Research Bulletin

COASTAL SALINE SOILS OF MAHARASHTRA

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Khar Land Research Station
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This publication is based on the research outcome generated from the completed research projects carried out at KLRS, Panvel under different research programmes. The institute duly acknowledge the contribution of past scientists associated in different projects who have contributed to implement the projects successfully with the generation of viable coastal saline management.

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FOREWORD

The beginning of 21st Century is marked by global scarcity of water resources, environmental pollution and increased salinization of soil and water. Among several abiotic stresses, soil salinity is one of the most devastating stress, which causes major reductions in cultivated land area, crop productivity and quality.

Konkan region of Maharashtra state is blessed with 720 km long sea coast. This coastal ecosystem is unique in terms of its use and potential. Ingress of saline water is one of the major causes in increasing soil salinity in coastal area and has an adverse effect on overall development and economy of this region. The changing climate might worsen this situation due to increase in sea water level in near future. Integrated use of technologies and diversification of farming system should be the prime focus area to improve social life of coastal community.

The noteworthy technologies developed in relation to soil science, rice breeding, agronomy, engineering and fisheries, since the inception of Khar Land Research Station at Panvel has compiled and the research achievements putforth for benefit of upcoming researchers, farmers and entrepreneurs.

I appreciate the painstaking efforts of the team of scientists engaged in the development of technologies to amoeliorate khar lands and also bringing out this information.

Tapas Bhattacharyya

Place : Dapoli,
Dated : 8th June, 2016

(Tapas Bhattacharyya)

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Message

The Maharashtra state is having 720 km of coastal length which comprises the district of Palghar, