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A Simplified $CaCl_2$–$Ca(OH)_2$ Equilibration Method to Determine the Lime Requirement of Acid Soils of Odisha

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Lime requirements (LR) of some acid soils of Odisha belonging to Alfisols, Inceptisols and Entisols were evaluated by $Ca(OH)_2$ equilibration, $CaCl_2$–$Ca(OH)_2$ equilibration and modified Woodruff buffer (mod. WB) methods. Lime requirement of the soils increased in the order of LR determined by $Ca(OH)_2$ equilibration method< LR determined by $CaCl_2$–$Ca(OH)_2$ equilibration method< LR determined by mod. WB method. A linear relationship existed between the OH^- added and increase in pH in $Ca(OH)_2$ and $CaCl_2$–$Ca(OH)_2$ equilibrations. On the basis of this linearity a simple and rapid method was tried to develop to determine LR of the soils by adding $Ca(OH)_2$ solutions of selected concentrations instead of adding $Ca(OH)_2$ solutions of several concentrations. It was observed that LR determined by adding saturated $Ca(OH)_2$ solutions of 0 & 4 mL in $Ca(OH)_2$ equilibration method and 0 & 8 mL in $CaCl_2$–$Ca(OH)_2$ equilibration method were close to the LR determined from the full equilibration study i.e. after adding $Ca(OH)_2$ solutions of several concentrations. These two methods were referred to as simplified $Ca(OH)_2$ equilibration and simplified $CaCl_2$–$Ca(OH)_2$ equilibration methods, respectively. Laboratory incubation and pot culture experiment showed that the simplified $Ca(OH)_2$ equilibration method underestimated, whereas simplified $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods overestimated LR of the soils to the desired pH 6.5 measured after 15 days of liming. Soil pH in the laboratory incubation study increased between 6.0 and 6.5 in different soils when lime was applied @ 0.5 LR as per simplified $CaCl_2$–$Ca(OH)_2$ equilibration method. It increased between 6.3 and 6.8 when lime was applied at the same rate as per mod. WB method. In the pot culture experiment, the change in soil pH at 15 days of liming showed that application of lime @ 0.5 LR by simplified. $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods slightly overestimated the LR to the desired pH 6.5. Liming the soil at 0.3 LR as per the simplified $CaCl_2$–$Ca(OH)_2$ equilibration method slightly underestimated the desired pH 6.5. Liming the soil as per the simplified $CaCl_2$–$Ca(OH)_2$ equilibration method was significantly superior to liming as per simplified $Ca(OH)_2$ equilibration method but equivalent to liming as per mod. WB method in producing the dry matter yield of maize. Increasing the lime level from 0.3 to 1.0 LR had no significant effect in increasing the dry matter yield of maize.

(***Key words:*** *Acid soils, Lime requirement, Modified Woodruff Buffer method, Simplified $Ca(OH)_2$ and $CaCl_2$–$Ca(OH)_2$ Equilibration methods)*

Several buffer-pH methods have been developed to determine the lime requirement of acid soils (Woodruff, 1948, Shoemaker *et al.*, 1961, Yuan, 1974, McLean *et al.*, 1978, Fox, 1980, Tran and Van Lierop, 1981). These methods are based on the relationships of the decrease in pH of the soil buffer suspension below the buffer pH and neutralizable soil acidity to attain the desired pH which is not exact but based on some approximations. Buffer pH method, therefore, either overestimates or underestimates the LR of soils in many cases. These methods are also expensive requiring a number of chemicals including toxic compounds like p-nitrophenol (Min Liu *et al.*, 2004) and K_2CrO_4 (Pagani and Mallarino, 2011). Lime requirement by incubation method although provides more accurate information but is time consuming for routine analysis.

Dunn (1943) determined lime requirement of soils by direct titration with $Ca(OH)_2$. Lime requirement by this method was calculated from the full titration curve which is also time consuming. This was simplified by M in Liu *et al.,* (2004) on the basis of the linear relationship between increase in pH and $Ca(OH)_2$ added. These authors calculated the lime requirement from a titration curve of soil pH against three additions of saturated $Ca(OH)_2$ solutions in equal volumes to 1:1 soil water suspension maintaining a time interval of 30 minutes between two successive additions. This method was still time consuming for routine analysis. Besides the concentration of Ca^{2+} in the saturated $Ca(OH)_2$ solution is too low to replace exchangeable Al^{3+} for neutralization. This method, therefore, has the possibility to underestimate the

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LR of the soils containing appreciable amount of exchangeable Al^{3+}.

Acid soils in Odisha constitute more than 70% of the cultivated area (Panda and Nanda, 1985). These soils are mostly light textured with low organic matter content and are dominated by low active clays. The modified Woodruff buffer method (Brown and Cisco, 1984) is commonly followed in the soil testing laboratories of Odisha and many parts of India to determine the LR of the soils. This method is expensive requiring a number of chemicals including a toxic compound like p-nitrophenol. Besides this method consists of adding a 0.01 M $CaCl_2$ which is too low to replace exchangeable Al^{3+} for neutralization. Considering all these problems an attempt was made in the present investigation to find out a simple, rapid and inexpensive method to determine LR with greater accuracy through $CaCl_2$-$Ca(OH)_2$ equilibration method using 0.5 M $CaCl_2$ to replace exchangeable Al^{3+} completely for neutralization. This method was compared with simplified $Ca(OH)_2$ equilibration method and mod. WB methods through laboratory incubation and pot culture studies.

MATERIALS AND METHODS

Surface soil samples (0-15 cm) were collected from twenty one representative acid soil areas belonging to eighteen districts of Odisha (Table 1). Some important physical and chemical properties of the soils were determined by standard procedures. Exchange acidity and potential acidity to pH 8.0 ± 0.02 were determined as per Black, 1965. The pH-dependent acidity at pH 8± 0.02 was calculated from the difference between potential acidity and exchange acidity.

Lime requirement of the soil to pH 6.5 was determined by mod. WB method as follows.

LR to pH 6.5 = LR to pH 7.0 x $(6.5\text{-}pH_S)/(7.0\text{-}pHs)$

where LR = cmole $Ca(OH)_2$ kg^{-1}

pHs = salt pH with 0.01 M $CaCl_2$

LR($CaCO_3$ kg ha^{-1})=LR [cmole $Ca(OH)_2$ kg^{-1}] x 2000

Determination of LR by $Ca(OH)_2$ equilibration method

Five gram of $Ca(OH)_2$ was dissolved in 1 liter of distilled water for 5 days and filtered. The filtrate was saturated $Ca(OH)_2$ solution which is 0.022 M at 25°C. The strength of the saturated $Ca(OH)_2$

Table 1. *Selected areas for collection of soil samples*

Sl. No.	Location	Districts	Soil classification
1	Kashipur	Rayagada	*Rhodic Paleustalfs*
2	Ainginia	Khurda	*Typic Haplustalfs*
3	Jajpur	Jajpur	*Aeric Fluvaquents*
4	Phulbani	Phulbani	*Typic Rhodustalfs*
5	Mahishapat	Dhenkanal	*Oxic Haplustalfs*
6	Nawarangapur	Nawarangapur	*Aeric Haplustalfs*
7	Koraput	Koraput	*Kandic Paleustalfs*
8	Chandaka	Khurda	*Typic Haplustalfs*
9	Baripada	Mayurbhanj	*Aeric Ochraqualfs*
10	Keonjhar	Keonjhar	*Typic Ustochrepts*
11	Sundargarh	Sundargarh	*Aeric Haplaquepts*
12	Belapada	Bolangir	*Typic Haplustalfs*
13	Rayagada	Rayagada	*Typic Propaquepts*
14	Nuagada	Gajapati	*Typic Rhodustalfs*
15	Nayagarh	Nayagarh	*Rhodic Paleustalfs*
16	Bhanjanagar	Ganjam	*Typic Ustochrepts*
17	Semiliguda	Koraput	*Typic Haplustalfs*
18	Athagarh	Cuttack	*Typic Ustochrepts*
19	Sonepur	Sonepur	*Typic Haplustalfs*
20	Jashipur	Mayurbhanj	*Typic Rhodustalfs*
21	Angul	Angul	*Typic Ustochrepts*

solution was determined by titrating against standard 0.02 N HCl using methyl red indicator. Saturated $Ca(OH)_2$ solutions of 0,.0.5,1,2,3,4, 5,6,7,8,9 and 10 mL were diluted to 25 mL in a series of 25 mL volumetric flasks. To 10 g of soils, 25 mL of the $Ca(OH)_2$ solutions of different concentrations, as prepared above, were added and pH was measured after 30 minutes of equilibration. Preliminary study on soil pH till 24 hours of equilibration period showed an insignificant change in pH after 30 minutes.

Lime requirement to pH 6.5 by $Ca(OH)_2$ equilibration method was calculated as follows.

LR to pH 6.5 [cmole $Ca(OH)_2$ kg^{-1}] =[{ (mb-ma)/(pH_b-pH_a)} x (6.5-pH_a)+ma]x10

where m = molarity of the saturated $Ca(OH)_2$ solution

'a' and 'b' were the volumes (mL) of saturated $Ca(OH)_2$ solutions added increasing the pH of the soil suspensions to pH_a and pH_b, respectively. pH_a was just below 6.5, whereas pH_b was just above 6.5 in the equilibration study for the particular soil.

(mb-ma)/(pH_b-pH_a) is the mmole of $Ca(OH)_2$ required to raise the pH by one unit between pH_a and pH_b for 10 g soil.

[{(mb-ma)/ (pH_b-pH_a)}] x (6.5-pH_a) is the mmole of $Ca(OH)_2$ required to increase the pH from pH_a to 6.5 for 10 g soil.

mmole of $Ca(OH)_2$ required to raise the initial soil pH to pH_a for 10 g soils = ma.

Initial soil pH is the pH when zero mL of saturated $Ca(OH)_2$ solution is added.

Calculating the LR from this formula is more appropriate than calculating the LR from the regression equation of the increase in the pH with $Ca(OH)_2$ added.

Determination of LR by $CaCl_2$–$Ca(OH)_2$ equilibration method

To 10 g of soils 25 mL of 0.5 M $CaCl_2$ containing different concentrations of $Ca(OH)_2$ were added . The solutions were prepared by adding 0,2,4,6,8,10,12, and 14 mL of saturated $Ca(OH)_2$ solutions to 10 mL of 1.25 M $CaCl_2$ in a series of 25 mL volumetric flasks and finally diluted to 25 mL. The pH of the soil suspensions were measured after 30 minutes. Lime requirement to pH 6.5 by $CaCl_2$–$Ca(OH)_2$ equilibration method was calculated by using the same formula for determining LR by $Ca(OH)_2$ equilibration method.

Development of simplified $Ca(OH)_2$ and $CaCl_2$ – $Ca(OH)_2$ equilibration methods to determine LR

A high degree of linearity existed between OH^- added and the increase in pH in both the equilibration methods with 'r' values varying from 0.951 to 0.994 in $Ca(OH)_2$ equilibration method and 0.958 to 0.997 in $CaCl_2$ –$Ca(OH)_2$ equilibration method (Table 4). Similar observation had also been reported by Magdoff and Bartlett (1985), Min Liu *et al.* (2004) and Weaver et *al.* (2004). On this basis of linearity LR was calculated by adding only two or three different volumes of saturated $Ca(OH)_2$ solutions instead of adding several volumes of saturated $Ca(OH)_2$ solutions. For $Ca(OH)_2$ equilibration method LR was calculated by adding 0&2; 0&3; 0&4; 0,1&3; 0,1&4 and 0,2&4 mL of saturated $Ca(OH)_2$ solutions. For $CaCl_2$–$Ca(OH)_2$

Table 2. *Some important physical and chemical properties and forms of acidity in the soils*

Properties	Range	Mean	Remarks
Texture	sl to cl	–	sl=15, scl=3, cl=1,c=1
Clay (%)	12.6 to 35.4	17.5	–
pH_w (1:2.5)	4.2 to 5.7	5.0	–
pH_s with 0.5 M $CaCl_2$ (1:2.5)	3.5 to 4.3	3.8	–
Organic carbon (kg^{-1})	1.8 to 8.6	4.7	Low=15, Med.=1, High=4
Forms of acidity	[cmole (p+) kg^{-1}]		–
Exchange acidity	0.12 to 2.32	0.78	–
Exchangeable H^+	0.04 to 0.52	0.20	–
Exchangeable Al^{3+}	ND to 2.20	0.58	ND=6
pH-dependent acidity	3.6 to 11.6	5.92	–
Potential acidity	4.1 to 12.1	6.70	–

NB: Figures in the remarks column indicate the number of soils.
ND = Not detectable

Table 3. *Lime requirement of the soils to pH 6.5 determined by $Ca(OH)_2$, $CaCl_2$–$Ca(OH)_2$ equilibration methods and mod. WB method*

Methods	LR to pH 6.5 [cmole $Ca(OH)_2$ kg^{-1}]	
	Range	Mean
$Ca(OH)_2$ equilibration	0.095 to 1.148	0.534
$CaCl_2$–$Ca(OH)_2$ equilibration	0.590 to 2.263	1.374
mod. WB	0.704 to 3.074	1.722

Table 4. *Regression equations and correlation coefficient values between OH^- added and increase in soil pH in $Ca(OH)_2$ and $CaCl_2$–$Ca(OH)_2$ equilibration methods*

Method	r	r^2	Y= a+bx	
			a	b
$Ca(OH)_2$ equilibration method	0.951**-0.994**	0.904-0.988	4.307-6.524	0.760-1.428
$CaCl_2$–$Ca(OH)_2$ equilibration method	0.958**-0.997**	0.917-0.995	3.373-5.007	0.564-1.098

* y = pH and x = OH^- added [cmole (e^-) kg^{-1}]

equilibration method, LR was calculated by adding 0&2; 0&4; 0&6; 0&8; 0,2&4; 0,2&6 ; 0,2&8; 0,4&6; 0,4&8 and 0,6&8 mL of saturated $Ca(OH)_2$ solutions. Soil pH was measured in the same procedure as described earlier.

Lime requirements to pH 6.5 for both the equilibration methods were calculated as follows when three different volumes of saturated $Ca(OH)_2$ solutions including zero mL were added

$$LR = \frac{my-mx}{pH_y-pH_x} (6.5-pH_0) \times 10$$

pH_0, pH_x and pH_y were the pH of the soil suspensions when 0, x and y mL of saturated Ca $(OH)_2$ solutions were added (y>x). When two different volumes of saturated $Ca(OH)_2$ solutions were added of which one was zero mL this equation changed to

$$LR = \frac{mz}{pH_z-pH_0} (6.5-pH_0) \times 10$$

Where, pH_z was the pH of the soil suspension when 'z' mL of saturated $Ca(OH)_2$ solution was added.

It was observed that LR calculated from the pH values of the soils after adding saturated $Ca(OH)_2$ solutions of 0&4 mL in $Ca(OH)_2$ equilibration method and 0&8 mL in $CaCl_2$–$Ca(OH)_2$ equilibration method were closest to the LR calculated from the full equilibration studies as indicated by the lowest $(L_2- L_1)^2$, lowest Sd and nonsignificant 't' values (Table 5). These two simple methods to determine LR were evaluated through laboratory incubation and pot culture studies along with the mod. WB method.

Laboratory incubation study

Laboratory incubation study was carried out with the soil samples collected from Angul, Athagarh, Belapada, Jajpur, Jashipur, Keonjhar, Koraput, Nayagarh, Rayagada and Sijua. Required quantities of pure $CaCO_3$ at 0.5 and 1.0 LR levels calculated according to the above three methods were added to 100 g soils and incubated for 15 days maintaining the moisture content at field capacity. After 15 days soil pH and exchange acidity were determined.

Pot culture study

The pot culture experiment was conducted with the surface soil (0-15 cm) samples collected from Sijua, Bhubaneswar (Odisha). The soil was sandy loam having 13.6% clay and organic carbon content of 2g kg^{-1}. Soil pH_w was 5.4 and pH_s with 0.5 M $CaCl_2$ was 3.8. Exchangeable Ca^{2+} and Mg^{2+} were 1.3 and 1.1 cmole(p+) kg^{-1}, respectively. Exchange acidity, exchangeable H^+, exchangeable Al^{3+}, potential acidity and pH-dependent acidity were 0.288, 0.156, 0.132, 4.08 and 3.79 cmole(p+) kg^{-1}, respectively. Available N (Alkaline $KMnO_4$), available P (Bray's I), available K (Neutral normal NH_4OAc extract) and available S (0.15%, $CaCl_2.2H_2O$ extract) were 60, 14, 54 and 5 mg kg^{-1} in soil, respectively. Lime requirement of the soil to pH 6.5 was 362, 1250 and 1421 mg $CaCO_3$ kg^{-1} as determined by simplified $Ca(OH)_2$ equilibration, simplified $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods, respectively.

Table 5. *Comparison of LR to pH 6.5 (L_2) calculated from the pH values after adding 2 or 3 different volumes of saturated $Ca(OH)_2$ solution with the LR to pH 6.5 obtained from full equilibration study (L_1) in $Ca(OH)_2$ and $CaCl_2$–$Ca(OH)_2$ equilibration methods*

Volumes of saturated $Ca(OH)_2$ solutions added (ml)	$\Sigma (L_2-L_1)^2$ [cmole $Ca(OH)_2$ kg^{-1}]^2	Standard deviation (Sd)	Cal. 't' value
$Ca(OH)_2$ equilibration method			
0 & 2	0.514	0.149	2.042
0 & 3	0.411	0.131	2.210*
0 & 4	0.279	0.106	2.013
0, 1 & 3	0.735	0.173	2.320*
0, 1 & 4	0.616	0.152	2.760*
0, 2 & 4	0.632	0.161	2.300*
$CaCl_2$–$Ca(OH)_2$ equilibration method			
0 & 2	10.008	0.704	1.080
0 & 4	3.865	0.444	0.738
0 & 6	0.672	0.187	1.790
0 & 8	0.497	0.151	1.620
0, 2 & 4	4.034	0.448	1.040
0, 2 & 6	1.236	0.254	0.194
0, 2 & 8	1.907	0.291	1.850
0, 4 & 6	5.722	0.533	1.030
0, 4 & 8	6.320	0.577	2.270*
0, 6 & 8	28.916	1.00	3.110**

*Significant at 5% level ** Significant at 1% level

Table 6. *Change in soil pH and exchange acidity with liming after 15 days of incubation in different soils*

Sl.No	Treatments	$CaCO_3$ added ([cmole kg^{-1}])	Soil pH	Exchange acidity [cmole(p+) kg^{-1}]	Exchangeable Al^{3+} [cmole(p+) kg^{-1}]
			Range		
1	0LR	0	4.5-5.6	0.180-1.980	0.022-1.672
2	1.0 LR by M_1	0.262-1.510	5.2-6.4	0.036-0.360	ND-0.220
3	0.5 LR by M_2	0.540-1.100	6.0-6.5	0.036-0.144	ND
4	0.5 LR by M_3	0.683-1.537	6.3-6.8	0.036-0.072	ND
5	1.0 LR by M_2	1.080-2.200	6.8-7.5	ND-0.036	ND
6	1.0 LR by M_3	1.367-3.074	7.0-7.9	ND-0.036	ND
	Initial	–	4.3-5.4	0.164-2.324	ND-2.200

Figures in parentheses indicate exchangeable Al^{3+} [cmole (p+) kg^{-1}]. ND= Not detectable
M_1= Simplified $Ca(OH)_2$ equilibration method, M_2= Simplified $CaCl_2$–$Ca(OH)_2$ equilibration method, M_3= mod. WB method

Five kg of air- dried and sieved (2mm) soils, after being thoroughly mixed with the required quantities of pure $CaCO_3$ (LR grade) were taken in earthen pots. There were ten treatments (Table 10) replicated thrice in factorial randomized design. The test crop grown was *Zea mays* cv Platinum. N, P_2O_5, K_2O and S were added @ 150-75-75-20 kg ha^{-1} as chemical grades (LR) of urea, KH_2PO_4, KCl and $(NH_4)_2$ SO_4, respectively in solution forms. Twenty five % of N, full dose of P_2 O_5 , 25% of K_2O and full dose of S were applied after germination of the seeds. Another 50% N and 50% K_2O were applied after 15 days of application of first dose of fertilizers and the rest 25% N and 25% K_2O were applied after 15 days of the application of second dose of fertilizers. The N content in $(NH_4)_2SO_4$ was considered while calculating the amount of urea to be applied in the first dose. Soil samples were collected at 15, 30, 45 and 60 days of liming and analyzed for pH and exchange acidity. Soil samples collected after

harvesting of the crop i.e. at 60 days of liming were analyzed for potential acidity, pH-dependent acidity and exchangeable Ca^{2+} and Mg^{2+} also. Dry matter yields of the harvested plants were recorded after initial sun-drying and then oven-drying at 60°C for 7 days.

RESULTS AND DISCUSSION

Most of the soils were sandy loam with low organic matter content (Table 2). The soils were moderately to strongly acidic. Positive difference between pH_w and pH_s indicated that the soils were net negatively charged. Of the potential acidity, 88 to 96% was formed by pH-dependent acidity and the rest by exchange acidity. Exchangeable Al^{3+} was detected below pH 5.4. Both potential and pH-dependent acidities were positively correlated with clay (r=0.62** and 0.57**, respectively) and organic carbon (r=0.57** and 0.68**, respectively).

Lime requirement of the soils

Lime requirement of the soils decreased in the order of LR determined by $Ca(OH)_2$ equilibration method < by $CaCl_2$–$Ca(OH)_2$ equilibration method < by mod. WB method (Table 3). In the determination of LR by $Ca(OH)_2$ equilibration, the concentration of Ca^{2+} in the $Ca(OH)_2$ solution added is too low to replace the exchangeable H^+ and Al^{3+} completely to the soil solution, whereas in $CaCl_2$–$Ca(OH)_2$ equilibration a 0.5 M $CaCl_2$ is used, which is sufficient to replace all the exchangeable H^+ and Al^{3+} to the soil solution. Besides the excess of Ca^{2+} in the soil solution suppress the hydrolysis of Ca-clay to prevent the rise in pH. More $Ca(OH)_2$ is, therefore, needed to raise the pH to 6.5 in $CaCl_2$–$Ca(OH)_2$ equilibration than in $Ca(OH)_2$ equilibration. The LR determined by $CaCl_2$–$Ca(OH)_2$ equilibration method is, therefore, greater than the LR determined by $Ca(OH)_2$ equilibration method. In mod. WB method a 0.01 M $CaCl_2$ is added to the soil. The concentration of Ca^{2+} in this solution is also too low to replace exchangeable Al^{3+} for neutralization. The $CaCl_2$–$Ca(OH)_2$ equilibration method is, therefore, expected to estimate higher LR than mod. WB method but the opposite was found in this study. This showed that the basis of LR calculation in mod. WB method that for each one unit decrease in pH of the soil buffer suspension below 7.0, 10 meq of acidity is to be neutralized per 100 g soil might be an overestimation. Over estimation of LR by mod. WB method has also been reported by Panda and Nanda (1985) and Das *et al.*, (2006). The r^2 values between the OH^- added and increase in pH indicated 90.4 to 99.8% of linearity between pH and OH^- added in $Ca(OH)_2$ equilibration method and 91.7 to 99.5% of linearity between these two variables in $CaCl_2$–$Ca(OH)_2$ equilibration method (Table 4). The intercept and slope values of the regression equations were higher in $Ca(OH)_2$ equilibration method than in $CaCl_2$–$Ca(OH)_2$ equilibration method.

Lime requirement determined by $Ca(OH)_2$ equilibration was negatively correlated with pH_w (r = - 0.81**) and positively correlated with exchange acidity (r = 0.70**). Lime requirement determined by $CaCl_2$–$Ca(OH)_2$ equilibration was negatively correlated with pH_w (r = - 0.48*) and was positively correlated with clay (r = 0.50*) and exchange acidity (r = 0.68**). Lime requirement determined by mod. WB method was positively correlated with clay (r = 0.73**) and exchange acidity (r = 0.51*). Lime requirement determined by all the three methods showed significant positive correlation with exchange acidity but a nonsignificant relationship with potential and pH-dependent acidities. Lime requirement calculated to attain the desired pH 6.5 includes neutralization of exchange acidity and pH-dependent acidity at pH 6.5. But the potential acidity determined includes exchange acidity and pH-dependent acidity at pH 8.0. This difference in pH-dependent acidities might be the reason of the nonsignificant relationship of LR with potential and pH-dependent acidities. Interrelationships existed among the LR values determined by the three methods (Table 5). Lime requirement determined by $Ca(OH)_2$ equilibration method was positively correlated with that determined by $CaCl_2$–$Ca(OH)_2$ equilibration method and mod. WB method (r = 0.65** and 0.56**, respectively). The LR values calculated by $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods, on the other hands, were positively correlated with each other (r = 0.84**). Buffering capacity of the soils determined from the reciprocal of the slopes of the regression equations of the increase in pH with OH^- added varied from 0.700 to 1.316 and 0.911 to 1.773 cmole(p+) kg^{-1} in $Ca(OH)_2$ equilibration and $CaCl_2$–$Ca(OH)_2$ equilibration methods, respectively. Buffering capacity determined by $CaCl_2$–$Ca(OH)_2$ equilibration method was positively correlated with clay (r = 0.77**) and organic carbon (r = 0.53*). Lime requirement determined by the simplified $Ca(OH)_2$ equilibration and simplified $CaCl_2$–$Ca(OH)_2$ equilibration methods varied from 0.247 to 1.510 and 0.828 to 2.200 cmole $Ca(OH)_2$ kg^{-1}, respectively.

Laboratory incubation studies on the change in soil pH and forms of acidity after liming according to different methods of LR determination

Soil pH after 15 days of incubation was the lowest in zero lime treatment varying from 4.5 to 5.6 in different soils (Table 6). Soil pH varied from 5.2 to 6.4, 6.8 to 7.5 and 7.0 to 7.9 when lime was added @1.0 LR as per simplified $Ca(OH)_2$ equilibration, simplified $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods, respectively. This showed that the simplified $Ca(OH)_2$ equilibration method underestimated the LR of the soils, whereas the simplified $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods overestimated the LR of the soils. The extent of overestimation was more in the mod. WB method than in the simplified $CaCl_2$–$Ca(OH)_2$ equilibration method. At 0.5 LR level, soil pH varied from 6.0 to 6.5 and 6.3 to 6.8 when lime was added as per simplified $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods, respectively.

Exchange acidity was the highest in zero lime treatment. Exchangeable Al^{3+} was detected in zero lime treatments varying from 0.02 to 1.672 cmole(p+) kg^{-1}. In lime treatments, exchangeable Al^{3+} was detected only in Rayagada soil [0.220 cmole(p+) kg^{-1}] when lime was added @ 1.0 LR as per simplified $Ca(OH)_2$ equilibration method. Soil pH in this treatment was 5.2.

Pot culture experiment

A high degree of linearity existed between the increase in pH and OH^- added in $Ca(OH)_2$ and $CaCl_2$–$Ca(OH)_2$ equilibration methods in the Sijua soil used for the pot culture study (Fig. 1).

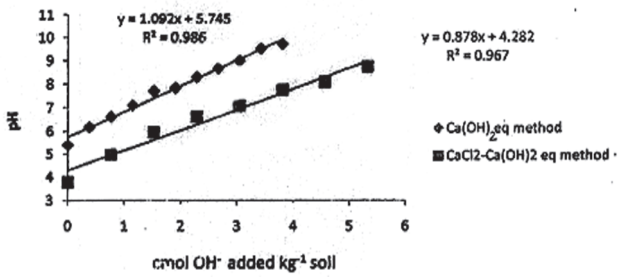

Fig. 1. Soil pH at different amounts of OH added in $Ca(OH)_2$ and CalCl-$Ca(OH)_2$ equilibration methods in Sijua soil

Change in soil pH

Soil pH at different time intervals was the lowest (5.3 to 5.5) in zero lime treatment (Table 7). It varied from 5.6 to 7.4 at 15 days in different treatments and either remained same or increased slightly at 30 days. It decreased to 5.5 to 7.5 at 45 days with further reduction of 5.3 to 6.5 at 60 days in different treatments. The decrease in pH at 45 days and further decrease at 60 days might be due to loss of Ca^{2+} from the exchange sites. At a given LR level, soil pH at different time intervals increased in the order of lime applied as per simplified $Ca(OH)_2$ equilibration method < lime applied as per simplified $CaCl_2$–$Ca(OH)_2$ equilibration method < lime applied as per mod. WB method.

Soil pH at 15 days of liming increased to 6.3, 7.1 and 7.4 when lime was added @ 1.0 LR as per simplified $Ca(OH)_2$ equilibration, simplified $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods, respectively. This showed that the simplified $Ca(OH)_2$ equilibration method slightly underestimated, whereas the simplified $CaCl_2$–$Ca(OH)_2$ equilibration method and the mod. WB method overestimated the

Table 7. *Soil pH at different time intervals in the pot study*

Sl. No.	Treatments	Soil pH at different days of liming			
		15	30	45	60
1	$CaCO_3$ @ 0LR	5.5	5.5	5.5	5.3
2	$CaCO_3$ @ 0.3 LR by M_1	5.6	5.8	5.5	5.3
3	$CaCO_3$ @ 0.3 LR by M_2	6.3	6.5	6.2	5.7
4	$CaCO_3$ @ 0.3 LR by M_3	6.5	6.6	6.3	6.1
5	$CaCO_3$ @ 0.5 LR by M_1	6.1	6.0	5.8	5.6
6	$CaCO_3$ @ 0.5 LR by M_2	6.7	6.7	6.5	6.2
7	$CaCO_3$ @ 0.5 LR by M_3	6.9	7.0	6.5	6.2
8	$CaCO_3$ @ 1.0 LR by M_1	6.3	6.3	6.0	5.8
9	$CaCO_3$ @ 1.0 LR by M_2	7.1	7.2	7.1	6.4
10	$CaCO_3$ @ 1.0 LR by M_3	7.4	7.6	7.5	6.5

NB: M_1 , M_2 & M_3 are as in table 6

LR of the soils to the target pH of 6.5. This overestimation was more in case of mod. WB method than in the simplified $CaCl_2$–$Ca(OH)_2$ equilibration method. At 0.5 LR level soil pH at 15 days was slightly higher than 6.5 by $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods. At 0.3 LR level, soil pH at 15 days was 6.3 and 6.5 when lime was added as per simplified $CaCl_2$–$Ca(OH)_2$ and mod. WB methods, respectively.

Change in exchange acidity

Exchange acidity was the highest in zero lime treatment and was nondetectable when soil pH increased to 7.0 and above with liming. (Table 8). There was almost an increase in exchange acidity in different treatments at 60 days of liming which might be due to decrease in pH. Exchangeable Al^{3+} was detected at 60 days in zero lime treatment and the treatment receiving 0.3 LR as per simplified $Ca(OH)_2$ equilibration method. Soil pH was 5.3 in these treatments at this period. Soil pH in all other cases was 5.5 and more and exchangeable Al^{3+} was nondetectable.

Change in potential acidity, pH-dependent acidity and exchangeable Ca^{2+} and Mg^{2+} after harvesting of the crop

The highest values of potential and pH dependent acidities were obtained in zero lime treatments (Table 9). These values decreased after liming. At a given LR level, potential as well as pH-dependent acidities decreased in the order of lime applied as per simplified $Ca(OH)_2$ equilibration method > lime applied as per the simplified $CaCl_2$–

Table 8. *Exchange acidity at different time intervals in the pot study*

Sl.No	Treatments	Exchange acidity at different days of liming [cmole(p+) kg^{-1}]			
		15	30	45	60
1	$CaCO_3$ @ 0LR	0.132	0.144	0.182	0.244 (0.132)*
2	$CaCO_3$ @ 0.3 LR by M_1	0.108	0.072	0.072	0.180 (0.130)
3	$CaCO_3$ @ 0.3 LR by M_2	0.036	0.036	0.036	0.072
4	$CaCO_3$ @ 0.3 LR by M_3	0.036	0.036	0.036	0.036
5	$CaCO_3$ @ 0.5 LR by M_1	0.072	0.072	0.072	0.108
6	$CaCO_3$ @ 0.5 LR by M_2	0.036	0.036	0.036	0.036
7	$CaCO_3$ @ 0.5 LR by M_3	0.036	ND	0.036	0.036
8	$CaCO_3$ @ 1.0 LR by M_1	0.036	0.036	0.036	0.072
9	$CaCO_3$ @ 1.0 LR by M_2	ND	ND	ND	0.036
10	$CaCO_3$ @ 1.0 LR by M_3	ND	ND	ND	0.036

Figures in parentheses indicate exchangeable Al^{3+} [cmole (p+) kg^{-1}]
NB: Exchangeable Al^{3+} was not detected in all other cases

Table 9. *Potential acidity, pH-dependent acidity, exchangeable Ca^{2+} and exchangeable Mg^{2+} contents at harvesting*

Sl. No.	Treatments	Potential acidity	pH-dependant acidity	Exchangeable Ca^{2+}	Exchangeable Mg^{2+}
		[cmole (p+) kg^{-1}]			
1	$CaCO_3$ @ 0LR	4.12	3.88	1.2	0.9
2	$CaCO_3$ @ 0.3 LR by M_1	4.03	3.79	1.2	0.7
3	$CaCO_3$ @ 0.3 LR by M_2	3.55	3.31	1.4	0.8
4	$CaCO_3$ @ 0.3 LR by M_3	3.44	3.20	1.7	1.0
5	$CaCO_3$ @ 0.5 LR by M_1	3.94	3.70	1.2	0.7
6	$CaCO_3$ @ 0.5 LR by M_2	3.45	3.21	1.8	1.2
7	$CaCO_3$ @ 0.5 LR by M_3	3.25	3.01	1.8	1.3
8	$CaCO_3$ @ 1.0 LR by M_1	3.55	3.31	1.4	1.1
9	$CaCO_3$ @ 1.0 LR by M_2	2.04	1.80	1.8	0.6
10	$CaCO_3$ @ 1.0 LR by M_3	1.76	1.52	2.0	1.2

Table 10. *Effect of different LR methods and levels of lime added on the dry matter yield of maize*

Methods	Dry matter yield (g/pot) Levels of lime applied				
	0 LR	0.3 LR	0.5 LR	1.0 LR	Mean
Simplified $Ca(OH)_2$ equilibration	–	26.21	28.56	29.90	28.22
Simplified $CaCl_2$-$Ca(OH)_2$ equilibration	–	32.48	35.02	35.27	34.26
Mod. WB	–	33.11	34.01	30.94	32.69
Mean	*23.1	30.60	32.52	32.04	–
CD at 5%	Lime level 6.007	Method 4.017	Lime x method 10.295	Control vs rest 7.756	

*Mean value of dry matter yield of the three replications of control i.e. maize grown without liming

$Ca(OH)_2$ equilibration method > lime applied as per mod. WB method. This trend was opposite for the change in exchangeable Ca^{2+} content at a given level of LR applied. No definite trend of the change in exchangeable Mg^{2+} content was noticed.

Effect of different LR methods and levels of lime added on the dry matter yield of maize

Dry matter yield was the lowest in the control i.e zero lime treatment (Table 10). It increased with liming. The increase in yield over control at different levels of lime added as per the simplified $Ca(OH)_2$ equilibration method was not significant but there was significant increase in yield over control at all the three levels of lime added as per the simplified $CaCl_2$–$Ca(OH)_2$ equilibration and mod. WB methods. Increasing the levels of lime from 0.3 to 1.0 LR had no significant effect on the dry matter yield of maize. Application of lime as per the simplified $CaCl_2$-$Ca(OH)_2$ equilibration and mod. WB methods were significantly superior to the application of lime as per the simplified $Ca(OH)_2$ equilibration method in producing the dry matter yield of maize. The former two methods, on the other hand, were statistically at par with each other in producing the dry matter yield of maize.

Results of the pot experiment revealed that application of lime at 0.3 LR level was sufficient for plant growth since a higher level of LR had no significant effect on the dry matter yield of maize. This showed that increasing the pH above 6.5 had no significant effect on crop yield. With rise in pH the concentration of different micronutrients in the soil solutions decreases which might be the cause of a nonsignificant increase in yield with increasing levels of lime added beyond 0.3 LR. Kanwar and Randhawa (1974) reported negative relationship between pH and metallic micronutrients that cause depression of the yield of maize, wheat, barley and legume crops. Sahu and Pal (1987) reported similar results in green gram, pigeon pea and groundnut. Application of lime as per simplified $Ca(OH)_2$ equilibration method is not effective for a satisfactory increase in yield. The simplified $CaCl_2$–$Ca(OH)_2$ equilibration method was equivalent to the mod. WB method in producing the dry matter yield of maize.

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Restoration of Degraded Coastal Agroecosystems through Phytoremediation

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The potential of phytoremediation for decontamination and restoration of an acid sulphate wetland agroecosystem was evaluated by taking *Kari* lands of Kuttanad, Kerala as the test site. Soil/sediment and water samples from rice fields and canals/waterways surrounding the rice fields were collected during summer season and analysed for different chemical parameters. The aquatic macrophytes from the same sites were also collected and analysed for elemental composition. Data on elemental status of soil indicated that the soil contains toxic levels of Fe, Al, S and contaminated with heavy metals like Cd, Zn, Cu and Pb. With regard to water quality, it was found that the water has been contaminated with NO_3-N, S, Fe, Mn and Al. Chemical analysis of native aquatic macrophytes revealed their ability for phytoextraction of elements from soil and their accumulation in plant parts. Bioconcentration factors were calculated for toxic elements and phytoextractors for different elements were identified. *Hydrilla verticilata* was the best phytoextractor for Fe, Zn, Cu and Al followed by *Eichhornia crassipes*. *Cyperus* species was a good phytoextractor for Mn and *Eichhornia crassipes* was the best phytoextractor for Cd and Pb.

(***Key words***: *Phytoremediation, Decontamination, Restoration, Heavy metals and Phytoextractors)*

Coastal agroecosystem is one of largest agroecosystem in India which is playing a major role in rice cultivation and aquaculture. It is comprised mainly of wetlands and water bodies with fringes of coastal shore, positioned at or even below mean sea level (MSL). This peculiar position make wetlands an ideal sink for waste materials and pollutants. These pollutants adversely affect the life of aquatic organisms as well as the human life. The agricultural produces from such tracts bear the signature of the contaminants present in each zone and interrupt the food chain with toxic materials. Therefore, the coastal agroecosystems have to be decontaminated and restored in an ecofriendly manner. Phytoremediation is an ideal technology for wetland restoration. The plants growing in the tract will absorb the elements from soil/sediment/ water by roots. The absorbed elements travel from the root, through the cell sap and finally get precipitated in vacuole or cell membrane, thereby reduces the level of contaminants in soil/water (Chaney *et al.*, 1995; Cunningham *et al.*, 1995). The present paper attempts an evaluation on the extent of contamination in an acid sulphate rice based wetland agroecosystem viz., *Kari* lands of Kuttanad and how the native aquatic macrophytes can be employed for the decontamination and restoration of the above wetland through phytoremediation.

MATERIALS AND METHODS

Kuttanad, the rice bowl of Kerala has been recently acronymed as the "poison bowl or weeping rice bowl of Kerala" because of the ensuing pollution in the tract. The paddy fields, waterways, canals, backwaters, soil, sediment, vegetation etc. experience different levels of contamination. The tract has been exposed to monsoon floods during rainy seasons and tidal flushing during summer, which facilitated a natural clean up of the ecosystem. But developmental measures taken for controlling the floods and saline water entry during the period of rice cultivation had aggravated the aquatic pollution in the tract by restricting the water flow. The soil, water and sediment of Kuttanad have been polluted with fertilizer residues/agrochemicals and other effluents discharged to the system (Thampatti and Jose,1998; Thampatti *et al.*, 2006).

