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Study on Physical and Hydrological Properties of Soil under Different Land-Uses in a Micro-Watershed of Sundarban

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The study was undertaken in a micro-watershed of Sundarban. Composite soil samples from 0-15 cm profile depths of four land use systems viz. double cropped, mono-cropped paddy, grass/forest and barren lands were selected under medium and low land situations were used to study its different physical and hydrological properties eg. Particle size distribution, bulk density, water stable aggregate, water holding capacity, plasticity and moisture evaporation. Result reveals that clay content of low land soils, in general, is higher (49.8%) than that under medium land situations. But it was more than 54% in both double and monocropped lands, which accounted for 99% soil aggregation. This resulted higher structural co-efficients (0.97) under these two systems. Better aggregation in soil structure resulted maximum water holding capacity (61.73%) under mono-cropped paddy land in medium land situation. Finding was further justified with relatively higher plasticity indices under these two systems. Conversely, moisture evaporation rate was maximum (1.05 mmd^{-1}) from the double cropped lands. All these physical and hydrological parameters were highly correlated with both clay and organic matter content. It was further revealed that organic matter, water stable aggregate, soil texture and mean weight diameter play significant positive role in retention and subsequent release of soil moisture under a particular land use system.

(**Key words:** *Sundarban, Land use, Physical properties, Hydrological properties*)

Suitability of soil for sustenance of plant growth and related biological activities is the function of physical, hydrological and chemical properties and a large number of these properties are function of soil organic matter content. The ability of soil to store and transmit water is a major factor regulating water availability to plant. But, continuous cultivation and intensive crop production for a long period decreases organic matter and physical conditions like structure, tilth, water holding capacity, infiltration. These, in the long run, impair growth and productivity of the plants.

Any land management system becomes sustainable only when it maintains or improves resource quality. Soil quality, which is basically a stable natural or inherent feature, its dynamic change is largely induced by soil management. Identifying and characterizing changes in the dynamic component is essential in evaluating performance and sustainability of any soil management system (Pierce and Larson, 1993). Investigations on Soil quality are, therefore, essentially needed to provide information for resource management and regulatory decisions on land use system.

Information on the quality of coastal saline soil of east coast of India is although available, but it is very limited for the deltaic ecosystem of Sundarban. Considering the ever-increasing population, it has become imperative to change the existing agricultural scenario with proper and effective management of its resources and water resources in particular, which is a pre-requisite for developing and planning any land and soil management system as well as quality and health of soil resources. The present study was, therefore, considered to investigate the effect of land use on some physical and hydrological properties of the soil. All the existing land-use systems viz. double cropped (L_1), mono-cropped (L_2), grassed (L_3), and barren (L_4) under medium (ML) and low (LL) land situations in the watershed (21°32′ and 22°40′ N latitude and 87°30′ and 89°E longitude) of Sundarban were considered for the study. Composite soil samples collected from 0.15 m were used for the analysis of both physical (soil particles, soil aggregate, porosity) and hydrological (water holding capacity (WHC), liquid limit, plastic limit, soil moisture evaporation) using standard laboratory methods.

RESULTS AND DISCUSSION

Physical Properties

The physical properties studied include soil particles (particularly clay), aggregate stability (WSA>2.5 mm) and porosity (P_o). In addition amount

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Table 1. *Various aggregate stability indices under different land use systems at two land situations in Sundarban*

Land use	Percentage of Aggregates > 0.25 mm			Mean Weight Diameter (MWD), mm			Total porosity, %			Clay %			Organic Matter, %		
	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean
L_1*	81.56	99.0	90.28	2.26	2.68	2.47	49.81	49.06	49.50	53.6	54.9	54.3	0.83	0.57	0.70
L_2	98.98	95.28	97.13	2.75	2.79	2.77	49.81	46.79	48.30	50.9	54.9	52.9	0.74	0.83	0.78
L_3	82.6	56.64	69.62	2.36	1.62	1.99	49.06	47.92	48.49	35.6	45.6	40.6	0.55	0.65	0.43
L_4	81.88	53.28	67.58	2.28	0.56	1.42	46.15	45.66	45.90	29.6	43.6	36.6	0.34	0.48	0.41
Mean	86.26	76.05	—	2.41	1.19	—	48.70	47.36	—	53.6	54.9	54.3	0.83	0.57	0.70

Note: (a) L_1, Mono-cropped land; L_2, Double Cropped Paddy Land; L_3, Grass/Forest Land; L_4, Barren Land. (b) LL, Low land and ML, Medium land situations

Table 2. *Influence of land use on plastic limit, liquid limit, plastic index, water holding capacity and rate of soil moisture evaporation at two land situations in Sundarban*

Land use	Plastic Limit, %			Liquid Limit, %			Plastic Index			Water Holding Capacity, %			Soil Evaporation Rate, mm/day		
	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean	ML	LL	Mean
L_1	25.04	29.96	27.50	45.15	55.60	50.38	20.11	25.64	22.87	56.09	54.86	55.48	1.05	0.95	1.0
L_2	25.82	33.05	29.44	50.71	58.62	54.67	24.89	25.57	25.23	61.73	50.68	56.20	0.90	0.94	0.92
L_3	27.17	23.79	25.48	51.77	44.22	48.00	24.60	20.43	22.51	56.88	56.67	55.28	0.91	0.79	0.85
L_4	22.81	28.36	25.59	37.84	51.64	44.74	15.03	23.28	19.15	51.31	50.33	50.82	0.85	0.84	0.85
Mean	25.21	28.79	—	46.37	52.52	—	21.15	23.73	—	56.50	52.39	—	0.93	0.88	—

Note : ibid

of organic carbon present in the soils was also studied. The result reveals that soil of the delta is heavy in nature due to proportionately higher amount of clay content than the other soil particles. It was revealed that clay content, in general, was higher (17.5%) under low land than that in the medium land situation (Table 1). Moreover, irrespective of land situations the soil contains more than 50 percent clay under both double (L_1) and mono-cropped land uses. But it was as low as 43.6 percent in barren land, under low land situation in particular. The torrential rain and occasional overland flood leads to deposition of suspended soil particles, which contributes to such high clay content in low lands. But, relatively higher clay content (54.9%) in cropped lands (both double-cropped and mono-cropped paddy lands) is possibly due to repeated ploughing and puddling, necessary for paddy and other crop cultivation. Besides, organic matter differed between 0.20 and 0.48 percent, amongst the land uses and it was relatively higher in cropped lands. Such high organic matter in the cultivated lands was mainly due to addition of organic matter through organic manure as well as in situ decomposition of plant and other organic residues. Similar results were reported by Egawa and Kozosekiya (1956) for grass land and Woodruff (1968) for corn field.

The clay and organic matter content resulted in maximum aggregation of water stable aggregate (WSA) > 0.25 mm, which was more than 95 percent in the cultivated lands and was highest in double-cropped land under low land situation. But, in general, 1.13 times higher aggregation was noted under medium lands irrespective of land uses. Nevertheless, better aggregation in both cropped and grassed lands were probably due to addition and accumulation of organic carbon through organic manure and crop residues respectively. This improved both mean weight diameter (MWD) as well as structural co-efficient. However, irrespective of land situations the order of structural co-efficient was double cropped > mono-cropped > grassed > barren lands. The aggregate > 0.25 was found to have significant linear relationship with organic matter (0.609*) and clay (0.584*) content Similar results were reported by Bavrer *et al.*, (1972) and Jo (1990).

Hydrological Properties

The hydrological Properties studied include plastic index (pi), water holding capacity (WHC) and soil moisture evaporation (Es). The result indicates that in low land situation plastic index was higher (23.73) than that in medium land situation. Further, it was highest in mono-cropped paddy land in the low land situation, which is due to the higher deposition of silt and clay resulting from repeated ploughing and puddling. Organic matter content also contributes to such hydrological characteristics (Table 2) of the soil, which varied with both land situation and land uses. Similarly, maximum water holding capacity (61.73%) was noted in mono-cropped paddy land in medium land situation (Table 2). However, irrespective of situations WHC varied amongst the land uses between 50.33 and 56.88 percent, indicating marginal difference. But between the land situations it was 4.11 percent higher for the soil under medium land. Such variation in WHC was associated with variation in amount of clay and organic matter content. This becomes transparent from significant positive correlation (0.625*) between WHC and organic matter as well as clay (0.504*), which corroborates the findings of Dutta and Barkakoty (1996). In addition, soil management practices also influence properties related to WHC of the soil.

Drying pattern of all the soils was more or less classical (Fig. 1). Similar trend in daily evaporation of soil moisture was reported by Penman (1941) and Lemon (1956). But maximum (1.05 mmd^{-1})

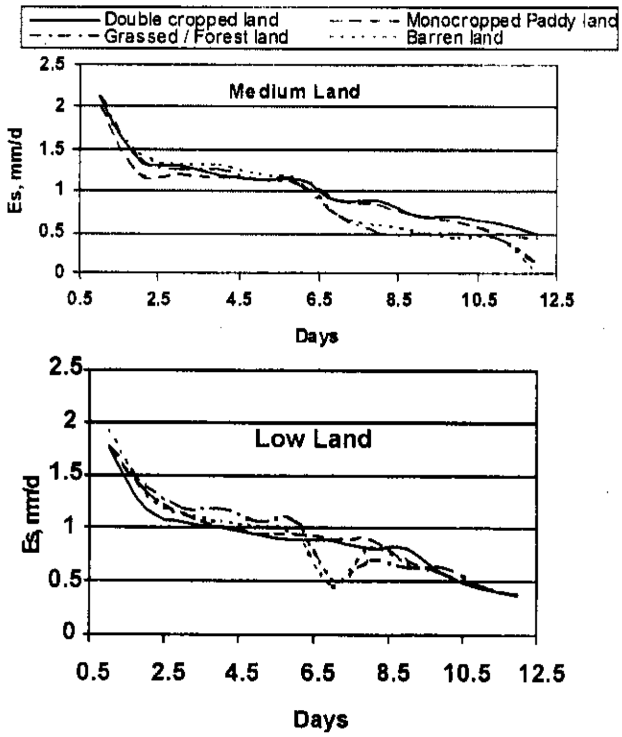

Fig. 1. Soil Moisture Evaporation Rate (mm/d) as influenced by Land Uses at Two Land Situations

Table 3. *Correlation Coefficients*

Variables	WHC	Wsa	Po	PI	Clay, %	OM	Es
Water Holding Capacity (WHC)	1.000	0.709*	0.901**	0.942**	0.775*	0.700	0.530
WSA>2.5mm (Wsa)		1.000	0.611	0.832**	0.960**	0.997**	0.785*
Porosity (Po)			1.000	0.735*	0.782*	0.609	0.721*
Plasticity Index (PI)				1.000	0.805**	0.821**	0.484
Clay, %					1.000	0.962**	0.902**
Organic Matter (OM)						1.000	0.795*
Evaporation (Es)							1.000

evaporation rate from double cropped land may be ascribed to the higher pore space distribution under this land use system. On the contrary, minimum rate of evaporation from barren land was due to poor pore space distribution as a result of compaction. The rate of drying of soil, in general, was also found to be highly significant and positively related with clay (0.837**) and organic matter (0.840**) content. As a matter of fact, soil containing higher organic matter and clay acts as sink of water for retention and simultaneous release for evaporation.

Relationship between Physical and Hydrological Properties

The correlation coefficients amongst physical and hydrological properties indicate significant positive linear relationships (Table 3). The influence of multiple physical factors on WHC and Es were tested with multiple correlations and ultimately the following two regression equations have been derived.

$$WHC = 67 \times 10^{-2} P_o + 18 \times 10^{-1} P_i - 17 \times 10^{-2}{}_{WSA} - 17 \times 10^{-1}; \quad R^2 = 0.827$$

$$Es = 2 \times 10^{-2}{}_{WSA} + 24 \times 10^{-4} P_o - 25 \times 10^{-2}; \quad R^2 = 0.801$$

Where WHC, water holding capacity, %; P_o, soil porosity, %; P_i, Plasticity Index; ${}_{WSA}$, Water stable Aggregate>2.5mm; and E_s, Rate of soil moisture evaporation, mm d^{-1}. The R_2 values indicate that the equations can explain more than 80% of the variables. Hence found to be useful for estimating WHC and Es of the soils of Sundarban.

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Effect of Land Configuration and Methods of Sowing on Fresh Biomass Production of Salicornia (S. *brachiata Roxb.*) for Vegetable Purpose

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A field experiments with twelve treatments combinations comprising of two types of land configuration (L_1: raised bed and L_2 : flatbed) allotted in main plot, two methods of sowing (S_1: dry sowing and S_2 : wet sowing) in sub plot and three methods of sowing levels (M_1 : broad casting, M_2 : line sowing and M_3:dibbling) in sub-sub-plot was conducted in double split plot design with five replications during *Kharif* seasons of 2006, 2007 and 2008 at Coastal Soil Salinity Research Station, Navsari Agricultural University, Danti–Umbharat (Gujarat). Based on the pooled results of fresh biomass yield and economics, dry sowing by broad casting method on raised bed configuration was found to be highly remunerative combination. This combination recorded significantly higher fresh biomass yield of salicornia (20.3 t ha^{-1}), net income (Rs. 88,300/-) and B: C ratio (1: 6.7) as compared to the remaining combinations. The results of present study indicated that salicornia can be cultivated profitably in the waste land located all along the sea shore of South Gujarat.

(Key word: *Salicornia brachiata, Land configuration, Sowing condition, Sowing method)*

An obligate halophyte *Salicornia brachiata* Roxb., (Chenopodiaceae) is inhabited to salt flats of Arabian Sea coast and coastal soil sustained environments (Sanish *et al.*, 1991). The annual leafless halophyte has green, jointed succulent stems that forms terminal fruit bearing spikes, in which the seeds are borne (Gallawa, 1996). Salicornia seed yields special quality oil, highly poly-unsaturated, similar to safflower oil is rich in linoleic acid. This halophytic shrub of coastal mud flats is potentially high biomass producing plant under marine ecosystem. This plant was identified from many halophyte species tested for possible domestication because of its field crop potential not only as an oilseed plant, but as a new biomaterial for vegetable salt and herbal drug potentials (Glenn *et al.*, 1991 and Ghosh *et al.*, 2003). In coastal areas of South Gujarat salicornia locally known as "Marchar" was growing naturally. Tender plant of salicornia was consumed by the people as leafy vegetable. As the plants were harvested before seed formation, its natural multiplication process stopped.

Because of continuation of this practice, salicornia almost impel out from the coastal areas of South Gujarat, present study was taken up for standardizing its method of sowing.

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MATERIALS AND METHODS

The field experiment were carried out during *kharif* seasons of 2006, 2007 and 2008 at Coastal Soil Salinity Research Station, Danti-Umbharat, Navsari Agricultural University, Navsari on the southwestern coast (Danti, India 20° 83' North, 72° 52' East). The mean height above the sea level ranges from 0-2.5 meters and therefore coastal area got submerged during tides. Soil at the site is saline-sodic in nature having pH: 8.40 to 9.00, EC (1:2.5): 10.3 to 14.02 dSm^{-1}, ESP: 25.8 to 28.4 and organic carbon 0.22 to 0.26 per cent.

The experiment was laid out in a Double split plot design with five replications adopting plot size of 13.2 m^2 (11 x 1.2 m^2) during 2006-07 to 2008-09 (Panse and Sukhatme, 1969). Land configuration was allotted in main plot, conditions of sowing in sub-plot and methods of sowing in sub-sub-plot. In all twelve treatments combinations involving two land configuration consisted [L_1: raised bed (120 cm breadth x 15-20 cm depth) and L_2 : flatbed], two conditions of sowing (S_1: dry sowing and S_2 : wet sowing) and three method of sowing [M_1 : broad casting, M_2 : line sowing at 30 cm spacing and M_3:dibbling at 30 x 10 cm). The crop was sown using seed rate of 2.5 kg ha^{-1} and the fertilizer were applied at the rate of 250- 75- 50 kg NPK ha^{-1}. Nitrogen was applied through urea in three splits i.e. basal, 45 and 90 days after sowing, P as SSP (Single Super Phosphate) and K through murate of potash as a basal dressing. After germinations, crop was irrigated with sea water. In all nine irrigations were applied an average interval of 10 days. The fresh biomass of Salicornia was harvested plot wise after 100 days of sowing.

RESULTS AND DISCUSSION

Fresh biomass yield

During the first year, fresh biomass yield of Salicornia was affected significantly only due to S and L x M effects (Table 1). Between the two methods (S), dry seeding (1.85 kg m^{-2}) performed better than wet seeding (1.58 kg m^{-2}). Among the different combinations of L x M, L_1M_3 recorded significantly higher biomass yield of 1.90 kg m^{-2} which was at par with L_1M_1 (1.86 kg m^{-2}). During second year (2007-08), only land configuration (L) effect was significant on biomass yield and raised bed sowing recorded significantly higher yield (1.49 kg m^{-2}) as compared to flat bed sowing (0.97 kg m^{-2}) (Table 2). Whereas during third year (2008-09), the main effect of S and interaction effect of L x M x S were turned out to be significant on biomass production of salicornia (Table 3). Between the two methods of sowing, dry seeding showed superiority over wet seeding. Among the combinations of L x M x S, the combinations L1S1M1 (2.53 kg m^{-2}), $L_1S_1M_3$ (2.43 kg m^{-2}), $L_1S_2M_2$ (2.23 kg m^{-2}) and $L_1S_1M_2$ (2.13 kg m^{-2}) recorded significantly more fresh biomass yield than rest of the combinations. However, these combinations were at par with each other.

In pooled analysis, main effect of L and interaction effect of L x M x S were significant on fresh biomass production of salicornia (Table 4). Sowing of salicornia on raised bed (1.83 kg m^{-2}) maintained its superiority over flat bed sowing (1.39 kg m^{-2}). Among all the possible combinations of L x M x S, $L_1S_1M_1$ (2.03 kg m^{-2}) and $L_1S_1M_3$ (2.04 kg m^{-2}) recorded significantly higher biomass yield in comparison to rest of the combinations but were at

Table 1. *Effect of different treatments on fresh weight (kg m^{-2}) of salicornia (2006- 07)*

Treatment	L_1		Mean	L_2		Mean	Mean (M)
	S_1	S_2		S_1	S_2		
M_1	1.89	1.83	1.86	1.77	1.63	1.70	1.78
M2	1.82	1.43	1.62	1.80	1.50	1.65	1.64
M_3	2.11	1.70	1.91	1.71	1.39	1.55	1.73
Mean	1.94	1.65	1.80	1.76	1.51	1.64	
Mean (S)	S_1 = 1.85 and S_2 = 1.58						
Source	L	S	M	L X S	S X M	L X M	LXMX S
SEm±	0.06	0.04	0.05	0.07	0.07	0.06	0.10
CD at 5%	NS	0.12	NS	NS	NS	0.17	NS
CV %	14				10		

Table 2. *Effect of different treatments on fresh weight (kg m^{-2}) of salicornia (2007-08)*

Treatment	L_1		Mean	L_2		Mean	Mean (M)
	S_1	S_2		S_1	S_2		
M_1	1.65	1.33	1.49	1.12	1.00	1.06	1.28
M_2	1.30	1.62	1.46	0.88	0.83	0.86	1.16
M_3	1.57	1.48	1.53	0.98	0.98	0.98	1.25
Mean	1.51	1.48	1.49	0.99	0.94	0.97	
Mean (S)	S_1 = 1.25 and S_2 = 1.21						
Source	L	S	M	L X S	S X M	L X M	LXMX S
SEm±	0.06	0.06	0.07	0.10	0.10	0.09	0.15
CD at 5%	0.38	NS	NS	NS	NS	NS	NS
CV %	21				20		

Table 3. *Effect of different treatments on fresh weight (kg m^{-2}) of salicornia (2008-09)*

Treatment	L_1		Mean	L_2		Mean	Mean (M)
	S_1	S_2		S_1	S_2		
M_1	2.53	1.90	2.22	1.83	1.53	1.68	1.95
M_2	2.13	2.23	2.18	1.67	1.18	1.53	1.85
M_3	2.43	1.90	2.17	1.57	1.50	1.53	1.85
Mean	2.37	2.01	2.19	1.76	1.41	1.58	
Mean (S)	S_1 = 2.06 and S_2 = 1.71						
Source	L	S	M	L X S	S X M	L X M	LXMX S
SEm±	0.11	0.05	0.07	0.10	0.10	0.08	0.13
CD at 5%	NS	0.16	NS	NS	NS	NS	0.40
CV %	24				12		

Table 4. *Effect of different treatments on fresh weight (kg m^{-2}) of salicornia (Pooled).*

Treatment	L_1		Mean	L_2		Mean	Mean (M)
	S_1	S_2		S_1	S_2		
M_1	2.03	1.69	1.86	1.57	1.39	1.48	1.67
M_2	1.75	1.76	1.76	1.52	1.17	1.34	1.55
M_3	2.04	1.70	1.87	1.42	1.29	1.36	1.61
Mean	1.94	1.71	1.83	1.50	1.28	1.39	
Mean (S)	S_1 = 1.72 and S_2 = 1.50						
Source	L	S	M	L X S	S X M	L X M	LXMX S
SEm±	0.046	0.066	0.037	0.043	0.053	0.053	0.075
CD at 5%	0.16	NS	NS	NS	NS	NS	0.21
CV %	21				14		

Table 5. *Economics of different treatments*

Sr. No.	Treatments	Fresh biomass yield		Gross income (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net income (Rs ha^{-1})	B : C ratio
		kg m^{-2}	t ha^{-1}				
1	$L_1S_1M_1$	2.03	20.3	1,01,500	13,200	88,300	1: 6.7
2	$L_1S_1M_2$	1.75	17.5	86,000	14,000	72,000	1: 5.1
3	$L_1S_1M_3$	2.04	20.4	1,02,000	15,000	87,000	1: 5.8
4	$L_1S_2M_1$	1.69	16.9	84,500	13,200	71,300	1: 5.4
5	$L_1S_2M_2$	1.76	17.6	88,000	14,000	74,000	1: 5.2
6	$L_1S_2M_3$	1.70	17.0	85,000	15,000	70,000	1: 4.6
7	$L_2S_1M_1$	1.57	15.7	78,500	13,200	65,300	1: 4.9
8	$L_2S_1M_2$	1.52	15.2	76,000	14,000	62,000	1: 4.4
9	$L_2S_1M_3$	1.42	14.2	71,000	15,000	56,000	1: 3.7
10	$L_2S_2M_1$	1.39	13.9	69,500	13,200	56,300	1: 4.3
11	$L_2S_2M_2$	1.17	11.7	58,500	14,000	44,500	1: 3.1
12	$L_2S_2M_3$	1.29	12.9	64,500	15,000	49,500	1: 3.3

Selling price: Rs 5 kg^{-1} of Salicornia par with each other. The present results are in agreement with Tripathi *et al.*, (2004) in wheat.

Economics

In view of significant effect of L x M x S, economics was calculated separately for each of the possible combination (Table 5). Among the different combinations, highest net realization of Rs. 88,300 ha^{-1} was obtained with $L_1S_1M_1$ combination and it was closely followed by $L_1S_1M_3$ which recorded net profit of Rs. 87,000 ha^{-1}. This was reflected on the B : C ratio, which was maximum with $L_1S_1M_1$ (1: 6.7) and the next in order was 5.8 with $L_1S_1M_3$ treatment.

Based on the pooled results of fresh biomass yield and economics, dry seeding by broad casting method on raised bed configuration seems to be highly remunerative combination as substantiated by net profit and B : C ratio. The results present study clearly indicates that salicornia can be grown successfully on the unproductive waste land adjoining the sea. For getting higher yield and net profit, they are recommended to broad cast salicornia seeds on dry raised bed.

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Sensitivity of Evapotranspiration to Solar Radiation, Vapour Pressure Deficit and Other Meteorological Parameters

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Study on sensitivity of evapotranspiration was carried out in coastal belt of Maharashtra State for Dapoli station. For estimation of reference evapotranspiration the data from 1st January 1985 to 31st December 2005 (21 years) was used for analysis. The study concluded that temperature, sunshine hours, wind speed, solar radiation and vapour pressure gradient had direct effect on estimation of annual and seasonal reference evapotranspiration while relative humidity found inverse association. The annual reference evapotranspiration estimates was most sensitive to relative humidity and least sensitive to wind speed. In general relative humidity was the most sensitive variable followed by sunshine hours and vapour pressure gradient. The solar radiation and air temperature had identical effect on annual reference evapotranspiration and found less sensitive. The order of sensitivity for summer season noticed was wind speed > sunshine hours > vapour pressure gradient > solar radiation > temperature. During monsoon and winter seasons the sunshine hours and vapour pressure gradient was most sensitive to reference evapotranspiration. The sensitivity coefficients showed seasonal variation to different climatic variables.

*(**Key Words:** Reference Evapotranspiration, Penman-Monteith model, Sensitivity analysis, Solar radiation, Vapour pressure deficit)*

The estimation of reference evapotranspiration is essential for irrigation scheduling and management. The crop water requirement is also depends upon the evapotranspiration. The effect of different parameters on evapotranspiration was tested by sensitivity analysis. The sensitivity analysis indicates the variation in the output of a mathematical model due to different source of error in the input parameters by assuming the original parameters. Sensitivity analysis also shows the effect of major influence parameters on output. Beven (1979) evaluated the sensitivity analysis for evapotranspiration based on Penman-Monteith equation and found that the actual ET is dependent on the values of aerodynamic and canopy resistance. Piper (1988) studied the sensitivity of Penman estimates of evaporation to error in input data for wide range of stations over the globe and showed that estimates are more sensitive to temperature and sensitivity has marked seasonal fluctuations.

The effects of uncertainty in the equation parameter values are small and comparable to the sensitivities of the input variables; wet bulb depression, wind speed and sunshine hours. According to Singh and Xu (2007) mass based evaporation estimates were found to be particular by sensitive to vapour pressure gradient, less sensitive to wind speed and most insensitive to temperature. The study also found that the evaporation estimates were much more sensitive to random errors in case of monthly data than daily data. Montaldo *et al.*, (2003) performed sensitivity analysis and confirms that evaporation is highly sensitive to the soil parameters and also sensitive to vegetation parameters. Goyal (2004) concluded that any change in evapotranspiration will be likely to have a profound effect on agriculture and water resource planning in arid regions. The sensitivity of the Penman-Monteith reference evapotranspiration was studied by Lebing Gong *et al.*, (2006) for Changjiang Basin. The study revealed that in general relative humidity was the most sensitive variable followed by short wave radiation, air temperature and wind speed. Kannan *et al.*, (2007) tested the sensitivity analysis using SWAT-2000 and claimed that the identification of most sensitive parameters within the array of model parameters is essential to reduce the calibration efforts. Ali *et al.*, (2009) examined for sensitivity to error in input data under the environment of semi-humid, semi-tropic region of Bangladesh and found that the evapotranspiration estimates are most sensitive to maximum temperature and least sensitive to minimum temperature. Estevez *et al.*, (2009) carried

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out the sensitivity analysis of a Penman-Monteith equation to estimate reference evapotranspiration in southern Spain and found that evapotranspiration overestimations were produced using positive errors in temperature, solar radiation and wind speed data, while these errors in relative humidity resulted in evapotranspiration underestimations. According to Yoder *et al.*, (2005) for humid climate some the VPD and Rn methods have a significant effect on the accuracy of the ETo estimated by using standardized ASCE-PM equation. These reviews showed that the Penman-Monetheith equation found superior over wide ranges of climate conditions. Similarly the different climatic parameters affect evapotranspiration at different levels according to spatial and temporal way. The variation or change in input data would be useful for identifying the most sensitive input parameter which governs the ETo. The aim of this study is to estimate the vapor pressure deficit and solar radiation and to examine the sensitivity of different meteorological parameters to error in input data on reference evapotranspiration.

MATERIALS AND METHODS

Sensitivity analysis

The sensitivity analysis showes how the variation in the output of a mathematical model can be apportioned, qualitatively or quantitatively, to different sources of variation in the input of a model (Saltelli *et al.*, 2008). In other words it is a technique for systematically changing parameters in a model to determine the effects of such changes. According to Ali *et al.*, (2009) the estimate of reference evapotranspiration may be expressed in the general form.

$$ETo = f(p_1, p_2 \ldots\ldots\ldots p_{n-1}, p_n) \qquad \ldots (1)$$

In the present study the sensitivity analysis for different parameters was done as per McCuen (1974) using equation:

$$Si = \frac{\partial ETo}{\partial pi} \cdot \frac{pi}{ETo} \qquad \ldots (2)$$

where, is sensitivity coefficient (dimensionless), is change in reference evapotranspiration, is change in ith parameter, is actual ith parameter, is actual reference evapotranspiration. The sensitivity analysis for reference evapotranspiration to different error in the input data namely, maximum and minimum temperature (STav), relative humidity (SRHav), wind speed (Sws), sunshine hour (Ssh), solar radiation S(Rn) and vapour pressure defiçit (SVPD) was done. The estimate of reference evapotranspiration was done for different errors in input parameters, i.e. meteorological variables. The level of errors for different meteorological parameters is depicted in Table 1.

Reference evapotranspiration (ETo)

In the present study the computation of reference evapotranspiration from meteorological data was done by FAO Penman-Monteith method (Allen *et al.*, 1998). The reference evapotranspiration was computed by assuming a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m^{-1} and albedo of 0.23 and given by equation

$$ET_0 = \frac{0.408\,\Delta\,(Rn - G) + \gamma \dfrac{900}{T + 273} u_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,u_2)} \qquad \ldots (3)$$

Where, ETo is reference evapotranspiration [mm day^{-1}], Rn is net radiation at the crop surface [MJ m^{-2} day^{-1}], G is soil heat flux density [MJ m^{-2} day^{-1}], T is mean daily air temperature at 2m height [°C], u_2 is wind speed at 2m height [m s^{-1}], es is saturation vapour pressure [kPa], e_a is actual vapour pressure deficit [kPa], e_s-e_a is saturation vapour pressure deficit [kPa], Δ is Slope vapour pressure curve [kPa °C^{-1}], γ is psychrometric constant [kPa °C^{-1}]. For a day calculation of the soil heat flux density is taken as zero.

Data

The study was carried out at Dapoli which is located at coastal belt of Maharashtra State. The region is characterized as humid zone. It lies at 15° 6′ N to 20° 22′N latitude and 72° 39′E to 73° 48′E longitudes with altitude of 250 m above msl. The climatic conditions are typical costal i.e. hot and humid. The region comes under heavy rainfall with average annual rainfall of 3500 mm. For estimation of reference evapotranspiration the different climatological parameters were collected. The meteorological data includes air temperature, relative humidity, sunshine hours, wind speed etc.

Table 1. *Different levels of errors in input parameters*

S. No.	Input parameters	Levels
1.	Air temperature (Max.and Min.)	+ 0.5°C to 3°C
2.	Relative humidity (Max.and Min.)	+ 5 % to + 20 %
3.	Wind speed	+ 0.5 km/hr to 3 km/hr
4.	Sunshine hours	+0.25 hr to +1 hr
5.	Solar radiation	+ 5 % to + 20 %
6.	e_s-e_a (VPD)	+ 5 % to + 20 %

The location specific data like longitude, latitude, and altitude was also collected. The data from year 1st January 1985 to 31st December 2005 i.e. 21 years was used for analysis which is collected from the Department of Agronomy, College of Agriculture, Dr. BSKKV. Dapoli.

RESULTS AND DISCUSSION

Evapotranspiration

The reference evapotranspiration using FAO-56 Penman-Montheith method was analysed and the daily trend of reference evapotranspiration is depicted in Fig. 1. It was observed that the maximum reference evapotranspiration were 5.41 mm day^{-1} and 2.55 mm day^{-1} on 27th May. And 23rd July respectively. The mean daily reference evapotranspiration for Dapoli was 3.90 mm day^{-1}. The detailed monthly trend of reference evapotranspiration was analyzed and depicted in Fig. 2 reveals that the maximum reference evapotranspiration of 5.41mm day^{-1} was in the month of May and minimum in the month of August (2.55 mm day^{-1}). The seasonal evapotranspiration was also studied and it was observed that the reference evapotranspiration in summer season (10-26 MW) ranges from 3.17 mm day^{-1} to 5.15 mm day^{-1}. Similarly for monsoon season (27-44 MW) it ranged from 2.70 to 3.69 mm day^{-1} with mean value of 3.11 mm day^{-1}. In winter season (45-52 and 1-9 MW) the maximum and minimum evapotranspiration were 4.23 and 2.97 mm day^{-1} respectively. The average reference evapotranspiration in winter season was 3.40 mm day^{-1}.

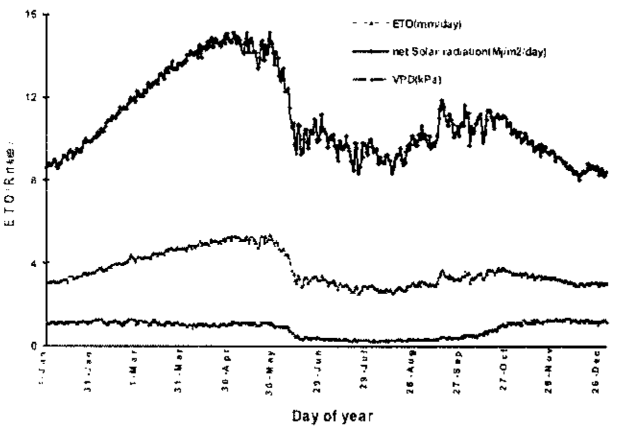

Fig. 1. Daily trends of reference evapotranspiration, net solar radiation and vapour pressure deficit for Dapoli station

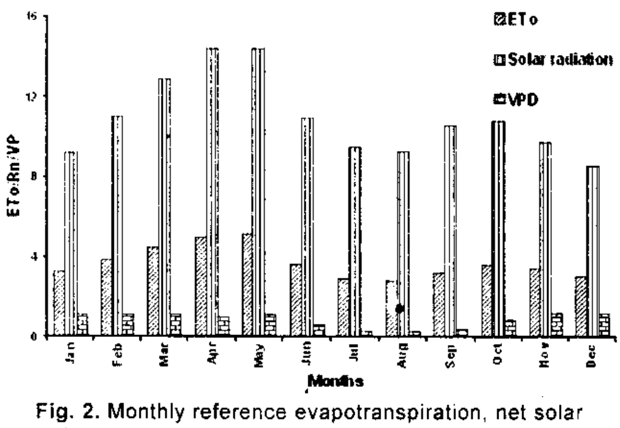

Fig. 2. Monthly reference evapotranspiration, net solar radiation and vapour pressure deficit for Dapoli station

Solar radiation

The detailed daily net solar radiation was analyzed as per the procedure given in FAO -56 and depicted in Fig. 1. The maximum (3rd May), minimum (13th December) and net solor radiation for Dapoli were 15.14, 7.99 and 10.93 MJ m^{-2} day^{-1} respectively. The standard meteorological weekwise net solar radiation was also predicted. The mean maximum and minimum net solar radiation were14.82 MJ m^{-2} day (18th MW) and 8.29 MJ m^{-2} day^{-1} (50th MW), respectively. The monthwise net solar radiation was estimated and the maximum net solar radiation of 14.44 MJ m^{-2} day^{-1} occurred in the month of May and minimum in the month of December (8.52 MJ m^{-2} day^{-1}). The monthwise net solar radiation for different months was shown in Fig. 2. The analyzed on seasonal net solar radiation revealed that during summer season (10-26 MW), the net solar radiation was from 9.96 to 14.82 MJ m^{-2} day^{-1}. Similarly for monsoon season (27-44 MW) it ranges from 9.00 to 11.05 MJ m^{-2} day^{-1} with mean value of 10.02 MJ m^{-2} day^{-1}. During winter season (45-52 and 1-9 MW) the maximum, minimum and average net solar radiation were 12.01 and 8.29 MJ m^{-2} day^{-1} and 9.63 MJ m^{-2} day^{-1} respectively.

