} \quad (25)$$

Rearranging,

$$h_3(t) = \frac{Dh_4(t)+k_r h_1(t)\{Z_f(t)-D\}}{k_r\{Z_f(t)-D\}+D} \quad (26)$$

The infiltration rate is given by:

$$i(t) = K^{*}(2,2)\left[\frac{h_3(t)-h_4(t)}{Z_f(t)-D}\right] = \frac{K^{*}(2,2)}{Z_f(t)-D}\left[\frac{k_r h_1(t)\{Z_f(t)-D\}+Dh_4(t)}{k_r\{Z_f(t)-D\}+D} - h_4(t)\right] = K^{*}(2,2)\left[\frac{h_1(t)-h_4(t)}{\{Z_f(t)-D\}+\frac{D}{k_r}}\right] \quad (27)$$

Making substitutions for h_1 (t) and h_4 (t) from Eq. (20) and Eq. (21),

$$i(t) = K^{*}(2,2)\left[\frac{H-W(t)-\{-H_f-Z_f(t)\}}{\{Z_f(t)-D\}+\frac{D}{k_r}}\right] = K^{*}(2,2)\left[\frac{H-W(t)+H_f+Z_f(t)}{\{Z_f(t)-D\}+\frac{D}{k_r}}\right] \quad (28)$$

Multiplying the numerator and denominator by $(\theta_s - \theta_f)$,

$$i(t) = \frac{dW(t)}{dt} = K^{*}(2,2)\left[\frac{(\theta_s-\theta_f)(H+H_f)-(\theta_s-\theta_f)W(t)+(\theta_s-\theta_f)Z_f(t)}{\{Z_f(t)-D\}(\theta_s-\theta_f)+\frac{D}{k_r}(\theta_s-\theta_f)}\right] \quad (29)$$

or

$$K^{*}(2,2)\,dt = \left[\frac{(\theta_s-\theta_f)\frac{D}{k_r}+W(t)-D(\theta_s-\theta_f)}{\{H+H_f\}(\theta_s-\theta_f)-W(t)(\theta_s-\theta_f)+W(t)}\right]dW(t) \quad (30)$$

Integrating Eq. (30),

$$K^{*}(2,2)\,t\Big|_{t_D}^{t} = \int_{W(t_D)}^{W(t)}\left[\frac{(\theta_s-\theta_f)\frac{D}{k_r}-D(\theta_s-\theta_f)+W(t)}{(H+H_f)(\theta_s-\theta_f)+W(t)-W(t)(\theta_s-\theta_f)}\right]dW(t) \quad (31)$$

where t_D is time when cumulative infiltration is equal to one pore volume that is equal to D $(\theta_s - \theta_f)$ = W (t_D)

Let,

$$A = (\theta_s-\theta_f)\frac{D}{k_r} - D(\theta_s-\theta_f)\,;\; B = (\theta_s-\theta_f)(H+H_f)\,;\text{ and}$$

$$C = 1-(\theta_s-\theta_f) \quad (32\text{ a, b, c})$$

Substituting A, B, C in Eq. (31),

$$K^{*}(2,2)(t-t_D) = \int_{W(t_D)}^{W(t)}\frac{A+W(t)}{B+CW(t)}dW(t) = \frac{1}{C}\int_{W(t_D)}^{W(t)}\frac{A+\frac{B}{C}-\frac{B}{C}+W(t)}{\frac{B}{C}+W(t)}dW(t) \quad (32)$$

or

$$K^*(2,2)(t-t_D)C=\int_{W(t_D)}^{W(t)}\frac{\left(A-\frac{B}{C}\right)+\frac{B}{C}+W(t)}{\frac{B}{C}+W(t)}dW(t)=W(t)-W(t_D)+\left(A-\frac{B}{C}\right)\ln\left[\frac{\frac{B}{C}+W(t)}{\frac{B}{C}+W(t_D)}\right] \quad (33)$$

Replacing A, B, C in Eq. (33),

$$\{1-(\theta_s-\theta_f)\}K^*(2,2)(t-t_D)+W(t_D)$$
$$=W(t)+\left[(\theta_s-\theta_f)\frac{D}{k_r}-D(\theta_s-\theta_f)-\frac{\{H+H_f\}(\theta_s-\theta_f)}{\{1-(\theta_s-\theta_f)\}}\right]\ln\left[\frac{\{H+H_f\}(\theta_s-\theta_f)+W(t)\{1-(\theta_s-\theta_f)\}}{\{H+H_f\}(\theta_s-\theta_f)+W(t_D)\{1-(\theta_s-\theta_f)\}}\right] \quad (34)$$

As $(\theta_s - \theta_f)$ D = W (t_D), Eq. (34) can be written as:

$$\{1-(\theta_s-\theta_f)\}K^*(2,2)(t-t_D)$$
$$=W(t)-W(t_D)+\left[\frac{W(t_D)}{k_r}-W(t_D)-\frac{\{H+H_f\}(\theta_s-\theta_f)}{\{1-(\theta_s-\theta_f)\}}\right]\ln\left[\frac{\{H+H_f\}(\theta_s-\theta_f)+W(t)\{1-(\theta_s-\theta_f)\}}{\{H+H_f\}(\theta_s-\theta_f)+W(t_D)\{1-(\theta_s-\theta_f)\}}\right] \quad (35)$$

Replacing k_r by $\frac{K^*(1,2)}{K^*(2,2)}$,

$$\{1-(\theta_s-\theta_f)\}K^*(2,2)(t-t_D)$$
$$=W(t)-W(t_D)+\left[W(t_D)\left\{\frac{K^*(2,2)}{K^*(1,2)}-1\right\}-\frac{\{H+H_f\}(\theta_s-\theta_f)}{\{1-(\theta_s-\theta_f)\}}\right]\ln\left[\frac{\{H+H_f\}(\theta_s-\theta_f)+W(t)\{1-(\theta_s-\theta_f)\}}{\{H+H_f\}(\theta_s-\theta_f)+W(t_D)\{1-(\theta_s-\theta_f)\}}\right] \quad (36)$$

or

$$\{1-(\theta_s-\theta_f)\}K^*(2,2)t=Z_f(t)(\theta_s-\theta_f)-D(\theta_s-\theta_f)+\left[D(\theta_s-\theta_f)\left\{\frac{K^*(2,2)}{K^*(1,2)}-1\right\}-\frac{\{H+H_f\}(\theta_s-\theta_f)}{\{1-(\theta_s-\theta_f)\}}\right]$$
$$\ln\left[\frac{\{H+H_f\}(\theta_s-\theta_f)+Z_f(t)(\theta_s-\theta_f)\{1-(\theta_s-\theta_f)\}}{\{H+H_f\}(\theta_s-\theta_f)+D(\theta_s-\theta_f)\{1-(\theta_s-\theta_f)\}}\right]+\{1-(\theta_s-\theta_f)\}K^*(2,2)t_D \quad (37)$$

Dividing both sides by $(\theta_s - \theta_f)$,

$$\frac{\{1-(\theta_s-\theta_f)\}K^*(2,2)t}{(\theta_s-\theta_f)}$$
$$=Z_f(t)-D+\left[D\left\{\frac{K^*(2,2)}{K^*(1,2)}-1\right\}-\frac{\{H+H_f\}}{\{1-(\theta_s-\theta_f)\}}\right]\ln\left[\frac{\{H+H_f\}+Z_f(t)\{1-(\theta_s-\theta_f)\}}{\{H+H_f\}+D\{1-(\theta_s-\theta_f)\}}\right]$$
$$+\frac{\{1-(\theta_s-\theta_f)\}K^*(2,2)t_D}{(\theta_s-\theta_f)} \quad (38)$$

Time for cumulative infiltration to be two pore volume (t = t_{2D}) is given by substituting Z_f (t) = 2D in Eq. (38):

$$\frac{\{1-(\theta_s-\theta_f)\}K^*(2,2)}{(\theta_s-\theta_f)}t_{2D}$$
$$=D+\left[D\left\{\frac{K^*(2,2)}{K^*(1,2)}-1\right\}-\frac{\{H+H_f\}}{\{1-(\theta_s-\theta_f)\}}\right]\ln\left[\frac{\{H+H_f\}+2D\{1-(\theta_s-\theta_f)\}}{\{H+H_f\}+D\{1-(\theta_s-\theta_f)\}}\right]+\frac{\{1-(\theta_s-\theta_f)\}K^*(2,2)}{(\theta_s-\theta_f)}t_D \quad (39)$$

c) Infiltration into a J Layered Soil System

When cumulative infiltration equals J number of pore volume, the wetting front reaches a depth equal to JD and the number of reservoirs which get saturated is J (Fig. 4). During the advancement of the wetting front in the J^{th} reservoir, all the $(J-1)^{th}$ reservoirs are conceptualized to be one reservoir with a harmonic mean hydraulic conductivity K^*_{hm} (1, J) having a thickness of (J – 1)D. K^*_{hm} (1, J) is given by:

$$K^*_{hm}(1,J)=\frac{(J-1)D}{D/K(1,J)+D/K(2,J)+...+D/K(J-1,J)}=\frac{J-1}{\sum_{I=1}^{J-1}1/K(I,J)} \quad (40)$$

The hydraulic conductivity in the J^{th} reservoir while the wetting front moving in it is K^* (J, J). The equivalent K^* (2, J)is taken as K^* (J, J).

Following Eq. (30)

$$K^*(2,J)\,dt=\left[\frac{(\theta_s-\theta_f)\frac{(J-1)D}{k_{hr}}+W(t)-(J-1)D(\theta_s-\theta_f)}{\{H+H_f\}(\theta_s-\theta_f)-W(t)(\theta_s-\theta_f)+W(t)}\right]dW(t) \quad (41)$$

Integrating

$$K^*(2,J)t\Big|_{t_{(J-1)D}}^{t}=\int_{(\theta_s-\theta_f)(J-1)D}^{W(t)}\left[\frac{(\theta_s-\theta_f)\frac{(J-1)D}{k_{hr}}-(J-1)D(\theta_s-\theta_f)+W(t)}{(H+H_f)(\theta_s-\theta_f)+W(t)-W(t)(\theta_s-\theta_f)}\right]dW(t) \quad (42)$$

Integrating and applying the limits and simplifying

$$\frac{\{1-(\theta_s-\theta_f)\}K^*(2,J)t}{(\theta_s-\theta_f)}$$
$$=Z_f(t)-(J-1)D+\left[(J-1)D\left\{\frac{K^*(2,J)}{K^*_{hm}(1,J)}-1\right\}-\frac{\{H+H_f\}}{\{1-(\theta_s-\theta_f)\}}\right]\ln\left[\frac{\{H+H_f\}+Z_f(t)\{1-(\theta_s-\theta_f)\}}{\{H+H_f\}+(J-1)D\{1-(\theta_s-\theta_f)\}}\right]$$
$$+\frac{\{1-(\theta_s-\theta_f)\}K^*(2,J)t_{(J-1)D}}{(\theta_s-\theta_f)} \quad (43)$$

Corresponding to J^{th} pore volume Z_f (t) = JD and t = t_{JD}. Substituting these in Eq. (43)

$$\frac{\{1-(\theta_s-\theta_f)\}K^*(2,J)t_{JD}}{(\theta_s-\theta_f)}$$
$$=D+\left[(J-1)D\left\{\frac{K^*(2,J)}{K^*_{hm}(1,J)}-1\right\}-\frac{\{H+H_f\}}{\{1-(\theta_s-\theta_f)\}}\right]\ln\left[\frac{\{H+H_f\}+JD\{1-(\theta_s-\theta_f)\}}{\{H+H_f\}+(J-1)D\{1-(\theta_s-\theta_f)\}}\right]$$
$$+\frac{\{1-(\theta_s-\theta_f)\}K^*(2,J)t_{(J-1)D}}{(\theta_s-\theta_f)} \quad (44)$$

Equation (44) is the infiltration model. This model can be used to compute infiltration through a multi-layered soil.

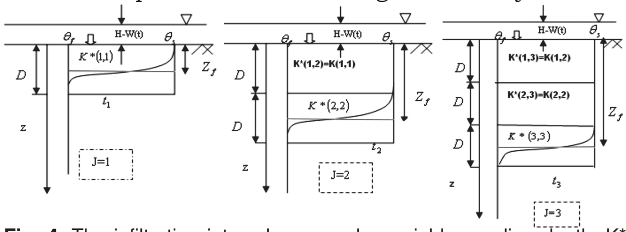

Fig. 4. The infiltration into n layers under variable ponding depth; K* (I, J) represents the hydraulic conductivity of layer I during infiltration of J^{th} pore volume; For I < J, K* (I, J) = K (I, J - 1), for I = J, K* (I, J) is computed using the bulk concentrations in the $(I-1)^{th}$ reservoir at $(J-1)^{th}$ pore volume. For I > 2, a harmonic mean hydraulic conductivity is taken for all the reservoirs except the last one in which the saturation front is moving. $K^*_{hm}(J)=\frac{J-1}{\sum_{I=1}^{I=J-1}\frac{1}{K^*(I,J)}}$

REFERENCES

Acar, Y. B., Hamidon, A., Field, S. D. and Scott, L. (1985). The effect of organic fluids on hydraulic conductivity of compacted kaolinite, In: *Hydraulic Barriers in Soil and Rock*, A. I. Johnson, R. K. Frobel, N. J. Cavalli, and C. B. Pettersson (eds.), ASTM STP **874**, American Society for Testing and Materials, Philadelphia. pp 171–187.

Alther, G., Evans, J., Fang, H. and Witmer, K. (1985). Influence of inorganic permeants upon the permeability of bentonite. In: *Hydraulic Barriers in Soil and Rock*, A. Johnson, R. Frobel and C. Petterson (eds.), STP **874**, American Society for Testing and Materials, Philadelphia. pp 64–73.

Bolt, G. H. (1978). Surface interaction between the soil solid phase and the soil solution. In: *Soil chemistry* A. Basic elements, G.H. Bolt, and M.G.M. Bruggenwert (eds.), Elsevier Scientific Publishing Company, Amsterdam-Oxford, New York.

Bodman, G. B. and Colman, E. A. (1943). Moisture and energy conditions during downward entry of water into soils. *Soil Science Society of America Proceeding* **8**:116 -122.

Bresler, E., Kemper, W. D. and Hanks, R . J. (1969). Infiltration, redistribution and subsequent evaporation of water from soil as affected by wetting rate and hysteresis. *Soil Science Society of America Proceedings* **33**: 832-840.

Dagan, G. and Bresler, E. (1983). Unsaturated flow in spatially variable fields, 1. Derivation of models of infiltration and redistribution. *Water Resource Research* **19**(2): 413-420.

Fukue, M., Minato, T., Horibe, H. and Taya, N. (1999). The micro structures of clay given by resistivity measurements. *Engineering Geology* **54**: 43–53.

Fukue, M., Minato, T., Taya, N. and Chida, T. (2001). Thickness of adsorbed water layer for clay particles. In: *Clay Science for Engineering*, K. Adachi and M. Fukue (eds.), Proceeding of the International Symposium on Suction, Swelling, Permeability and Structure of Clays. Rotterdam, Brookfield. pp 423–427.

Green, W.H. and G. Ampt. (1911). Studies of soil physics, part I – the flow of air and water through soils. *Journal of Agriculture Science* **4**: 1-24.

Grim, R.E. (1953). *Clay Minerology*. International Series in the Earth Sciences. McGraw-Hill Book Company, Inc., New York, Toronto, Londan.

Hanks, R. J., Klute, A. and Bresler, E. (1969). A numeric method for estimating infiltration, redistribution, drainage and evaporation of water from soil. *Water Resource Research* **5**: 1064-1069.

Hanks, R. J. and Bowers, S. A. (1962). Numerical solution of the moisture flow equation for infiltration into layered soils. *Soil Science Society of America Proceedings* **26**: 530-534.

Harr, M. E. (1962). *Groundwater and seepage*. Dover Publications Inc.

Hillel, Daniel. (1998). *Environmental soil physics*. Academic press.

Jury, W.A., Gardner, W.R. and Gardner, W.H.(1991). *Soil physics*. Fifth edition. John Wiley & Sons, New York.

Keren, R. (2000). *Salinity*. In Handbook of soil science, M.E. Sumner (ed.), CRC press.

Mitchell, J. K., Madsen, F. T. (1987). Chemical effects on clay hydraulic conductivity. In: *Proc. Specialty Conference on Geotechnical Practice for Waste Disposal Proceeding,* Woods R. D. (ed.), June 15–17 1987. Ann Arbor, MI: 87–116.

Narasimhan, T. N. and Witherspoon, P. A. (1977). Numerical model for saturated-unsaturated flow in deformable porous media: 1. Theory, *Water Resource Research* **13**: 657–664.

Philip, J. R. (1969). Theory of infiltration. *Advances in Hydroscience* **5**: 215-96.

Philip, J. R.(1957). The theory of infiltration: 6. Effect of water depth over soil. *Soil Science* **85**: 278-286.

Polubarinova-Kochina, P.Ya. (1962). *Theory of ground water movement*. Translated from Russian by J.M. Roger De Wiest, Princepton University Press, Princepton, New Jersey.

Quirk, J. P. (1986). Soil permeability in relation to sodicity and salinity, Phil. Trans. *Royal Society of London* A **316**: 297-397.

Rhoades, J. D. (1982). *Cation exchange capacity, methods of soil analysis,* Part 2, Chemical and microbiological properties - Agronomy Monograph No. 9, 2nd edition, ASA and SSSA, Madison, WI: 149–158.

Rubin, J. and Steinhardt, R. (1963). Soil water relation during rain infiltration: I. Theory. *Soil Science Society of America Proceedings* **27**: 246-251.

Schofield, R. K. (1947). Calculation of surface areas from measurements of negative adsorption. *Nature* (London) **160**: 408–410.

Van Olphen, H. (1977). *An introduction to clay and colloidal chemistry*. Wiley Interscince, New York.

Voyutsky, S.(1978). *Colloid chemistry*. Mir Publishers, Muscow.

Whisler, F. D. and Klute, A. (1965). The numerical analysis of infiltration, considering hysteresis into a vertical soil column at equilibrium under gravity. *Soil Science Society of America Proceedings* **29**: 489-494.

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Assessing Water Resources Status for Crop Planning – A Study in Coastal Paddy Ecosystem of Odisha

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Assessment of the water resources was made in a coastal paddy ecosystem in Pattamundai block in Kendrapara district of Odisha for productive crop planning. Two-parameter Gamma distribution model at 30 per cent probability level was found best rainfall predicted model for the study area. It is observed that there is vulnerability of occurrence of dry spell to the tune of 17-55 per cent during monsoon period, when modeled through Markov chain probability model. Based on water budget technique on weekly basis, gross excess water availability of 1182 mm is reported occurring mostly during monsoon period. When computed through USDA SCS CN procedure, extreme peak runoff event of 358 mm/day generating from 370 mm/day rainfall amount emphasized for adequate provision of surface drainage network in the study area to drain out the excess runoff water. Provision of supplemental irrigation with rescheduling of canal water supply is envisaged for catering the contingent need of monsoon crop during dry spell and post monsoon crops to bring sustainable production.

(***Key Words :*** *Water resources, Gamma distribution model, Markov chain model, USDA SCS CN model, Water budget, Crop plan)*

As an agrarian economy that employs around 73 per cent of its population in farming and related activities, agriculture contributes around 30 per cent to the net state domestic product in Odisha. But a major portion of the agricultural land is rainfed. The soils are variable characteristics with the colour ranging from light gray and pale yellow to deep gray; and the textures ranging from coarse sand to silty-clay to clay. The Bay of Bengal remains the centre of low pressures causing heavy rains and cyclones during monsoon season in the coastal Odisha. Thus, within 10 km proximity of the sea, the soils are saline and waterlogged to various degrees. Rice is grown by the farmers in waterlogged soils for general amelioration of chemical fertility, preferential accumulation of organic matter and improved availability of micronutrients, which facilitates the long-term maintenance of soil fertility and sustainability of wetland rice systems (Sahrawat, 2008).

Perpetual waterlogging condition due to saucer shaped land and frequent floods occurring through active south-west monsoon every year remain victim for low productivity in coastal districts of Odisha. As a result, a large area remains mono cropped. According to the Food and Agriculture Organization (FAO), the overall water use efficiency for irrigated agriculture in developing countries averages to 38 per cent (Tropp, 2006). But even if the coastal paddy ecosystem in Odisha has 42 per cent irrigated area, poor delivery mechanism and ill maintenance limits the cultivation during rabi season. The problem of equity, timeliness and reliability and the low efficiency in regards to conveyance, distribution and application of irrigation are considered as a main cause for the low productivity, where there is sufficient scope of improvement (Singh, 1999). For instance, 10 per cent improvement in water use efficiency (WUE) will add 14 million ha of additional irrigation in India (Saleth, 1996).

Apart from waterlogging condition, there is wide spread salinity problem in the area also. Bringing these problematic areas under cultivation would be of immense help to improve agricultural scenario in the coastal area. Quantification of the available water resources, which is basic database for crop planning, is of paramount importance to bring sustainable agriculture in the area. Thus, an attempt is made in the present paper to investigate temporal rainfall and runoff status using two - parameter Gamma distribution function and USDA SCS CN procedure, respectively; prevalence of dry spell and wet spell conditions using Markov chain model, status on seasonal excess - deficit water condition using water budgeting procedure in a coastal paddy ecosystem in Pattamundai block in

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Kendrapara district of Odisha, which further can help in compiling strategic crop planning.

MATERIALS AND METHODS

Two parameter Gamma distribution function

The Probability Distribution Function (PDF) and Cumulative Distribution Function (CDF) of two parameter Gamma distribution function, which are used in the present study (based on best fitted χ^2 values), are described in Eqn. (1 and 2).

Two - parameter Gamma distribution

$$\text{PDF} = f(x) = \frac{x^{\alpha-1}}{\beta^{\alpha}\Gamma(\alpha)}\exp(-x/\beta) \quad (1)$$

$$\text{CDF} = F(x) = \frac{\Gamma_{x/\beta}(\alpha)}{\Gamma(\alpha)} \quad (2)$$

Where, α = constant shape parameter (α>0), β = constant scale parameter (β>0), Γ and $\Gamma_{x/\beta}$ are the Gamma and incomplete Gamma functions.

Chi-square test for goodness of fit

The chi-square test, which is widely applicable to problems of significance of hydro-meteorological nature is used in the present study to test the significance level of data set. The test statistic is as follows.

$$\chi^2 = \sum_{i=1}^{k}\frac{(O_i - E_i)^2}{E_i} \quad (3)$$

Where, Oi is the observed frequency for ith observation, and Ei is the expected frequency

Markov chain probability model for dry and wet spell analysis

The dry and wet spell analysis was carried out using Markov chain probability model as described by Reddy *et al.*, (2008), which helped to establish drought frequencies on weekly basis. Initial and transitional probabilities using this model are computed as follows:

Initial probability

Probability of dry week = P(d) = F(d)/N; and Probability of wet week = P(w) = F(w)/N Where, F(d) = frequency of dry weeks; F(w) = Frequency of wet weeks and N = Total no. of years of data used.

Conditional probability

Probability of a dry week preceded by a dry week = P(dd) = F(dd)/F(d); Probability of a wet week preceded by a wet week = P(ww) = F(ww)/F(w); Probability of a dry week preceded by a wet week = P(dw) = 1- P(ww); Probability of a wet week preceded by a dry week = P(wd) = 1- P(dd)

Where, F(dd) = Frequency of dry week preceded by another dry week, F(ww) = Frequency of wet week preceded by another wet week.

Consecutive dry and wet week probability

Probability of two consecutive weeks are dry = P(2d) = P(dw_1) * P(ddw_2); Probability of two consecutive weeks are wet = P(2w) = P(ww_1) *P(www_2).

Where, P(dw_1) = Probability of first week being dry, P(ddw_2) = Probability of second consecutive week being dry given the preceding week dry, P(ww_1) = Probability of first week being wet, P(www_2) = Probability of second consecutive week being wet given the preceding week wet.

Estimation of surface runoff using USDA SCS-CN procedure

An attempt is made to estimate event based surface runoff using USDA SCS-CN method. The value of the parameter CN was considered as 95 for monsoon paddy crop as reported by USAID (1991). Rainfall and irrigation contribution, if any from the canal were considered together while computing daily runoff depth. Daily estimation of runoff from total event based rainfall in a 24-hour period was computed by reducing AMC (II) (Antecedent Moisture Condition II), curve number value by 5 units as suggested by Rao (1995) and Krishna Rao (2001). The value of curve numbers for AMC (I) and AMC (III) conditions were further modified based on 5-days antecedent moisture conditions as suggested by Chow *et al.*, (1988).

Direct runoff can be computed based on the following equation;

$$Q = \frac{(P-0.2S)^2}{P+0.8S}, \text{ when } P > 0.2S$$

Q = 0, when P < 0.2S

Where, Q = direct runoff, mm; P = storm rainfall and irrigation, mm and S = maximum potential difference between rainfall and runoff, mm

The initial abstraction, I_a = 0.2S was considered. For convenience in evaluating antecedent rainfall, soil conditions, land use and conservation practices, USDA-SCS (1972) defined

$$S = \frac{25400}{CN} - 254$$

Where, CN = Curve Number varying between 0 to 100.

Study area

The study area (Fig. 1) comprising of 837 ha situated in Pattamundai block of Kendrapara district of Odisha comes under Mahanadi-Chitrotpala-Luna-Birupa drainage sector and East & South Eastern Coastal plain zone. It lies between 86° 14′ - 87° 3′ East longitude and 20° 21′ - 20o 47′ North latitude. The climate is generally hot (maximum 42°C) with high relative humidity (90 per cent) during April and May and cold (minimum 14°C) during December and January. Pattamundai main canal and Gobari extension canal passes close proximity to the study area. Field drains executed by Command Area Development (CAD), Department of Water Resources, Govt. of Odisha in the study area have varied success in improving the waterlogged condition in the crop fields.

Data base

Twenty years of daily rainfall data (1990-2009), ten years of daily canal water release data (2001-2010) and five years of daily evaporation data (2004-2008) were collected from Office of the DAO, Kendrapara (Odisha); Office of S.D.O., Department of Water Resources, Pattamundai (Odisha) and CRRI, Cuttack (Odisha), respectively and analysed for assessing the temporal availability of water resources for crop production.

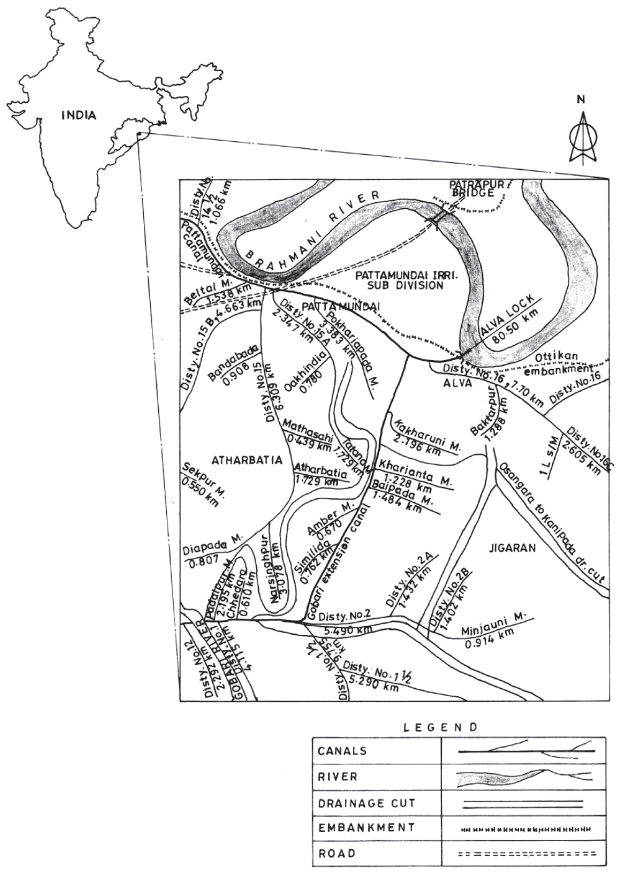

Fig. 1. Study area

RESULTS AND DISCUSSION

Present canal and surface drainage system and their functioning

A wide network of canal and field drainage system is being operated in the study area with varied degrees of functioning. The total length of primary, secondary and link drains comprising of 113, 452 and 342 km are working in Mahanadi-Chitrotpala-Luna-Birupa drainage sector. As to canal system, Pattamundai canal off takes from Kendrapara canal near Jagatpur, Cuttack (Odisha) with carrying capacity of 24 cumec and Kendrapara canal off takes from left side of Mahanadi barrage near Jagatpur, Cuttack (Odisha). After running 80 km distance, Pattamundai canal joins Gobari extension canal at its tail end near Alva (Fig. 1). The minors running in the study area are Kakharuni, Khadianta, Baipada and Amber and have lengths, CCA and design discharges varying between 0.7 - 2.2 km, 10.8 - 194.7 ha and 0.01 to 0.1 cumec, respectively. But practically, it is observed that much less flow is occurring in the minors due to either serious siltation or poor maintenance. Kakharuni Pani Panchayat is being operational since 2006 in the study area. Naladholia – Jigaran field drainage system having length of 3.5 km length helps in draining excess water from 837 ha area. As a result, total 745 nos. of farmers are being benefited from the drainage system. However, in spite of the active functioning of the Pani Panchayat, there have been many unauthorized outlets and farmers' are in practice of putting cross bunds across the minors for either catching fish or illegally diverting water to their crop fields, which is aggravating in reduction of the carrying capacity of the minors.

Table 1. *Socio-economic condition*

Category	Caste			Economic condition	
	General	OBC	SC	BPL	APL
Marginal (<2.5 acres)	18.6	3.4	20.3	42.4	–
Small (2.5-5 acres)	27.1	10.2	10.2	27.1	20.3
Medium (5-25 acres)	8.5	1.7	–	5.1	5.1
Total	54.2	15.3	30.5	74.6	25.4

Present land use pattern and socio-economic conditions

Out of the geographical area of 2.24 lakh ha of the study district, total problematic area is 1.68 lakh ha, respectively. As to total cultivated area, low, medium and up lands constitute to 49029, 71890 and 31081 ha, respectively. The district has mainly two varieties of soils viz. alluvial soil in the south-east and northern parts and normal strip of saline soil in the north-east along the coastal belt (District statistical handbook, 2007). Pattamundai block is predominant with low-lying and medium cultivated areas (76 per cent as against of total cultivated area of 15076 ha) and out of 11620 ha paddy area, lowland and medium land paddy area covers 83 per cent. Clay loam soil predominates 46.3 per cent area over total cultivated area, which remains for poor drainage situations during monsoon season. Total ninety per cent farmers are in marginal (< 2.5 acres) and small (2.5-5.0 acres) categories. Total 75 per cent farmers are under BPL category (DWM Annual Report, 2009-10). Due to lack of adequate in-situ water harvesting measures, there have been only 37 and 19 per cent coverage under crop during Rabi and Summer season, respectively.

Temporal rainfall distribution modeled through probability functions

Rainfall analysis for the period 1990-2009 revealed that average weekly rainfall varied between 6.5 - 102.3 mm, maximum of 102.3 mm occurring during 31st week (July 29 - August 4) followed by 89.6 mm during 32nd week (August 5 – August 11). Rainfall variability less than 100 per cent is observed during 25th - 27th, 33rd and 37th weeks implying uniform wetness period (Fig. 2). As to annual variations, there have been wide differences among the years with minimum, maximum and average rainfall of 461 mm (during 2002), 3271 mm (during 1997) and 1452 mm, respectively.

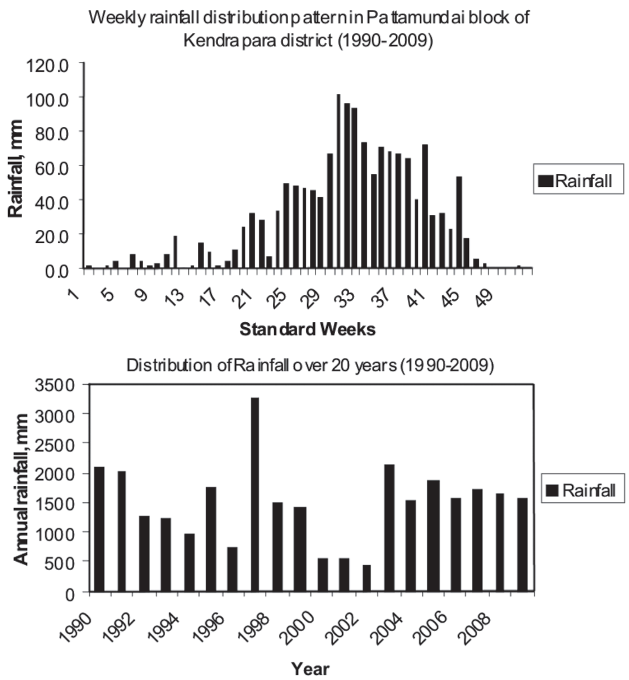

Fig. 2. Rainfall distribution pattern

Two-parameter Gamma, Normal, Log Pearson and Log Normal probability distribution functions were tested for modeling the rainfall distribution pattern. Among the distribution functions, when modeled through two-parameter Gamma distribution at 30 per cent probability level, there was no significant difference established between the observed and predicted weekly rainfall for the period (24th – 41st weeks) inferring the best fit distribution (Table 2 and Fig. 3). Both the data series were found no significant difference at $\alpha = 0.05$ level when tested through paired t-test. Same observations were also reported by Subash and Das (2004), while attempting to fit two – parameter Gamma distribution in standard weekly probability analysis of rainfall for Patna and was found best fit

Table 2. *Observed and predicted weekly rainfall at various probability levels using two - parameter Gamma distribution model*

Weeks	Observed data	Predicted data at different probability levels				
		30%	40%	50%	60%	70%
24	47.1	59.3	43.9	32.2	22.9	15.3
25	44.4	58.5	45.9	35.8	27.5	20.1
26	44.6	57.8	47.0	38.3	30.7	23.8
27	50.1	55.5	44.2	35.2	27.5	20.7
28	39.5	46.9	31.7	20.9	13.0	7.3
29	76.9	76.4	54.4	38.2	25.8	16.0
30	81.1	112.3	75.9	50.1	31.4	17.7
31	102.3	106.9	72.4	47.9	30.2	17.1
32	89.6	97.9	62.7	38.9	22.6	11.5
33	69.1	89.9	70.6	55.3	42.4	31.2
34	61.4	64.7	46.6	33.1	22.6	14.3
35	61.9	83.8	60.8	43.6	30.2	19.4
36	76.8	81.3	60.9	45.4	32.8	22.4
37	66.6	81.7	63.8	49.6	37.8	27.5
38	61.1	63.3	37.2	20.8	10.6	4.6
39	45.8	48.2	37.2	28.7	21.6	15.5
40	72.0	68.7	40.6	22.9	11.8	5.2
41	30.6	26.8	14.7	7.6	3.5	1.3

to the rainfall data series. Similarly, Sarkar (1994) found Gamma distribution as best fit to weekly rainfall, while estimating assured weekly rainfall at 30, 40, 50, 60, and 70 per cent probability levels for crop planning in the low water holding capacity soils of eastern Ganga plains of West Bengal. During the period, maximum, minimum, average and total rainfall were predicted as, 112.3 mm (31st week), 26.8 mm (41st week), 71.1 mm and 1280 mm as against of observed values of 102.3 mm, 30.6 mm, 62.3 mm and 1121 mm, respectively (Panda *et al.*, 2011).

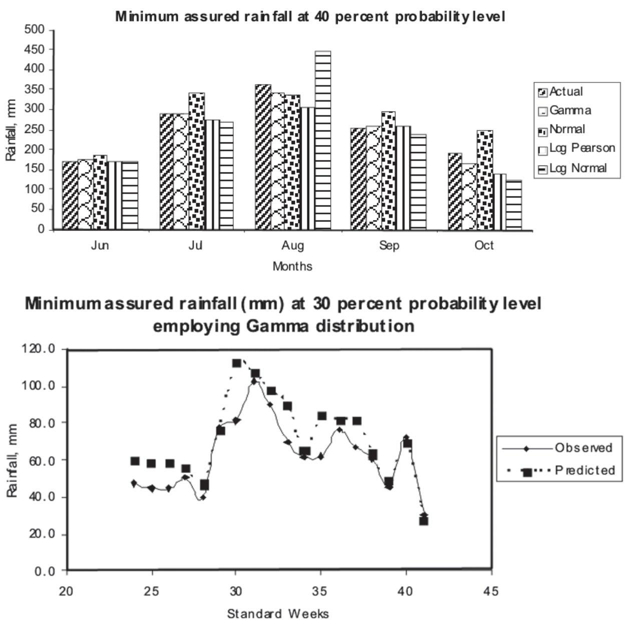

Fig. 3. Rainfall modeled through probability functions

Weekly dry and wet spell conditions

Initial and transitional probabilities were computed using Markov chain model (Fig. 4). Results revealed that the probability of occurrence of dry week is higher during 1st - 22nd, and 41st - 52nd weeks. The range of probability of occurrence of dry week in these weeks varies from 60 - 100 percent. The probability of dry week preceded by another dry week is higher during 1st - 23nd and 42nd - 52nd weeks, ranging between 69.2 - 95 percent. Probability of occurrence of dry week proceeded by wet week is 100 per cent during 1st - 14th, 16th - 18th and 47th - 52nd weeks. Probability of occurrence of wet week and the transitional probability of wet week preceded by wet week is higher during 23rd – 41st weeks with the range of probability varying between 40 - 90 percent. Probability of wet week preceded by dry week is higher in weeks 24th – 41st with the range varying between 45.4 - 83.3 per cent, implying vulnerability of dry spell of 17 - 55 per cent during the monsoon period. Consecutive probability of two wet weeks is varying from 31.8 - 75 per cent during 23rd – 40th weeks. The result infers that apart from the usual phenomena of prevalence of dry spell or wet spell during post monsoon and monsoon seasons, respectively, there is probability of occurrence of dry spell to the tune of up to 55 per cent during monsoon season. Thus it necessitates contingent plan through in-situ conservation measures for meeting the eventualities for crop sustenance.

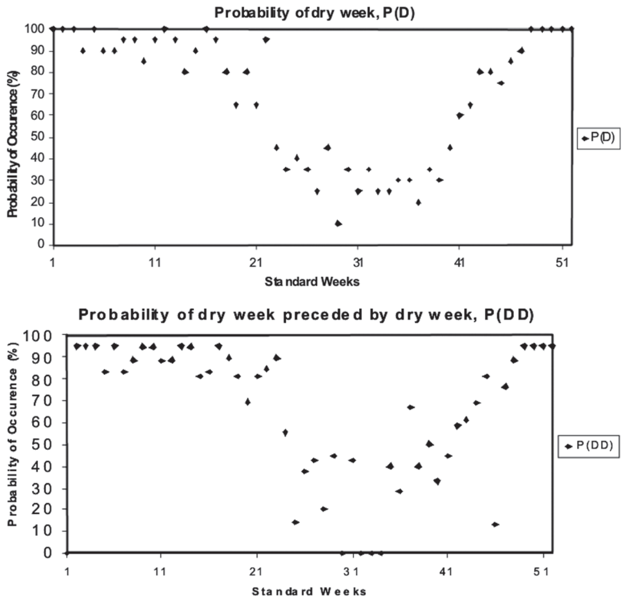

Fig. 4. Dry spell analysis using Markov chain model

Water budgeting

An attempt was made to budget the water for the study area. While budgeting through rainfall, irrigation and evaporation on weekly basis were used. When analyzing the canal irrigation water supply, as usual practices were noticed as prevalent in many other canal systems in the country elsewhere. Present canal water supply schedule (2006-2009) operated through the Department of Water Resources, Govt. of Odisha revealed that the supply of canal water continued from 2nd week of July - 3rd week of November, when almost 70 per cent of monsoon rain occurs; where as a short supply continued during 2nd week of January - 1st week of February during rabi season, when there is no rainfall (Fig. 5). There has been mismatch in occurrence of rainfall and canal water supply in the area. Water budget procedure revealed that total excess water of 1575 mm is available during 23th – 47th weeks (1519 mm) and 4th – 7th weeks (56 mm) with total deficit water amounting to 393 mm

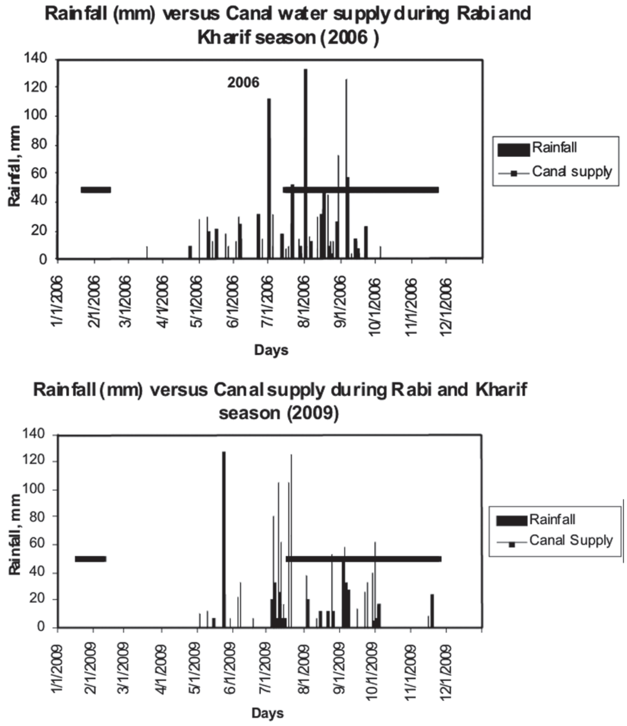

Fig. 5. Canal operational schedule of two representative years

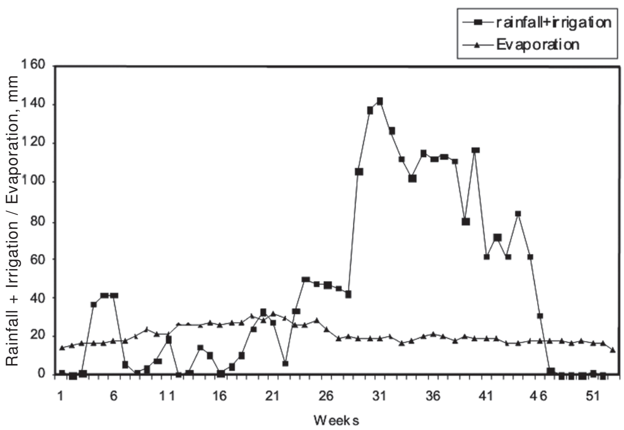

Fig. 6. Weekly water budgeting

occurring during 7th -23rd weeks (235 mm) and 47th – 3rd weeks (158 mm). Thus, there is gross excess water availability of 1182 mm occurring mostly during monsoon season (Fig. 6).

Predicted surface runoff

Event based runoff was estimated using USDA SCS CN procedure during period 1990 -2009. The result revealed that as against of maximum daily rainfall of 370 mm occurring during 1997, a runoff event of 358 mm is estimated. This emphasized for creation of adequate surface drainage provision in the study area for evacuating unprecedented runoff events.

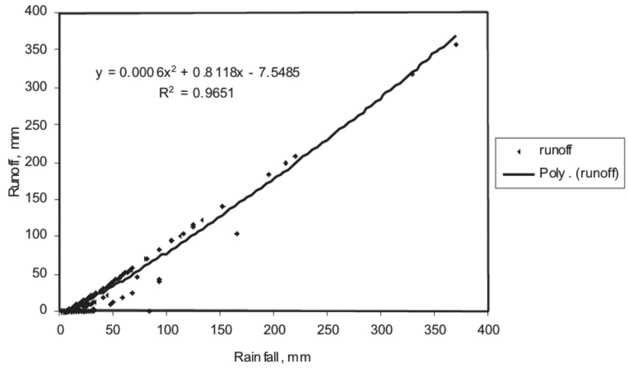

Fig. 7. Observed rainfall versus predicted runoff

An attempt was made to develop an empirical function for predicting the surface daily runoff through various best fit functional relationships without computing through the rigorous USDA SCS CN procedure. Total 255 data sets were randomly selected from the data series and among various functional relationships, 2nd order polynomial function i.e. $Y_{runoff} = 0.0006X_{rainfall}^2 + 0.812 X_{rainfall} - 7.549$, $R^2 = 0.97$, where, Xrainfall = daily observed rainfall, mm and Yrunoff = daily predicted runoff, mm (Fig. 7). This empirical relationship shall be useful in similar crop ecosystems in predicting daily runoff, which can help in planning and designing irrigation and drainage structures to accommodate the peak rainfall events.

CONCLUSION

Provision of creation of supplemental in-situ water harvesting devices for catering the need of monsoon crops at critical stages during dry spells and post monsoon crops, rescheduling of canal water supply with efficient delivery mechanism and adequate provision of surface drainage network are required in the study area to introduce diverse crop plan for higher productivity.

REFERENCES

Chow, V. T. (1988). *Handbook of applied hydrology.* McGraw Hill Book co., New York, U. S. A.

District Statistical Handbook (Kendrapara). (2007). Directorate of Economics and Statistics, Bhubaneswar, Orissa, p 107.

DWM Annual Report. (2009-10). Directorate of Water Management, Bhubaneswar, Orissa. pp 59-60.

Krishna Rao, B. (2001). Investigation on impact of rainfall distribution on runoff estimation using SCS CN method. *Unpublished M. Sc. Thesis,* IARI, Pusa, New Delhi.

Panda, R. K., Singh R., Kar, G. and Kumar Ashwani (2011). Resources appraisal of coastal paddy ecosystem of Orissa – A case study. In: Raychaudhuri *et al.*, (eds.) Souvenir, Seminar on *Water use in Agriculture; Challenges Ahead*, Indian Society of Water Management, Orissa Chapter, Directorate of Water Management, Indian Council of Agricultural Research, Bhubaneswar-751023, Odisha, India. p 10.

Rao, K. V. R. (1995). Runoff estimation from daily total rainfall using curve number method, *Unpublished M. Sc. Thesis*, IARI, Pusa, New Delhi.

Reddy, G. V. S., Bhaskar, S. R., Purohit, R. C. and Chittora, A. K. (2008). Markov chain model probability of dry, wet weeks and statistical analysis of weekly rainfall for agricultural planning at Bangalore, Karnataka. *Journal of Agricultural Sciences*, **21**(1): 12-16.

Sahrawat, K. L. (2008). Soil fertility advantages of submerged rice cropping systems. *Journal of Sustainable Agriculture* **31**(3): 5 – 23.

Sarkar, J. (1994). Crop planning on the basis of assured rainfall in low water holding capacity soils of eastern Ganga plains ecozone of West Bengal. *Mousam* 633 : 631.15 : 631.4 (541.2) : 194-195.

Singh, G. B. (1999). Natural resource management for sustainable agriculture in "Fifty years of natural resource management in India". ICAR, New Delhi.

Subash, N. and Das, P. K. (2004). Rainfall characteristics and probability analysis for crop planning under rice-wheat system in sub-humid (dry) climate. *Indian Journal of Soil Conservation* **32**(2): 124-128.

Saleth, R. M. (1996). Water institutions in India: Economics, law, policy, Common Wealth Publishers, New Delhi.

Tropp, H. (2006). Developing water governance capacities, Stockholm Water Front: *A Forum for Global Water Issues*, 2, Stockholm International Water Institute (SIWI), Stockholm, p 10.

USAID. (1991). *Drainage aspects of Eastern region and the Eastern coastal areas of India*. Technical Report No. 38, Louis Berger International, Inc. and WAPCOS (India) Ltd.

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Effect of Degree of Milling on Proximate Composition of Hybrid Rice

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Degree of milling is very important as it affect the pasting characteristics as well as nutritional qualities of the rice. This study was undertaken for the hybrid rice variety (Pant Sankar Dhan-1) to evaluate the effect of degree of milling on nutritive value of rice due to consumer awareness and their greater concern for the nutritive aspect of the food product. The study was undertaken at seven different degree of milling i.e. 0%, 3.77%, 5.62%, 6.56%, 7.93%, 9.12% and 10.33% and experiments were conducted in triplicate to obtain the proximate composition of milled rice. The protein, fat, ash and carbohydrate ranges from 9.020%-7.432%, 2.200% - 0.900%, 1.067% - 0.506% and 74.073%-77.522% respectively for brown rice to milled rice of 10.33% degree of milling. Simple models for prediction of protein, fat, ash and carbohydrate by linear regression were developed with high coefficient of determination. The results obtained showed that protein, fat and ash content decreases with degree of milling. This is due to the removal of aleurone layer during milling, which has significant amount of fat, protein and mineral content.

(***Key words:*** *Milling, Composition, Protein, Fat, Ash, Carbohydrate)*

It is well known that rice is the most consumed food on earth. More than 65% of the nutrition from the rice kernel is locked away in rice bran (the outer layer of the kernel) and is removed by milling operations. The precious nutrirents are routinely thrown away as an unused food resource. More than 60 million metric tons of rice bran is removed during the milling process each year. Rice has been a staple food of the human diet since antiquity. A quick look at world consumption shows that it provides 20% per capita energy and 13% of the protein consumed worldwide (Juliano, 1985).

MATERIALS AND METHODS

Raw material viz. paddy, Pant Sankar Dhan-1 variety was procured from the Department of Plant Breeding and Genetics, GBPUAT, Pantnagar. The proximate analysis of the rice was done for values of moisture content, fat, protein and ash. The moisture content was determined by the hot air oven drying method and percentage of moisture was calculated according to AOAC (1984) methods. Fat content of the sample was determined by using soxhlet apparatus as per the AOAC (1984). Protein content was also determined by Kjeldhal methods of AOAC (1984). The amount of protein was calculated by multiplying the nitrogen percentage with an appropriate conversion factor vof 6.25. Ash content is the inorganic residue remained after the destruction of organic matter and was also determined as per the AOAC (1984) method.

RESULTS AND DISCUSSION

The experiments were planned to study the effect of milling on nutritive value of milled rice. The hybrid rice variety Pant Sankar Dhan-1 was obtained from Department of Plant Breeding & Genetics, Pantnagar. The moisture content of milled rice was maintained at 13.64% (w.b.). The brown rice yield and husk content of Pant Sankar Dhan-1 were 75.86% and 21.06% respectively. The degree of milling was obtained by varying the time of milling from 0 sec to 60 sec, at an interval of 10 sec (Table 1). It shows that, the degree of milling during the first 30 sec of milling was 6.559%, second 30 sec of milling was 3.767%. These values indicate that, the degree of milling increased from 0 sec to 30 sec, but further increase in the milling time produced progressively less increase in degree of milling. The results were attributed to the fact that, with the increase in the time of milling, the surface becomes smoother on abrasion and reduces the rate of bran removal. Similar results were also reported by others (Sidhu *et al.*, 1975).

Few researchers has attempted mathematical models to correlate time with degree of milling. They indicated that, the rate of bran removal varied non linearly with time. Pal (1997) has tested different models to correlate time with degree of milling. She found that the Power model fitted the best. For the present study, the power model was tested and the coefficient of determination and standard error was found to be 0.994 and 0.0296 respectively.

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Table 1. *Effect of time on degree of milling of rice*

Sl. No.	Time of milling (sec)	Degree of milling (%)
1.	0	0.000
2.	10	3.773
3.	20	5.615
4.	30	6.559
5.	40	7.931
6.	50	9.120
7.	60	10.326

Table 2. *Effect of degree of milling on proximate composition*

Sl. No.	Degree of milling(%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)
1.	0.000	9.020	2.200	1.067	74.073
2.	3.773	8.375	1.800	0.768	75.417
3.	5.615	8.113	1.492	0.707	76.081
4.	6.559	7.778	1.300	0.586	76.696
5.	7.931	7.747	1.216	0.949	76.874
6.	9.120	7.560	1.240	0.948	77.282
7.	10.326	7.432	0.900	0.506	77.522

proximate composition values of protein, fat, ash and carbohydrate for different degree of milling are given in Table 2. The protein content of milled rice varied from 9.020% to 7.432% as the degree of milling increased from 0% to 10.326%. The reported value for protein in milled rice varies from 4.5% to 14.3% (Juliano, 1966). It is evident from the data that, as milling progressed, the protein content of milled rice decreased consistently.

The ash content decreased from 1.067% to 0.056% as the degree of milling increased from 0% to 10.326%. The low ash content of milled rice was attributed to the removal of the peripheral layers of the bran from the brown rice. The extended milling time caused a heavy reduction in the ash content.

The fat content varied from 2.2% to 0.9%, while the carbohydrate content increased from 74.073% to 77.5219% for milled rice of 0% to 10.326% respectively. Similar results were also reported by others (Shams-ud-din, 1978).

Simple models for prediction of protein, fat, ash and carbohydrate by linear regression were also developed with high coefficient of determination (r2=0.9332). The developed models for protein, fat, ash and carbohydrate are as follows-

Protein (%) = 8.9667- 0.1579 X Degree of milling (%)

Fat (%) = 2.219 – 0.1259 X Degree of milling (%)

Ash (%) = 1.0161 – 0.0551 X Degree of milling (%)

Carbohydrate (%) = 74.158 + 0.3425 X Degree of milling (%)

Proximate composition values predicted based on the above models are given in Table 3.

Table 3. *Predicted values for proximate composition based on developed model*

Sl. No.	Degree of milling(%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)
1.	0.000	8.967	2.220	1.016	74.500
2.	3.773	8.371	1.744	0.808	75.450
3.	5.615	8.080	1.512	0.706	76.081
4.	6.559	7.931	1.393	0.654	76.404
5.	7.931	7.714	1.220	0.580	76.874
6.	9.120	7.526	1.071	0.513	77.281
7.	10.326	7.336	0.919	0.447	78.054

CONCLUSIONS

The studies revealed that protein, fat and ash decreases with degree of milling. This is due to the removal of aleurone layer during milling which has a significant amount of fat, protein and mineral content in it.

REFERENES

AOAC (1984). *Official methods of analysis*. Association of official analytical chemists. 14 th edition, Chicago, III, USA.

Juliano, B. O. (1966). *Physicochemical data on the rice grain*. Technical Bulletin No. 6, International Rice Research Institute, Los Benos, Philippines. 150 p.

Pal, V. (1997). Effect of Degree of polish on milling: physicochemical and storage properties of milled rice. *Unpublished M. Tech Thesis*, G.B.P.U.A & T, Pantnagar, India.

Sidhu (1975). Milling of paddy in relation to yield and quality of rice of different Indian varieties. *Journal of Agriculture Food Chemistry* **23**: 1183-1188.

Shams – ud – din, M. D. and Bhattacharyya, K. R. (1978). On the meaning of the degree of milling of rice. *Food Technology* **13**: 99-105.

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Constraints in Adoption of Moongbean Production Technology in Sundarban, West Bengal

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The new agricultural technologies are considered to be the prime mover to the process of agricultural development in India. Understanding farmers' perceptions of a given technology is crucial in the generation and diffusion of new technologies and farm household information dissemination. Pulses in India have long been considered as the poor man's only source of protein. Moongbean (green gram) is one of the important pulse crop in India, plays a major role in augmenting the income of small and marginal farmers of Sundarban. Constraints are the circumstances or causes, which prohibit farmer to adopt improved farm technology. This constraint study was carried out in Sundarban area of West Bengal state, to record the constraints responsible for the non adoption of moongbean production technology. The proposed study was conducted in Kakdwip and Namkhana block of South 24 Parganas district. The constraints were recorded under five broad categories namely knowledge and information, technical, socio-economic, infrastructural and managerial. Financial limitations, harvesting and disposal troubles, non availability of rhizobium inoculam, small holdings, lack of timely availability of inputs, marketing of output, lack of timely assured irrigation, high cost of inputs, security of crops, risk and uncertainty were the major constraints found in the adoption of recommended practices by the farmers cultivating moongbean in Sundarban. For effective and better adoption of new technologies these barriers should be taken care of by the researchers, state departments and the other extension agencies. If a technology is highly observable, the diffusion process via the imitation mechanism is likely to proceed more rapidly. The constraints expressed for non adoption of recommended package of practices should be taken care by the researchers, state agricultural departments personal, extension agencies and commercial firms to orient their infrastructure for higher adoption of recommended technology by moongbean growers for maximum production.

(***Key Words:*** *Moongbean, Production technology, Constraints, Sundarban)*

Pulses in India have long been considered as the poor man's only source of protein. Pulses are grown on 22-23 million hectares of area with an annual production of 13-15 million tones (mt). India accounts for 33% of the world area and 22% of the world production of pulses. The major pulse crops grown in India are chickpea, pigeonpea, lentil, moongbean, urdbean and fieldpea (Reddy, 2009).

Moongbean crop is one of the important pulse crops cultivated after the harvest of aman rice. The cultivation of moongbean has been introduced in the rice- fallow cropping system of Sundarban in the eighties. Moongbean contains 25 percent of high digestible proteins and consumed both as whole grain as well as dal. It is a soil building crop which fixes atmospheric nitrogen through symbiotic action and can also be used as green manure crop adding 34 kg N ha^{-1}.

Several high yielding varieties like Pusa Baishakhi, K-851 and PDM 54 (Moti) are available with the farmers but a wide gap is conspicuous in the actual potentiality of the variety (Chandra, 2010), the reasons for which need to be ascertained. Constraints are the circumstances or causes, which prohibit farmer to adopt improved farm technology. It was ascertained by asking open-end questions to the respondent farmers regarding the different factors, which were responsible for non-adoptions of, recommended cultivation practices. Since adoption pattern of moongbean cultivation is of utmost importance for increasing the production as well as productivity levels, this study was undertaken to know the constraints which are responsible for non adoption of moongbean production technology in Sundarban, West Bengal. There is a wealth of empirical evidence on the factors that influence farmers' adoption of innovations (Feder and Umali (1993), Lindner (1987) and Rogers (1995). There is a plethora of studies related to adoption of different agricultural technologies but these are crop-specific, input-specific or location-specific (Singh, 1993).

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MATERIALS AND METHODS

The proposed study was conducted in Kakdwip and Namkhana block of South 24 Parganas districts of West Bengal. Four villages having a large number of moongbean growers were selected namely Nandabhaga, Debnibas, Belpukur and Gangadharpur from the selected blocks. Fifteen farmers belonging to marginal, small, medium and large farmer categories (five from each category) who are growing moongbean were selected randomly from each selected village thus making the total sample size of 60 respondents. Relevant information was collected with the help of questionnaire and schedule by holding personal interview with the selected respondents. Percent score was allotted for each of the constraints affecting the adoption of moongbean production technology. For the sake of convenience all the constraints were divided into five categories viz. knowledge and information, technical, socio-economic, infrastructural and managerial. Multiple responses were recorded because of the open ended nature of the questionnaire.

RESULTS AND DISCUSSION

Knowledge and information constraints

It is evident from table 1 the two constraints recorded were lack of information and lack of knowledge about Rhizobium inoculation under knowledge and information. Lack of technical knows how about the scientific moongbean production technology has been ranked first among this group by the farmers and only 31 percent of them faced this. A key to the diffusion of a new technology is providing information about its existence and properties. The lack of technical knowledge as a constraint has given a scope to train farmers about the new package of practices for better results. More over the second constraint perceived only by 10 percent of the farming population. The practical training of Rhizobium inoculation has provided the opportunity to the farmers to understand the role of Rhizobium in pulse cultivation.

Table 1. *Knowledge and information constraints faced by the farmers (N=60)*

Sr. No.	Constraints	Frequency	Percentage	Rank
1	Lack of information on production technology	19	31	I
2	Lack of knowledge about Rhizobium inoculation	10	16	II

*Multiple responses

Technical constraints

The first important constraint as perceived by the farmers was harvesting and disposal troubles because of the shattering of moongbean pods at the time of physiological maturity, non synchronous maturity and the non availability of suitable harvester, processor and small scale milling units at the village levels. A suitable harvesting and disposal mechanism should be developed through the introduction of synchronous maturity strain.

Risk and uncertainty has been ranked as second important technical constraints affecting the adoption of moongbean production technology uncertainty and risk are major obstacles for the adoption of new technologies. Farmers to a large extent are risk averse (Bar-shira *et al.*, 1997) meaning that they are willing to give up some average profit in order to reduce fluctuations in, or uncertainty about, profit. In many cases adoption of new technologies is gradual so farmers can experiment with them and have more reliable assessments of their impacts. One of the main activities of extension agents is to reduce farmers' uncertainties about new technologies. Effective plans that educate farmers about the properties of a new technology and reduce their uncertainty about it will likely result in higher adoption rates (Pannell and Zilberman, 2001).

The third constraints as perceived by the farmers are incompatibility with other crops and enterprise. The farmers in summer season are also cultivating watermelon and chili, the two most important cash crops in this region in the same season hence, the farmers are averse of cultivating moongbean in a large area. The other two technical constraints are complexity and not convinced of superiority (Table 2).

Table 2. *Technical constraints faced by the farmers (N=60)*

Sr. No.	Constraints	Frequency	Percentage	Rank
1.	Not convinced of superiority	9	15	IV
2.	Harvesting and disposal trouble	39	65	I
3.	Risk and uncertainty	24	40	II
4.	Incompatibility	14	23	III
5.	Complexity	11	18	IV

*Multiple responses

Socio-economic constraints

The most important constraint recorded was financial limitation, which can be ascribed to the non availability of credit at affordable interest rates. Despite the vast expansion of the formal credit system in India, the dependence of the rural poor on money lenders continues especially for meeting emergency credit requirement. Such dependence is more pronounced in resource poor areas like Sundarban and in case of poor marginal and small farmers. The expert committee on rural credit of NABARD has suggested that the rural financial institutions should adopt a holistic approach using the portfolio strategy. They were also advised to lend through a group approach through self help groups or joint liability groups (Satyasai and Patil, 2002). But the recommendation has still to take its shape in Sundarban. The Financial institutions like commercial banks, RRBs and primary cooperative society should be equipped to provide credit to the farmers at an appropriate time.

Second important socio economic constraint in the adoption of Moongbean production technology was small holdings of land. Sixty four percent lands holding of the district South 24 Parganas is of less than one hectare size and because of their small holding farmers always prefer to grow food grain and cash crops over moongbean cultivation which has been given subsidiary status.

Unsustainable farming situation was ranked third as most of the lands in Sundarban delta area are saline and alkaline having its own impact on the yield of moongbean. Moreover lack of improved strains for the coastal agricultural areas is also creating a vacuum in proper agriculture diversification. High cost of inputs was considered the fourth constraints by the farmers as most of the farmers are resource poor in this region. Soaring prices of seeds, fertilizers and pesticides were a cause for great concern (Table 3).

Table 3. *Socio-economic constraints perceived by the farmers (N-60)*

Sr. No.	Constraints	Frequency	Percentage	Rank
1.	Small holding	36	60	II
2.	Unsustainable farm situation	32	53	III
3.	Financial Limitation	45	75	I
4.	High cost of inputs	29	48	IV

*Multiple responses

Understanding farmers' perceptions of a given technology is crucial in the generation and diffusion of new technologies and farm household information dissemination (Kivlin and Fliegel, 1967; Ashby and Sperling, 1992).

Infrastructural constraints

Fifty six percent of the respondents had indicated that lack of timely availability of inputs as the first important infrastructural factor of non adoption. The supply of inputs viz. seeds, fertilizers, pesticides etc. should be maintained for greater adoption of improved technologies in Sundarban. Seed, fertilizer, Rhizobium culture and plant protection chemicals should be made available in sufficient quantity and in time. Kohli and Singh (1989) found that inputs played a large role in the rapid adoption of HYVs in the Punjab.

Fifty percent of the farmers have ranked lack of timely assured irrigation as third infrastructural constraints. Moongbean crop is grown in Sundarban on residual moisture of kharif paddy crop. Scheduling single irrigation even at the time of critical growth period of crop was very difficult. The other infrastructural problem faced by the farmers was difficulties in transport because of the difficult and remote nature of the islands in Sundarbans (Table 4).

Table 4. *Infrastructural constraints perceived by the farmers (N-60)*

Sr. No.	Constraints	Frequency	Percentage	Rank
1.	Marketing of output	31	51	II
2.	Lack of timely availability of input	34	56	I
3.	Lack of timely assured irrigation	30	50	III
4.	Difficulties in transport	18	30	IV

*Multiple responses

The economic constraint model contends that input fixity in the short run, such as access to credit, land, labor or other critical inputs limits production flexibility and conditions technology adoption decisions (Aikens *et al.*, 1975; Smale *et al.*, 1994; Shampine, 1998).

Managerial Constraints

Sixty three percents of the respondents had ranked non availability of Rhizobium culture as the most important constraint. The problem of timely availability, storage and technique of application of Rhizobium inocula is one of the causes of concern. Woomer et al., (1996) have observed that Rhizobium inocula are not being adopted because of the ignorance of small holders as well as the unstable supply mechanism. The state agricultural department and State agricultural university must be equipped to maintain the supply of Rhizobium inocula for farmers.

Forty five percents of the farmers have ranked security of crop as second managerial constraints affecting moongbean cultivation. The unfavourable weather condition like erratic and uncertain rainfall, low and high temperature at the time of various crop growth stages, cyclone and low pressure formation in the bay of Bengal were the another cause of poor productivity of moongbean in this area. Management and labour supply are the two other constraints perceived by the farmers (Table 5).

Table 5. *Managerial Constraints perceived by the farmers (N-60)*

Sr. No.	Constraints	Frequency	Percentage	Rank
1.	Labour Supply	12	20	V
2.	Management	13	21	IV
3.	Harvesting and d isposal trouble	39	65	I
4.	Security of crops	27	45	III
5.	Non availability of rhizobium culture	38	63	II

*Multiple responses

Observability and trialability are closely related to the issue of uncertainty. If a technology is highly observable, the diffusion process via the imitation mechanism is likely to proceed more rapidly. Perhaps even more important is the potential to trial the innovation on a small scale, so that information can be obtained, uncertainties reduced and skills developed without the risk of large financial loss if the technology turns out to be uneconomic or fails due to inexperience (Pannell and Zilberman, 2001).

CONCLUSION

The findings stresses upon the need that the extension agencies should gear up its various programmes to improve the adoption level of the farmers. The constraints expressed for non adoption of recommended package of practices should be taken care by the researchers, state agricultural departments personal, extension agencies and commercial firms to orient their infrastructure for higher adoption of recommended technology by moongbean growers for maximum production. Proper guidance and awareness for the farmers should be created through practical skill oriented training, field visits, field demonstrations and through various extension literatures (printed as well as video). The maximum participation of farmers in technology generation process as well as in the production enhancements strategies are required to thwart any risk of technological failures.

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REFERENCES

Aikens, M. T., Havens, A. E., and Flinn, W. L. (1975). The adoption of innovations: the neglected role of institutional constraints. Mimeograph. Department of Rural Sociology. The Ohio State University. Columbus, Ohio, USA.

Ashby, J. A., and Sperling, L. (1992). Institutionalizing participatory, client-driven research and development in agriculture. Paper presented at the Meeting of the CGIAR Social Scientists. The Hague. September 15-22.

Bar-Shira, Z. Just, R. and Zilberman, D. (1997). Estimation of farmers' risk attitude: an econometric approach, *Agricultural Economics* **17**: 211-221.

Chandra, Ganesh. (2010). Evaluation of Frontline Demonstration of Greengram (*Vigna radiata* L.) in Sundarbans, West Bengal. *Journal of Indian Society of Coastal Agricultural Research* **28**(1): 12-15.

Feder, G. and Umali, D. (1993). The adoption of agricultural innovations: a review. *Technological Forecasting and Social Change* **43**: 215-239.

Kivlin, J.E., and Fliegel, F.C. (1967). Differential perceptions of innovations and rate of adoption. *Rural Sociology* **32**(1): 78-91.

Kohli, I., and Singh, N. (1989). "Exports and Growth: Critical minimum effort and diminishing returns." *Journal of Development Economics*. **30**(2): 391-400.

Kotler, P. (1997). *Marketing Management: Analysis, Planning, Implementation, and Control*,. 9th edition. Prentice Hall, Upper Saddle River, New Jersey, USA.

Lindner, R. K. (1987). Adoption and diffusion of technology: an overview, **In** *Technological Change in Post Harvest Handling and Transportation of Grains in the Humid Tropics*, B.R. Champ, E. Highley and J.V.Remenyi (eds.), ACIAR Proceeding **19**:144-151.

Pannell, D.J. and Zilberman, D. (2001). Economic and sociological factors affecting growers' decision making on herbicide resistance. In: D.L. Shaner and S.B. Powles (eds.) *Herbicide Resistance and World Grains*, CRC Press, Boca Raton, pp. 251-277. (SEA Working Paper 00/07, Agricultural and Resource Economics, University of Western Australia).

Reddy, A.A. (2009). Pulses production technology: status and way forward. *Economic and Political Weekly* **44**(52):73-80.

Rogers, E.M. (1995). *Diffusion of Innovations*. Free Press, New York, USA.

Satyasai, K. J. S., and Patil, A. S. (2002). Revitalizing rural credit system: view of expert committee. *Economic and Political Weekly* **37**(31): 3235-3238.

Shampine, A. (1998). Compensating for information externalities in technology diffusion models. *American Journal of Agricultural Economics* **80**(3): 337-346.

Singh, D. K. (1993). Technological Change and Agriculture Development. Deep and Deep Publications, New Delhi.

Smale, M., Just, R., and Leathers, H. D. (1994). Land Allocation in HYV Adoption Models: An Investigation of Alternative Explanations. *American Journal of Agricultural Economics* **76**(3): 535-46.

Woomer, P.L, Kahindi, J.H.P., and Karanja, N. (1996). Nitrogen replenishment in the east African highlands through biological nitrogen fixation and legume inoculation. Paper presented at the 7th International Conference on the African Association for Biological nitrogen Fixation (AABNF) held at ENSA - Yamoussoukro in Côte d'Ivoire, September 4-11.

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Contribution of Fiddler Crabs *Uca* spp. (Brachyura: Ocypodidae) towards Soil Inorganic Nitrate Production and Mangrove Sustenance in Indian *Sundarbans*

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As mangrove ecosystem is generally nitrogen-limited, extent of contribution of key mudflat macrofauna like fiddler crabs towards soil inorganic nitrate production was the primary focus of the present study. The study was conducted in the mangrove forests of Indian *Sundarbans* at Bakkhali, Jharkhali and Jhingakhali from March, 2009 to February, 2010. Fiddler crab burrows and soil inorganic nitrate were recorded from four 50 x 50 cm (0.25 m^2) squares spaced at lower, mid and upper-intertidal zones on each of the three transects in the study sites on a seasonal basis during low tides. Soil inorganic nitrate content was found to be positively correlated with fiddler crab density. Regression analysis illustrated the possible role of fiddler crabs towards soil inorganic nitrate production, sustaining the mangrove vegetation through their burrow formations and foraging activities in the soil, aided by complex bacterial action.

(**Key words:** *Burrow, Fiddler crab, Inorganic nitrate, Mangrove, Soil, Sundarbans*

There is considerable interest in the nitrogen nutrition of plants growing in waterlogged saline soils (Boto *et al.*, 1985). It has been proposed that the apparent nitrogen limitation may be due to the anaerobic nature of most marsh soils (Meldenssolen, 1979; Howes *et al.*, 1981; Morris, 1980). Studies, although much limited, have been made for mangrove ecosystems. Boto *et al.*, (1985) showed that *Avicennia marina* (Forsk.) Vierh. seedlings require some degrees of nitrate availability for optimal growth and particularly for root development. Fiddler crabs, *Uca* (Crustacea: Ocypodidae) characterize the intertidal zones of estuarine and mangrove ecosystems, feeding and digging burrows in the inshore muddy or sandy substratum. However, they do not depend entirely on mangroves for shelter or food, but rotting mangrove leaves enrich the muddy substratum providing the primary food to sustain the crabs (Kwok and Tang, 2006). These crabs constitute a significant component of the intertidal macrofaunal biomass of temperate and tropical estuaries (Crane, 1975) and influence the transfer of nutrients and energy from intertidal areas to estuaries in general (Montague, 1980 & 1982). Moreover, they act as significant ecosystem engineers by virtue of their extensive burrowing capacities. Not only do they alter the physical structure of their environment by this act, but they also significantly affect the growth and productivity of the mangrove trees (Hogarth, 2007). The present study thereby deals with the contribution of fiddler crabs towards soil inorganic nitrate production through their burrow formations in the mangrove ecosystems of Indian Sundarbans.

MATERIALS AND METHODS

The field work was carried out in three mangrove areas in Sundarban Biosphere Reserve (21°30′ to 22° 40′ N, 88° 05′ to 89° 55′ E) of West Bengal, Eastern India throughout one year, from March 2009 to February 2010. The sampled areas were Bakkhali (lat. 21°33′ N; long. 88°17′ E), Jharkhali (lat. 22°1′ N; long. 88°40' E) and Jhingakhali (lat. 22°12′ N; long. 89° 1′ E) of the south-western, central and north-eastern part of Indian *Sundarbans* respectively (Fig. 1). The climate of the area was characterized by relatively high temperature and humidity (>80 %) throughout the year and well distributed rainfall during the monsoon season (July-October). The mean maximum and minimum temperatures were 29°C (June-July) and 20°C (December-January) respectively. The average annual rainfall in the Indian region was only 180 cm. Humidity ranges normally between 70 and 88%. The mangrove vegetation in these areas was dominated by *Avicennia marina* (Forsk.) Vierh., *A. officinalis* Lamarck, *A. alba* Blume, *Excoecaria agallocha* Lamarck, *Bruguiera gymnorrhiza* (L.) Savigny, *Ceriops tagal* (Per.) Robins, *C. decandra* (Grift) Ding Hou and *Acanthus ilicifolius* Linn.

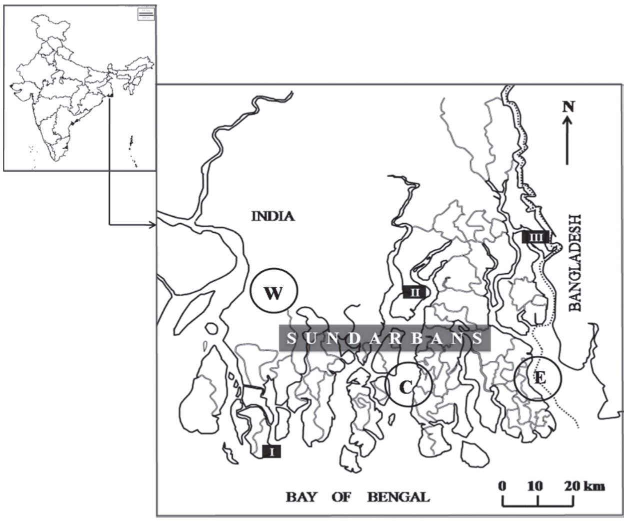

Fig. 1. Map of Sundarban Biosphere Reserve (Eastern India), showing the study sites at Bakkhali, Jharkhali and Jhingakhali as I, II and III respectively. W, C and E represent Western, Central and Eastern parts of Indian *Sundarbans*

Three transects were delimited in each of the three study sites of *Sundarbans*. On each transect, four 50 x 50 cm (0.25 m^2) squares spaced at lower-intertidal (low tide zone: Zone I), mid-intertidal (mid tide zone: Zone II) and upper-intertidal (high tide zone: Zone III), were sampled on a seasonal basis (Pre-monsoon: March-June, Monsoon: July-October, Post-Monsoon: November-February) during low tides from March, 2009 to February, 2010. At each season the same squares were sampled. The transects ran from the creek-edge of mudflats to the edge of the mangrove vegetation to sample the whole habitat occupied by the fiddler crabs (*Uca* spp.). In each square, the number of fiddler crab burrows was recorded.

The soil inorganic nitrate in the study sites was measured by 1:5 dilution method (Charman and Murphy, 2007) using Nitrate test kits (Aquamerck, Germany) and applying the colorimetric method.

For analysis of the functional dependence of soil inorganic nitrate (N) production on the density of fiddler crab (D), data were analyzed using the linear regression function (Y= a + bX) on SPSS (SPSS Inc., Version 16 for Windows, Release Sep 13, 2007).

RESULTS AND DISCUSSION

Soil inorganic nitrate content was found to correspond with mean fiddler crab densities in the three intertidal zones at Bakkhali, Jharkhali and Jhingakhali mangroves for pre-monsoon, monsoon and post-monsoon months (Fig. 2). The mean annual inorganic nitrate content in the soil was 1.78 mg 100 g^{-1} of soil (Table 2). Fig. 3 illustrates variation in soil inorganic nitrate on a seasonal basis in the study sites. The mean annual density of fiddler crabs was 24.5 individuals m^{-2} (Table 1). Monsoon months showed highest crab densities (31.9 individuals m^{-2}) with nitrate production at its peak (2.14 mg100 g^{-1} of soil). This was followed by the pre-monsoon (density: 26.1 individuals m^{-2}; nitrate: 2.04 mg 100 g^{-1} of soil) and post-monsoon (density: 15.5 individuals m^{-2}; nitrate: 1.16 mg100 g^{-1} of soil) months (Table 1 and 2).