The *Kari* wetlands of Kuttanad region covers an area of 14277 ha, lying 0.5 to 2.0 m below MSL and characterized by the presence of acid sulphate soils. The tract is highly acidic with a pH below 4.0, moderately saline and possesses toxic quantities of Fe, Al and S, which are mainly geogenic in origin. Apart from the above, the tract has been subjected to organic and inorganic contamination due to anthropogenic activities. To assess the extent of pollution, soil and water samples from rice fields,

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and sediment and water from canals/waterways surrounding the rice field were collected from 20 locations and analysed for different quality parameters. The profusely growing natural flora were collected from canals, cultivated rice fields and abandoned rice fields from the above locations of the study area. The chemical characteristics of soil and sediment were analysed as per procedures described by Page (1982) and that of water as described by Guptha (1999). The chemical composition of aquatic macrophytes was estimated as per standard procedures described by Jackson (1973).

RESULTS AND DISCUSSION

The results of chemical characteristics of *Kari* lands (Table 1) depicts that the soil and sediment were highly acidic and moderately saline. Perusal of the data on elemental status indicated that this ecosystem contains toxic levels of Fe, Al, S and are contaminated with heavy metals like Cd, Zn, Cu and Pb. The accumulation of heavy metals in wetlands, especially in paddy fields is drastically increasing through the inputs of fertilizers, waste water, pesticides, organic manure and disposal of wastes from industrial and mining process. Among the essential primary elements, S alone is present in excess quantity in the tract. Among the micronutrients, Fe exceeds the toxicity limit. Another non essential element viz., Al and two heavy metals viz., Cd and Pb are also present in toxic quantities.

On evaluating the water quality (Table 1), the elements NO_3-N, S, Fe, Mn and Al contents exceeded the permissible limits prescribed by Indian Bureau of Standards. The phytoremediators could phytomine the toxic metals from soil/sediment/ water and retain them in plant parts itself, or allows its volatilization as in the case of Hg and Se, so that their concentration in soil/water can be can be reduced which will help the ecorestoration by lessening the threat from pollutants to the living community. Several lakes/water bodies are being restored through phytoremediation (Kumar *et al.*, 2008) in India

Kuttanad has been blessed with a large variety of plants and is really a hot spot of biodiversity. The green plants are most relevant component in decontamination of negative effects of pollution. These plants could act as sentinels for monitoring trace element pollution and hence they can be successfully employed for phytoremediation (Bashmakov *et al.*, 2005). On evaluating the dominance of aquatic macrophtes of the study area, it was observed that *Hydrilla verticilata*, *Eichhornia crassipes, Salvinia molesta* and *Ludwigia parviflora* were the dominant vegetation within the canals (Table 2). *Eichhornia crassipes* was the most dominant species present in almost all waterways/ canals. In the peripheral regions of the waterways/ canals, the active species identified were *Eclipta alba*, *Cynadon dactylon*, *Cyperus* sp., *Alternathera sissiles, Emelia sonjifolia* and *Panicum* sp., the last one being the most dominant species. In cultivated rice fields the actively growing species generally categorized as weeds includes *Eclipta alba*, *Hydrocotyle asiatica, Commolina bengalensis, Cyperus* sp., *Panicum* sp., *Eichnochloa* sp., *Oryza rufipogon* and *Ludwigia parviflora*. In the abandoned rice fields the dominant species were *Ludwigia parviflora*, *Eichnochloa* sp., *Emelia sonjifolia*, *Alternathera sissiles, Colocasia esculenta* (wild taro), *Eleocharis* sp. and *Eichhornia crassipes*. More than 70 per cent of the abandoned rice fields are covered by *Eichhornia crassipes*. All together 22 dominant species were identified.

The elemental concentrations of the plants having potential for phytoextraction are presented in Table 3 and 4. Out of the twenty two dominant aquatic macrophytes, nine species alone were found to accumulate metals in plant parts. Their growth rate and biomass production were also satisfactory. The above plant species were successful in phytoextracting toxic metals from their growing

Table 1. *Chemical characteristics of rice soil, sediment, field water and canal water of Kari lands of Kuttanad (Mean values) during summer season*

	pH	EC	NH_4-N	NO_3-N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	Al	Cd	Pb
		(dS m^{-1})	(mg kg^{-1})												(µg kg^{-1})	
Rice soil	3.8	1.08	103	16	1.8	156	854	384	2662	342	5.0	2.5	2.0	88	170	750
Sediment	3.8	0.92	156	7.2	3.8	191	1095	489	2158	584	8.6	4.4	4.0	102	210	805
Field water	4.9	0.8	6.0	6.3	0.07	2.9	20.2	10.3	10.2	1.2	0.23	0.05	0.07	0.16	10	40
Canal water	4.8	0.85	3.6	4.7	0.09	3.2	19.2	9.7	8.2	1.4	0.18	0.05	0.05	0.14	25	78

***Table 2**. Dominant aquatic macrophytes found in Kari lands of Kuttanad and their distribution*

Sl.No	Aquatic macrophytes	(I) No. of sites at which the plant were observed and (II) their intensity (%)							
		Canal/ waterways				Cultivated rice fields		Abandoned rice fields	
		Within		Periphery					
		I	II	I	II	I	II	I	II
1	*Eclipta alba*	–	–	–	–	14	5	2	10
2	*Hydrocotyle asiatica*	–	–	12	50	14	10	7	15
3	*Bacopa monnieria*	–	–	11	45	11	10	4	20
4	*Hydrilla verticilata*	15	55	11	40	–	–	–	–
5	*Commolina bengalensis*	–	–	–	–	12	12	–	–
6	*Marselia quadrifolia*	6	20	9	32	–	–	4	20
7	*Eichhornia crassipes*	18	65	–	–	2	5	17	85
8	*Cynadon dactylon*	–	–	–	–	11	5	11	15
9	*Cyperus* sp.	10	35	13	55	12	15	11	35
10	*Eleocharis* sp.	–	–	13	45	4	15	7	30
11	*Colocasia esculenta* (Wild taro)	6	25	6	20	–	–	16	25
12	*Alternanthera sissiles*	6	15	11	25	5	5	13	30
13	*Hydrophila auriculata*	10	25	14	25	–	–	3	15
14	*Salvinia molesta*	13	50	–	–	4	8	8	30
15	*Panicum* sp.	11	35	–	–	12	10	13	28
16	*Borreria stricta*	–	–	18	30	–	–	–	–
17	*Eemelia sonjifolia*	–	–	5	15	11	5	12	5
18	*Pistia striata*	–	–	8	55	–	–	–	–
19	*Eichnochloa* sp.	–	–	10	35	16	18	13	25
20	*Oryza rufipogon*	–	–	–	–	18	20	12	15
21	*Monochoria vaginalis*	–	–	–	–	–	–	–	–
22	*Ludwigia parviflora*	13	20	12	30	16	5	8	15

***Table 3.** Chemical composition of aquatic macrophytes (shoot) of Kuttanad - Kari lands*

Sl. No.	Species	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	Al	Cd	Pb
		(mg kg^{-1})		(%)			(mg kg^{-1})					(µg kg^{-1})	
1	*H. asiatica*	2625	7250	3.76	0.76	0.13	1295	25	80	17	1867	359	921
2	*B monnieria*	3200	18500	3.44	2.20	0.17	2375	20	34	19	1798	508	935
3	*C. bengalensis*	3287	18500	2.64	0.52	0.170	2185	5	66	20	1982	156	788
4	*E. crassipes*	0.41	2.15	3.75	1.68	0.45	22865	120	125	95	1728	2200	6163
5	*C. dactylon*	3666	43000	4.96	1.62	0.22	7480	175	112	41	1420	1612	658
6	*Cyperus* sp.	361	31000	4.46	2.30	0.28	5780	205	76	28	969	808	968
7	*Eleocharis* sp.	6102	45000	3.05	0.70	0.31	10051	178	64	22	1529	811	853
8	*S. molesta*	4105	21500	3.75	1.68	0.45	11460	62	71	95	1115	869	1130
9	*H. verticilata*	2000	5500	4.00	0.60	0.32	24251	53	211	198	2526	390	566

media and accumulate them in above ground plant parts as evidenced by a bioconcentration factor (BCF) for shoot, greater than one (Table 5).

Among the identified phytoextractors, *Hydrilla verticilata* recorded the highest concentration for Fe, Zn, Cu and Al in shoot and Fe and Zn in root followed by *Eichhornia crassipes.* This has clearly indicated that *Hydrilla verticilata and Eichhornia crassipes* were capable of removing the above elements from the soil/water and lessens the extent

Table 4. *Chemical composition of natural flora (root) of Kari lands*

Sl. No.	Species	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	Al	Cd	Pb
		(mg kg^{-1})		(%)			(mg kg^{-1})					(µg kg^{-1})	
1	*H. asiatica*	0.21	0.90	1.6	1.2	0.22	1640	20	58	46	759	202	745
2	*B monnieria*	0.19	1.72	4.5	1.2	0.21	3735	25	26	15	1967	315	613
3	*C. bengalensis*	0.27	1.95	0.96	0.57	0.26	2750	10	46	15	1669	322	419
4	*E. crassipes*	0.30	1.2	3.75	1.20	0.32	8405	74	105	90	2300	1065	9114
5	*C. dactylon*	0.15	2.60	4.52	2.68	0.55	4200	100	40	22	1039	710	744
6	*Cyperus* sp.	0.48	1.55	3.92	1.39	0.19	6140	125	56	38	1563	916	880
7	*Eleocharis* sp.	0.51	2.25	2.95	1.10	0.27	8427	94	59	43	1425	714	1102
8	*S. molesta*	0.31	1.36	2.74	0.89	0.44	8245	96	105	21	1250	845	878
9	*H. verticilata*	0.20	0.60	2.8	0.61	0.16	10620	58	196	49	1238	324	658

Table 5. *Bioconcentration factors for various toxic elements showed by aquatic macrophytes (shoot) of paddy fields of Kari lands*

Species	Fe	Mn	Zn	Cu	Al	Cd	Pb
H. asiatica	3.78	5.00	32.0	3.00	21.2	2.11	1.23
B monnieria	6.94	4.00	17.0	7.50	20.4	2.98	1.25
C. bengalensis	6.38	0.58	33.0	7.50	22.5	0.917	1.05
E. crassipes	66.9	24.0	62.5	45.0	19.6	12.94	8.22
Cynadon dactylon	21.9	35.0	56.0	11.0	16.1	9.48	0.87
Cyperus sp.	16.9	41.0	38.0	19.0	11.1	4.75	1.29
Eleocharis sp.	29.4	35.6	32.0	21.5	17.3	4.77	1.14
S. molesta	33.6	24.0	62.5	11.5	12.6	5.11	1.51
*H. verticilata**	41.5	6.30	47.9	12.5	24.6	1.86	0.70

*BCF calculated based on elemental content of sediment

of pollution. *Cyperus* species was found to accumulate highest quantity of Mn in both shoot and root. *Eichhornia crassipes* recorded the highest concentration of Cd and Pb in both shoot and root. The highest bioconcentration factor (BCF) was recorded by the same plants for the respective metals, except for Fe, Zn and Cu which were present in highest quantity in *Hydrilla verticilata* while the BCF was highest for *Eichhornia crassipes*. This was mainly because of the higher concentration of Fe, Zn and Cu in the sediment compared to rice soil. Since *Hydrilla verticilata* was present mainly in waterways/canals the amount of the above elements present in sediment sample was used for calculation of BCF. Though the above three macrophytes had recorded the highest content of toxic elements, the other plants also possess fare hyperaccumulation ability, since all of them have a BCF greater than one, which is an essential criterion for the selection of hyperaccumulators/phytoextractors.

The presence of aquatic macrophytes with good phytoextracting ability in waterways/canals could remove substantial quantities of contaminants from water/soil/sediment and make the wetland ecosystem safer for aquatic organisms. Similarly the technology can be successfully utilized for purifying metal loaded effluents discharged from factories by growing them in constructed lagoons containing the effluent. Thus, the aquatic macrophytes viz., *Hydrilla verticilata, Eichhornia crassipes* and *Cyperus* sp. can be utilized for improving water quality and safe guarding the water bodies/rice fields from metal contamination by removing an appreciable quantity of toxic metals from soil/water and make the ecosystem more healthy and sustainable.

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Evaluation of Soil Nutrient Balance with Varying Organics and Doses of Inorganics under Double Sucker System of Planting Banana

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Banana is an exhaustive feeder of nutrients due to its rapid and vigorous growth and high productivity. Competition for nutrients is one of the factors which result in reduced bunch weight under high density planting of banana. This necessitates the need for augmenting and optimizing the nutritional requirement of banana under double sucker planting. An integrated nutrient management practice combining organic and inorganic nutrient sources has to be adopted for better results. Different levels of inorganic nutrients and organic sources on double sucker planting were studied. The treatments constituted three levels of nutrients viz., recommended dose of nutrients, 133 per cent of recommended dose of nutrients and 167 per cent of recommended dose of nutrients as well as three sources of organic manure viz., farmyard manure, banana residue in fresh state and vermicomposted. Balance sheet of soil nutrients were worked out utilizing the nutrient gains and losses recorded in the experiment. Soil nutrient status improved after two years of experimentation in all the treatments.

(Key words: *Banana, Double sucker planting, Inorganic nutrients, Organic source, Soil nutrient balance sheet)*

Banana is an important fruit crop having great socio-economic significance in India. It supports the livelihood of millions of people. It is interwoven with national heritage and due to its multi-faceted uses it is referred to as 'Kalpatharu' (Plant of Virtues) meaning 'herb with all imaginable uses'. It can grow well under a wide range of agro climatic situations, ecological conditions and various systems of production. Commercial banana cultivation is taken up by small and marginal farmers on a large scale as an answer to low returns from agriculture. Increasing agricultural production by increasing area is no longer possible as cultivable land left over is only marginal. Hence, self sufficiency can be attained by increasing the yield per unit area per unit time through adoption of modern agricultural technology and crop intensification is perhaps the only possible solution for the same. Being adapted to grow under low light intensities, banana plants can withstand shade and hence are highly suitable for high density planting. Adopting high density with more number of suckers per pit in single row planting with wider spacing provides more space for intercropping. It also helps to reduce labour cost and increase the efficiency of input utilization.

Banana being a heavy remover of nutrients, high yields of quality bananas can only be sustained through the application of optimal doses of nutrients in balanced proportion. Nutrient application throughout the growth stages is important in realizing the economic yield in Nendran banana. Competition for nutrients is one of the factors which result in reduced bunch weight under high density planting of banana. This necessitates the need for augmenting and optimizing the nutritional requirement of banana under high density planting. An integrated nutrient management practice combining organic and inorganic nutrient sources has to be adopted for better results. Existing technologies of nutrient supply are to be refined for judicious use to enhance the profitability under double sucker planting as increased manurial dose may not be required for increased number of suckers per pit. The socio-economic conditions of farming community and prevalent local edaphic factors should also be taken into account before nutrient recommendations are advocated. Traditional manuring system utilizing FYM is already under pressure due to non availability, high cost and drudgery in transporting and spreading the same. Hence, the possibility of including alternative organic sources in the nutrient package by recycling

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banana residues as such or as vermicompost has to be assessed. Though banana pseudostem is a rich source of plant nutrients, its disposal after harvest creates great problem. The efficacy of incorporation of fresh crop residue (pseudostem) as such or as vermicompost needs to be evaluated. This practice helps to meet the organic manure requirement of the crop and also ensures sustainability by recycling of crop waste.

MATERIALS AND METHODS

The investigation on nutrient management was conducted in two consecutive cropping seasons at the Instructional Farm attached to College of Agriculture, Vellayani, Kerala Agricultural University. Different levels of inorganic nutrients and organic sources on double sucker system of planting were studied. The treatments constituted three levels of nutrients viz., recommended dose of nutrients (RDN-300: 119 : 450 g NPK pit^{-1}), 133 per cent of RDN and 167 per cent of RDN as well as three sources of organic manure viz., (FYM) @ 15 kg pit^{-1}, banana residue in fresh state (BR) @20 kg pit^{-1}and vermicomposted (VC) @ 5 kg pit^{-1}. The experiment was in factorial randomized block design with three replications. The plot size used was 6 m x 4 m. Pits of 50 cm x 50 cm x 50 cm were dug to accommodate two suckers as per the treatment schedule. In double sucker planting two suckers were planted with 3 m x 2 m spacing towards the sides of the pit at a spacing of 30 cm between plants.

The treatment combinations are detailed below

T_1 – f_1o_1 – RDN + FYM @ 10 kg pit^{-1}

T_2 – f_1o_2 – RDN + VC @ 5 kg pit^{-1}

T_3 – f_1o_3 – RDN + BR @ 20 kg pit^{-1}

T_4 – f_2o_1 – 133 per cent of RDN + FYM @ 10 kg pit^{-1}

T_5 – f_2o_2 – 133 per cent of RDN + VC @ 5 kg pit^{-1}

T_6 – f_2o_3 – 133 per cent of RDN + BR @ 20 kg pit^{-1}

T_7 – f_3o_1 – 167 per cent of RDN + FYM @ 10 kg pit^{-1}

T_8 – f_3o_2 – 167 per cent of RDN + VC @ 5 kg pit^{-1}

T_9 – f_3o_3 – 167 per cent of RDN + BR @ 20 kg pit^{-1}

To ensure maximum homogeneity in physiological maturity, tissue cultured plantlets of two and a half to three months old were used for planting the first crop. Selected suckers of first crop having uniform size and age were used for planting the second crop. As per the POP Recommendations of Kerala Agricultural University (2002) the fertilizers were applied in splits. Nitrogen and potassium were given in 6 splits (1, 2, 3, 4, 5 months after planting and at bunch emergence) and phosphorus in two splits (1 and 3 months after planting).In situ green manuring of banana with cowpea was followed uniformly for all the treatments.

The plant was separated into rhizome, pseudostem, leaves and fruits at harvest and was analyzed for nitrogen, phosphorus and potassium content. Uptake of nutrients by each plant part at harvest was calculated from the values of dry matter production and per cent nutrient content of each plant part and expressed in kg ha^{-1}. Soil samples were collected from the experimental area before and after the investigation and analyzed for nitrogen, phosphorus and potassium. Balance sheet of soil nutrients were worked out utilizing the nutrient gains and losses recorded in the experiment.

RESULTS AND DISCUSSIONS

Balance sheet of soil nutrients worked out in the experiment was furnished in Table 1. Levels of nutrients, organic sources and their interactions caused variation on available nitrogen, phosphorus and potassium status of the soil. In general there was a buildup of soil nutrients after the experiment. The computed values were more than the actual values obtained by the direct analysis of the soil. Available soil nitrogen recorded high values with f_2 which might be due to decreased losses of the nutrient in the treatment (Fig. 1). Inorganic nitrogen added to all experimental plots might have enhanced the nitrate nitrogen content of the soil, possibly due to conversion of applied mineral nitrogen through nitrification process (Krishnan, 1986).

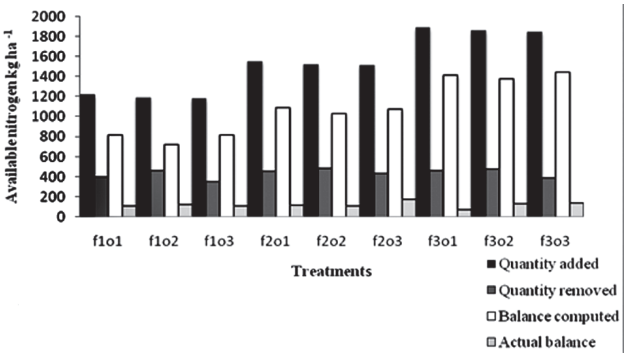

Fig. 1. Soil nutrient balance sheet of available nitrogen as influenced by nutrient levels and organic sources

Higher status of available P in the soil after harvest was noticed as the phosphatic fertilizers which are highly reactive might got fixed in the soil and released phosphorus slowly to the available pool. Maximum value of available soil phosphorus with vermicompost addition could be attributed to the formation of phospho - humic complexes (Fig. 2).

Table 1. *Balance sheet of the soil nutrients (kg ha^{-1})*

Treatments	Initial status			Quantity added as fertilizer		
	N	P	K	N	P	K
f_1o_1	103.49	7.2	82.4	1000	384	1500
f_1o_2	103.49	7.2	82.4	1000	384	1500
f_1o_3	103.49	7.2	82.4	1000	384	1500
f_2o_1	103.49	7.2	82.4	1332	510	2000
f_2o_2	103.49	7.2	82.4	1332	510	2000
f_2o_3	103.49	7.2	82.4	1332	510	2000
f_3o_1	103.49	7.2	82.4	1666	638	2500
f_3o_2	103.49	7.2	82.4	1666	638	2500
f_3o_3	103.49	7.2	82.4	1666	638	2500
Treatments	Quantity added as organic manure			Quantity added as green manure		
	N	P	K	N	P	K
f_1o_1	44.8	25	25	71.64	42.98	57.31
f_1o_2	16.8	6.6	30	71.64	42.98	57.31
f_1o_3	4.2	1	23.2	71.64	42.98	57.31
f_2o_1	44.8	25	25	71.64	42.98	57.31
f_2o_2	16.8	6.6	30	71.64	42.98	57.31
f_2o_3	4.2	1	23.2	71.64	42.98	57.31
f_3o_1	44.8	25	25	71.64	42.98	57.31
f_3o_2	16.8	6.6	30	71.64	42.98	57.31
f_3o_3	4.2	1	23.2	71.64	42.98	57.31
Treatments	Total quantity added			Quantity removed		
	N	P	K	N	P	K
f_1o_1	1219.93	555.47	1685.8	399.3	82.5	1304.8
f_1o_2	1191.93	537.07	1690.8	469.1	91	1281.4
f_1o_3	1179.33	531.47	1684	355.7	90.2	1167.6
f_2o_1	1551.93	681.47	2185.8	456.1	95.3	1299.1
f_2o_2	1523.93	663.07	2190.8	486.1	98.3	1207.9
f_2o_3	1511.33	657.47	2184	435.2	94.3	1187.6
f_3o_1	1885.93	809.47	2685.8	468.5	81.7	1015.7
f_3o_2	1857.93	791.07	2690.8	479.5	87	1429.3
f_3o_3	1845.33	785.47	2684	394.5	77.4	1497.6
Treatments	Soil status after the experiment					
	Computed			Actual		
	N	P	K	N	P	K
f_1o_1	820.63	473	381	109.8	9.44	239.53
f_1o_2	722.83	446.1	409.4	130.7	11.64	463.83
f_1o_3	823.63	441.3	516.4	112.9	11.33	626.01
f_2o_1	1095.8	586.2	886.7	119.2	12.58	499.97
f_2o_2	1037.8	564.8	982.9	112.9	14.26	306.13
f_2o_3	1076.1	563.2	996.4	182.3	9.65	489.51
f_3o_1	1417.4	727.8	1670.1	75.26	7.66	725.46
f_3o_2	1378.4	704.1	1261.5	138	11.12	575.83
f_3o_3	1450.8	708.1	1186.4	142.2	16.46	565.38

Table 2. *Effect of nutrient levels and sources of organic manure on the yield of banana*

Treatments	Yield (t ha^{-1})			Net income (Rs ha^{-1})		
	Season I	Season II	Pooled	Season I	Season II	Pooled
f_1o_1	35.89	34.44	35.16	399115	380326	389721
f_1o_2	36.22	38.55	37.38	396697	400049	384874
f_1o_3	33.55	33.33	33.44	375034	372146	373590
f_2o_1	35.33	41.11	38.21	386393	461536	423965
f_2o_2	36.88	32.77	34.82	372863	319409	346136
f_2o_3	34.00	36.22	35.10	375312	404172	389742
f_3o_1	30.11	38.33	34.22	313466	420351	366909
f_3o_2	37.88	38.11	37.99	380817	383697	382258
f_3o_3	34.55	39.22	36.88	377488	438127	407808
$F_{4,16}$	0.26^{ns}	5.23**	3.41*	1.45^{ns}	5.23**	3.41*
SEm±	2.601	1.479	1.170	23906.6	19233.9	15197.0
CD	–	4.436	3.350	–	57665.9	43563.9

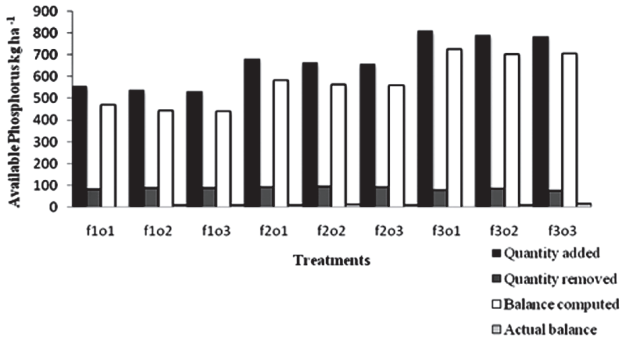

Fig. 2. Soil nutrient balance sheet of available phosphorus as influenced by nutrient levels and organic sources

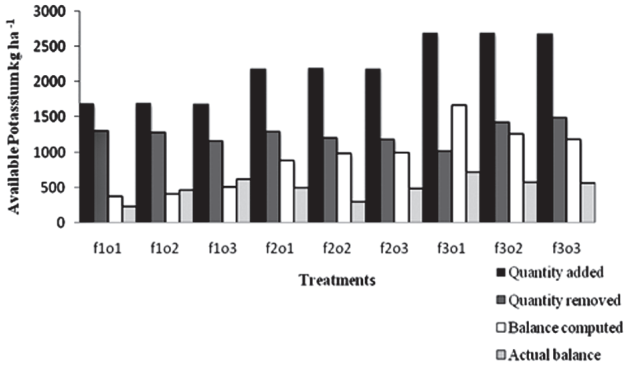

Fig. 3. Soil nutrient balance sheet of available potassium as influenced by nutrient levels and organic sources

Improvement in soil potassium at f_3 level could be related to the higher dose of potassium added (Fig. 3). Available N, P and K in soil were more with incorporation of fresh banana pseudostem, could be attributed to low uptake values of nitrogen, phosphorus and potassium noticed in the treatment. In addition, crop residues add to slow and passive recalcitrant pools of soil organic matter. Their nitrogen release potential is rather low due to higher C : N ratio and consequent slow rate of mineralization. Under adequate supply of N and P when crop residues are returned to the soil, the added nutrients might be immobilized in fairly stable organic carbon compounds (Tisdale *et al.*, 1995). Less loss could be noticed due to slow mineralization. Application of banana stems may significantly increase soil potassium (Lassoudiere and Godefroy, 1971) also supports the result.

Both the actual and computed values of soil nutrients in the balance sheet are on positive side indicating good nutrient management in all treatment combinations. The variation in the computed values and actual values for nitrogen might be due to low nitrogen use efficiency and different types of losses like leaching, surface runoff and immobilization by microbes. The actual phosphorus was very low compared to computed value since the soil in experimental field belongs to the order oxisol which is characterized by high P fixation due to increased weathering and increased clay fraction dominated by hydrous oxides, iron and aluminium. In general not much variation in K status between actual and computed values except at highest dose of nutrients applied. This can be attributed to interaction of potassium with other cations, leaching losses and luxury consumption.

From the present study we can recommend farmyard manure and fresh banana pseudostem with 133 per cent of RDN and vermicompost with RDN which recorded maximum yield per hectare (Table 2) as economically viable and sustainable practice for banana var. Nendran under paired

system of planting. However, soil nutrients in the balance sheet are on positive side indicating good nutrient management in all treatment combinations.

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Length of Growing Period and Water Productivity of Important Crops and Cropping Systems for Coastal Areas of Haldia, Paradip and Visakhapatnam

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Scarcity of water is going to be more acute under changing climate in the coastal areas of India due to uncertainity in rainfall amount and distribution. Analysis of rainfall data from 1990-2011 at three sites *viz.* Visakhapatnam, Paradip and Haldia in Andhra Pradesh, Odisha and West Bengal respectively revealed that the co-efficient of variation of annual rainfall was the highest for Visakhapatnam (26.4), followed by Paradip (22.7) and Haldia (21.5). The trend analysis of long-term rainfall data revealed that the average annual rainfall declined by 6.3% at Haldia, increased by 8.5% at Paradip and declined by 14.3% at Visakhapatnam during 2001-2010 from that of 1991-2000. The crop evapotranspiration (ET_{crop}) computed by modified Penman method revealed that during dry season highest ET_{crop} was observed in case of boro rice (604.8 mm) at Haldia, for brinjal (507.2 mm) at Paradip and for sugarcane (1178.9 mm) at Visakhapatnam, whereas water productivity (WP) on the basis of economic yield was highest in case of potato at Haldia (7.2 kg m^{-3}) and Paradip (6.6 kg m^{-3}) and sugarcane at Visakhapatnam (6.7 kg m^{-3}). Suitable cropping systems like rice-potato, rice-sunflower for Haldia, rice-tomato, Rice-potato and rice-brinjal for Paradip and rice-chilli for Visakhapatnam may be followed to get higher WP on net return basis. Irrespective of location, the WP on net return basis was more than ₹ 20 m^{-3} in case of rice-tomato, rice-potato, rice-brinjal, rice-onion, rice-sunflower and rice-chilli. Under changing climatic conditions, increasing degradation as well as limited availability of natural resources in coastal areas suitable cropping systems should be identified and followed for better water productivity as well as profitability.

(Key words: *Crop coefficient, Cropping system, Evapotranspiration, Growing period)*

The coastal region of India is traditionally disadvantaged and backward with low livelihood security of the farmers. The ecology of the coastal region is also highly fragile and vulnerable to further degradation due to anthropogenic activities. The farming communities of the coastal region are dominated by backward classes of people who are the poorest of the poor in the country. Low agricultural productivity and high unemployment among the rural people is the characteristic feature of the area. The degraded soil and water quality, together with climatic adversities contribute to low cropping intensity and agricultural productivity.

The constraints like, waterlogging, drainage congestion, lack of irrigation water**,** salinity of soil and underground water, etc. have turned almost the entire coastal region of the country as mono-cropped area growing traditional rice varieties with very poor yield in monsoon season. Most of the lands remain fallow during the rest period of the year. Due to heavy concentrated rainfall in a short span of a few monsoon months (June-September), flat topography, low infiltration rate, presence of ground water at the surface and lack of proper drainage facility most of the cultivated fields are deeply waterlogged during *Kharif* season (June – November). Due to presence of brackish water table at a shallow depth there is always an increase in soil and water salinity in dry months. However, the region is endowed with bounty of natural resources like high precipitation, diverse and fertile soils rich in phosphorus and potassium, flat topography and crop and varietal biodiversity. In spite of the vast resource potentials in the coastal region, the enhancement of the agricultural productivity of coastal lands has been slow and much below the potential. The coastal areas are much lagging behind many inland areas in terms of agricultural productivity and livelihood security of the farmers.

Low land productivity and consequently, poor socio-economic condition of coastal region in India, is one of the key problems in the overall development of the country in spite of spectacular progress in the field of agriculture in other regions. The demand

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for food, fodder and fibre are increasing in this fragile ecosystem. Soil salinity and water scarcity of different degrees and duration occur in these areas and reduce the choice of crop/variety and yield. Sen *et al.*, (2009) reported that the rice yield during the wet season is as low as 1.0 to 1.5 t ha^{-1} in the coastal saline areas of eastern India due to erratic rainfall, abiotic stresses viz. salinity, drought, submergence and natural calamities (storms and cyclones). Average land holding of most farmers (more than 80%) in the coastal area is marginal (<1 ha), land is fragmented in to multiple parts and in majority cases the holding size is even below 0.5 ha. Hence to raise the income of the farming community, it looks imperative to diversify the mono cropping of rice with other farming options (Sarangi *et al.*, 2014a). The coastal saline soil in eastern India is concentrated mainly in three states like West Bengal, Odisha and Andhra Pradesh, with about 1.5 mha area out of total coastal saline area of 3.09 mha (Yadav *et al.*, 1983). The cropping intensities in the east and west coasts of India are only 134 and 125%, respectively. The major parts of the coastal tracts of West Bengal, Odisha and southern Andhra Pradesh – comprising nearly 50% of the cultivated coastal saline areas where rice largely grown under rainfed conditions – constitute the low-productivity rice belt in India. To increase cropping intensity and ensure food and economic security in the coastal saline areas, efforts must be focussed on developing diversified rice-based integrated farming systems by including low water-requiring, salt-tolerant non-rice crops (Mahata *et al.*, 2009). Appropriate technologies and cropping pattern with respect to the extent of salinity and available resources is needed to overcome the problems in these areas. One of the major impediments to cropping system intensification in coastal areas of India is lack of availability of good quality irrigation water during dry season. Avenues to improve crop production include, adopting cropping systems which make maximum use of available water, increasing the length of the growing season by advancing planting dates, adopting cropping systems which avoid mid- or end-season droughts and adopting improved agronomic practices such as crop rotation and moderate inputs (Virmani, 1987). For almost similar agroclimatic conditions in coastal Bangladesh, Mainuddin *et al.*, 2014 contemplated strategies for cropping system intensification with emphasis on knowledge-driven water harvesting, management, conjunctive use of surface and ground water, careful planning of crop calendar, efficient and timely agronomic management practices of crops and benchmarking them with their suitability to different saline zones to provide farmers with the choice to fit appropriate crops into their appropriate niche. To fit the suitable crop to a particular region, ensuring availability of irrigation water for that crop is essential. The average per capita water availability, estimated at 1600 m^3 $year^{-1}$ is expected to fall around 1000 in 2050 based on current projected population. Again, the effect of climate change will increase frequency of extreme events like flood and droughts and this makes future water availability and resources uncertain (Biswal *et al.*, 2014). With growth of other sectors of economy, there will be cross-sectoral competition for access to and control over water, which will aggravate the situation of water scarcity in agriculture sector, as a result the poor smallholder farming communities inhabiting in coastal areas would face extreme difficulties in getting sufficient irrigation water for dry season cropping. In view of this the present study was undertaken to address such problems. Growing of non-rice crops during dry season by conserving the excess rainwater of wet season in on-farm reservoirs is possible in the coastal areas. Shift from rice to non-rice crops could also help enhance land and water productivity, crop diversification and farmer's income and reduce the risk of yield losses due to shortage of irrigation water during the grain filling of rice (Singh *et al.*, 2010). Irrigation water during dry season being limited in availability, choice of crops should be on water productivity basis. Producing more food for each drop of water will be a crucial strategy to address twin challenges of water stress and food insecurity (Molden, 2007).

MATERIALS AND METHODS

Experimental site

The study area covers Haldia, Paradip and Visakhapatnam areas of West Bengal, Odisha and Andhra Pradesh respectively in the eastern coast of India within 50 km from the Bay of Bengal (Fig.1). The basic soil characteristics of the study sites are given in Table 1.

Haldia soil is mostly heavy textured, low saline with acidic to neutral pH, medium in phosphorus (P) and potassium (K), at Paradip the soils are sandy to sandy clay loam, low to moderate saline with acidic pH, medium in P and K, at Visakhapatnam, the soils were sandy to sandy clay in texture with neutral pH, low in P and high in K. The soils

classification for study area are typic endoaquepts for Haldia, typic ustipsamments, vertic and aeric tropaquepts for Paradip and typic ustropepts, mixed haplustalfs for Visakhapatnam (Sarangi *et al.*, 2012).

Fig. 1. Study locations are in the eastern coast of India

Cropping system, crops and varieties

Rice based cropping system is the predominant one in the study sites except at Visakhapatnam where farmers grow sugarcane. The dry season crops were selected on the basis of suitability to the soil and weather conditions as well as local market demand. At Haldia four crops (summer/boro rice, potato, sunflower and lathyrus), at Paradip seven crops (brinjal, chilli, ladies finger, tomato, potato, onion and green gram) and at Visakhapatnam four crops (sugarcane, chilli, sesame and horse gram) were evaluated. Generally at these sites the land remain fallow or in very limited area crops like lathyrus (Haldia), green gram (Paradip) and horse gram (Visakhapatnam) are grown. In the present study, during wet season locally adapted rice varieties were grown (Dudheswar, Harisankar and Pushkala at Haldia, Paradip and Visakhapatnam respectively) and during dry season mostly high yielding varieties were selected except for onion, sesame and horse gram. At Haldia, the varieties for boro rice, potato, sunflower and lathyrus were MTU 1010, Jyoti, PAC 36 and Nirmal respectively. At Paradip, the varieties

Table 1. *Location of study sites and soil characteristics*

Location and village	Coordinates	Distance from sea coast (km)	Soil characteristics					
			Texture	ECe (dS m^{-1})	pH	Total N (%)	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Haldia								
Geondab	22^0 05.024´ N 88^0 04.604´ E	8	sic	2.52	5.23	0.04	14.6	147.4
Barabari	22^0 05.553´ N 88^0 04.810´ E	12	cl	1.75	7.40	0.05	11.1	134.3
Bholsara	22^0 11.208´ N 87^0 59.058´ E	25	sc	2.60	6.20	0.07	16.2	128.7
Paradip								
Saraba	20^0 10.602´ N 86^0 25.481´ E	12	scl	3.28	6.05	0.01	23.7	136.5
Badilo	20^0 13.340´ N 86^0 21.335´ E	21	scl	2.66	5.09	0.07	21.8	142.1
Sandhapur	20^0 18.829´ N 86^0 30.354´ E	5	s	4.13	5.14	0.06	24.4	146.5
Visakhapatnam								
Appikonda	17^0 38.987´ N 83^0 12.931´ E	1	sl	4.32	7.19	0.03	8.54	467.7
Rishikonda	17^0 46.152´ N 83^0 22.224´ E	5	s	2.56	6.36	0.01	5.65	295.5
Ankapalle	17^0 41.373´ N 83^0 00.787´ E	30	sc	1.61	7.47	0.05	8.85	245.6

s = sandy, sl = sandy loam, sc = sandy clay, cl = clay loam, scl = sany clay loam, sic = silty clay

for brinjal, chilli, ladies finger, tomato, potato and green gram were BB44, Utkal Rashmi, Utkal Gaurav, BT -1, Jyoti and Durga respectively. The sugarcane and chilli varieties were Co 6907 and Bhagya lakshmi (G-4) respectively at Visakhapatnam.

Data collection and statistical analyses

Rainfall and evaporation data from 1990-2011 were collected from these three sites and analyzed for standard deviation (SD), co-efficient of variation (CV), potential evapotranspiration (PET), length of growing period (LGP) distribution pattern. For computation of reference evapotranspiration (ET_0) four empirical methods (Blaney-Criddle, Radiation, Modified Penman and Pan evaporation) were used (Table 2). The data obtained from Modified Penman method was used for calculation of crop evapotranspiration (ETcrop), which was again used for computation of water productivity.

Table 2. *Different methods and parameters used in the estimation of ET_0 at the study sites*

Method	T	H	W	S	R	E	En
Blaney-Criddle	*	0	0	0			0
Radiation	*	0	0	*	(*)		0
Modified Penman	*	*	*	*	(*)		0
Pan evaporation		0	0			*	*

T: Temperature, H: Humidity, W: Wind, S: Sunshine, R: Radiation, E: Evaporation, En: Environment, * Measured data; 0 estimated data; (*) if available, but not essential

The empirical formulae of different methods are given below. Tables and figures refereed in the following four methods are from FAO Irrigation and Drainage Paper 24 (Doorenbos and Pruitt, 1977).

1. Blaney-Criddle Method: $ET_0 = c[p(0.46T + 8]$ mm day^{-1}

Where: ET_0 = reference crop evapo-transpiration in mm day^{-1} for the month considered, T = mean daily temperature in °C over the month considered, p = mean daily percentage of total annual daytime hours obtained from Table 1 for a given month and latitude, c = adjustment factor which depends on minimum relative humidity, sunshine hours and daytime wind estimates.

2. Radiation Method: $ET_0 = c(W.Rs)$ mm day^{-1}

Where: ET_0 = reference crop evapo-transpiration in mm day^{-1} for the month considered, Rs = solar radiation in equivalent evaporation in mm day^{-1}, Rs = (0.25+ 0.50 n/N)Ra, Ra = Extra Terrestrial Radiation (Ra) expressed in equivalent evaporation in mm day^{-1} from Table 2, W = weighting factor which depends on temperature and altitude from Table 4, c = adjustment factor which depends on mean humidity and daytime wind conditions from Fig. 2.

3. Modified Penman Method: $ET_0 = c[W.Rn + (1-W).f(u).(ea-ed)]$ mm day^{-1}

Where: ET_0 = reference crop evapo-transpiration in mm day^{-1} for the month considered, W = temperature related weighting factor from Table 8, Rn = net radiation in equivalent evaporation in mm day^{-1}, f(u) = wind related function = 0.27(1+U/100), U = 24-hr wind run in km day^{-1} at 2 m height, ea-ed = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar from Table 5 & 6, c = adjustment factor to compensate for the effect of day and night weather conditions from Table 16.

Modified Penman Method is a fairly accurate method for estimation of reference evapotranspiration as it utilizes almost all the meteorological parameters responsible for the process of evapotranspiration.

4. Pan Evaporation Method: ET_0 = Kp.Epan

Where Kp = pan coefficient, Epan = measured pan evaporation data, Values for Kp were obtained from Table 18 for the Class A pan and in Table 19 for the sunken Colorado pan for different humidity and wind conditions and pan environment.

The four methods described above, predict the effect of climate on ET_0. To account for the effect of the crop characteristics on crop water requirements, crop coefficients (kc) are required to relate ET_0 to ET_{crop}. The kc value relates to evapotranspiration of a disease-free crop grown in large fields under optimum soil water and fertility conditions and achieving full production potential under the given growing environment. ETcrop can be found by:

$$ET_{crop} = ET_0 \times kc$$

Based on the procedure suggested by Doorenbos and Pruitt (1977), kc values were found out (Table 3) for different crops at different locations taking into account crop characteristics, time of sowing, stages of crop development and general climatic conditions.

The crop yield data of various crops were collected from field experiments conducted during 2010-11 and 2011-12 in randomized block design (RBD) at these sites in the farmer's fields (3 farmers at each site). There were three replications in each farmer field, the mean data of each farmer was considered as one replication for analysis of data. At harvest, grain yield was recorded from a net area of 30 m^2 (6 m x 5 m) marked at the middle of each

plot and converted into t ha^{-1} by multiplying suitable conversion factor. Water Productivity (WP) of each crop and cropping system was calculated by using the following formula.

WP (kg m^{-3}) on produce basis = Grain Yield (kg)/ Amount of water used through evapotranspiraiton (m^3), WP (m^{-3}) on return basis = Return (₹)/Amount of water used through evapotranspiraiton (m^3)

The benefit cost ratio (BCR) was calculated as gross return accrued divided by total variable cost. Total variable cost was calculated by taking into account the costs of inputs (seed, fertilizer, and pesticides), costs of human labour for land preparation, irrigation, fertilizer, and pesticide application, bunding, harvesting and threshing; and costs of hiring power tillers for land preparation and an irrigation pump. Gross return was calculated by multiplying the amount of produce by its corresponding market price at harvest. Net return was the gross return minus total variable costs. The economic analyses were conducted by taking into account the prevailing market prices of inputs, labour, and produce during the year 2011-12. The data were subjected to analyses by STAR (Statistical Tool for Agricultural Research) package developed by International Rice Research Institute, Philippines (IRRI). Treatment means were compared using the least significant difference (LSD) tests and compared at p=0.05 level of significance (Gomez and Gomez, 1984). Since the interaction between year and different characters studied in this experiment were non-significant, hence mean data are presented.

RESULTS AND DISCUSSION

Rainfall, evaporation and evapo-transpiration

The analyzed rainfall data from 1990-2011 for study sites are given in Table 4. The annual mean rainfall is highest (1784.2 mm) for Haldia followed by Paradip (1635.9 mm) and Visakhapatnam (1175.5 mm). The co-efficient of variation of annual rainfall was highest for Visakhapatnam (26.4) followed by Paradip (22.7) and Haldia (21.5). The trend analysis of long-term rainfall data revealed that the average annual rainfall declined by 6.3% at Haldia, increased by 8.5% at Paradip and declined by 14.3% at Visakhapatnam during 2001-2010 from that of 1991-2000.

The rainfall pattern at Haldia, Paradip and Visakhapatnam of West Bengal, Odisha and Andhra Pradesh during 2009, 2010 and 2011 reveal that rainiest months were August, July and September for Haldia, Paradip and Visakhapatnam respectively (Fig. 2).

***Table 3**. Crop coefficient (kc) values used for estimation of crop water requirements (ET_{crop})*

Crops at different locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Haldia												
Kharif rice							*1.15	1.05	1.1	0.95	1.0	
Boro rice	1.2	1.4	1.3	1.0								
Potato	1.05	0.7										*0.7
Sunflower	0.6	1.2	0.8									
Lathyrus	0.3										*0.5	1.05
Paradip												
Brinjal	*0.35	0.6	0.8	0.95	0.8							
Chilli	0.8									*0.6	0.95	0.9
Ladies finger	*0.5	0.95	0.9	0.8								
Tomato	0.6									*0.4	0.6	1.05
Potato	0.6	1.05	0.7									*0.4
Onion	0.55	0.95	0.75									*0.35
Green gram	1.05	0.3										*0.4
Visakhapatnam												
Sugarcane	*0.4	0.5	0.6	0.7	1.0	1.0	1.3	1.3	1.3	0.7	0.8	
Chilli	0.95	0.8	0.5							*0.3	0.5	0.7
Sesame	*0.8	1.05	0.25									
Horse gram	1.05	0.3										*0.8

*Initial crop period

***Table 4**. Rainfall parameters for Haldia, Paradip and Visakhapatnam (1990-2011)*

Parameters	Haldia	Paradip	Visakhapatnam
Mean (mm)	1784.2	1635.9	1175.5
Range (mm)	1053-2581	793-2272	732-1763
SD (mm)	383.72	370.90	310.12
CV (%)	21.5	22.7	26.4

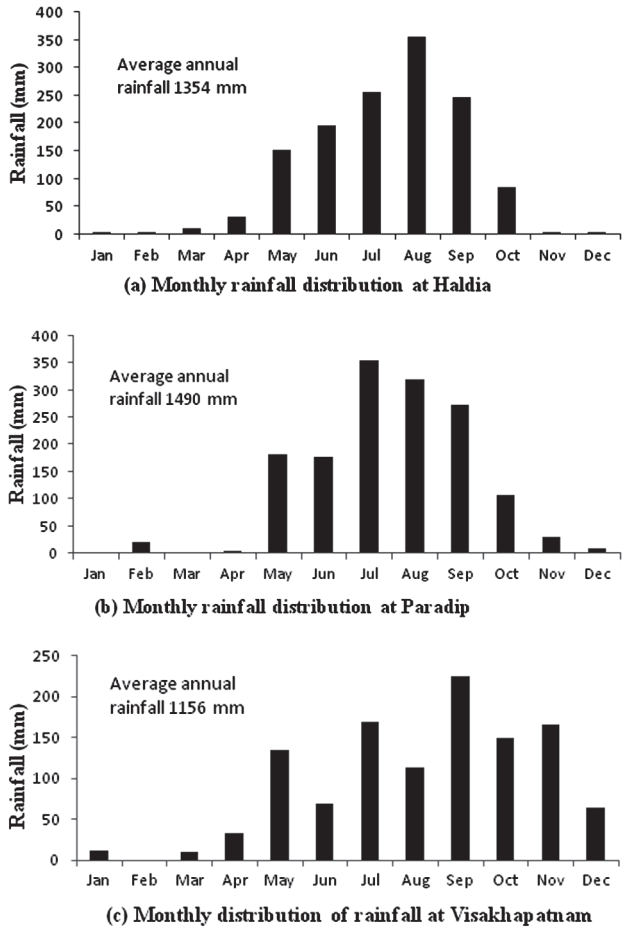

Fig. 2. Monthly rainfall distribution at (a) Haldia, (b) Paradip and (c) Visakhapatnam of West Bengal, Odisha and Andhra Pradesh respectively (mean data of 2009-2011)

A study of annual rainfall and evaporation reveal that annual evaporation exceeded rainfall by 79 and 347 mm at Paradip and Visakhapatnam respectively, whereas at Haldia the annual rainfall exceeds evaporation by 270 mm. The reference evapotranspiration (ET_0) for the three locations were computed by the modified Blaney-Criddle, radiation, modified Penman and Pan evaporation methods. The ET_0 was highest for Radiation method for all the locations and the total annual ET_0 were 2112.6, 2032.5 and 2075.5 mm for Haldia, Paradip and Visakhapatnam respectively (Table 5). The estimates by modified Penman and Blaney-Criddle were found be moderate among all the methods. Pan evaporation method underestimated the ET_0 when compared with the actual pan evaporation data (Epan).

The distribution of rainfall over pre-monsoon (April-May), monsoon (June-October) and post monsoon (November –March) was studied and it was found that though the annual rainfall was lowest at Visakhapatnam the distribution was more uniform *i.e.* 14.7, 63.1 and 22.2% during the pre-monsoon, monsoon and post monsoon period respectively (Table 6).

Length of Growing Period (LGP)

The length of the "growing season" or "growing period" (LGS or LGP), as defined by the Agro-Ecological Zones project (FAO, 1978-81) is the period (in days) during a year when precipitation (P) exceeds half the potential evapotranspiration (PET). On this basis the LGP was 150 (last week of May to last week of October), 170 (first week of May to third week of October) and 165 (first week of July to last week of December) days for Haldia, Paradip and Visakhapatnam respectively (Fig. 3).

Water Productivity (WP)

The crop evapotranspiration (ET_{crop}) was computed for potential crops at Haldia, Paradip and Visakhapatam, taking into consideration the ET_0 values obtained by Modified Penman method (Table 7). Highest ET_{crop} was observed in case of boro rice (604.8 mm) at Haldia, for Brinjal (507.2 mm) at Paradip and for Sugarcane (1178.9 mm) at Visakhapatnam. The economic yield was highest for potato at Haldia (14.5 t ha^{-1}) and Paradip (19.0 t ha^{-1}) and for sugarcane (69.5 t ha^{-1}) at Visakhapatnam, similarly WP on the basis of economic yield was highest in case of potato at Haldia (7.2 kg m^{-3}) and Paradip (6.6 kg m^{-3}) and sugarcane at

***Table 5.** Annual ET_0 (mm) in the coastal areas of West Bengal, Odisha and Andhra Pradesh*

Location	Blaney-Criddle	Radiation	Modified Penman	Pan evaporation	Epan
Haldia	1523.2	2112.6	1467.3	830.0	1081.9
Paradip	1496.4	2032.5	1476.3	1167.4	1572.9
Visakhapatnam	1396.2	2075.5	1427.5	1240.8	1155.7

Visakhapatnam (5.9 kg m-3). Brauman *et al.*, 2013 reported that water consumption by crops varies substantially, reflecting differences in cropping density, crop choice, soil characteristics, irrigation availability and agricultural management as well as climatic drivers of evapotranspiration. The choice of suitable crop likely to contribute substantially towards water saving without affecting food production, where water resources are scarce. Singh *et al.*, 2010 reported that across seasons and salinity levels in coastal saline soils of the Mahanadi delta, India, dry season crops like watermelon, chilli, pumpkin and sunflower were the best performers based on rice yield equivalent, net return, benefit-cost ratio and water productivity, with sunflower and chilli giving consistent yield. Studies at West Bengal, India also suggests farmers particularly with small and marginal holding size (< 1 ha) are interested for crop diversification towards vegetable crops and are interested to invest on water and inputs to achieve greater returns from crops other than rice (Chatterjee *et al.*, 2013). Since, irrigation water is a precondition for successful cropping during dry season in coastal areas, every drop of precious water could be used effectively by choosing water productive crops and cropping patterns, which not only increase production but also reduce the pressure on natural resources. However, suitable crops and varieties should be integrated with efficient irrigation methods and moisture conservation practices (e.g. mulching).

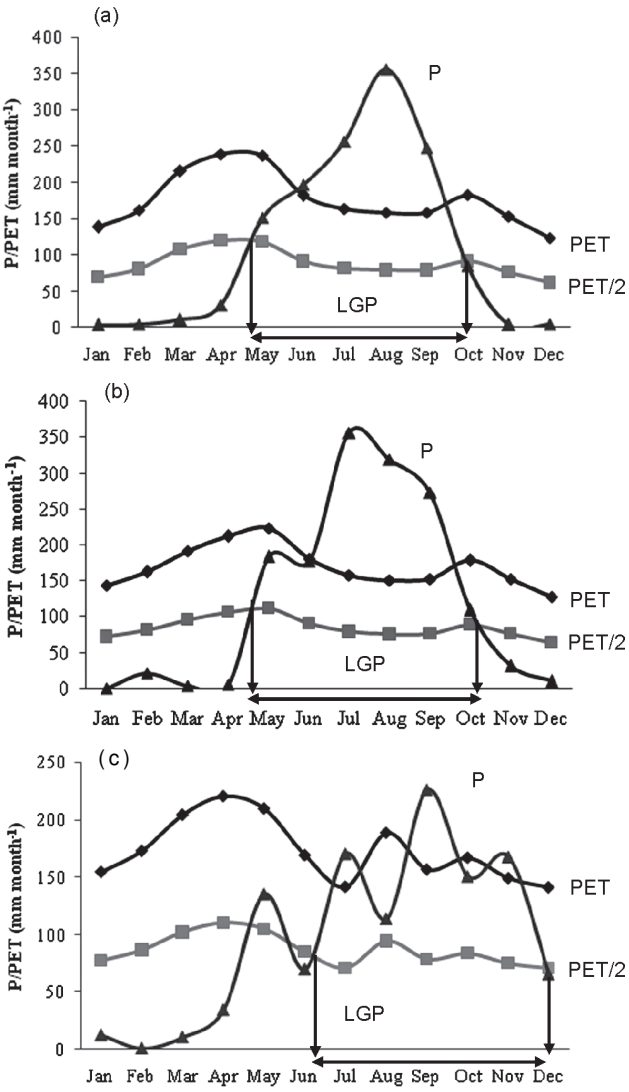

Fig. 3. Length of growing period (LGP) at (a) Haldia, (b) Paradip and (c) Visakhapatam

In order to find out suitable cropping systems for the study areas the water productivity was calculated for potential cropping systems on the basis of gross as well as net return basis (Table 8). The economic water productivity though blurred by fluctuations in market prices, still preferable and is more appropriate for comparing different crops (Droogers *et al.*, 2003). In the coastal areas of eastern India, rice-vegetable and rice-oilseeds were found to be remunerative cropping systems for getting higher WP. At Haldia highest WP on gross return basis was observed in Rice-potato (₹ 76 m^{-3}), followed by Rice-sunflower (₹ 36 m^{-3}), at Paradip Rice-tomato (₹ 102 m^{-3}) and Rice-potato (₹ 70 m^{-3})

Table 6. *Distribution of rainfall (R), evaporation (E) and evapo-transpiration (ET) in selected coastal areas of eastern India*

Location	April-May	June-October	November-March	Total
Haldia	R = 183.2 (13.5%) E = 299.3 ET = 355.4	R = 1142.6 (84.4%) E = 423.9 ET = 620.2	R = 27.9 (2.1%) E = 360.9 ET = 491.7	R = 1353.7 E = 1084.1 ET = 1467.3
Paradip	R = 188.8 (12.7%) E = 323.3 ET = 349.8	R = 1235.3 (82.9%) E = 648.9 ET = 621.9	R = 65.7 (4.4%) E = 596.8 ET = 504.6	R = 1489.8 E =1569.0 ET =1476.3
Visakhapatnam	R = 169.5 (14.7%) E = 370.5 ET = 313.8	R = 728.9 (63.1%) E = 552.3 ET = 591.0	R = 257.3 (22.2%) E = 580.2 ET = 522.7	R = 1155.7 E = 1503.0 ET = 1427.5

Table 7. *ET_{crop} and water productivity of important crops at Haldia, Paradip and Visakhapatnam (mean data of 2010-11 and 2011-12)*

Crop	ET_{crop} (mm)	Economic yield (tha^{-1})	WP* based on economic yield (kg m^{-3})
Haldia			
Kharif rice	599.8	2.35	0.39
Boro rice	604.8	4.50	0.74
Potato	201.1	14.49	7.21
Sunflower	286.0	2.49	0.87
Lathyrus	143.9	0.78	0.54
SEm±	–	0.29	0.13
$LSD_{0.05}$	–	0.87	0.40
Paradip			
Kharif rice	602.1	2.28	0.38
Brinjal	507.2	18.00	3.55
Chilli	308.1	2.32	0.75
Ladies finger	399.1	7.17	1.80
Tomato	243.7	16.00	6.57
Potato	288.5	18.97	6.59
Onion	276.7	5.50	1.99
Green gram	153.7	0.50	0.33
SEm±	–	0.20	0.06
$LSD_{0.05}$	–	0.58	0.18
Visakhapatnam			
Kharif rice	585.4	1.62	0.28
Sugarcane	1178.9	79.51	6.74
Chilli	387.1	3.43	0.89
Sesame	222.9	0.42	0.19
Horse gram	288.7	0.73	0.25
SEm±	–	0.27	0.03
$LSD_{0.05}$	–	0.82	0.07

*Water Productivity in kg yield $m^{-}3$ of water used through ET_{crop}

produced highest WP on gross return basis, whereas at Visakhapatnam, Rice-chilli (₹ 47 m^{-3}) followed by Sugarcane (₹ 13 m^{-3}) produced highest WP on gross return basis. Similar trend was also observed for WP on net return basis. However, some cropping systems were at par with respect to WP on net return basis e.g. at Paradip, Rice-greengram and Rice-ladies finger produced net return of ₹ 4.6 – 4.9 m^{-3} of water and at Visakhapatnam Rice-sesame, Rice-horsegram and sugarcane produced statistically similar net return (₹ 2.8 – 3.0 m^{-3}). It was found that suitable cropping systems like Rice-potato, Rice-sunflower for Haldia, Rice-tomato, Rice-potato, Rice-brinjal, Rice-onion and Rice-chilli for Paradip and Rice-chilli for Visakhapatnam may be followed to get higher water productivity on net return basis. Total cultivated area in the eastern coastal plain is about 8.58 million hectares and the cropping intensity is only 134% (Subba Rao, 2001), with introduction of water productive crops and suitable varieties in these areas, the cropping intensity, land and water productivity could be increased substantially. However, cropping options should be suitably integrated with sustainable management of water resources focusing on artificial recharge of the aquifer, recycling of water, desalinization of seawater, weather modification, improved irrigation management practices and use of marginally poor quality water (Sen *et al.*, 2011). The European Commission (2007) observed, based on a study by Spanish researchers, how an inappropriately planned coastal development could lead to increasing water consumption to unsustainable levels, for which future planning for sustainable development, based particularly on water resources, should be such as not to disturb the ecosystem in the long run. Crop diversification in coastal areas, should take into account the WP, as seen in the present study some of the dry season crops (*e.g. Boro* rice) are high water consumers, yet produce less per unit of water.

Table 8. *Economic water productivity of different cropping systems for Haldia, Paradip and Visakhapatnam (mean data of 2010-11 and 2011-12)*

Cropping system at study sites	WP* on gross return basis (₹ m^{-3})	Cost of cultivation* (₹ m^{-3})	WP on net return basis (₹ m^{-3})
Haldia			
Rice-potato	77.00	44.13	32.87
Rice-sunflower	37.13	12.04	25.09
Rice-rice	14.13	10.39	3.74
Rice-lathyrus	20.00	12.12	7.88
SEm±	0.20	0.11	0.28
$LSD_{0.05}$	0.59	0.33	0.84
Paradip			
Rice-tomato	83.50	28.41	55.09
Rice-potato	70.50	36.31	34.19
Rice-brinjal	40.25	13.24	27.01
Rice-green gram	16.13	10.23	5.90
Rice-chilli	42.38	18.31	24.07
Rice-onion	44.50	18.57	25.93
Rice-ladies finger	19.13	13.55	5.58
SEm±	0.30	0.12	0.31
$LSD_{0.05}$	0.88	0.35	0.91
Visakhapatnam			
Rice-chilli	47.75	20.28	27.47
Rice-horse gram	9.88	6.27	3.61
Rice-sesame	11.50	7.72	3.78
Sugarcane	14.88	8.93	5.95
SEm±	0.24	0.06	0.27
$LSD_{0.05}$	0.71	0.19	0.81

*Water Productivity and cost of cultivation in ₹ m^{-3} water used through ET_{crop}

However, productivity of boro rice is much higher in comparision to *kharif* rice mainly due to favorable weather conditions also when combined with better management practices (Sarangi *et al.*, 2014b) Diversification of crops should be for higher profits to farmers, sustainability of resources as well as for mitigating risks (Singh *et al.*, 2006).

CONCLUSION

Good quality irrigation water scarcity is the major constraint for dry season cropping in the coastal areas of eastern India, therefore selection of crops on the basis of water productivity, fitting these crops to the appropriate growing period are essential for efficient use of limited quantity of irrigation water. Choice of crops particularly during dry season varied across locations, however growing of vegetable crops like tomato, potato, brinjal, onion and chilli in the rice fallows in the eastern coast of India produced higher net income per unit of water used for evapo-transpiration. Among field crops, sunflower, green gram, horse gram and oilseed crop like sesame may be selected depending upon location. Diversification of dry season rice with water efficient crops not only save precious water resources, but also help increase the cropping intensity by growing water efficient crops through the saved water. However, besides choosing water efficient crops, water efficient varieties also be adopted wherever genetic diversity exists along with other resource conservation and management practices in a holistic manner for sustainability of rice based cropping systems in the eastern coast of India. Our study will help in judicious use of good quality irrigation water as well as in designing irrigation reservoirs in the coastal areas of India based on targeted crops as well as adopting conservation measures to achieve higher efficiency.

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Influence of Organics on Phosphorus Fractions under Sweet Corn in Coastal Region of Guntur District, Andhra Pradesh

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A field experiment was conducted during *Kharif,* 2013 at Agricultural College Farm, Bapatla, Guntur district to study the influence of farm yard manure (FYM) and poultry manure (PM) alone and in combination with fertilizers on different P fractions viz., saloid-P, Al-P, Fe-P, Ca-P and total P in soil at different stages of sweet corn. Among various P fractions saloid-P was significantly influenced by application of organics over sole fertilizer treatment at all stages. The treatment supplied with 50 % of N through PM and 50% through inorganics registered 71% increase in saloid -P over 100% N through fertilizers at knee-high stage, while the per cent increase was only 20 % at harvest. The remaining P fractions viz., Fe-P, Al-P, Ca-P and total-P were not markedly influenced by the application of organics at any stage of crop growth. Al -P ranged from 25.67 to 32.40, 27.97 to 42.73 and 31.00 to 42.83 mg kg^{-1} at knee high, tasseling and harvest stages, respectively. Highest Fe-P was recorded in treatment with 100 % N through PM at all stages whereas, the lowest Fe-P was observed in no nitrogen treatment. Maximum Ca-P values of 171 and 207 mg kg^{-1} at knee high and tasseling stages, respectively were registered in the treatment supplied with 100% N through PM while, 185 mg kg^{-1} was observed at harvest in the 50% N-PM+50% N- Fertilizer treatment. Regarding total-P, treatment supplied with 100 % N through poultry manure recorded maximum values at all stages of crop growth. All the inorganic fractions of phosphorus exhibited a significantly positive correlation with organic carbon.

(Key words: *Saloid-P, Iron-P, Aluminium-P, Calcium-P, Poultry manure, Farm yard manure)*

Phosphorus, an essential plant nutrient being a constituent of the energy currency adenosine triphosphate (ATP), plays a vital role in all biochemical process involving energy transfer. Phosphorus is important for cell elongation, respiration, root growth, early plant maturity, stalk strength and also imparts resistance to stress conditions. Despite wide distribution of phosphorus in nature, it is often a limited source for crop production. About 80 to 90% of the soils are deficient in plant available phosphorus. The P problem in soils is attributed to various adsorption and precipitation reactions of both the applied as well as indigenous soil P with Ca and/or Fe and Al compounds (Reddy *et al.*, 2005). This demands application of large quantities of inorganic P fertilizers, which are expensive inputs across the globe for successful crop production putting extra economic burden on resource poor farmers of the developing countries like India.

It is thus, imperative to develop some practicable and cost effective P management strategies in order to increase P use efficiency and maintain soil fertility using the existing natural resources. Organic manures are rich source of nutrients and are known to enhance efficient use of applied fertilizer. Wang *et al.,* (2008) reported that organic amendments consisting a mixture of humic acids and fulvic acids increased recovery of applied P due to decreases in the rate of precipitation in to poorly soluble Ca phosphates. The farm yard manure (FYM) and poultry manure (PM) are the two commonly available bulky organic manures, which influence the chemical and biotic processes, and can affect the availability of applied and native soil P. Keeping this in view, the present study was carried out to investigate the effects of FYM and PM on distribution of soil P into different forms viz., Saloid-P, Al-P, Fe-P, Ca-P and total P.

MATERIAL AND METHODS

A field experiment was carried out during *Kharif*, 2013 at Agricultural College Farm, Bapatla. The experimental field was a slightly alkaline, non saline clay loam soil with medium organic carbon (0.51%), low available nitrogen (198 kg ha^{-1}), medium available phosphorus (32.98 kg ha^{-1}) and high potassium (821 kg ha^{1}). The experiment consisted of eight treatments laid out in a randomized block design replicated thrice. The treatment combinations imposed were : T_1 - Control,

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T_2 - 100% N - Fertilizers, T_3 - 100% N - FYM, T_4 - 100% N - PM, T_5 - 75% N- FYM + 25% N - Fertilizers , T_6 - 75% N - PM + 25% N - Fertilizers, T_7 - 50% N- FYM + 50% N - Fertilizers , T_8 - 50% N - PM + 50% N - Fertilizers. Necessary quantities of well decomposed FYM and dried poultry manure were applied 15 days before sowing. Nitrogen was applied in three splits as per the treatments in the form of urea. Phosphorus and potassium were applied in the form of SSP and muriate of potash, respectively considering their contents in organics. The P fractions in the soil samples were sequentially extracted following the procedure outlined by Hedley *et al.*, (1982) and the P in the extract was estimated colorimetrically by ascorbic acid method using spectrophotometer at 660 nm (Murphy and Riley, 1962). The Olsen P was extracted with 0.5M $NaHCO_3$ and estimated colorimetrically using spectrophotometer at 660nm (Watanabe and Olsen, 1954). The total P was estimated in diacid extract following the method suggested by Jackson (1967). The correlations between different P forms and soil properties at harvest stage were worked out as per Panse and Sukhatame (1978).

RESULTS AND DISCUSSION

Saloid-P

Data presented in table 1 indicated a significant influence of treatments on the saloid -P at all stages of crop growth while, Fe-P was not influenced. At knee high stage application of entire nitrogen through fertilizer was superior to control but inferior to organic treatments in different combinations. Among organic treatments nitrogen application in equal doses from organic and inorganic sources (T_8 and T_7) and 75 % N - PM + 25 % N- Fertilizers (T_6) recorded higher saloid -P over the other treatments. Treatment T8 recorded 70% increase in saloid P over sole fertilizer application. The higher performance of integrated treatments could be due to the retention of applied P by organics. At tasseling, the highest saloid - P was recorded in 100 % N through poultry manure (T_4), which was on par with all organic and inorganic treatments. At harvest the sole organic treatments recorded higher saloid -P values which were comparable with other organic combinations and statistically superior over sole inorganics. Though application of 100 % N - through fertilizers recorded 37 per cent higher saloid-P and it was comparable with control. At various stages of plant growth release of chelating agents obtained from decomposition of manures capable of forming complexes with calcium, manganese, iron and aluminium salts of phosphates might have enhanced the solubilisation of phosphorus leading to more saloid -P. At harvest the significant influence of sole organics could be due to the slow and steady release of available forms over a long period. The findings are in agreement with Subbiah *et al.,* (2013).

Iron-P (Fe-P)

At knee high stage the values ranged from a minimum of 42.87 mg kg^{-1} in control to a maximum of 69.67 mg kg^{-1} with application of 100 % N through fertilizer. The high amount of Fe-P in inorganic treatments and all the integrated treatments except T_5 (75 % N - FYM + 25 % N - Fertilizer) in the initial stages might be due to the rapid conversion of applied P in to Fe-P compared to sole organics. At tasseling, values of Fe-P ranged from 65.83 to 45.23 mg kg^{-1} with highest and lowest recorded in T_2 (100 % N - Fertilizers) and T_1 (control), respectively. At harvest the highest (55.53 mg kg^{-1}) and the lowest (40.08 mg kg-^{1}) were recorded in the treatments which received complete nitrogen through fertilizers (T_2) and no nitrogen (T_1), respectively (Table 1). The decrease in Fe- P at later stages in the treatments supplied with nitrogen irrespective of source could be due to its conversion in to more available forms with enhanced root exudates or in to less available forms as in case of control where crop performance was poor. The decomposition of manure might have also produced organic compounds capable of chelating iron and organic acids which affected the dissolution of Fe-P (Bahl and Singh, 1997).

Aluminium-P (Al-P)

Data from table 2 revealed the occurrence of lower values of Al - P at knee high stage compared to tasseling and harvest. At knee high the values ranged from 25.67 mg kg^{-1} in control (T_1) to 32.40 mg kg^{-1} in 75 % N - PM + 25 % N - Fertilizers (T_6). Relatively higher values were recorded in integrated treatments. At tasseling, the values ranged from 27.97 to 42.73 mg kg^{-1} with the highest and lowest recorded in T_4 (100 % N -PM) and T_1 (control), respectively. Comparatively higher values were recorded in complete organic treatments. At harvest stage the maximum Al- P was recorded in the treatment T_5 (42.83 mg kg^{-1}) and the minimum in T_1 (31.0 mg kg^{-1}). It did not follow any particular trend.

Calcium -P (Ca-P)

Significant difference was not observed in Ca - P at all the stages of crop growth by the imposed treatments (Table 2). At knee high stage, Ca -P was maximum (171 mg kg^{-1}) in the treatment which received nitrogen completely through poultry manure (T_4) and minimum (112 mg kg^{-1}) in the treatment with

Table 1. *Influence of organics on saloid-P and Fe-P fractions (mg kg^{-1}) in soils*

Treatments	Saloid -P			Fe -P		
	Knee high	Tasseling	Harvest	Knee high	Tasseling	Harvest
T_1 - Control (No nitrogen)	5.53	6.92	6.33	5.53	6.92	6.33
T_2 - 100% N- Fertilizers	7.46	8.87	8.69	7.46	8.87	8.69
T_3 - 100% N - FYM	9.43	9.92	11.87	9.43	9.92	11.87
T_4 - 100% N - PM	9.70	10.26	12.22	9.70	10.26	12.22
T_5 - 75% N - FYM + 25% N - Fertilizers	9.33	9.75	10.97	9.33	9.75	10.97
T_6 -75% N - PM + 25% N - Fertilizers	11.38	9.83	11.08	11.38	9.83	11.08
T_7 - 50% N - FYM + 50% N - Fertilizers	12.39	9.20	9.67	12.39	9.20	9.67
T_8 - 50% N - PM + 50% N - Fertilizers	12.75	10.17	10.50	12.75	10.17	10.50
SEm±	0.50	0.58	1.02	0.50	0.58	1.02
CD (0.05%)	1.50	1.78	2.56	1.50	1.78	2.56
CV (%)	8.81	10.72	14.39	8.81	10.72	14.39

Table 2. *Influence of organics on Al-P and Ca-P fractions (mg kg^{-1}) in soils*

Treatments	Al-P			Ca-P		
	Knee high	Tasseling	Harvest	Knee high	Tasseling	Harvest
T_1 - Control (No nitrogen)	25.67	27.97	31.00	112	115	98
T_2 - 100% N- Fertilizers	29.23	37.76	39.58	147	153	168
T_3 - 100% N - FYM	29.55	41.21	39.07	158	184	178
T_4 - 100% N - PM	28.60	42.73	36.56	171	207	158
T_5 - 75% N - FYM + 25% N - Fertilizers	30.23	35.55	42.83	147	203	159
T_6 - 75% N - PM + 25% N - Fertilizers	32.40	39.26	35.73	159	193	183
T_7 - 50% N - FYM + 50% N - Fertilizers	30.23	30.49	41.06	161	188	171
T_8 - 50% N - PM + 50% N - Fertilizers	31.80	38.23	39.79	169	190	185
SEm±	3.53	2.97	3.66	15	16	19
CD (0.05%)	NS	NS	NS	NS	NS	NS
CV (%)	18.26	12.94	16.28	17.08	15.57	17.19

no nitrogen (T_1). At tasseling, the values ranged from 115 mg kg^{-1} in control (T_1) to 207 mg kg^{-1} in treatment with 100 % N - PM (T_4). Relatively higher values were recorded in treatments supplied with organics. At harvest the values ranged from 98 to 185 mg kg^{-1} with the lowest recorded in T_1 (control) and the highest in T_8 (50 % N -PM + 50 % N- Fertilizers).

Among different fractions of phosphorus, contribution of Ca-P towards total P was highest when compared to Fe-P, Al-P and saloid -P in all the treatments at all the stages of the crop indicating the cumulative accumulation of phosphorus mostly in to Ca-P. It may be due to the slightly alkaline soil reaction (pH 7.7) under which, calcium system is more stable, irrespective of the nature and kind of fertilizer. Similar observations were made by Abolfazli *et al.,* (2012).

Olsen P

The Olsen P was not significantly influenced by imposed treatments at knee high and tasseling stages of the crop (Table 3). However, at harvest application of different sources of nitrogen significantly influenced the available phosphorus content of the soil. At knee high stage and tasseling

Table 3. *Influence of organics olsen P and total P in soils*

TTreatments	Olsen P (kg ha^{-1})			Total -P (mg kg^{-1})		
	Knee high	Tasseling	Harvest	Knee high	Tasseling	Harvest
T_1 - Control (No nitrogen)	33.7	32.6	32.6	672	722	692
T_2 - 100% N- Fertilizers	36.5	41.4	38.4	709	789	782
T_3 - 100% N - FYM	38.5	43.4	43.8	762	793	832
T_4 - 100% N - PM	39.3	45.5	45.3	897	835	854
T_5 - 75% N - FYM + 25% N - Fertilizers	36.3	44.9	42.0	774	817	824
T_6 - 75% N - PM + 25% N - Fertilizers	38.5	45.3	45.3	781	830	853
T_7 - 50% N - FYM + 50% N - Fertilizers	38.0	43.8	43.7	792	802	819
T_8 - 50% N - PM + 50% N - Fertilizers	38.2	44.2	44.5	849	794	821
SEm±	4.2	2.5	1.9	12	16	18
CD (0.05%)	NS	NS	5.6	NS	NS	NS
CV (%)	18.7	10.3	7.7	6.93	8.17	7.89

Table 4. *Correlation coefficients among different soil parameters at harvest*

	pH	CEC	OC	Olsen P	Saloid-P	Fe-P	Al-P	Ca-P	Total-P
Olsen P	–0.095	0.240*	0.790**	1					
Saloid-P	–0.060	–0.081	0.566**	0.545**	1				
Fe-P	–0.049	0.212*	0.135*	0.221*	0.098	1			
Al-P	–0.041	–0.181	0.220*	0.175*	0.449*	0.266*	1		
Ca-P	–0.163	0.193*	0.572**	0.626**	0.088	0.298*	0.150	1	
Total-P	–0.162	0.279*	0.788**	0.644**	0.561**	0.085	0.375*	0.571**	1

*Significance of r at 5% , ** Significance of r at 1%

available phosphorus content ranged from 33.7 to 39.3 kg ha^{-1} and 32.6 to 45.5 kg ha^{-1}, respectively with the highest and the lowest observed in 100 % N through poultry manure (T_4) and no nitrogen (T_1) treatments, respectively.

At harvest, treatments supplied with sole organics (T_3 and T_4) or in combination with fertilizers (T_5 to T_8) registered values, which were statistically equal and significantly superior to inorganic (T_2) and no nitrogen (T_1) treatments. Poultry manure application at different doses recorded relatively higher values to that of corresponding FYM values emphasizing the role of PM in holding phosphorus in available forms due to the low C: N ratio which might have enhanced faster decomposition of poultry manure. Subbaiah *et al.*, (2013) also reported similar results

Total P

Total phosphorus was not significantly influenced by the imposed treatments at all the stages of crop growth (Table 3). At knee high stage, the organic treatments and their combinations recorded higher total P compared to sole inorganics and control. The highest total P of 897 mg kg^{-1} was recorded in the treatment which received nitrogen completely through poultry manure (T_4) while, the minimum of 672 mg kg^{-1} in treatment with no nitrogen (T_1). At tasseling stage, the values ranged from 722 to 835 mg kg^{-1}. Sole poultry manure (T_4) recorded the maximum while, no nitrogen treatment (T_1) the minimum. At harvest the values of total -P ranged from 692 to 854 mg kg^{-1} with highest and lowest recorded in T_4 (100 % N - PM) and T_1 (control), respectively. Whereas, comparatively higher values were recorded in the treatments which received the nitrogen through organics either completely or partially (T_3 to T_8) than sole inorganic (T_2) and no nitrogen (T_1) treatments. Over all, lower total -P in no nitrogen could be due to loss of applied nutrients due to lack of organic chelates or lesser production of root exudates which help in retaining the phosphorus in soil. Similar increase in total phosphorus over control with application of organics was reported by Ganai *et al.,* (2013).

Pearson correlation coefficients

Data in table 3 revealed that all the P fractions showed positive correlation among one another. The Olsen P had a significant positive correlation with the saloid-P (r=0.545**) which indicated that saloid-P is the most readily available form of phosphorus to the plant. The Ca-P and total-P were also significantly positively related with Olsen extractable P (r=0.626** and r=0.644**, respectively) indicating their favourable contribution towards available P pool. All the inorganic fractions of phosphorus were negatively correlated with pH while, the organic carbon showed a significant positive correlation with all the inorganic P fractions and total P. Results indicated that total P showed a highly significant positive correlation with the saloid-P (r=0.561**) and Ca-P (r=0.571**).

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Performance of Heliconia-An Exotic Cut Flower Crop as Intercrop in Coconut under Coastal Climatic Conditions of Goa

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A study on the performance of twenty three heliconia types/varieties was under taken under twenty year old coconut plantation as intercrop under coastal humid conditions of Goa for three years during 2010-2013. Suckers of different varieties/types of heliconia were planted at 1.5x1.5m spacing so as to accommodate twenty five plants in four coconut trees. Analysis of variance indicated that all the traits observed differed significantly. The earliest flowering was noticed in heliconia type *Choconiana* (124 days) and *Sexy Pink* took 445 days for first flowering. Number of flowering suckers per clump was highest in Bihai (15) followed by *Lobster Claw Two* (13). Spike length was highest in *Sexy Pink* (108.15 cm) indicating its potential as cut flower followed by *Kenya Red* (67.83 cm) and *St. Vincent Red* (66.41 cm). It is concluded from the study that intercropping heliconia in coconut plantation can give an additional income in the range of Rs. 32,160 in H-4 (*Rostrata type*) to Rs. 1, 37,200 in H-6 (*Hybrid type*). The heliconia types *Golden Torch* (H-2), *Hybrid type* (H-6), *Sexy Pink* (H-8) and *Wagneriana* (H-9) recorded a total income of more than one lakh rupees by sale of flower and suckers from an area of one hectare under coconut plantation and recommended as suitable intercrop in coconut.

(***Key words***: *Heliconia, Intercrop, Coconut, Coastal Area)*

Heliconias, which are native to South and Central America, are popular as ornamental plants and cut flowers because of their brilliant colours and exotic appearance. Their enhancing beauty had made them, a best landscape and as a potential cut flower (Janakiram and Pavan Kumar, 2011). The heliconias exhibit a wide array of colours led by red, pink, orange, yellow, green combined with different sizes and shapes (Goel, 2004). Due to its exotic appearance and brilliant colours, it fetches premium price in the market. Leaves of some varieties of heliconia are also sold as cut leaves for flower decoration. The genus *Heliconia* (*Heliconiaceae*) includes a number of species showing potential as commercial cut flower crops. *H. psittacorum* and some of its hybrids (*i.e.* 'Golden Torch') are particularly promising because of their attractive flowers, long straight clean peduncles, prolific year round flower production, excellent post harvest characteristics, and few pest problems. The inflorescences can be used in a manner similar to those of bird of paradise, but they are less massive and are therefore, easily incorporated into smaller floral arrangements.

Coconut is an important plantation crop in Goa next only to Cashew. It is cultivated in an area of 25,730 ha with an average yield of 5014 kg ha^{-1} translating to only 32 nuts per tree per year. In general, coconut is planted at a spacing of 8 x 8m and interspaces in majority of the coconut farms is either unutilized or underutilized. Generally various intercrops are advocated to enhance the profitability of coconut in Goa. Heliconia- an exotic introduced flower crop performs extremely well under partial shade in coastal humid conditions of Goa. Hence, a study was planned to evaluate the performance of 23 varieties/types of heliconia under coconut as an intercrop for vegetative and flower characteristics.

MATERIALS AND METHODS

The present study was undertaken in the 20 year old coconut plantation (Cv. *Benaulim*) in ICAR Research Complex for Goa, Old Goa for three years. Only the heliconia cultivars that have eye appeal, productivity, robust and healthy growth, long vase life and suitable size and shape for packing can be commercialized (Criley and Broschat, 1992). Though institute germplasm bank has got several types and varieties of heliconia, only those suitable for commercialization were selected for this particular study. The flowers of selected types were supplied to market to document the feedback from the market so as to short list the most promising heliconia types with high floral value. The study included 23 varieties (Fig. 1) of heliconias planted as intercrop

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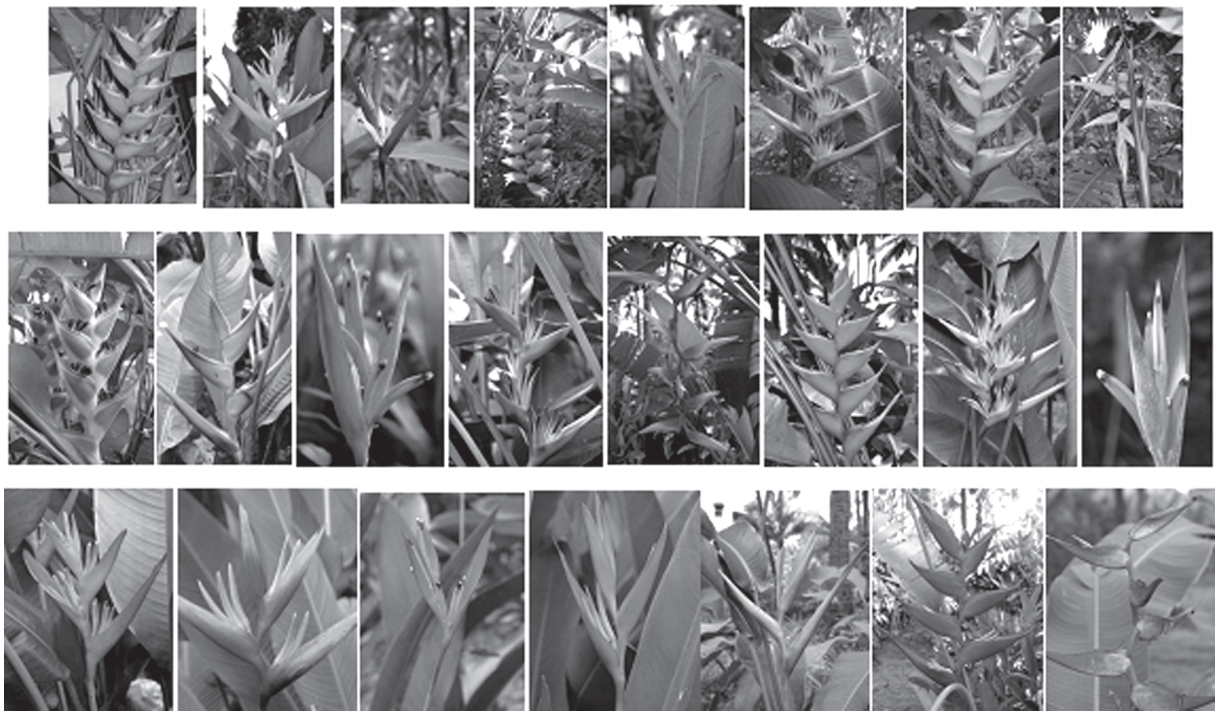

Fig. 1. Glimpse of heliconia types used in the study

in the existing coconut plantations. The study was conducted from 2010-2013 for different purpose like cut flower production, cut leaves production, suckering habit, vase life studies *etc.* The coconut spacing was 8x8m, where in 25 heliconia plants were accommodated in the interspaces of four. Initially, suckers were planted in a pit where in 250g each of NPK was thoroughly mixed in soil. Immediately after planting, the plants are watered thoroughly for better establishment. Generally, it takes about 30-45 days for the sucker to establish. Hence periodic watering is important. Various vegetative traits *viz.,* number of suckers per clump, flowering suckers per clump, leaf traits and several floral characters which are important for cut flower purpose were recorded six months and twelve months after planting and the same is presented in table 1 and 2.

RESULTS AND DISCUSSION

Vegetative characters

The data pertaining to different morphological traits are presented in Table 1. The productivity of any heliconia type depends on important characters like days to flowering, suckering habit and number of flowering suckers per clump in a year. The data indicated that the heliconia type *Choconiana* took only 123.50 days for flower initiation followed by commercial heliconia type *Golden Torch* (136.00 days). The most popular and costly heliconia type *Sexy Pink* took the maximum (444.50) days for flower initiation. Majority of the heliconia types recorded first flowering within 300 days of planting from sucker under coastal condition of Goa as intercrop in coconut. Wider variability was reported for vegetative and floral traits by Pavan Kumar *et al.,* (2011) in different heliconia types.

The suckering habit of any heliconia type decides its commercial viability as cut flower crop. The cost of planting material accounts for 50 per cent of the total cost of production. Therefore profuse suckering habit is a desirable trait in commercial cultivation of heliconia. The data for three years indicated that there was wide variation in sucker production among the heliconia types evaluated. The highest number of suckers per clump (41.09) was recorded in heliconia type *Golden Torch* followed by heliconia type *Lady Di* (37.08). Other popular heliconia types *viz., Tagami, Latispatha* and *Pedro Ortiz* recorded only 6.25, 6.25 and 6.75 suckers per clump respectively. Important cut flower type heliconias *viz., Sexy Pink, Temptress, Wagneriana etc.* also recorded medium to high sucker production per clump. Ramachandrudu and Thangam (2012) also reported high sucker production in heliconia types *viz., Golden Torch, Lady Di* and *Choconiana* under coconut plantation.

Table 1. *Performance of different heliconia types for vegetative characters*

Heliconia Types	Days to 1st flowering	No. of suckers plant^{-1} at 6 months	No. of suckers plant^{-1} at 12 months	No. of flowering suckers plant^{-1}	Leaf length (cm)	Leaf width (cm)	Leaf area (cm ^{2})	No. of leaves sucker^{-1}
Lobster Claw One	264.25	6.75	19.09	2.00	84.03	25.75	1953.57	4.60
Golden Torch	136.00	11.10	41.09	4.90	53.77	12.71	605.86	4.90
Lady Di	152.25	7.09	37.08	4.67	38.28	9.46	460.09	4.40
Rostrata type	248.25	4.00	13.34	1.69	61.53	13.88	738.64	6.05
Choconiana	123.50	10.12	35.92	3.78	89.35	9.38	297.88	4.10
Hybrid type	234.00	11.25	33.75	6.50	74.03	10.90	600.74	5.15
Lobster Claw Two	257.75	10.49	18.50	13.25	85.47	30.46	2189.57	5.42
Sexy Pink	444.50	4.76	9.50	4.00	42.79	28.20	717.13	5.25
H. wagneriana	254.00	4.75	11.75	10.25	77.05	38.42	756.60	5.58
Eden Pink	237.00	4.38	8.50	5.00	61.48	10.08	490.91	4.83
Petra Orange	284.50	11.25	18.00	10.75	50.05	14.35	565.87	4.00
Guyana	382.00	11.63	17.67	12.75	88.73	21.43	1541.07	4.75
Temptress	381.00	7.00	10.50	3.50	65.46	30.40	803.85	4.83
Bihai	411.00	13.50	20.25	14.50	99.65	28.64	2319.45	4.25
Alan Carle	385.00	9.00	17.25	6.50	86.69	22.09	1614.09	5.25
Sassy	376.00	13.75	21.25	5.75	51.88	14.08	584.55	5.50
Tropics	360.50	10.63	19.00	5.00	84.60	24.28	1756.93	5.00
Adrian	293.50	12.75	22.00	5.75	38.95	14.53	488.14	4.75
St.Vincent Red	319.25	7.88	16.25	8.75	52.90	13.13	542.72	4.50
Kenya Red	352.50	13.25	22.75	10.00	49.20	14.70	610.75	4.75
Tagami	372.50	3.13	6.25	3.00	33.20	13.40	396.16	5.25
Pedro Ortiz	309.75	3.75	6.75	3.75	79.60	36.47	1595.70	5.75
Latispatha	284.75	3.63	6.25	4.25	68.77	32.28	851.52	5.00
CD (5%)	16.05	1.91	4.65	1.43	7.92	2.36	227.53	0.74
CV	3.36	15.70	22.00	13.50	8.48	7.29	15.26	10.42

Leaf characters

Leaves of heliconia are used as backdrop material in flower arrangement, bouquet making as well as stage decorations in floriculture enterprise. Sometime, the leaves are used as substitute to *Dracaena* leaves. Hence observation of leaf characters *viz.,* leaf length, leaf width, leaf area and number of leaves produced per sucker is of paramount importance. In the present study, wide variability was noticed for different leaf traits. A leaf of lanceolate shape with medium width is highly preferred for floral decoration. Heliconia types *viz., Lobster claw one* and *two*, *Guyana, Tropics, Pedro Ortiz etc.* produced desirable quality leaves for decoration purpose. The highest number of leaves per suckers was recorded in *Rostrata* type (6.05) followed by *Pedro Ortiz* (5.75). The leaves of highly popular heliconia types *viz., Sexy Pink* and *Temptress* cannot be used since they produce only cut leaves, but their flower compensates the price among the heliconia types evaluated.

Flower characters

The ultimate aim of the present study is to find out the attractive heliconia types along with other desirable traits like productivity, eye appeal, easy packing and more shelf life. The length of spike decides the eye appeal and further usefulness for floral decoration. The data on various floral traits is presented in Table 2. Among the heliconia types evaluated, *Sexy Pink* recorded the longest spike (108.15 cm) followed by *Kenya Red* (67.83 cm). Both the types were highly preferred in the flower market for arrangement and backdrop display. Other commercial types *viz., Lobster Claw One and Two, Wagneriana, Temptress, Sassy, St. Vincent Red* and *Adrian* also produced an average spike length of more than 50 cm which is an ideal spike for flower

Table 2. *Performance of different heliconia types for floral characters*

Heliconia Types	Stalk length (cm)	Spike length (cm)	No. of bracts spike^{-1}	Bract length (cm)	No. of flowers bract^{-1}
Lobster Claw One	87.10	51.99	10.53	20.86	8.21
Golden Torch	66.96	18.44	5.95	17.39	22.00
Lady Di	83.28	16.01	5.80	13.21	13.80
Rostrata type	67.79	49.13	16.55	8.62	11.45
Choconiana	86.09	13.25	4.00	12.83	10.38
Hybrid type	74.46	43.01	6.13	15.09	10.25
Lobster Claw Two	85.87	60.46	10.55	12.45	10.07
Sexy Pink	153.18	108.15	14.92	23.56	10.92
H. wagneriana	69.10	44.98	8.25	19.08	15.78
Eden Pink	60.51	37.72	5.51	16.86	7.92
Petra Orange	40.44	29.98	4.13	14.54	8.86
Guyana	77.59	49.51	4.88	14.44	12.25
Temptress	80.95	55.37	11.63	17.29	9.50
Bihai	47.15	37.88	8.38	24.33	13.65
Alan Carle	64.64	48.07	7.75	18.31	18.36
Sassy	83.60	63.53	3.88	14.69	10.24
Tropics	79.54	49.84	5.22	15.62	9.64
Adrian	79.79	56.53	5.10	15.58	10.71
St.Vincent Red	90.78	66.41	4.88	12.65	9.31
Kenya Red	96.90	67.83	6.25	17.80	18.13
Tagami	48.52	34.06	4.50	11.74	9.79
Pedro Ortiz	61.62	32.40	8.00	8.85	11.63
Latispatha	53.46	27.98	7.50	11.55	7.88
CD (5%)	9.82	7.73	0.80	2.52	1.81
CV	9.22	10.62	7.92	11.18	11.14

decoration. Varying spike length for different heliconia types was earlier reported by Sheela *et al.,* (2007).

Economics of heliconia production under coconut plantation

The economics of heliconia production was worked out for ten promising heliconia types for two years. A total of 600-700 heliconia plants can be accommodated in an area of one hectare as inter crop. The economics of flower production was calculated by taking in to account of total number of flowers produced in a year and the cost of flower at farm. Among the heliconia types evaluated for flower sales, *Wagneriana* (H-9), *Sexy Pink* (H-8), *Hybrid type* (H-6) and *Golden Torch* (H-2) produced more number of flowers per hectare and fetched premium price in the market (Fig. 2). The highest income (Rs. 93, 824) per hectare was recorded in H-9 followed by H-8 (Rs. 89, 600). The heliconia type *Rostrata* recorded the lowest income due to less number of flowers and priced low among the types evaluated in the market.

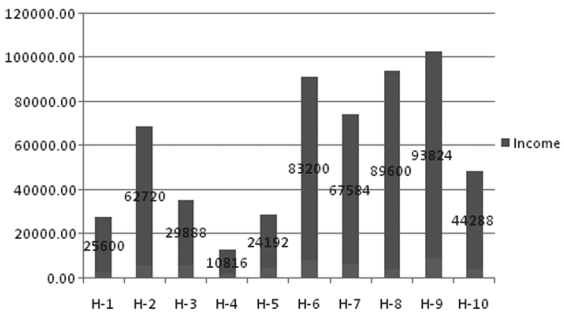

Fig. 2. Income (Rs. ha^{-1}) from heliconia cut flower sales per hectare

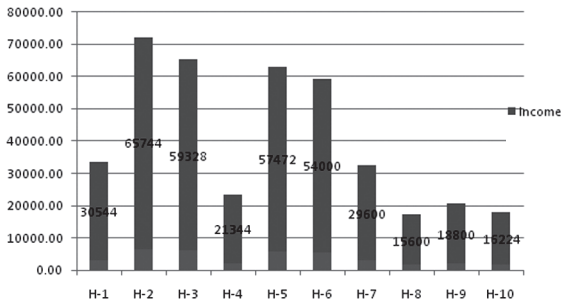

Fig. 3. Income (Rs. ha^{-1}) from sale of heliconia sucker per hectare

But in case of sucker production, the heliconia types *viz., Golden Torch* (H-2), *Lady Di* (H-3), *Choconiana* (H-5) and *Eden Pink* (H-6) produced more numbers of suckers per hectare due to their high suckering ability (Fig. 3). The highest income through the sale of suckers was recorded in *Golden Torch* (Rs.65, 744) followed by *Lady Di* (Rs.59, 328) and other types *viz., Sexy Pink* (H-8), H-9 (*Wagneriana*) and H-10 (*Eden Pink*) recorded the lowest income from sucker due to their low suckering habit under coconut plantation.

The heliconia types *Golden Torch* (H-2), *Hybrid type* (H-6), *Sexy Pink* (H-8) and *Wagneriana* (H-9) recorded a total income of more than one lakh rupees by sale of flower and suckers from an area of one hectare under coconut plantation. Hence it is recommended to grow these heliconia types for increasing the income from coconut plantation.

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Yield Gap Analysis of Rice through Front Line Demonstrations in Tropical Andaman Islands

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The present study aimed to know the gaps for yield performance between potential and actual yield of rice through 137 Front Line Demonstrations (FLD) conducted across 3 years in the Andaman Islands. Improved rice varieties with recommended package of practices could give on an average yield of 4.72 t ha^{-1} to 5.78 t ha^{-1} as compared to local varieties yielding 3.21 t ha^{-1} to3.69 t ha^{-1} under rainfed conditions of Andaman and Nicobar Islands. The extension gap ranged between 1.22 to 1.70 t ha^{-1} in improved varieties as compared to 1.55 to 2.70 t ha^{-1} under hybrid varieties. The trend of technology gap ranged from 0.15 to0.30 t ha^{-1} in hybrid varieties compared to 0.18– 0.35 t ha^{-1} in case of pure line varieties. The technology index showed the feasibility of realising the performance of evolved technology at the farmer's fields. The value technology index showed wide range of 3.60 to 15.80 for HYVs and 2.50 to 5.00 in hybrid varieties. The benefit cost ratio was slightly high in hybrids than pure line varieties. The yield of rice could be increased from 36% to 54% by high yielding varieties and from 37% to 86 % by rice hybrids complimented by improved seed and appropriate crop management technologies. Availability of improved seed of high yielding rice varieties and required inputs along with timely extension interventions can greatly narrow the gap between potential yield and actual yield to reap high rice productivity in Andaman and Nicobar Islands.

(Key words: *Rice, FLD, Technological gap, Extension gap, Technological index)*

National food security bill envisages availability of food for all. In this respect, productivity potential especially of disadvantaged and less explored areas has to be assessed and accordingly production strategies to be followed. Rice is the main cereal crop cultivated in Andaman and Nicobar Islands. The climatic conditions including more than 3180 mm rainfall annual also favours rice cultivation. Rice crop is annually grown on about 8,100 hectares of cultivated land producing over 23976 tons of paddy, with productivity of about 2.96 t ha^{-1} (Anonymous 2012) against the annual rice demand of 60,000 tons for the islands. The substantial gap between annual demand and production is bridged by shipment of rice from mainland, India and thus causing transport price rise and subsidy costs to the government exchequre.

The main reason for large gaps between production and demand is low productivity of rice varieties (photosensitive, tall, very late, low yielding and susceptible to biotic and abiotic stresses) which grown on about 50 percent of paddy area. Other major reasons for low productivity which are include imbalanced and inadequate use of fertilizer, non-availability of improved seed of HYVs, heavy and prolonged rain up to December month, constant warm temperature and high humidity favouring pest and disease incidence. About 3000 ha area of rice is also affected by costal salinity especially in the aftermath of *tsunami* of 2004.

In view of high demand of rice and existing climatic conditions of Bay Islands the rice varieties should preferably possess long duration, high yield ability, fertilizer responsiveness, semi-tall stature, good grain and straw quality, resistance/tolerance to biotic and abiotic stresses especially salinity and submergence. Productivity can be increased to about 4.5 to 5.0 t ha^{-1} through appropriate varieties and other crop management and protection technologies (Gautam *et al.*, 2013). The available agricultural technology does not serve the very purpose until it uniformly reaches and adopted by its ultimate users the farmers. Technology transfer refers to the spread of new ideas from originating sources to ultimate users (Prasad *et al.*, 1987). It is also important to ensure uniform adoption of recommended package of practice through understanding the extent of gaps between actual and potential yield for introducing the urgency and extent of technology interventions. Conducting of

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Front Line Demonstrations (FLDs) on farmer's fields helps to identify the constraints and potential of the rice in specific area as well as it helps in improving the economic and social status of the farmer's. The aim of the FLDs is to convince the farmers through "seeing is believing" approach. Farmers use recommended package and practices then the yield of this crop can be easily increased existing levels. Several biotic, abiotic and socio-economic constraints inhibit realization of the yield potential and these needs to be alleviated. North and middle Andaman district has the maximum area under rice cultivation but the productivity level is very low. The reasons for low productivity include poor knowledge about newly released crop varieties and recommended production and protection technologies. Keeping the above points in view, the FLDs, comprising of high yielding rice varieties and improved production technologies were conducted for 3 years to know yield gaps and extant of intervention required.

MATERIALS AND METHODS

The present study was carried out by Central Island Agricultural Research Institute, Port Blair during *Kharif* season from 2010 to 2012 (three years) at farmers field in 16 villages of rice dominant district of North and Middle Andaman through NABARD funded Out Reach Centre (ORC) in Diglipur, North Andaman. Under these Front Line Demonstrations (FLDs) a total of 39.13 ha area was covered. Farmers were selected through group meetings and training programmes on different aspects of rice cultivation were imparted for knowledge skill development (Choudhary, 1999 and Venkattakumar *et al.*, 2010). The details of the technical practices for FLDs and farmers' practices have been given in Table 1. A total of 137 FLDs were conducted during 3 years. Recommended cultivation practices were adopted under FLDs including improved rice varieties (CARI Dhan 3, CARI Dhan 4, CARI Dhan 5, CSR 23, CSR 36, Varsha, Ranjeet and Savitri) and hybrids (VNR 2355, US 312 and US 316). Crop was planted in rows and recommended dose of fertilizer (90:60:40 NPK kg ha^{-1}) was applied. The pests and diseases were controlled through need based application of pesticides at economic threshold level. In case of local check plots, existing practices being used by farmers were followed. Soils of the area were mostly sandy loam and crop totally depended on rains. In demonstration plots, quality seeds of improved varieties, line sowing and timely weeding, need based application of pesticides, use of balanced fertilizer were implemented as per technical recommendations. Recommended package of practices for the Andaman and Nicobar was followed and comparison made with the existing practices. Visits of farmers and the extension functionaries were organized at demonstration plots to disseminate the technical know how at large scale. The farmers under demonstration were facilitated in performing field operations like sowing, spraying, weeding, harvesting etc. during the course of

Table 1. *Details of improved varieties and recommended practices vis a vis farmer's practice under FLDs on rice in Andaman Islands.*

Particulars	Demonstrated varieties with package of practices		Farmers varieties with own package of practices
	Improved varieties	Hybrid varieties	Farmers varieties
Farming situation	Rain fed lowland	Rain fed lowland	Rain fed lowland
Variety	CARI Dhan 3, CARI Dhan 4, CARI Dhan 5, CSR 23, CSR 36, Gayatri, Varsha and Ranjeet	VNR 2355, US 312 and US 316	Lal Sanno, BPT, Jaya,
Time of sowing	First week of June	First week of June	First week of June
Method of sowing	Line transplanting	Line transplanting	Un even planting (Random)
Seed rate (kg ha^{-1})	25	25	35
Fertilizer dose(NPK kg ha^{-1})	90:60:40	90:60:40	20-30 kg N or Nil
Plant protection	Need based use of pesticides	Need based use of pesticides	Nil
Weed management	Two hand weedings i.e., on 25th & 45th day	Two hand weedings i.e., on 25th & 45th day	One hand weeding at 40th day

trainings and field visits. The selection of sites and farmers and layout of demonstration were followed as suggested by Choudhary (1999). The traditional practices followed by farmers were maintained in case of local checks.

The data outputs were collected from both FLD plots as well as control plots (farmer's practices) and finally the extension gap, technology gap, technology index and benefit cost ratio were worked out as per Samui *et al.*, (2000) as given below:

Technology gap = Potential yield – Demonstration yield

Extension gap = Demonstration yield – Farmers yield

$$\text{Technology index} = \frac{(\text{Potential yield} - \text{Demonstration yield})}{\text{Potential yield}} \times 100$$

RESULTS AND DISCUSSION

The results of FLDs of HYVs and promising hybrids conducted during 3 years (2010, 2011 and 20112) in North Andaman are presented in Table 2 and Table 3 respectively. FLDs on HYVs (4.72 t ha^{-1}) showed on an average 47.55% more yield of rice as compared to local varieties (3.21 t ha^{-1}) as shown in Table 2. Similarly hybrids gave an average yield of 5.78 t ha^{-1} which is 58.83% more compared to local varieties 3.69 t ha^{-1} (Table 3). The data of Tables 2 and 3 revealed that the yield of rice varied from 4.65 to 4.82 t ha^{-1} in pure line varieties whereas from 5.70 to 5.85 t ha^{-1} in case of hybrids across three years. It is also pertinent to mention that the yield of farmers varieties varied from 3.08 to 3.43 t ha^{-1} and 3.15 to 4.15 t ha^{-1} in case of FLDs on HYVs and hybrids, respectively.

The percentage increase in yield over the local varieties ranged from 36% to 55% and 37% to 86% across years in HYVs and hybrids, respectively. Tiwari *et al.*, (2014) have also performed yield gap analysis in chickpea through FLDs. The results indicated that the Front Line Demonstrations have given a good impact on the farming community of this district as they were motivated by the improved rice varieties and agricultural technologies used in the Front Line Demonstrations. The results clearly indicated the positive effects of improved rice varieties over the existing rice varieties towards doubling the rice productivity in Diglipur area, North Andaman.

Benefit-Cost ratio was also recorded higher under demonstration plots against control plots in all the years of study. The findings revealed that a gap exists between the actual farmer's yield and realizable yield potential of the varieties. Use of improved varieties has the potential to enhance the present level of rice productivity which is not percolating down at desired pace due to communication gap and lack of confidence among the farmers. Hence, to exploit the potential of improved rice varieties coupled with production and

Table 2. *Productivity, technology gaps, extension gaps, technology index and cost benefit ratio of high yielding varieties under FLD's of rice in North Andaman district*

Years	Area (ha)	Grain yield (t ha^{-1})			% increase over control	Technology gap (t ha^{-1})	Extension gap (t ha^{-1})	Technology index (%)	B : C ratio	
		Potential	FLD's	Control					FLD's	Control
2010	13.30	5.00	4.70	3.08	53	0.30	1.62	6.00	2.97	1.95
2011	2.25	5.00	4.65	3.43	36	0.35	1.22	7.00	2.94	2.17
2012	14.69	5.00	4.82	3.12	54	0.18	1.70	3.60	3.04	1.97
Average	10.08	5.00	4.72	3.21	48	0.28	1.51	5.53	2.98	2.03

Table 3. *Productivity, technology gaps, extension gaps, technology index and cost benefit ratio of promising rice hybrids under FLD's in North Andaman district.*

Years	Area (ha)	Grain yield (t ha^{-1})			% increase over control	Technology gap (t ha^{-1})	Extension gap (t ha^{-1})	Technology index (%)	B : C ratio	
		Potential	FLD's	Control					FLD's	Control
2010	6.30	6.00	5.80	3.78	53	0.20	2.02	3.33	3.31	2.39
2011	2.60	6.00	5.85	3.15	86	0.15	2.70	2.50	3.34	1.99
2012	1.60	6.00	5.7	4.15	37	0.30	1.55	5.00	3.26	2.62
Average	3.5	6.00	5.78	3.69	59	0.22	2.09	3.61	3.30	2.33

protection technologies, efforts through FLDs have to be increased among the farmers. The extension gap was found to range from 1.22 to 1.70 t ha^{-1} in HYVs and from 1.55 to 2.70 t ha^{-1} in case of hybrids during the study period. This highlights the need to educate the farmers through various means for adoption of improved varieties and agricultural production technologies to achieve higher rice productivity in the islands.

The technology gap ranged from 0.18 to 0.35 t ha^{-1} and from 0.15 to 0.30 t ha^{-1} in HYVs and hybrid FLDs, respectively. This reflects farmer's cooperation in carrying out such demonstrations with encouraging results in subsequent years. The varying technology gaps might have arisen due to the dissimilarity in soil fertility status and weather conditions. Mukharjee (2003) stated that depending on identification and use of farming situation, specific interventions may have greater implications in enhancing system productivity. Similar findings were also recorded by Mitra and Sanajdar (2010) and Katare *et al.*, 2011. The magnitudes of technology index showed the technical feasibility of the evolved technology at the farmer's fields. The lower the value of technology index, the more is the feasibility of technology implementation. Over here the technology index ranged from 3.60 to 7.00% in improved varieties and from 2.50 to 5.00% in hybrids during the study period. This implies that the technology (rice varieties recommended) in field conditions is very much accepted by the farmers and varietal approach is practically feasible and implementable. The lateral spread of the variety technology is found to be remarkably acceptable which is evidenced by the large scale cultivation of CIARI recommended varieties especially in the North and Middle Andaman district. The component of benefit cost ratio of front line demonstrations has clearly showed higher BC ratio of FLDs than control plots *i.e.* farmers practice in all the years of study. The benefit cost ratio of improved varieties FLDs in demonstrated *vis a vis* control plots were 2.97 and 1.95, 2.94 and 2.17, 3.04 and 1.97 and in case of hybrid varieties, benefit cost ratios were 3.31 and 2.39, 3.43 and 1.99, 3.26 and 2.62 during 2010, 2011 and 2012, respectively. Hence, technology index and favourable benefit cost ratios proved the technical and economic viability respectively of the interventions and convinced the farmers on the utility of these simple, economical and ecologically safe interventions. Similar findings were also reported by Sharma *et al.*, (2003) in moth bean and Gurumukhi *et al.*, (2003) in sorghum and Mitra and Samajdar (2010) in rapeseed mustard.

CONCLUSION

The results of rice front line demonstrations convincingly brought out that the yield of rice could be increased by 36% to 54% by improved varieties and 37 – 86 % by adaptation of hybrids in conjunction with their improved seed with balanced fertilizer application and disease management in the Andaman and Nicobar Islands. From the above findings, it can also be concluded that use of scientific methods of rice cultivation can reduce the technology gap to a considerable extent thus leading to increase in rice productivity in these Islands. Moreover, extension agencies in the Islands need to provide proper and timely technical support to the farmers through different educational and extension methods to reduce the extension gap for achieving higher rice production and productivity. Favourable benefit cost ratio of these interventions indicates economic viability and convinced the farmers for adoption of interventions towards high productivity and better livelihood of the Islands farmers.

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Studies on Performance of Some Elite Traditional Varieties of Rice of West Bengal with Popular HYVs during Wet Season

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Ten elite germplasm of traditional rice varieties of West Bengal along with two HYVs (IET 5656 and MTU 7029), used as checks were grown at Rice Research Station (RRS), Chinsurah, Hooghly, West Bengal as replicated yield trial during *Kharif* 2011. These traditional varieties have been chosen on the basis of their high yield potential and popularity among the farmers. Observations were taken on agromorphic traits (yield, days to 50% flowering, no. of panicles m^{-2}, no. of filled grains $panicle^{-1}$, test weight, sterility%, etc.), physical grain quality parameters (grain length, grain breadth, grain L/B ratio, kernel length, kernel breadth, kernel L/B ratio etc), milling quality traits (hulling%, milling% and head rice recovery%), and some cooking and eating quality parameters (volume expansion, elongation ratio, alkali spreading value, gel consistency and amylose content). Genetic analysis was conducted for all the parameters biometrically. Genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV), were found to be maximum for cooking quality trait and alkali spreading value, followed by number of filled grains $panicle^{-1}$, panicle weight, amylose content, test weight and kernel breadth, respectively. Heritability ranged from 20.33% (Elongation ratio) to 96.93% (Alkali spreading) and high heritability was found in filled grains $panicle^{-1}$, test weight, alkali spreading value, amylose content, grain breadth, grain L/B, kernel breadth, kernel L/B, kernel length, panicle weight, yield, plant height and gel consistency. Alkali spreading value, no of filled grains $panicle^{-1}$, test weight, amylose content, kernel breadth, kernel L/B, panicle weight, plant height, gel consistency and yield showed high heritability with high GCV which indicates the effectiveness of selection based on these traits. Filled grain $panicle^{-1}$, test weight, plant height, yield, gel consistency and amylose content showed high heritability coupled with high GCV and high GA indicating that these characters are mostly governed by additive gene action and hence, can be considered as the basis of selection for varietal improvement. Out of 10 traditional rice varieties, five viz. Jamainadu, Talmari, Kerala Sundari, Jugal and Binni gave at par yield with high yielding checks IET 5656 and MTU 7029. Dudheswar, Binni, Jamainadu and Sarunagra were found to have better cooking and eating quality than both the high yielding checks while Kerala Sundari, Jugal and Dudheswar had better milling quality over the checks.

(Key words: *Traditional rice varieties, HYVs, GCV, PCV, GA, Kernel length, Kernel breadth)*

Rice, the most important food crop of the developing world, feeds more than two billion people as a staple food worldwide and is the number one staple food in Asia, where it provides 40-70% of the total food calories consumed. Rice is also used for animal feed and provides the major source of income for rural people. Due to the Green Revolution, a quantum leap in rice yield took place over the past three decades, although increased food production did not eliminate poverty and hunger. Rice yield has been stagnant for the last three decades, despite the improved varieties and technologies in place. All over the world, every night at least two billion people go to sleep hungry and in India, the number is miserably 320 millions.

Due to introduction of high-yielding varieties (HYVs), presently only a few of traditional varieties (TRVs) exist in farmers' fields. Despite increase in cost of production, aromatic rice Gobindobhog, Badsabhog, Radhatilak, Kalonunia, Tulaipanji etc and fine rice like Dudheswar, Seetasail etc still fetches good price. The chemical intensive agriculture of Green Revolution has not only expunged the local crop genetic diversities but also their wild relatives that are the only source of unique of genes for disease and pest resistance. Farmers were impressed by the initial high yields of these so-called 'miracle' seeds and ignored the associated costs of external inputs, subsequent loss of non-grain bio-mass, loss of desirable traits (like tolerance to diseases and pests, drought, floods, etc.), and the extensive deterioration of the environment, including soil and water. Over the years, the average grain yield of 'popular' modern variety (HYV) MTU-7029 of West Bengal has plummeted to the tune of 3.75 t ha^{-1} from 5 t ha^{-1} in most of the farmers' fields. These HYV cannot give substantial yield advantage in the marginal lands like drought prone, saline track and in deep water situation.

A World Wildlife Fund (WWF)- India survey, conducted in 1994 in six districts of southern West Bengal, recorded 137 traditional rice varieties still surviving in marginal farms (Deb, 1995). An investigation into the reasons for the continuation of their cultivation highlighted the following factors:

- The small and marginal farmers who grow the TRVs were too impoverished to buy the costly inputs for growing HYVs.
- The HYVs failed to grow in dry uplands and wet lowlands, where only a few specially adapted local varieties could grow.
- Many native varieties were grown for their special aroma and flavour, which were distinctly lacking in the HYVs.
- A small number of native varieties fetched higher market prices than the HYVs.

There are many varieties which are drought tolerant, flood-tolerant and amenable to ill-drained and lowland cultivation. A large number of varieties possess the characteristics of disease and pest-resistance. Some of them have the unique characteristics of tolerance to salinity, alkalinity and being able to grow in 'deep-water' inland areas. In this perspective a study had been undertaken to evaluate the performance of some traditional rice varieties in comparison to popular HYVs along with genetic analysis.

MATERIALS AND METHODS

The experimental materials consisted of 10 traditional varieties viz. jugal, jamainadu, patnai 23, kerala sundari, binni, latisail, dudheswar, talmari, saru nagra and kalma 222 along with two high yielding varieties viz. IET 5656 and MTU 7029 which were used as checks. The crops were grown during *kharif* 2011, in Randomized Block Design in 4 replication, in plot size of 6m x 2m, in 20cm x 15cm spacing, at Rice Research Station, Chinsurah, located at New Alluvial Zone of West Bengal at ($22^0 52'$N latitude and $88^0 24'$E longitude and at an elevation of 8.62 meter from Mean Sea Level). The soil of this location is texturally, sandy clay and is mainly characterized by neutral reactions (pH 6.5-7.8) and normal EC (less than 1 dSm^{-1}). The nutrient status of the soil is low to medium N, medium to high P_2O_5 and medium of high K_2O. Normal agronomic practices were done in raising the crops.

The observations were taken on 8 agromorphic characters viz. date of 50% flowering, plant height, panicle length, panicle weight, no. of filled grain per panicle, sterility percentage, test weight and yield; 5 cooking qualities viz. elongation ratio, volume expansion, alkali spreading value, amylose content and gel consistency and 9 physical and milling characteristics viz. grain length, grain breadth, grain L/B ratio, kernel length, kernel breadth, kernel L/B ratio, hulling percentage, milling percentage and head rice recovery.

RESULTS AND DISCUSSION

The ANOVA of the various grain characters was shown in the Table 1. It was found that all the grain characters had significant differences which indicate presence of wide variability among genotypes.

Agromorphic characters

Mean value, range, CD, CV and standard error of agromorphic, characters were presented in Table 2. Days to 50% flowering ranged from 105 days (Kerala Sundari) to 120 days (IET 5656) with mean 115 days. Plant height recorded from field ranged from 122.00 cm (IET 5656) to 174.67 cm (Kalma 222) with the mean 147.47 cm. The number of panicle m^{-2} ranged from 331(Kalma 222) to 488 (Jamainadu) with the mean 409. Panicle length of experimental materials varied from 21.28 cm (Binni) to 25.51 cm (Talmari) with the mean 23.76 cm. Panicle weight is maximum in Jamainadu (3.84 g) and minimum in Binni (1.97 g) and the mean is (3.09 g) Number of filled grains per panicle varied from 74 (Binni) to 167 (Kerala Sundari) with the mean of 127. Sterility percentage was least in Kerala Sundari (14.76) and highest in Kalma 222 was (22.45) with mean 18.51%. The test weight i.e. the 1000 grain weight varied from 16.49 gm (Dudheswar) to 29.11 g (Patnai 23) with the mean value 22.83g. The yield varied from 3.28 t ha^{-1} (Latisail) to 4.55 t ha^{-1} in Jamainadu which was higher than both the high yielding check varieties. The mean value was found to be 4.08 t ha^{-1}.

Cooking Qualities

Mean value, range, CD, CV and standard error of cooking quality were presented in Table 3. Kernel elongation ratio ranged from 1.43 (Binni) to 1.69 (Dudheswar) with the mean of 1.54. Volume expansion vareed from 3.78 (Kalma 222) to 5.17 (Sarunagra) with the mean 4.44. Alkali spreading value recorded from 1.35 (Dudheswar) to 6.15 (Kerala Sundari) with mean 3.71. The value showed that all the varieties were ranged from high-intermediate gelatinization temperature to intermediate gelatinization temperature. Amylose content was lowest (19.70%) in Binni and highest (33.13%) Kalma 222, with mean value of 25.46%. According to the standard analytical methods for

estimating amylose content (Juliano, 1971) low amylase content belonged to a single variety Binni and highest to Talmari, Sarunagra, Kalma 222 and high yielding check variety IET 5656. Remaining all belonged to intermediate amylase content. Gel consistency value ranged from 64.00 mm (Talmari) to 89.67 mm (Sarunagra) for different varieties indicating significant variation for this trait with the mean value of 77.28 mm. According to classification of Cagampang *et al.*, 1973, out of 12 varieties, all the varieties showed soft gel consistency.

Physical & Milling Characteristics

Mean value, range, CD, CV and standard error of physical and milling characters are presented in Table 4. Grain length was observed lowest in Kerala Sundari (7.57 mm) and highest in Patnai 23 (10.61 mm) with the mean 8.63 mm. The grain breadth varied from 2.45 mm (Binni) to 3.02 mm (Latisail) with the mean value 2.74 mm. Grain L/B ratio varied from 2.80 (MTU 7029) to 3.68 (Patnai 23). The mean value was 3.16. Kernel length was found to be lowest in Jugal (5.5 mm) and highest in Patnai 23 (7.61 mm) with the mean of 6.78 mm. The Kernel breadth varied from 1.76 mm (Jugal) to 2.75 mm (Latisail) with the mean value 2.35 mm. Kernel L/B ratio varied from 2.25 (Kerala Sundari) to 3.7 (Sarunagra) with the mean value of 2.93. Hulling percentage varied from 77.33 (Jamainadu) to 83.50 (Jugal) with the mean of 79.21. Milling percentage ranged from 65.83 (Jamainadu) to 73.5 (Jugal) and the mean value was 68.51. Head rice recovery had the highest value of 65.00 (Kerala Sundari) and lowest value of 55.83 (Patnai 23) with the mean value of 61.82%.

Genotypic and phenotypic variance

Genotypic and phenotypic variances of agromorphic, cooking quality and physical characters are presented in Table 5. Genotypic variance was highest in yield (166172.22) whereas it is least in case of elongation ratio (0.01). The genotypic variance is also low in case of milling percentage (2.90), kernel length (0.37) and grain breadth (0.04). Similarly the phenotypic variance was highest in yield (220656.31) and lowest in elongation ratio (0.02).

***Table 1**. Analysis of variance (ANOVA) of various grain characters (mean sum of square)*

Sl. No.	Characters	Source of variance		
		Replication (2)	Variety (11)	Error (22)
1.	50 % flowering	5.36	40.03	28.13
2.	Filled grain/panicle	21	2869.28	54.454
3.	Panicle length	2.44	5.16	2.292
4.	Panicle weight	0.002925	0.91	0.086
5.	Plant height	415.19	971.79	109.39
6.	Sterility %	2.95	20.24	3.45
7.	Test weight	4.85	35.04	0.93
8.	Panicle/ m^2	1924	6515.30	1157.03
9.	Yield	10508.33	553000	54484.09
10.	Alkali spreading	0.014	5.28	0.0522
11.	Amylose content	1.76	46.40	3.375
12.	Elongation ratio	0.0432	0.0197	0.0111
13.	Gel consistency	34.194	264.72	32.043
14.	Volume expansion	0.098	0.43	0.056
15.	Grain breadth	0.05	0.111	0.0028
16.	Grain length	1.88	2.19	0.394
17.	Grain L/B	0.027	0.296	0.021
18.	Kernel breadth	0.0015	0.347	0.004
19.	Kernel length	0.220	1.218	0.111
20.	Kernel L/B	0.036	0.577	0.025
21.	Hulling %	2.521	12.987	6.468
22.	Milling %	6.861	14.507	5.816
23.	Head rice recovery	10.361	28.461	4.058

Table 2. *Mean values of agromorphic traits of 10 traditional rice genotypes with 2 high yielding checks*

Sl. No.	Name of Variety	Days to 50% flowering	Plant height (cm)	No. of panicle/ m^2	Panicle length (cm)	Panicle weight (g)	No. of filled grains/ panicle	Sterility %	Test weight (g)	Yield (t ha^{-1})
1.	Jugal	116	153.33	430.00	23.18	3.46	132.78	20.26	23.35	4.27
2.	Jamainadu	114	156.67	488.33	25.47	3.84	143.11	20.67	24.71	4.55
3.	Patnai 23	114	165.00	403.33	23.95	3.32	114.00	15.07	29.11	3.88
4.	Kerala Sundari	105	135.00	429.00	25.11	3.61	167.00	14.76	20.79	4.41
5.	Binni	113	150.00	429.33	21.28	1.97	74.33	15.05	21.29	4.16
6.	Latisail	118	127.67	371.33	23.18	2.51	85.67	20.70	25.57	3.28
7.	Dudheswar	112	159.00	388.00	24.63	2.54	146.89	16.29	16.49	3.44
8.	Talmari	117	163.00	399.33	25.51	3.51	136.78	19.74	23.00	4.44
9.	Sarunagra	116	144.33	484.67	23.25	3.08	135.89	18.36	21.29	3.91
10.	Kalma 222	115	174.67	331.00	24.31	2.69	82.00	22.45	25.78	3.71
11.	IET 5656	120	122.00	389.00	22.96	3.26	151.44	19.00	24.00	4.51
12.	MTU 7029	115	119.00	362.67	22.26	3.34	155.00	19.77	18.53	4.38
	Range	105-120	122-174.67	331-488.33	21.28-25.51	1.97-3.84	74.33-167	14.76-22.45	16.49-29.11	3.28 4.55
	Mean	115	147.47	409	23.76	3.09	127.1	18.51	22.83	4.08
	CV	4.114	7.092	8.32	6.37	9.45	5.81	10.04	4.234	5.72
	SEm±	3.85	8.54	27.77	1.236	0.239	6.03	1.52	0.789	0.19
	$CD_{(0.05)}$	7.61	16.91	54.991	2.45	0.473	11.93	3.0037	1.562	0.38

Table 3. *Mean values of cooking quality of 10 traditional rice genotypes & 2 high yielding checks*

Sl. No.	Name of Variety	Elongation ratio	Volume expansion ratio	Alkali s preading value	Amylose content (%)	Gel consistency
1.	Jugal	1.66	4.27	4.17	24.07	79.33
2	Jamainadu	1.57	4.86	2.67	23.93	87.67
3	Patnai 23	1.51	4.48	5.86	29.53	87.67
4	Kerala Sundari	1.55	4.31	6.15	24.47	67.00
5	Binni	1.43	4.33	3.18	19.70	75.00
6	Latisail	1.60	4.05	3.17	23.67	70.33
7	Dudheswar	1.69	4.84	1.35	20.70	81.67
8	Talmari	1.49	4.29	3.83	25.93	64.00
9	Sarunagra	1.60	5.17	3.57	25.33	89.67
10	Kalma 222	1.45	3.78	4.41	33.13	66.67
11	IET 5656	1.50	4.33	2.97	30.80	71.33
12	MTU 7029	1.49	4.60	3.22	24.20	87.00
	Range	1.43-1.69	3.78-5.17	1.35-6.15	19.7-33.13	64-89.67
	Mean	1.54	4.44	3.71	25.46	77.28
	CV (%)	6.84	5.34	6.33	7.217	7.325
	SEm±	0.086	0.194	0.192	1.5	4.623
	$CD_{(0.05)}$	0.17	0.383	0.38	2.97	9.15

Genotypic, phenotypic coefficient of variation, heritability and genetic advance

The genotypic and phenotypic coefficient of variation, heritability (%) and genetic advance at 5% Selection Intensity (SI) of agromorphic, cooking quality and physical characters are presented in Table 6. The magnitude of PCV was higher than the corresponding GCV for all the characters and their

differences were low indicated that these traits have less environmental influence. The GCV (35.55) and the PCV (36.11) both were found to be highest for the trait Alkali spreading value. High estimates of GCV and PCV were recorded for filled grain/panicle, test weight, panicle weight, amylose content, kernel breadth and kernel L/B ratio. Sawant *et al.*, (1994) reported high GCV and PCV for grains/panicle, plant height, 1000 grain weight and grain yield per plant; Singh and Choudhary (1996) for number of panicle per plant, number of grains per panicle, grain yield per plant and 1000 grain weight; Nayak *et al.*, (2002) for number of panicle per plant, number of spikelet per panicle, number of grains per panicle and grain yield per plant; Sarkar *et al.*, (2005) for number of panicle per plant, number of tiller per plant and grain yield per plant; Panwar *et al.*, (1989) for straw yield per plant, grain yield per plant, total biological yield per plant, number of fertile floret per plant and number of branches per panicle; Raut *et al.*, (2009) for seed yield per plant, 1000 grain weight, grains per panicle and effective tiller per plant; Karthikeyan *et al.*, (2009) for straw yield per plant, total biological yield per plant, number of fertile florets per panicle and number of branches per panicle and Anjaneyulu *et al.*, (2010) for number of grain per panicle, fertility % and grain yield per plant.

The range of heritability varied from 20.33% (Elongation ratio) to 96.93% (Alkali spreading value). High heritability was observed for filled grains panicle^{-1}, test weight, alkali spreading, amylose content, grain breadth, grain L/B ratio, kernel breadth, kernel L/B ratio and yield. These findings were earlier corroborated by Yadav *et al.*, (1995) for plant height, yield per plant, sterility, harvest index, days to 50 % flowering and days to maturity; Bihari *et al.*, (2004) for days to 50 % flowering and test weight; Panwar *et al.*, (1989) for days to 50 % flowering, days to maturity and 1000 grain weight and Karthikeyan *et al.*, (2009) for days to 50 % flowering, days to maturity and 1000 grain weight.

Yield had highest GA followed by panicle m^{-2} and plant height. These findings were in agreement with that of Kumar and Ramesh (2008) for plant height and Vishwakarma *et al.*, (1989) for grain per panicle.

All the characters except filled grains panicle^{-1}, test weight, alkali spreading, amylase content, grain breadth, grain L/B ratio, kernel breadth, kernel L/B ratio showed high heritability with low GA value indicated that the traits were under the influence of non additive genetic component in their expression. High heritability coupled with GA was obtained for yield, panicle m^{-2}, plant height and filled grain per panicle. these findings were earlier

***Table 4**. Mean of Physical and Milling Traits of 10 traditional Rice Genotypes with 2 High Yielding Check*

Sl. No.	Name of Variety	Grain length (mm)	Grain breadth (mm)	Grain L/B ratio	Kernel length (mm)	Kernel breadth (mm)	Kernel L/B ratio	Hulling %	Milling %	Head rice recovery %
1.	Jugal	7.92	2.46	3.22	5.50	1.76	3.12	83.50	73.50	60.83
2	Jamainadu	8.26	2.86	2.89	6.76	2.13	3.17	75.50	65.50	58.67
3	Patnai 23	10.61	2.90	3.68	7.61	2.68	2.85	78.67	68.50	55.83
4	Kerala Sundari	7.57	2.63	2.87	6.11	2.71	2.25	79.33	68.33	65.00
5	Binni	8.11	2.45	3.30	6.98	2.15	3.25	77.67	66.17	62.50
6	Latisail	8.55	3.02	2.83	6.91	2.75	2.51	78.67	65.83	56.83
7	Dudheswar	8.92	2.65	3.39	6.59	2.06	3.20	82.00	70.00	63.50
8	Talmari	9.45	2.88	3.25	7.48	2.45	3.06	78.83	68.00	63.17
9	Sarunagra	9.33	2.63	3.51	7.10	1.92	3.70	77.33	68.50	64.33
10	Kalma 222	8.77	2.61	3.45	7.59	2.36	3.21	79.33	68.50	64.17
11	IET 5656	8.24	2.97	2.81	6.49	2.62	2.48	80.17	70.50	63.67
12	MTU 7029	7.83	2.83	2.80	6.26	2.65	2.37	79.50	68.83	63.33
	Range	7.57-10.61	2.45-3.02	2.80-3.68	5.5-7.61	1.76-2.75	2.25-3.7	77.33-83.5	65.83-73.5	55.83-65
	Mean	8.63	2.74	3.16	6.78	2.35	2.93	79.21	68.51	61.82
	CV	7.276	1.916	4.569	4.916	2.7	5.393	3.21	3.52	3.259
	SEm±	0.513	0.043	0.118	0.272	0.052	0.129	2.077	1.969	1.645
	$CD_{(0.05)}$	1.015	0.085	0.234	0.539	0.103	0.256	4.11	3.899	3.257

corroboratd by Singh *et al.*, (2005) for plant height; Sanker *et al.*, (2006) for days to 50 % flowering, plant height, productive tiller per plant, panicle length, grain per panicle, 1000 seed weight and single plant yield.

In case of filled grain/panicle, plant height, panicle weight, amylose content, gel consistency and yield, the high heritability% combined with high GA and high GCV which indicated that the character was mostly governed by the additive gene action. These characters can be considered as the basis of selection for varietal improvement.

Selection of best traditional varieties on the basis of agromorphic traits

Days to 50% flowering are a parameter to decide the duration of a crop like short, medium or long duration. Kerala sundari was found to be the shortest days to 50% flowering (105 days), five other traditional varieties Dudheswar (112), Jamainadu (113), Patnai 23 (113), Binni (113) and Kalma 222 (115) also had shorter days to 50% flowering than that of two high yielding check varieties. It showed that these traditional varieties were even better in total time (as sown late) required for the crop than the two HYV checks used. Almost all traditional varieties had higher no. of panicle/m^2 than the check varieties. Only Kalma 222 (331 panicle/ m^2) have less no. of panicle m^{-2} than that of the two checks Filled grains panicle^{-1} of Kerala Sundari (167 filled grains panicle^{-1}) had a better count than the two high yielding checks IET 5656 (151) & MTU 7029 (155) while Dudheswar (148) and Jamainadu (143) also had at par count on this yield attribute. So these traditional varieties can be preferred over the two high yielding checks under selection program. Test weight of Patnai 23 (29.11 g), Latisail (25.57 g) and Kalma 222 (25.78 g) showed better result than that of the two HYV checks IET 5656 (24 g) and MTU 7029 (18.53 g). So, for this particular yield attribute under a breeding program Patnai 23, Latisail and Kalma 222 can be preferred over IET 5656 and MTU 7029. Kerala Sundari (sterility 14.76%) along with Patnai 23, Binni, Dudheswar and Sarunagra showed a lower degree of grain sterility than two high yielding checks, IET 5656 (19%) and MTU 7029 (19.77%). It meant these traditional varieties have a higher degree of grain filling than the HYV checks used, which was also a desirable parameter under any breeding program. The yield of varieties Jamainadu (4.55 t ha^{-1}), Talmari (4.43 t ha^{-1}), Kerala Sundari (4.41 t ha^{-1}), Jugal (4.27 t ha^{-1}) and Binni (4.18 t ha^{-1}) gave at par yield with the two HYV checks IET5656 (4.51 t ha^{-1}) and MTU7029 (4.38 t ha^{-1}) which suggested that these traditional varieties can be recommended for cultivation to the resource poor farmers in West Bengal and also can be used under the most desired breeding objective of a rice breeding program, the yield, as a donor.

Table 5. *Genotypic and phenotypic variances of agromorphic, cooking quality and physical characters*

Sl. No.	Characters	Phenotypic variance	Genotypic variance
1.	50 % flowering	28.13	5.95
2.	Filled grains panicle^{-1}	992.73	938.28
3.	Panicle length	3.25	0.96
4.	Panicle weight	0.36	0.27
5.	Plant height	396.87	287.46
6.	Sterility %	9.05	5.59
7.	Test weight	12.30	11.37
8.	Panicles m^{-2}	2943.12	1786.09
9.	Yield	220656.31	166172.22
10.	Alkali spreading	1.80	1.74
11.	Amylose content	17.72	14.34
12.	Elongation ratio	0.02	0.01
13.	Gel consistency	109.60	77.56
14.	Volume Expansion	0.18	0.12
15.	Grain breadth	0.04	0.04
16.	Grain length	0.99	0.60
17.	Grain L/B	0.11	0.09
18.	Kernel breadth	0.12	0.11
19.	Kernel length	0.48	0.37
20.	Kernel L/B	0.21	0.18
21.	Hulling %	8.64	2.17
22.	Milling %	8.71	2.90
23.	Head rice recovery	12.19	8.13

Selection of best traditional varieties on the basis of physical grain quality

All the traditional varieties had a grain L/B ratio greater than the two high yielding check varieties, IET 5656 (2.81) and MTU 7029 (2.80). It suggested that the high effectiveness of selection based on these traits. Except for the Kerala sundari (2.25), all the traditional varieties show a greater Kernel L/B ratio than high yielding check varieties, IET5656 (2.52) and MTU7029 (2.24).

Selection of best traditional varieties on the basis of cooking and eating traits

Six traditional varieties out of ten, Jugal, Jamainadu, Patnai 23, Kerala Sundari, Latisail and

Table 6. *Genotypic and Phenotypic coefficient of variation, Heritability and Genetic Advance at 5% Selection intensity*

Sl. No.	Characters	GCV	PCV	Heritability (%)	GA
1.	50 % flowering	2.13	4.63	21.15	1.063
2.	Filled grains panicle^{-1}	24.11	24.79	94.51	59.64
3.	Panicle length	4.12	7.59	29.43	0.593
4.	Panicle weight	16.94	19.40	76.25	0.823
5.	Plant height	11.50	13.51	72.43	25.298
6.	Sterility %	12.78	16.25	61.84	3.013
7.	Test weight	14.47	15.37	92.41	6.418
8.	Panicle m^{-2}	10.34	13.27	60.69	52.834
9.	Yield	9.99	11.52	75.31	632.40
10.	Alkali spreading	35.55	36.11	96.93	2.635
11.	Amylose content	14.88	16.53	80.95	6.315
12.	Elongation ratio	3.46	7.66	20.33	0.0224
13.	Gel consistency	11.40	13.55	70.76	12.738
14.	Volume expansion	7.95	9.58	68.96	0.502
15.	Grain breadth	6.94	7.20	92.91	0.364
16.	Grain length	8.96	15.55	60.29	0.961
17.	Grain L/B	9.56	10.60	81.41	0.508
18.	Kernel breadth	14.38	14.63	96.59	0.673
19.	Kernel length	8.96	10.22	76.85	0.962
20.	Kernel L/B	14.64	15.60	88.05	0.7783
21.	Hulling %	1.86	3.71	25.15	0.764
22.	Milling %	2.48	4.31	33.25	1.166
23.	Head rice recovery	4.61	5.65	66.72	3.92

Sarunagra had greater ratio of elongation than the two high yielding checks IET 5656 (1.50) and MTU 7029 (1.49). So, these traditional varieties could be considered over the two high yielding checks. Four of the ten traditional varieties, Sarunagra being maximum (5.17), Jamainadu (4.86), Patnai 23 (4.48) and Dudheswar (4.87), showed volume expansion ratio more than that of the two high yielding checks IET 5656 (4.33) & MTU 7029 (4.60). Gel consistency for all the varieties including all ten traditional varieties and two high yielding checks falls under the single category i.e. soft. Amylose content is high in IET5656 (30.8%) and intermediate in MTU7029 (24.2%), while four traditional varieties show high level of amylose content (25-32%). Binni (19.7%) and Dudheswar (20.7%) having intermediate amount of amylose were the best. In alkali spreading, both the high yielding checks fall in the category of low intermediate rating and high intermediate gelatinization temperature while traditional varieties range from low intermediate to high rating and from high intermediate to low gelatinization temperature; so there is scope of selection in the traditional varieties for the alkali spreading.

Selection of best traditional varieties on the basis of milling qualities

Jugal and Dudheswar showed higher hulling% as well as milling% than the two high yielding checks IET5656 and MTU7029. The head rice recovery% for the traditional variety Kerala sundari (65.00) is better over the two high yielding checks, IET 5656 (63.57) & MTU 7029 (63.33). This indicates that in the similar conditions some of the traditional varieties gives a better milling results well over and above the two high yielding check varieties used.

It can be concluded from the above discussion that the traditional varieties Jamainadu, Talmari, Kerala Sundari, Jugal & Binni gave at par yield with two high yielding checks IET 5656 & MTU 7029. Dudheswar, Binni, Jamainadu & Saru Nagra found better in cooking and eating quality than both the high yielding checks while Kerala Sundari, Jugal and Dudheswar had better milling quality over the checks. Therefore, the above mentioned traditional rice varieties having high yield potentiality & good quality may be recommended for widespread cultivation in West Bengal, especially in resource poor districts as they can successfully be grown with low input management practices.

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Evaluation of F_1 Hybrids of Cucumber (*Cucumis sativus* L.) under Naturally Ventilated Polyhouse

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Seventeen cucumber hybrids were evaluated for growth, yield and yield attributing characters under naturally ventilated polyhouse in Konkan agroclimatic condition. The study revealed that the hybrid US-800 recorded highest main vine length (7.30 m), hybrid Malini recorded highest number of branches per vine (14), hybrid Daynasty recorded lowest days to appearance of first male flower (35 days), hybrid Swati recorded lowest days to appearance of first female flower (36 days), hybrid NCH-160 recorded lowest nodal position of first male flower (1.1 node), hybrid Sahyadri recorded lowest nodal position of first female flower (3.80 node), hybrid Shighra recorded lowest days to first harvest (51.10 days), hybrid Malini recorded highest days to last harvest (87.80 days), hybrid Shighra recorded highest harvest span (35.90 days), hybrid Daynasty recorded highest number of harvesting (14.40 days), hybrid Mahabharat recorded highest length of fruit (19.10 cm), hybrid Malini recorded highest diameter of fruit (4.36 cm), highest fruit weight (241.18 g), highest number of fruit per vine (23.70), highest fruit yield per vine (4.92 kg) and highest yield per hectare (716.46 qt). Hybrid Sahyadri recorded highest leaf area (422.00 cm^2). Hybrid Malini was found superior based on the overall performance of different cucumber hybrids for growth, yield and yield attributing character for cultivation of cucumber under naturally ventilated polyhouse.

(***Key words***: *Cucumber, F_1 hybrids evaluation, Polyhouse)*

Cucumber (*Cucumis sativus* L.) is one of the most popular vegetable of the family Cucurbitaceae with a chromosome number 2n=14. Cucumber is originated in India. It is an ideal summer vegetable crop chiefly grown for its edible tender fruits, preferred as salad, pickles, and desert fruit and as a cooked vegetable. Cucumber is mainly cultivated in the belts of the Konkan region of the Maharashtra. Though, it is common and popular crop in growers as a sole crop, it is also planted in kitchen garden or an inter crop in mango, arecanut, coconut, cashew plantation, near fencing, near some trees and even on the thatches of the dwelling, particularly during *Kharif* season. Farmers use their own seed or available seed on large scale hence, the yields are low. Now-a-days trend of growing F_1 hybrids is increasing among the farmers of Konkan region due to its high yield potential over local and improved varieties. Similarly, due to their easy availability and uniform crop stand. Protected cultivation has higher water and nutrient use efficiencies.

Both of these factors are of vital importance for healthy and luxuriant growth of crop plants Information about the evaluation of cucumber hybrids under naturally ventilated polyhouse in the Konkan is not available; hence, the study of selection of proper hybrids which will grow successfully,especially for off season cultivation under naturally ventilated polyhouse is necessary.

MATERIALS AND METHODS

The present investigation was carried out in a polyhouse Department of Horticulture, College of Agriculture, Dapoli, Dist. Ratnagiri (Maharashtra) during the year 2012-13. The experiment was carried out with 17 hybrids of Cucumber *viz* Swati, Victoria, Ankur, Mahabharat, Nirmal 434, Cucumber NS-46, Nirmal 388 and NCH- 160.All the hybrids were sown on 7th December 2013 on raised bed method with spacing 1m x 0.45 m between rows and plants within row, respectively. Adopting the recommended cultivation practices for raising a healthy crop and used the trellis system for vines climbing. The experiment was laid out in Randomized Block Design with two replications. Observations on various characters namely, main vine length (m), number of branches per vine, days to appearance of first male and female flower, nodal

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position of first male and female flower appears, days to first harvest, days to last harvest , harvesting span, number of harvesting, leaf area (cm^2), fruit length (cm), fruit diameter (cm), fruit weight (g), number of fruits per plant, fruit yield per plant (kg) and fruit yield per ha (q) were recorded from five randomly selected plants of each hybrid. Data was statistically analyzed for the evaluation of hybrids.

RESULTS AND DISCUSSION

The highest vine length was found with US-800 (7.30 m) and lowest vine length was recorded with Nirmal-388 (3.78 m) (Table 1). The variation in vine length might have been due to specific genetic makeup of different hybrids, inherent properties, environment factor, hormonal factor and vigour of the crop. Similar results have been reported by Patel *et al.,* (2013) and Solanki and Seth (1980) in cucumber. Maximum number of branches per vine was recorded in Malini (14.00) followed by Mahabharat (13.00), the lowest branches per vine was recorded in Shighra (6.10) (Table 1). Variation in number of branches among cucumber hybrids might be due to their own genetic makeup, hybrid vigour, and their interaction with environment factor confirming to reports of Patel *et al.,* (2013) and Sharma and Bhattarai (2006) in cucumber.

The lowest days to appearance of first male flower were observed in Daynasty (35.4 days) followed by Swati (35.6 days), Swati (35.7 days), Victoria (35.8 days) and Mahabharat (36.1 days). The highest days to appearance of first male flower were found in Nirmal 388 (37.59 days) (Table 1). The number of days from sowing to appearance first of male flower is an important character that indicates earliness of the crop. The lowest days to appearance of first female flower were observed in Swati (36.3 days) followed by Shighra (38.0 days), Victoria (36.3 days), VNR Kumud (36.5 days), Daynasty (36.6 days), Mahabharat (36.6 days), US-800 (37.8 days) and Shighra (38.00 days). Lowest days to appearance of first female flower was recorded in Cucumber NS-46 (42.40 days) (Table 1). The variation in first appearance of male and female

Table 1. *Mean performance of different hybrids of cucumber (Cucumis sativus L.) under naturally ventilated polyhous*

Hybrids	Length of main vine (m)	Number of branches per vine	Days to first appearance of male flower	Days to first appearance of female flower	Nodal position of first male flower	Nodal position of first female flower	Days to first harvest	Days to last harvest	Leaf area (cm^2)
Malini	5.35	14.0	37.8	39.1	2.4	6.9	54.0	87.8	286.45
Nandini	5.17	10.5	37.9	39.3	2.0	6.0	54.0	86.4	271.34
VNR Kumud	4.68	10.1	38.7	36.5	3.4	5.1	52.4	86.4	219.51
Shighra	5.35	6.1	35.8	38.0	2.1	6.3	51.3	87.2	370.00
Nazia	4.50	8.7	39.4	40.4	2.7	6.0	52.8	87.4	307.22
US-800	7.30	11.0	36.9	37.8	2.3	5.5	56.1	79.2	247.17
Sahyadri	5.60	11.0	38.7	39.0	2.8	3.8	56.5	86.8	422.00
Daynasty	4.11	7.4	35.4	36.6	2.3	4.9	52.0	86.4	391.50
Gypsy	6.32	7.2	36.7	38.1	2.2	6.1	57.2	82.0	314.73
Swati	6.93	7.6	35.6	36.3	2.4	4.9	57.6	85.4	201.21
Victoria	6.86	8.9	35.7	36.3	2.3	5.3	55.3	84.6	198.64
Ankur	4.00	7.4	39.5	38.7	3.0	5.0	52.8	86.2	175.24
Mahabharat	5.50	13.0	36.1	36.6	2.1	5.4	51.9	85.6	171.65
Nirmal 434	3.86	9.5	38.6	40.2	1.9	4.8	55.7	87.6	191.54
Cucumber Ns-46	4.56	10.5	38.8	42.4	2.0	6.3	53.6	86.8	166.03
Nirmal 388	3.78	6.8	39.7	40.6	2.9	5.7	53.3	86.0	299.11
NCH-160	3.90	8.6	37.8	40.3	1.1	6.1	53.5	86.6	312.94
Mean	5.16	9.3	37.6	38.6	2.4	5.5	54.1	85.8	267.43
SEm ±	0.04	0.7	0.5	0.7	0.2	0.3	0.3	0.7	14.37
C.D. at 5%	0.12	2.1	1.4	2.0	0.5	1.0	1.0	2.2	43.09

flower might have been due to internodal length, number of internodes, genetic makeup and vigour of the crop. This result is inconformity with Sahni *et al.,*(1987) in ridge gourd, Badgujar and More (2004), Bairagi *et al.,*(2005) and Patel *et al.,* (2013) in cucumber.

The lowest nodal position of first male flower was recorded in NCH-160 (1.1 node) and highest nodal position of first male flower was noticed in VNR Kumud (3.4 node) (Table 1). Lowest nodal position of first female flower was recorded in Sahyadri (3.8 node) followed by 434 (4.8 node). Highest nodal position of first female flower was noticed in Malini (6.9 node) (Table 1). Similar finding were reported by Sharma and Bhattarai (2006), Patel *et al.,* (2013) in cucumber.

The lowest days to first harvest was recorded in the Shighra (51.10 days) followed by Mahabharat (51.9 days) and Daynasty (52.0 days). Highest days to first harvest was noticed in Swati (54.12 days) (Table 1). The highest days to last harvest was recorded in the Malini (87.8 days) followed by Nirmal 434 (87.6 days), Nazia (87.4 days), Shighra (87.2 days), Cucumber Ns-46 (86.8 days), Sahyadri (86.8 days), NCH-160 (86.6 days), Daynasty (86.4 days), VNR Kumud (86.4 days), Nandini (86.4 days), Ankur (86.2 days), Nirmal 388 (86 days), Mahabharat (33.70 days). Lowest days to last harvest was recorded in US-800 (79.2 days) (Table 1). The variation in days to first and last harvest might be due to genetic factor, hormonal factor and vigour of crop. Similar result have also been reported by Sharma and Bhattarai (2006) in cucumber.The highest harvest span was recorded in the Shighra (35.9 days) followed by Nazia (34.6 days), Daynasty (34.4 days), VNR Kumud (34.0 days), Malini (33.8 days) and Mahabharat (33.7 days). Lowest days for harvesting span was noticed in US-800 (23.1 days) (Table 1). The highest number of harvesting was recorded in Daynasty (14.4) followed by Shighra (13.8). Lowest number of harvesting was noticed in Cucumber NS-46 (3.9). The variation in harvesting span and number of harvesting in different cucumber hybrid have might be due to appearance of first female flower, genetic and varietal factor. Comparable result have been reported by Sharma and Bhattarai (2006) in cucumber.

The highest leaf area was recorded in the F1 hybrid Sahyadri (422.00 cm^2) followed by Daynasty (391.50 cm^2) and the lowest leaf area was noticed

Table 2. *Mean performance of different hybrids of cucumber (Cucumis sativus L.) under naturally ventilated polyhouse.*

Hybrids	Length of fruit (cm)	Diameter of fruit (cm)	Fruit weight (g)	Number of fruits per vine	Fruit yield per vine (kg)	Yield per ha (qt)
Malini	18.81	4.36	241.18	23.7	4.92	716.46
Nandini	16.96	4.05	200.08	19.7	3.92	571.00
VNR Kumud	15.99	3.80	172.79	20.1	3.47	505.27
Shighra	18.36	3.73	171.25	19.4	3.32	483.67
Nazia	16.05	3.96	205.22	18.4	3.77	549.45
US-800	17.57	3.91	197.71	10.0	1.98	287.95
Sahyadri	17.93	3.94	195.27	13.6	2.63	382.88
Daynasty	18.94	3.88	189.63	21.2	3.97	578.05
Gypsy	18.82	3.92	197.78	13.8	3.26	474.76
Swati	14.59	3.43	136.29	7.5	1.06	153.97
Victoria	15.72	3.86	183.43	12.8	2.34	341.43
Ankur	12.82	4.03	167.84	18.2	3.12	454.95
Mahabharat	19.10	3.96	218.19	11.8	2.60	378.92
Nirmal 434	14.70	4.12	189.42	12.1	2.24	326.94
Cucumber Ns-46	18.34	3.65	163.38	6.7	1.10	160.40
Nirmal 388	17.23	3.89	179.83	16.1	2.89	420.77
NCH-160	14.25	4.05	161.76	16.0	2.60	378.96
Mean	16.83	3.91	186.53	15.4	2.89	421.52
SEm ±	0.20	0.06	8.02	0.3	0.23	33.12
C.D. at 5%	0.60	0.17	24.03	0.8	0.68	99.29

in Cucumber NS-46 (166.03 cm^2) (Table 1). These findings were supported by Patel *et al.,* (2013) and Sharma *et al.,* (2010). Data presented in Table 2 revealed that the highest length of fruit was recorded in the Mahabharat (19.10 cm) followed by Daynasty (18.94 cm), Gypsy (18.82 cm) and Malini (18.81 cm). The lowest length of fruit was noticed in Ankur (12.82 cm). Fruit yield is also depend on fruit length, increasing fruit length will increase the fruit yield. The variation in fruit length might be due to genetic nature and vigor of crop. Similar results have also been reported by Patel *et al.,* (2013) and Sharma *et al.,* (2010) in cucumber. The highest diameter of fruit was recorded in the Malini (4.36 cm) and lowest diameter of fruit was noticed in Ankur (3.43 cm) (Table 2). Increase in fruit yield is mostly influenced by fruit diameter. When fruit diameter was high then automatically fruit yield was also high. The variation in fruit diameter might have been due to genetic factor and vigour of the crop. Similar results have also been reported by Patel *et al.,* (2013) and Sharma *et al.,* (2010) in cucumber.

The highest fruit weight was recorded in Malini (241.18 g) and the lowest fruit weight was noticed in Swati (136.29 g) (Table 2). The highest fruit weight in Malini may be due to its hybrid vigour, similar result have been reported by Patel *et al.,* (2013) and Sharma *et al.,* (2010) in cucumber.

The highest number of fruit per vine was recorded in Malini (23.70) and the lowest number of fruit per vine was noticed in Cucumber NS-46 (6.70) (Table 2). The variation in fruit per vine might have been due to sex ratio, fruit set percentage, genetic nature of hybrids. Similar result have been reported by Patel *et al.,* (2013) and Sharma *et al.,* (2010) in cucumber.The highest fruit yield per vine was recorded in Malini (4.92 kg) and the lowest fruit yield per vine was noticed in Swati (1.06 kg) (Table 2). The significant variation in yield per vine might have been due to fruit set percentage, fruit length, number of fruit per vine, fruit weight, fruit width, genetic nature and vigour of crop. These findings were supported by Patel *et al.,* (2013), Sharma *et al.,* (2010) and Sharma and Bhattarai (2006) in cucumber.

The highest yield per ha was recorded in Malini (716.46 qt) and the lowest yield per ha was noticed in Swati (153.97 qt) (Table 2). The significant variation in yield per ha might have been due to number of vines per ha, number of fruit per vines, yield per vines and yield per plot. This investigation was also supported by Patel *et al.,* (2013) and Sharma and Bhattarai (2006) in cucumber.

CONCLUSION

From the present findings, it could be concluded that the cucumber hybrid Malini had shown better performance with regards to the highest fruit weight (241.18 g), number of fruit per vine (23.70) as well as the highest marketable fruit yield per vine (4.92 kg) and yield per ha (716.46 qt) in naturally ventilated polyhouse under Konkan agroclimatic condition.

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Standardization of Callus derived *in vitro* Screening Technique for Salt Tolerance in Rice (*Oryza sativa* L.)

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***In-vitro* studies on salt tolerance were carried out with callus of three indica varieties, Karjat-5 (salt susceptible), Panvel-3 and FL-478 (salt tolerant). The study was conducted to obtain higher salt tolerant genotypes with variable characters of local rice varieties through somaclonal variations. Various concentration and combinations of plant growth regulators were supplemented with MS medium to develop friable callus and plantlet regeneration ability of mature embryo of rice. The calli were transferred to the proliferation medium of different concentration of NaCl to check the inherent capacity of calli to proliferate on medium under salt stress condition. Maximum percentage of callus induction observed in MS medium supplemented with 2.5 mg L^{-1} 2,4-D along with 0.5 mg L^{-1} BAP and 0.1 mg L^{-1} NAA in all three varieties. Calli derived from the different concentration of 2, 4-D and other plant growth regulators were transferred on MS medium supplemented with various concentrations of BAP, Kinetin, NAA and IAA for plantlet regeneration. The weight of callus was decreased with increased in salt concentration. The variety FL-478 showed proliferation of the callus upto 10 dS m^{-1} salinity followed by Panvel-3 (upto 8 dS m^{-1} salinity) whereas the callus of Karjat-5 was survived only up to 4 dS m^{-1} salinity. It indicates that variety FL-478 and Panvel-3 are potential variety for development of novel somaclones for salinity tolerance as compared to Karjat-5. It was also observed that MS medium supplemented with 4 mg L^{-1} BAP and 1 mg L^{-1} IAA produced highest of plantlets for variety FL-478 (77.50) followed by Karjat-5 (69.17) and Panvel-3 (53.33).**

(***Key words:*** *Callus, In vitro Screening, Salt tolerance, Rice)*

Salinity is widespread soil problem in rice growing countries. Rice production has mostly been observed to be affected by soil salinity. In India, saline soil covers nearly 4 million ha of land under rice production (Paul and Ghosh, 1986). In Maharashtra the total area occupied by this crop was about 14.87 lakh hectares with annual production of 26.01 lakh tones and productivity was about 1.74 t ha^{-1} (Anonymous, 2012). Rice is rated as an especially salt-sensitive crop (Shannon *et al.*, 1998). Apart from a delayed germination, salinity was found to reduce the germination percentage (Akbar and Yabuno, 1974). Early seedling stage of rice was found to be highly sensitive to salinity (Kaddah and Fakhrys, 1961).

An improvement of salt tolerance in rice is well documented (Flower and Yeo, 1995). Tissue culture approach might have proven effective in gaining phenotypic variation in regenerated plants. An implication of somaclonal variation in breeding is that, novel variation can arise and these can be of agronomic use. The plants generated from callus cultures show heritable variation in both qualitative and quantitative traits. It also act as a continuous reservoir of genetic variability in crop production, thereby making selection in the population easier for further improvement. Keeping this in view present investigation was carried out to obtain somaclonal variants of rice for higher salt tolerance and desirable character.

MATERIAL AND METHODS

MS medium supplemented with 2, 4-D, NAA, BAP, Kinetin and IBA in different combinations and concentrations were included in the study. For preparation of explants the excised seed were washed in Ethyl alcohol (70 %) followed by washing with double distilled water for 3-4 times. The explants were dipped in $HgCl_2$ solution of different concentrations (0.1%, 0.5% and 1.0%) for varied time period and then washed with double distilled water for several times. Then seeds were soaked for 12-14 hours in distilled water. Treated seeds were inoculated on callus induction media. Observations were recorded on callus induction response (%), days to initiation of callus, weight of callus after 4 weeks. After that six-week-old callus was divided into pieces of 100 mg. These pieces were transferred to the same medium those were used for callus induction, supplemented with different NaCl

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concentrations for salt stress responses. To prepare media of different salt concentration of salt was added per lit by using following formula.