Vapour pressure deficit (VPD)

The mean daily VPD for Dapoli was 0.86 kPa (Fig. 1). The maximum VPD was 1.34 kPa observed on 28th November and minimum of 0.25 kPa was occurred on 19th July. The meteorological weekwise maximum vapour pressure deficit was 1.28 kPa in 49th MW and minimum of 0.28 kPa in 32nd MW. From Fig. 2, it is seen that the monthwise VPD was maximum in the month of December (1.22 kPa) and minimum in the month of August (0.30 kPa). The seasonal VPD revealed that in summer season (10-26 MW), it ranges from 0.39 to 1.14 kPa and in winter season (45-52 and 1-9 MW) the maximum, minimum and average VPD were 1.28 kPa and 1.1 kPa and 1.18 kPa respectively. In monsoon season (27-44 MW) it ranges from 0.28 kPa to 1.12 kPa with mean value of 0.47 kPa.

Effect of meteorological parameters on reference evapotranspiration

Temperature

On daily basis the effect of temperature on reference evapotranspiration was tested. It was observed that over the years if there is increase in temperature there is increase in reference evapotranspiration and vice-versa. This indicates that temperature is affecting the evapotranspiration directly. If temperature was raised by 0.5°C there was increase in annual evapotranspiration by 17.47 mm. Similarly, rise of temperature by 3°C, enhance the annual reference evapotranspiration by 70.01 mm. If the temperature is reduced by 1°C, the evapotranspiration decreases by 34.56 mm. This indicates that the radiation in temperature by 1°C reduces the demand of water will be reduced by 34.56 mm. The total reference evapotranspiration for different temperatures levels is depicted in Table 2. From Table 2 it is observed that for base year (mean values of 21 years data) the evapotranspiration for different season ranges from 392.36 to 540.95 mm. The total annual evapotranspiration was 1344.61 mm. The rice in temperature by 2°C there is increase in annual evapotranspiration by 5.25 percent (1415.22 mm) over the base year. The raise in evapotranspiration for different season i.e. summer, monsoon and winter was 27.8 mm (5.14 per cent), 20.34 mm (5.18 per cent) and 22.47 mm (5.46 per cent) respectively. For raise of 2°C temperature the difference in the seasonal evapotranspiration over the base year was more in summer followed by winter and monsoon. Similar trend was also observed for different levels of temperature. This was due to higher temperature in summer followed by winter. If the temperature was reduced by 1°C by keeping other parameters constant the annual evapotranspiration was reduced by (2.57 percent) i.e. 34.56 mm. The seasonal evapotranspiration was also reduced by 13.64 mm (2.52 per cent), 9.99 mm (2.55 per cent) and 10.93 mm (2.66 per cent) in summer, monsoon and winter season respectively.

Relative humidity

It was observed that if relative humidity is raised by 5 percent the annual evapotranspiration decreases by 30.81 mm (2.29 per cent). The seasonal evapotranspiration was also reduced 2.35 per cent (528.26 mm), 3.76 per cent (377.62 mm), and 0.82 percent (407.92 mm), during summer, monsoon and winter season respectively. It is observed that by 5 percent radiation in relative humidity, the annual reference evapotranspiration increases by 30.70 mm (1375.31mm). The seasonal evapotranspiration was also ranges from 0.80 to 2.33 percent in different seasons. The results showed the increase in relative humidity tend to decrease in reference evapotranspiration and decrease relative humidity tend to increase in reference evapotranspiration This indicates that relative humidity was affecting the rate of evapotranspiration inversely. The total reference evapotranspiration for different relative humidity is depicted in Table 2. From Table 2, it is observed that if relative humidity rises by 10 percent there is decrease in annual evapotranspiration by 4.09 percent (55.02 mm). The effect of relative humidity on seasonal evapotranspiration was also estimated. If the humidity was increased by 10 percent there is decrease in seasonal evapotranspiration by 4.51 percent (24.37mm) in summer season. For monsoon season the reduction in evapotranspiration was 24.14 mm i.e. 6.15 per cent over the base year. The percent deviation due to increase in relative humidity on evapotranspiration is more in monsoon season followed by summer season and then winter season. For decrease in relative humidity showed similar trend was obsered for different season.

Sunshine hours

When the sunshine hour was raised by 30 minutes, there was increase in annual evapotranspiration by 53.16 mm (3.95 per cent). The rise in sunshine hours by 60 minutes enhanced the annual reference evapotranspiration by 89.60 mm over base year. Similarly if the sunshine was decreased by 30 minutes the annual evapotranspiration reduces to1324.88 mm (1.47 per cent). This indicates that the reduction in sunshine hours was reduced by 30 min, the annual depth of water is reduced by 19.73 mm. The total reference evapotranspiration for different sunshine hours is depicted in Table 2. From Table 2 it was observed that the rise in one hour sunshine leads to season evapotranspiration 31.52 mm (5.83 per cent), 29.59 mm (7.54 per cent) and 28.50 mm (6.93 per cent) for summer, monsoon, and winter respectively. These results showed that there was much difference in evapotranspiration during summer season followed by winter and monsoon. These results confirm that increase in sunshine hours increases reference evapotrans-piration and vice-versa. This indicates that sunshine hours is affecting the evapotranspiration directly.

***Table 2.** Change in seasonal and annual evapotranspiration to change in different parameters*

Meteorological parameters	Seasons	Change in total evapotranspiration (mm) due to change in parameters								
		+0.5 °C	**+1 °C**	**+2 °C**	**+3 °C**	**0**	**-0.5 °C**	**-1 °C**	**-2 °C**	**-3 °C**
Temperature	Summer	547.84	554.76	568.75	582.92	540.95	-534.11	-527.31	-513.82	-500.47
	Monsoon	397.39	402.46	412.7	423.09	392.36	-387.35	-382.37	-372.5	-362.74
	Winter	416.84	422.43	433.77	445.33	411.3	-405.81	-400.37	-389.61	-379.02
	Annual	1362.08	1379.66	1415.22	1451.34	1344.61	-1327.27	-1310.05	-1275.93	-1242.23
		+15 (0.25 hrs)	**+30(0.5 hrs)**	**+45(0.75 hrs)**	**+60(1 hrs)**	**0**	**-15(0.25 hrs)**	**-30(0.5 hrs)**	**-45(0.75 hrs)**	**-60(1 hrs)**
Sunshine	Summer	552.29	559.02	565.74	572.47	540.95	-538.84	-532.11	-525.39	-518.66
	Monsoon	400.87	407.9	414.92	421.95	392.36	-386.82	-379.79	-372.77	-365.74
	Winter	426.39	430.86	435.53	439.8	411.3	-417.45	-412.98	-408.51	-404.04
	Annual	1379.55	1397.77	1415.99	1434.21	1344.61	-1343.1	-1324.88	-1306.66	-1288.44
		+0.5 km/hr	**+1 km/hr**	**+2 km/hr**	**+3 km/hr**	**0**	**-0.5 km/hr**	**-1 km/hr**	**-2 km/hr**	**-3 km/hr**
Wind speed	Summer	545.57	550.08	558.84	567.26	540.95	-536.25	-531.44	-521.5	-511.13
	Monsoon	393.85	395.3	398.12	400.82	392.36	-390.83	-389.28	-386.05	-382.67
	Winter	421.92	432.27	452.25	471.3	411.3	-400.42	-389.27	-366.07	-341.64
	Annual	1361.33	1377.65	1409.21	1439.37	1344.61	-1327.5	-1309.98	-1273.63	-1235.43
		+5%	**+10%**	**+15%**	**+20%**	**0**	**-5%**	**-10%**	**-15%**	**-20%**
RH	Summer	-528.26	-516.58	-506.56	-499.28	540.95	553.53	565.99	578.31	590.49
	Monsoon	-377.62	-368.22	-361.55	-359.51	392.36	407.2	421.95	436.6	451.15
	Winter	-407.92	-404.78	-402.43	-400.13	411.3	414.58	417.73	420.75	423.62
	Annual	-1313.8	-1289.59	-1270.53	-1258.93	1344.61	1375.31	1405.67	1435.66	1465.27
Rn	Summer	562.19	583.43	604.67	625.9	540.95	-519.72	-498.48	-477.24	-456.01
	Monsoon	409.48	426.61	443.73	460.86	392.36	-375.23	-358.11	-340.98	-323.86
	Winter	427.01	442.72	458.43	474.13	411.3	-395.6	-379.89	-364.18	-348.47
	Annual	1398.68	1452.75	1506.82	1560.89	1344.61	-1290.54	-1236.89	-1182.41	-1128.34
VPD	Summer	546.76	552.58	558.39	564.2	540.95	-535.14	-529.33	-523.52	-517.71
	Monsoon	394.85	397.34	399.84	402.33	392.36	-389.96	-387.37	-383.88	-382.38
	Winter	416.16	421.02	425.88	430.73	411.3	-406.45	-401.59	-396.73	-391.87
	Annual	1357.78	1370.94	1384.1	1397.26	1344.61	-1331.45	-1318.29	-1305.13	-1291.97

Wind speed

The effect of wind speed on reference evapotranspiration on daily basis was tested and found that rise in wind speed by 1 km hr^{-1} there is increase in annual evapotranspiration by 33.04 mm (1377.65 mm). Similarly, for rice in wind speed by 3 km/hr the annual reference evapotranspiration is1439.37 mm. The response of evapotranspiration to different levels of wind speed was very less during the monsoon season as compared to summer and winter season. From Table 2, it is observed that rise in wind speed by 1 km hr^{-1} there is increase in evapotranspiration by 2.46 percent over the base year. Similarly the rise in evapotranspiration for different seasons viz. summer, monsoon, winter was 9.13 mm (1.69 per cent), 2.94 mm (0 .75 per cent) and 20.97 mm (5.10 per cent) respectively. The effect of wind speed on seasonal evapotranspiration was more in winter followed by summer and less in monsoon. The per cent deviation during the monsoon season to different levels of wind speed was nearly constant. These results showed that there was much difference in evapotranspiration in winter followed by summer and less during monsoon. The analysis found that over the years if there is increase in wind speed there is increase in reference evapotranspiration. This indicates that wind speed is directly proportional to evapotranspiration.

Solar radiation

The rise in net solar radiation by 5 percent there is increase in annual evapotranspiration by 54.07 mm. Similarly rise of net solar radiation by 15 percent enhance the annual reference evapotranspiration by 162.21 mm. Similarly if the net solar radiation is decreased by 5 percent, the reduction in annual evapotranspiration is 54.07 mm. From Table 2 it is observed that of net solar radiation rises by 5 percent, there is increase in evapotranspiration by 4.02 percent over the base year. Similarly the raise in evapotranspiration for different season viz. summer, monsoon, and winter was 21.24 mm (3.93 per cent), 17.12 mm (4.36 per cent) and 15.71 mm (3.82 per cent) respectively. These results showed that there was much difference in evapotranspiration in summer followed by monsoon and lastly in winter. This was due to the accessibility of net solar radiation in different seasons. As the net solar radiation was more in summer season and which is the main source of energy for vaporization of water due to which the evapotranspiration was more and affecting it directly. The results showed that increase in net solar radiation, increase reference evapotranspiration and vice versa. This indicates that net solar radiation affects the rate of evapotranspiration directly.

VPD

The VPD analysis showed that of it is raised by 5 percent there was increase in annual evapotranspiration by 13.17 mm. Similarly if there is rise of VPD by 15 percent, enhances the reference evapotranspiration by 39.49 mm. When the VPD, was decreases by 5 percent, the evapotranspiration reduces by 13.16 mm. Table 2 shows that of the VPD rises by 5 percent there is increase in evapotranspiration by 0.98 percent over the base year. Similarly the rise in evapotranspiration for different season viz. summer, monsoon, and winter were 5.81 mm (1.07 per cent), 2.49 mm (0.63 per cent) and 4.86 mm (1.18 per cent) respectively. These results showed that there was much difference in evapotranspiration in summer followed by winter and lastly in monsoon. As the gradient of VPD was more in summer season, which increase the rate of evapotranspiration and less in winter and very less in monsoon. The study indicated that VPD is affecting the rate of evapotranspiration directly.

Sensitivity analysis

The sensitivity for different meteorological parameters was computed and the sensitivity coefficients were calculated on daily basis for mean air temperature, relative humidity, sunshine hours, wind speed, solar radiation and vapour pressure deficit. The annual as well as seasonal sensitivity coefficients were also obtained and showed in Table 3.

Temperature

The effect of mean temperature on reference evapotranspiration for different ranges of change in temperature was tested in terms of sensitivity. From Table 3 it is seen that the annual variation in relative sensitivity ranged from 0.96 to 1.05 with mean value of 1.00. The seasonal sensitivity values also ranges from 0.94 to 1.06. The maximum sensitivity occurred during winter season. The higher value of sensitivity represents that temperature is more sensitive to reference evaporatranspiration. Thokal and Mahale (2007) also showed that maximum temperature affected pan evaporation directly. These results were also confirmed by Chattopadhyay and Hulme (1996); Edoga and Suzzy (2008); Ali *et al.*, (2009) and Estervez *et al.*, (2009).

Table 3. Sensitivity values to seasonal and annual evapotranspiration

Parameters/season	Sensitivity values							
Temperature	**+0.5°C**	**+1°C**	**+2°C**	**+3°C**	**-0.5°C**	**-1°C**	**-2°C**	**-3°C**
Summer	0.99	0.99	0.98	0.97	0.94	0.96	1	1.05
Monsoon	0.99	0.99	0.97	0.96	0.94	0.96	1	1.05
Winter	0.99	0.98	0.97	0.95	0.94	0.96	1.01	1.06
Annual	0.99	0.99	0.97	0.96	1.01	1.02	1.03	1.05
Relative humidity	**5%**	**10%**	**15%**	**20%**	**-5%**	**-10%**	**-15%**	**-20%**
Summer	0.93	0.89	0.86	0.84	1.03	1.08	1.15	1.22
Monsoon	0.91	0.89	0.87	0.87	1.01	1.07	1.13	1.2
Winter	0.94	0.91	0.89	0.88	1.04	1.1	1.17	1.24
Annual	0.93	0.88	0.85	0.83	1.08	1.17	1.26	1.37
Sunshine	**+15 min**	**+30 min**	**+45 min**	**+60 min**	**-15 min**	**-30 min**	**-45 min**	**-60 min**
Summer	0.98	0.95	0.92	0.89	1.06	1.11	1.16	1.22
Monsoon	0.95	0.9	0.85	0.8	1.1	1.2	1.33	1.5
Winter	1.01	0.98	0.95	0.92	1.07	1.1	1.14	1.18
Annual	0.98	0.95	0.93	0.91	1.05	1.09	1.14	1.21
Wind speed	**+0.5 km/hr**	**+1 km/hr**	**+2km/hr**	**+3km/hr**	**-0.5km/hr**	**-1km/hr**	**-2km/hr**	**-3km/hr**
Summer	0.93	0.86	0.75	0.67	1.1	1.22	1.56	2.23
Monsoon	0.9	0.82	0.7	0.61	1.14	1.33	2.31	-1.38
Winter	0.88	0.77	0.61	0.51	1.24	1.57	3.71	-6.48
Annual	0.9	0.83	0.71	0.63	1.13	1.31	2.28	-1.13
VPD	**5%**	**10%**	**15%**	**20%**	**-5%**	**-10%**	**-15%**	**-20%**
Summer	0.96	0.93	0.9	0.87	1.04	1.09	1.14	1.2
Monsoon	0.96	0.92	0.89	0.85	1.05	1.1	1.15	1.22
Winter	0.96	0.93	0.9	0.87	1.04	1.09	1.14	1.19
Annual	0.96	0.93	0.89	0.87	1.04	1.09	1.14	1.2
Net radiation	**5%**	**10%**	**15%**	**20%**	**-5%**	**-10%**	**-15%**	**-20%**
Summer	0.99	0.98	0.97	0.96	1.01	1.02	1.04	1.05
Monsoon	0.99	0.99	0.98	0.98	1.01	1.01	1.02	1.03
Winter	0.99	0.98	0.97	0.96	1.01	1.03	1.04	1.06
Annual	0.99	0.98	0.98	0.97	1.01	1.02	1.03	1.05

Relative humidity

Table 4 shows that the annual sensitivity variation to different levels of relative humidity ranges from 0.83 to 1.37 with mean value of 1.05. The seasonwise sensitivity for different season ranges form 0.84 to 1.24. The maximum mean sensitivity of 1.02 was occurred in winter season which indicates that relative humidity was more sensitive to evapotranspiration in winter season followed by summer and lastly to monsoon. According to Thokal and Mahale (2007) the maximum relative humidity was affecting pan evaporation during non-monsoon season. Such results were also suggested by Lebing Gong *et al.*. (2006).

Sunshine hours

The sensitivity for change in sunshine hours was tested and found that annual values ranges from 0.91 to 1.21 with mean value of 1.03. The monsoon season was found more sensitive to sunshine hours. Piper (1988) also reported similar type of results. Thokal and Mahale (2007) stated that pan evaporation was affected by sunshine hours during Kharif season (monsoon season). The summer and winter season were less to sensitive sunshine hours.

Wind speed

The sensitivity of annual evaporation varies from -1.13 to 2.28 with average value of 0.83. During summer season wind speed was most sensitive which affects the reference evapotranspiration. During monsoon season the sensitivity varies from -1.38 to 2.31 with mean of 0.80. Thokal and Mahale (2007) found that wind velocity was most affecting parameter to pan evaporation during summer season.

Solar radiation

The effect of solar radiation on reference evapotranspiration for different ranges of change in solar radiation was tested in terms of sensitivity. The sensitivity to annual evapotranspiration ranges from 0.97 to 1.05. The winter season was most sensitive to solar radiation, while monsoon and summer seasons were found less sensitive to solar radiations. (Beven, 1979; Llasat and Snyder, 1998; Hupet and Vanclooster, 2001 and Yoder *et al.*, 2005).

VPD

The effect of VPD on reference evapotranspiration for different ranges of change tested in terms of sensitivity. From Table 3, the annual variation in relative sensitivity ranges from 0.87 to 1.20 with mean value of 1.02. The vapour pressure gradient was most sensitive during monsoon season followed by summer and winter. According Singh and Xu (2007) evaporation estimates were found to be particular sensitive to vapour pressure gradient.

CONCLUSIONS

The analysis revealed that temperature, sunshine hours, wind speed, solar radiation and vapour pressure gradient had direct effect on estimation of annual and seasonal reference evapotranspiration while relative humidity found inverse association. The annual reference evapotranspiration estimates was most sensitive to relative humidity and least sensitive to wind speed. In general relative humidity was the most sensitive variable followed by sunshine hours and vapour pressure gradient. The solar radiation and air temperature had identical effect on annual reference evapotranspiration and found less sensitive. The order of sensitivity for summer season noticed was wind speed > sunshine hours > vapour pressure gradient > solar radiation > temperature. The sensitivity analysis found that during monsoon and winter seasons the sunshine hours and vapour pressure gradient was most sensitive to reference evapotranspiration had profound effect on reference evapotranspiration. The sensitivity coefficients showed seasonal variation to different climatic variables.

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Development of Rainfall Intensity nomograph for Mulde of South Konkan Region of Maharashtra State

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The rainfall charts of 14 years of Mulde, Dist. :Sindhudurg were analyzed in the form of annual maximum series of various duration, viz. 5, 10, 15, 30 minutes and 1, 3, 6, 12 and 24 hours. The rainfall intensity (I) duration-return period (T) relationship as $I = \frac{KT^a}{(t+b)^b}$ has been developed for Mulde, South Konkan region under sub-humid high rainfall zone of Maharashtra. The values of parameters a and b were determined by using graphical method and the values of K and d by least square method in the rainfall intensity-duration-return period relation. The values of constants K, a, b and d were found to be 3.729, 0.1558, 0.5, 0.7138 respectively. The nomograph was developed for Dapoli station from intensity-frequency-duration relationship. The per cent deviation in rainfall intensity values observed from mathematical and nomographic solution ranged from (–) 0.55 to 6.38 per cent, which lies within the acceptable limit. The developed nomograph can be used for computation of rainfall intensity for different duration upto 24 hours for 100 years at Mulde.

(**Key words:** *Nomograph, Intensity-duration-return period relation, Rainfall intensity*)

Rainfall intensity is the important parameter need to be determined properly to be used in rational formula. Rational formula, because of its simplicity is being used extensively for estimating peak runoff rate from small drainage areas. In U.S.A. the generalized charts of rainfall intensity-duration-return period developed earlier by Yarnell (1935) and later revised by U.S. Weather Bureau (1961) are being used for obtaining the values of 'I', the rainfall intensity in the rational formula (Ram Babu *et al.*, 1979).

Rainfall intensity-duration-return period equation on regional basis can provide solution for computation of rainfall intensity required in estimation of peak flow, which is necessary for design of soil conservation and runoff disposal structures and for planning flood control project (Barai *et al.*, 2005). In order to simplify the procedure and to facilitate the computation for field workers the nomograph can prove to be a better option (Mane *et al.*, 2007).

MATERIALS AND METHODS

Various equations, that were found to represent the rainfall intensity-duration-return period relationship in India and abroad, were summarized and discussed by Raghunath *et al.*, (1969). However the most satisfactory general equation is,

$$I = \frac{KT^a}{(t + b)^d} \qquad ...(1)$$

where,

I = rainfall intensity, cm hr^{-1}

T = return period, year

T = duration, hr

K, b = derived constants

a, d = derived exponents

The altitude of raingauge station located at Mulde, Tal- Kudal is 17 m above MSL. The longitude and latitude are 73°42' E and 16°20' N, respectively. Climatically the area falls under sub-humid zone. The annual average rainfall is 3152.3 mm. In the present study the rainfall charts of 14 years from 1992 to 2005 of meteorology observatory of the Central Research Station, Mulde, Tal:Kudal, Dist:Sindhudurg were obtained. The rainfall charts were analyzed in the form of annual maximum series for various durations viz. 5, 10, 15, 30 minutes and 1, 3, 6, 12 and 24 hours. The maximum depth of rainfall for various durations was worked out employing 'Original trace method' suggested by Ogrosky and Mockus (1957) for all duration (Table 1). Using the rainfall intensities obtained for three different per cent chances, the return period lines were developed and rainfall intensities for 1 per cent (100 years), 2, 4, 10, 25 and 50 per cent (2 years) were obtained (Table 2) and can be considered as observed values of rainfall intensities. The rainfall intensity-duration-return period equation was developed using the following steps (Ram Babu *et al.*, 1979).

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Table 1. *Plotting positions for different duration*

Duration, hr	Rainfall intensity, mm h^{-1}		
	50% chance line	15.9% chance line	84.1% chance line
0.25	50.26	63.66	39.67
0.50	36.76	50.21	26.91
1.0	26.75	40.16	17.81
2.0	18.81	28.87	12.26
3.0	14.83	20.55	10.70
6.0	9.51	13.20	6.71
12.0	6.54	8.94	4.79
24.0	4.24	5.70	3.14

Table 2. *Return period of rainfall intensity (mm hr^{-1}) for different duration*

Duration, hr	Per cent frequency					
	1%	2%	4%	10%	25%	50%
	Return period, year					
	100 yrs	50yrs	25 yrs	10 yrs	4 yrs	2 yrs
0.25	90	85	78	70	60	50
0.50	74	68	61	54	44	36
1.0	62	56	50	42	33	26
2.0	47	42	37	31	25	18
3.0	33	29	26	22	18	14
6.0	20	18.5	16.7	14	11.5	9
12.0	13	12	11	9.5	7.8	6
24.0	8.5	7.8	7	6.2	5.2	4

The values of rainfall intensities for all durations were plotted on Y-axis and values of return period on X-axis on log-log paper. The geometric mean slope of the lines represents the exponent 'a' in the equation 1. A line representing the geometric mean slope was drawn at the base through origin. The lines parallel to this slope line were drawn by cutting the Y-axis against 1-year return period. The values of rainfall intensities on Y-axis and selected durations on X-axis plotted on log-log paper. The points so plotted are not in a straight line. To align the points into a straight line, suitable constant 'b' is to be added to duration. After adding this constant to the values of duration the points were aligned into a straight line. Then the constants 'K' and 'd' were solved by least square method. The adequacy of rainfall data has been ensured based on Mockus (1960) criteria as follows,

$$Y = (4.3\ t\ \log_{10} R)^2 + 6 \qquad ...(2)$$

Where,

Y = minimum acceptable years of record,

t = students t test at 10 per cent level of significance

R = ratio of magnitude of 100 years events to 2 years event

The values of 'Y' for all duration obtained from the test of length of record are sown in Table 3.

Table 3. *Computation of minimum acceptable years of record (t_{10} = 1.39 at d.f. = 8)*

Sr. No.	Duration, h	R	Y
1.	0.25	1.80	8.49
2.	0.50	2.05	9.72
3.	1.0	2.38	11.43
4.	2.0	2.61	12.65
5.	3.0	2.36	11.33
6.	6.0	2.22	10.59
7.	12.0	2.16	10.28
8.	24.0	2.12	10.08

A nomograph is an alignment chart consisting of a set of suitably graduated parallel scales. The procedure suggested by Luzzadar (1964) was adopted for development of nomograph. In the present study there are three variables viz. rainfall intensity, duration and return period. Thus the alignment chart should have three parallel scales, so graduated that a line which joins values on any two scales intersects the third scale at a point which satisfies he given equation. The developed nomograph for Mulde is shown in Fig. 1.

Table 4. *Comparisons between calculated and nomographic intensities of rainfall at Mulde (cm hr^{-1})*

Duration min/h	'I' cal frequency,yr			'i' nomo frequency,yr			sp nomo frequency,yr		
	10	20	50	10	20	50	10	20	50
15 min	6.55	7.7	8.4	6.6	7.65	8.2	0.76	-0.64	-2.38
30 min	5.33	6.3	6.8	5.5	6.1	6.7	3.18	-3.17	-1.47
1 h	3.99	4.7	5.1	4.1	5	4.91	2.7	6.38	-3.73
3 h	2.18	2.6	2.8	2.1	2.59	2.75	-3.6	-0.38	-1.78
6 h	1.40	1.7	1.8	1.39	1.6	1.79	-0.71	-5.8	-0.55

i cal = Calculated intensity of rainfall (cm.hr^{-1}) from developed equation
i nomo = Observed intensity of rainfall (cm.hr^{-1}) from nomographs
sp nomo = Per cent deviation of nomographic values from those calculated by developed equation

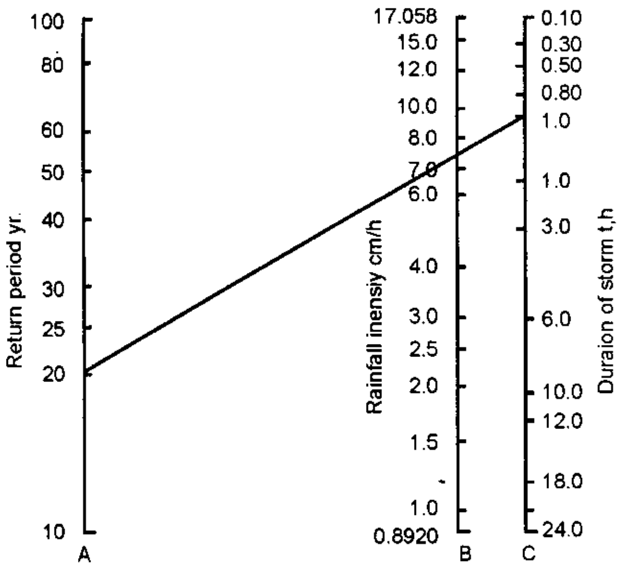

Fig. 1. Nomograph for solving intensity-duration-return period equation at Mulde

RESULTS AND DISCUSSION

Based on the 14 years maximum rainfall intensity data for varying duration, a relationship between rainfall intensity-duration-return periods was developed conforming to the form of equation 1. This relationship for Mulde is given by equation 3.

$$I = \frac{7.9932 \ T^{0.1814}}{(t + 1.0)^{0.811}} \qquad ...(3)$$

Using this equation 3, the intensity for any duration t up to 24 hours and any return period, T up to 100 years can be determined.

Per cent deviation of rainfall intensity values observed from nomograph and those calculated from corresponding mathematical equation for various duration and return period is shown in Table 4. The data revealed that maximum deviation between the nomographic solutions and mathematical equation ranges from (-) 0.55 to 6.38 per cent, which is quite low and acceptable. Such handy tool will be of use for the designers as well as for field workers engaged in soil and water conservation in computing the peak runoff rate using rational formula.

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Effect of Blackgram (*Vigna mungo*) Stubble and Nitrogen Management on FCV Tobacco (*Nicotiana tabacum*) in Blackgram - Tobacco Cropping System

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A field experiment was conducted during rainy and post rainy seasons of 2001-04, to evaluate the effect of different pre-treatment practices to hasten blackgram [*Vigna mungo* (L.) Hepper] stubble decomposition along with sunnhemp [*Crotalaria juncea* (L.) Rotar and Joy] *in-situ* green manuring and fallow plots and nitrogen levels on performance of Virginia tobacco (*Nicotiana tabacum* L.) in blackgram-tobacco cropping system in the irrigated Alfisols. The sunnhemp green manuring-tobacco increased the mean yields of green-leaf, cured leaf, grade index and cured leaf production efficiency of tobacco by 37.9, 21.4, 25 and 21.4%; status of soil organic C, available N and P by 0.11, 14.2 and 11.7%, respectively compared with those of fallow-tobacco; also increased the lamina N, P, K, and nicotine and reducing sugars of tobacco when compared with other stubble decomposition methods and fallow-tobacco. This was followed by spray of 4% urea on blackgram stubbles and incorporation into the soil preceding tobacco. The highest leaf-equivalent yield of tobacco was accrued with spray of 4% urea on blackgram stubbles and incorporation into the soil preceding tobacco. The grade index was comparable with 110 and 130 kg N ha^{-1} and significantly superior to 90 kg N ha^{-1}. Application of 130 kg N ha^{-1} increased the mean yields of green-leaf, cured leaf, grade index and cured leaf production efficiency of tobacco, which were 25.1, 16.8, 12.9 and 16.9%, more, respectively; the leaf-equivalent yield of tobacco and status of available soil N, which were 13.7and 3.74% more, respectively compared with those of 90 kg N ha^{-1} application. Leaf lamina concentration of N and nicotine increased while reducing sugars decreased with increase in the level of N from 90 to 130 kg N ha^{-1}. It was concluded that spray of 4% urea on blackgram stubbles and incorporation into the soil preceding tobacco gave higher system productivity and leaf-equivalent yield of tobacco. Nitrogen dose of 130 kg N ha^{-1} would be needed for tobacco succeeding blackgram, while 110 kg N ha^{-1} would be sufficient for tobacco succeeding sunnhemp *in-situ* green manuring.

(**Key words:** *Blackgram-tobacco system, Economics, Nitrogen, Productivity, Quality, Soil fertility, Stubble incorporation*)

Semi-flavourful to flavourful flue-cured Virginia (FCV) tobacco (*Nicotiana tabacum* L.) targeted for domestic as well as international markets is traditionally grown as a monocrop on irrigated northern light soils of East Godavari, West Godavari and Khammam districts of Andhra Pradesh on an area of around 26 thousand ha, producing around 55 million kg tobacco leaf annually (Tobacco Board, 2008). Continuous monoculture of tobacco has adverse effect on soil health, ultimately reducing the crop quality and productivity. The fertility status of soil and annual rainfall of around 1100 mm received through south-west and north-east monsoons, good quality underground water and suitable soil conditions provide ample scope for crop intensification through cultivation of a number of *Kharif* crops (Kasturi-Krishna *et al.*, 2004). Of late, sunnhemp [*Crotalaria juncea* (L.) Rotar and Joy] *in-situ* green manuring preceding tobacco is being mostly followed as farmers realized its importance. Growing of green manure leads to no marketable crop and sometimes the cost of green manure crop may exceed the potential soil and N benefits. Studies indicated that tobacco yields in blackgram [*Vigna mungo* (L.) Hepper]-tobacco sequence were on par with that of sunnhemp green manuring-tobacco sequence. Moreover, blackgram-tobacco sequence accrued additional net returns also during *Kharif* in addition to yield improvement in succeeding tobacco. However, while doing preparatory cultivation for tobacco planting leftover stubbles and leafy materials of blackgram are to be removed from the field, as short period is available for decomposition of blackgram stubbles and field preparation between harvesting of blackgram pods and tobacco planting. Instead, incorporation of these stubbles not only increases the productivity of succeeding tobacco but also sustains the soil

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health for a longer period. Hastening the stubble decomposition process by inclusion of N, cellulolytic microbes and other decomposing materials at the time of residue incorporation may solve the problems associated with decomposition (Krishna-Reddy *et al.*, 2008). As the information available regarding blackgram-stubble decomposition and N requirement of tobacco succeeding *Kharif* blackgram is meager, the present investigation was carried out to devise appropriate technology for effective in-situ management of blackgram stubbles and to find out optimum nitrogen dose to tobacco for getting higher productivity, quality and monetary returns of tobacco, as well as to study the changes in the soil fertility in blackgram-tobacco cropping system.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (*Kharif*) and post rainy (*Rabi*) seasons of 2001-02, 2002-03 and 2003-04 at the Central Tobacco Research Institute Research Station, Jeelugumilli, (17°11′ 30″ N and 81°07″ 50″ E at 150 m above mean sea-level), West Godavari district, Andhra Pradesh under semi arid tropical climate on fixed permanent plots. The soil (0-22.5 cm) was sandy loam and deeper layers (22.5-45 cm) were sandy clay and classified as Typic Haplustalfs with slightly acidic pH (6.30), low electrical conductivity (EC) (0.21 dS m^{-1}), chlorides (30 mg kg^{-1}), organic C (0.22%), available N (155 kg ha^{-1}), high available P (27 kg ha^{-1}) and medium available K (225 kg ha^{-1}).

The treatments consisted of six main plots in rainy season and three sub-plots in winter season. During rainy season (June-Sept.) blackgram was grown in four plots along with sunnhemp and fallow in two plots. The main-plot treatments in rainy season consisted four pretreatment practices to hasten blackgram stubble decomposition before in situ incorporation viz. application of 8.6 kg P ha^{-1}, spray of 4% urea, spray of cellulose degraders (cellulolytic bacteria, Cellulomonas sp) and removal of blackgram stubbles, along with sunnhemp in-situ green manuring and fallow. During winter season each main plot was divided into three sub-plots, and N levels (90, 110 and 130 kg ha^{-1}) were allotted to tobacco. The experiment was conducted in a split-plot design, and replicated three times. The bacterium Cellulomonas sp. was obtained from T. Stanes Co. Ltd., Coimbatore, Tamil Nadu. Phosphorus was applied through single super phosphate.

Sunnhemp was sown @ 50 kg ha^{-1} in the first week of June and was incorporated in-situ at the start of flowering in the first week of August in all the years. A uniform dose of 25.0 and 21.8 kg ha^{-1} of N and P, respectively was applied through urea and single super phosphate before sowing blackgram. Blackgram cv LBG 20 seed after inoculation with biofertiliser cultures of the symbiotic N_2-fixing bacteria 'Bradyrhizobium spp. RBG 314 strain' and phosphate solubilising bacteria 'Bacillus megatherium var. Phosphaticum AMT 1003' (brought from ARS, Amaravathi, ANGRAU, Andhra Pradesh) was sown at 30 x 10 cm spacing on the same day of sunnhemp sowing. Blackgram pods were harvested at physiological maturity and stubble decomposition hastening pre-treatments imposed on stubbles and in-situ incorporation was done on the next day in the third week of September. The gross plot size was 6 X 6 m (60 plants) and the net plot size was 4 X 4.8 m (32 plants). Sixty-day-old tobacco cv. Kanchan seedlings were planted at 100 x 60 cm spacing during Rabi in first week of October in all the three years. Nitrogen (as per treatment) and 99.9 kg K ha^{-1} were applied in three splits at 7-10, 25-30 and 40-45 days after planting (DAP) in 1:2:1 proportion. The entire dose of P (26.2 kg ha^{-1}) was applied basal along with N and K at 7-10 DAP. The N, P and K were applied by dollop method through calcium ammonium nitrate, di-ammonium phosphate and potassium sulphate, respectively. The crops were raised with recommended package of practices except the inputs applied as treatments.

The rainfall received during *Kharif* was 586 mm (49 rainy days) in 2001, 523 mm (39 rainy days) in 2002 and 886 mm (70 rainy days) in 2003. The amount of rainfall received during *Rabi* tobacco was 188 mm (19 rainy days) in 2001-02, 236 mm (10 rainy days) in 2002-03 and 305 mm (15 rainy days) in 2003-04. Mean maximum and minimum temperatures during *Rabi* were respectively 31.4 and 19.0 in the first season, 31.3 and 18.3 in the second season and 31.3 and 17.1°C in the third season. During rainy season, biomass production of sunnhemp (3.14% N on dry weight basis), biological yield and grain yield of blackgram were recorded, and harvest index was calculated. During winter season, tobacco leaves were harvested at maturity by priming 1-2 leaves each time at 7-8 days interval and cured in the flue-curing barn. On an average 12 primings were done to complete the harvesting of tobacco. After curing and bulking, leaves were graded based on plant position, colour and blemish. The data on green-leaf and cured-leaf yields were recorded and grade index was calculated. Grade index was calculated (first grade equivalent) by summing the product of each grade cured leaf quality and the value of that grade in comparison to first grade cured leaf (Gopalachari, 2004). System production efficiency was calculated by deviding the tobacco leaf- equivalent yield with total duration of the cropping system (blackgram-tobacco 260 days and Fallow tobacco 165 days) in the field. Cured leaf efficiency was worked out in terms of kg ha^{-1} day^{-1} by deviding the cured leaf with tobacco duration (165 days) in the field. The tobacco leaf-equivalent yield was computed by converting *Kharif* blackgram grain yield to tobacco cured leaf yield based on the market prices. The cured leaf samples collected from different plant positions viz. Primings (P), Lugs and Cutters (X), Leaf (L) and Tips (T) were analyzed for lamina total N, P, K, nicotine, reducing sugar and chloride contents as per the standard procedures. Soil samples were collected from 0-22.5 cm depth at pre-sowing and post-harvest after three crop cycles and estimated pH, EC, organic C, available N, P and K contents following standard procedures. Same trend was obtained in three years of experimentation and hence, the data were pooled and analysed. Interaction effects were non significant, hence only results of main effects were presented.

RESULTS AND DISCUSSION

Kharif crop productivity

Kharif blackgram and sunnhemp for *in-situ* green manuring performed well in all the three seasons. The blackgram economic yield was 1.37, 1.39 and 1.32 t ha^{-1}, and biological yield was 4.36, 4.40 and 4.23 t ha^{-1} with harvest index of 31.4, 31.6 and 31.2% during the first, second and third years, respectively. This variation in productivity could be attributed mainly to the differences in quantity and distribution of rainfall during *Kharif*. The mean grain yield of blackgram was 1.36 t ha^{-1} and biological yield was 4.33 t ha^{-1} with harvest index of 31.41%. The dry matter production of sunnhemp ranged from 3.95 to 4.25 with a mean of 4.12 t ha^{-1} (3.14% N) adding 129 kg N ha^{-1} every year. The study revealed that *Kharif* blackgram, and sunnhemp for *in-situ* green manuring can be grown successfully before *Rabi* tobacco taking the advantage of South-West monsoon rains.

Rabi tobacco productivity

Pooled results showed that the tobacco grown after sunnhemp in-situ green manuring recorded significantly higher green-leaf yield, cured-leaf yield, grade index, grade index/cured-leaf percent and cured-leaf production efficiency compared with those of tobacco grown after blackgram stubble decomposition hastening methods and fallow-tobacco (Table 1). This treatment was followed by spray of 4% urea on blackgram stubbles, application of 8.6 kg P ha^{-1} on blackgram stubbles and spray of cellulose degraders on blackgram stubbles and incorporation into the soil preceding tobacco in respect of yield parameters and cured leaf production efficiency. Lower values for all the yield parameters were recorded in fallow – tobacco, which was on a par with that of removal of blackgram stubbles preceding tobacco. Sunnhemp green manuring-tobacco increased yields of green-leaf by 5.32 (37.9), cured-leaf by 0.42 (21.4), grade index by 0.34 t ha^{-1} (25%) and cured-leaf production efficiency by 2.63 kg ha^{-1} day^{-1} (21.4%), respectively compared with that of fallow-tobacco. In general, tobacco yield improvement ranged from 0.40 to 2.48 (2.85 to 17.7) in green-leaf, 0.07 to 0.27 (3.57 to 13.8) in cured-leaf, 0.05 to 0.19 t ha^{-1} (3.68 to 14.0%) in grade index and 0.44 to 1.69 kg ha^{-1} day^{-1} (3.59 to 13.8%) in cured-leaf production efficiency with different blackgram stubble decomposition-hastening methods preceding tobacco compared with that of fallow-tobacco. Higher tobacco yields with sunnhemp green-manuring might be owing to ploughing in of all the green matter into the soil in addition to symbiotic biological N_2 fixed through its roots. As the soils are sandy loam, addition of organic matter through green-manuring aids in improvement of soil organic C, available N and P status of soil and thereby nutrient-use efficiency and might have also improved soil physical properties, especially water holding capacity. In blackgram stubble decomposition hastening methods, the fallen leaf material, left over stubbles after harvesting pods (above ground material) and residual biologically fixed N_2 was available to tobacco. The higher tobacco yield on incorporation of blackgr m stubbles after spray of 4% urea could be due to relatively narrow C: N ratio that created favourable conditions for speedy microbial decomposition and early mineralization of blackgram stubbles. The timely mineralization with urea spray resulted in timely release of nutrients as per the need of the tobacco crop compared with wider C: N ratio under other decomposition-hastening methods (Krishna-Reddy *et al.*, 2008).

Table 1. Virginia tobacco green-leaf yield, cured-leaf yield, grade index, grade index/ cured-leaf percent, cured-leaf production efficiency, tobacco leaf- equivalent yield and system production efficiency as influenced by blackgram stubble decomposition method and nitrogen application (Pooled)

Treatment	Tobacco yield (t ha^{-1})			Grade index/ Cured-leaf (%)	Cured-leaf production efficiency (kg ha^{-1} day^{-1})	Tobacco leaf-equivalent yield (t ha^{-1})	System production efficiency (kg ha^{-1} day^{-1})
	Green-leaf	Cured-leaf	Grade index				
Stubble decomposition method							
Application of 8.6 kg P ha^{-1}	14.99	2.13	1.49	70.17	13.31	2.81	10.81
Spray of 4% urea	16.51	2.23	1.55	69.47	13.94	2.90	11.15
Spray of cellulose degraders	16.51	2.11	1.48	70.14	13.19	2.80	10.77
Stubbles removed	14.43	2.03	1.41	69.49	12.69	2.71	10.42
Sunnhemp green manuring	19.35	2.38	1.70	71.67	14.88	2.38	9.15
Fallow	14.03	1.96	1.36	69.89	12.25	1.96	11.88
SEm±	0.24	0.03	0.02	0.24	0.19	0.04	0.16
CD (P=0.05)	0.70	0.09	0.07	0.69	0.57	0.11	0.45
N levels to tobacco (kg ha^{-1})							
90	14.03	1.96	1.40	71.42	12.25	2.41	9.94
110	16.33	2.17	1.53	70.18	13.56	2.63	10.85
130	17.55	2.29	1.58	68.81	14.32	2.74	11.30
SEm ±	0.16	0.02	0.02	0.19	0.13	0.03	0.12
CD (P=0.05)	0.44	0.06	0.06	0.53	0.36	0.08	0.33
Seasons							
2001-02	15.24	2.11	1.48	70.34	13.17	2.56	10.56
2002-03	15.52	2.07	1.42	68.83	12.92	2.53	10.43
2003-04	17.15	2.25	1.60	71.24	14.04	2.69	11.10
SEm ±	0.82	0.11	0.08	0.24	0.69	0.12	0.49
CD (P=0.05)	NS	NS	NS	0.82	NS	NS	NS

There was a significant increase in green-leaf and cured-leaf yields, green-leaf/ cured-leaf and cured-leaf production efficiency with increase in N level from 90 to 130 kg N ha^{-1}. Grade index showed significant increase up to 110 kg N ha^{-1} and was comparable with that at 130 kg N ha-1. Grade index/ cured-leaf percent was higher with 90 kg N ha^{-1} and decreased with increase in N level. Application of 110 and 130 kg N ha^{-1} increased the yields of green-leaf by 2.3 (16.4) and 3.52 (25.1), of cured-leaf by 0.21 (10.7) and 0.33 (16.8), and of grade index by 0.13 (9.28) and 0.18 t ha^{-1} (12.9%), and of cured-leaf production efficiency by 1.31 (10.7) and 2.07 kg ha^{-1}/day (16.9%), respectively compared with that of 90 kg N ha^{-1}. The Increase in N dose from 90 to 110 kg resulted in 0.21 t ha^{-1} increase in cured-leaf yield, but the same increment of N from 110 to 130 kg ha^{-1} showed only 0.12 t ha^{-1} increases in its yield. The increase in yield with successive addition of N was progressively smaller, because the agronomic-use efficiency of N decreases with increasing N level. These results corroborate the findings of Krishna-Reddy *et al.* (2008).

Lamina N, P, K content and quality parameters

Lamina nitrogen, phosphorus, potassium, nicotine, reducing sugars, reducing and chlorides in leaf are important quality parameters and are influenced by the stubble decomposition methods and N levels to tobacco (Tables 2 and 3). Higher values of lamina N, P, K, and nicotine and lower values of reducing sugars in all the plant positions of tobacco were recorded in sunnhemp green manuring-tobacco system when compared with other stubble decomposition methods. This was followed by spray of 4% urea on blackgram stubbles, application of 8.6 kg P ha^{-1} on blackgram stubbles and spray of cellulose degraders on blackgram stubbles and incorporation into the soil. Among these three stubble decomposition methods, spray of 4% urea on blackgram stubbles and then incorporation had resulted in relatively higher N and nicotine and lower reducing sugars, whereas application of 8.6 kg P ha^{-1} on blackgram stubbles and their incorporation had resulted in relatively higher P, K, reducing sugars and lower N and nicotine concentration of tobacco lamina. This trend could be attributed to higher organic matter accretion and residual nitrogen in sunnhemp green manuring-tobacco and blackgram-tobacco treatments compared to fallow-tobacco (Kasturi-Krishna *et al.*, 2004). Lowest values of lamina N and nicotine and higher values of reducing sugars in all the plant positions of tobacco were recorded in fallow-tobacco which was attributed to lower organic C and residual available soil N.

There was a significant increase in lamina total N and nicotine content with successive increase in N level up to 130 kg N ha^{-1}. Highest nicotine content was recorded with 130 kg N ha^{-1}. Reducing sugars and reducing sugars: nicotine were significantly higher with 90 kg N ha^{-1}, which decreased significantly up to 130 kg N ha^{-1}. Nitrogen is a component of the nicotine molecule and is important in its synthesis in tobacco. The concentration of nitrogen in leaves is positively correlated with nicotine and negatively with starch and sugar concentrations (Flower, 1999). Thus in the present study, an increase in the rate of fertilizer N increased the concentration of total nitrogen and nicotine and decreased the reducing sugars in cured-leaf of tobacco. Phosphorus and potassium content in leaf was not altered by N levels. Lamina chloride content was well within the acceptable limits (<1.50%) of good quality leaf.

The climatic conditions influenced leaf quality characters, wherein significantly lower levels of lamina total N, nicotine, and higher levels of sugars were obtained in 2001-02 season than during the other two seasons. The study also revealed that total nitrogen and nicotine contents increased and P and K contents decreased gradually with leaf positions from P to T. Reducing sugars increased from P to X position and there after decreased gradually up to T position in all the stubble decomposition methods and N levels (Tables 2 and 3). Distribution of N, P, K, nicotine and sugars in different plant positions followed the normal trend in all the treatments (Gopalachari, 1984). All the chemical quality characters were well within the acceptable limits of good quality leaf in all the plant positions.

System productivity

The highest leaf-equivalent yield of tobacco and system production efficiency (Table 1) was obtained with spray of 4% urea on blackgram stubbles and incorporation into the soil preceding tobacco, than that of the sunnhemp-tobacco system. Relatively higher cured-leaf productivity of tobacco with spray of 4% urea on blackgram stubbles coupled with Kharif blackgram yield resulted in higher leaf equivalent yields of tobacco and system production efficiency. Although sunnhemp-tobacco recorded the highest cured-leaf yield, the tobacco leaf-equivalent yield and the system production

Table 2. *Virginia tobacco lamina N, P and K content as influenced by blackgram stubble decomposition hastening method and nitrogen application (Pooled)*

Treatment	Nitrogen (%)				Phosphorus (%)				Potassium (%)			
Stubble decomposition method	P	X	L	T	P	X	L	T	P	X	L	T
Application of 8.6 kg P ha^{-1}	1.79	2.16	2.57	2.72	0.27	0.25	0.22	0.20	2.65	2.42	2.03	1.83
Spray of 4% urea	1.87	2.24	2.67	2.79	0.25	0.23	0.21	0.18	2.57	2.34	1.95	1.74
Spray of cellulose degraders	1.76	2.09	2.55	2.66	0.25	0.23	0.21	0.18	2.64	2.41	2.02	1.81
Stubbles removed	1.70	2.03	2.44	2.61	0.23	0.21	0.18	0.17	2.59	2.36	1.97	1.77
Sunnhemp green manuring	2.02	2.37	2.84	3.03	0.34	0.33	0.31	0.28	2.89	2.66	2.27	2.07
Fallow	1.63	1.96	2.33	2.52	0.27	0.25	0.23	0.20	2.69	2.46	2.07	1.88
SEm±	0.03	0.06	0.06	0.07	0.01	0.01	0.01	0.01	0.05	0.04	0.04	0.04
CD (P=0.05)	0.10	0.19	0.19	0.19	0.02	0.02	0.02	0.02	0.14	0.12	0.13	0.10
N levels to tobacco (kg ha^{-1})												
90	1.61	1.86	2.30	2.42	0.28	0.26	0.23	0.21	2.69	2.45	2.06	1.86
110	1.83	2.19	2.62	2.77	0.27	0.25	0.22	0.20	2.67	2.44	2.05	1.85
130	1.94	2.37	2.78	2.97	0.27	0.25	0.22	0.20	2.66	2.43	2.04	1.84
SEm ±	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	0.03	0.03	0.03	0.03	NS	NS	NS	NS	NS	NS	NS	NS
Seasons												
2001-02	1.68	1.97	2.46	2.64	0.29	0.27	0.24	0.21	2.44	2.21	1.81	1.62
2002-03	1.81	2.17	2.56	2.75	0.27	0.25	0.22	0.20	2.73	2.50	2.13	1.91
2003-04	1.90	2.28	2.67	2.77	0.26	0.24	0.21	0.20	2.85	2.62	2.21	2.02
SEm ±	0.05	0.03	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CD (P=0.05)	NS	0.10	NS	0.08	NS	NS	NS	NS	0.05	0.05	0.03	0.04
Acceptable limits	1.0 - 3.0				0.20 -0.40				1.5-3.0			

efficiency were lower compared to blackgram-tobacco system, as there was no *Kharif* crop yield addition in this system. Lowest leaf-equivalent yield of tobacco and system production efficiency were recorded with fallow-tobacco. Among the N doses, higher leaf-equivalent yield of tobacco and system productivity day^{-1} were recorded with application of 130 kg N ha^{-1}, compared with those of 90 kg N ha^{-1} application. This was due to the higher cured-leaf yield of tobacco in this treatment.

Residual soil fertility

Residual soil fertility indicated significant variation in the pH, EC, organic C, available N, P and K status of soil (Table 4). Among different methods of stubble decomposition, soil pH ranged from 6.00 to 6.24 and EC ranged from 0.19 to 0.27 dSm^{-1}, where sunnhemp green manuring-tobacco being comparable with blackgram-tobacco treatments recorded significantly lower pH (6.00) and higher EC (0.27 dSm^{-1}), compared to fallow-tobacco, while reverse trend was recorded with fallow-tobacco plots. Status of soil organic C, available N and P was significantly higher by 0.11, 14.2 and 11.7%, respectively with sunnhemp green manuring-tobacco compared with those of fallow-tobacco plots. The higher organic C, available N and P in sunnhemp-tobacco system might be the result of higher organic matter accretion and microbial activity due to the in-situ incorporation of sunnhemp into the soil. Change in soil pH may be attributed to the legume (sunnhemp and blackgram), which takes up high concentrations of base cations, and in the process of balancing internal charge, release H+ into the rhizosphere; this can result in soil acidification (Crews and Peoples, 2004). Electrical conductivity values were higher with crop sequences involving legumes than fallow-tobacco sequence. Although the cause of

Table 3. *Virginia tobacco lamina sugars, nicotine and chlorides as influenced by blackgram stubble decomposition hastening method and nitrogen application (Pooled)*

Treatment	Reducing sugars (%)				Nicotine (%)				Chlorides (%)			
Stubble decomposition method	P	X	L	T	P	X	L	T	P	X	L	T
Application of 8.6 kg P ha⁻¹	13.94	18.77	14.29	13.19	1.64	1.98	2.40	2.64	0.60	0.63	0.66	0.69
Spray of 4% urea	13.25	17.87	13.29	12.29	1.70	2.04	2.47	2.70	0.59	0.62	0.65	0.68
Spray of cellulose degraders	13.99	18.99	14.53	13.77	1.61	1.94	2.37	2.60	0.61	0.64	0.67	0.70
Stubbles removed	14.71	19.82	15.34	14.18	1.57	1.89	2.31	2.56	0.58	0.61	0.64	0.67
Sunnhemp green manuring	11.81	16.36	11.83	11.16	1.82	2.17	2.63	2.92	0.54	0.57	0.60	0.63
Fallow	15.04	20.72	15.82	14.88	1.53	1.85	2.23	2.47	0.48	0.50	0.53	0.56
SEm±	0.18	0.19	0.18	0.15	0.02	0.03	0.03	0.04	0.03	0.03	0.03	0.03
CD (P=0.05)	0.52	0.55	0.52	0.44	0.06	0.09	0.09	0.10	0.08	0.09	0.09	NS
N levels to tobacco (kg h-a⁻¹)												
90	14.77	20.96	15.81	14.76	1.47	1.71	2.11	2.34	0.58	0.61	0.65	0.69
110	13.69	18.20	13.82	12.92	1.68	2.02	2.45	2.70	0.56	0.59	0.62	0.65
130	12.92	17.11	12.93	12.05	1.78	2.20	2.64	2.90	0.55	0.58	0.60	0.63
SEm ±	0.18	0.21	0.19	0.18	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02
CD (P=0.05)	0.50	0.58	0.53	0.50	0.06	0.06	0.06	0.08	NS	NS	NS	NS
Seasons												
2001-02	14.60	19.82	15.01	13.81	1.52	1.80	2.31	2.57	0.52	0.55	0.58	0.62
2002-03	13.62	18.71	14.30	13.20	1.68	2.01	2.40	2.64	0.57	0.61	0.63	0.66
2003-04	13.15	17.74	13.24	12.73	1.73	2.12	2.50	2.73	0.61	0.63	0.66	0.69
SEm ±	0.18	0.26	0.20	0.19	0.01	0.02	0.04	0.03	0.02	0.02	0.02	0.02
CD (P=0.05)	0.61	0.89	0.68	0.66	0.05	0.07	NS	0.09	NS	NS	NS	NS
Acceptable limits	8.0 -24.0				0.7 - 3.5				<1.5			

P = Primings (first and second harvest from bottom), X = Lugs and cutters (third and fourth harvest), L = Leaf (fifth to 10th harvest) and T= Tips (11th and 12th harvest) @ two leaves per harvest.

differences in EC is not clear, it could be explained with the soil acidification, which increases total anions and cations in solution. Acidification of soil and organic matter accretion through nitrogen fixation by legumes was also reported by Yan *et al.* (1996). Spray of 4% urea on blackgram stubbles recorded 9.5% increase in status of soil available N, and 10.3% decrease in status of soil available P compared with those of fallow plots. Significantly lower available P in blackgram-tobacco system might be due to higher P uptake by blackgram owing to its high protein content thus depleting most of the symbiotically fixed N, available P and to some extent other nutrients (Przednowek *et al.*, 2004). Among nitrogen levels to tobacco, higher values of soil available N, lower values of available P and K were recorded with 130 kg N ha^{-1}. This could be due to the application of higher dose of N to tobacco in this treatment with constant level of P and K application in all treatments. As a consequence of higher N availability at 130 kg N ha^{-1}, higher leaf yield and more dry matter was produced which could have led to depletion of soil available P and K. Average pH status of soil decreased slightly and organic C, available N, P and K status of soil improved slightly as compared to initial soil test value. Differences were not discernible with regard to EC.

It was concluded that spray of 4% urea on blackgram stubbles and incorporation into the soil preceding tobacco gave higher leaf-equivalent of tobacco yield and system productivity. Nitrogen dose of 130 kg N ha^{-1} would be needed for tobacco

Table 4. *Post-harvest soil chemical parameters as influenced by blackgram stubble decomposition hastening method and nitrogen application (2003-04)*

Treatment	pH	EC (dSm^{-1})	Organic C (%)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)
Stubble decomposition method						
Application of 8.6 kg P ha^{-1}	6.10	0.21	0.28	169.7	28.5	230.5
Spray of 4% urea	6.08	0.23	0.29	171.9	26.1	227.5
Spray of cellulose degraders	6.10	0.22	0.28	171.0	26.2	229.2
Stubbles removed	6.11	0.20	0.26	166.3	25.7	228.5
Sunnhemp green manuring	6.00	0.27	0.34	179.3	32.5	237.0
Fallow	6.24	0.19	0.23	157.0	29.1	231.8
SEm±	0.04	0.01	0.01	2.73	0.78	1.77
CD (P=0.05)	0.13	0.03	0.04	8.72	2.50	NS
N levels to tobacco (kg ha^{-1})						
90	6.07	0.21	0.27	165.8	29.9	233.9
110	6.11	0.22	0.28	169.8	27.6	230.2
130	6.14	0.23	0.29	172.0	26.5	228.1
SEm ±	0.02	0.01	0.01	0.59	0.32	0.89
CD (P=0.05)	NS	NS	NS	1.86	1.02	2.79
Initial soil test value	6.30	0.21	0.22	155.0	27.0	225.0

succeeding blackgram, while 110 kg N ha^{-1} would be sufficient for tobacco succeeding sunnhemp in-situ green manuring.

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Promising Varieties of Rice for Rabi and Kharif Seasons in the Coastal Areas of India

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Due to the limitation of water in Boro/Rabi season in the coastal areas in India the farmers are not advised to grow rice. Though the situation otherwise, prevails quite congenial for it. They grow rather secondary crops, mainly vegetables requiring less water. But the profit, after meeting the exorbitant costs, is marginal and that is also at stake due to crop failure owing to heavy untimely shower in February to March, causing waterlogging for several days. The farmers may be advised to grow rice in less areas during Rabi based on the limited water in possession and keep those seeds for cultivation in the upland situation in Kharif season for better production and higher income. The upland situation in Kharif suits the short duration, semi-tall and salt tolerant varieties but the area suffers due to non-availability/non-utilization of proper varieties. The paper deals with promising salt tolerant rice varieties developed for the coastal situation both during Rabi and Kharif. The best variety in Rabi had produced a mean grain yield of over 5.0 t ha^{-1} and the same variety had also yielded highest producing 3.62 t ha^{-1} in Kharif season.

(***Key words:*** *Coastal salinity. Performance. Rice varieties. Seasons*)

Through there remains ideal situation for growing rice in the Rabi season in the coastal areas, viz. long day, profuse sunshine with clear sky, high humidity and free wind etc. but is not fulfilled due to scarcity of water for irrigation together with the building up of soil salinity progressively. The situation compels the area to adopt low water requiring alternate crops, mainly vegetables in only 8-10 percents area and keeping the rest almost fallow. However, growing those secondary crops require lot of inputs towards fertilizers, pesticides, labour and finally seeks good market. After meeting all those expenses the profit is marginal. That too is at stake as the untimely heavy showers in February-March in the recent years hamper those crops totally creating temporary water logging for grew days. Ultimately, the farmers are dragged to choose rice as the non-risk crop and manage it with the limited water kept in the ponds, canals etc. Still they suffer using unidentified varieties, which require longer period for maturity as well as face water stress and disease-pest infestation etc.

The situation demands the generation of some short duration semi-tall, salt tolerant and photoperiod insensitive varieties, which could be gown in Rabi as well as in Kharif (in the upland situation) in the coastal areas. This will help the farmers to prepare and collect their own seed cheaply and easily and at the same time utilize the situation for achieving higher production of rice. The coastal areas in the country are low-lying in general, with serious drainage congestion. The heavy rains in the Kharif season in short period of 3-4 months from June to September creates variable waterlogging, when rice crop is grown. There are about 3.5 M ha areas where water regime average is 30-50 cm and the rice yield is 0.80 MT using better agronomic and other management practices. Some improved cultures of rice are evolved by using useful donors, which after testing for several years in the coastal areas have shown overall grain yield over 4.0 t ha^{-1}. Developing soil salinity along with scarcity of irrigation water in the dry season in the coastal areas of India restricts cropping in about 8-10% areas and the remaining areas are kept fallow. On the contrary, Kharif is the principal cropping season with heavy rains, 1400-1500 mm is 3-4 months, i.e. June to September, resulting in variable water-logging, when the indigenous rices are grown in over 95% percent areas. There are about 3.5 M ha i.e. 20-25% of area in the coastal areas where a water regime of 30-40 cm prevails and the rices grown there produce again yield around 1.0 t ha^{-1}. This is poor yield is not sufficient to meet even the production costs of rice. For these situations, it requires special breeding programme for evolving suitable varieties and better management practices

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for enhancing grain yield. Siddiq (1994) emphasized on evolution of better varieties with higher genetic yield ceiling coupled with better adaptability traits for the problem soils of coastal salinity.

In this paper, the performances of some short duration, salt tolerant, photoperiod insensitive varieties/lines which could be grown both in Kharif and Rabi in the coastal areas are highlighted also the varieties/lines for semi-deep water situation are presented.

MATERIALS AND METHODS

A set of new salt tolerant and short duration varieties including two checks were selected for growing in both Rabi and Kharif seasons in the coastal saline soils at CSSRI, RRS, Canning Town. Among the seven test varieties five were developed from this Institute through hybridization of diverse parents (Table 1). The study was aimed to evaluate the reaction of the varieties in respect of plant height, ear bearing tillers, heading duration and grain yield in Rabi and Kharif seasons.

For *Rabi* season the seeds of the varieties were sown in late December and transplanted in late January every year in replicated plots with 15 x 20 cm spacing. Irrigation was given to avoid drying similarly, for Kharif season sowing was done in early July and planting was done in late July in replicated plots with same spacing. N fertilizer @ 100 kg ha^{-1} was applied in three splits as was done in case of Rabi season. Plant protection measures were taken as and when required. The soil salinity (ECe) was recorded in the field and grain yield data were collected after threshing. The seeds were dried and stored for use in the next season.

For semi-deep water situation, the varieties/lines were grown during Kharif season only. The parentage of the varieties/lines is given in Table 2.

Pankaj was the high yielding variety for the normal soils with water regime upto 20-25 cm. It was used as the ovule-Parent in all the cases. The pollen parents where the cultivated varieties of the coastal areas of West Bengal. Those were SR 26B, Najani, NC 678 and Gavir Saru, suiting to the shallow to semi-deep water very well. The test varieties on being stable along with the check varieties were grown in the seed beds in June and were transplanted in the field in the end of July in replicated plots, water regime prevailed 30 to 60 cm. N @ 40 kg ha^{-1} was applied when water regime was at the minimum. Copper sulphate @ 15-20 kg ha^{-1} was applied against algae infestation. Soil pH was around 6.0 and soil salinity (ECe) was 5.5 to 6.0 dSm^{-1}. Plant characters were recorded in the field. The crop was harvested at the end of November when the water is drained. The grain yield was recorded after threshing.

RESULTS AND DISCUSSIONS

For the short duration photo-insensitive varieties the overall plant height (Table 3&4) of the varieties was more in Rabi season than that in Kharif season invariably: minimum difference in case of varieties IR 308645, CSRC (S) 32-B-B-1-B, and CSRC (S) 36-B-B-2-B (5, 8 and 3 cm, respectively). The Rabi season may be the favourable weather condition encouraging growth. Heading during of the varieties in Kharif season ranged between 83 to 86 days with an exception of CST 7-1 (96 days) whereas the same in Rabi was increased in general, ranging of between 93 to 104 days. The varieties with delayed flowering in Rabi season were CSR 4(19), Canning 7 (19), CB 96009 (17), Pusa NR 580-6 (16), CSRC (S) 26-B-B- (12) and CSRC (S) 36-B-B-2-B (11) and 64 (18) whereas the delay was lower in case of CST 7-1 (6) and IR 30864 (7). The overall grain yield (t ha^{-1}) in *Kharif* was highest in CSRC

Table 1. *Varieties used in the experiment and their parentage*

Sl. No.	Varieties / Lines	Pedigree
1.	CST 7-1	CSRI / IR 24
2	CSR-4	IR8 Mutant
3	Canning - 7	Sec. Sel. BG 35-2
4	CB 96009	IR50 / Kundalika
5	IR 30864	Rasi / IET 6238
6	CSRC (S) 36-B-B-1-B	IR 28153-1-3-3 / IR 36
7	CSRC (S) 36-B-B-1-B	IR 10206-29-2-1 / IR 17751
8	Pusa NR 580 - 6	Check
9	IR 64	Check

Table 2. *Eight varieties developed through hybridization and four adopted varieties used in the crosses, where studied in the replicated plots*

Varities/lines	Pedigree
CSRC (D) 2-22-6	Pankaj x NC 678
CSRC (D) 2-7-8	Pankaj x NC 678
CSRC (D) 7-5-4	Pankaj x SR 26B
CSRC (D) 13-9-1	Pankaj x Gavir Saru
CSRC (D) 12-8-12	Pankaj x Najani
CSRC (D) 2-17-5	Pankaj x NC 678
CSRC (D) 7-0-4	SR 26 B x Pankaj
CSRC (D) 13-16-9	Pankaj x Gavir Saru
SR 26B	Check
Najani	Check
NC 678	Check
Gavir Saru	Check

(S) 32-B-B-1 (3.62), followed by CST 7-1 (3.46). The check varieties Pusa NR 580-6 (2.90) and IR 64 (3.00) yielded moderately. In general the grain yield during the Rabi season was higher than that in *Kharif*. The overall grain yield (t ha^{-1}) during the *Rabi* season was highest in CSRC (S) 32-B-B-1-B (5.23), followed by CSRC (S) 36-B-B-2-B (5.09) and Canning 7 (4.97). The variety CST 7-1 yielded the lowest (3.82) and appeared to be unbefitting for growing during the Rabi season. The varieties taking longer heading duration in Rabi had expressed higher overall grain yield, in comparison with that of *Kharif* season. The variety CSR 4 produced the overall grain yield increase of 57.7% over *kharif*, similarly Canning 7 (59.8), CB 96009 (63.3) and IR 30864 (83.4%) and the check varieties Pusa NR 589-6 (73.9) and IR 64 (29.6%). The variety CST 7-1 with minimum delayed flowering in *Rabi* (6 days) also had minimum increase of grain yield in *Rabi* (22.8%). Hence, it will be proper to delete it from the *Rabi* group.

Mandal (1999) had reported some salt tolerant and short duration rice varieties suitable for growing in Rabi in the coastal areas of West Bengal, where IR 30864 produced highest mean grain yield (4.24 t ha^{-1}) followed by other varieties. Considering peculiar situation in the coastal areas during Rabi season and upland situation in *Kharif* season salt tolerant and short duration varieties of rice are mostly required for achieving higher grain yield. Siddiq (1992) emphasized for evolving better varieties with higher genetic yield ceiling for the constrained areas of the country. Siddiq (1994) has also opined that, in spite of all odds; the breeders have been successful to an extent in evolving higher yielding varieties for coastal saline soils through various means. Muralidharan *et al.*, (1996) observed that introduction of short stature, non-lodging rice varieties in the mid sixties led to green revolution. But that did not make a dent in the coastal area in a big way, so far. Venkatswarlu, (1992) had assessed an area of 5.8 M ha^{-1} shallow low lands existing mostly in the coastal areas of which about 25–30% area belong to the upland situation in Kharif season, where the present grain yield of 1.0-1.5 t ha^{-1} could very well be enhanced by use of the present varieties. Growing rice in the Rabi season is restricted due to lack of irrigation water; as such fewer areas with secured irrigation could give a higher production with the use of these improved varieties.

High precipitation in the wet season creates serious problems of waterlogging though easing out soil salinity problem to a great extent. As such more than 80% of the cultivated lands remain submerged of varying depths and duration of the crop growth period and as a result suffer yield loss. About half of the lands are highly constrained shared almost equally by semi-deep and deep water.

The performances of the rice varieties along with the check varieties are presented in the Table 5. It is observed that the maximum grain yield (t ha^{-1}) was produced by CSRC (D) 7-0-4 (3.79) with a heading duration 133 days, followed by 12-8-12 (3.65) with a lower heading duration of 129 days and CSRC (D) 2-22-6 (3.61) with heading duration 135 days. The check varieties SR 26B (2.43), NC 678 (2.44) and Najani (2.57) had produced almost similar grain yield but Gavir Saru (2.26) had a low gain yield but all the varieties had a comparable heading duration ranging between 127 to 132 days. Pankaj is a high yielding variety for the normal soils but does not perform well in high soil salinity or in high water regime. In fact, the tillers are affected over 25 cm water regime. Again the varieties used as the pollen parents are mostly grown in semi-deep and deep areas along the coastal belts. Similarly SR 26B is a variety suitable for the shallow low lands in the coastal areas, having potentiality to tolerate moderate soil salinity and semi-deep water. Gavir Saru is a variety for deep water in the coastal areas having small grains with some aroma. The objective behind the generation of the varieties by incorporating the high yield potential of Pankaj with

Table 3. *Performances of the short duration salt tolerant rice varieties in Kharif in the coastal area at Canning 2004-2006 & 2010*

Sl. No.	Varieties	Cross	IET No.	Grain Yield (t ha^{-1})				Mean over years		
				2004	2005	2006	2010	Plant ht (cm)	Heading (days)	Grain Yield (t ha^{-1})
1	CST 7-1	CSRI / IR 24	9341	4.23	2.97	3.17	2.07	75	96	3.11
2	CSR 4	IR 8 MUTANT	4098	3.07	3.04	3.27	3.01	82	85	3.10
3	Canning 7	Sec. Sel. BG 35-2	11697	3.02	3.03	3.74	2.65	79	84	3.11
4	CB 96009	IR 50 / Kundalika	16065	2.87	2.78	3.36	-	78	84	3.00
5	IR 30864	RASI / IET 6238	10356	3.03	3.20	3.26	1.09	91	86	2.65
6	CSRC(S) 32-B-B-1-B	IR 28153-1-3-3 / IR 36	16347	3.21	3.21	4.44	3.08	91	84	3.49
7	CSRC(S) 36-B-B-2-B	IR10206-29-1 / IR 17751	-	3.85	3.01	3.31	2.87	89	86	3.26
8	Pusa NR 580-6	Check	-	2.70	2.89	3.12	2.17	77	83	2.72
9	IR 64	Check	-	2.90	3.12	3.00	-	82	86	3.01
		CD at P=0.05	-	0.22	0.28	0.25	-	-	-	-

Table 4. *Performances of the short duration salt tolerant rice varieties in Rabi in the Coastal area at Canning 2005-2007 & 2009-2010.*

Sl.No.	Varieties	Grain Yield (t ha^{-1})					Mean over years				
		2005	2006	2007	2009	2010	Plant Height (Cm)	Heading duration	(%) days delayed over *Kharif*	Grain Yield (t ha^{-1})	(%) more yield over *Kharif*
1	CST 7-1	3.98	3.15	4.32	-	-	88	102	6.3	3.82	22.8
2	CSR 4	4.17	3.56	6.22	5.06	5.44	97	104	22.4	4.89	57.7
3	Canning 7	3.82	3.85	6.58	4.62	5.98	93	103	22.6	4.97	59.8
4	CB 96009	4.19	4.31	6.21	-	-	97	101	20.2	4.90	63.3
5	IR 30864	3.91	3.41	5.42	5.93	5.63	96	93	8.2	4.86	83.4
6	CSRC (S) 32-B-B-1-B	5.25	4.84	6.32	5.31	4.44	99	96	14.3	5.23	49.8
7	CSRC (S) 36-B-B-2-B	5.08	4.48	6.30	4.69	4.91	92	97	12.8	5.09	56.1
8	Pusa NR 580-6	2.87	3.16	5.72	5.52	6.39	90	99	13.3	4.73	73.9
9	IR 64	4.53	3.26	-	-	-	97	104	20.9	3.90	29.6
	CD at P = 0.05	0.20	0.18	0.15	-	-	-	-	-	-	

Table 5. Performances of the rice varieties under coastal semi-deep water (30-50 cm) situation Kharif 2004-2006 & 2009-2011

Sl. No.	Varieties / Lines	Cross	Grain Yield (t ha^{-1})						Mean over years			
			2004	2005	2006	2009	2010	2011	Plant ht (cm)	EBT	Heading	Grain Yield (t ha^{-1})
1	CSRC (D) 2-22-6	Pankaj x NC 678	3.71	3.93	3.18	-	-	-	147	7.0	135	3.61
2	CSRC (D) 2-7-8	Pankaj x NC 678	4.75	3.84	3.26	2.74	1.92	-	160	5.9	133	3.30
3	CSRC (D) 7-5-4	Pankaj x SR 26B	3.63	3.89	3.91	2.71	1.99	3.42	152	6.3	129	3.26
4	CSRC (D) 13-9-1	Pankaj x Gavir Saru	3.41	3.49	4.03	2.99	2.33	-	141	7.5	131	3.25
5	CSRC (D) 12-8-12	Pankaj x Najani	4.55	3.88	4.14	3.44	2.24	3.63	145	6.2	129	3.65
6	CSRC (D) 2-17-5	Pankaj x NC 678	-	-	-	3.31	1.99	3.88	173	5.7	133	3.06
7	CSRC (D) 7-0-4	SR 26 Bx Pankaj	4.79	4.18	4.37	3.27	2.26	3.58	159	6.7	133	3.74
8	CSRC (D) 13-16-9	Pankaj x Gavir Saru	-	-	-	2.99	2.33	3.56	169	7.7	133	2.96
9	SR 26B	Check	2.52	2.72	2.73	2.63	1.97	2.04	146	7.0	129	2.43
10	Najani	Check	2.34	2.52	2.89	2.92	1.72	3.04	153	6.8	130	2.57
11	NC 678	Check	2.56	2.78	2.44	3.04	1.16	2.69	151	7.0	127	2.44
12	Gavir Saru	Check	2.41	2.31	2.22	2.07	1.88	2.68	147	6.6	132	2.26
	CD at P = 0.05	0.28	0.25		0.22	-	-	-	-	-	0.25	

the adaptability traits of the local varieties, appear to be quite fulfilled. The yield obtained over 3.50 t ha^{-1} was quite superior in the backdrop of high water regime. Higher water regimes create problems of algal infestation affecting the growth and survival parameters of the standing rice crop seriously, which the improved varieties do not tolerate. But the adaptability traits inherited in the newly bred varieties can survive the situation well. Mandal (1994) had reported a number of promising rice varieties suitable for the coastal semi-deep water in India. Again Mandal (1996) had highlighted an elite variety CSRC (S) 11-5-0-5 given popular name as "UTPALA", developed from the cross of Pankaj and Jhingasal, suiting to the intermediate rice lands with a water regime over 30 cm. Mandal (2007) had reported the performances of a shuttle bred variety IR 16294 CS 9-1-30 in the coastal low lands having performed well consistently. Venkatswarlu (1992) had assessed 3.5 M ha of semi-deep water (30-50 cm) in the coastal areas of India having a general grain yield of 0.8-1.2 t ha^{-1}. If the newly evolved varieties are grown, the productivity would surely be enhanced. Mangala Rai (2004) had endorsed the assessment of coastal lands made by Venkatswarlu and emphasized for enhancing production and productivity of rice in the constrained land in the coastal India by evolving better varieties and using proper management practices. Siddiq (1994) had emphasized for improving genetic yield ceiling of rice for the problem soils of the coasts. The elite varieties are expected to be quite helpful to the farmers of the coastal areas with higher water regimes.

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Influence of Seed Size on Seed Germination and SeedlingVigour in *Calophyllum inophyllum*: an Important Multipurpose Tree of Coastal Region

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The effect of seed size (small, medium and large) on germination, early seedling vigour and biomass was studied in *Calophyllum inophyllum*, an important timber and bio-fuel yielding tree species of the coastal region of India. Seeds were collected from different trees near the coast of Kumta of Uttara Kannada district, Karnataka. The trial was undertaken at College of Forestry, Sirsi, Karnataka. The entire seed lot was categorized into three different classes viz., small (< 1 cm diameter), medium (1-3 cm diameter) and large (>3 cm diameter) based on seed size. Regular observation on daily seed germination, seedling growth and dry biomass was recorded. Results showed that bigger sized seeds produced quick, uniform and maximum germination than those of medium and small sized seeds. Similarly, maximum seedling vigour and dry biomass was recorded by bigger seeds as compared to those of medium and small. Seed size showed a positive relationship with seedling vigour characteristics. It is revealed that the grading of seeds before sowing is an essential step to improve the quality of nursery stock of this species. Finally, it is recommended to use bigger sized seeds of *C. inophyllum* to get uniform and higher seed germination as well as more seedling vigour.

(**Key words:** *Calophyllum inophyllum, Bio-fuel, Seed size, Seedling vigour*)

Calophyllum inophyllum (Family: Clusiaceae) is a moderate sized evergreen tree species popularly called as *Wundi*. Species is mostly distributed in the coastal regions of south India, Andaman Islands, Burma and Sri Lanka (Anon, 1989). C. inophyllum is one of the multipurpose trees grown for ornamental purpose due to its fragrant white flowers, especially in south India. Kernels yield about 50 to 73 percent of dark green viscous oil known as poonseed oil, which is also used by soap industries. The wood is reddish-brown, moderately heavy, interlocked grained, medium textured and durable under sea-water. Hence, wood of this species is most suited for ship building and fishing boats (Anon, 1989). Recently, this species is considered as one of the bio-fuel yielding species, where crude oil extracted from the seed kernel can be used as bio-diesel. Hence, there is great demand for seeds of this species. At present, seeds are being collected from the natural source. However, efforts are being made to raise plantations in commercial scale that needs quality seedlings in large quantity. Understanding seed germination behavior of the species is very essential for planning of quality nursery stock for large scale plantation programme. Hence, the present study was undertaken to know the influence of seed size on germination and seedling vigour in *Calophyllum inophyllum*.

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MATERIAL AND METHODS

The study was conducted in the department of Forest Biology, College of Forestry, Sirsi, Karnataka. Matured fruits were collected from trees near sea-coast of Kumta, Uttara Kannada district of Karnataka during June 2007. Immediately after collection, fruits were soaked in water for 72 hr and then de-pulped. These healthy seeds were grouped into three different classes viz., small (< 1 cm diameter), medium (1-3 cm) and large (> 3 cm) based on the seed diameter. Seeds of different seed classes were exposed to mechanical treatment i.e., cracking of seed-coat by hammer. These cracked seeds were sown on germination tray filled with sterilized sand medium with six replications of 100 seeds each, following randomized block design (RBD) under poly-tunnel. Regular watering was done as per the requirement. Daily observation on germination count was made up to 21 days from the date of sowing. After one month of sowing, seedlings from different treatments were transplanted to nursery bags of size 8'x12' containing potting mixture of soil, sand and FYM in the ratio of 1:1:½. Seedling growth parameters such as plant height, collar diameter and number of leaves were recorded at monthly interval up to six months period. Destructive samples of five seedlings each from six replications were pricked out randomly from all the three

Table 1. *Influence of seed size on seed germination and seedling vigour in Calophyllum inophyllum*

Seed size classes	Seed germination (%)	Seedling height (cm)	Root length (cm) (mm)	Collar diameter	No. of Leaves
Small	79.0 (62.73b)	14.91c	14.87b	2.71b	4.50 b
Medium	83.0 (65.90b)	17.20b	15.66b	2.83b	5.00 b
Big	95.0 (78.00a)	20.83a	17.96a	3.06a	5.88 a
Mean	85.8 (68.87)	17.65	16.16	2.87	5.13
CD at 5%	10.46	1.48	1.87	0.17	0.75
CV (%)	3.32	11.60	15.98	8.21	20.31

Note: Figures in the parenthesis are arc-sine transformed values

treatment for recording dry biomass after 6 months of transplanting. Observation on fresh weight of shoot, leaves and root was recorded using electronic balance. Dry weight of these samples were kept under hot air oven at 50° C for 72 hrs until samples show constant values. Date was subjected to statistical analysis using a statistic package, mSTAT-C and analysis of variance has been created. A simple correlation analysis was done to know the influence of association of seed size on germination, seedling growth and dry biomass, if any using the same statistical package.

RESULTS AND DISCUSSION

There are several studies that demonstrating intra-specific variation in seed size with respect to their fitness in tropical trees. Murali (1997) reported that the influence of seed size on seed germination and seedling vigour is species specific and controlled by internal and external factors. In this study, a significant variation among three different seed size classes viz. small, medium and large for seed germination, seedling growth and dry biomass of seedlings were recorded (Table 1 and 2). Larger sized seeds showed quicker as well as higher seed germination of 95 per cent, followed by medium (83%) and small (79%). This could be due to the presence of higher amount of carbohydrates and

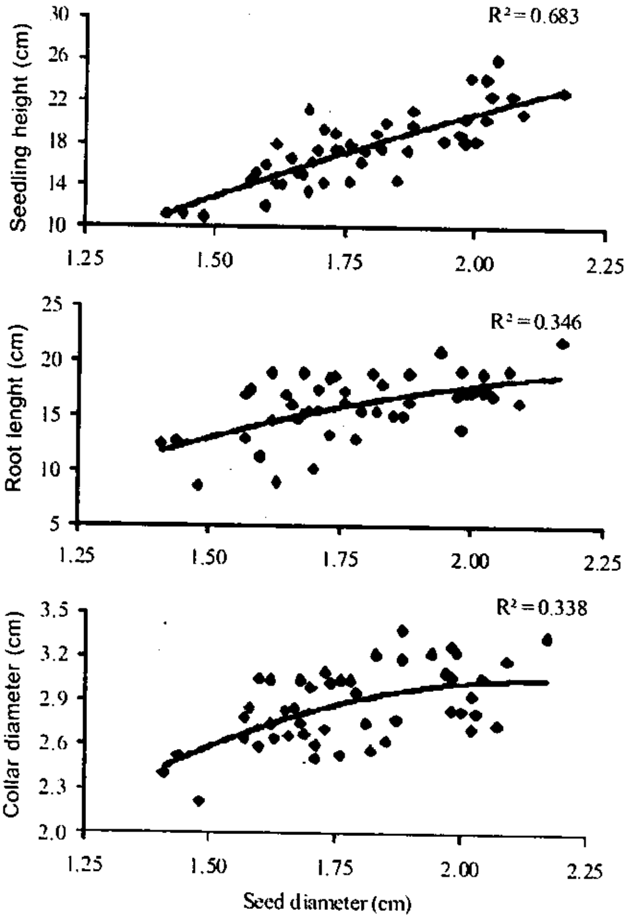

Fig. 1. Influence of seed size on seedling growth parameter (n=48)

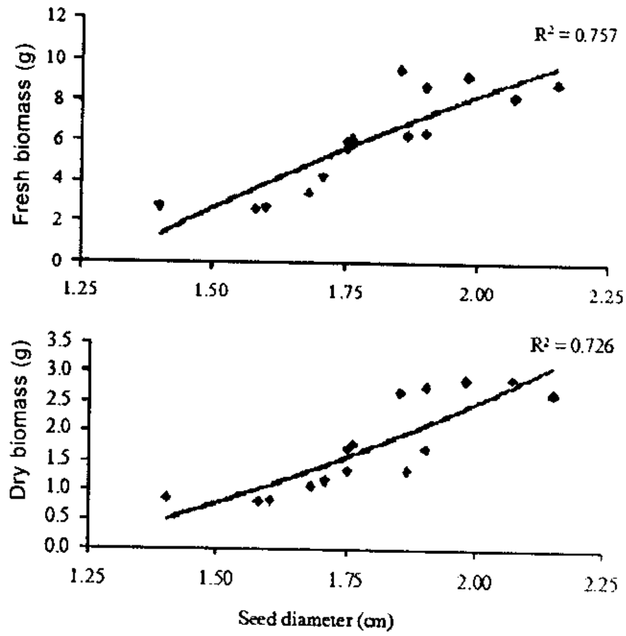

Fig. 1. Influence of seed size on fresh and dry biomass of seedling (n = 15)

***Table 2.** Influence of seed size on seedling biomass in Calophyllum inophyllum*

Seed size classes	Dry weight (g)				
	Shoot	Leaves	Root	Cotyledon	Total seedling
Small	0.13c	0.16b	0.05c	0.59b	0.94c
Medium	0.24b	0.39a	0.12b	0.67b	1.42b
Large	0.29a	0.48a	0.19a	1.75a	2.71a
Mean	0.22	0.35	0.12	1.00	1.69
CD at 5%	0.046	0.092	0.015	0.342	0.292
CV (%)	14.47	17.73	10.68	23.47	11.91

***Table 3.** Association among seed size with seedling growth and biomass characteristics*

Sl. No.	Parameters	1	2	3	4	5	6	7	8	10	11
1	Seed size	-									
2	Seedling height	0.728	-								
3	Root length	0.695	0.470	-							
4	Collar diameter	0.590	0.572	0.466	-						
5	No. of leaves	0.587	0.641	0.572	NS	-					
	Fresh weight of										
6	Shoot	0.809	0.603	0.571	0.455	0.538	-				
7	Leaves	0.893	0.682	0.656	0.590	0.598	0.923	-			
8	Root	0.886	0.737	0.584	0.476	0.627	0.940	0.909	-		
	Dry weight of										
10	Shoot	NS	NS	-0.328	0.321	NS	NS	NS	NS	-	
11	Leaves	0.762	0.656	0.505	0.327	0.619	0.955	0.892	0.935	NS	-
12	Root	0.894	0.747	0.561	0.502	0.595	0.932	0.929	0.974	NS	0.942

NS = Non Significant

other nutrients in the larger seeds. Such trend is also reported in many tropical species. For instance, Seth (1956) and Anmol Kumar (1979) have recorded higher seed germination and germination value in bigger sized teak seeds. Pathak *et al.*, (1974) also reported similar observation on *Leucaena leucocephala*, Manonmani *et al.*, (1996) on *Pongamia pinnata* and Mandal *et al.*, (1997) on *Artocarpus heterophyllus* and Negi and Todaria (1997) on some multipurpose tree species. In contrast, Dar *et al.* (2002) reported that medium and small sized seeds produced higher seed germination in some of the multipurpose tree species at Jammu region. However, Malavasi and Malavasi (1996) and Agboola (1996) reported non-influence of seed size on seed germination and seedling vigour on few tropical species.

Seedling growth characteristics such as seedling height, collar diameter, number of leaves and root length were found to be significant among three seed size classes. Bigger sized seeds showed higher seedling vigour (Table 1) than those of medium and smaller. The similar trend was also recorded for fresh and dry weight of shoot, leaves and root (Table 2). The biomass production (total seedling dry weight) was found to be highest in the bigger sized seeds (2.71 g plant^{-1}), followed by medium (1.42 g plant^{-1}) and it was the least in small sized seeds (0.94 g plant^{-1}).

In this study, a strong association was recorded among seed size with seedling growth traits like plant height (r=0.728), root length (r=0.696), collar diameter (r=0.590, number of leaves (r=0.587; Table 3 and Fig. 1) as well as seedling biomass traits like dry weight of leaf (r=0.762) and root (r=0.894; Fig. 2). Such trend is also reported in *Leucaena leucocephala* (Ponnammal *et al.*, 1993), *Acacia tortilis* (Pathak *et. al.*, 1974) and *Vateria indica* (Gunaga *et al.*, 2007). Hence, seed grading is very essential for this species. Further, it is suggested to use bigger sized seeds (more than one centimeter in diameter) to obtain higher and uniformity seed germination and better seedling quality in *Calophyllum inophyllum*.

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Genetic Analysis in Very Early Rice under Two Culture Systems in the Coastal Region of Cauvery Delta Zone

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A study was conducted with thirty early genotypes under two sets culture systems i.e., direct wet seeding and transplanting to understand the influence of culture systems on the genetic parameters. The grain yield hill^{-1}, grains panicle^{-1}, dry matter production and panicle weight exhibited high genetic variability in conjunction with high heritability and genetic advance in both the systems. But the characters, days to maturity, panicle length, spikelet fertility and harvest index showed fluctuating values for the above parameters among the two culture systems. Based on strength of observation, genotypic correlation and magnitude of direct effect, it was suggested that dry matter production and harvest index are the selection indices for yield improvement in direct seeded rice, whereas dry matter production alone needs to be considered as selection parameter for transplanted rice. The methods of cultivation greatly influenced the direction and magnitude of correlations of the other characters in the study. Separate breeding programme are required for each culture system.

(**Key words:** *Rice, Very early, Culture systems, Variability, Correlation, Path analysis*)

In the absence of varieties developed exclusively for wet seeding, the farmers use the varieties developed for transplanting. Differential response of varieties under direct wet seeded and transplanted conditions has been brought about by agronomists (Balasubramanian and Hill, 2000). Rice (*Oryza sativa* L.) is the main crop grown in the coastal region of Cauvery delta zone in the states of Tamil Nadu and Puducherry. Cultivation of very early rice of less than 100 days duration is best suited for the first rice growing season of this region called kuruvai. Transplanting is the traditional method of rice culture in this area. But this cultivation is highly labour intensive as it involves raising of nursery and planting and thus, costly. Besides, labour scarcity also adds to the problem. Therefore, there is a general tendency among the farmers to shift from transplanting to direct seeding. Direct seeding in irrigated/puddled condition, commonly known as wet or puddled seeding is a best substitute for transplanting.

This type of direct seeded culture is cheaper as the requirement of labour is considerably reduced. The growth and yield of rice are modified to a greater extent by agronomic practices. But breeding work in this aspect is meager. An attempt was made in the present study to analyze the effect of these two culture methods on the genetic expression of different traits in rice and to ascertain the need for separate breeding programme for the two agronomic practices.

MATERIALS AND METHODS

Thirty diverse very early rice genotypes consisting of varieties and breeding lines were grown in randomized block design with three replications separately under direct seeding and transplanting methods in the same field. For direct wet seeding, the dry seeds were dibbled in the puddled condition in lines at the rate of five seeds per hill. On seventh day, the seedlings were thinned to three seedlings per hill. For transplanting, the dry seeds were sown on the raised bed on the same day of puddled seeding and normal nursery practices were followed. Twenty days old seedlings were transplanted in the main field at the rate of three seedlings per hill. Other crop management practices adopted in both the culture systems were similar. In both culture systems, the spacing followed was 30 x 10 cm and each genotype was raised in five rows of one meter length each. Observations were recorded on five randomly selected hills per replication from each genotype in each of the two culture methods for days to flowering, days to maturity, plant height, panicles hill^{-1}, panicle length, panicle weight, spikelet fertility, grains panicle^{-1}, 100 grain weight, dry matter production, harvest index and grain yield hill^{-1}. The data were subjected to analysis of variance, genetic variability, heritability, genetic advance, genotypic correlation and path analysis as per the standard procedures described by Singh and Chaudhary (1977).

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Table 1. *Pooled analysis of variance over culture systems for twelve traits in very early rice*

Source	df	Mean squares											
		Days to flowering	Days to maturity	Plant height	Panicles per hill	Panicle length	Panicle weight	Spikelet fertility	Grains per panicle	100 Grain weight	Dry matter production	Harvest Index	Grain yield per hill
Genotype	29	163.89**	139.79**	701.96**	5.90**	14.29**	0.52**	0.01**	980.03**	0.22**	47.18**	0.01**	11.81**
Culture systems	1	1798.68**	1792.37**	144.62**	50.35**	25.10**	1.87**	0.00	810.06**	0.05**	1271.30**	0.02**	4.07**
Genotype x Culture systems	29	23.29**	8.43**	70.13**	5.45**	2.70	0.17**	0.01**	215.25**	0.00	22.96**	0.01**	7.92**
Error (Pooled)	116	1.01	1.92	4.03	0.91	1.82	0.04	0.00	16.06	0.00	0.66	0.00	0.33

Table 2. *Mean and genetic parameters for different traits under two culture systems*

Character	Mean		GCV (%)		h^2 (%)		GA (%)	
	DS	TP	DS	TP	DS	TP	DS	TP
Days to flowering	64.67	70.32	9.87	6.43	96.35	97.68	19.98	13.11
Days to maturity	90.38	96.48	4.78	5.04	89.99	94.77	9.35	10.12
Plant height (cm)	94.23	92.44	13.16	10.86	96.51	97.55	26.66	22.12
Panicles per hill	9.68	8.63	12.94	14.60	62.39	64.39	21.08	24.15
Panicle length (cm)	20.45	19.70	8.43	6.15	55.76	53.36	12.98	9.27
Panicle weight (g)	1.79	1.58	18.08	19.45	65.49	69.12	30.17	33.35
Spikelet fertility (%)	0.80	0.79	5.81	6.59	80.68	82.55	10.00	12.35
Grains per panicle	72.70	62.36	21.67	18.93	93.96	89.59	43.31	36.96
100 grain weight (g)	2.35	2.32	7.88	8.47	93.39	88.96	15.71	16.47
Dry matter production (g)	19.83	14.52	18.65	20.93	97.08	90.95	37.89	41.17
Harvest index	0.36	0.38	15.08	8.53	73.84	57.11	26.73	13.30
Grain yield per hill (g)	8.48	8.18	22.58	20.10	88.53	93.06	43.82	39.78

DS - Direct seeding TP - Transplanting

Table 3. *Genotypic correlation and direct (diagonal) and indirect effects of component traits on grain yield under two culture systems*

Characters	Culture system	Days to flowering	Days to maturity	Plant height	Panicles hill⁻¹	Panicles length	Panicle weight	Spikelet fertility	Grains panicle⁻¹	100 Grain weight	Dry matter production	Harvest index	rg with grain yield
Days to flowering	DS	0.011	0.020	-0.001	-0.017	-0.058	-0.112	0.009	0.014	0.021	0.311	0.096	0.294
	TP	-0.064	-0.028	0.002	0.002	-0.054	0.046	-0.014	-0.040	0.030	0.474	0.144	0.476**
Days to maturity	DS	0.005	0.041	0.053	-0.081	-0.012	0.045	0.004	-0.001	0.010	-0.131	0.022	-0.043
	TP	-0.023	-0.081	0.072	0.010	0.003	-0.132	-0.043	0.044	0.056	0.288	0.113	0.306
Plant height	DS	0.000	-0.012	-0.183	0.102	-0.023	-0.050	-0.002	0.007	0.011	0.325	-0.303	-0.128
	TP	0.000	0.021	-0.283	0.000	-0.077	0.207	0.019	-0.085	0.014	0.334	-0.053	0.097
Panicles per hill	DS	0.001	0.015	0.085	-0.220	0.028	0.069	0.001	-0.010	0.005	-0.029	0.247	0.191
	TP	0.003	0.018	-0.001	-0.046	0.090	-0.127	-0.010	0.122	-0.070	-0.132	-0.016	-0.170
Panicle length	DS	0.009	0.007	-0.057	0.083	-0.074	-0.153	0.002	0.020	0.019	0.192	0.173	0.224
	TP	-0.023	0.001	-0.143	0.027	-0.152	0.207	0.032	-0.150	0.010	0.439	0.045	0.383*
Panicle weight	DS	0.005	-0.008	-0.040	0.066	-0.049	-0.231	0.002	0.025	-0.001	0.467	0.279	0.516**
	TP	-0.009	0.032	-0.175	0.017	-0.094	0.335	0.045	-0.191	0.015	0.012	-0.070	-0.082
Spikelet fertility	DS	-0.003	-0.006	-0.010	0.007	0.005	0.015	-0.030	0.003	0.002	-0.146	0.117	-0.047
	TP	0.005	0.022	-0.034	0.003	-0.030	0.093	0.162	-0.106	-0.017	-0.225	-0.081	-0.209
Grains per panicle	DS	0.005	-0.001	-0.043	0.077	-0.053	-0.202	-0.003	0.028	0.021	0.361	0.036	0.226
	TP	-0.010	0.013	-0.090	0.021	-0.085	0.239	0.064	-0.268	0.078	0.072	-0.036	-0.001
100 Grain weight	DS	-0.004	-0.007	0.033	0.017	0.024	-0.005	0.001	-0.010	-0.060	0.039	0.094	0.123
	TP	0.009	0.021	0.019	-0.015	0.071	-0.024	0.013	0.097	-0.214	-0.241	-0.068	-0.331
Dry matter production	DS	0.004	-0.006	-0.061	0.007	-0.015	-0.110	0.005	0.010	-0.002	0.977	-0.131	0.778**
	TP	-0.029	-0.022	-0.090	0.006	-0.064	0.004	-0.035	-0.018	0.049	1.048	0.049	0.897**
Harvest index	DS	0.001	0.001	0.059	-0.058	-0.014	-0.069	-0.004	0.001	-0.006	-0.241	0.937	0.608**
	TP	-0.027	-0.026	-0.143	0.002	-0.019	-0.068	-0.038	0.028	0.042	0.348	0.246	0.430**

DS – Direct seeding TP – Transplanting * Significant at 1% ** Significant at 5% rg- Genotypic correlation

RESULTS AND DISCUSSION

The two culture systems showed significant difference for all the traits except spikelet fertility and interaction of genotypes with culture systems was also significant for all the traits except panicle length and 100 grain weight (Table 1). The presence of strong genotype x system interaction for grain yield and its component traits suggested that it is necessary to test and choose different varieties for each system. More number of panicles hill^{-1} with longer panicle, higher panicle weight, more number of grains panicle^{-1} and increased grain weight apparently contributed for higher grain yield in direct seeding than in transplanting (Table 2). Direct seeded rice produced taller plants with higher dry matter production than transplanted rice, while harvest index was high under transplanting. Plants flowered and matured a week early in direct seeding which may be due to the absence of planting shock in this culture system as observed by Balasubramanian and Hill (2000).

High genetic variability in terms of genotypic coefficient of variation (GCV), heritability (h2) and genetic advance (GA) was observed for grain yield hill^{-1}, grains panicle^{-1}, panicle weight and dry matter production in both the culture systems, indicating improvement of these traits effectively through a simple phenotypic selection in very early rice irrespective of the methods of cultivation. Shanmugavalli *et al.*, (1999) also reported similar results for these traits in very early rice. The traits, days to maturity, panicle length, spikelet fertility and harvest index showed fluctuating values for these three genetic parameters among direct seeding and transplanting, the maximum fluctuation was observed for harvest index. This showed that the culture systems had significant influence on the expression of genetic potentiality of characters. In general, direct seeding provided a better environment than transplanting for good expression of characters, particularly harvest index.

Results on genotypic correlation and path analysis indicated that the strength and direction of correlations and direct effects of component traits on grain yield fluctuate among the culture systems (Table 3). Dry matter production and harvest index are identified as the selection indices for improvement of grain yield in direct seeded very early rice as these two component traits showed more or less equal and strong positive correlations as well as high positive direct effects on grain yield under this culture system. Whereas, for very early rice grown under transplanting the dry matter production alone is considered as the single most yield contributing trait as this trait alone recorded strong positive correlation in combination with high positive direct effect with grain yield. Such a difference in selection parameter was noted among two cropping systems viz., sole crop and intercrop in soybean by Sood and Sood (2001). Other than dry matter production, all the remaining component traits studied showed great difference among the two culture systems in the magnitude and direction of their correlations, direct effects and indirect effects with grain yield, indicating high influence of culture systems on the expression of characters.

High positive genotypic correlation between two culture systems for dry matter production, days to maturity and plant height indicated that there is no need for adopting separate breeding programme to improve these traits. All the other traits including grain yield showed insignificant correlation coefficients among the culture systems. These traits also recorded significant genotype x culture system interaction (Table 1). Under such circumstances separate breeding programme are required to be adopted to improve yield and its components for each culture system. Sood and Sood (2001) also reported such a requirement of separate breeding programme for mono and intercropping in soybean. It is thus justified from the present study that separate breeding programme are essential for direct wet seeding and transplanting rice culture systems.