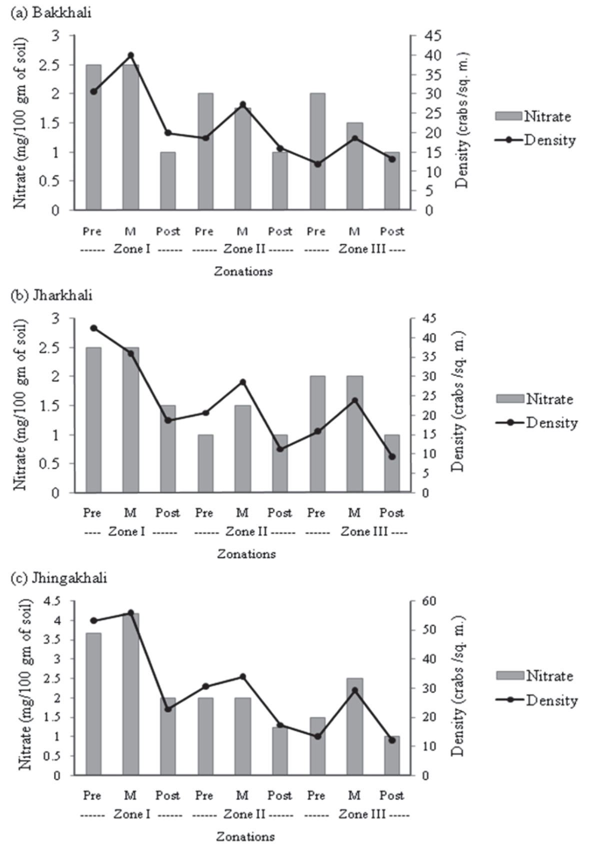

Fig. 2. Variations in soil inorganic nitrate (mg 100g^{-1} of soil) and crab density (nos. m^{-2}) over the seasons along the intertidal gradient in (a) Bakkhali, (b) Jharkhali and (c) Jhingakhali in *Sundarbans* mangrove ecosystems of India

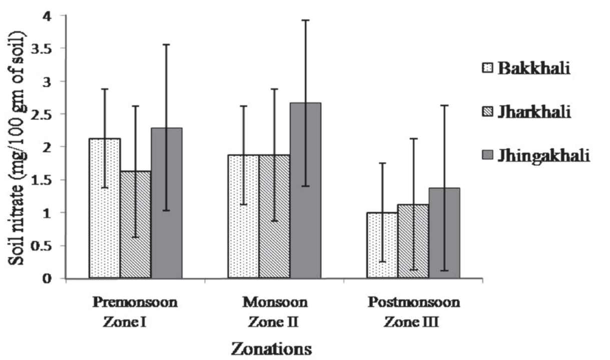

Fig. 3. Soil inorganic nitrate (mg 100 g^{-1} of soil) variations over the seasons along the intertidal gradient (Zone I, Zone II and Zone III) in Bakkhali, Jharkhali and Jhingakhali mangroves in Indian *Sundarbans*. Bars indicate standard deviation

Table 1. *Density of fiddler crab at each season and yearly mean (number of individuals m^{-2}) in Sundarban mangroves, Eastern India from March, 2009 to February, 2010.*

Uca species	Mean seasonal density (individuals m^{-2})			Mean yearly density (individuals/m^2) for each species
	Pre-monsoon	Monsoon	Post-monsoon	
Uca rosea	11.7	12.4	7.0	10.4
Uca triangularis	9.5	12.2	4.7	8.8
Uca lactea	4.9	7.3	3.8	5.3
Total	26.1	31.9	15.5	
Mean yearly density (individuals m^{-2})				24.5

Table 2. *Soil inorganic nitrate content in each season and annual mean (mg 100 g^{-1} of soil) in Sundarban mangroves from March, 2009 to February, 2010.*

UStudy Site	Mean soil inorganic nitrate (mg 100 g^{-1} of soil)			Mean nitrate (mg 100 g^{-1} of soil) production over seasons
	Bakkhali	Jharkhali	Jhingakhali	
Pre-Monsoon	2.21	1.62	2.29	2.04
Monsoon	1.87	1.87	2.67	2.14
Post-Monsoon	1.0	1.12	1.37	1.16
Mean annual soil nitrate (mg 100 g^{-1} of soil) production			1.78	

Soil inorganic nitrate content (N) was found to be positively correlated with fiddler crab density (D) and the resulting scatter plot shows a linear trend (Fig. 4), expressed by the function N = 0.452 + 0.057D (r^2 = 0.769, n= 27). 77% of the variability in inorganic nitrate production in soil can be explained by the density of fiddler crab in the mangrove ecosystems of Sundarbans.

Mangrove communities are highly productive communities with rates comparable to many terrestrial forest communities (Lugo and Snedaker, 1974). They form an important source of organic matter for food chains both within the mangroves and in neighbouring estuaries and coastal areas. However, these ecosystems are often nitrogen-limited and any additional sources of nitrogen, even though quantitatively small, may be valuable (Hogarth, 2007). The availability of inorganic nitrogen depends on a complex pattern of bacterial activity within the soil. Mangrove soil is largely anoxic, apart from a very thin aerobic zone at the surface. Ammonia produced principally in the anoxic zone, by nitrification process, is oxidized mostly by aerobic bacteria in the upper aerobic zone into nitrite and then into nitrate. Nitrate then diffuses back down through the anoxic layer, where it may be taken up by mangrove roots; assimilated by bacteria and immobilized; or may be reduced by further (anaerobic) bacterial action into either gaseous nitrogen or nitrous oxide. In this last case, the gas is likely to diffuse through the soil and may be lost to the atmosphere (Boto, 1982; Hutchings and Saenger, 1987). The amount of nitrate actually available to mangrove roots depends on the balance between these processes, hence on the degree of oxygenation of the soil. This, in turn, depends on the inundation régime and on soil composition. Much of the microbial activity of mangrove mud occurs within a short distance of the surface, to a depth limited by diffusional gas exchange with the atmosphere. This activity are generally enhanced

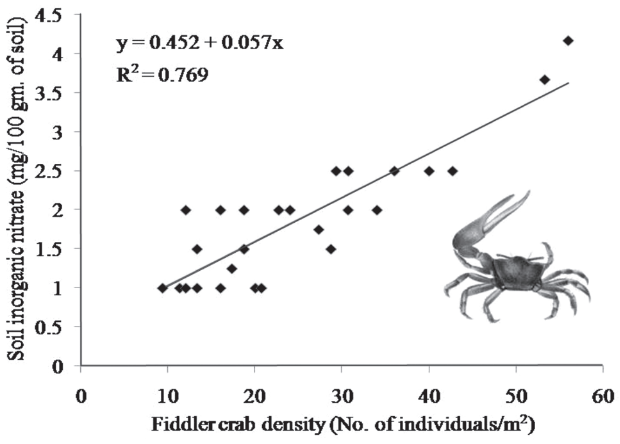

Fig. 4. Scatter plot relationship between soil inorganic nitrate (mg/100 g^{-1} of soil) and fiddler crab density (individuals m^{-2}) from the mangroves of Indian *Sundarbans*

by fiddler crabs working over the surface as they extract food, continually exposing fresh mud to the surface and sorting soil particles by size and composition. As soil oxygenation is largely affected by animal burrows, extensive burrowing by the fiddler crabs has the further effect of increasing the surface area of mud exposed more or less directly to the atmosphere. An analysis of the effects of fiddler crabs in a saltmarsh indicated that burrowing increased the surface area by 59% (Katz, 1980).

The positive correlation between the fiddler crab density and soil inorganic nitrate content in the present study illustrates the possible role of these crabs in the production of inorganic nitrate in *Sundarbans* mangroves through their burrow formations and foraging activities and hence towards increased nitrification. The monsoon months show maximum density of these crabs. The soil nitrate, henceforth show a corresponding increase in its production during the monsoon season due to increased fiddler crab activity, as evident from Fig. 4. Such interdependence between the fiddler crabs and soil inorganic nitrate production, in turn, enhances the nitrogen-poor mangrove ecosystem with nitrogen nutrition, sustaining the mangrove vegetation in *Sundarbans*.

REFERENCES

Boto, K., Saffigna, P. and Clough, B. (1985). Role of nitrate in nitrogen nutrition of the mangrove *Avicennia marina. Marine Ecological Progression Series* **21**: 259-265.

Boto, K. G. (1982). Nutrient and organic fluxes in mangroves. In: *Structure, Function and Management of Mangrove Ecosystems in Australia*, B. F. Clough (ed.), ANU Press, Canberra, pp 239 - 258.

Charman, P. E. V and Murphy, B. W. (2007). *Soils: Their Properties and Management*, Third edition, Oxford University Press, South Melbourne. 448 p.

Crane, J. (1975). *Fiddler crabs of the world. Ocypodidae: Genus Uca*, Princeton University Press, Princeton, New Jersey, 736 p.

Hogarth, P. J. (2007). *The biology of mangroves and seagrasses*, Oxford University Press, New York. 273 p.

Howes, B. L., Howarth, R. W., Teal, J. M. and Valiela, I. (1981). Oxidation-reduction potentials in a salt marsh: spatial patterns and interactions with primary production. *Limnology Oceanogaphy* **26**: 350-360.

Hutchings, P. and Saenger, P. (1987). *Ecology of mangroves*. University of Queensland Press. Queensland. Australia, 388 p.

Katz, L. C. (1980). Effects of burrowing by the fiddler crab *Uca pugnax* (Smith). *Estuarine and Coastal Marine Science* **11**: 233-37.

Kwak, W. P. W. and Tang, W. (2006). Fiddler Crabs in Hong Kong - An Overview. *Hong Kong Biodiversity* **12**(Sepember): 1 - 7.

Lugo, A. E. and Snedaker, S. C. (1974). The ecology of mangroves. *Annual Review of Ecology, Evolution and Systematics* **5**: 39-64.

Mendelssohn, I. A. (1979). Nitrogen metabolism in the height forms of *Spartina altemiflora* in North Carolina. *Ecology* **60**: 574-584.

Montague, C. L. (1980). A natural history of temperate western Atlantic fiddler crabs (Genus Uca) with reference to their impacton the salt marsh. *Contributions in Marine Science* **23**: 25-55.

Montague, C. L. (1982). The influence of fiddler crab burrows and burrowing in metabolic processes in salt marsh sediment. In: *Estuarine Comparison*, V. S. Kennedy (ed.), Academic Press, London. pp 283-301.

Morris, J. T. (1980). The nitrogen uptake kinetics of *Spartina altemiflora* in culture. Ecology **61**: 1114-1121.

SPSS Inc. (2007). *SPSS Version 16 for Windows*, Release Sep 13, 2007, Chicago.

J. Indian Soc. Coastal agric. Res. 30(1): 88-89 (2012) **Short Communication**

Effect of Irrigation Regimes Coupled with Organic and Inorganic Fertilizers on the Yield of Cabbage under Micro Sprinkler in Lateritic Soil of Konkan

Cabbage (*Brassica oleracea* L.) is an important cruciferous vegetable crop grown in winter season in India. Cabbage is a heavy feeder, especially for nitrogen and potash. Vegetable crops needs nitrogen in large quantity as it constitutes 40-50 per cent of dry matter. The demand for nitrogen is high when growth is in rapid stage. It is well documented that the nitrogen deficiency and excessive application may cause sever losses in yield and quality of produce and hence optimum fertilization is needed to overcome the problem. Besides this irrigation management with appropriate micro irrigation method is also necessary to minimize the water losses and to increase water use efficiency thereby increasing fertilizer use efficiency which in turn optimizes yield levels. Micro irrigation methods economize the use of irrigation water. A very meager work has been carried out on irrigation and fertilization under lateritic soil conditions for cabbage crop. Also in Konkan region there is wide scope during rabi season for the cultivation of cabbage as the temperature is low in the month of November - January. It can be a profitable crop as it fetches bitter market prices if timely sown and proper managerial practices are followed. Thus an attempt was made to study the effect of organic manures, fertilizers and irrigation scheduling on yield of cabbage.

A field experiment on newly developed terraced land was conducted during rabi seasons of 2005-2007 at Central Experiment Station, Wakawali. The experimental soil was sandy loam in texture, moderately acidic in reaction (pH 5.8), medium in organic carbon content (0.59), medium in available nitrogen content (275.30 kg ha^{-1}), medium in available phosphorus content (15.4 kg ha^{-1}) and low in available potassium content (135.3 kg ha^{-1}). The experiment was laid out in split plot design and replicated thrice. The main plot treatments comprised five irrigation regimes i.e. I_1 – Irrigation 100% PE by micro, I_2 – Irrigation 80% PE by micro sprinkler, I_3 – Irrigation 60% PE by micro sprinkler, I_4 – Irrigation 40% PE by micro sprinkler, I_5 – Irrigation at 1.0 IW/CPE ratio with 5 cm depth of irrigation. Sub plot treatments comprised of three levels of fertilizers i.e. F_1 – Recommended dose of fertilizer (120:60:60 kg N P_2O_5, K_2O ha^{-1}), F_2– 100% N through FYM and F_3– 100% N through poultry manure. The net plot size was 3.15 cm x 3.00 m. The transplanting of seedlings was made on flat beds with 45 cm x 30 cm spacing. All the recommended package of practices and plant protection measures were followed. The common irrigations were given for the establishment and uniform moisture distribution. The irrigation schedule was followed as per the treatments. The yield was recorded and considering the present market prices economics was worked out.

The effect of irrigation schedules on yield of cabbage was found to be non-significant. The treatment I_2 recorded higher cabbage yield (142.97 q ha^{-1}) followed by I_1 (124.37 q ha^{-1}) and I_3 (116.84 q ha^{-1}) respectively while there was no appreciable yield difference in I_4 and I_5 treatments. These findings corroborate the findings of Gethe *et al.*, (2006).