1000 EC units = 1000 iS cm^{-1} = 1.0 mS cm^{-1} = 1.0 dS m^{-1} = 640 Mg L^{-1} TDS = 640 ppm TDS. i.e. 640 Mg L^{-1} (Salinity measuring units, NSW Environment and Heritage) to prepare media of 1 dS m^{-1} and subsequent salty media were prepared. At the end of the four-week period, the callus was taken for growth analysis. Observations were recorded weight of callus increased, regeneration response (%), days to shooting, number of shoots per explant and days to rooting.

Hardening and establishment of rooted plants

Plantlets with healthy root systems were washed (especially the root portions) by double distilled water to clear off the entire residual agar medium so as to check the chances of fungal contamination in soil. The root portions were then dipped for about 5-10 minutes in an antifungal solution 0.1% (w/v) Bavistin. The plantlets were then transplanted in small (5 cm diameter) plastic tea cups containing pre-soaked sterilized vermiculite medium and kept in growth chamber. For the initial 10-15 days high humidity was main tented and was gradually reduced to the ambient level over a period of 2 weeks. The potting mixture containing soil, sand, and vermiculite (1:1:1) was used for transplantation of the plants. Factorial Completely Randomized Design (FCRD) was employed for the present study. The pooled data was analyzed in SASs (Statistical Analysis System software V. 9.1). The observations of callus response and shoot response expressed in terms of percentage were transformed into arcsine value.

RESULTS AND DISCUSSION

Effect of media combination on callus induction

MS medium supplemented with different concentration of 2, 4-dhormone were employed for callus induction. Callus induction was stated at 12th to 24th days after transferring the caryopsis to culture tube and there incubation (Table 1). The final data on callus induction was recorded after four weeks of inoculation.

Table 1. *Callus induction frequency (%) and days to callus induction*

Sr. No.	Treatment details	Karjat-5 (%)	Panvel-3 (%)	Fl-478 (%)	Days to callus induction			Nature of callus
					Karjat-5	Panvel-3	FL-478	
T_1	M.S. medium (control)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.000	0.000	0.000	No callus
T_2	M.S.+ 1.5 mg/l 2,4-D + 0.5 mg/l KIN	9.17 (17.5)	7.50 (15.75)	7.50 (15.75)	14.00	20.33	22.50	Yellowish-white, compact
T_3	M.S.+ 2.0mg/l 2,4-D + 0.5 mg/l KIN	14.17 (22.09)	15.00 (22.79)	14.17 (22.09)	15.25	20.08	17.33	Copious, compact
T_4	M.S. + 2.5 mg/l 2.4-D + 0.5 mg/l KIN	16.67 (24.08)	1500 (22.74)	17.50 (24.73)	20.75	15.50	16.41	Soft, friable
T_5	M.S. + 1.5 mg/l 2.4-D + 0.5 mg/l BAP	23.33 (28.88)	25.83 (30.54)	25.83 (30.54)	14.00	13.66	24.33	Soft, friable
T_6	M.S.+ 2.0mg/l 2,4-D + 0.5 mg/l BAP	32.50 (34.75)	26.67 (31.07)	30.83 (33.73)	15.25	20.41	19.75	White, Soft, friable
T_7	M.S. + 1.0 mg/l 2.4-D + 0.5 mg/l BAP +0.1 mg/l NAA	41.67 (40.20)	37.50 (37.75)	39.17 (38.74)	15.33	15.50	22.25	Yellowish-white, compact
T_8	M.S. + 1.5 mg/l 2.4-D + 0.5 mg/l BAP +0.1 mg/l NAA	68.33 (55.76)	64.17 (53.23)	63.33 (52.74)	15.08	12.41	19.83	Copious, compact
T_9	M.S. + 2.0 mg/l 2.4-D + 0.5 mg/l BAP +0.1 mg/l NAA	72.50 (58.39)	76.67 (61.38)	76.67 (61.22)	22.50	13.83	17.16	Yellowish-white, compact
T_{10}	M.S. + 2.5 mg/l 2.4-D + 0.5 mg/l BAP +0.1 mg/l NAA	83.33 (65.92)	85.00 (67.26)	81.67 (64.66)	23.25	12.91	20.91	Soft, friable
T_{11}	M.S. + 2.0 mg/l 2.4-D + 0.5 mg/l KIN +0.1 mg/l NAA	94.17 (76.09)	93.33 (75.10)	90.83 (73.43)	19.91	15.25	17.25	Yellowish-white, compact
	SEm ±	0.71	1.37	1.65	0.642	1.077	3.037	
	CD at 1%	2.81	5.46	6.56	0.308	0.516	1.455	
	C.V.	3.17	6.24	7.51	2.365	4.348	9.913	

(*Figures in parenthesis are arcsine values)

It was noticed that MS medium supplemented with 2.0 mg L^{-1} 2,4-D along with 0.5 mg L^{-1} kinetin and 0.1 mg L^{-1} NAA (T11) produced higher percentage of callus, 94.17% in karjat-5 followed by 93.33% in Panvel-3 and 90.83% in FL-478. On the other hand T2 treatment produced the lowest percentage of callus, 9.17 %, 7.50% and 7.50% in Karjat-5, Panvel-3 and FL-478, respectively.

Nature of callus

A reasonable callus formed after about four weeks of culture. Callus formed on different media combinations observed different in nature. Embryogenic calli were found to be yellow to white, dry, compact and nodular. On the other hand, non-embryogenic calli appeared to be watery, light yellow to tan and non-nodular. Further a soft, friable and non-organogenic callus formation occurred in rice cuticular rice embryo when the medium contained M.S. + 1.5 mg L^{-1} 2.4-D and 0.5 mg L^{-1} BAP. Soft and friable callus was recorded on media supplemented with 2.5 mg L^{-1} 2.4-D + 0.5 mg L^{-1} KIN and 2.5 mg L^{-1} 2.4-D + 0.5 mg L^{-1} BAP + 0.1 mg L^{-1} NAA. (Table 1).

Effect of salinity on callus proliferation

In Panvel-3 weight of callus was increased by 121 mg on media treatment T1, which was significantly superior over all other treatments. Callus growth was rapidly reduced with relative increase of NaCl concentration in callus proliferation media. These results are in accordance with Senadhra (1987). Weight of callus decreased up to 78 mg on media having salt concentration of 4 dS m^{-1}. Callus was not proliferated on T4 i.e. salt concentration of 10 dS m^{-1}. Blackening and drying

Table 2. *Weight of callus per 100 mg in MS media supplemented with various concentration of NaCl*

Sr.No	Treatment	Karjat-5 (mg)	Panvel-3 (mg)	FL-478 (mg)
1	MS+ 2.0mg/l 2,4-D+0.5mg/l KIN	152	121	153
2	MS+ 2.0mg/l 2,4-D+0.5mg/l KIN+4 dS/m NaCl	99	78	89
3	MS+ 2.0mg/l 2,4-D+0.5mg/l KIN+6 dS/m NaCl	0.000	51	65
4	MS+ 2.0mg/l 2,4-D+0.5mg/l KIN+8 dS/m NaCl	0.000	89	64
5	MS+ 2.0mg/l 2,4-D+0.5mg/l KIN+10 dS/m NaCl	0.000	0.000	46
6	MS+ 0.5mg/l 2,4-D+0.5mg/l KIN+ 12 dS/m NaCl	0.000	0.000	0.000
	SEm ±	0.005	0.078	0.005
	CD at 1%	0.002	0.036	0.002
	C.V.	7.080	7.697	4.014

Table 3. *Frequency of callus regeneration and days required for shoot induction in various media combination*

Sr. No.	Treatment details	Callus regeneration frequency			Days to shoot induction		
		Karjat-5 (%)	Panvel-3 (%)	FL-478 (%)	Karjat-5 (%)	Panvel-3 (%)	FL-478 (%)
T1	MS medium(control)	0.00(0.00)	0.00(0.00)	0.00(0.00)	–	–	–
T2	MS+0.5 mg/l BAP+0.2 mg/l IAA	0.00(0.00)	0.00(0.00)	0.00(0.00)	–	–	–
T3	MS+0.5 mg/l BAP+0.5 mg/l IAA	0.00(0.00)	0.00(0.00)	0.00(0.00)	–	–	–
T4	MS+0.5 mg/l BAP+1.0 mg/l IAA	0.00(0.00)	0.00(0.00)	0.00(0.00)	–	–	–
T5	MS+1.0 mg/l BAP+0.5 mg/l IAA	0.00(0.00)	0.00(0.00)	0.00(0.00)	–	–	–
T6	MS+1.5 mg/l BAP+1.0 mg/l IAA	61.67(51.81)	60.83(51.46)	64.17(53.23)	29.25	29.33	29.08
T7	MS+2.0 mg/l BAP+1.0 mg/l IAA	65.00(53.85)	67.50(55.25)	60.83(51.29)	18.75	27.58	25.41
T8	MS+2.5 mg/l BAP+1.0 mg/l IAA	50.83(45.48)	70.00(56.80)	60.83(51.32)	18.16	21.50	24.00
T9	MS+3.0 mg/l BAP+1.0 mg/l IAA	54.17(47.39)	65.00(53.74)	60.83(57.32)	26.41	29.08	18.16
T10	MS+3.5 mg/l BAP+1.0 mg/l IAA	65.83(54.25)	80.00(63.46)	70.83(61.75)	13.08	20.16	13.75
T11	MS+4.0 mg/l BAP+1.0 mg/l IAA	69.17(56.27)	53.33(46.91)	77.50(46.92)	25.58	16.08	26.58
	SEm ±	1.75	1.71	1.60	0.659	0.420	0.659
	CD at 1%	6.99	6.83	6.38	0.316	0.201	0.316
	C.V.	6.85	6.40	5.80	3.242	1.884	3.106

of callus was observed on this combination. Decrease in weight was observed in variety FL- 478 as the concentration of NaCl was increased. The 100 mg of callus proliferated and increased its weight when it put on media combination of T1 which was free from NaCl. It was also observed that the callus of FL-478 was survived up to the 10 dS m^{-1} of NaCl concentration. This showed that NaCl had an inhibitory effect on the growth of callus with increasing NaCl concentration inducing the inability of plant cell and tissue to adjust with incremental increase of salt over sufficient time period might be due to osmotic or ionic shock (Shanti *et al.,* (2010). Among all these three varieties, the callus of FL-478 survived at higher salt concentration (10 dS m^{-1}) followed by Panvel-3 (8 dS m^{-1}) and Karjat-5 (4 dS m^{-1}) (Table 2).

Frequency of callus regeneration in various media combination

Callus of all three varieties not regenerated on media combination treatment T_1 to T_6. Maximum regeneration frequency recorded on MS media supplemented with 3.5 mg L^{-1} BAP +1.0 mg L^{-1} IAA (T_{10}) in Panvel-3 (80.00%) followed by FL-478 (70.83%) and Karjat-5 (65.83%) irrespective of media combination. (Table 3). Variety Karjat-5 and FL-478 recorded early shoot initiation (13.08 days and 13.75 days, respectively.) whereas Panvel-3 showed late shoot initiation (16.08 days). In Karjat-5, minimum number of days to shoot initiation was recorded in treatment T_{10} (13.08) which were significantly superior over all other treatments. The maximum shoot induction was recorded in treatment containing highest concentration of BAP (T_{10} containing 3.5 Mg L^{-1} BAP) for the varieties Karjat-5 and FL-478 *i.e.,* 7.17 and 7.27, respectively. While higher shoot multiplication in Panvel-3 recorded on MS supplemented with 3.0 mg L^{-1} BAP +1.0 mg L^{-1} IAA.

Effect of media on root induction

It was observed that, the maximum days to rooting ranged between 04 to 18 days. Among all three varieties Karjat-5 and FL-478 showed early root induction as compared to Panvel-3. In Karjat-5, minimum number of days to root initiation were recorded in treatment T_{10} (4.16).In Panvel-3, half MS supplemented with 0.5 mg L^{-1} IBA+ 0.1 mg L^{-1} BAP showed minimum number of days to root initiation (5.0). In FL-478, minimum number of days to root initiation were recorded in treatment T_9 (4.5). The per cent of root induction was observed from 0.00 to 51.67. In all three varieties, no root induction observed on treatment T_1 i.e. control and T_2 to T_4. The root induction frequency observed maximum in Karjat-5 on media combination T_{11} (51.67%)

Table 4. *Root induction frequency and days required for root induction*

Sr. No.	Treatment	Regeneration frequency			Days to induction		
		Karjat-5	Panvel-3	FL-478	Karjat-5	Panvel-3	FL-478
1	MS medium (control)	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.000	0.000	0.000
2	MS+ 0.5 mg/l NAA	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.000	0.000	0.000
3	MS+ 1.0 mg/l NAA	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.000	0.000	0.000
4	MS+ 1.5 mg/l NAA	0.00(0.00)	0.00(0.00)	0.00(0.00)	0.000	0.000	0.000
5	MS+ 2.0 mg/l NAA	15.00 (22.74)	15.00 (22.74)	18.33 (25.34)	15.33	15.25	17.91
6	MS+ 3.0 mg/l	15.00 (22.66)	15.83 (23.35)	13.33 (21.40)	12.583	12.66	15.33
7	MS +1.0 mg/l NAA + 2.0mg/l BAP	15.00 (22.79)	15.83 (23.39)	12.50 (20.64)	14.00	15.66	14.16
8	1/2 MS+ 0.2 mg/l IBA+ 0.1mg/l BAP	15.83 (23.43)	16.67 (24.08)	57.50 (49.31)	5.08	15.75	5.83
9	1/2 MS+ 0.2 mg/l IBA+ 0.2mg/l BAP	49.17 (44.52)	47.63 (45.48)	45.00 (42.13)	4.33	5.08	4.50
10	1/2 MS+ 0.5 mg/l IBA+ 0.1mg/l BAP	50.83 (45.48)	49.83 (45.48)	45.83 (42.61)	4.16	5.00	4.66
11	1/2 MS+ 0.5 mg/l IBA+ 0.2mg/l BAP	51.67 (45.96)	50.83 (45.48)	49.17 (44.52)	4.917	5.16	4.91
	SEm ±	0.94	0.88	0.57	0.603	1.261	1.120
	CD at 1%	3.74	3.52	2.27	0.289	0.604	0.537
	C.V.	7.87	7.31	4.42	6.437	10.911	10.735

In Panvel-3, the root induction frequency observed maximum on media combination T_{11} (50.83%).The root induction frequency was observed maximum in FL-478 on media combination T_8 (57.50%), followed by T_{11} (49.17%) (Table 4).

Hardening and establishment

Rooted plants were transferred to the potting mixture of soil, sand and vermiculite (1:1:1).The average lower percentage of survival was recorded 23.33 while average maximum survival recorded 74.17. The study concluded that for callus induction M.S. + 2.0 mg L^{-1} 2.4-D + 0.5 mg L^{-1} KIN +0.1 mg L^{-1} NAA proved to be the best media combination for callus induction. Better callus proliferation up to level of 10 dS m^{-1} was observed in FL-478, followed by Panvel-3 which showed better callus proliferation up to 8 dS m^{-1}. Karjat-5 callus was not survived on 6 dS m^{-1}. MS+ 3 mg L^{-1} BAP proved to be the best media combination for shoot induction.

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Exploration of Artificial Groundwater Recharge in Coastal West Bengal

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Fresh water scarcity is the main problem for growing crops in the coastal West Bengal beyond the rainy season. To alleviate the water scarcity during the non-monsoon period, augmentation of capacity of ground water through artificial recharge during the rainy season was experimented at ICAR-CSSRI, RRS, Canning Town farm. A recharge tube well of 12.7 cm diameter and 40.5 m depth was installed in the year 2011. As the water table came up very close to the surface (< 1 m bgl) during the rainy season, an experiment was carried out for lowering the water table by pumping during summer and artificial recharge of runoff water during the rainy season. For pumping out the ground water, 1 HP electrical pump with discharge of 0.64 lps was used. In spite of 30 days (6 hours per day) of pumping in the summer season, the pumping water level was not lowered below 6 m depth. There was depletion of the water table due to pumping till 27th week from January, 2012. Later the water table moved up due to recharge in the monsoon period. The rising of water table near to the surface was similar to previous year when tube well was installed during July/August, 2011 and there was no artificial recharge. Therefore, the present situations are not conducive for artificial recharge in the Canning area. However, if at any location the water table in post monsoon season depletes regularly beyond 3m bgl, there artificial recharge may be done.

(***Key words:*** *Artificial recharge, Ground water, Aquifer, Coastal, Water table)*

Despite of high rainfall (average annual rainfall: 1768 mm) in coastal West Bengal, fresh water scarcity is felt in the non-monsoon period. More than 80 % of the annual rainfall occurs only in the few months of monsoon (June-Sept.). The lands are flat or having little slope, remain inundated during the rainy season and mostly mono-cropped with paddy. The water sources in this area as tidal rivers and rivulets are not utilizable because of the high salinity. These sources of water also influence the soil and water salinity in the inlands by intrusion as surface/ground water. The ground water available at shallow depths is also saline and not usable for agriculture. The water quality of deeper aquifers may be fresh or saline depending upon the location specific geo-hydrological conditions.

The farmers of the Sundarbans region have been exploiting the ground water since a few years back through shallow tube wells for cropping in post-kharif and summer period. According to the farmers, the capacities of the tube wells are decreasing time to time and the quality of ground water is deteriorating. Overexploitation of groundwater (Custodio, 2002) through shallow tube wells may lead to decline in water quality as well as water table, consequently resulting in failure of the shallow tube wells. Under such circumstances, besides augmenting groundwater resources, recharge can help improvement of groundwater quality (Kamra, 2010). Gupta and Paudwal (1988) developed a technique to estimate recharge from rainfall and to estimate aquifer parameters using ground water level records and available climatological data. The methodology combines a hydro-meteorological model which links rainfall and evaporation to the effective ground water recharge and a geo-hydrological model which links the recharge to the water level in the aquifer. Well injection technique can be adopted to reduce decline in water table and to improve the ground water quality (Kumar et al., 2010). Akther *et al.* (2009) observed that compared to the exploitation of groundwater, the recharge to aquifer in Dhaka was very negligible.

As per the findings of Central Ground Water Board (2000) in the state of West Bengal, the formation in coastal areas: North 24 Parganas, South 24 Parganas, Medinipur, Haora are unconsolidated recent alluvium. Fresh ground water bearing aquifers occur in varying depth ranges

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within 180-360 mbgl (within the depth of 600 mbgl). The fresh water aquifers are sandwiched between saline/brackish aquifers. The top saline/brackish aquifer lies within the depth span of 20~180 m with maximum depth of 320 mbgl in the extreme south. Suitably constructed tubewell tapping 35 m cumulative thickness can yield 100~150 m^3/hr. Shallow fresh water aquifers occur in present day dunes in Digha-Ramnagar area of Medinipur (East) dist. down to the depth of 9 mbgl & in levee deposit within 50 mbgl in Baruipur-Sonarpur-Bhangar-Canning tract in South 24 Parganas.

Artificial groundwater recharge began early in last century in the Europe. First infiltration basis for recharging the groundwater was constructed at Goteborg, Sweden in 1897 and subsequently several basins were developed. Infiltration rates ranging from 2.1 to 15.6 m/day was reported for these basins (Jansa, 1952). In Spain, groundwater recharge was started in 1953 in Besos are with a special well, surrounded by a crown of 16 small diameter tube-wells, in order to accomplish an intense back washing of coarse and gravel confined aquifer was done by treated river water in excess of city distribution using tubewells since 1969. During the period of shortage of water, the injected water was abstracted by other wells (Custodio et al., 1979). Johansson (1987) applied two methods for estimation of ground water recharge both based on groundwater level fluctuations. These methods were applied in a marine area in South Eastern Sweden. The first method utilized a one dimensional model which was tested against observed ground water level. The boundary conditions were defined by using meteorological data and sub-models for precipitation, snow dynamics interception, evapotranspiration and horizontal ground water outflow. The second method directly transformed groundwater level fluctuations to equivalent amount of water from a constructed recession curve and the specific yield concept. Recharge to underground formations is possible depending upon natural geo-hydrological conditions. Sophocealous and Perry (1985) stated that antecedent moisture condition, thickness and nature of the unsaturated zone were found as major factors affecting recharge.

There is little information available about the water table situations and need of artificial recharge in the coastal region. Hence, artificial recharge in the rainy season was experimented at the institute farm.

MATERIALS AND METHODS

An artificial recharge tube well was designed and installed at the ICAR- Central Soil Salinity Research Institute, Canning Town farm. The location was previously the bed of tidal river Matla a few decades back. The highly saline sea water swells in this river during the high tide. The present river course is almost 1 km away shifted by sedimentation and other anthropogenic activities. The drilling was carried out manually near a drain where runoff water is collected during the rainy season by reverse circular rotary drilling method up to depth of 45 m. The drilling was made first by 12.7 cm diameter and later 20.32 cm diameter. The soil and water samples were collected at every 3m interval. The recharge tube well installed was of 12.7 cm diameter and 40.5 m depth with the strainer placed at 28.5~36 m depth during the year 2011. The water table was monitored throughout the year. As the water table came very close to the surface (<1 m) during the rainy season, pumping during the summer for lowering the water table and recharging the aquifer with runoff water during the rainy season was experimented.

RESULTS AND DISCUSSION

While drilling manually by reverse circular rotary drilling method, the soil and water samples were collected at every 3 m depth. The soil texture analyzed for different depth intervals and are presented in Table 1. Sandy soil was found at depth

Table 1. *Litholog of the drilling site at CSSRI, RRS, Canning farm*

Depth (m)	Soil type
0~3	Silty clay
3~6	Silty clay
6~9	Sticky clay
9~12	Fine sand
12~15	Fine sand
15~18	Fine sand
18~21	Fine sand
21~24	Fine sand
24~27	Fine to medium sand
27~30	Fine to medium sand
30~33	Fine+Medium+Coarse sand
33~36	Fine+Medium+Coarse sand
36~39	Clay+Fine sand
39~42	Clay+Fine sand
42~45	Clay+Fine sand

Table 2. *Depth-wise water quality while drilling for installation of recharge tubewell*

Depth (m)	EC(dS/m)	pH
0~3	4.5	6.8
3~6	9.8	7.1
6~9	6.0	7.2
9~12	5.4	7.0
12~15	3.6	7.3
15~18	4.1	6.8
18~21	3.1	6.8
21~24	3.1	7.1
24~27	3.3	6.7
27~30	3.3	6.9
30~33	3.7	7.2
33~36	3.6	7.3
36~39	5.4	7.0
39~42	4.0	6.9
42~45	4.8	7.0

12 m onwards till 36 m. As the aquifer was better in the 24 m~36 m range, the strainer was placed at 28.5~36 m bgl.

The water quality parameters (EC and pH) of samples collected depth-wise are presented in Table 2. The data in Table 2 represents the mixed water of ingoing surface fresh water and existing ground water. The mixing was taken place while drilling manually.

The water table is the primary indicator of ground water status. So, the water table was monitored periodically and observed that it is coming very near to the surface (< 1 m) during the monsoon period. Apprehending that the aquifer may not receive much in this high water table condition, it was perceived to pump out the saline water during summer as much as possible, and recharge the fresh water in the rainy season when plenty of runoff is available through the heavy rainfall. A 1 HP motorized electrical pump with discharge of 0.64 lps was used for pumping out ground water from the aquifer during summer. The pumping was carried out (Fig. 1) for 30 days (6 hours per day) and the water table was recorded by the water level indicator. It was observed that the pumping water level was not lowered below 6 m depth during the summer season.

Artificial Recharge of Ground water

The monsoon rainfall was insufficient at the beginning to produce effective rainfall. The rainfall data collected is presented in Fig. 2 in weekly basis starting from the month of June, 2012. The effective rainfalls which produced runoff in different times of the monsoon period are presented in Fig. 2.

The runoff water collected in the nearby water channel was diverted to the recharge structure

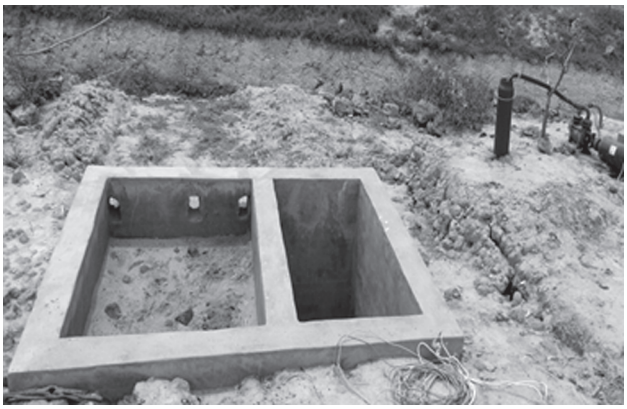

Fig. 1. The withdrawal of ground water during the summer season

Table 3. *The recharge amounts in different weeks*

Week	Total head (cm)	Av. Head (cm)	$H^{5/2}$	Rate of Recharge (lps)	Amount of Recharge (l)
July 5-11	16.9	2.414	9.056	0.125	75589.68
July 19-25	19.4	2.771	12.786	0.176	106721.1
July 28-Aug.3	20.6	2.942	14.856	0.205	123997.8
Aug.5-11	18.9	2.700	11.978	0.165	99977.04
Aug.13-19	23.6	3.371	20.870	0.288	174191
Aug.20-27	24.6	3.514	23.152	0.319	193234
Aug.29-Sept.3	23.8	3.400	21.315	0.294	177905
Sept.6-12	17.9	2.557	10.456	0.144	87272.69
Oct. 10-16	16.4	2.343	8.401	0.116	70122.18
Total					1109010

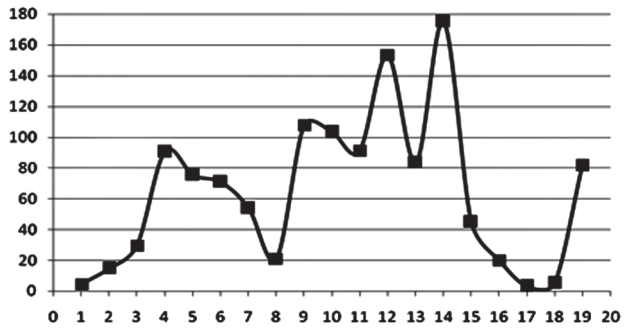

Fig. 2. The weekly rainfall in different weeks during monsoon (June, 2012 onwards)

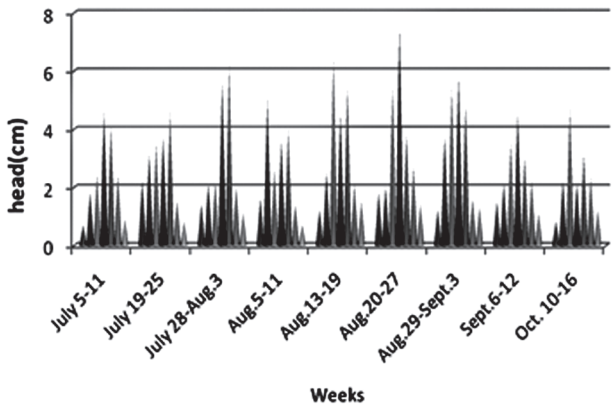

Fig. 3. The hydraulic head of the recharged water in the 90° V-notch during the effective rainfall

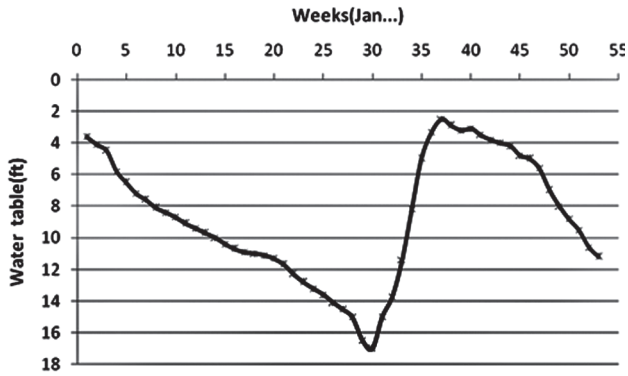

Fig. 4. The water table in the recharge tubewell in different weeks (Starting from January, 2012)

through a 90^0 V-notch for quantifying the recharge amount. Four readings of the hydraulic head were taken in the V-notch daily and the average was noted (Fig. 3). As seen in figure the highest hydraulic head was observed during August, 2012 (Fig. 3).

The corresponding discharge can be computed by the equation: $Q=0.0138\ H^{5/2}$ where Q= discharge (lps), H= head (cm). The recharge amount in different weeks of effective rainfall are presented in Table 3.

Due to recharge, the water table was observed closest to the ground surface during the months September/October, 2012 at about 0.75 m below ground level (Fig. 4). In figure 4, it is seen that there is depletion of the water table due to pumping till the 27 weeks. Later there is rise of the water table due to recharge of the runoff water in the monsoon period.

CONCLUSIONS

The rising of water table to the shallow depth below the ground surface during the rainy season is at par as the previous year when tube well was installed but artificial recharge was not carried out. The frequent pumping during the summer was also insufficient to create desired space in the fresh water aquifer for recharge. The water table was rising very near to the surface as usual. Therefore, it may be concluded that the present conditions are inconvenient for artificial recharge in the Canning area.

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Knowledge and Adoption of Improved Practices by Trawl Net Operators of Ratnagiri Coast of Maharashtra State

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Trawl net operators of Ratnagiri coast were selected for assessing knowledge and adoption of improved practices. Formulated interview schedule was used as method of collecting data in face-to-face situation. Thirty-three recommended practices regarding vessel construction, engine, gear, depth of operation accessories, fish handling, preservation, disinfectant, fish hold, marine fishing regulation act, day night signal, navigational equipments and instruments for safety were analysed. Trawler owner's knowledge on group of improved practices with regard to engine, gear, fish handling and preservation, marine fishing regulation act and day night signal was comparable with adoption. Knowledge with regard to improved practices such as vessel construction, accessories, fish hold and instrument for navigation and safety was more as compared to adoption. The average knowledge quotient was found to be 74.19. Knowledge levels of trawler owners were slightly high, moderately high and high than the expected number. The coefficient of skewness for the knowledge quotient (0.032) and value of kurtosis (3.22) showed positively skewed leptokurtic distribution pattern. The average adoption quotient was found to be 66.44. However, least trawler owners were observed in the lower adoption category. The positive skewness value of 0.085 and kurtosis 2.31 clearly showed a normal destitution pattern. It is interesting to note that trawler owners had no knowledge and therefore, adoption with respective disinfection practices was nil.

(***Key words:*** *Adoption quotient, fishermen, knowledge quotient)*

Marine fisheries sector of India has undergone rapid change during last three decades. The introduction of synthetic nets coupled with high export demand for shrimp has intensified mechanised fishing along the coastal waters (Sathiadhas *et al.,* 1989). The lucrative external market for shrimp and constant rise in the mechanised trawl fishing fleets not only enhanced the marine fish production of our country but also showed the way for the growth of an organised sea food export industry and increase in the employment opportunities in the subsidiary sector. Although with the development of designs of several generations of mechanised boats, investigations on fishing gear have been carried out on the net and accessories. Since trawl fishing continued to be a predominant method, investigations are more on this gear than the others.

Maharashtra is an important maritime state with respect to marine fish production, where both mechanised and non-mechanised vessels operate along the coast. It contributed 4,30,231 metric tonne (MT) of fish production. The total fish production of Ratnagiri district was 1,05,069 mt while total fish production of Ratnagiri block was 13,244 MT. Contribution of trawlers in marine fish production of Maharashtra state was 1,85,837 MT and that of Ratnagiri district was 70,641 MT while contribution of trawlers in marine fish production of Ratnagiri block was 10,443 MT. Considering the economic importance of trawling, the extent of knowledge and adoption of improved scientific technology by trawl net operators were studied.

MATERIAL AND METHODS

The state of Maharashtra has five coastal districts. Trawl net operators of Ratnagiri coast were selected for the present study. Formulated interview schedule was used as method of collecting data in face-to-face situation. Descriptive score sheet for each of the recommended practices was constructed as per Das *et al.*, (1988). The knowledge of fishermen was studied as per knowledge test used by Haque (1981)

The formula used to estimate knowledge quotient is as follows.

$$\text{Knowledge quotient} = \frac{\text{Total score obtained by fishermen}}{\text{Maximum score}} \times 100$$

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The formula for the adoption quotient used was as given by Sengupta (1967)

$$\text{Adoption quotient} = \frac{\text{Total score obtained by fishermens}}{\text{Maximum score}} \times 100$$

Thirty-three recommended practices regarding vessel construction, engine, gear, depth of operation, preservative technique, accessories, fish handling & preservation, disinfectant, fish hold, marine fishing regulation act, day night signal, navigational equipments and instruments for safety were analysed by using above formula.

RESULTS AND DISCUSSIONS

Relationship of socio-personal variables with adoption quotient

In view to study relationship between the socio-personal variables with adoption quotient, correlation analysis was performed and results are given in table 1. Results revealed that education is positively and significantly correlated with the adoption of improved practices by trawler owners of Ratnagiri coast, Maharashtra.

Knowledge and Adoption

Knowledge level of trawler owner was found reasonably high indicating 95.40% trawler owner in the higher knowledge category, followed by 4.60% in medium knowledge category (Table 6). Regarding adoption of improved practices by trawler owners, it was observed that 43.67% trawler owners were in medium adoption category whereas, 56.33% were in high adoption category. None of the trawler owners were found in low knowledge and low adoption category.

The results of the study on knowledge and adoption of group of improved practices by trawl net owners of Ratnagiri are presented in Table 7. Trawler owner's knowledge of group of improved practices with regard to engine, gear, fish handling and preservation, marine fishing regulation act and day night signal was comparable with adoption. Knowledge with regard to improved practices such as vessel construction, accessories, fish hold and instrument for navigation and safety was more as compared to adoption. It is interesting to note that trawler owners had no knowledge and therefore did not adopt practice of disinfecting vessel.

The relationship between knowledge quotient and adoption quotient (r = 0.6465) indicated a positive significant relationship (P<0.05). The equation of relationship observed between adoption quotient and knowledge quotient is as follows:

$$Y = 19.8526 + 0.6279\ X$$

The coefficient of determination (r^2) was 0.4129. The regression coefficient was estimated as 0.6279 inferring that increase in knowledge quotient by one increases the adoption quotient by 0.6279.

Several improved technologies have been developed for the increasing production of fish from marine sector along with the safety and maintenance of fishing vessel. In order to have sustainable development in capture fishery, ultimate follow up of recommended improved practices will play and imperative role.

Traditionally, majority of the trawler owners use either wooden or metallic fasteners as they are available at comparatively cheaper rate than the recommended brass fasteners. It is therefore, the adoption of use of brass fasteners was found to be less. Vasanthakumar and Sundarvardarajan (1990) studied adoption of scientific technology by trawler owners of Tamil Nadu and found that the practice of using correct type of fasteners or tacks for sheathing was cent percent adopted by trawler owners because respondents normally leave the job of boat building to contractors. Balasubramaniam and Kaul (1984) in Kerala also found that cent percent trawler owners used of correct type of fasteners/tacks for sheathing.

Majority of the trawler owners adopted improved practice of net preservation and cent percent fishermen adopted nylon as a netting material. The

Table 1. *Mean, Standard deviation and correlation coefficient of personal variables with adoption of improved practices by trawler owner fishermen*

Sl. No	Particulars	Mean	SD	r
1	Age (Years)	42.58	10.94	-0.05
2	Education	8.06	2.83	0.28*
3	Experience (Years)	16.22	10.01	-0.14
4	Number of fishing days per year	133.67	98.39	-0.10
5	Income (Rs)	6047	1875	-0.04

(*Significant at 5 per cent level (P < 0.05)

Table 2. *Classification of trawler owners according to level of knowledge and adoption of recommended improved practices*

Sl. No.	Category	Knowledge	Adoption
1	Low	0(00)	0(00)
2	Medium	4 (4.60)	38 (43.67)
3	High	83 (95.40)	49 (56.33)

(Figures in parenthesis indicates percentage value)

trawler owner used nylon as netting material because of the awareness about the advantages of nylon netting material. As per the Maharashtra Marine Fishing Regulation Act, 1981 trawlers should be operated beyond 10 fathom depth. Both these conditions were followed by cent percent of trawler owners in present study area. Maximum trawler owners followed the provisions of the Maharashtra Marine Fishing Regulation Act, 1981, such as no fishing during the monsoon season, obtaining license for fishing, insurance of the crewmembers and registration of fishing vessel. Majority of the trawler owners used wood for vessel construction. Maximum numbers of trawler owner used teak wood for vessel construction, since it has long life and comparatively less troublesome during the construction of vessel. However, some trawler owners did not adopt teak wood as a material for vessel construction due to high cost and alternatively they adopted the other woods such as *Ain, Mango* etc.

Maximum number of trawler owners adopted the use of antifouling paints to protect the vessel from fouling agents. However, some time they used traditional antifouling preparations to protect the vessel from fouling organisms. Similarly, cent percent trawler owners adopted recommendations of antifouling painting schedule (Vasanthakumar and Sundarvardarajan, 1990; Balasubramaniam and Kaul, 1984). Preference of some fishermen for traditional antifouling preparations may be due to high cost of commercial antifouling paints.

Majority of trawler owners used only one trawl net at a time during fishing operations. Trawler owners resisted the use of more than one net on single vessel at a time during fishing operation because such multi-gear operation require engine of more horsepower to drag the net by single vessel. Similarly, the cost of operation also increases whenever more than one net operated from the single vessel. Kandoran *et al.*, (1996) in Kerala found that use of more number of fishing net require more dissemination of information and supply of inputs to improve their extent of adoption. Vasanthakumar and Sundarvardarajan (1990) in Tamil Nadu observed that very few respondents adopts multi-gear operations.

Maximum trawler owners used rectangular flat otter boards for keeping the net mouth open during the fishing operations. It was observed that the mini trawl nets used the conventional flat rectangular otter board for bottom trawling.

Adoption of recommended standard mesh size for fish, shrimp and cod end of the trawl net is very important from the point of view of the management of fisheries resources. More number of trawler owners adopted the recommended standard mesh size for fish, shrimp and cod end of trawl net. Majority of the trawler owners adopted the recommendations regarding use of lead material for sinkers and brass for propeller. Majority of them used HDPE plastic material as floats though the recommended material is aluminium since HDPE plastic floats were cheaper than aluminium. None of the author studied adoption of these aspects.

In the case of fish handling and preservation, majority of the trawler owner fishermen adopted the use of proper fish and ice ratio (i.e. 1:1), because the proper use of ice increases the shelf life and quality of fish, which in turn gives better price to the produce. In all 59.77 per cent trawler owners used proper ice ratio for fish preservation. The use of recommended 'flake ice' on vessel is not possible to trawler owners since recommended 'flake ice' was not available near landing and berthing centre. Trawler owner of Mirkarwada had the facility of crushed ice near the landing and berthing station and therefore, majority of them used crushed ice for preservation of fish on vessel. Mohan *et al.*, (1995) studied the technological gap in the adoption of post-harvest technology from Ernakulam district of Kerala and results revealed that in all 67.50 per cent adopted the use of proper ice and fish ratio in view to maintain longer keeping quality of fish. However, the results of the present study are similar with the Vasanthakumar and Sundarvardarajan, 1990, Balasubramaniam and Kaul, 1984.

Adoption of the good fish handling practices targeted at prevention of contamination is necessary as most of the quality fishes are the items of export. Now a days most of the fish importing countries emphasises on the quality of the product starting it from the point of origin and handling onboard.