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Performance Evaluation of Jute Fibre Based Pads in Evaporatively Cooled Storage Structure

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Jute, the golden fibre, has the pride of place in Indian agriculture sector providing livelihood to millions of families. Apart from the use of jute for packaging material such as sacking, hessian, carpet backing etc., it finds versatile applications ranging from geotextiles to high value diversified products like upholstery furnishings, decoratives, carpets, apparels, handicrafts, fancy items, non-woven and composites. To investigate into the evaporative cooling effect of jute fiber based non-woven pads, its performance was studied in an evaporatively cooled storage structure designed and developed at Central Institute of Post Harvest Engineering and Technology, Ludhiana. The result shows that, jute-fibre based cooling pads has substantially lower down the temperature (upto 14°C), but increase in relative humidity of the ambient air was low (maximum upto 19 %). As evapo-transpiration and respiration are the main causes of weight loss in fruits and vegetables, the effect can be minimized by increasing the relative humidity and reducing the temperature of the storage environment. Evaporative cooling structures with jute-fibre based cooling pads could maintain longer shelf lives and freshness of these commodities than those under ambient conditions.

(**Key words:** *Evaporation, Cooling pad, Humidity, Temperature, Storage*)

Evaporative cooling is generally accepted to be an adiabatic humidification process (Abdalla *et al.*, 1995). This process takes place when unsaturated air is brought into contact with a free water surface in the absence of other sources of heat. Water evaporates into the air stream resulting in a drop in the air dry bulb temperature due to sensible heat removal while the humidity and latent heat content of the air increases. Evaporative cooled (EC) storage structures can be utilized in places where the fresh perishable commodities are readily spoiled by high temperature and low relative humidity. It is not a competitor of the refrigerated storages and the quality of the produce stored in the EC chamber should not be compared with that in refrigerated storages. In the EC structures, we cannot maintain a temperature, which is optimum for storage of any particular commodity; rather, we try to take the maximum advantage of the natural environment by manipulating the ambient air and bringing down the temperature to a considerable low level. EC system consists of a pad (moist material), storage cabin, and an air pump (fan or natural breeze). The pad is the most important component of the system as temperature and humidity changes takes place there (Dzivama *et al.*, 1999). A good pad material should be porous enough to allow free flow of air to effect evaporation. It should be locally available and inexpensive and should easily be constructed into the required shape. Keeping in view of the above, jute fibre based cooling pads were prepared and tested in an evaporatively cooled storage structure designed and developed at CIPHET, Ludhiana (Fig. 1).

MATERIALS AND METHODS

Sample Preparation

Jute woven and non-woven fabric of different area density (gsm) were procured from M/S Gloster Jute Mills Ltd. Kolkata. Both for woven and non-woven fabric, the area density were chosen at 200, 400 and 600 gsm. Samples of the dimension of 0.304 m x 0.304 m square size were cut from the original samples for studies on surface evaporation properties.

Surface evaporation of water

The weight of jute woven and non-woven pads of each specification was taken using a digital balance and they were dipped in potable water in a plastic tub till the constant weight of pad after removing free water. The time of maximum amount of absorption was estimated initially trough-primary

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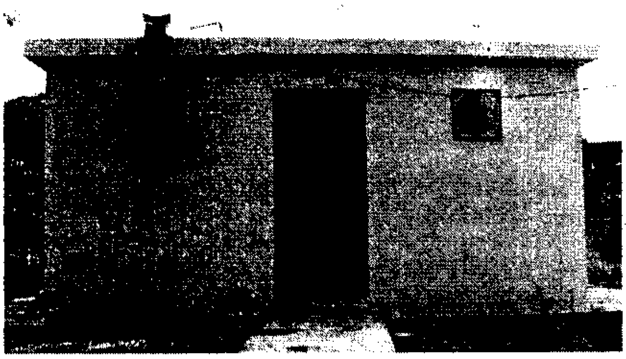

Fig. 1. Evaporatively cooled storage structure (ECS)

trial in absorption studies. Weight of the completely soaked pad after removing free water was taken and the samples were hanged vertical across the wind direction. Temperature and Relative humidity of the experimental place were measured using a digital thermo-hygrometer. The temperature of potable water during dipping of the sample was also recorded. The weight of the drying pad was recorded at one minute interval of time till it reached to almost constant weight. Reduction of weight of the pad was computed using the following equation and taken as surface evaporation of water (Es, g min^{-1}) from the cooling pad (Jha and Kudos, 2006).

$$Es = (Ww - Wd) / t$$

Where, Ww and Wd are the initial weight of wet pad and weight of dried pad in grams in time t, min. All the experiments were replicated thrice and the mean values are reported.

Installation of the cooling pads

From the surface evaporation studies, the rate of evaporation of moisture for non-woven samples was found higher than the corresponding woven samples of a particular gsm. Though the change is not uniform in the case of woven samples, non-woven samples shows an increase in evaporation rate with increase in area density (gsm). The highest rate was observed in the case of 600 gsm. Accordingly, based on evaporation rate, 600 gsm non-woven samples were chosen for mounting into the evaporative cooled storage structure for studies on cooling augmentation characteristics. Samples of 6.08 m x 6.08 m square size were cut from the original roll of 30 mt^2 and put into the fixing stand manually (Fig. 2). After mounting the pads, potable tap water was circulated on cooling pads using a water pump to cool the inner chamber of evaporatively cooled stotage structure. The temperature drop and increase in relative humidity was noted after equilibrium between outside environment and evaporatively cooled stotage structure.

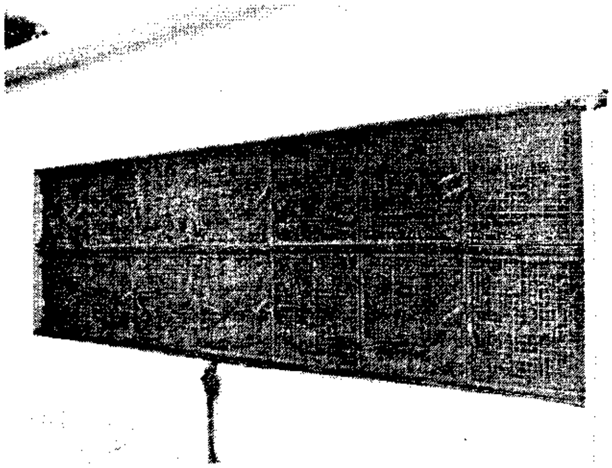

Fig. 2. Jute-fibre based non-woven pads fixed into the ECS

Measurement of cooling augmentation characteristics

Cooling performance of evaporatively cooled stotage structure depends on outside environmental conditions, mainly temperature, relative humidity and wind velocity in the vicinity of structure (Jha, 2008). Accordingly the parameters were studied for six days (22nd – 27th April, 2010) from 11 A.M. to 5 P.M. after keeping the whole set-up in equilibrium for one day (21st April, 2010).

Measurement of pad efficiency

The performance of jute – fibre based cooling pad was evaluated in terms of cooling efficiency as the equation given below (Dzivama *et al.*, 1999 and Harris, 1978).

$$\text{Cooling efficiency, } uc\ (\%) = \frac{T_1(db) - T_2\ (db)}{T_1(db) - T_1\ (wb)}$$

where,

$T_1(db)$ = dry bulb outdoor temperature °C

$T_2\ (db)$ = dry bulb cooler temperature °C

$T_1\ (wb)$ = wet bulb out door temperature °C

Performance evaluation of pad on storage studies

To study the reduction in weight due to loss of moisture and rotting, 12 kg of fresh tomato harvested from CIPHET farm was kept inside evaporatively cooled stotage structure after sorting and removal of injured & damaged tomatoes (Fig. 6). For comparison, an equal amount was kept in room condition and weight loss was recorded on daily basis.

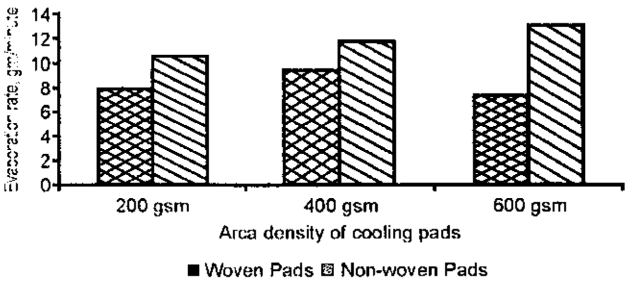

Fig. 3. Surface evaporation of water from woven and non-woven pads

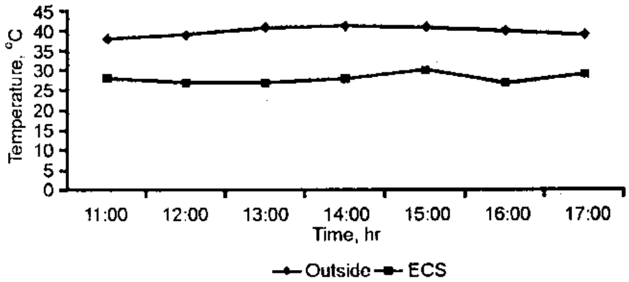

Fig. 4. A typical time temperature graph outside and inside ECS on 26/04/2010

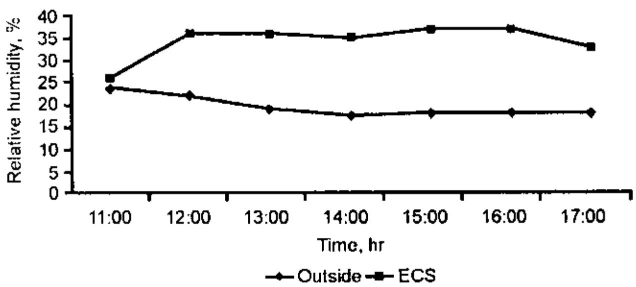

Fig. 5. A typical time relative humidity graph outside and inside ECS on 26/04/2010

RESULTS AND DISCUSSIONS

The surface evaporation rate (g/min) for woven and non-woven cooling pads of different specifications are shown in Fig. 3. The highest rate of evaporation was found to be 12.91 g of water per minute for non-woven pad of 600 gsm. The highest rate of evaporation for partal pad of 7 mm thickness was found to be 14.87 g of water per minute (Jha and Kudos, 2006). The lesser surface evaporation from the jute-fibre based non-woven pad in comparison to partal pad may be due to retaining of absorbed water by fibre itself.

Results of studies on cooling augmentation in evaporatively cooled stotage structure showed that maximum drop in temperature with respect to outside temperature (41°C) was about (14°C) (Fig. 4), whereas, relative humidity increase was about (19 %) from (18 %) to (37 %) (Fig. 5). The wind velocity range

Fig. 6. Tomato stored in ECS

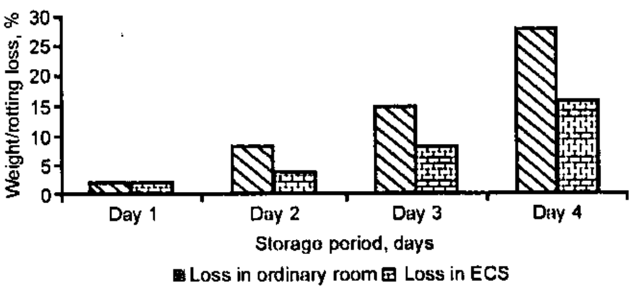

Fig. 7. Loss in weight of tomato stored in ECS and Ordinary room

during the day was 2.23 km/hr - 4.60 km/hr. Results of studies on cooling augmentation by using partal pad showed maximum drop in temperature in evaporatively cooled stotage structure in unloaded condition with respect to outside temperature was about 20°C, whereas, relative humidity reached to the level of 75 % during the month of April and May, the hottest and driest of the year (Jha, 2008). The lesser temperature drop and relative humidity increase for jute pads may be due to less rate of evaporation from its surface.

The saturation efficiency of the jute-fibre based cooling pads was found to be (65.95%). Precaution was taken to note the T2 (db), near to the cooling pads so as to minimize the temperature variation from wall to centre.

The weight loss/rotting (%) plotted against storage period, days for four consecutive days (Fig. 7). Total percentage of total loss of 10 % or above (14.70%) was observed on 3rd day in ordinary room, whereas, during the same period the total loss in evaporatively cooled stotage structure was about 8.33%.

Jute fiber based non-woven pads can give substantial cooling effect by reduction of ambient temperature thus increasing the shelf life of stored fruits and vegetables through reduction in spoilage and weight loss.

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Effect of Sowing Times and Weed Control Measures on Yield Attributes, Yield and Quality of Rice

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An experiment was conducted on sowing times and weed control measures in rice during Kharif, 2009 at College of Agriculture, Dapoli in split plot design with three replications. The main plot treatment comprising of three different sowing times viz. before onset of monsoon, one week after onset of monsoon and two weeks after onset of monsoon. The sub-plot treatment consists of weed control measures i.e. pretilachlor @ 0.5 kg a.i. ha^{-1}, butachlor @1.5 kg a.i. ha^{-1} + one hand weeding, fenoxaprop-p-ethyl @ 60 g a.i. ha^{-1}, Sesbania rostrata intercropping with rice + 2, 4-D @ 0.5 kg a.i. ha^{-1}, weedy check and weed free check. The grain yield of direct seeded dibbled rice was increased significantly when sown before onset of monsoon than rest of the sowing times. In case of weed control measures, keeping weed free upto 42 days which is critical period of rice weed competition was proved excellent for weed control of all dominant weed floras. The use of butachlor @ 1.5 kg a.i. ha^{-1} + one hand weeding and pretilachlor @ 0.5 kg a.i.ha^{-1} gave better weed control and can be recommended very safely wherever labour is an acute shortage.

(**Key words:** *Sowing time, Weed control measures, Yield, Quality and Rice*)

Rice (*Oryza sativa* L.) is one of the most important staple food grain crop of the world, which constitute the principle food for about 60 per cent of the world's human population and 2/3rd of Indian population (Anonymous, 2006). Hence, a significant portion of the world's agricultural research has been focused on rice, leading to development of high yielding rice varieties and their improved technologies that have greatly increased the global rice production. The main reason of low productivity and profitability are vagaries of nature, low fertilizer use efficiency, poor crop management and adherence of farmers to traditional crop management practices. Rice is grown either by direct seeding or by transplanting method. In Konkan, it is mostly grown by puddled transplanted method, however, there are some of the pockets, where direct seeding can also be practiced. The transplanted rice gives higher grain yield over direct sown crop, however, it is realized that transplanting of rice involves intensive labour oriented operations like raising of nursery, puddling and transplanting which are time consuming and costlier too. With the rapid industrialization in the region, scarcity of labour is posing a severe problem to agriculture in general and rice cultivation in particular. Direct sowing of rice is quicker, easier and economical one, but weed infestation is the main problem and weed pressure is often two to three times more in direct seeded rice as compared to transplanted one. The yield losses due to weeds are 36 per cent in transplanted rice but as high as 84 per cent in direct sown rice (Ravichandran, 1991). Keeping these points in view present investigation was undertaken.

MATERIALS AND METHODS

A field trial was conducted to study the "Effect of sowing times and weed control measures on the yield attributes, yield and quality of rice" during *Kharif*, 2009, at Agronomy Farm, College of Agriculture, Dapoli. The experiment was conducted in split plot design with three replications. The main plot treatment comprising of three different sowing times viz. S_1-Before onset of monsoon, S_2-One week after onset of monsoon and S_3-Two weeks after onset of monsoon. The sub plot treatment consists of weed control measures i.e. T_1- Pretilachlor @ 0.5 kg a.i. ha^{-1}, T_2-Butachlor @1.5 kg a.i. ha^{-1} + 1 H.W. T_3-Fenoxaprop-p-ethyl @ 60 g a.i. ha^{-1}, T_4- *S. rostrata* intercropping with rice + 2, 4-D @ 0.5 kg a.i. ha^{-1}, T_5-Weedy check and T_6-Weed free check. The soil of the experimental field was sandy clay loam in texture and slightly acidic in reaction, medium in available nitrogen and phosphorus and moderately high in available potassium. The rice crop was fertilized @ 79.50 kg N and 42.06 kg P_2O_5 ha^{-1} by

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using Urea- DAP briquettes each weighing 2.7 g and containing 34.8 per cent N and 18.4 per cent P as basal dose at 10 days after regular onset of monsoon for before onset of monsoon (S_1) and 10 days after sowing for one week after onset of monsoon (S_2) and two weeks after onset of monsoon (S_3), respectively. The green manure crops viz. Sesbania rostrata was fertilized by band placement of urea and single super phosphate for supplying 13.8 kg N and 30 kg P_2O_5 ha^{-1} at the time of sowing. Data on growth, yield attributes, yield, weed density, weed growth and nutrient uptake by rice crop and weeds were recorded.

RESULT AND DISCUSSION

Effect of sowing times on yield attributes, yield and quality of rice

The beneficial effect of sowing times on vegetative growth ultimately reflected in increasing the yield contributing characters. The different sowing times did not affect the number of survived hills plot^{-1}. Before onset of monsoon sowing (S_1) produced significantly higher panicles hill^{-1} (5.73 panicles hill^{-1}), least number of unfilled grains panicle^{-1}, higher number of filled grains panicle^{-1}, longer panicle (25.57 cm), higher weight of filled grains panicle^{-1} and higher test weight (24.63 g) over all other sowing times. Sowing one week after onset of monsoon (S_2) was also superior over two weeks after onset of monsoon sowing (S_3) due to low crop weed competition and better stand of the crop. These results are in close conformity with the findings of Ramana *et al.*, (2007), Singh and Srivastava (1991), Gill *et al.*, (2006) and Shah and Bhurer (2005).

The sowing times significantly influenced grain, straw yield and total produce. The maximum grain, straw yield and total produce was significantly higher due to early sowing i.e. sowing before onset of monsoon (S_1) (50.29 q ha^{-1}, 49.58 q ha^{-1} and 99.87 q ha^{-1}) than rest of sowing times. While, sowing one week after onset of monsoon (S_2) also superior over sowing two weeks after onset of monsoon (S_3). The lowest grain, straw yield and total produce (42.93, 44.41 and 87.34 q ha^{-1}) were significantly noted by sowing two weeks after onset of monsoon (S_3). The decreasing trend in the grain yield was noticed in delayed sowing this might be associated with significantly lower number of effective tillers hill^{-1}, panicles m^{-2}, less number of filled grains panicle^{-1} and low 1000-grain weight and higher spikelet sterility. Similar results were reported by Shah and Bhurer (2005) and Gill *et al.*, (2006). Usually, under upland conditions the growth stature and canopy coverage of the crop provides the competition ability to with stand weed menace. A clear and undisputed inverse relationship exists between the stature of crop and the weeds under upland condition and such effect was also noticeable in the present

Table 1. *Yield contributing characters as affected by sowing times and weed control measures in rice*

	Treatments	Number of panicles hill^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Test weight (g)
A	**Sowing times**				
S_1	Before onset of monsoon	5.73	88.72	30.67	24.63
S_2	One week after onset of monsoon	5.63	81.94	38.56	24.28
S_3	Two weeks after onset of monsoon	5.21	75.67	43.78	23.75
	S.Em.±	0.10	0.41	0.99	0.09
	C.D. (0.05)	0.37	1.61	3.87	0.35
B	**Weed control measures**				
T_1	Pretilachlor @ 0.5kg a.i. ha^{-1}	5.58	84.56	34.89	24.44
T_2	Butachlor @1.5 kg a.i. ha^{-1} + 1 H.W.	5.69	86.00	31.53	24.57
T_3	Fenoxaprop-p-ethyl at 60 ga.i. ha^{-1}.	5.40	78.67	41.89	23.94
T_4	S. rostrata intercropping with rice + 2,4-D @ 0.5 kg a.i. ha^{-1}	5.49	79.56	40.72	24.14
T_5	Weedy check	5.11	75.89	46.56	23.50
T_6	Weed free check	5.89	88.00	30.44	24.71
	S.Em.±	0.11	0.73	1.51	0.13
	C.D. (0.05)	0.31	2.10	4.35	0.38

Table 2. *Gain yield (q ha^{-1}), straw yield (q ha^{-1}), total yield produce (q ha^{-1}) and protein (%) as influenced by sowing times and weed control measures*

	Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Total produce (q ha^{-1})	Protein content (%)
A	Sowing times				
S_1	Before onset of monsoon	50.29	49.58	99.87	7.09
S_2	One week after onset of monsoon	47.74	46.59	94.33	6.59
S_3	Two weeks after onset of monsoon	42.93	44.41	87.34	6.11
	S.Em.±	0.29	0.38	0.50	0.09
	C.D. (0.05)	1.12	1.49	1.95	0.34
B	**Weed control measures**				
T_1	Pretilachlor @ 0.5 kg a.i. ha^{-1}	48.50	47.39	95.89	6.72
T_2	Butachlor @1.5 kg a.i. ha^{-1} + 1 H.W.	49.87	48.79	98.67	6.93
T_3	Fenoxaprop-p-ethyl at 60 g a.i. ha^{-1}	44.85	45.41	90.26	6.42
T_4	S. rostrata intercropping with rice + 2,4-D @ 0.5 kg a.i. ha^{-1}	45.82	45.86	91.68	6.47
T_5	Weedy check	42.17	43.64	85.81	5.89
T_6	Weed free check	50.71	50.08	100.78	7.15
	S.Em.±	0.76	0.51	0.81	0.09
	C.D. (0.05)	2.21	1.46	2.35	0.25

investigation. The crop sown at the best time of sowing put forth good and quick canopy due to enhanced initial seedling vigour and thereby offering competition for the existence of the weeds. Similar findings were reported by Shah and Bhurer (2005), Ramana *et al.*, (2007), Singh and Srivastava (1991) and Gill *et al.*, (2006).

In case of protein content, before onset of monsoon sowing (S_1)(7.38 %) recorded significantly higher protein content over one week after onset of monsoon sowing (S_2) (6.90 %) and two weeks after onset of monsoon sowing (S_3) (6.42 %). Similarly, one week after onset of monsoon sowing (S_2) also superior over two weeks after onset of monsoon sowing (S_3).

Effect of weed control measures on yield attributes, yield and quality of rice

The beneficial effects of weed control measures to control the weed flora in rice ultimately reflected in increasing the yield attributes in rice. The lowest number panicles hill^{-1} (5.11), number of filled grains panicle^{-1} and maximum number of unfilled grains panicle^{-1} (75.89 and 46.56), weight of filled grains panicle^{-1} (1.81 g) as well as test weight (23.50 g) was recorded in weedy check (T_5). While, weed free check (T_6) recorded significantly maximum yield attributes and lowest number of unfilled grains panicle^{-1}, followed by butachlor @1.5 kg a.i. ha^{-1} + 1 H.W. (T_2) and pretilachlor @ 0.5 kg a.i. ha^{-1} (T_1). This might be due to effective controlling of the weeds and creating more favourable microclimate for the growth of rice crop and reduced crop weed competition and better crop growth helped in the synchronization of yield attributes. Similar results were reported by Sharma *et al.*, (2007) and Raju and Pandian (2002).

The differential behaviour in respect of several yield attributes ultimately reflected in to the significant differences in grain and straw yield of rice. The highest grain and straw yield was significantly recorded due to weed free check (T_6) (50.71 and 50.08 q ha^{-1}, respectively) followed by butachlor @1.5 kg a.i. ha^{-1} + 1 H.W. (T_2). While butachlor @1.5 kg a.i. ha^{-1} + 1 H.W. (T_2) and pretilachlor @ 0.5 kg a.i. ha^{-1} (T_1) was also recorded significantly higher grain yield over all the remaining weed control measures. The highest grain as well as straw yield was recorded significantly in weed free check (T_6), while butachlor @1.5 kg a.i. ha^{-1} + 1 H.W. and (T_2) pretilachlor @ 0.5 kg a.i. ha^{-1} (T_1), was at par with former treatment, this might be due to the more number of panicles hill^{-1}, and higher grain weight. These results are inclose agreement with the findings reported by Tripathi *et al.*, (2005), Attri and Angiras (2001), Kolhe (1999). *S. rostrata* intercropping with rice + 2, 4-D @ 0.5 kg a.i. ha^{-1} (T_4) and fenoxaprop-p-ethyl @ 60g a.i. ha^{-1} (T_3) also noted superiority over weedy check (T_5). While the difference between former two weed control measures were of similar magnitude. This is obviously due to efficient control of weeds at critical stages. On the contrary, weedy check (T_5) recorded the lowest grain and straw yield (42.17 and 43.64 q ha^{-1}, respectively). The lowest yield in weedy check (T_5) was attributed due to the weed competition prior to early stages of crop growth, hindered the development of spikelets and reduced number of filled grains ultimately affected the test weight and weight of filled grain $panicle^{-1}$. These results are in agreement with the findings reported by Selvam *et al.*, (2001), Sharma *et al.*, (2007).

All the weed control measures registered in higher protein content in grains compared to weedy check (T_5). Weed free check (T_6) recorded significantly higher protein content over all the remaining weed control measures, except butachlor @1.5 kg a.i. ha^{-1} + 1 H.W. (T_2). Similar results were reported by Nikam (2000), and Dattatraya (2003).

CONCLUSION

On the basis of present investigation it can be concluded that direct seeded dibbled rice sown before onset of monsoon sowing was beneficial for growth and development, thereby increasing the yield of rice crop than rest of the sowing times. In case of weed control measures, it is very clear that rice crop keeping weed free upto 42 days which is critical period of rice weed competition was proved excellent for weed control of all dominant weed floras. The use of butachlor @ 1.5 kg a.i. ha^{-1} + 1 H.W. and pretilachlor @ 0.5 kg a.i.ha-1 gave better weed control and can be recommended very safely wherever labour is an acute shortage.

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Impact of Season and Planting Dates on Rice Hybrids for Physiological Attributes, Grain Yield and Nutrient Uptake under Coastal Orissa

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The experiment was conducted during wet and dry seasons of 2002-03 and 2003-04 to study the performance of rice hybrids in coastal Orissa with thirty two treatment combinations of eight hybrids ('CRHR 1', 'CRHR 4', 'CRHR 5', 'DRRH 1', 'PHB 71', 'PA 6201', 'PA 6444' and 'KRH 2') and four dates of planting during each of rainy (15 June, 15 July, 15 August and 15 September) and dry season (15 November, 15 December, 15 January and 15 February). Significantly highest effective tillers hill^{-1} (6.8), filled grains panicle^{-1} (130.2), 1000 grain weight (23.45 g) and LAI at flowering (6.20), coupled with significantly lower sterility percentage (25.4) were observed with 15 July planting during the wet season. Whereas during the dry season significantly highest effective tillers hill^{-1} (8.3), filled grains panicle^{-1} (129.2) 1000 grain weight (23.14 g) and LAI at flowering (5.90), coupled with significantly lowest sterility percentage (23.14) with 15 January planting. Hybrid 'CRHR 5' recorded maximum grain yield of 5.69 and 7.16 t ha^{-1} in the wet and dry season, respectively. 15 June and 15 July planted crop performed better with respect to yield of all the hybrids whereas for the dry season 15 January followed by 15 December planted crop proved to be best for greater yield. Hybrids were reported to be more efficient in yield during the dry season than in the wet season. N, P and K uptake varied from 93.7 to 105.4, 17.4 to 22.1, and 99.4 to 108.3 kg ha^{-1} in the wet season and 95.5 - 111.0, 18.6 - 22.6 and 98.4 - 106.5 kg ha^{-1} in the dry season, respectively due to hybrid. The crop planted on 15 July in the wet season and 15 January in the dry season removed maximum quantity of N, P, K. from the soil.

***(Key Words:** Hybrid rice, Date of planting, Leaf area index, Nutrient uptake, Yield)*

Hybrid rice technology is the most proven technology and a more practical one to raise productivity and production. Rice hybrids are likely to behave and interact differently with various environmental conditions, which is ultimately expressed in economic yield. It is therefore imperative to find out suitable rice hybrids, which can express its yield potential fully under the prevailing weather conditions during the wet and dry seasons. Time of planting and season mostly governed by climatic conditions, has a pronounced influence on yield and yield components of rice hybrids. This aspect is very important while developing region and hybrid specific cultivation package. Optimum temperature required for rice is 20 to 350C. Both high and low temperature at different growth phases adversely affects growth and development of the crop. Delayed planting exposes the crop at the reproductive phase to low temperature during the wet season and high temperature during the dry season. Stake and Yoshida (1978) observed that spikelet sterility is induced by high temperature Therefore seeding time of hybrids can be adjusted in a particular region to fit the temperature, best suited to different growth stages. Since information on the response of hybrid rice to sowing time is meagerin the coastal ecosystem, hence present experiment was conducted to study the effect of different dates of planting on yield attributes and grain yields of recent rice hybrid at Central Rice Research Institute during the wet season and dry seasons of 2002-03 and 2003-04.

MATERIALS AND METHODS

Field experiments were conducted to find out a suitable transplanting date and its impact on yield attributes, yield and nutrient uptake of rice hybrids during wet season and dry season of 2002-03 to 2003-04 under favourable shallow lowland condition at Central Rice Research Institute farm, Cuttack. The soil of the experimental site is alluvial origin in the Mahanadi Delta and is classified as Aeric Haplaquept. The dominant clay minerals found in the soil are keolinite and illite having sandy clay loam soil (pH 6.5) with Total N - 0.08%, available P - 14.5 kg ha^{-1}, available K -118 kg ha^{-1} and CEC 22.5 meq 100-1soil. There were 32 treatment combinations of eight varieties ('CRHR 1', 'CRHR 4', 'CRHR 5', 'DRRH 1', 'PHB 71', 'PA 6201', 'PA 6444'

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and 'KRH 2') and four dates of planting, evaluated during the wet (15 June, 15 July, 15 August and 15 September) and dry seasons (15 November, 15 December, 15 January and 15 February) in a split plot design replicated thrice. Twenty five day old seedlings during the wet season and thirty day old seedling during the dry season were transplanted at a spacing of 15 x 15 cm with one seedling hill-1. Recommended fertilizer of 120 kg N, 40 kg P_2O_5 and 60 kg K_2O and 135 kg N, 50 kg P_2O_5 and 90 kg K_2O was applied uniformly during the wet and dry season, respectively. Nitrogen was applied in four equal splits at 7 DAT, at 21 DAT, panicle initiation and at heading. The entire amount of phosphorus and 50% of potash (K_2O) was applied as basal, while rest 50% of potash was applied at panicle initiation stage. Periodical samples of 10 randomly selected hills were taken for different growth parameters and observations on grain yield and yield attributes were recorded at the time of harvest. NPK uptake in the plant material was determined by method by Jackson, 1967. Statistical analysis of data was done following Gomez and Gomez (1984).

RESULTS AND DISSCUSION

Yield attributes and growth parameters

On an average plants grew taller (109.4 cm) and produced longer panicles (26.25cm) with more sterile spikelets panicle^{-1} (51.8) and sterility percentage of spikelets (31.9) in the wet season than those in the dry season (96.3 cm, 23.7 cm 43.57 and 27.2). But effective tillers clump^{-1} (6.3), dry matter accumulation (31.43 g clump^{-1}), fertile spikelets panicle^{-1} (117.2), and harvest index (42.8 %) were more in the dry season than those in the wet season (8.7, 26.77 g, 112.2, and 38.8 %). However, leaf area index and test weight of grains remained unaffected by the season (Table 1 & 2).

Reduction in plant height was observed during the wet season when planting was delayed from 15 June to 15 September whereas on the contrary during the dry season plant height increased with delay in planting from 15 November to 15 February. High solar radiation during the winter season (mid January to February) might have induced the vigour of the plant in case of delayed planting (January and February) whereas it was reversed in case of wet season because of reduced photosynthesis under low light (Murty and Prasad, 1994). In general, significantly highest effective tillers hill^{-1} (6.8), LAI at flowering (6.20), filled grains panicle^{-1} (130.2) and 1000- grain weight (23.45 g) coupled with significantly lower sterility percentage (25.4) were observed with 15 July planting during the wet season. Similarly during the dry season significantly highest effective tillers hill^{-1} (8.3), LAI at flowering (5.90), filled grains panicle^{-1} (129.2) and 1000-grain weight (23.14 g) coupled with significantly lowest sterility percentage (23.14) with 15 January planting. Dry matter production was highest with 15 June planting and thereby reduced further with the delayed planting during the wet season. These findings are in agreement with Hassan et al., (2003). During the dry season it was highest with 15 January planting, early and delayed planting exhibited reduction in total dry matter accumulation.