Recommended dose of fertilizers i.e. (120:60:60 kg N P_2O_5, K_2O ha^{-1} (F_1) registered significantly higher yield of cabbage (146.05 q ha^{-1}) over rest of the treatments. While the treatment F_3 i.e. F_3– 100% N through poultry manure was found significantly superior over 100% N through FYM. Increase in the yield of cabbage due to the treatment F_1 was to the tune of 65% and 12% than treatments F_2 and F_3, respectively. Similar results resemble the findings of Tanpure *et al.*, (2007), Gethe *et al.*, (2006), Khokhar *et al.*, (1971).

The interaction effect among various treatments was found to be significant. The treatment combination I2F1 (80% PE by micro sprinkler + RDF) recorded significantly higher yield of cabbage (176.98 q ha^{-1}), which was at par with the treatments I_1F_3 I_2F_3, I_3F_1, I_3F_3, I_4F_1 and I_5F_1, respectively.

Maximum water use efficiency was recorded in treatment combination I_4F_4 i.e. irrigation at 40% of PE by micro sprinkler with recommended dose of fertilizer (821.88 kg ha^{-1} cm). While the minimum water use efficiency was recorded in treatment combination I_5F_2 (119.97 kg h^{a-1} cm).

The treatment combination I_2F_1 gave the highest net returns of Rs. 31803/- with maximum B:C ratio 1.37 while lowest net returns of Rs. 15057/- with B:C ratio 1.20 was recorded in the I_4F_2 treatment combination.

From the three years pooled results it is concluded that rabi cabbage (cv. Golden Acre) is to be irrigated by 80% of PE micro sprinkler irrigation at 3 days interval along with the recommended dose of fertilizer @ 120:60:60 kg N P_2O_5, K_2O ha^{-1} for obtaining higher yield under lateritic soil of Konkan.

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REFERENCES

Gethe, R. M., Pawar, V. S. Pathan, Sonawane, D.A. and Kadlag, A.D. (2006). Influence of planting layouts, irrigation regimes and fertilizer levels on growth and yield of onion under micro sprinkler. *Journal of Maharashtra Agricultural Universities* **31**(3): 272-274.

Khokhar, N.S., Singh, R.P. and Oarshad, M. (1971). Effect of different levels of nitrogen phosphorus, potassium and FYM on the yield of cabbage. *Indian Journal of Agronomy* **15**: 9-12.

Tanpure, S. N., Patil, P. V., Pingale, L.V., Guntal, G. B. and Bote, N. L. (2007). Effect of different levels of fertilizer applications on yield of cabbage. *Journal of Maharashtra Agricultural Universities* **32**(1): 151-152.

J. Indian Soc. Coastal agric. Res. 30(1): 90-92 (2012) **Short Communication**

Birds as an Ecological Safeguard for Paddy Crop in Coastal Region of Maharashtra

Rice field provide important habitats for farmland biodiversity, especially birds, all over the world. In turn, birds have been hailed as 'technologically and advanced, highly motivated, extremely efficient and cost-effective' predators of insect-pests in a fact-sheet brought out by the Migratory Bird Centre of Smithsonian National Zoological Park. In a review of agricultural ornithology in India, Dhindsa and Saini (1994) had pointed out the urgency in research on the role of birds in the control of insect pests of agricultural ecosystem. Moreover, the demand for organic food-grains is on rise. Ultimately many growers will shift to organic farming. Comparison of conventional farms with organic farms has already been started from the perspective of effect on agrobiodiversity (Roschewitz, 2005). The basic objective of the present study was to provide baseline data to initiate some experimentation involving quantification of role of birds in pest control, to explore various aspects of structure and diversity of these bird communities. This study was conducted at Jalgaon village in Dapoli taluka of Ratnagiri district in Maharashtra. An extensive paddy cultivation area was identified. The geographic coordinates of the approximate centre of this study area are N 17° 44′ 28″ and E 73° 11′ 45″. The extent of this site is nearly 120 ha. Average altitude of the area is 200m above msl. It is a low lying flat area that remains inundated for the most part of the paddy growing season of monsoon. The area includes hundreds of paddy plots of size ranging from 0.1 to 0.2 ha. Some of them are cultivated annually and others remain fallow. The entire site is surrounded by habitation and associated vegetation like orchards of Coconut, bamboo groves etc. The plots also exhibit variety in terms of vegetation structure on their bunds. Most of the plots do not have any vegetation on bunds. On the other hand, at some places, plantation of Acacia auriculiformis and other species exists on the bunds. Some plots adjacent to streams have riparian vegetation along the stream-side. At other places, the plots are completely enclosed by thick vegetation in terms of orchards, natural vegetation etc.

Bird surveys were carried out on nine paddy fields strategically identified in this area so that no two fields were less than 100 m apart. Each field was visited 68 times from 2nd May to 29th November 2009 to cover the paddy growing period preceded and succeeded by a short period of non-crop period. The visits were arranged so that each plot was visited at least thrice every week and at different times of day. Birds were observed with the help of Olympus 10 x 50 binocular. The technique used for survey was point count method modified to suit requirements of this study (Javed and Kaul, 2002). The formal point count method is a census techniques involving observer standing at an identified point and recording birds seen for a predetermined time. An imaginary circular plot having a radius of 60m (equivalent to ≈ 1 ha circular plot) was overlaid on each field. The first author stood at the edge of the circle and counted bird species active in this plot. Each sampling instance lasted for 10 minutes. During this period, all birds sighted inside the circular plot were recorded to the species. Field guides (Grimmett *et al.*, 2001 and Pande *et al.*, 2003) were used for identification of birds. Observation began three minutes after arrival at each observation plot. To obtain integrated information from different aspects of community structure, we calculated Importance Value Index (IVI) for each species. IVI was the sum of relative frequency, relative density and relative dominance of each species in the community. These relative measures fro each species were the absolute measures expressed as percentage of sum of the respective measures for all species. The absolute measures were worked out using following formulae –

Frequency = k/K, Density = n/K, Dominance = n/K

Where, k = Number of surveys in which a species was recorded

K = Total number of surveys carried out

n = Number of individuals of a species recorded

Species diversity estimates including species richness and nonparametric estimators were worked out with the help of Biodiversity. R software (R Development Core Team, 2005). Diversity indices were worked out separately for each plot. Further, as a test of completeness of the surveys, the observed species richness was compared with species richness estimated by various estimators.Bird families are preferential in their diets and usually indicate different feeding guilds. The species were looked from this point of view to assess their effectiveness as a potentially pest-controlling measure. In this study, a total of 2534 individual birds were recorded. Of these, 2493 individuals belonged to 71 species of 31 families. The remaining 41 individuals that could not be surely identified were excluded from further analysis. At least 71 bird species of 31 families were associated with paddy crop in the study area during the study period. This number of species is almost 35% of the recorded bird species of Konkan region (Pande *et al.*, 2003). Amano *et al.*, (2008) observed 51 and 73 species in paddy fields in Japan in the breeding and wintering seasons respectively. Maeda (2001) recorded 50 species throughout the 54 weeks in rice fields of Japan.

Calculating importance value of a species within an assemblage in an ecosystem helps in assessing its association with that ecosystem. Traditionally, this has been practiced in the discipline of phytosociology. It relies on the construction of IVI – and Cover Value Index (CVI). This approach has not been used much in studies of faunal assemblages. We attempted to calculate IVI of each bird species by modifying the formula used by phytosociologists. They depend on basal area or cover as a measure of dominance. We assumed number of individuals of a bird species at a given site determine their dominance in a loosely created assemblage at any given moment. Therefore, dominance was calculated by dividing number of individuals recorded by the number of sampling units in which they were recorded. Correlation was tested among these structural attributes of community after log transformation. The IVI was found to be highly correlated with absolute abundance values and thereby with density and relative density ($r = 0.97$ and Spearman's Rho = 0.96). Absolute abundance, density and relative density were found to be different expressions of the same quantity. Frequency and dominance and their relative measures had the weakest correlations among themselves. Interestingly, frequency and density had a comparatively higher correlation. This observation ultimately validates the assumption made in the beginning that importance of a species in its assemblage is dependent on its numbers more than its occurrence. Some researchers use IVI is a proxy of ecological abundance of species in an assemblage. In this study absolute abundance itself was found to be a good indicator of ecological abundance. We can conclude that the concept of IVI needs to be applied to more and more studies on faunal assemblages to refine its usage.

Open-source software like Biodiversity R and Estimate S are available for performing the complicated computations. We have presented Shannon diversity index and Simpson's index of dominance for both of which plot 3 was found to have minimum value and plot 9 the minimum. Whereas a higher value of Shannon index indicates a higher diversity, a higher value of Simpson's index indicates lower dominance of few species. Values for both these indices showed similar trends for all sites and for overall bird species diversity of the study area. However, they were not reflected as such in the observed species richness. The variable diversity among plots during the study period within same general ecosystem goes on to substantiate the importance of micro-habitat conditions especially the habitat heterogeneity. Diversity estimates are worked out by repeatedly sampling a given ecosystem either spatially or temporally. Theoretically, species accumulation curves reach an asymptote indicating the level of sampling that is adequate to sample those ecosystems. However, even a large amount of sampling in species rich ecosystems rarely results in asymptote (Gotelli and Colwell, 2001). Species accumulation curves for individual plots and for the overall area did not give asymptotic accumulation curves. This is an indication of the inability of the sampling regime to cover the entire range of species in an ecosystem. We used the approach of Hore and Uniyal (2008) to assess the completeness of the inventories. The ratio of observed species richness with these estimators gives the completeness of inventory. For the entire study area, the completeness ranges from 84-91%. For individual plots, the completeness ranges from 55-81%. There was no visible linkage between diversity indices and per cent completeness. These results conform with those of Hore and Uniyal (2008) that indicate more complete inventories when pooled over a region – thus increasing the spatial extent – than temporally extensive inventories.

Muscicapidae is the dominant family on paddy fields followed by Accipitridae and Columbidae. Muscicapidae is a typically insectivorous family whereas Accipitridae is typically carnivorous. Additionally, bird species were assigned to their respective feeding guilds viz. Omnivorous (21), insectivorous (21), granivorous (12), carnivorous (15), and nectarivorous (2). Parasharya *et al.*, (1994) have documented natural control of white grub by bird predators. Shivankar *et al.*, (2008) also recorded typically insectivorous birds significantly reducing pest population in sugar beet fields. On the other hand, this predominance of insectivorous and carnivorous families in the assemblage, in turn, is an indicator of the abundant availability of insect and small vertebrate food in paddy fields. Marques and Vicente (1999) have also documented that the peaks in prey biomass were matched by peaks in water bird abundance in rice fields in Portugal. Thus, it could be concluded that paddy fields in Konkan are inhabited by highly diverse bird assemblages dominated by potentially pest-controlling species. This, further, necessitates studies on quantification of pest-control potential and on habitat level measures to selectively attract beneficial bird species.

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REFERENCES

Amano, T., Kusumotoa, Y., Tokuokaa, Y., Yamadaa, S., Kimb, E., and Yamamotoa, S. (2008). Spatial and temporal variations in the use of rice-paddy dominated landscapes by birds in Japan. *Biological Conservation* **141**: 1704-1716.

Dhindsa, M. S. and Saini, H. K. (1994). Agricultural ornithology: An Indian Prespective. *Journal of Bioscience* **19**(4): 391-402.

Gotelli, N. J. and Colwell, R. K. (2001). Quantifying biodiversity: Procedures and pitfalls in the measurement and comparison of species richness. *Ecological Letters* **4**: 379-391.

Grimmett, R., Inskipp, C. and Inskipp, T. (1999). *Pocket Guide to the Birds of the Indian Subcontinent*, Oxford University Press, New Delhi. 384 p.

Hore, U. and Uniyal, V. P. (2008). Diversity and composition of spider assemblages in five vegetation types of the Terai Conservation Area, India. *Journal of Arachnology* **32**(2): 251-258.

Javed, S. and Kaul, R. (2002). *Field methods for bird's surveys*, Bombay Natural History Society, Mumbai. 61 p.

Maeda, T. (2001). Patterns of bird abundance and habitat use in rice fields of the Kanto plain, Central Japan. *Ecological Research* **16**: 569-585.

Marques, P. A. M. and Vicente, L. (1999). Seasonal variation of waterbird prey abundance in the Sado estuary rice fields. *Ardeola* **46**(2): 231-234.

Pande, S., Tambe, S., Clement Francis, M. and Sant, N. (2003). *Birds of Western Ghats, Kokan and Malabar (including Birds of Goa)*, BNHS, Mumbai & OUP, New Delhi. 371 p.

Parasharya, B. M., Dodia, J. F. and Yadav, D. N. (1994). Natural regulation of white grub (Holotrichia sp: Scarabidae) by birds in agroecosystem. *Journal of Bioscience* **19**: 381-389.

R Development Core Team (2005). R: A language and environment for statistical computing. R Foundation for Statistical Computing Vienna, Austria.

Roschewitz, I. (2005). Farming systems and landscape context: effects on biodiversity and biocontroal. Ph D Dissertation, Gottingen University, Germany.

Shivankar, S. B., Magar, S. B., Shinde, V. D., Ghodake, P. V., Yadav, R. G. and Patil, A. S. (2008). Role of avian community in reduction of *Spodoptera pest* population in Sugar beet at Pune. *Our Nature* **6**: 19-25.