Table 3. *Knowledge quotient and adoption quotient as per the individual practices*

Sl. No.	Improved practices	Quotient	
		Knowledge	Adoption
1	**Vessel construction**		
	1.1Material for vessel construction	71.83	50
	1.2 Type of wood	91.95	77.58
	1.3 Fasters	100	100
	If metal	75.28	59.77
	1.4 Type of net used from vessel	73.56	50.57
	1.5 Mouth opening of net	85.63	50
	1.6 Antifouling paint	78.16	77.01
2	**Engine**		
	2.1Appropriate Horse power engine	88.50	88.50
	2.2 Engine cylinder	100	100
	2.3Engine maintenance	95.97	95.87
3	**Gear**		
	3.1 Netting material	100	100
	3.2 Net mesh size for shrimp	83.33	83.33
	3.3 Net mesh size for fish	86.78	86.78
	3.4 Cod end mesh size	66.09	65.51
4	**Depth of operation**	100	100
5	**Preservative techniques for net**	99.42	98.85
6	**Accessories**		
	6.1 Floats	77.01	54.02
	6.2 Sinkers	99.42	98.85
	6.3 Propeller	89.08	85.05
7	**Fish handling and preservation**		
	7.1 Fish: Ice ratio	79.88	79.88
	7.2 Type of ice	50.57	50.57
8	**Disinfectant**		
	8.1 Use of chlorine for washing equipment	00	00
	8.2 Use of chlorine for washing fish hold	00	00
9	**Fish hold**		
	9.1 Type of box	94.82	83.33
	9.2 Types of crates	97.70	97.12
10	**Marine Fishing Regulation Act**	83.33	79.88
11	**Day Night Signal**		
	11.1 Night signal	100	100
	11.2 Day signal	1.14	1.14
12	**Navigational equipment**		
	12.1 Equipment for direction	97.70	94.25
	12.2 Equipments for communication	90.22	50
	12.3 Equipments for fish finding	25.86	5.74
13	**Instrument for safety**		
	13.1 Fire fighting	4.59	1.14
	13.2 Life saving	60.91	28.16

However, awareness about this important aspect is not observed along the Ratnagiri coast and cent percent non-adoption was observed in practices such as use of chlorine for washing equipments and fish hold.

Maximum trawler owners adopted the recommendation of use of plastic crates to store the fish on board. This may be due to increased awareness regarding the perishable aspect of the fish, which resulted in the low price for the produce,

if not dealt carefully. Similarly majority of trawler owners used recommended thermal insulated boxes to store fish after segregation of catch.

The use of navigational equipment such as use of equipment for direction like magnetic compass, etc were adopted by majority of trawler owner fishermen. However, adoption of electronic instruments such as equipment for communications and fish finding were very less. Similarly, in case of life saving devices more trawler owners were observed to be non-adopters. Balasubramaniam and Kaul (1984) in their studies of adoption of improved practices by fish trawler owners in Kerala also observed that none of the trawler owners used electrical instruments and they concluded that adoption of electrical and electronic equipments warrants financial assistance from nationalised banks along with offer of training in operating skill.

Improved practices such as fasteners, engine cylinder, netting material, depth of operation and use of night signals were found under high knowledge and high adoption category. None of the trawler owner fishermen were observed in low knowledge and low adoption category. Use of chlorine for washing equipments, use of chlorine for washing fish hold, use of day signals and use of instruments for safety, fire fighting were not adopted or rarely adopted by trawler owner fishermen. These improved practices needs to be adopted for safety of food and crew members. Positive and significant relationship was observed between knowledge and adoption, indicating 0.6279 increases in adoption quotient with corresponding increase in knowledge quotient.

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Economic Efficiency of Purse-Seine Fishing Operation along Ratnagiri Coast of Maharashtra State

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Purse-seining is one of the most advanced and efficient fishing methods. Considering the purse-seine fishing as an important pelagic fishing activity along the West coast of India, study was carried out to analyze its costs and earning as well as its economic efficiency. Purse-seine vessels operated along the Ratnagiri coast during 16th August 2008 to 31st May 2009 (fishing period of year) were considered for collection of primary data related to costs and earning. In catch composition, Indian oil sardine (28.58%) and cat fish (24.30%) contributed more in the fish catches of purse-seine operated from Mirkarwada fish landing centre. Though the major species caught were not high priced, the quantity of catch was enough to earn adequate revenue and to make purse-seine operation profitable. Capital turnover ratio was estimated at 2.15 which measure the efficiency of purse-seine owner in managing and utilizing fixed assets. Operating cost fixed and variable cost ratios were 0.63, 0.45 and 0.17 respectively. The ratio of annual net profit to the capital investment was estimated at 0.80 which indicated the efficient financial performance of purse-seine fishing vessels. Payback period for capital investment was 1.09 years. All these efficiency ratios showed that the purse-seine fishing along Ratnagiri coast was highly profitable and economically viable business during the fishing season.

(***Keywords:*** *Economics, Purse-seine fishing, Payback period)*

Purse-seine fishing method accounts for 25 to 30 per cent to the total world marine catch. Considering the purse-seine fishing as an important pelagic fishing activity along the West coast of India, economic viability needs to be explored. This information would provide a basis to the planner for proper planning and implementation of fisheries development as well as management programmes for the region. The factor determining the items of cost and net profit would help to reduce the costs in order to increase profit in mechanized fishing. Moreover, the economic analysis of purse-seine operations would help the financial institutions to take a decision on providing credit to the fishermen. This study would provide entrepreneurs necessary information to invest in purse-seine fishing related with initial investment for the purse-seine fishing, variable cost and other daily expenses. Entrepreneurs will get detailed information, so that they will invest their money efficiently. Such an efficient gear is a boon to the fishing sector, provided the resources are judiciously exploited. Certain review needs to be done to justify the present work.

MATERIALS AND METHODS

Maharashtra, a coastal state having 720 km long coastline comprising Thane (112 km), Mumbai (80 km), Raigad (240 km), Ratnagiri (167 km) and Sindhudurg (121 km) districts engaged in marine fishing with various types of gears like trawl net, gill net and purse-seine net. Purse-seine net was selected for the study area. Purse-seines operated along Maharashtra coast were 288 in number and out of which 167 were operated from Mirkarwada fishing harbour of Ratnagiri district (Anon, 2008). Almost all purse-seiners operating along Ratnagiri district landed their catch at Mirkarwada fishing harbour. Therefore, Mirkarwada, a minor fishing harbour situated in Ratnagiri district 2 km away from Ratnagiri at 17° 00′ 00″ North and 73° 16′ 23″ East was selected as sampling area for economic analysis of purse-seine fishing along Ratnagiri coast.

Fishing season considered for the data collection was from 16th August to 31st May as fishing was closed from 1st Jun to the 15th August, considering the peak spawning season of many fish species and rough conditions of sea. Information related to initial investment in business was

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collected from randomly sampled 50 fishermen operating purse-seine. Data regarding fishing operation, day-to-day expenses on purse-seine fishing as well as details of catch and revenue earned in single trip of fishing was collected from randomly selected five vessels in a week throughout the fishing season. This information about quantity of catch and value was gathered by inquiry and by actual observations at landing centre.Different cost-benefit ratios like payback period (Bensam, 1999), capital turn over ratio, rate of return to loan amount, expense-income ratios (Salim and Biradar, 2001) were estimated to examine economic efficiency of purse-seine operation.

RESULTS AND DISCUSSIONS

Capital cost

Average expenditure on capital cost for acquiring assets for operation of purse-seine was estimated at Rs. 33,55,318. The major components were the vessel cost Rs. 12,68,200 (38%), for purse-seine net Rs. 13,16,000 (39%) and engine with propeller and shaft Rs. 4,69,40 (14%). These three components together contributed 91.00 per cent of average total capital investment. Other than this, average expenditure on cost of *Dingi,* purse-line hauler and purse-line was observed as Rs. 47,280, Rs. 48,060, and Rs. 42,122 respectively.

Remaining 4.90 per cent of capital cost included fish finder of Rs. 48,960, navigational equipments like GPS (Global Positioning System) costing Rs. 21,420, magnetic compass of Rs. 3,000, communication devices like VHF (Very High Frequency) costing Rs. 16,860 and mobile phone of Rs. 2,856. The average expenditure on the cost of two batteries was Rs. 19,880, while cost of anchors (two numbers) and purse-seine drum was Rs. 9,412 and Rs. 19,520 respectively. Average expenditure towards the cost of other accessories like water pump, water storage tank, brail, cans, crates, used vehicle tyres were estimated as Rs. 3,104, Rs. 1,964, Rs. 3,148, Rs. 3,510, Rs. 7,459 and Rs. 574 respectively (Table 1 and Fig. 1).

Table 1. *Average per vessel expenditure (Rs) on the Capital cost items for purse-seiners*

Sr. No.	Particulars	Amount (Rs.)	%
1.	Vessel	12,68,200	37.80
2.	Dingi	47,280	1.41
3.	Electric fitting	2,750	0.08
4.	Engine	4,37,500	13.04
5.	Propeller, shaft	31,740	0.95
6.	Water pump	3,104	0.09
7.	Battery @ Rs. 9,940 per battery and for 2 batteries	19,880	0.59
8.	Hauler	48,060	1.43
9.	Purse drum	19,520	0.58
10.	Purse line	42,122	1.26
11.	Anchor @ Rs. 4,706 per anchor and for 2 anchors	9,412	0.28
12.	Nets @ Rs. 6,58,000 per net and for 2 nets	13,16,000	39.22
13.	Fish finder	48,960	1.46
14.	GPS	21,420	0.64
15.	Compass	3,000	0.09
16.	VHF	16,860	0.50
17.	Mobile phone	2,856	0.09
18.	Brail @ Rs. 1,574 and for 2 brail nets	3,148	0.09
19.	Cans @ Rs. 140 and for 25 cans	3,510	0.10
20.	Crates @ Rs. 265 per crate and for 25 crates	7,459	0.22
21.	Water tank	1,964	0.06
22.	Tyres @ Rs. 48 per tyre and for 12 tyres	574	0.02
	Total	**33,55,318**	**100**

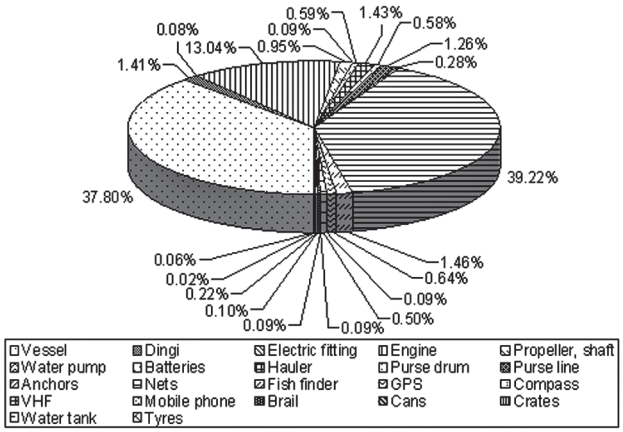

Fig. 1. Average per vessel expenditure on capital cost items for purse-seiner operated along Ratnagiri coast

Variable cost

The major items in the variable cost of purse-seine fishing were cost of salary of crew, diesel expenses, cost of ice, expenditure on grocery and maintenance of net, boat and engine. Average per vessel expenditure on the items of variable cost was Rs. 32,85,916. It was observed that average per vessel expenses on diesel and crew salary were contributing 40 and 34 per cent respectively. Average per vessel expenditure towards ice was estimated at Rs. 3,57,000 contributing 11 per cent, while grocery shared 6 per cent of the total variable cost.

Share of average expenditure on purse-seine net maintenance was Rs. 1,37,500 (4%) while for vessel, engine and equipments maintenance it was Rs. 60,400 (2%), Rs. 21,100 (0.6%) and Rs. 11,050 (0.3%) respectively. Remaining 2.2 per cent included expenditure on oil (Rs. 19,791), drinking water (Rs. 22,015), material transportation (Rs. 18,540), bottom paint (Rs. 10,780) and baskets (Rs. 1,782) (Table 2 and Fig. 2).

Fixed cost

The main elements of the fixed cost associated were depreciation on the items of capital assets, interest paid on the loan amount and the insurance. The total fixed cost estimated was Rs. 12,64,703, out of that total estimated expenditure on depreciation was Rs. 3,88,348 (31%) of total fixed cost whereas, expenditure on interest payment on project cost was Rs. 6,90,688 accounting 55 per cent of total fixed cost. Expenditure on insurance was estimated at Rs. 1,80,000 (15%). Remaining 0.13 per cent in the fixed cost included registration fees of vessel, fishing license fees and port duty (Table 3 and Fig. 3).

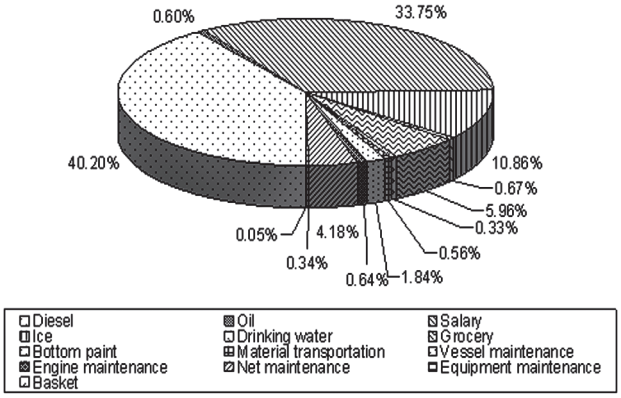

Fig. 2. Average per vessel expenditure on variable cost items for purse-seiner operated along Ratnagiri coast

Table 2. *Average per vessel expenditure (in Rs) on the Variable cost items for purse-seiners*

Sr. No.	Particulars	Amount (Rs.)	%
1.	Diesel @ 325.6 litre per trip and for 119 trips @ Rs. 34 per litre	13,20,900	40.20
2.	Oil	19,791	0.60
3.	Salary	11,09,160	33.75
4.	Ice @ 4 tone per trip and for 119 trips @ Rs. 750 per tonne	3,57,000	10.86
5.	Drinking water @ Rs. 185 per trip and for 119 trips	22,015	0.67
6.	Grocery @ Rs. 4,778 per week and for 41 weeks	1,95,898	5.96
7.	Bottom paint	10,780	0.33
8.	Material transportation	18,540	0.56
9.	Vessel maintenance	60,400	1.84
10.	Engine maintenance	21,100	0.64
11.	Net maintenance	1,37,500	4.18
12.	Equipment maintenance	11,050	0.34
13.	Basket	1,782	0.05
	Total	**32,85,916**	**100**

Table 3. *Average per vessel expenditure (in Rs) on the Fixed cost items for purse-seiners*

Sr. No.	Particulars	Amount (Rs.)	%
1.	Vessel depreciation @ 4%	50,728	4.01
2.	Engine depreciation @ 10%	46,924	3.71
3.	Net depreciation @ 20%	2,63,200	20.81
4.	Equipments depreciation @ 10%	9,310	0.74
5.	Accessories depreciation @ 10%	18,187	1.44
6.	Insurance	1,84,000	14.55
7.	Interest @ 13%	6,90,688	54.61
8.	Registration fees	500	0.04
9.	Fishing License fee	167	0.01
10.	Custom	1,000	0.08
	Total	**12,64,703**	**100**

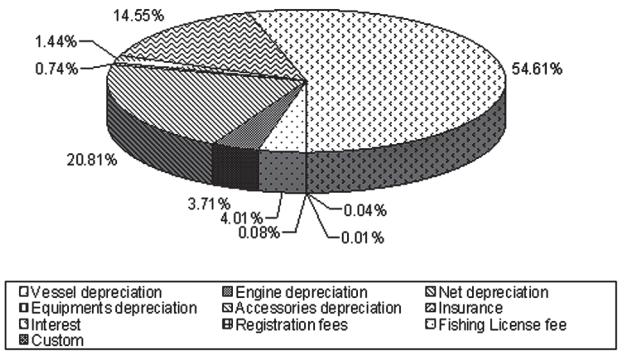

Fig. 3. Average per vessel expenditure on fixed cost items for purse-seiner operated along Ratnagiri coast

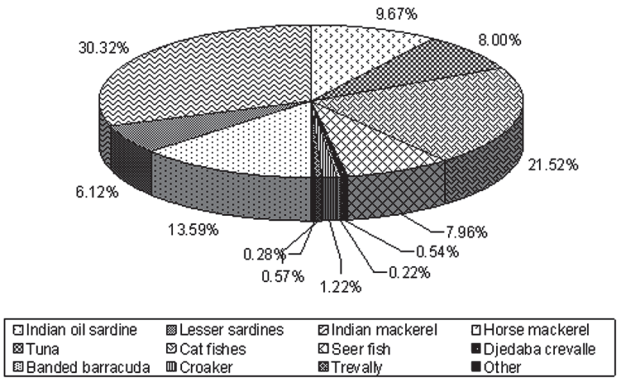

Fig. 4. Average species-wise revenue for purse-seiners operated along Ratnagiri coast during 2008-09

Total cost

The total cost, which was derived after summation of variable cost and fixed cost, for the purse-seine operations along the Ratnagiri coast was estimated at Rs. 45,50,619.

Average gross revenue

After analysis of data, per week revenue was Rs. 1,76,267 and for the entire fishing season (annual) it was Rs. 72,26,940. Annual per vessel revenue was estimated for 41 weeks (Fig. 4). The major contributors to revenue of purse-seine fishing were Indian mackerel (30%), cat fishes (22%), Indian oil sardine (14%) horse mackerel (10%), tuna (8%), seer fish (8%), lesser sardines (6%) and Croaker (1%). Other species individually contributed less than one per cent of total revenue generated throughout the total fishing period.

Economic efficiency measures

Estimated aggregate measures (Table 4) and economic efficiency measures (Table 5) showed higher returns as compared to returns observed in earlier studies. Capital turn over ratio indicated the proportion of revenue with respect to the capital investment in fixed assets and it was estimated at 2.15. It measures the efficiency of purse-seine owner

Table 4. *Aggregate measures of purse-seine fishing*

Particular	Quantity
Total number of fishing days	238
Number of fishing trips	119
Time for single fishing trip	45.55
Number of crew per trip	24
Total capital cost	33,55,318
Total variable cost	32,85,916
Total project cost	66,41,234
Total loan amount	53,12,987
Total fixed cost	12,64,703
Total cost	45,50,619
Annual catch	2,74,591
Annual revenue	72,26,940
Net annual profit	26,76,321
Income over variable cost	39,41,024
Quantity of fuel	41,174
Cost of fuel	13,20,900

Table 5. *Economic efficiency measures for purse-seiners operating from Mirkarwada fishing harbour during fishing season 2008-09*

Economic efficiency measures	Per fishing trip	Per day	Per kg of fish production	Per litre of fuel
Catch (kg)	2,307	1,154		6.67
Revenue (Rs)	60,731	30,365	26.32	175.52
Variable cost (Rs)	27,613	13,806	11.97	–
Income over variable cost (Rs)	33,118	16,559	14.35	95.72
Net profit (Rs)	22,490	11,245	9.75	65.00
Diesel per trip (litre)	346	173	–	–
Cost of fuel (Rs)	11,100	5,550	4.81	–

in managing and utilizing fixed assets. The rate of return to loan amount was higher in purse-seiners (63%). Gross ratio was estimated at 0.63 by taking ratio of total cost and total revenue of entire fishing season. Operating cost ratio and fixed cost ratio was estimated by dividing the total annual revenue to respective operating cost and fixed cost and the values of ratio were 0.45 and 0.17 respectively. Ratio of total cost to net annual profit, ratio of operating cost to net profit, ratio of net profit to gross revenue and ratio of operating profit to operating cost were also estimated as 1.70, 1.25, 0.37 and 1.20 respectively. The ratio of annual net profit to the capital investment was estimated as 0.80, which indicated the financial performance of purse-seine fishing vessels. Payback period for capital investment was 1.09 (Table 6). According to Lery *et al.*, (1999) capital turnover ratio was 0.75 and gross ratio was 1.30 whereas, Tietze *et al.*, (2001) found capital turnover ratio as 0.67 and gross ratio as 0.97 for the purse-seiners operating along the Kerala coast of India. Panikkar *et al.*, (1993) found capital turnover ratio and gross ratio 0.95 and 0.81 respectively, therefore, it can be concluded that purse-seine fishing along Ratnagiri coast was more efficient than the results obtained by earlier workers.

Table 6. *Efficiency ratios*

Turnover ratio	2.15
Gross ratio	0.63
Operating cost ratio	0.45
Fixed cost ratio	0.17
Ratio of total cost to net profit	1.70
Ratio of operating cost to net profit	1.25
Ratio of Net profit to gross revenue	0.37
Ratio of operating profit to operating cost	1.20
Rate of return to loan	63.37
Payback period	1.09
NCF/TE	0.37
ROI	0.80

According to Panikkar *et al.*, (1993), ratio of net profit to annual gross revenue and rate of return on investment (ROI) of purse-seine operated along Kerala coast of India were 19 and 33 per cent. Lery *et al.*, (1999) estimated ratio of net profit to annual gross revenue for purse-seiners of India, was 0.22 whereas, rate of return on investment (ROI) was 16 per cent. Tietze *et al.*, (2001) stated that purse-seiners operating along the Kerala coast were in loss because of over-exploitation of target species but then also they managed to recover their cost of operation. In that case ratio of net profit to annual gross revenue and rate of return on investment (ROI) was 0.03 and 0.02 respectively. Panikkar *et al.* (1993) given the per day details of purse-seiner operating along Kerala coast. Per day average catch recorded was 2,500 kg and earned Rs. 8,500 as a revenue for a day by expending Rs. 4,387 on items of operating cost, while generated profit of Rs. 1,609 per day of fishing. They reported diesel consumption for single fishing trip of vessel as 220 litres with the cost was of Rs. 1,320.

CONCLUSION

The purse-seine fishing along Ratnagiri coast was highly profitable and economically viable business during the fishing season August 2008 to May 2009. Cost of fuel and labour charges contributed more as compared to other components of variable cost. Though the major species caught were not highly priced, the quantity of catch was enough to earn adequate revenue and to make purse-seine operation a profitable venture.

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Determinants to Climate Change Adaptation among the Livestock-Rearers of Eastern Coastal Region of India

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Adaptation to climate change and variability has recently become a subject of increasing importance in climate change research with an objective to reduce the vulnerability of climate sensitive people. The present study was designed to identify the determinants of differential adoption of adaptation strategies by the livestock rearers of eastern coastal region of India. Total 480 livestock rearers were selected randomly from the four coastal districts of the Odisha and West Bengal. ORDINAL LOGIT model was used to assess the determinants of differential level of adoption of adaptation strategies among the livestock rearers of eastern coastal region. It was found that 'extension contact' and 'farmer to farmer extension' showed significant positive effect whereas 'numbers of extreme climatic events experienced' and 'proportion income from livestock' showed significant negative effect on adoption of adaptation strategies among the livestock rearers of eastern coastal region.

(***Key words***: *Adaptation, Climate change, Coastal area, Livestock-rearer)*

Climate change induced sea level rise is likely to result in loss of land due to submergence of coastal areas, inland extension of saline intrusion and ground water contamination may have wide economic, cultural and ecological repercussions. Observations suggest that the sea level has risen at a rate of 2.5 mm per year along the Indian coastline since 1950s. A mean sea level rise of between 15 and 38 cm is projected by the mid 21st century along India's coast. It has been estimated that 1 meter rise in sea-level could displace nearly 7 million people from their homes in India (IPCC 2001). Added to this, a 15% projected increase in intensity of tropical cyclones would significantly enhance the vulnerability of populations living in cyclone prone coastal regions of India.

Length of coastline of India including the coastlines of Andaman and Nicobar Islands in the Bay of Bengal and Lakshadweep Islands in the Arabian Sea is 7517 km. Length of coastline of Indian mainland is 6100 km. and divided into east coast and west coast. Eastern Coastal region lies between Eastern Ghats and Bay of Bengal, stretching from Tamil Nadu in the south to West Bengal in the east. Patnaik and Narayanan (2005) reported that eastern coast is more vulnerable than the west coast with respect to the frequency of occurrence extreme climatic events. East coast of India is the house of several livestock breed like Chilka buffalo; Ganjam, Dalua, Garole breed of sheep; Ganjam, Black Bengal, Dalua breed of goat etc. Therefore, coastal region is as productive in livestock as good in crop production and fisheries. The phenomenon of global climate change occurring due to GHG emissions has also been directly affecting the livestock production system world over. The studies have shown milk yield of crossbred cows (e.g., Karan Fries, Karan Swiss and other Holstein and Jersy crosses), Haryana cows, Sahiwal cows and buffalo to be negatively correlated with temperature humidity index (Kaur and Arora 1982; Lal *et al.*, 1987; Shinde *et al.*, 1990, Kulkarni *et al.*, 1998, Mandal *et al.*, 2002, Tailor and Nagda 2005). The direct heat stress on lactating cows and buffaloes causes a production loss of more than 1.8 million tones of milk. The increase in thermal stress days due to temperature rise has been estimated to cause an additional loss in milk production of 1.6 million tonnes in 2020 accounting about 2365.8 crores INR at current price rate (Upadhyay *et al.*, 2009).

More recently, adaptation to climate change and variability has also come to be considered an important response option worthy of research and assessment, not simply in order to guide the selection of the best mitigation policies, but rather to reduce the vulnerability of groups of people to the impacts of climate change, and hence minimize the costs associated with the inevitable (Kane and

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Shogren, 2000; Pielke, 1998; Smit and Pilifosova, 2001). Adaptation refers to adjustment in ecological, social or economic systems in response to actual or expected climate stimuli and effects or impacts. It is often heard about different adaptation strategies like micro-environment modification like shelter management, ventilation in shelter, heat alleviation by water cooling or sprinkler system; strategic nutrient supplementation etc. But, not to forget the ground reality that out of 529.7 million livestock, 440 million livestock reared by 100 million household with/without any housing system and by crop residue. But, livestock rearers modify themselves in this changing climatic scenario for sustainable productivity of their livestock. There are several factors lying behind skilful implementation of these adaptation strategies helps to reduce vulnerability to prosper their 'socio-economic status' and overall 'quality of life'. Therefore, a comprehensive study on the determinants of differential adoption of adaptation strategies by the livestock rearers of eastern coastal region was conceptualized.

MATERIALS AND METHODS

Sampling plan

Eastern Coastal region lies between Eastern Ghats and Bay of Bengal, stretching from Tamil Nadu in the south to West Bengal in the east. There are four states in eastern coastal region of India namely West Bengal, Odisha, Andhra Pradesh and Tamil Nadu. Among these four states, two states *i.e.* Odisha and West Bengal were selected randomly. There are 6 districts in coastal Odisha namely Balasore, Bhadrak, Kendrapara, Jagatsighpur, Puri and Ganjam. In West Bengal, three districts namely South 24 Parganas, North 24 Parganas and Purba Medinipur lies in its coastal region. Two districts *i.e.* Ganjam and Bhadrak were selected randomly among six coastal districts of Odisha. From West Bengal, Purba Medinipur and South 24 Parganas were selected randomly. Thus, total 4 districts were selected randomly for the present study.

Three blocks namely Rangeilunda, Ganjam, and Chhtrapur were selected randomly from the coastal blocks of Ganjam district of Odisha. Basudevpur, Tihidi, and Chandbali block were selected randomly from the coastal blocks of Bhadrak districts of Odisha. Deshapran (Contai-II), Ramnagar-I and Ramnagar-II blocks of Purba Medinipur district of West Bengal were selected randomly from its coastal blocks. In South 24 Parganas, three blocks *i.e.* Gosaba, Basanti and Namkhana were selected randomly from its coastal blocks. Thus, the present study was confined in 12 blocks of 4 selected coastal districts.

A block wise list of villages, where few numbers of livestock depended households were existing, were prepared in consultation with the block level veterinary officers. Subsequently, total 24 villages were selected randomly by selecting 2 villages from each selected block. A livestock-rearer who has more than 30 years of experience in livestock rearing of at least one species among cattle, buffalo, goat, sheep and pig; and having main income from livestock was considered as respondents for the present study. Village wise lists of livestock depended households were prepared with the help of livestock enumerator of that respective villages. Household head was considered as respondents for the present study. Subsequently, 20 (twenty) respondents from each village were selected randomly. Thus, a total sample size of the present study was 480.

Differential level of adoption among the sampled households

Climate change in Intergovernmental Panel on Climate Change (IPCC) usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and /or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any changes in climate over time, whether due to natural variability or as a result of human activity. At first, the respondents was directly asked

Box – I. *Adaptation strategies followed by the livestock-rearers of eastern coastal region*

1. Extra concentrate to livestock
2. Providing minerals supplementation and feed additives
3. Use of more amount of crop residue and hay
4. Change in feeding schedule
5. Change in grazing time
6. Providing frequent clean and fresh drinking water
7. Extra bathing of cattle and buffaloes
8. Reduction in herd size
9. Change in micro-climate in cattle shed/grazing area/stall
10. Shifting to small ruminant from large ruminant
11. Keeping/promoting/interested in local breed
12. Providing more healthcare practices to the livestock
13. Using mosquito net to protect from mosquito
14. Selling of few animals from the stock
15. Livestock insurance
16. Social migration
17. Search of alternate sources of income

whether they feel any change in climate over the past 30 years on the binary response 'YES' or 'NO'. livestock rearers who recognised the changing climatic scenario during last 30 years were again directly asked whether they adopt any measure to cope up with the negative impact of climate change on the binary response 'YES' or 'NO'. Those who responded 'YES', again they were requested to put their response on a three point continuum viz. continued the adoption, discontinued the adoption and never followed/adopted with the score of 2,1, and 0 on a prelisted adaptation strategies (Box-I) for both the region.

Adaptation strategies was operationalized as the measures adopted and/or followed by the livestock rearers of coastal region to cope up with the adverse impact of climate change on livestock rearing and/ or their livelihood for sustainable livestock productivity and/or sustainable livelihood security. Therefore, in order to quantify the adaptation strategies, an exclusive 'Climate Change Adaptation Index (CCAI)' was developed by using the following formula:

$$\text{Climae Change Adaptation Index (CCAI)} = \frac{\text{Obtained Score}}{\text{Maximum Obtainable Score}} \times 100$$

All the sampled household were categorised into three differential level of adoption of adaptation strategies on the basis of obtained index score by the respective households. Cumulative square root frequency method was used to categories households into three categories i.e. lower level of adoption, medium level of adoption and higher level of adoption.

Determinants of differential level of adaptation among the livestock rearers

To trace out the determinants of differential level of adoption of adaptation strategies among the livestock-rearers, the ordinal logit# model was used as the outcome variable, the level of adoption, was categorised on an ordinal scale and ordered as: 1 for lower level of adoption, 2 for medium level of adoption and 3 for higher level of adoption. The following Greene (1993), the reduced form of ordinal logit model is as given below:

$$Y^* = \beta' Z + \varepsilon \qquad \text{(I)}$$

Where y* is the given level of adoption, Z is the set of explanatory variables, β' is the vector of coefficient to be determined and å is a random error with zero mean and unit variance. Y* is unobserved; what we do observe is:

$$Y = 1, \text{ if } y^* \text{ d" } \mu_2$$
$$Y = 2, \text{ if } \mu_2 < y^* \text{ d" } \mu_3$$
$$Y = 3, \text{ if } \mu_3 \text{ d" } y^*$$

The μ- values (μ_2, μ_3), referred to as cut-off points, are unknown parameters to be estimated along with β. A positive coefficient indicates an increased chance that a respondent with higher score on the independent variable will be observed in a higher level of adoption. A negative coefficient indicates the chances that a respondent with higher score on the independent variables will be observed in a lower level of adoption. The explanatory variables included in the empirical model on the basis of theoretical logic are given in Table 1 meant for independent variable. The estimated coefficients of the ordinal logit model provide only the direction of the effect of the independent variables on the dependent variables; they do not represent actual magnitude of change or probabilities. Thus, the marginal effect from the ordinal logit, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable, are reported and discussed.

RESULTS AND DISCUSSION

Climate change adaptation among the livestock rearers of eastern coastal region who recognised changing climatic scenario

Table 2 depicts that 92 percent of the livestock rearers of eastern coastal region recognised the changing climatic scenario. Again these 92 percent of livestock were asked if they had adopted any adaptation strategies to reduce the negative impacts of climate change and 81 percent of them expressed that they adopted at least one adaptation strategies to cope up with negative impacts of climate change. It was also found that 19 percent of the livestock rearers of coastal region did not adopt anything.

Differential level of adoption of adaptation strategies among the livestock rearers who adopted in eastern coastal region

All the sampled households of eastern coastal region who recognised the changing climatic scenario and adopted at least one adaptation strategy were categorised into three differential level

#Proportional odds assumption was satisfied (Chi-Square value for the test of proportional Odds Assumption was 21.451 with p value 0.1230) in ordinal logit by using SAS 9.2 analytical software.

of adoption of adaptation strategies *i.e.* low, medium, and high on the basis of obtained index score by the respective households. Cumulative square root frequency method was used to categories households into three categories and result is presented in Table 3. It was found that 37 percent of livestock rearers were having medium level of adoption followed by 36 percent and 27 percent were having higher and lower level of adoption, respectively.

Determinants of differential level of adoption of adaptation strategies in coastal region

ORDINAL LOGIT was used to assess the determinants of differential level of adoption of adaptation strategies among the livestock rearers of eastern coastal region (Table 1). In this analysis, the first category *i.e.* lower level of adoption was considered as the reference level. Statistical software SAS 9.2 has been used to calculate LOGIT coefficients and result has been presented in Table 4.

Table 1. *Explanatory variables used in ordinal logit model meant for determinants of differential level of adoption in coastal region*

Explanatory variables (x_i)	Expected Sign
Education of the household head	+
Family Education Status	+
Social Participation	+/–
Extension Contact	+
Farmer to Farmer Extension	+
Productive Animals in the Herd	+
Extreme Climatic Events Experienced	+
Sources of Climatic Information	+
Proportion of Income from Livestock	+/–
Distance from household to purchase critical inputs	–
Credit accessibility	+
Proportion of expenditure to livestock	+

The results of the Ordinal Logit model indicate that different socio-economic and environmental factors affect the ability to cope with different climate extreme events. These factors include education of the household head, family education status, social participation, extension contact, farmer to farmer extension, ratio of the productive animal in the herd, extreme climatic events experienced, sources of climatic information, distance from household to purchase critical inputs, proportion of income from livestock, credit accessibility and proportion of expenditure to livestock.

The Table 4 depicts that extension contact and farmer to farmer extension were significantly (both at $p<0.05$) contributing to the adoption of the adaptation strategies among the livestock rearers of coastal region. It is also revealed from the same table that increasing the extension contact by one unit increases the probability of a respondent to be in higher level of adoption by 2.3 percent. Whereas increasing the farmer to extension by one unit increases the probability of a respondent to be in higher level of adoption by 10.4 percent.

Extension officers and/or agents of state and central Govt. departments, KVK and fellow farmers/ progressive were the most important source of information to the livestock rearers of the coastal region regarding the different adaptation strategies. This may be the reason of extension contact and

Table 2. *Climate change adaptation among the livestock rearers of eastern coastal region who recognised changing climatic scenario*

Particulars		Frequency	Percentage
Changing climatic scenario	Not recognised	39	8.12
	Recognised	441	91.88
Adaptation among those who recognised	Adopted	358	81.18
	Not adopted	83	18.82

Table 3. *Differential level of adoption of adaptation strategies among the livestock rearers who adopted in eastern coastal region*

Differential level of adoption	Score for categorisation	Frequency	Percentage
Lower level of adoption (Low)	8.824 - 38.277	96	26.82
Medium level of adoption (Medium)	38.278 – 52.502	134	37.43
Higher level of adoption (High)	52.503 – 79.412	128	35.75

Table 4. *Estimated ORDINAL LOGIT Coefficients of factors determining level of adoption of adaptation strategies among the livestock-rearers of eastern coastal region*

Dependent Variable: Y (Y= Level of Adoption; Ordered variable: 1= Lower level, 2 = Medium level, 3 = Higher level of adoption)

Explanatory Variables (X_i)	Estimated Coefficient	Standard Error	P > □ Chisq □	Odds Ratio 95% Confidence Limit			Predicted Marginal Effect (dP/dx)
				Point Estimate	Lower Limit	Upper Limit	
Education of the household head: Primary	0.445	0.309	0.151	1.56	0.851	2.859	0.106
Education of the household head: Secondary	0.683*	0.366	0.062	1.98	0.966	4.059	0.152
Education of the household head: Higher Secondary	0.386	0.486	0.427	1.471	0.568	3.813	0.093
Education of the household head: Graduate and Above	1.072*	0.644	0.096	2.922	0.827	10.326	0.204
Family Education Status	-0.004	0.047	0.937	0.996	0.908	1.093	-0.001
Social Participation	-0.073	0.060	0.228	0.93	0.826	1.047	-0.018
Extension Contact	0.091**	0.043	0.034	1.095	1.007	1.191	0.023
Farmer to Farmer Extension	0.438**	0.176	0.013	1.549	1.097	2.188	0.104
Productive Animals in the Herd	0.021	0.017	0.213	1.021	0.988	1.054	0.005
Extreme Climatic Events Experienced	-0.101**	0.046	0.028	0.904	0.827	0.989	-0.025
Sources of Climatic Information	0.097	0.084	0.249	1.102	0.935	1.299	0.024
Distance from household to purchase critical inputs	-0.063	0.047	0.180	0.939	0.855	1.030	-0.016
Proportion of Income from Livestock	-0.023**	0.010	0.014	0.977	0.959	0.995	-0.006
Credit Accessibility	0.054	0.232	0.817	1.055	0.669	1.664	0.013
Proportion of expenditure to livestock	0.007	0.024	0.780	1.007	0.96	1.056	0.002

-2 Loglikelihood	751.593
McFadden R-squared	0.073
LR statistic (15 df)	26.068**
Probability (LR stat)	0.037
Observations	358
Score test for Proportional Odd Assumption	21.451 (p > 0.1230)

**Indicates significant at 5 % level of significance, in a two tail test *Indicates significant at 10 % level of significance, in a two tail test

farmer to farmer extension to be the significant determinants of differential level of adoption. From this result we may conclude that having extension services and strong bonding among the livestock rearers increased the likelihood of livestock rearers' adaptation to climate change.

Deressa *et al.*, (2011), Mandleni (2011), Dhaka *et al.* (2010), Hassan & Nhemachena (2008) and Nhemachena & Hassan (2007) also reported that access to extension service was one of the important determinants of farm level adaptation. Deressa *et al.*, (2011) also reported that farmer to farmer extension was the important determinant of adaptation strategies.

The same table also stated that number of extreme climatic events experienced and proportion of income from livestock were negatively significantly (both at $p<0.05$) contributing to the adoption of adaptation strategies among the livestock rearers of coastal region. The same table depicts that increasing one unit of extreme climatic events experienced by one unit of decrease the probability of a respondent to be in higher level of adaptation. Tropical cyclone, heavy rainfall, flood etc are the major extreme climatic events experienced by the livestock rearers of coastal region. For example livestock rearers of Coastal South 24 Paragans experienced one cyclone every year namely *Aila, Laila, Mahasen* etc during last 3-4 years. With these events, other related events like floods, inundation, salinization etc. also experienced by them. Therefore, they discontinued adaptation strategies. This may the reason of negative influence of extreme climatic events to the adoption of adaptation strategies.