Grain yield

During both the seasons mean data over the two years revealed that 'CRHR 5' produced maximum grain yield of 5.69 t ha^{-1} and 7.16 t ha^{-1} and was significantly better than rest of the hybrids. Date of planting of the test crop was spread over four months during both the seasons and was exposed to varied weather condition which has been reflected in the yield of hybrids. The crop planted early on 15 June and 15 July performed better with respect to yield of all the hybrids during the wet eason, has been reported by several workers. (Om *et al.*, 1997 and Nayak *et al.*, 1999). Very early planting on 15 November and very late planting on 15 February decreased grain yield drastically by 38.2 and 22.7%, respectively during the dry season. Several reports with high yielding varieties (Haldar, 1996 and Deb Choudhary and Guha, 2000) indicated that mid January planting as best for higher yield and delay in planting from 15 and 30 days from January reduces yield by 21 and 34 %, respectively. Assuming the grain yield of 'CRHR 5' to be 100 hybrids can be rated as 'CRHR 5' and 'KRH 2' (98 to 100 %) > 'PHB 71' and 'PA 6444' (90 to 92 %) > 'PA 6201' , 'DRRH 1', 'CRHR 4' and 'CRHR 1'(75 to 80 %) during the wet season whereas during the dry season 'CRHR 5' (100 %) > 'PA 6444', 'KRH 2' and 'PHB 71' (87 to 92 %) > 'PA 6201' and 'DRRH 1' (83 to 85 %) > 'CRHR 4' (76 %) > 'CRHR 1' (60 %). Reddy *et al.*, (1995) reported grain yield was 56 % less in the wet season from that in the dry season. Simillar observation was also made by, Pamplona *et al.*, (1995) and Beena and Balachandran (2001). Hybrids are reported to be more efficient in yield during the dry season with high solar radiation (Ponnuthurai *et al.*, 1984). Besides solar radiation yield advantage during dry season was also due to

Table 1. *Effect of planting dates on the yield attributes of rice hybrids during the wet and dry season*

	Wet season						Dry season					
	Plant Height	Effective tillers	Panicle length $hill^{-1}$	Filled grains (cm)	Sterility (%) $Panicle^{-1}$	1000 grain	Plant Height Weight (g)	Effective tillers	Panicle length $hill^{-1}$	Filled grains (cm)	Sterility (%) $Panicle^{-1}$	1000 grain Weight (g)
Varieties												
CRHR 1	100.6	5.5	24.6	102.6	33.8	22.41	89.9	5.5	20.7	85.0	42.3	21.74
CRHR 4	108.8	5.3	25.8	107.7	35.1	21.28	92.5	6.0	23.8	120.5	25.8	21.16
CRHR 5	108.6	5.6	27.7	122.3	28.8	24.10	93.4	7.2	24.5	130.3	22.1	22.86
DRRH 1	102.7	5.3	26.3	93.9	42.7	23.23	97.8	5.9	24.3	104.5	36.3	23.50
PHB 71	114.3	6.2	27.6	119.2	28.5	22.93	97.1	6.2	24.3	123.2	21.8	22.99
PA6201	106.8	6.4	25.7	109.0	31.0	21.58	95.9	6.4	23.6	119.9	23.7	21.76
PA 6444	116.0	6.2	26.4	121.4	27.7	23.17	100.0	6.3	24.3	121.6	23.3	23.12
KRH 2	117.6	7.0	25.7	121.3	27.4	23.51	103.5	7.2	24.5	132.6	22.5	23.14
CD (P=0.05)	1.57	0.37	0.50	2.03	1.05	0.38	2.78	0.45	1.39	1.53	0.70	0.79
Planting Dates												
D1	120.0	6.0	27.8	120.3	30.1	22.53	78.7	6.1	23.0	100.8	29.6	22.58
D2	117.3	6.8	27.0	130.2	25.4	23.45	92.5	6.3	23.1	121.6	25.5	22.81
D3	106.4	5.8	26.3	110.7	31.9	23.00	103.7	7.0	23.3	129.2	21.7	23.14
D4	94.1	5.3	23.9	87.6	40.3	22.12	110.1	5.8	25.7	117.2	31.3	21.60
CD(P=0.05)	1.11	0.26	0.35	1.43	0.74	0.53	1.69	0.37	0.75	1.06	0.51	0.40

Wet season- D1-15 June; D2-15 July; D3-15 August; D4-15 September
Dry season-D1-15 November; D2-15 December; D3-15 January; D4- 15 February

Table 2. *Effect of date of planting on Yield and growth parameters of rice hybrids during the wet and dry season*

Treatments	Wet season					Dry season				
	DFF Yield (t ha^{-1})	Grain (%)	HI	LAI	DMP (g $hill^{-1}$)	DFF	Grain Yield (t ha^{-1})	HI (%)	LAI	DMP (g $hill^{-1}$)
Hybrids										
CRHR 1	91.0	4.22	31.0	4.65	26.32	100.0	4.29	33.0	4.18	30.68
CRHR 4	86.0	4.47	35.0	5.49	25.25	93.8	5.46	37.0	5.34	30.57
CRHR 5	75.0	5.69	41.0	5.97	28.74	94.0	7.16	42.0	6.25	35.18
DRRH 1	87.5	4.52	37.0	4.59	25.29	95.8	5.94	39.0	4.39	30.57
PHB 71	91.0	5.16	41.0	5.85	26.74	92.8	6.25	43.0	6.10	29.86
PA 6201	88.3	4.62	38.0	5.25	26.27	92.0	6.10	39.0	5.22	29.72
PA 6444	87.5	5.10	40.0	5.94	28.06	96.0	6.58	40.0	6.17	32.07
KRH 2	79.8	5.53	42.0	5.97	27.54	94.5	6.36	43.0	6.17	31.33
CD(P=0.05)	-	**0.19**	**1.98**	**0.25**	**0.75**	-	**0.35**	**2.19**	**0.35**	**1.18**
Date of planting										
D1	93.1	5.60	37.0	5.46	30.58	108.9	4.83	40.0	4.94	27.42
D2	89.1	5.83	42.0	6.20	29.82	97.3	7.11	43.0	5.65	34.74
D3	86.1	4.94	41.0	5.55	26.19	90.5	7.14	40.0	5.90	33.72
D4	81.5	3.30	33.0	4.66	20.53	82.6	5.52	35.0	5.43	29.84
CD(P=0.05)	-	**0.14**	**1.01**	**0.18**	**0.53**	-	**0.23**	**1.50**	**0.19**	**0.84**

Wet season- D1-15 June; D2-15 July; D3-15 August; D4-15 September
Dry season-D1-15 November; D2-15 December; D3-15 January; D4- 15 February

Table 3. *Effect of date of planting on nutrient uptake (kg ha^{-1}) at harvest of rice hybrids during the wet and dry season*

Treatments	Wet season			Dry season		
	N	P	K	N	P	K
Variety						
CRHR 1	94.0	18.4	99.4	95.5	19.1	98.5
CRHR 4	99.0	20.0	104.3	104.4	18.6	101.8
CRHR 5	103.4	22.0	105.8	109.7	21.4	103.4
DRRH 1	93.7	18.6	99.3	96.6	19.3	98.4
PHB 71	103.1	19.1	108.3	107.4	20.4	105.4
PA 6201	100.3	18.9	101.5	111.0	20.4	104.3
PA 6444	105.4	21.5	106.9	109.5	22.6	102.3
KRH 2	105.2	22.1	107.4	110.8	21.5	106.5
SE (m)±	**1.99**	**0.25**	**0.64**	**1.14**	**0.36**	**1.17**
CD (P=0.05)	**5.56**	**0.69**	**1.78**	**3.82**	**1.19**	**3.90**
Date of planting						
D1	107.2	20.8	109.3	104.6	18.2	92.5
D2	112.2	22.6	110.4	110.0	22.5	114.7
D3	105.7	22.0	108.5	115.6	24.8	113.2
D4	77.1	14.9	88.4	92.3	16.2	90.0
SE (m)±	**1.40**	**0.17**	**0.45**	**0.75**	**0.28**	**0.77**
CD (P=0.05)	**3.93**	**0.49**	**1.26**	**2.14**	**0.80**	**2.18**

Wet season- D1-15 June; D2-15 July; D3-15 August; D4-15 September
Dry season-D1-15 November; D2-15 December; D3-15 January; D4- 15 February

better response to nitrogen (Sahu and Murty 1976, CRRI 1998b). Accumulated rainfall, sunshine hours and relative humidity during the wet season adversely affected the grain yield. These factors are not limiting during the dry season (Varadan, 2000).

Nutrient uptake

During the wet season N uptake was maximum (105.4 kg ha^{-1}) with rice hybrid 'PA 6444' closely followed by 'KRH 2' (105.2 kg ha-1) and 'CRHR 5' (103.4 kg ha^{-1}) while minimum uptake (95.5 kg ha^{-1}) was recorded with "CRHR 1". Whereas during the dry season hybrid 'PA 6201' registered maximum N uptake (110.99 kg ha^{-1}) while minimum N uptake (95.49 kg ha^{-1}) was recorded with 'CRHR 1'. Almost similar quantity of N (107.4 to 110.8 kg ha^{-1}) was removed by 'KRH 2', 'CRHR 5', 'PA 6444', and 'PHB 71'. Effect of date of planting on N uptake was more conspicuous than that of hybrids. Planting hybrid rice on 15 July during the wet season and 15 January during the dry season recorded maximum N uptake while minimum uptake was registered with the crop planted on 15 September in the wet season and 15 February in the dry season. Higher N content in grain and straw coupled with higher yield accounted for higher N uptake by 15 July and 15 January planted crop. Average P uptake was almost similar during both the wet and dry seasons. Maximum P uptake was registered with hybrid 'KRH 2' during the wet season and 'PA 6444' during the dry season. 15 July and 15 January planted crop removed maximum P from the soil whereas 15 September and 15 February planted crop registered minimum P uptake during respective season. Similar decline in P uptake due to delay in planting has been reported by **Haldar** (1996) under Bhubaneswar condition. Hybrid 'PHB 71 and 'KRH 2' removed maximum and 'CRHR 1' removed minimum K from the soil during both the seasons. June, July and August planted crop in the wet season (108.5-110.4 kg ha^{-1}) and December and January planted crop in the dry season (113.2-114.7 kg ha^{-1}) removed identical quantities of K while there was drastic reduction in it, when planting was delayed to 5 September and 15 February in respective season. Variation in K uptake has been mainly due to variation in grain and straw yield.

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Reclamation of Coastal Waterlogged Wasteland through Biodrainage

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A Study on reclamation of coastal waterlogged wasteland through biodrainage plantation of trees like *Acacia mangium* and *Casuarina equisetifolia* and intercropping of pineapple, turmeric and arrowroot was taken up in Khurda district of Orissa coast. *Acacia mangium* was faster both in height, growth and collar diameter than *Casuarina*. However *Casuarina* stem was less tapering than *Acacia mangium* at 12 months after planting. The average mortality of trees after one year for both the species were very less (< 6%). After four years of planting, the highest diameter at breast height (DBH) reached up to 20.1 cm for acacia and for casuarinas it reached up to 12.5 cm. However the average values of collar diameter, DBH, height and canopy area were 178 mm, 143 mm, 15.4 m and 3.7 m respectively. For casuarina the average values of collar diameter, DBH, height and canopy area were 143.7 mm, 108 mm, 13.5 m and 3.85 m respectively by the same four years period. Intercropping of pineapple, arrowroot, turmeric among the trees was also done successfully. In a year on an average 220 pieces of pineapple was harvested and 50 kg of turmeric seed and 40 kg of arrowroot seed was produced as intercropping in bio-drainage plantation. The depth to pre-monsoon water table changed from 0.5 m to 1.67 m due to well drained condition as well as due to bio drainage after one year of plantation and even went down to 2.20 m in the next year and to 3.20 m below ground level in third year and continuously declining. The soils of the experimental plots were highly acidic (pH: 3.5 - 5.0), low organic carbon (0.13-0.67%), and low in available nutrients (N<280 kg ha^{-1}, K: 50-170 mg kg^{-1} of soil, P: 5-10 mg kg^{-1} of soil) and high iron contamination which was restricting the growth and yield of crop prior to intervention, but got improved by land modification and biodrainage plantations over time. Successful establishment of trees and intercrops and its vigorous growth revealed that bio drainage species of acacia and casuarinas can be adopted for reclamation of waterlogged wasteland. However acacia has better performance over casuarina.

*(**Key words:** Biodrainage, Wasteland reclamation, Inter cropping, Waterlogging, Water table)*

The task of providing food security to our country's burgeoning population is becoming increasingly difficult. Around 70% of the India's population is living in rural area with agriculture as their livelihood support system. The vast majority of Indian farmers are small and marginal. Their farm size is decreasing further due to population growth. The quality of land is also degrading due to various reasons resulting decline in agricultural productivity leading to food insecurity. Land degradation can be defined as a temporary or a permanent lowering of land productivity through deterioration of land's physical, chemical and biological conditions. It represents a complex ensemble of water erosion, wind erosion, soil compaction, saliniszation and waterlogging. An area is said to be waterlogged when the water table rises to an extent that the soil pores in the root zone of a crop become saturated, resulting in restriction of the normal circulation of air, decline in the level of oxygen and increase in the level of carbon dioxide. The water table which is considered harmful would depend upon the type of crop, type of soil and the quality of water (Jena, 2006). In India the total degraded land due to waterlogging is 6.41 M ha out of which 1.66 M ha is mainly wasteland due to surface ponding and rest area of 4.75 M ha is under subsurface waterlogging. (Maji *et al.*, 2010). High intensity of rainfall combined with saucer shaped physiography and flat land near the coastal area in deltaic alluvial region is the most important reason for waterlogged wasteland (Jena *et al.*, 2006). Since land resources are finite, requisite measures are required to reclaim degraded and wastelands, so that areas going out of cultivation due to social and economic reasons are replenished by reclaiming these lands and by arresting further loss of production potential.

There are several measures to reclaim waterlogged area. Drainage is one of the measures to control waterlogging which is defined as the natural or artificial removal of surface and

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subsurface water from a given area. Traditionally management strategies to address waterlogging problem have often focused on engineering approaches such as deep open ditches, vertical drainage (groundwater pumping) or horizontal sub-surface drainage which all require expensive capital investment and operation and maintenance. Biodrainage i.e. the use of vegetation to manage water fluxes in the landscape through evapotranspiration is an alternative technique that has recently attracted interest in drainage and environmental management circles. Biodrainage can be either remedial (i.e. lowering water table after they have risen; discharge control), or preventative (i.e. intercepting soil water before it reaches the water table; recharge control) (Thiyagarajan and Umadevi, 2006). Heuperman (1999) found out the lowering of water table due to biodrainage for 10 years through planting trees having high water requirement. Biodrainage presents itself as a feasible and environment friendly option that farmers could adopt to reclaim their land. It is based on the ability of plants and trees to transpire water and thus remove excess water and salinity. Considering all above a study on reclamation of waterlogged wasteland through biodrainage was undertaken in coastal region of Orissa.

MATERIALS AND METHODS

Bio drainage Principles

Biodrainage is a combined drainage-cum-disposal system and is less costly and more environmentally friendly. It relies on vegetation, rather than mechanical means, to remove excess water. The driving force behind the biodrainage concept is the consumptive water use of plants. It is economically attractive because it requires only an initial investment for planting the vegetation, and when established, the system could produce economic returns by means of fodder, wood or fibre harvested. There is consensus that biodrainage, when properly implemented, can lower the water table. It could solve problems associated with waterlogged areas and canal seepage. Biological systems make use of the evapotranspirative power of plants, especially of trees, to lower groundwater tables. Low cost technology such as biodrainage could be an alternative providing several advantages as the negative side effects of conventional drainage systems are reduced and, as they require less investment, may find quicker application. They are environmentally friendly, provide fuel wood, timber, fruits, shade and shelter, function as windbreaks and yield organic matter for fertilizer. In addition, they contribute to the enhancement of biodiversity, as flora and fauna flourish, air pollution is diminished and they contribute to carbon sequestration.

Australian researchers (Bari and Schofield, 1992) have reported the ability of different trees in influencing water tables. Thus a new approach is gaining momentum to use different types of plants to control shallow water tables. These plants draw their main water supply from groundwater or from the capillary fringe just above it. Such types of plants are called phreatophytes. Main physiological features of such plants are luxriant transpiration in contact with groundwater. Examples are tree species like poplar, eucalyptus, tamarix, muskit, acacia, sissoo etc.

Kapoor (1999) estimated annual rate of transpiration from (*Eucalyptus*) plantation area over 6 year period (1991-1997) and the average was 3446 mm. The plantations were visualized as wells 500 m apart with pumping capacity of 33 m3 hr^{-1}. The observed draw down during a period of 6 yrs is between 7.8 - 8 m at various point of the plantation area with maximum draw down being 13-15 m (Kapoor, 1999). However the efficacy of biodrainage has been established through various reports (George *et al.*, 1999) after surveying of 80 sites in western Australia concluded that extensive planting covering as much as 70 -80% of catchment area is necessary to achieve significant water table reduction in deep water table (often recharge area) situation. In shallow water table (often discharge areas) zones, for every 10% increase in planted area water table was lowered by about 0.4 m. A comparative study of Casurina glanca and Eucalyptus camaldulensis (Cramer *et al.*, 1999) showed that former had greater potential to discharge saline groundwater.

Study area

The study was conducted in the Directorate of Water Management (formerly Water Technology Centre for Eastern Region) farm, Mendhasal, Khurda, Bhubaneswar, India (20°30′ 0″ N latitude and 84°48′10″ E longitude). There was a patch of 3 ha area under severe waterlogging. Continuous waterlogging has converted that land to wasteland. No crop was possible to be grown in those fields and it was remaining fallow in almost all years. The soil pH observed ranged from 3.5 to 6.5; soil texture is sandy clay loam; soil organic carbon was low (< 0.5%); soil available nitrogen was low (< 280 kg ha^{-1}); soil available potassium was medium (50-170 mg kg^{-1} of soil); soil available phosphorous was medium (5-10 mg kg^{-1} of soil); iron toxicity was present. Depth of groundwater table was ranging from 20-40 cm as minimum and 50-150 cm as maximum from ground surface during December to June. During monsoon it is above ground surface. The yield of shallow aquifer is low. The land is unsuitable for ploughing except during May- early June, left fallow in almost all years.

Lay-out of experimental plot

An area of 2640 m^2 of the waterlogged wasteland was converted into four elevated platforms (P1, P2, P3 and P4) of 20 m x 20 m each with the excavated soils from the adjacent 20 m x 10 m area (D1, D2, and D3) and also from a strip of 110 m x 4 m (Fig. 1). There was a net increase in elevation of platforms by 0.65 m in comparison to original ground level. After the modification of the land there were four elevated platforms and three depressions. Platform 1 (P1) and platform 2 (P2) was under acacia plantation with pineapple as intercrop, platform 3 (P3) was under casurina with pine apple, turmeric and arrowroot as intercrop, and platform 4 (P4) was under casurina. Depression 1 (D1) is between P1 and P2, depression 2 (D2) is between P2 and P3 and depression 3 (D3) is between P3 and P4 from where soil had been removed.

Acacia mangium and *Casuarina equisetifolia* planting material having average length of 45 cm was procured from College of Forestry, Orissa University of Agriculture and Technology. They were planted in two platforms each with a spacing of 2 m x 2 m in the fourth week of July 2004. The layout of the experimental plot is given in Fig. 1. Normal procedure of agro-forestry planting was followed. Pits of 30 cm length, breadth and depth were excavated. Those pits were filled with well decomposed compost and farm yard manure @ 4 kg pit^{-1} and fertilizer (25 g DAP) was also applied per pit. One liter of water was applied per plant at the time of planting.

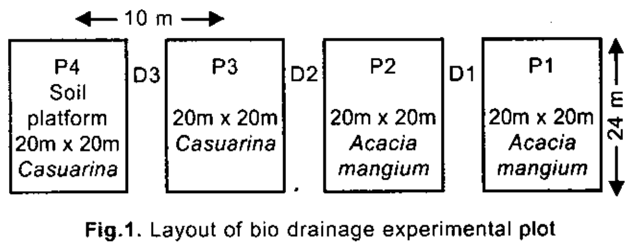

Fig.1. Layout of bio drainage experimental plot

The different growth parameters observed were height (cm), collar diameter (mm), and diameter at breast height (DBH) (mm) at the time of planting and then at every 3 months after planting (MAP). Bottle gourd was taken as intercrop after the establishment of tree plantation for one season. After 12 months of planting pineapple was planted as intercrop in paired rows between two rows of acacia mangium as well as between two rows of casuarina. The spacing of pineapple between rows as well as plants was kept at 60 cm. In platform 1 and 2 the intercrop taken was pineapple and on platform 3 half of the area was covered with pineapple and rest half with turmeric and arrowroot as intercrop. The reason for taking pineapple, turmeric and arrowroot as intercrop was due to the fact that all these crops are shade loving and performs better in diffused light. All of them also perform relatively better in acid soils (where pH is low) in comparison to other type of crop.

Soil samples were taken from the experimental field prior to planting and then after one year of planting and after four years of planting. Standard procedure was followed for soil analysis in the laboratory of DWM (formerly WTCER). The different parameters used to find out the change of soil quality in this study are pH, electrical conductivity (EC), organic carbon (OC), N (nitrogen), P (phosphorous), K (potassium) availability and other micro-nutrients such as copper (Cu), manganese (Mn), iron (Fe) and zinc (Zn). In this paper the results and discussions are made on change of pH, EC and OC of the soil over time to know whether biodrainage has improved the soil quality and reclaimed the waterlogged wasteland or not.

Observation wells were installed one on the platform and other in depression so as to measure the depth of water table from ground level throughout the year. The observations were taken once in a week. The transpiration and stomatal conductance of the trees were also measured.

RESULTS AND DISCUSSIONS

Growth parameters of bio drainage plantation

The different growth parameters observed were height (cm), collar diameter (mm), and diameter at breast height (DBH) (mm) at the time of planting and then at every 3 months after planting (MAP). In *Acacia mangium*, the net increment in plant height over initial was 128.8%, 270.8%, 632%, 803% after 3, 6, 9 and 12 months after planting (MAP).

respectively. The net increment (NI) in collar diameter was 154%, 1057%, 2002%, and 2528% respectively during the same period. However DBH (diameter at breast height i.e. at 1.37 m from ground) was seen as 20.6 mm, 36.2 mm and 51.4 mm at 6, 9 and 12 MAP respectively. In *Casuarina equisetifolia* plant height increased to 105.3 cm (net increment of 56%), 209.6 cm (NI 210%), 342.4 cm (NI 407%), and 428.0 cm (NI 534%) after 3, 6, 9 and 12 months after planting, respectively. The net increment in collar diameter was 152%, 490%, 1157%, and 1420% after 3, 6, 9, and 12 MAP respectively. The diameter at breast height attained 11.3 mm, 20.7 mm and 31.1 mm after 6, 9, and 12 months after planting. Thus *Acacia mangium* was faster both in height growth and collar diameter than Casuarina. However Casuarina stem was less tapering than Acacia mangium at 12 months after planting. The average mortality of trees after one year for both the species were very less (< 6%).

After about four years of planting (during July 2008), for acacia the highest DBH reached up to 20.1 cm and in casuarinas it reached up to 12.5 cm. However the average collar diameter at bottom, DBH, height and canopy area were178 mm, 143 mm, 15.4 m and 3.7 m respectively by fourth year of planting. For casuarinas the average collar diameter at bottom, DBH, height and canopy area are 143.7 mm, 108 mm, 13.5 m and 3.85 m respectively by the same period. The growth characteristic curve of both the species are given in Fig. 2 and 3.

The transpiration in acacia ranged between 1.95-2.32 m mol $m^{-2} s^{-1}$ with stomatal conductance 69.4 to 84.5 m mol $m^{-2} s^{-1}$ during March 2008 (after 44 months of planting). Incase of casuarina the range of transpiration was between 2.34-2.75 m mol $m^{-2} s^{-1}$ with stomatal conductance up to 183.1 m mol $m^{-2} s^{-1}$ during the same time. The progressive

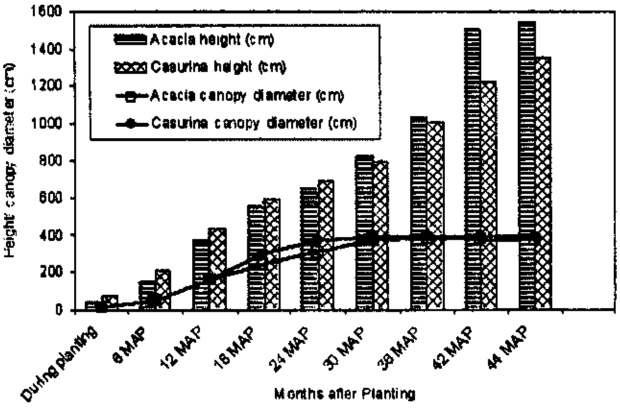

Fig. 2. Height and canopy diameter growth of Acacia and casurina observed in modified waterlogged wasteland

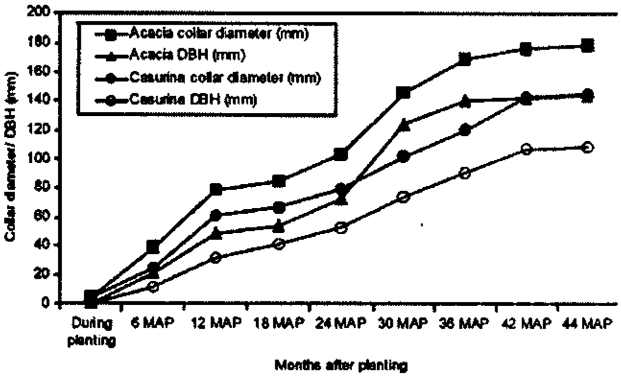

Fig. 3. Progressive growth of collar diameter and diameter at breast height (DBH) of Acacia and casurina observed in modified waterlogged wasteland

shade has significantly reduced the intensity of incident radiation to up to 50%. This has affected the transpiration efficiency and stomatal conductance of mainly bottom tier leaves of acacia and casuarina vegetation. However up-tier leaves showed transpiration at normal range i.e. up to 5.7 and 5.3 m $mol^{-1} m^{-2} s^{-1}$ in casuarina and acacia respectively.

Intercropping of bottle gourd among the trees on the raised platforms was undertaken after the monsoon season was over in the first year of planting. Due to earth work the top soil was less fertile and the soil was acidic. Therefore bottle gourd which was planted in basins was chosen over other crops. One pit was made among four trees. So the plant to plant spacing in bottle gourd was also kept at 2 m. From one platform of dimension 20 m x 20 m on an average 360 kg of bottle gourd was harvested which is about 9 t ha^{-1}. After one year of planting as it is observed from Fig. 2 that the average height and canopy of acacia was 3.61 m and 1.58 m and for casuarina the height was 4.28 m and canopy 1.62 m. The canopy cover restricted growing of other crops. Therefore intercropping of crops which grow better under diffused light and also suit inside plantation area were chosen. Intercropping of pineapple, arrowroot, turmeric among the trees was done successfully. About 220 pieces of pineapple was harvested after 18 months of planting and continuing and 50 kg of turmeric seed and 40 kg of arrowroot seed was produced during each season as intercropping in bio-drainage plantation.

Soil analysis

The soil analysis done prior to the plantation showed that the experimental plots had highly acidic soil with pH around 3.5 which might have happened due to continuous water logging and washing of top soil and base materials. The electrical conductivity

(EC) of soil was 0.14 dSm^{-1} and organic carbon (OC) was 0.16% prior to the plantation. The soil analysis done after one year of plantation showed remarkable improvement in soil pH. The pH of the soils of the raised beds/ platforms (P1 and P4) is comparatively better and close to neutral or slightly acidic after one year of planting, where as EC is well within the permissible limit. The available organic carbon improved from very low status to low-medium but was not that remarkable in elevated platform under plantation or in depressions after one year of plantation. However after four years of plantation the pH of all the elevated platforms as well as depressions have become near neutral (Fig. 4.a). The EC of the soil was well within permissible limit. But there was no remarkable change even after four years of planting (Fig. 4.b). There was improvement in organic carbon from very low status prior to plantation to little improvement after one year of plantation and marked improvement after four years of plantation (Fig. 4.c).

Hence from all the above figures (4.a, 4.b and 4.c) it is observed that biodrainage plantation has improved the soil quality and enhanced the organic carbon status of the soil. Improvement in soil organic carbon is due to incorporation of dry leaves

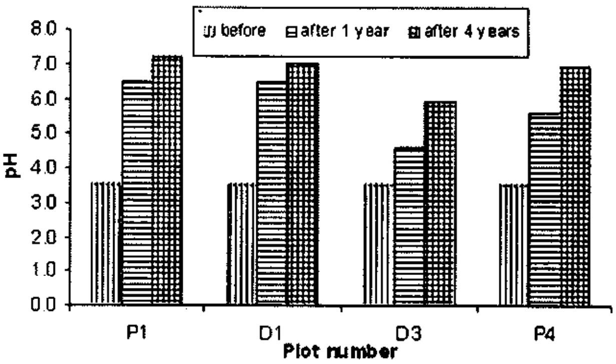

Fig. 4a. Change of soil pH over time in bio-drainage plantation

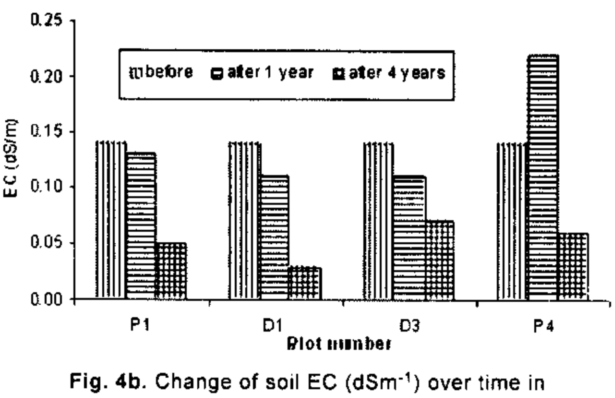

Fig. 4b. Change of soil EC (dSm^{-1}) over time in bio-drainage plantation

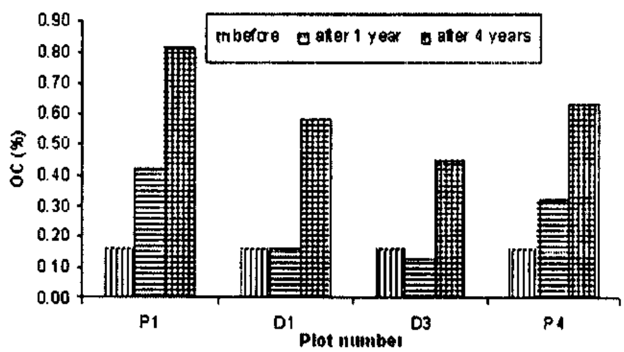

Fig. 4c. Change of soil organic carbon (%) over time in bio-drainage plantation

and addition of organic manures in soils through intercropping. The soil from highly acidic has been improved to neutral due to well drained condition of the soils and restricting the washing out of base material.

Impact of biodrainage plantation on water table

The water table depth was observed every week. These observations were taken to find out whether biodrainage plantations have positive impact of lowering water table or not. The depth to water table in different standard meteorological week is presented in Fig. 5. In the first year of experiment and prior to plantation, the water table remained above ground surface during 25th to 48th week where as during the driest period it lowered up to 1.67 m. During the first year of planting due to land modification the drainage condition of the soil got improved as well as due to little consumption of water by the biodrainage plants the water table got lowered to 2.20 m during driest period and water table was above ground surface during 27th to 48th week. It further lowered to 3.20 m during 2005 summer. Water table observation after three years of planting showed the duration of water table above ground surface has minimized and during driest period it was lowered down to 3.65 m. However the soil profile remains almost saturated during 33rd to 44th week.

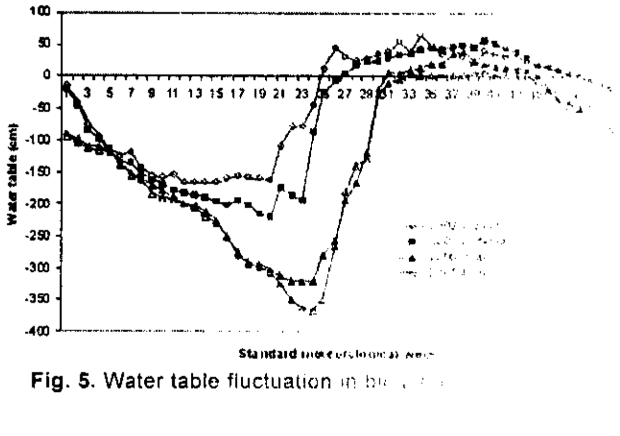

Fig. 5. Water table fluctuation in bi...

Hence after initial years of work, where the bio drainage component is negligible, it is seen that the land modification has changed the water table regime making it better and suitable for crop growth and crop diversification in comparison to other plots. Once the tree grew it had prominent effect on water table and it is further expected that over time it would further lower and would help in reclaiming the waterlogged degraded land.

CONCLUSIONS

Successful establishment of trees and intercrops and its vigorous growth revealed that bio drainage species of acacia and casuarinas can be adopted for reclamation of waterlogged wasteland. Bottle gourd can successfully be taken as an intercrop among biodrainage plantation during the first year of plantation where the canopy of the trees are limited and have not resulted complete shading. Pine apple, turmeric and arrowroot are suitable intercrops after one year of planting as they like diffused light for their better growth. The mortality of biodrainage plantation in highly acidic, non-fertile waterlogged waste land is not much. Acacia mangium has better performance over casuarinas in the initial years of planting. Biodrainage has improved the soil quality making the soil to near neutral from highly acidic condition. There is remarkable improvement of soil organic carbon from low to medium due to incorporation of dry leaves of biodrainage plantation as well as due to intercropping. The water table which was above ground surface during rainy season and within 2 m during summer season before biodrainage plantation was lowered down to more than 3.6 m depth from ground surface after three to four years of plantation. From all above observations it could be said that the reclamation of waterlogged degraded land through biodrainage gives encouraging results. Drainage engineers should no longer ignore the opportunities that biodrainage systems can offer. Biodrainage is an attempt for cheaper drainage technology that could replace some of or be complementary to the more expensive remedies for solving the waterlogging/ drainage problems.

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Effect of Nutrient Management in Rice-*Lathyrus* (*paira*)-Greengram Cropping System under Coastal Saline Zone of West Bengal

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A field experiment was undertaken at Regional Research Station (Coastal Saline Zone) of Bidhan Chandra Krishi Viswavidyalaya during 2006-07 and 2007-08 under coastal saline soil (pH-7.6, organic carbon-0.53%, total N 1140 kg ha^{-1}, available phosphorus 15.20 kg ha^{-1} and available potassium 186.21 kg ha^{-1} respectively) of Kakdwip (Latitude-21°90'N, longitude-88°10'E and altitude-5.5m), West Bengal. The experiment was laid out in Randomized Block Design (RBD) with 9 different nutritional treatments each replicated four times, to evaluate the growth, productivity and economics in rice-*lathyrus* (*paira*)-greengram sequence. The growth parameters, yield components and seed yield of all the crops in sequence were the maximum when organic manure was applied along with inorganic fertilizer at 75% of the recommended dose (RD). The effect of well decomposed fishmeal (WDFM) was as good as farm yard manure (FYM) vis-à-vis vermicompost and sometimes it showed better result over FYM and vermicompost. The maximum rice equivalent yield, net returns and net production value in rice-lentil (*paira*)-sesame sequence were obtained from the crops treated with 75% RD of NPK+2 t WDFM ha^{-1} only to rice.