The commercial livestock rearers followed the scientific packages of practices for their livestock. Therefore, their animals were not susceptible to the negative impact of climate change. Hence, adoption level of afore said adaptation strategies were too low among them. This may be the reason of negative influence of proportion of income from livestock to the adoption of adaptation strategies.

CONCLUSION

Livestock rearers of eastern coastal region recognised changing climatic scenario and adopted several adaptation strategies mechanism to cope up with its negative impact of climate change. It is found that extension contact is one of the most important determinants of differential level of adoption of adaptation strategies. Therefore, a dedicated team of veterinary /livestock extensionist must be trained or promoted to teach livestock rearers in different aspects of climate change including scientific adaptation strategies. Other important determinants like farmer to farmer extension showed significant positive effect whereas numbers of extreme climatic events experienced and proportion income from livestock showed significant negative effect on adoption of adaptation strategies among the livestock rearers of eastern coastal region.

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Impact of Soil and Water Conservation Measures on Productivity and Groundwater Recharge in a Micro-watershed in Coastal Zones of Odisha

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There is a need to precisely monitor and to evaluate the impact of soil and water conservation measures/projects that are multi-sectoral in essence from various angles to achieve the objectives of sustainable development. The National Watershed Development Programme is a single window delivery system, in which, participatory, integrated and sustainable development of watershed is achieved. The literature related to various studies and researches on impact of soil and water conservation measures in micro-watersheds are readily available. Prasad, 1999 studied the impact of watershed management on runoff, water resource activity and productivity of arable lands in Chhaljawa watershed of Baran district in Eastern Rajasthan and results indicated that integrated watershed development treatment such as graded bunds, gulley control structures etc. halted the process of land degradation and improved the ground water recharge which could be successfully exploited for increasing the productivity of arable land. The investment made recovered in four years indicating that the programme was economically viable. Panda (2009) in his case study on "Economics of watershed treatments in Odisha", two stage stratified random sampling techniques was used for the study. He concluded that the beneficiary village recorded 36% to 114% higher productivity of crops in comparison to non-beneficiary village. The production of paddy, sesamum and groundnut in watershed area was 198%, 152% and 173%, respectively higher than that of the non-beneficiary village. The productivity of paddy and groundnut was 114% and 105% higher in watershed area respectively in comparison to non-beneficiary village. Black gram also registered 75% higher productivity. Cattle per household of the beneficiary village were 3.5 against 1.36 of non-beneficiary village. Various soil and water conservation, water harvesting and vegetal cover improvement viz. bunding, staggered trenching, loose boulder checks and vegetative barriers, earthen embankment and ponds, pasture and plantation etc. were taken up. After 4 years they surveyed and concluded that the area under paddy, sorghum, wheat, gram, mustard and linseed increased by 60, 102, 179 and 83 % respectively. Before implementation of watershed works, the irrigated area was 34.7 ha through one earthen embankment, one pond and one natural stream. After execution of soil conservation works and construction of earthen embankments across natural stream and ponds, the irrigated area was increased by 2.53 times i.e. 87.8 ha in 4 yrs. Yield of paddy, sorghum, wheat, barley, pigeon pea, gram and mustard had increased by 51, 22, 65, 43, 25, 57 and 70% ,respectively. Sharda *et al.*, (2005) studied the participatory watershed management programmes for sustainable development and the research area located in diverse ecological region of the country, namely Eastern Ghats, Western Ghats (Nilgiris), Shiwaliks (Himalayan foot hills), Bundelkhand region, western coast Gujarat plains and Chambal ravines. They concluded that the various agronomical interventions improved the yield of traditional crops. The overall crop productivity of watersheds measured in terms of crop productivity index (CPI) increased by 12 to 45% and considering 5 watersheds together, CPI improved from 0.50 in pre-project to 0.64 after project implementation. The crop diversification index considering all watersheds together improved from 0.67 in pre project period to 0.82 after implementation of the project. Also they concluded that the overall cultivable land utilization showed that CLUI had increased from 0.26 in pre-project period to 0.33 in post-project period. Mondal *et al.*, (2006) studied the impact evaluation of watershed development works on socio-economic indicators in Andhra Pradesh. The results showed that the total cultivable area was 4677 ha which constituted 93.5% of the total geographical area of watershed before implementation of the project. During the project period an additional area of 14 ha (out of 17 ha of cultivable waste) and 9 ha of endowment land which was also not under cultivation were converted

in to cultivated land and 3 ha degraded land was brought under social forestry which resulted in an increase of 47% in cultivated area. Introduction of soil and water conservation programme improved cropping intensity from 97% during pre- project period to 114% during post- project period. Increased ground water availability and improved packages of practices for crops in study area brought 67.9 ha area under double cropping. They also concluded that the adoption of package of practices and land treatment increased the level of production and productivity. Goel *et al.*, (2007) studied the performance evaluation of some soil and water conservation measures in hot arid zone of India. During 1993-2004 the soil and water conservation measures adopted in Jhanwar watershed located in Rajasthan. They revealed that the natural resource base in arid region can be substantially improved and the agricultural productivity could be sustained even in extreme arid condition through watershed approach. Introduction of improved crop varieties and other dryland framing techniques has resulted in substantial improvement in productivity of various dryland crops viz. *pearl-millet* (52 %), *mung bean* (177 %), *moth bean* (394 %) and cluster bean (547 %). Similarly adoption of alternate land use system like agriculture with ber (agri-horti), agro-forestry with *Prosopis Cineraria* and farm forestry with *Acacia tortilis* resulted in production of various products and byproducts like fruit, fuel, fodder, pods, top feed grains etc. resulting in better sustainability of farmers of the project area. Naik (2009) studied the impact of the National Watershed Development Programme for Rainfed Areas and the programme was implemented in Sukli watershed which is situated near to Nagpur- Hyderabad highway, Maharashtra. He concluded that the post project cropped area was increased by 32 ha but gross cropped area was increased by 175 ha with a significant increase in the area under horticulture (139.5 ha) and flower cultivation (3.5 ha) With adoption of integrated watershed management the productivity of major *Kharif* crops increased by 25% to 37% and figure for *Rabi* crops was 33% to 44%. Training of primary stakeholders, field demonstration on crops, agro-forestry and improved composting had created mass awareness on soil and water conservation in the area and expected to yield good results in long run. Panda (2000) observed the water table level in wells during study period of both watershed and non- watershed villages and concluded that the average annual water table depth in non -watershed area was 5.2 m. The watershed area was found with average ground water table of 9.1 m, which was 3.9 m higher than that of the non- watershed area in the state of Odisha.

Gitte and Pendke (2002) reported that the water table in all the wells started rising since mid of June and attended its peak in September. There was steady decline in water table since September to December and then that water table was maintained a constant level up to March in almost all wells. The water conservation measures were found to be effective for increasing water table in observation wells located in middle and lower reaches of watershed. Generally, it was seen that there was overall build up in water levels in entire watershed area due to impoundment of water in water harvesting structures. Naik (2009) studied that rise in the water table was found to be in order of 0.30 to 0.45 m adjoining to the structures. In *Rabi* season water pumping was increased for 2-3 hrs and in summer for 1.0-1.5 hrs. Hence farmers were encouraged to construct more number of wells which was evidenced from the pre-project figure of 124 to post project figure of 141. Number of bore wells was also increased from 3 to 8 during this period.

The present study area Barapita-Nalla Micro-Watershed comes under agro-climatic zone of south-eastern coastal plain (Code No.-078) of the state of Odisha. The project is coming under the range of Chandaka P.S. of Bhubaneswar Block in Khurda District, at a distance of 15 to 18 km from Bhubaneswar. The project area is located in between 20°17′ to 20°20′ N latitude and 85°40′ to 85°44′ E longitude. It comprises of three villages such as (1) Giringaput, (2) Bhagabatipur and (3) Barapita with a total geographical area of 1442.71 ha. The watershed is generally flat with undulating topography. Physiographically the zone is located in the coastal belt and has an altitude ranging from 40 to 70 m from mean sea level. The area is a sedentary landscape with two distinct phases, such as, erosion phase which includes the ridge and up land and depositional phase which includes medium and low land. There is a small fringe of level on both sides of the stream. Detailed soil survey of the area revealed that the soil is mostly sandy loam to sandy clay loam and depth of soil is about 90 cm (d_5 class). The details of soil mapping units are given in Table 2. Basically it is a fan shaped watershed. Water from entire project area drained by a number of small channels into the Gangua watershed of Chilika catchment. Morphological characteristics of the watershed are given in Table No. 1.

Monitoring and evaluation of various developmental interventions was carried out during the implementation phase to quantify their impact on ecology, productivity and socio-economic conditions by evolving and employing appropriate indicators/ indices. The following indicators were used in pre-project and post-project scenarios to evaluate the overall impact of the watershed development programme. For comparing the efficiency of land leveling activity during the pre- project and post-project periods, an index called as Land Leveling Index was employed, which is ratio of recommended land slope to the existing land slope as defined below

$$\text{Land Leveling Index (LLI)} = \frac{\text{Recommended slope}}{\text{Existing or treated slope}} \quad (1)$$

Where, existing slope is referred to as the individual land slope before the commencement of the project and treated slope is the moderate slope resulting from land leveling activities. Higher value of LLI is a measure of better moderation in land slope. LLI can attain a maximum value of 1.0, which refers to a perfectly leveled field. Crop Diversification Index (CDI) was used to assess the changes in the cropping patterns/systems due to crop improvement programmes. It is defined as:

$$\text{Crop Diversification Index (CDI)} = \sum_{i=1}^{n} P_i \log\left(\frac{1}{P_i}\right) \quad (2)$$

Where, P_i is the proportion of the ith crop in comparison with total cropped area and n is the total number of crops in the watershed. The CDI can attain any value > 0 and higher value of CDI is an indicator of better crop diversification. Cultivated Land Utilization Index (CLUI) is an indicator of the use of land for intercropping and multiple cropping systems. It indicates that the impact of watershed interventions on changes in cultivable land area and duration of crop cultivation in pre-project and post-project periods. It is calculated by summing the products of land area under each crop and actual duration of days of that crop, and dividing the sum by the product of cultivated land area and 365 days as stated below.

$$\text{Cultivated Land Utilization Index (CDI)} = \frac{\sum_{i=1}^{n} a_i d_i}{A \times 365} \quad (3)$$

Where, n is the total number of crops; a_i is the area occupied by i^{th} crop; d_i is the days of duration that the ith crop occupied in area; and A is cultivated land area. The CLUI can attain a maximum value 1.0 and higher values of CLUI indicate more uses of available cultivable land area of the watershed and/or duration of crop cultivation period.For assessing the overall improvement in crop productivity at the watershed level, Crop Productivity Index (CPI), which indicates the extent

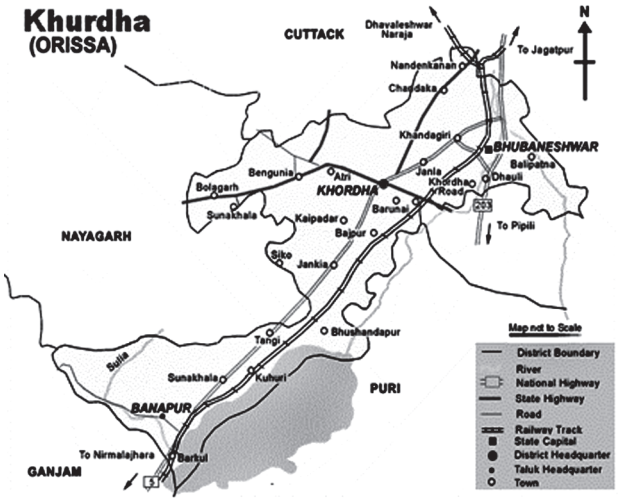

Fig. 1. Location of study area

Table 1. *The morphological characteristics of Barapita Nalla micro-watershed*

Sl. No.	Watershed characteristics	Value	Sl. No.	Watershed characteristics	Value
1	Stream order	III	6	Basin perimeter (km)	13.50
2	Number of streams				
	I	5	7	Basin area (km^2)	14.42
	II	2	8	Drainage density (km/km^2)	0.70
	III	2	9	Length of overland flow (km)	0.71
3	Stream length (km)				
	I	4.15	10	Circulatory ratio	0.99
	II	4.35	11	Elongation ratio	0.87
	III	1.58	12	Stream frequency(per km^2)	0.62
4	Length ratio	1.35	13	Form factor	0.59
5	Basin length (km)	4.95	14	Bifurcation ratio	2.69

of crop productivity level in comparison to the normal yield of crops before and after the project, is calculated by dividing the crop yield obtained in the watershed by the yield obtained under recommended package of practices.

$$\text{Crop Productivity Index (CDI)} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{y_i}{Y_i}\right) \quad (4)$$

Where, n is the total number of crops in watershed, is the average yield of ith crop cultivated in watershed, and is the yield of ith crop with standard package of practices. The CPI can attain any value in a given location. Higher value of CPI is an indicator of crops' yield closer to the maximum attainable yield under standard package of practices. Major utilization of harvested water is for irrigation of crops to ensure sustainable agricultural production in the watershed. Irrigability Index (II) is a ratio of additional gross irrigated area and net incremental irrigated area. Gross irrigated may be estimated by adding the net incremental irrigated area as many times as it was irrigated. The index can attain any value more than 0, and a higher value will indicate successful utilization of harvested water in watershed management project. Productivity of paddy crop increased by 19% in *Kharif* and 26% in *Rabi.* Productivity of vegetable crops increased by 25% in *Kharif* and in *Rabi* it gave production equal to 42 q ha^{-1}. A land of 6.4 ha. was under cashew nut plantation ,from which, 12 q ha^{-1} production was obtained. One of the beneficiaries produced 17,000 numbers of rose flower per ha. With reference to all these outputs it was found that the Crop Productivity Index was increased from 0.49 to 0.52. The concept of mono-cropping system was changed and farmers were taking interest in cultivating vegetable crops and floriculture on experimental basis in *Rabi* season. Community cashew nut plantation was adopted and was fruitful. This resulted in increase in Crop Diversification Index from 0.301 to 0.775. Near about 25, 27,720 litres of water was stored throughout the year in 6 ponds located in the village. As a result of this harvested water, the irrigation intensity was increased from 143% to 187% and cropping intensity was increased from 114% to 186%. It was observed that Cultivable Land Utilization Index was increased from 0.103 to 0.670. During the period under study, considerable development in water resources such as construction of tube wells, wells and installation of hand pumps were increased from 5 to 13, 10 to 12 and Nil to 7, respectively in the study village.

From the study it was concluded that total income of households generated from agriculture, off-farm activities and minor forest activities. The income contributions from all these three activities were changed from 41% to 85%, 35% to 8%, and 23% to 7%. in case of agriculture, forest, and off farm activities, respectively. It was observed that the income contribution from forest activities was considerably reduced which ultimately helped in preservation and conservation of forest resources. It was also observed that the contribution through off-farm activities was decreased considerably; which indicated reduction in migration of people to near-by city/town area as most of the people were engaged in farm activities.

Table 2. *Details of soil mapping unit with present land use*

Mapping unit no	Soil Mapping Unit	Area in ha	Capability classification	Physiographic classification
1	SCL-d5/C-e2	16.50	IV e	Up existing cashew pl.
2	SCL- d_5/C-e_2	36.40	III e	Up C_1
3	SCL- d_5/B-e_2	13.10	II e	Medium C_1
4	SCL- d_5/C-e_2	9.80	IV e	Up existing misc. Pl.
5	SCL- d_5/C-e_2	58.53	IV es	Up gochar
6	SCL- d_5/C-e_2	105.50	IV es	Up F_0
7	SCL- d_5/C-e_2	19.14	III e	Up C_1
8	SCL- d_5/B-e_2	11.10	II e	Medium C_1
9	SCL- d_5/B-e_2	25.28	II e	Low C_1
10	SCL- d_5/C-e_2	29.12	II e	Medium C_1
	Total	324.47		
	Homestead	7.17		
	Others	21.65		
	Grand Total	353.29		

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J. Indian Soc. Coastal agric. Res. 32(2): 92-96 (2014) **Short communication**

An Analysis of Marketing of Mat in Paschim Medinipur District of West Bengal

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Mat is an interior decorative of house, made of synthetic fiber, cotton, bamboo and mat-stick (*Cyperus tegetum*) etc. The demand of hand- made mat is declining in this day due to increased globalization. Our indigenous products are becoming more and more commoditized and artisans find their products competing with goods from open economy. Thus it is not possible for our artisan to overlook their product from the present market situation. But this type of cottage industry has capacity to absorbed surplus labour of our country (Joy and Kani, 2013). The handicraft has a significance role to Indian economy, which lies in its employment potential as well as export earnings. But this industry has not received much attention due to lack of financial and marketing support (Dash, 2011). The artisan habitually depends on market intermediaries for their produce (Dash, 2011). Mat-stick made handicraft has an important role in livelihood of rural economy of West Bengal. Mat-stick is a wetland weed; it is economically grown in some rainfed area of West Bengal. Paschim Medinipur, North 24 Parganas and Nadia are major district of this state, where growing and weaving of mat are observed. Mat weaving is an indigenous and ancestral practice of some community in Paschim Medinipur. Finished weaved mats are also exported to various countries. It is opined to be a good source of income and provides gainful employment to family member who otherwise have remained idle (Maiti and Das, 2012). Beside cultivator and weavers, a good number of people earned their livelihood from mat marketing. The marketing of mat is unorganized but mainly centered in Barabazer market of West Bengal. Considering its importance in providing employment and being a source of income, the present work intends to examine the price spread of marketing of mat and efficiency of existing marketing system of mat weaved in Paschim Medinipur district. Though mat-stick cultivated in North 24 Parganas and other districts, but mat-stick and mat weaved in Paschim Medinipur district is well known for its quality and concentration of cultivators and weavers. Hence, the present study is restricted to Paschim Medinipur district only. The field survey has been under taken for the agriculture year 2011-12. Three primary wholesale markets *viz.* Sabong, Temathani and Dashagram bazaar of Paschim Medinipur are selected purposively as the bulk of mat weaved in the district are marketed through these markets. One secondary wholesale market *viz.* Barabazar market of Kolkata is selected purposively because of most of mat is transacted through this market. Beside, 10 retail markets are also selected randomly. From the existing marketing channels 10 secondary wholesaler, 20 primary wholesaler, 20 commission agent, 20 paikers and 40 retailers are selected for the present study. Market informations are collected with the help of pre-tested survey schedule by interviewing personally.

Average cost per mat is calculated by considering the total mat-stick produced per hectare and number of mats presumably prepared by that amount of mat-stick and adding to it the expenses incurred for processing mat from mat stick. Producer's price, producer's share in consumer's Rupee, marketing margin of middleman, cost of marketing, price spread for each market are analyzed by using conventional formulae and index of marketing efficiency is worked out by Shepherd's method. The price spread in agriculture is assessed by estimating price received by the farmers expressed as a percentage of the retail price (i.e. the price paid by the consumer). If it is the retail price, the weaver share in the consumer's rupee (Ws) is expressed as follows.

$$Ws = \frac{\text{Net price received by the producer}}{\text{Price paid by the consumer}} \times 100$$

The efficiency measurement methods used in the study are presented as follows:

Shepherd's method:

$$ME = \frac{RP}{MC + MM} = \frac{RP}{GMM}$$

Where,

ME: Marketing efficiency

MME: Modified measure of marketing efficiency

MC: Total marketing costs

MM: Total net marketing margin

GMM: Gross marketing margin

RP: Retailer's price or Price paid by the consumer

Table 1 represents the marketing cost of mat from Sabong market of the district during the year 2011-12. Mat is noted to passing through four stages of marketing namely, weaver, primary wholesaler, secondary wholesaler and retailer. The maximum cost of marketing is found at secondary wholesaler level and least at retailer level. At each level, this cost has increase with the increase in size of mat. Octroi is observed only at weaver's level. Transportation is noted to consume maximum cost in total cost of marketing. The increase in marketing cost is mainly due to transportation cost.

Table 2 depicts the price spread of mat at Sabong, Temathani and Dashagram primary wholesale market of the district. It is clear from the table that weaver's share in consumer's rupee, marketing cost, and middleman profit has increased with increase in size of mat. According to percent share of weaver in price paid by consumer, it is

Table 1. *Marketing cost of mat from Sabong market of Paschim Medinipur district*

(Rs./ Pair of Mat)

Sl. No.	Item	Size of Mat		
		Small	Medium	Large
a)	Cost incurred by the weaver			
	Transport	0.46	0.51	0.63
	Octoroon	1.03	1.25	1.48
	Misc.	0.40	0.46	0.63
	Sub total	1.88	2.22	2.74
b)	Cost incurred by Primary wholesaler			
	Transport	0.51	0.68	0.80
	Packaging	0.57	0.74	0.91
	Loading &unloading	0.34	0.40	0.51
	Storage	0.30	0.40	0.40
	Misc.	0.21	0.29	0.34
	Sub total	1.93	2.51	2.96
c)	Cost incurred by Secondary wholesaler			
	Transport	2.62	3.19	3.59
	Packaging	0.32	0.34	0.51
	Loading &unloading	0.41	0.51	0.57
	Storage	0.29	0.34	0.34
	Market fees	0.23	0.34	0.57
	Misc.	0.40	0.57	0.86
	Sub total	4.26	5.30	6.44
d)	Cost incurred by Retailer			
	Transport	0.51	0.74	0.80
	Loading & unloading	0.14	0.29	0.40
	Storage	0.40	0.63	0.57
	Market fees	0.29	0.34	0.57
	Misc.	0.23	0.29	0.34
	Sub total	1.56	2.28	2.68

Table 2. *Price spread of mat by size from Sabong, Temathani and Dashargram market of Paschim Medinipur district*

Particular	Rs./ pair of mat			% share in price paid by consumer		
	Small	Medium	Large	Small	Medium	Large
Sabong market						
Weaver's share or net receipt of the farmer	62.93	139.42	249.38	63.67	71.50	70.94
Marketing cost	9.63	12.31	14.82	9.75	6.31	4.22
Middlemen's Profit	26.28	43.26	87.35	26.59	22.19	24.85
Price paid by the consumer	98.84	195.00	351.54	100.00	100.00	100.00
Temathani market						
Weaver's share or net receipt of the farmer	60.14	126.37	242.04	60.40	69.16	68.47
Marketing cost	9.48	12.03	14.85	9.53	6.58	4.20
Middlemen's Profit	29.95	44.31	96.59	30.08	24.25	27.33
Price paid by the consumer	99.57	182.71	353.49	100.00	100.00	100.00
Dashargram market						
Weaver's share or net receipt of the farmer	55.08	120.04	232.28	57.75	61.86	65.77
Marketing cost	9.80	12.65	14.36	10.28	6.52	4.07
Middlemen's Profit	30.50	61.35	106.53	31.97	31.62	30.16
Price paid by the consumer	95.38	194.05	353.17	100.00	100.00	100.00

found to be maximum in medium size and least in case of larger size mat. But in respect of percentage share in price paid by consumer, middlemen's profit is observed to be highest in case of small size mat and least in case of medium size mat.

Table 3 present the marketing cost of mat in Temathani and Dashagram primary wholesale markets of Paschim Medinipur. Transportation cost noted to be most expensive component, except at weaver's stage in the marketing of mat. This cost increase with the increase in size of mat. Cost of storage is noted to be another major cost item due to less bulkiness than other two size. It is expected that mat takes considerable time to reach the ultimate consumer and hence may require higher cost in storing the mat. It is noted to be more at retail level. However, all these cost as well as middleman profit have a direct relationship with the size of mat.

It is clear from the table that weaver's share in consumer's price has increased with the increase in size of mat. A similar observation is also noted in case of marketing cost, middlemen's profit and price paid by consumer. But according to percentage share in the price paid by the consumer, marketing cost has decreased with the increase in size of mat. But weaver's share is noted to be maximum in case of medium sized mat and least in case of small sized mat.

Marketing cost is observed to be maximum in case of secondary wholesaler level and least in case of retailer level. Here octroi charge also found at weaver level. It is also found that the total amount of cost has increased with the increase in size of mat. Storage is one of the influential costs of mat marketing. Though it increase the marketing cost but required for maintain the quality of mat.

The percentage share of weaver in the consumer's rupee is minimum in small size mat and maximum in case of larger size mat. The fewer shares of weavers in case of medium and larger size mat are mainly due to increase in the percentage share of profit of middlemen in this market. It is also observed that weavers share in consumer's price, marketing cost, middlemen's profit and price paid by consumer have increase in size of mat.

Marketing efficiency is of the highest degree in case of larger size and minimum in case of small size mat for all three markets during the study period (Table 4). But inter market comparison reveals that Sabong market is observed to be most efficient one, followed by Temathani and Dashgram market during the study period. The higher efficiency of marketing may be due to location of the market because of its easy accessibility. However, marketing system of mat is noted to be efficient as the indices are noted to be more than unity in all the case.

Table 3. *Marketing cost of mat from Temathani market of Paschim Medinipur district*

(Rs./ Pair of Mat)

Sl. No.	Item	Size of Mat					
		Temathani Market			Dasharam Market		
		Small	Medium	Large	Small	Medium	Large
a)	Cost incurred by the weaver						
	Transport	0.46	0.63	0.74	0.68	0.74	0.91
	Octoroon	0.91	1.25	1.48	0.97	1.25	1.48
	Misc.	0.23	0.34	0.46	0.29	0.34	0.46
	Sub total	1.60	2.22	2.68	1.94	2.34	2.85
b)	Cost incurred by Primary wholesaler						
	Transport	0.97	0.74	0.91	0.86	0.91	0.11
	Packaging	0.46	0.57	0.68	0.40	0.57	0.68
	Loading &unloading	0.40	0.40	0.51	0.29	0.40	0.51
	Storage	0.29	0.34	0.34	0.23	0.29	0.40
	Misc.	0.17	0.29	0.32	0.29	0.40	0.57
	Sub total	2.28	2.34	2.77	2.05	2.57	2.28
c)	Cost incurred by Secondary wholesaler						
	Transport	2.57	3.42	3.88	0.29	0.34	3.99
	Packaging	0.34	0.40	0.40	0.29	0.51	0.63
	Loading &unloading	0.34	0.40	0.46	0.34	0.57	0.51
	Storage	0.23	0.29	0.40	0.40	0.57	0.34
	Market fees	0.29	0.34	0.51	0.23	0.34	0.46
	Misc.	0.29	0.34	0.34	0.23	0.46	0.34
	Sub total	4.05	5.19	5.99	1.77	2.79	6.27
d)	Cost incurred by Primary wholesaler						
	Transport	0.57	0.63	0.80	0.46	0.513	0.627
	Loading &unloading	0.14	0.29	0.46	0.17	0.23	0.29
	Storage	0.34	0.63	0.74	0.40	0.46	0.57
	Market fees	0.23	0.34	0.46	0.17	0.29	0.46
	Misc.	0.29	0.34	0.57	0.29	0.40	0.34
	Sub total	1.56	2.22	3.02	1.48	1.88	2.28

Table 4. *Market wise and mat size wise marketing efficiency of mat in Paschim Medinipur district during 2011-12*

Name of market	Size of Mat		
	Small	Medium	Large
Sabong	1.75	2.51	2.44
Temathani	1.52	2.24	2.17
Dashagram	1.37	2.62	2.92

The study represents the marketing of mat marketed through different primary wholesale market of Paschim Medinipur of during 2011-12. In general three size mat are found to exist in the market. The price of these mats has been observed to increase with increase in size of mat. The total cost components and amount of cost is observed to be maximum in case of secondary wholesaler level. The transportation cost is most expensive cost in the marketing of mat. It is also found that that the percentage share of weaver in price paid by the consumer has direct relation with size of mat whereas marketing cost is inversely related with the size of mat. According to marketing efficiency Sabong market is the most efficient market irrespective of size of mat. The higher efficiency of marketing may be due to location of market because of its easy accessibility. However, marketing of mat is found to be efficient one as the indices are noted to be more than unity.

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Special Features and Characterization of Rice Land Races of *Karen* Community in Andaman and Nicobar Islands, India

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Rice is the most important and traditional food crop of Andaman and Nicobar Islands. The crop has wide spectrum of genetic variability owing to ethnic diversity of the settlers' population thus more than 50% of rice area in the islands is still under traditional land races. Many years ago these ethnic land races were brought by different settlers from different states of mainland India and even neighbouring countries. *Karen* community who originally came from Burma now called Myanmar settled quite long back in North and Middle Andaman and brought ethnic rice cultures like *Khushbaya, Black Burma, White Burma, Mushley* and *Yaeon* etc which suit to their likings and requirements. These land races are still popular with the community and *Karens* are thus indirectly playing a vital role in conservation and cultivation of these rice cultures. Through social surveys and interviews, the special features of these rice landraces were elicited. These cultures have also been characterized in a systematic and scientific manner to establish their unique identity and morphological descriptors in the light of IPR scenario.

Andaman and Nicobar group of islands located in the Bay of Bengal is about 1200 km distant from mainland India. The International Union for Conservation of Nature has recently declared 19 "hope spots" in 2013 including A&N Islands, India (Anonymous, 2013). The hope spot refers to an area of ocean which deserves special protection because of wild life & significant wild life habitats. Rice is the mainstay cereal crop of the Andaman and Nicobar Islands and supports the lifeline of the islanders. Rice is cultivated in an area of about 8390 ha with a total production of 23,916 t resulting in productivity of 2.85 t ha^{-1} (Gautam *et al.*, 2013). Rice cultivation started during post- independence era with the settlement of various communities in the Islands. More than 50% rice area is under traditional land races in the islands (Mandal *et al.*, 2004). The availability of fertilizer is also a major constraint and hence the adoption of high yielding, fertilizer responsive varieties is quite less. Though several efforts have been made to replace these old land races with new high yielding varieties, the farmers of these Islands are not ready to give up these landraces due to their unique characteristics including better response to low management conditions, tolerance to adverse weather conditions and better grain quality liked by the diverse ethnic groups.

Karen community who originally came from Burma (now Myanmar) settled quite long back in North & Middle Andaman and brought rice cultures of their taste and other special features. Initially, 12 Karen families from Burma came to Andaman after persuasion by Beroti officer Dr. H. I. Marshall in 1925 for clearing jungles for making settlements (Mary Pee, 2013). The word "Karen" was coined by British, whereas Burmese called them as "Kaylin" meaning "polite and good hearted" The present population of Karens in the Andaman Islands is about 2000 and are mostly protestant Christian. They are by nature artistic and love music, dance, diving, singing and trekking. Predominantly they are agriculturist and earn their livelihood by rice farming, making mats, baskets, grain storing bins etc. The senior citizens of Karens mostly lived longer and some even up to 105 years. Their longevity is ascribed to their love for nature, plants, herbs and hard work. They practiced the concept of *early to bed and early to rise* and had only two meals in a day i.e. early brunch and supper.

The field exploration and surveys were conducted from 2011 to 2013 in the Karen villages in Middle Andaman. The location of the study areas is shown in Figure 1. The interaction interviews were done with key informants having the knowledge of the history of introduction and cultivation of ethnic land races of rice. The President, *Karen* Welfare Association, Webygram facilitated the collection of the information from the custodian farmers of Karen

rice land races through prior informed consent (Singh *et al.*, 2013). The seeds of their traditional rice cultures like Khushbaya, Black Burma, White Burma, Mushley, Yaeon etc. were collected, evaluated and characterized during *Kharif* 2013 at CIARI, Bloomsdale Farm, Port Blair.

The crop was transplanted following row and plant spacing of 20 and 15 cm, respectively. The recommended package of agronomic practices was followed for raising the crop. Their detailed characterization for the DUS (Distinctness, Uniformity and Stability) traits as recommended by Protection of Plant Varieties and Farmers' Rights Authority for rice crop was done at different growth stages to know their minute phenotypic details.

A field survey and interaction interview with the respondents revealed that they still cultivate old rice cultures like Khushbaya (*Choi-chi-mannai*), Black Burma, White Burma, Mushley, Yaeon etc due to their special features. These rice land races were originally brought by their forefathers somewhere around 1925 from Burma to suit to their taste and other growing requirements. These rice types are anciently and deeply ingrained in the livelihood and culture of Karen people. As per information derived from the interviews with key informants, some special features of these varieties which are mentioned in Table1.

The population of Karen settlers is about 2000 who are residing in Webygram, Karmatang, Lataw, Burmadera, Basecamp, Borang and Chipo villages. The ethnic affinity towards the rice landraces could be adjudged from the respondents that once originally pure Burmeese "Karen race" has become impure due to inter-marrying with other population, but the rice land races preserved and grown by them are pure. Though some of the *Karen* rice germplasm has already been characterized including the Black Burma and White Burma (Elanchezhiyan and Mandal, 2001), yet the significant differences have been revealed for some DUS traits as per the current study. These changes may be due to inherent variability present in each landrace due to the forces of evolution, or selection cycles by different custodians themselves.

Though there seems to be some variation persistent within the land races making each landrace a subgroup of diverse genotypes, however, the current study aimed at the detailed characterization as mentioned in Table 2 which is expected to keep genetic identity of selected landraces in present situation documented and preserved. These traditional landraces are not only important from social and cultural points of view but are valuable genetic resources to meet the needs and challenges of the future too. Earlier researchers indicated that Khushbaya rice can act as donor for quality traits, Black Burma can be used as source for abiotic stress tolerance particularly for salt and aluminium toxicities (Mandal *et al.*, 2004). White Burma was reported to be bearing good carbohydrate balance as preferred for breakfast dish, Mushley is useful germplasm for adaptability traits.

The Bay Islands are home to several unique rice land races patronised by different settlers communities. These land races reveal their historical and cultural identities and preferences. In view of their economic, genetic and cultural importance, prominent Karen rice types have been characterized in details as per standard system and custodian farmers' interviews. This information is

Table 1. *The special features of rice landraces still grown by Karen community in Andaman*

Land race	Origin	When brought	Salient features
Khushbaya	Burma	1925	Also called as "*Choi-chi-manai* which in Burmese means it can grow without manure. It is nutritive, gives high yield and used for lunch.
White Burma	Burma	1925	Sticky when cooked and used for *Lassa*/breakfast and gives energy for long time.
Black Burma	Burma	1925	It is sticky when cooked and 'halwa' is prepared from its flour which is better than 'maida' and used for breakfast. It has low grain yield.
Mushley	Burma	1925	It is used for both lunch and dinner. It has high yield, small grains and good taste.
Yaeon	Burma	1925	It is best in terms of taste, quality and soft like basmati rice. It is used for both lunch and dinner preparation but has low yield.

***Table 2**. Characterization of popular Karen rice varieties performed by CIARI, Port Blair*

Variety Characteristics	Khusbaya	Red Burma	White Burma	Black Burma	Musley	Yaeon
Coleoptile colour	Green	Green	Green	Purple	Green	Green
Basal leaf Sheath colour	Green	Green	Green	Light purple	Green	Green
Leaf: intensity of green colour	Light	Medium	Medium	Dark	Dark	Light
Leaf: anthocyanin colouration	Absent	Absent	Present	Present	Absent	Absent
Leaf: distribution of anthocyanin colouration	Uniform	Uniform	Uniform	On tips only	Uniform	Uniform
Leaf sheath: anthocyanin colouration	Absent	Absent	Absent	Present	Absent	Absent
Leaf sheath: intensity of anthocyanin colouration	Very weak	Very weak	Very weak	Weak	Very weak	Very weak
Leaf: pubescence of blade surface	Absent	Weak	Strong	Strong	Weak	Weak
Leaf: Auricles	Present	Present	Present	Present	Present	Present
Leaf: anthocyanin colouration of auricles	Colourless	Colourless	Colourless	purple	purple	purple
Leaf: Collar	Present	Present	Present	Present	Present	Present
Leaf: anthocyanin colouration of collar	Present	Present	Present	Present	Present	Present
Leaf: ligule	Present	Present	Present	Present	Present	Present
Leaf: shape of ligule	Split	Split	Truncate	Split	Split	Acute
Leaf: colour of ligule	White	White	purple	White	White	White
Leaf: length of blade	Long	Long	Long	Long	Long	Long
Leaf: width of blade	Medium	Medium	Medium	Medium	Medium	Medium
Days to 50 % heading	91	91	91	107	107	91
Flag leaf: attitude of blade	Erect	Erect	Erect	Erect	Erect	Erect
Spikelet: density of pubescence of lemma	Strong	Medium	Medium	Medium	Strong	Strong
Male sterility	Absent	Absent	Absent	Absent	Absent	Absent
Lemma: anthocyanin colouration of area below keel	Absent	Absent	Absent	Absent	Absent	Absent
Lemma: anthocyanin colouration of area below apex	Absent	Medium	Medium	Medium	Absent	Absent
Spikelet: colour of stigma	Light green	Light purple	Light purple	Light purple	Light green	Light green
Stem: thickness	Thick	Thick	Thick	Thick	Thick	Thin
Stem: length (excluding panicle; excluding floating rice)	Long	Short	Short	Short	Short	Short
Stem: anthocyanin colouration of nodes	Absent	Absent	Absent	Absent	Absent	Absent
Stem: intensity anthocyanin colouration of nodes	Absent	Absent	Absent	Weak	Absent	Absent
Stem: anthocyanin colouration of internodes	Absent	Absent	Absent	Present	Absent	Absent
Panicle: length of main axis	Very long	Medium	Medium	Medium	Very long	Very long
Flag leaf: attitude of blade (late observation)	Semi-erect	Horizontal	Horizontal	Horizontal	Erect	Semi-erect
Panicle: curvature of main axis	Droopy	Semi-straight	Semi-straight	Semi-straight	Droopy	Semi-straight
Panicle: number per plant	Few	Few	Few	Few	Few	Few

Contd.

VarietyCharacteristics	Khusbaya	Red Burma	White Burma	Black Burma	Musley	Yaeon
Spikelet: colour of tip of lemma	White	Purple	Purple	Purple	White	White
Lemma and Palea: colour	Straw	Reddish to light purple	Reddish to light purple	Brown furrows on straw	Reddish to light purple	Reddish to light purple
Panicle: awns	Absent	Absent	Absent	Absent	Absent	Absent
Panicle: secondary branching	Clustered	Weak	Weak	Strong	Weak	Weak
Panicle: attitude of branches	Semi erected	Semi erected	Semi erected	Semi erected	Semi erected	Semi erected
Panicle: exsertion	Partly exserted	Mostly exserted	Well exserted	Well exserted	Well exserted	Well exserted
Time maturity (days)	117	117	117	125	125	117
Leaf: senescence	Medium	Medium	Medium	Medium	Medium	Medium
Sterile lemma: colour	Absent	Absent	Absent	Absent	Absent	Absent
Plant height (cm)	140	158	140	174	132	–
Grain : weight of 1000 fully developed grains (g)	23.5	23.3	30.0	24.1	27.1	–
Grain : length (L) in mm	8.73	9.78	10.75	9.7	8.75	–
Grain: breadth (B) in mm	3.48	3.83	3.95	3.85	3.25	–
Grain : L/B ratio	2.51	2.53	2.72	2.52	2.69	–
Gelatinization temperature	Medium	Low	Low	Low	Medium	–
Amylose content	High	Very high	High	High	Low	–
Yield (t/ha)	2.5	1.5	2.4	2.1	2.5	2.1

being used for documenting the DUS traits and registration of these important rice land races with Protection of plant varieties and Famers' Right Act (PPV & FRA), a *sui-genris* system to enable the *Karen* community to have exclusive rights for utilization and get benefits for society foreseeing the IPR regime.

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