*(**Key Words:** Fishmeal, FYM, Vermicompost, Paira cropping, Coastal saline zone, Nutrient management)*

Presently fertilizer application is based on the nutrient requirement of individual crop and the carry-over effect of the manures or fertilizers applied to preceding crop are generally ignored. Further, application of inorganic fertilizers even in balanced amount can not sustain the soil fertility and crop productivity under diversified continuous cropping or mono-cropping and as a result of these things agriculture is now facing a lot of stresses. Integrated nutrient management involving conjunctive use of organic and inorganic sources of nutrients may improve the soil productivity (Patra *et al.*, 2000), and system productivity becomes sustainable (Raju and Reddy, 2000), rather to say, the soil-water-plant-animal-human continuum is maintained i.e. the agriculture is thus conserved to a large extent. It is fact that in the village cowdung is becoming scarce day-by-day, a large part of the available amount of it is used for preparing cowdung cakes for fuel purpose. So, emphasis should be given to use alternative sources (specifically different for different areas) for organic manures. In the coastal saline zone of West Bengal, farmers are habituated in applying raw fishmeal in the vegetables and some other crops, but it causes problems of disease and insect occurrence. Preparation of well-decomposed fishmeal (WDFM) from dried fish, easily and amply available at low cost in this zone and application of it increases the yield of crops without causing any pest problem and improves soil fertility simultaneously. In this context, with a broader objective of utilizing the organic resources for substituting the chemical fertilizer partly, augmenting the soil health for sustainability in agricultural production and increasing the cropping intensity of the coastal saline zone in an eco-friendly manner. Inclusion of low water requiring crop like pulses in the cropping sequence after kharif rice not only increases the cropping intensity but also promote optimal utilization of land-water-nutrient resources. Again, inclusion of grain legumes in rice based cropping system improves the soil health as a whole. Keeping this view in the background, a field experiment was conducted at Regional Research Station (Coastal Saline zone), Bidhan Chandra Krishi Viswavidyalaya, Kakdwip, 24 Pgs. (South), West Bengal during 2006-07 and 2007-08.

MATERIALS AND METHODS

The experiment was carried out at Regional Research Station of Coastal saline Zone, Bidhan Chandra Krishi Viswavidyalaya during rainy season

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(*Kharif*), winter season (*Rabi*) and summer season (pre-*kharif*) of 2006-07 and 2007-08 under coastal saline soil of Kakdwip (Latitude-21°90'N, longitude-88°10'E and altitude-5.5m), 24 Parganas (South), West Bengal. The experimental soil is silty clay loam in texture having pH 7.6, Bulk density 1.43 g cm^{-3}, EC 2.80 dSm^{-1}, organic carbon 0.53%, total nitrogen 1140.00 kg ha^{-1}, available phosphorus 15.2 kg ha^{-1} and available potassium 186.2 kg ha^{-1} respectively. The experimental site was subtropical humid climate with an average rainfall ranging between 1370 mm to 2280 mm and means maximum, minimum temperature of 15 to 37°C respectively. 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 T_1: 100% Recommended Dose (RD) of NPK; T_2: 75% RD of NPK; T_3: 50% RD of NPK; T_4: 75% RD of NPK+4 t vermicompost ha^{-1}; T_5: 50% RD of NPK+4 t vermicompost ha^{-1}; T_6: 75% RD of NPK+2 t well decomposed fishmeal (WDFM) ha^{-1}; T_7: 50% RD of NPK+2 t WDFM ha^{-1}; T_8: 75% RD of NPK+10 t farm yard manure (FYM) ha^{-1} and T_9: 50% RD of NPK+10 t FYM ha^{-1}.

The experiment was conducted for six consecutive seasons in the same piece of land without change in the layout. Starting with *Kharif* rice (cv. Khitish i.e. IET-4094) in 2006, was transplanted in the end of July in every year with recommended dose of fertilizers (60:30:30 kg NPK ha^{-1}), one popular grain legume lathyrus (cv. Nirmal i.e. N.P-24) widely cultivated as a Rabi pulse in the coastal saline zone of West Bengal, was grown as a paira crop at end of October with residual nutrient and moisture and it was followed by another short duration grain legume, greengram (cv. Panna i.e. B-105) was sown at 1st part of March in every year with residual nutrient. The sources of NPK were urea, single super phosphate (SSP) and muraite 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).

RESULTS AND DISCUSSION

Rice

The growth parameter of rice i.e., leaf area index (LAI), drymatter accumulation (DMA), plant height and crop growth rate (CGR) were differed significantly with the different nutritional management treatments at time of harvest (Table 1). The maximum LAI (0.95) and DMA (787.5 g m^{-2}) were recorded when the rice crop was fertilized with 75% RD of NPK along with 2 t WDFM ha^{-1} (T_6) and this treatment was statistically at par with the treatment T_1 (100% RD of NPK) and T_4 (75% RD of NPK+4 t vermicompost ha^{-1}). The significantly lowest value of LAI (0.66) and DMA (538.6 g m^{-2}) were obtained under the treatment where the rice crop was fertilized with only 50% RD of NPK (T_3). The maximum plant height (85.75 cm) at the time of harvest was recorded from the treatment T1 which had no significant difference with T_6. In case of CGR at 60-90 DAT, maximum (6.94 g m^{-2} day^{-1}) and minimum (4.18 g m^{-2} day^{-1}) values were found in the treatment T_6 and T_3 respectively, among all the treatment.

The yield components of rice like, number of panicles m^{-2} (306.7 m^{-2}), number of filled grains $panicle^{-1}$ (82.0) and percentage of grain filling (77.7%) were maximum under the treatment T_6 and it was statistically at par with treatment T_4. Conjunctive use of chemical fertilizer along with organic manure in general showed higher number of panicles m^{-2} as compared to use of inorganic fertilizer alone to the crop. The significantly lowest number of panicles m^{-2} (219.6 m^{-2}), filled grains $panicle^{-1}$ (69.5) and lowest percentage of filled grain (61.0%) were recorded from T_3 among all the treatment. The 1000 grain weight of rice did not differ significantly with different nutritional management treatment. The maximum grain yield (3760 kg ha^{-1}) was recorded in the treatment T_6 and it was closely followed by the treatment T_4. The significantly lowest grain yield of rice (2557 kg ha^{-1}) was found from the treatment T_3 among all the treatments. In case of straw yield and harvest index of rice showed similar trend as in grain yield. This result is an agreement with the findings of Patil *et al.*, (2000); they opined that application of 1, 2 and 3 t fishmeal ha^{-1} increased the grain yield of rice by 0.75, 1.86 and 2.93 t ha^{-1} respectively over no application of fishmeal.

***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 parameter (At harvest)				Yield components				Yield		Harvest
	LAI	DMA	Plant height (cm)	CGR 60-90 DAT	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})	index (%)
T_1	0.94	767.1	85.75	6.59	288.6	76.8	70.4	20.5	3506	4655	42.96
T_2	0.75	623.7	75.39	5.43	245.1	73.2	65.5	20.3	2968	4207	41.37
T_3	0.66	538.6	70.04	4.18	219.6	65.5	61.0	19.3	2557	3723	40.72
T_4	0.91	740.8	82.40	6.63	297.5	80.4	75.5	21.1	3627	4760	43.25
T_5	0.80	686.1	77.74	6.18	271.1	74.5	69.2	20.7	3396	4507	42.97
T_6	0.95	787.5	84.98	6.94	306.7	82.0	77.7	21.5	3760	4843	43.71
T_7	0.86	713.6	81.57	6.38	279.9	77.6	71.7	21.2	3425	4567	42.86
T_8	0.86	719.6	79.97	6.49	289.2	78.6	73.6	21.1	3541	4702	42.96
T9	0.77	664.9	76.14	5.77	262.2	73.4	68.3	20.8	3235	4486	41.90
SEm(±)	0.026	16.84	1.030	0.072	4.27	0.69	1.22	0.63	32.89	36.74	---
CD (P=0.05)	0.078	50.48	3.09	0.216	12.80	2.07	3.66	NS	98.60	110.15	---

*LAI - Leaf Area Index (%), 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: T_1: 100% Recommended Dose (RD) of NPK; T_2: 75% RD of NPK; T_3: 50% RD of NPK; T_4: 75% RD of NPK+4 t vermicompost ha^{-1}; T_5: 50% RD of NPK+4 t vermicompost ha^{-1}; T_6: 75% RD of NPK+2 t well decomposed fishmeal (WDFM) ha^{-1}; T7: 50% RD of NPK+2 t WDFM ha^{-1}; T8: 75% RD of NPK+10 t farm yard manure (FYM) ha^{-1} and T_9: 50% RD of NPK+10 t FYM ha^{-1}.

Lathyrus

Lathyrus crop was grown as a paira crop with residual nutrient and moisture. The growth parameter of lathyrus i.e., drymatter accumulation (DMA), crop growth rate (CGR) plant height and number of branches plant^{-1} were differed significantly with the different nutritional management treatments at time of harvest (Table 2). In case leaf area index (LAI) of lathyrus, did not differ significantly with different nutritional management treatment. At harvest, maximum value DMA (287.6 g m^{-2}) was observed where the previous crop, rice received 75% RD of NPK along with 2 t WDFM ha^{-1} (T_6) and this treatment was closely followed by the treatment T_4, T_8, T_7 and T_5 respectively. The maximum plant height (32.78 cm) and highest number of branches plant^{-1} (6.7) of lathyrus were obtained from the treatment T_6 which had no significant difference with the treatment T_4, and T_8. The shorter plant (23.61 cm) was found from the treatment T_3 (where the previous crop, rice received only 50% RD) whereas it produced the least number of branches plant^{-1} (4.9) among all the treatments. The CGR at 75-90 DAS, was varied significantly with the variation in nutritional management treatments. It ranged from 2.76 g m^{-2} day^{-1} (T_6) to 1.93 g m^{-2} day^{-1} (T_3).

Yield component of lathyrus like, number of pods plant^{-1} was maximum (13.6) in the treatment T_6 among all the treatments, which was closely followed by the treatment T_4 (Table 2). Though, the number of seeds pod^{-1} and 1000 seed weight did not significantly differ with the difference in nutritional treatments. The highest seed yield of lathyrus (905 kg ha^{-1}) was obtained from the treatment T_6 and it was statistically at par with the treatments T_4 and T_8, respectively. The lowest seed yield (631 kg ha^{-1}) of lathyrus was recorded from the treatment T3 among all the treatments. In case of straw yield of lathyrus showed similar trend as in seed yield. In case of harvest index treatment T4 (where the previous crop, rice received 75% RD of NPK along with 4 t vermicompost ha^{-1}) produced the highest value (32.89%) and this treatment was closely followed by the treatment T_6, T_8 and T_7, respectively. The similar finding reported by Bandyopadhyay and Puste (2002), they showed that higher yield and yield attributes of lentil, gram and grasspea were achieved where 25% of chemical fertilizer in winter (Kharif) rice was replaced by organic manure.

Greengram

Greengram is a good option as a summer (pre-*kharif*) crop in coastal saline zone of West Bengal due to its low water requiring and short duration nature. The growth parameter of greengram i.e., leaf area index (LAI), drymatter accumulation (DMA), plant height and number of branches plant^{-1} were differed significantly with the different nutritional management treatments at time of harvest (Table 3). In case of LAI (1.59), DMA (322.5 g m^{-2}), plant height (47.28 cm) and number of branches plant^{-1} was maximum (6.5) were maximum under the Treatment T6 where rice was fertilized with 75% RD of NPK along with 2 t WDFM ha^{-1}, where as T_3 produced least number of branches plant^{-1} (4.9) and it closely followed by the treatment T_2 and T_1 respectively. The CGR of greengram at 45 to 60 DAS ranged from 9.26 g m^{-2} day^{-1} (T_6) to 6.71 g m^{-2} day^{-1} (T_3) respectively.

The yield components of greengram i.e., number of pod plant^{-1} and numbers of seed pod^{-1} were varied significantly with the variation in nutritional management treatments (Table 3). The maximum number of pod plant^{-1} (13.2) and number of seed pod^{-1} (9.1) were noticed in the treatment T_6 flowed by T_4, and T_8 respectively. The lowest number of pod plant^{-1} (9.5) and number of seed pod^{-1} (6.6) were recorded from T_3 among all the treatment. The 1000 seed weight of greengram did not vary significantly with different nutritional management treatments. The maximum seed yield (723 kg ha^{-1}) and stover yield (2271 kg ha^{-1}) were recorded under the treatment T_6 and it was closely followed by the treatments T_4 and T_8 respectively, whereas the treatment T_3 produced the lowest seed yield (457 kg ha^{-1}) and stover yield (1830 kg ha^{-1}) of greengram followed by T_2 and T_1 among all the treatments. In case of harvest index, the maximum (24.15%) and minimum (19.63%) values were found in the treatment T_6 and T_2, respectively among all the treatment.

Rice equivalent yield

From the Table 4, it is cleared that the maximum rice equivalent yield (6329.4 kg ha^{-1}) was found where the rice crop received 75% RD of NPK along with 2 t WDFM ha^{-1} (T_6) and this treatment was closely followed by the treatment T_4 (6213.4kg ha^{-1}) where the rice crop was fertilized with 75% RD of NPK along with 4 t vermicompost ha^{-1}. The treatment T_3 (where the rice crop received only 50% RD of NPK) recorded the lowest value of rice equivalent yield (4383.9 kg ha^{-1}) among all the treatments. This is corroborated with the findings of Brahmachari *et al.*, 2009.

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

Treatments	Growth parameter (At harvest)					Yield components			Yield		Harvest index (%)
	LAI	DMA	Plant height (cm)	No. of branches $plant^{-1}$	CGR 75-90 DAS	No. of pod $plant^{-1}$	No. of seed pod^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	
T_1	0.39	235.0	26.05	5.5	2.27	9.3	3.0	61.3	687	1570	30.44
T_2	0.35	223.3	24.03	5.3	2.18	7.9	2.9	61.9	664	1507	30.59
T_3	0.33	219.4	23.61	4.9	1.93	7.3	2.7	60.7	631	1429	30.63
T_4	0.63	271.2	31.98	6.5	2.71	12.9	3.6	61.3	846	1726	32.89
T_5	0.54	242.5	29.84	5.7	2.31	10.2	3.3	61.0	771	1653	31.81
T_6	0.65	287.6	32.78	6.7	2.76	13.6	3.8	61.6	905	1851	32.84
T_7	0.57	254.1	30.26	5.9	2.40	11.3	3.4	61.4	803	1698	32.11
T_8	0.55	262.9	30.72	6.1	2.63	11.5	3.5	61.0	819	1725	32.19
T_9	0.42	240.8	27.70	5.6	2.25	9.9	3.1	62.3	737	1606	31.46
SEm(±)	0.11	18.7	1.08	0.55	0.15	0.82	0.39	1.88	30.15	45.36	—
CD (P=0.05)	NS	56.06	3.24	1.65	0.45	2.46	NS	NS	90.39	135.99	—

*LAI- Leaf Area Index (%), DMA- Dry Matter Accumulation (g m^{-2}), CGR- Crop Growth Rate (g m^{-2} day^{-1}) **DAS- Days After Sowing ***NS- Non Significant

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

Treatments	Growth parameter (At harvest)					Yield components			Yield		Harvest index (%)
	LAI	DMA	Plant height (cm)	No. of branches $plant^{-1}$	CGR 45-60 DAS	No. of pod $plant^{-1}$	No. of seed pod^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	
T_1	1.39	268.2	39.00	4.8	7.48	10.2	7.9	32.9	516	2060	20.03
T_2	1.37	249.3	35.98	4.5	7.07	9.8	7.4	33.6	485	1986	19.63
T_3	1.34	238.5	34.77	4.3	6.71	9.5	6.6	32.5	457	1830	19.98
T_4	1.55	311.0	46.58	6.1	9.17	12.8	8.7	33.8	696	2254	23.59
T_5	1.46	266.8	42.53	5.4	7.70	11.1	8.3	33.6	582	2104	21.67
T_6	1.59	322.5	47.28	6.5	9.26	13.2	9.1	32.8	723	2271	24.15
T_7	1.48	278.5	44.20	5.7	7.94	11.7	8.4	33.0	627	2150	22.58
T_8	1.53	301.3	45.73	5.8	8.70	12.3	8.2	32.8	639	2174	22.72
T_9	1.42	261.63	41.85	5.0	7.28	10.6	8.1	33.1	545	2079	20.77
SEm(±)	0.04	12.45	1.70	0.44	0.29	0.57	0.34	0.66	24.72	87.92	—
CD (P=0.05)	0.119	37.33	5.10	1.32	0.869	1.71	1.02	NS	74.11	263.58	—

*LAI- Leaf Area Index (%), DMA- Dry Matter Accumulation (g m^{-2}), CGR- Crop Growth Rate (g m^{-2} day^{-1}) **DAS- Days After Sowing ***NS- Non Significant

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

Treatments	Rice equivalent yield (kg ha^{-1})	Net Returns (Rs. ha^{-1})	Net Production Value (NPV)
T_1	5105.3	24346.82	1.20
T_2	4705.4	21347.28	1.09
T_3	4383.9	20726.95	1.06
T_4	6213.4	32609.11	1.52
T_5	5602.7	28249.53	1.40
T_6	6329.4	33946.16	1.55
T_7	5740.9	29294.75	1.43
T_8	5939.0	31022.74	1.42
T_9	5346.7	26981.49	1.25

Net production values (NPV) per unit investment

From Table 4, it may be conclude that the maximum net production value (1.55) was obtained where the rice crop received 75% RD of NPK along with 2 t WDFM ha^{-1} (T_6) and it was closely followed by that (1.52) recorded in the treatment T_4 (75% RD of NPK along with 4 t vermicompost ha^{-1}). Among all the treatments, T_3 (where the rice crop received only 50% RD of NPK) showed the minimum value of net production value (1.06). This result corroborates with the findings of Pal *et al.*, (2005). Application of fishmeal at 2 t ha^{-1} along with 75% RD of NPK in rice showed the best result under coastal saline zone of West Bengel (Brahmachari *et al.*, 2009 and Pal *et al.*, 2010).

Thus, it may be concluded that utilization of different organic resources of the coastal saline zone for partial substitution of chemical fertilizers not only offers higher crop yields but also augments the soil fertility as a whole for sustainability in agricultural production vis-à-vis eco-friendly recycling of different organic matter or waste. Inclusion of different winter (*Rabi*) and summer (pre-*kharif*) crop after winter (*Kharif*) rice may increase the cropping intensity of the conventional mono-cropped coastal areas properly. The growth parameters, yield components and productivity of all the crops in sequence were the maximum when organic manure was applied along with inorganic fertilizer at 75% of the recommended dose. The effect of well decomposed fishmeal was as good as farm yard manure (FYM) vis-à-vis vermicompost and sometimes it showed better result over FYM and vermicompost. The maximum rice equivalent yield and net returns in rice-*lathyrus* (*paira*)-greengram sequence were obtained from the crop treated with well decomposed fishmeal.

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A Variant of Van der Molen's Model for Leaching in Saline Soils

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The productivity of the saline agricultural lands is very much affected by the accumulated salts in the crop root zone, which reduces the intake of soil water by the plants through the osmotic effect. To enhance the crop productivity, reclamation of the saline soils through leaching is essential for reducing the salt concentration in the crop root zone. During the process of leaching, the encroaching water mixes with the soil solution. Since the mixing of solutes in the inflow with the soil water is different in different soil reservoirs, the concept of series of reservoirs with bypass is advocated to model the process of solute movement through porous media. Although the Van der Molen's model based on the concept of cascade of reservoirs connected in series has been popular among the researchers for the study of the desalinization process, in this study, the generalized model is found to be inappropriate; especially in the cascades of higher order reservoirs. Consequently, this paper presents the detailed rederivation of the Van der Molen's model to model the process of solute transfer in porous media based on the same assumptions and found to be different. A numerical experimental study of the variations among the models indicated that the original model always over-predicts the salt concentrations than the newly derived model.

(***Keywords:*** *Desalinization, Leaching, Reclamation, Solute transfer, Series of reservoirs*)

The reclamation of saline soils involves leaching of the excess salts from the crop root zone (FAO-UNESCO, 1973; Diamantis and Voudrias, 2008; Fahad et al., 1988), by which the excess salts are removed to lower the electrical conductivity (EC) of the soil water below the permissible limit. The main aim of an effective amelioration of the saline soils is to keep the water table below the critical depth by drainage and to reduce the salt concentration in the root zone (Szabolcs, 1989; Ritzema, 1994; United States Salinity Laboratory Staff, 1954). However, the complete mixing of solutes in soil water over the entire depth of root zone (often 1 m or more) is unrealistic (ILRI, 1979). For the study of the desalinization phenomena, the Van der Molen's model based on the concept of cascade of reservoirs connected in series has been popular among the researchers. To account for the limited range over which mixing is complete, the Van der Molen's model (Van der Molen, 1957) assumes that the root zone of the soil consists of different reservoirs horizontally, where the depth of each reservoir is equal. Each reservoir receives the outflow from the overlying one where the reservoir mixing is complete. For irrigation water with the salt concentration of C_1 and leaching efficiency of f, the Van der Molen's model for the salt concentrations in successive soil reservoirs of equal volume is given by (ILRI, 1979).

1st reservoir : $$C_I = C_i + (C_0 - C_i)e^{-\frac{ft}{T}} \quad (1)$$

2nd reservoir : $$C_{II} = C_i + (C_0 - C_i)\left(1 + \frac{ft}{T}\right)e^{-\frac{ft}{T}} \quad (2)$$

3rd reservoir : $$C_{III} = C_i + (C_0 - C_i)\left(1 + \frac{ft}{T} + \frac{f^2t^2}{2T^2}\right)e^{-\frac{ft}{T}} \quad (3)$$

4th reservoir : $$C_{IV} = C_i + (C_0 - C_i)\left(1 + \frac{ft}{T} + \frac{f^2t^2}{2T^2} + \frac{f^3t^3}{6T^3}\right)e^{-\frac{ft}{T}} \quad (4)$$

Nth reservoir : $$C_N = C_i + (C_0 - C_i)e^{-\frac{ft}{T}}\sum_{n=0}^{n=N-1}\left(1 + \frac{f^nt^n}{n!T^n}\right) \quad (5)$$

where C_N = salt concentration in the Nth reservoir [ML^{-3}]; C_1 = salt concentration of the irrigation water used for leaching [ML^{-3}]; C_0 = original salt concentration of the reservoir solution [ML^{-3}]; f = leaching efficiency (0< <1); t = time [T]; T = v/Q = ratio of the volume of reservoir to the flow rate at which the soil moisture is replaced [T]; v = volume of reservoir [L^3]; and Q = rate of inflow [L^3T].

As mixing of the solutes in the inflow with soil water of root zone is different in different soil reservoirs, the series of reservoirs concept is conceived. To account for the cracks and crevices, reservoir with bypass is considered. Each reservoir receives the outflow from the upper reservoir, where mixing is complete. In this study, two variants of the Van der Molen's model are derived from the basic equations of solute transfer which are compared with the original model through numerical experiments.

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MATERIALS AND METHODS

In actual condition, the water infiltrated into the soil, does not become completely miscible with the existing ground water. Part of the infiltrated water percolates through macro-pores and cracks but difficult to pass through micropores. The bypass flow concept takes into account this situation. The main assumption is that, there is no chemical or physical reaction during the flow of water. Following the same bypass principle for series of reservoirs as Van der Molen (1957), the mathematical model for each reservoir in reservoirs in series is rederived below. To verify the performance of the two variants of the Van der Molen's model with respect to the original model, a numerical experimental study is carried out at Central Soil Salinity Research Institute, Regional Research Station, Canning Town during 2009-11.

RESULTS AND DISCUSSION

Model Development

The top soil layer is designated as the first reservoir, ~~and the subsequent soil layers below~~ the top soil layer of equal depth is designated as the higher order reservoir.

Single Reservoir with Complete Mixing

The salt balance for a reservoir with complete mixing can be given by

$$C_1Qdt = C_eQdt + vdC \qquad (6)$$

where C = average salt concentration of the reservoir solution [ML^{-3}]; and C_e = salt concentration of the effluent [ML^{-3}].

When mixing is complete, and, hence,

$$C_1Qdt = C_eQdt + vdC \qquad (7)$$

or

$$\frac{dC}{C - C_i} = -\frac{1}{T}dt \qquad (8)$$

Integrating both sides of Eq. (8) yields:

$$\int_{C_0}^{C}\frac{dC}{C - C_i} = \int_{0}^{t}-\frac{1}{T}dt \qquad (9)$$

i.e.,

$$\ln\frac{C - C_i}{C_0 - C_i} = -\frac{t}{T} \qquad (10)$$

i.e.,

$$C = C_i + (C_0 - C_i)e^{-\frac{t}{T}} \qquad (11)$$

First Reservoir with Complete Mixing and Bypass

During the process of leaching, the irrigation or rainwater is unlikely to mix completely with the soil solution. Thus, considering the reservoir with bypass, the concentration of solute in the outflow can be computed as (ILRI, 1979)

$$C_e = fC + (1 - f)C_1 \qquad (12)$$

The salt balance equation (7) can be rewritten as

$$C_1Qdt = C_eQdt + vdC \qquad (13)$$

Substituting from Eq. (12) in (13), one obtains

$$C_1Qdt = \{fC + (1 - f)C_1\}\ Qdt + vdC \qquad (14)$$

Rearranging Eq. (14), we get

$$\frac{dC}{C - C_i} = -\frac{1}{T}dt \qquad (15)$$

Integrating both sides of Eq. (15) yields:

$$\int_{C_0}^{C}\frac{dC}{C - C_i} = \int_{0}^{t}-\frac{f}{T}dt \qquad (16)$$

i.e.,

$$\ln\frac{C - C_i}{C_0 - C_i} = -\frac{ft}{T} \qquad (17)$$

i.e.,

$$C = C_{e1} = C_i + (C_0 - C_i)e^{-\frac{ft}{T}} \qquad (18)$$

Second Reservoir with Complete Mixing and Bypass

As the second reservoir receives the outflow from the first reservoir ($C_{e1} = C_{i2}$), the effluent concentration in the 2nd reservoir can be given as

$$C_{e2} = C_{e1} + (C_0 - C_{e1})e^{-\frac{ft}{T}} \qquad (19)$$

Using Eq. (18) in (19), one obtains

$$C_{e2} = C_i + e^{-\frac{ft}{T}}(C_0 - C_i)\left(2 - e^{-\frac{ft}{T}}\right) \qquad (20)$$

Using the first two terms of the Taylor series expansion that

$$e^{-\frac{ft}{T}} = 1 - \frac{ft}{T} + \frac{f^2t^2}{T^2} - \frac{f^3t^3}{T^3}\ldots \qquad (21)$$

Equation (20) can be modified as

$$C_{e2} = C_i + (C_0 - C_i)\left(1 + \frac{ft}{T}\right)e^{-\frac{ft}{T}} \qquad (22)$$

Third Reservoir with Complete Mixing and Bypass

The third reservoir receives the effluent from the second reservoir. Hence,

$$C_{e3} = C_{e2} + \left(C_0 - C_{e2}\right)e^{-\frac{ft}{T}} \tag{23}$$

Using Eq. (20) in (23) and after simplification, one obtains

$$C_{e3} = C_i + e^{-\frac{ft}{T}}\left(C_0 - C_i\right)\left(3 - 3e^{-\frac{ft}{T}} + e^{-2\frac{ft}{T}}\right) \tag{24}$$

Using the first two terms of the Taylor series expansion of Eq. (21) in (24), and after simplification, we get

$$C_{e3} = C_i + e^{-\frac{ft}{T}}\left(C_0 - C_i\right)\left[1 + \frac{ft}{T} + \frac{f^2t^2}{T^2}\right] \tag{25}$$

Fourth Reservoir with Complete Mixing and Bypass

The effluent concentration from the 4th reservoir can be given as

$$C_{e4} = C_{e3} + \left(C_0 - C_{e3}\right)e^{-\frac{ft}{T}} \tag{26}$$

Using Eq. (24) in (26) and after simplification, one obtains

$$C_{e4} = C_i + e^{-\frac{ft}{T}}\left(C_0 - C_i\right)\left(4 - 6e^{-\frac{ft}{T}} + 4e^{-2\frac{ft}{T}} - e^{-3\frac{ft}{T}}\right) \tag{27}$$

Using the first two terms of the Taylor series expansion of Eq. (21) in (27), and after simplification, we get

$$C_{e4} = C_i + e^{-\frac{ft}{T}}\left(C_0 - C_i\right)\left[1 + \frac{ft}{T} + \frac{f^2t^2}{T^2} + \frac{f^3t^3}{T^3}\right] \tag{28}$$

Hence, the generalized form of the effluent concentration from the Nth soil reservoir can be expressed as

$$C_{eN} = C_i + e^{-\frac{ft}{T}}\left(C_0 - C_i\right)\left(\sum_{n=0}^{n=N-1} \frac{f^n t^n}{T^n}\right) \tag{29}$$

Based on the above derivation, the two variants of the Van der Molen's model can be deduced as: a) the approximated model derived using the Taylor's series approximation (Variant model-I) represented by Eq. (29); and b) the full model derived without using the Taylor's series approximation (Variant model-II) represented by Eqs. (18), (20), (24), and (27) for the first, second, third, and fourth reservoirs, respectively.

Numerical Experiment

The desalinization of the soil profile represented by Table 1 by rainfall is considered, wherein the salt concentration is not the same over the entire depth of the soil profile. It is assumed that the electrical conductivity of rainwater, $C_0 = 0$, and the leaching efficiency of all the soil layers, $f = 1$. However, in reality, the leaching efficiency decreases with the increase in soil depth.

Table 1. *Salt concentrations in different soil layers*

Soil layer (cm)	0-25	25-50	50-75	75-100
ECe (mmhos/cm)	12	18	24	28

The normalized salt concentrations (C_e / C_0) in different soil layers (reservoirs) are calculated corresponding to the normalized time (t/T). The full model (i.e., variant model-II) is considered as the benchmark model and the performance of all the models are calculated in comparison with this benchmark model. The percentage error in the estimation of C_e with respect to the benchmark model is calculated as

$$Err = \left(1 - \frac{C_{ecomp}}{C_{ebm}}\right) \times 100 \tag{30}$$

where C_{ecomp} = computed C_e by the original model; and C_{ebm} = computed C_e by the benchmark model.

Fig. 1 shows the normalized plots of salt concentrations with normalized time by different models at different soil layers of 0-25 cm, 25-50 cm, 50-75 cm, and 75-100 cm. Figure 1a reveals that, for the first reservoir (soil layer of 0-25 cm), all the models perform equally. However, with the increase in the order of the soil reservoir, the performance of the original model and the variant model-I decreases drastically. Moreover, as envisaged from Figures 1c and 1d, the computed value of C_e /C_0 by the variant model-I is greater than 1, which is practically impossible. Hence, the variant model-I, given by Eq. (29), is discarded in this study for its field use.

The percentage error in the estimation of by the original Van der Molen's model with respect to the full model (i.e., variant model-II) is illustrated in Fig. 2. For the first soil reservoir, both the models

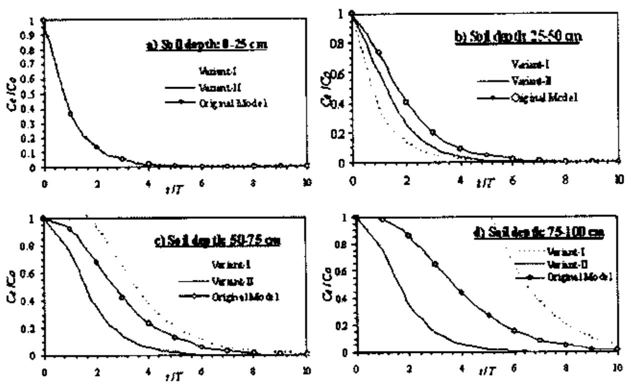

Fig. 1. Salt concentrations simulated by the variants of Van der Molen's model at different soil layers of a) 0-25 cm, b) 25-50 cm, c) 50-75 cm, and d) 75-100 cm

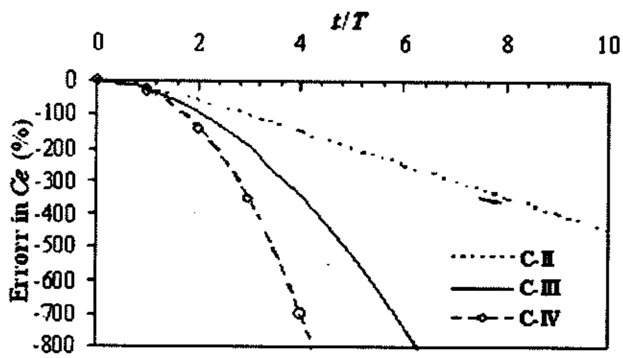

Fig. 2. Error in salt concentrations simulated by the Van der Molen's model with respect to the variant model-I at different soil layers of C-II (25-50 cm), b) C-III (5-75 cm), and d) C-IV (75-100 cm)

perform equally. However, with the increase in the order of the soil reservoir, the error level increases with . Note that the original Van der Molen's model always over-predicts the value of than the full model. Hence, it is always better to use the full model (variant model-II) than the original approximated model for field application.

One advantage of using the original Van der Molen's model over the full model could be for its general expression as given by Eq. (5). However, with the recent advances of computing skill, the full model can be used efficiently for the field application.

The Van der Molen's model for desalinization of the soil profile is re-derived from the basic equations of solute transfer, which differs from the original model, especially in the higher order reservoirs. The numerical experimental study reveals that the original model always over-predicts the salt concentrations than the full model. Hence, the full model derived without using the Taylor series expansion is recommended for its field use than using the original Van der Molen's model for predicting the solute concentration in the effluent.

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Crop Establishment Techniques for Sustaining Productivity of Wet Direct-sown Summer Rice in Flood-prone Lowlands of Coastal Orissa

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A field experiment was conducted during the dry seasons of 2008 and 2009 at Cuttack to study the effect of different crop establishment methods on yield and economics of wet direct-sown summer rice. The highest grain yield (6.05 t ha^{-1}) was recorded in transplanted plots (TPR). But comparable yield (5.89 t ha^{-1}) was also obtained from wet spot seeding (WSS) at 15 cm x 15 cm row spacing. Greater tiller number as well as higher panicle number and filled grains per panicle resulted in significant increase in grain yield in TPR and WSS (at 15 cm x 15 cm). About 17% yield reduction was recorded in wet broadcast sown (WBS) plots over TPR. The highest net return (Rs. 24,780 ha^{-1}) was obtained in WSS (15 cm x 15 cm) due to higher yield and less labour requirement with respect to TPR. All the direct-sown plots showed higher benefit : cost ratio (2.70-2.83) over TPR (2.56) and the highest benefit : cost ratio (2.83) was recorded in plots where the crop was established by plastic drum seeder (DS) at 15 cm apart rows. Thus, establishment of rice crop by wet direct seeding with pre-germinated (sprouted) seeds was more economic and served as alternate method of crop establishment for sustaining the productivity of flood-prone lowlands of coastal Orissa.

(**Key Words:** *Sowing methods, Grain yield, Economics, Summer rice, Coastal Orissa*)

About 89% of the total flood prone lowlands in the country are distributed in five states of eastern India viz., Assam, West Bengal, Bihar, Orissa and eastern Uttar Pradesh. Rice farming has been found to be very risky in those areas during the wet season due to unpredictable hydrology. The flood-prone lowlands of coastal Orissa are highly diverse, complex and fragile in nature. The productivity of rice is very low (0.8 - 1.0 t ha^{-1}) and uncertain due to lack of suitable rice varieties and poor management techniques (Saha *et al.*, 2008). During wet season, it experiences abiotic stresses viz. drought, submergence, waterlogging, flash floods etc. along with the additional problems of salinity (in certain pockets) and cyclonic disturbances. Besides these, the crop also suffers due to several biotic stresses too viz, weeds (mostly broad-leaf and aquatic weeds), diseases (like bacterial blight, false smut, sheath blight etc.) and insects (like stem borer, leaf folder, plant hopper etc.).

To meet the daily food requirement, farmers are now slowly shifting to summer rice cultivation by utilizing the harvested rain water stored in small ditches, village ponds etc. scattered in this ecosystem and also by trapping the under ground water through shallow tube well. Cultivation of rice during dry season (summer rice) offers a great potential for boosting and stabilizing the yield. The normal practice of crop establishment under such situation is transplanting. However, establishing rice crop by transplanting becomes a major constraint due to acute shortage of labour during the time of planting and high labour cost. Sowing pre-germinated (sprouted) seeds in wet (saturated) puddle soils offers a good alternative method of crop establishment under such situation (Moorthy and Saha 2002). It also offers several advantages like faster and easier establishment, less drudgery, earlier crop maturity by 7-10 days, more efficient water use and higher tolerance to water deficit, and often higher profit in areas with an assured water supply (Balasubramanian and Hill 2002). The Asian rice farmers started shifting to direct seeding as an attractive alternative of transplanting since 80s' to reduce labour input, drudgery and cultivation cost (De Datta 1986; De Datta and Flinn 1986). It is becoming now very popular in several Asian countries like Malaysia, Thailand, Philippines, Vietnam and even Bangladesh during the dry season under controlled water condition. The increased availability of short duration rice varieties has further encouraged farmers to explore this new

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method of establishing rice (Saha, 2008). In wet seeded rice, farmers generally broadcast pre-germinated seeds directly on the puddle and leveled field (Moody and Cornova, 1985). It was found that crop establishment was not uniform and weed control was also difficult in broadcast seeding (Jaffar *et al.*, 1995). However, such operational problems for better crop establishment and weeding can be minimized through line or spot sowing of pre-germinated seeds on puddle field. Hence, the present investigation was undertaken to study the effect of different crop establishment methods on yield performance and economics of wet direct-sown summer rice in flood-prone lowlands of coastal Orissa.

MATERIALS AND METHODS

A field experiment was carried out during the dry seasons (January-May) of 2008 and 2009 at the Central Rice Research Institute, Cuttack in an alluvial (*Haplaquept*) clay loam soil with pH 6.4, organic carbon 0.63%, total nitrogen 0.070%, Olsen's P 27 kg ha^{-1} and available K 99 kg ha^{-1} to standardize the crop establishment methods of wet direct-sown summer rice. The treatments consisted of different sowing methods viz., broadcast seeding with 70 and 80 kg seeds ha-1, spot (dibble) seeding at 15 cm x 15 cm and 20 cm x 20 cm row spacing, continuous line seeding at 15 cm apart rows, sowing by drum seeder at 15 cm row spacing and transplanting at 15 cm x 15 cm spacing as check.. The total 7 treatments were evaluated in a randomized complete block design with four replications. The rice variety 'Naveen' (115 days duration) was established as per the treatments with recommended fertilizer dose of 100 : 50 : 50 kg N, P_2O_5 and K_2O ha^{-1}. Full dose of P_2O_5 and 2/3rd of K_2O were applied before sowing at final land preparation and N was applied in 3 splits, half at early vegetative stage (2 weeks after sowing) and the rest half at two equal splits at 5 and 8 weeks after sowing. The rest 1/3rd of K_2O was applied along with third dose of N. For all the six methods of wet seeding, pre-germinated (sprouted) seeds were sown on January 11 and January 15 during 2008 and 2009, respectively, in properly leveled field under saturated puddle condition with no standing water on the surface. Three weeks old seedlings uprooted from the nursery beds were used for transplanting. An herbicide mixture of bensulfuron methyl + pretilachlor (50 + 450 g a.i. ha^{-1}) was applied in saturated rice field at 18 days after sowing (DAS) as post-emergent spray using knapsack sprayer fitted with flat fan nozzle at spray volume of 500 litre ha^{-1} for controlling the predominant weeds. The experimental field kept saturated during first 7-10 days, and then maintained water level at 3-5 cm for the next 21 days except at the time of herbicide application (on 18 DAS). Afterwards, irrigation water was applied at 3-5 cm depth after disappearance of water from the field till 15 days prior to maturity. All the other recommended agronomic and plant protection measures were adopted. Rice plants were collected from one square meter sample area of each plot for the measurements of the parameters viz., tiller number, panicle number and number of grains per panicle. Grain and straw yield of rice were recorded at harvest. The data were analysed according to randomized block design by standard ANOVA. Regression analysis between tiller number and panicle number with grain yield was also carried out. Economics were calculated following standard technique.

RESULTS AND DISCUSSION

Grain yield and its components

Tillering efficiency (tiller number per sq m) was found significantly better under transplanted rice (TPR) as compared to other planting methods but it was comparable with wet seeding in spots (WSS) at 15 cm x 15 cm spacing (Table 1). Among all the direct seeding methods, WSS showed higher number of tillers due to more space available between hills, leading to better plant growth and grain yield compared to wet seeding in line (WSL), drum seeding (DS) or wet seeding by broadcast (WSB). The tiller number increased by about 21% in WSS at 15 x 15 cm spacing over WSB with 70 kg seed ha^{-1}. However, increasing the seed rate from 70 kg ha^{-1} to 80 kg ha^{-1} in case of WSB did not show any significant increase in tiller number. Furthermore, spot seeding helped to maintain optimum plant population avoiding either low or high plant density as frequently encountered in broadcasting of seeds. Thakur *et al.*, (2004) also opined alike. The tiller number and crop yield was positively correlated (Fig 1). The increase in number of tillers had higher incremental effect on TPR and WSS (slope : 0.0126, r^2 = 0.976). The panicle number was also found to be significantly higher in TPR and WSS (at 15 cm x 15 cm) compared to other methods of crop establishment. The main factor affecting rice yield i.e., panicle number is directly proportional to tiller

Table 1. *Effect of different crop establishment methods on yield components, grain yield and economics of wet direct-sown rice (pooled data of 2 years)*

Sowing method	Tiller no./ m^2	Panicle/ m^2	Grain/ panicle	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Net return (Rs. ha^{-1})	B:C Ratio
WBS (70)	286	264	82	5	5.26	20,865	2.77
WBS (80)	298	277	86	5.1	5.40	21,085	2.70
WSS (15x15cm)	361	343	107	5.89	6.19	24,780	2.77
WSS (15x20cm)	344	329	101	5.79	6.04	23,975	2.70
RSL (15)	313	291	91	5.29	5.55	21,700	2.64
DS (15)	329	302	97	5.65	5.85	23,725	2.83
TPR (15 x 15 cm)	372	349	110	6.05	6.31	24,450	2.56
CD (P=0.05)				0.20	0.24		

WBS : wet broadcast seeding; WSS : wet spot seeding; RSL : row seeding in lines; DS : drum seeding; TPR : transplanted rice

number, which is function of the number of seedlings per unit area. The WSS method at both the spacing (15 x 15 cm and 15 x 20 cm) ensured more seedlings per unit area compared to other methods of wet seeding. Thus from results, it appeared that WSS at 15 cm x 15 cm spacing promoted comparable tiller frequency as well as panicle number with transplanting (Table 1). The increase in panicle number per unit area also showed positive correlation with grain yield (slope: 0.0121, r^2 = 0.955) (Fig 2). Yoshida (1981) also reported that rice yield has a strong functional relationship with the number of tillers as well as the number of panicles per hill.

The number of filled grains per panicle was significantly higher in both TPR and WSS. This might be due to better crop establishment as reflected from higher number of tillers and panicles per unit area in TPR and WSS (Table 1). It was also observed that WSS (at 15 cm x 15 cm spacing) produced significantly the highest number of grains per panicle among different wet seeding treatments. It was 23% more over WSB with recommended seed

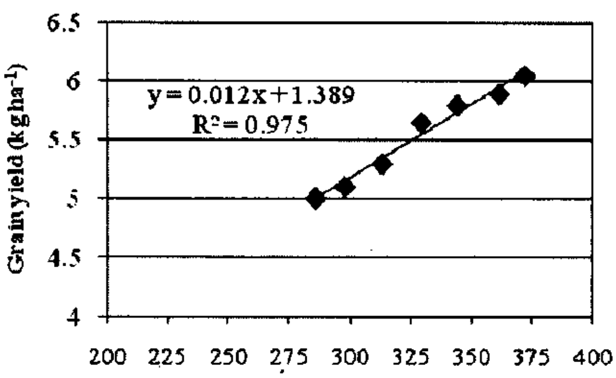

Fig 1. Regression between tiller number and grain yield

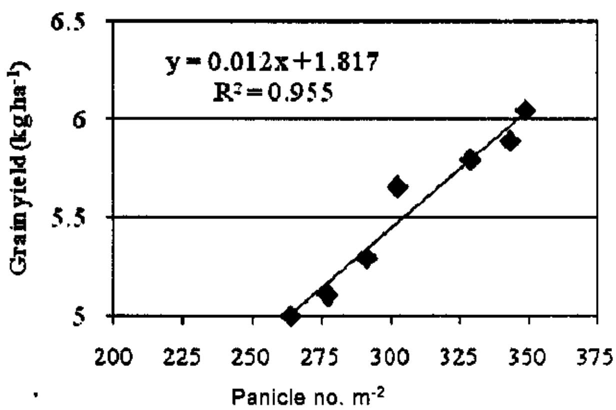

Fig. 2. Regression between panicle number and grain yield

rate of 70 kg ha^{-1}. Thus, it was found that establishment of crop played a major role on grain filling and final yield of wet direct-sown rice. The highest grain yield (6.05 t ha^{-1}) was recorded in transplanted plots. But comparable yield (5.89 t ha^{-1}) was also obtained when the crop was established by WSS (at 15 cm x 15 cm spacing). Higher number of tiller and panicle per unit area and filled grains per panicle resulted in significant increase in grain yield in TPR and WSS (at 15 x 15 cm). Continuous seeding in lines at 15 cm apart rows showed 10% yield reduction over WSS (at 15 cm x 15 cm). The lower yield was recorded in WSB method. This might be due to poor crop establishment as reflected from less tiller and panicle numbers per unit area in these treatments. About 17% yield reduction was recorded in plots sown by broadcast with 70 kg seed ha^{-1} over transplanted rice (Table 1). Similar (Reddy *et al.*, 1995) or higher (Shekar and Singh, 1991, Thakur *et al.*, 2004) grain yields under wet seeding compared to transplanted rice were also observed by several other researchers. Straw yield also showed similar trend as in grain yield (Table 1).

Economics and return

The highest net return (Rs. 24,780 ha^{-1}) was obtained in WSS at 15 cm x 15 cm row spacing. Though the grain yield of rice was higher in TPR but the net income was little less in TPR (Rs 24,450 ha^{-1}). It might be due to relatively better yield and less labour requirement in wet seeding with respect to TPR. Wet seeding reduced the amount of labour needed for growing a rice crop compared to TPR (Erguiza *et al.*, 1990, Polvatana, 1995). Thakur *et al.*, (2004) reported that there was 5-20% reduction in total labour requirement in wet seeding depending upon the methods of crop establishment. Wet seeding eliminates the use of seedlings and related operations such as seedling nursery preparation, care of seedling, pulling, bundling, transporting and transplanting (Serrano, 1975). The net return and crop yield was positively correlated with correlation coefficient of 0.960 (Fig 3). This was further supported by the regression analysis (Equation III).

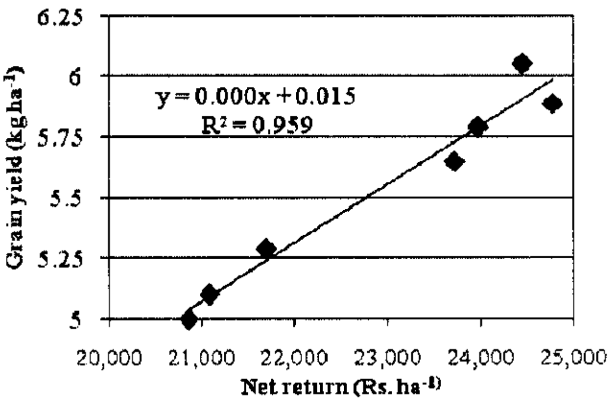

Fig 3. Regression between grain yield and net return

$$Y = 0.0152 + 0.0002X \qquad ......(III)$$

The highest benefit : cost ratio i.e., income per rupee investment (2.83) was recorded in plots where the crop was established by plastic drum seeder (DS) at 15 cm apart rows. It was also found that all the direct-sown plots showed higher benefit : cost ratio (2.70-2.83) than TPR (2.56). Thus, it may be concluded that establishment of rice crop by wet direct seeding with pre-germinated (sprouted) seeds is more economic and serve as alternate method of crop establishment for sustaining the productivity of flood-prone lowlands of coastal Orissa.

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J. Indian Soc. Coastal agric. Res. 29(2): 78-79 (2011) **Short Communication**

Impact of Subsurface Drainage System on Reduction of Soil Salinity at Kalipatnam : A case Study

In Andhra Pradesh, the command areas affected by waterlogging and salinity are estimated to be 2.74 lakh ha and 1.15 lakh ha respectively in canal commands alone. In many canal commands, there has been a rise in the water table and consequent degradation of soils through waterlogging and secondary salt build-up and the impact of irrigation over many years has caused the ground water table to rise into root zones in these command areas, which led to reduction in crop yield. This problem is found to be aggressive along the coastal line of Andhra Pradesh. The soils of Godavari Western delta near to the sea are experiencing problem of salinity and waterlogging due to seawater intrusion. The technology of sub-surface drainage system is the most appropriate under the salinity and waterlogging conditions to leach out the harmful excess salts from the crop root zone, providing a better environment to the plants to grow (Anonymous, 2000a and Anonymous, 2000b). Hence, Kalipatnam drainage pilot area was selected to study the impact of sub-surface drainage system on reclamation of salt affected soils under Godavari western delta.

Kalipatnam drainage pilot area (16°23′ N, 81°32′ E) is located in Godavari Western Delta near east coast of Peninsular India. The soils are saline sodic and water logged. Soils are alluvial and adjacent to salt stream (Upputeru) which is joining sea at a distance of 9 km is also having influence on the ground water quality. Therefore, effective salinity control must include not only adequate drainage to control and stabilize the water table but also a net downward movement of water to prevent salinization by capillary rise.

The water table fluctuated between the soil surface in the monsoon season and 0.9 m from the ground level in summer season. The mean annual, summer and winter temperatures are 26.9°C, 30.1°C and 23.8°C respectively and the mean annual rainfall is 853 mm. The soils of the pilot area are saline sodic with ECe of 4.03 to 16.00 dSm^{-1} during summer. The main crop at the pilot area is paddy followed by paddy with a fallow period of two months. This area receives irrigation water from Kalipatnam main channel of Godavari Western Delta with an average EC of 0.4 dSm^{-1}. Flooding method of irrigation is adopted and water is allowed to flow from field to field. The water from the fields is drained to Upputeru through a separate drain called Magaleru drain.

Sub-surface drainage system with a pumped outlet is installed in summer 2005, in an area of 18 ha and adjacent 18 ha were selected as control area. Based on the drainage investigations for the design of the sub-surface drainage (SSD) system with 50 m lateral spacing and nylon mesh was used as filter material. On the western side of the collector line, seven lateral drains named as W1, W2.....W7 and on the eastern side of the collector line, seven lateral drains named as E1, E2.....E7 were installed. SSD was operated for 778 hours for the year under review (summer 05 to summer 06) covering both *Kharif*, 2005 and Rabi, 2005-06. Soil samples were collected and analyzed for ECe (Richards, 1968) from the 24 grid points spread over the entire pilot area and 24 grid points at control at 100 m x 100 m spacing. Data were tabulated and graphs were prepared using surfer 7.0 package. To compare the salinity reduction trend, data on salinity levels of before (summer, 05) and one year after (summer, 06) installation of SSD system from the 48 grid points at two different depths (0-15 cm & 15-30 cm) have been analyzed and contour maps prepared for soil salinity for summer, 2005 and 2006.

Data analysis indicates that there was considerable reduction in soil salinity in the pilot area. Overall effect was positive one year after installation, ECe has been lowered. ECe of soils were reduced by 11.7 % in surface soil and 8.8 % in sub-surface soil. Area under >10 dSm^{-1} range has decreased from 16 % to 3.5 % after first year of SSD operation. The depth wise reduction in soil salinity, because of subsurface drainage system at pilot area was effective. The upper layers are reclaimed at a faster rate (7.59 to 6.70 dSm^{-1}, 11.70%) than the deeper layers (9.62 to 8.77 dSm^{-1}, 8.80%). Within first year after installation of SSD system, the depthwise reduction in soil salinity was effective thus proving that this technology can also be effectively used in the saline and sodic soils to remove the salts in huge quantities from the profile in shortest possible time. The relation between yield and salinity will be approached by a straight line for the important range of yield decrease (van Hoorn and van Alphen, 1994). Crop yield was increased 0.4 t ha^{-1} during *Kharif*, 2005 and 0.8 t ha^{-1} increased during *Rabi*, 2005-06. The reason for the increase in rice yield was due to the removal of salts from root zone through the SSD system installed in the pilot area. Similar kinds of results were also reported by Lakshmi *et al.*, (2003) for saline soil reclamation of Konanki pilot area, Krishna Western Delta of Andhra Pradesh.

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J. Indian Soc. Coastal agric. Res. 29(2): 80-81 (2011) **Short Communication**

Effect of Bio-control Agents and Plant Extracts Against (*Colletotrichum gloeosporioides*) Causing Anthracnose Disease of Alphonso Mango

Mango (*Mangifera indica* L.) is one of the oldest choicest and third widely produced fruit crop of the tropics. Konkan region in the west coast of Maharashtra is emerging as one of the largest mango growing belt in the country particularly for growing Alphonso variety locally known as 'Hapus'. Althouth, most of the quality merits are confirmed on this variety, there are several diseases, which do limit the successful cultivation, production, marketing and storage of the fruits. Among the different diseases, the anthracnose (*Colletotrichum goleosporioides* Penz.) is one of the most serious diseases in orchards, which decreases the quality and quantity of the produce. The use of bio-control agents and plant extracts for the control of disease is a new trend in organic farming. In comparison to synthetic compounds the natural compounds provide less phyto-toxic, more systemic and easily biodegradable compound. Secondary metabolites from fungal bio-agents against the anthracnose fungus (C. *goleosporioides*) causing pre and post-harvest disease of Alphonso mango also effective. Three species of *Trichoderma viz. T. viride*, *T. harzianum*, *T. koninge*, along with its culture filtrates and phyto-extracts of five plant species viz. *Allium sativum* (Garlic) *Pongamea pinnata* (Karanj), *Katharanthus roseus* (Sadaphuli), *Glyricidia maculata* (Giripushp) and *Occimum sanctum* (Tulasi) were evaluated under *in-vitro* condition. The bio-agents along with its culture filtrates were studied against test fungi. The bio-agents and test fungus were inoculated side by side on petri plates containing Potato Dextrose Agar (PDA) medium. Three replications were maintained for each isolate with one control by maintaining only pathogen and bio-agent and incubated for 6-7 days. The colony diameter and percent inhibition of the test pathogen was calculated. Fifty ml of Potato Dextrose Broth (PDB) was added into each of 150 ml conical flask and sterilized. The mycelial disc cut from the margin of a week old culture grown on petridish was inoculated into PDB under aseptic condition. The flasks were incubated at 28 $\pm$ 1°C for 15 days. The culture filtrates were collected after 15 days of inoculation by filtering in Whatman No. 42 filter paper. The culture filtrate thus obtained was used for further experiment. The requisite quantity of culture filtrates was added to sterilize PDA. The culture filtrate was thoroughly mixed before solidification of PDA and poured into sterilized petri-plates. The mycelial discs of 10 mm diameter of test fungi was inoculated aseptically at the center of each petri plate already poured with poisoned medium. The inoculated PDA medium without incorporation of the culture filtrate served as control.

The extracts of locally available five plants were evaluated against the test fungi, as per the procedure given by Shinde and Patel (2004). One hundred gram fresh plant material was weighed and thoroughly washed with sterilized water. The plant material was homogenized in sterile distilled water @ 1 ml g^{-1} of tissues with a pestle and mortar. The crude material was then expressed through double-layered muslin cloth and was centrifuged at 5000 rpm for 20 minutes. After centrifugation, the supernatant was filtered through Whatman filter paper No. 1. This extract was passed through Sintered glass filter to avoid bacterial contamination. This formed the standard plant extract solution (100 per cent). The effect of plant extracts on mycelial growth was studied by Poisoned Food Technique (Nene and Thapliyal, 1993). The requisite quantity of plant extract was added to sterilize PDA medium by means of a sterile measuring cylinder under aseptic conditions so as to get desired concentration i.e. 10 per cent. These were poured into sterilized petri plates. The mycelial discs of 8 mm diameter of test fungi were cut with the help of sterile cork borer and transferred aseptically at the centre of each sterilized plate already poured with poisoned medium. The inoculated PDA medium without incorporation of plant extract served as the control. The plates were incubated at room temperature with three replications per treatment. The observations for colony diameter of the test fungi were recorded when control plates were fully covered by mycelial growth of the fungi and percent inhibition of the mycelial growth were calculated. Among the bio-agents and its culture filtrates tested all the bio-agents found effective for inhibition of the test fungus as compared to the culture filtrate of the same. Maximum inhibition (95%) was noticed in *T. harzianum* followed by *T. viride* (89%) whereas others were found to be least effective. These observations were in accordance with the earlier findings of Mondal *et al.* (1995), Mishra *et al.* (2004) and Lakshmi *et al.* (2004). Dalvi (2007) showed the efficacy of *T. harzianum* against *C. gloeosporioides*. Among the phyto-extracts *A. sativam* (98.52%) was the best in restricting the growth of the pathogen followed by P. pinnata (90.40%) and *G. maculate* (86.96%) over control. The fungi-toxic properties of garlic extract was reported by Ahamed and Sultana (1984); Dalvi 2007, Ribiero and Bedendo (1999) and Shirsekar (2002). Chaval (1996) reported the efficacy of *A. sativum, O. sanctum, P. pinnata* and *V. negundo* at 10% concentration against *C. gloeosporioides* at greater extent.

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J. Indian Soc. Coastal agric. Res. 29(2): 82-83 (2011) **Short Communication**

Study of Efficiency of Different Sealant Material for Lateritic Soils of Konkan Region

Konkan region of Maharashtra is bestowed with unique geo-physical condition and high annual rainfall of about 3000 to 3500 mm. In spite of the heavy rainfall, scarcity of water after November is the normal phenomena of this region. This region comprises of five districts viz. Thane, Mumbai, Raigad in the north, while Ratnagiri and Sindhudurg in the south. The soils of Ratnagiri and Sindhudurg district are coarse and shallow derived mostly from lateritic rock and their water retentive capacity is very low. Dongale *et al.*, (1987) reported the available water capacity of lateritic soils as low as 10.55 to 13.30 per cent. In this situation the only alternative left for effective harvesting of the rainwater is in suitable structures. The high basic infiltration rate of 3.18 to 6.20 cm/hr for monocropped area, while 8.86 to 13.12 cm hr^{-1} for double cropped area (Dongale *et al.*, 1987) is the major bottleneck storage of rain water for in surface structures. In view of this the materials like bauxite mixed soil and bentonite clay were tested in laboratory for their basic property of infiltration rate.

The experiment was conducted in the laboratory at the All India Co-ordinated Research Project on Water Management, Central Experiment Station, Wakawali in July 2007. The infiltration rate was calculated using the single cylinder infiltrometer with sieved plate at bottom. The infiltrometer was filled up to the depth of 25 cm by the fine sieved lateritic soil. The sieve plate was kept at the bottom of infiltrometer and the whole set was installed on the plane platform. Water was poured up to the top of the cylinder and the readings of subsidence of water level in respective time intervals were noted. The test was carried out till the constant infiltration rate i.e the basic infiltration rate was obtained.

The bauxite mixed soil collected from the Hindalco Company located at Bahadurgad, District Kolhapur and the standard bentonite clay was used for the said trial. Two-inch layer of each sealant was placed uniformly on the soil surface in the infiltrometer. The results of cumulative depletion of water in the infiltrometer with respect to time for the sieved lateritic soil were obtained and the Kostikov infiltration equation was developed and it is as follows,

$$Y = 0.1026x^{1.1429} \qquad ...(1)$$

$$R^2 = 0.937$$

The basic rate of infiltration as worked from the experiment for this soil was 7.2 cm hr^{-1}. This revealed that fine lateritic soil cannot serve as effective sealant material in surface storage structures.

The cumulative depletion of water with respect to time for bauxite mixed soil was also noted. The basic rate of infiltration as worked from the experiment for this soil was 3.6 cm hr^{-1}, which was exactly half the value of basic infiltration rate of normal lateritic soil. The maximum water holding capacity of these bauxite mixed soils varies from 48.32 to 66.86 per cent (Shinde and Kulkarni, 2005). This increased water holding capacity and reduced infiltration rate might be due to metallic (bauxite) content of the soil, which needs to be analysed further. The Kostikov's infiltration equation developed for this soil is as follows,

$$Y = 0.1869x^{0.786} \qquad ...(2)$$

$$R^2 = 0.9779$$

The data on cumulative water level subsidence with respective time interval for bentonite clay showed that the subsidence of water level was there only for initial 10 min. after that it remains stagnant, indicating the potential sealant characteristics of this material to arrest the infiltration almost completely. The Kostikov's infiltration equation developed for this soil is as follows,

$$Y = 0.4845x^{0.3575} \qquad ...(3)$$

$$R^2 = 0.8216$$

These results indicated the superiority of bentonite clay as sealant agent compared to bauxite mixed soil and lateritic soil. Hence, it is recommended to use bentonite as effective sealant material. Bauxite mixed clay being low cost material and having sealant characteristics needs to be tested in mixture with bentonite clay to reduce cost of bentonite.

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Key words: To be given in bracket, italics (Title in bold but words are normal), each item starts with a capital letter and items are separated by a coma, 12 pt. (Times New Roman), justified alignment, double space as: '*(**Key words:** Copper fungicides, Movement of copper, Iron deficiency)*'

Introduction: Without formal heading, text in 12 pt. (Times New Roman), justified alignment, double space

Materials and Methods: Heading in 14pt (Times New Roman) centre alignment, bold as: '**Materials and Methods**'. Text: double space, 12 pt. (Times New Roman), justified alignment.

Results and Discussions: Heading in 14pt (Times New Roman), centre alignment, bold as: '**Results and Discussions**'. Text: Double space, 12 pt. (Times New Roman), justified alignment. In text, the tables to be referred as Table 1 or (Table 1) and Figures as Fig. 1 or (Fig. 1) as the case may be.

Table title: Title of the Table to be in italics and placed at the top of the Table. The Table number to be given in bold (italics) with a space as: '***Table 3.*** *Characteristics of the soil profiles*'.

Each Table should be typed in separate sheet. Maximum size of a Table should be such that it can be conveniently accommodated in a A4 size paper. Over-sized Tables will be rejected. Approximate position of the Tables in the text to be indicated on the margin of the manuscript.

Figure: Figures include diagrams and photographs. Title of the Figure to be in italics and placed at the bottom of the Figure. The Fig. number to be given in bold (italics) with a space as: '***Fig. 3***. *Salinity of groundwater in different months*'.

Laser print outs of the diagrams are acceptable but not the dot-matrix print outs. Alternatively, each illustration can be drawn on white art paper or tracing paper using proper stencil so that it can be reduced to accommodate in the single column in the Journal page. Figures with free hand drawing or free hand writing will be rejected. Legends if any should be included within the illustration but the title of the figure should be at the outside of the illustration. The name of the authors and the title of the article should be written well below the illustration for identification. One set of original figure along with its soft copy must be submitted along with the manuscript.

Only Black and white photographs are accepted. Two hard copies of the photograph along with a soft copy in digital form are to be submitted.

References: Heading in 14pt (Times New Roman, centre alignment), bold as: '**References**'. The text/ citations should be in 12 pt. (Times New Roman), double space and left alignment. The style of citing different categories of literature is given below.

Journal articles: Abbreviations of periodicals are not acceptable. Fully expanded name of the Journal is to be given and volume number be bold as: Sen, H. S., Mandal, A. B. and Mahanta, K. K. (2007). Characteristics of salt tolerant rice varieties for the coastal region. *Journal of the Indian Society of Coastal Agricultural Research* **25**: 45-52.

Citing reference in the running text: As : 'It was observed by Biswas and Prasad(2008) that......; Similar results were also reported by others (Panigrahi *et al.*, 2006; Dutt and Polara, 2004)' as the case may be.

Books: As: (i)Russel, E.W. (1973).*Soil Conditions and Plant Growth*, Tenth edition, The English Language Book Society and Longman, London. 848 p. (ii) Biswas, T. D. and Mukherjee, S. K. (1989). *Text Book of Soil Science*, Second edition, Tata McGraw-Hill Publishing Company Limited, New Delhi. pp 90- 152.

Book Chapter: As: Inasi, K. A. and Philip, J. (1996). Crop production strategies of tuber crops. In: *Tropical Tuber Crops*, G. T. Kurup and V. P. Potty (eds.), Kalyani Publishers, Ludhiana. pp 264-274.

Bulletin: As: (i) Bandyopadhyay, B. K., Maji, B., Sen, H. S. and Tyagi, N. K. (2003). *Coastal Soils of West Bengal—Their Nature, Distribution and Characteristics*. Technical Bulletin No. 1/2003, Central Soil Salinity Research Institute, Regional Research Station, Canning Town, India. 62 p. (ii) Bandyopadhyay, B. K., Sahu, G. C. and Maji, B. (1998). Status, nature and composition of organic matter in coastal areas. In: *Soil Organic Matter and Residue Management*. Bulletin No. 19, Indian Society of Soil Science, New Delhi. pp 58- 67.

Symposium Proceedings: As: Pampattiwar, P. S. and Mane, T.A. (1983). Evaluation of sprinkler method of irrigation for summer groundnut, Proceedings National Seminar on *Evaluation of sprinkler irrigation*, Indian Society of Agricultural Engineers, January 2-5, 2008, Engineering Staff College, Pune, Maharastra, India. pp 88-95.

Thesis: As: Sarangi, S. K. (2003). Studies on the effect of modes of iron application and growth regulators on the performance of direct seeded upland rice (*Oryza sativa* L.) varieties under rainfed condition. *Unpublished Ph. D. Thesis*, Banaras Hindu University, Varanasi, India.

Units to be used: SI Units (Le *Système international d'unités* or the International System of Units) to be used. For this, Clark's Tables: '*Science Data Book*' by Orient Longman, New Delhi (1982) may be consulted as a guideline.

In expressing doses of nitrogen, phosphorus and potassic fertilizers, those should be in the form of N, P, K, respectively and be expressed in terms of kg ha^{-1} for field experiments and mg kg^{-1} for pot culture studies. Some of the common units with the corresponding symbols are reproduced below for convenience.

Common units and symbols: length= l, time= t, metre = m, second = s, centimeter = cm, cubic centimeter = cm^3, cubic metre =m^3, decisiemens = dS, degree-Celsius = ^0C , day = d, gram = g, hectare = ha (10^4 m^2 = 2.47 acre), 1 ha plough layer (15cm) of soil = 2.25 x10^6 kg (assuming bulk density of soil is 1.5 Mg m^{-3}), Hour = h, Kilometer = km, kilogram= kg, litre= L (=dm^3), Megagram = Mg (=10^3 kg or 10^6 g), microgram = μg (=10^{-6} g), Micron = μm (=10^{-6} m), milimole = mmole, miliequivalent = meq, micromol= μmol, milligram = mg, milliliter= mL, minute= min, nanometer= nm ((10^{-9}m), square centimeter= cm^2 , square kilometer = km^2, Tonne = t (Mg, 10^6 g or 10^3kg),*electrolytic conductivity* = dS m^{-1} (= mmhos cm^{-1}), *gas diffusion* = g m^{-2} s^{-1} or mol m^{-2} s^{-1}, *water flow*= kg m^{-2} s^{-1} (or) m^3 m^{-2} s^{-1} (or) m s^{-1}, *hydraulic conductivity* = m s^{-1}, *ion uptake (per kg of dry plant material)* =mol kg^{-1}, *leaf area* = m^2 kg^{-1}, *nutrient content in plants* = μg g^{-1}, mg g^{-1} or g kg^{-1} (dry matter basis), *root density or root length density* =m m^{-3}, *soil bulk density* = Mg m^{-3} (= g cm^{-3}), *transpiration rate* = mg m^{-2} s^{-1}, *water content of soil* = kg kg^{-1} or m^3 m^{-3}, *water tension* = kPa (or) Mpa, *yield (grain or forage)* = Mg ha^{-1} (= t ha^{-1}), organic carbon content of soil = g kg^{-1} (= percent (%) x 10), milligram per kg = mg kg^{-1}= parts per million (ppm), cation exchange capacity of soil = cmole(p+) kg^{-1} (= meq 100 g^{-1})

The authors are advised to look into a latest issue of the Journal of the Indian Society of Coastal Agricultural Research for preparation of manuscript for publication.

A set of manuscript (one soft copy (CD) + two hard copies) complete in all respect is to be submitted to 'The Secretary, Indian Society of Coastal Agricultural Research, Central Soil Salinity Research Institute, Regional Research Station, Canning Town, West Bengal, India, PIN- 743329'. Authors are also required to submit a copy of the Manuscript to the Society through e-mail <iscar.c@gmail.com>. The receipt of the manuscript will be communicated (electronically), provided the corresponding author's e-mail address is given in the manuscript. All the subsequent correspondences regarding the Manuscript will be done electronically only. Utmost attempts are made to expedite review of Manuscripts and publish the accepted ones at the earliest opportunity.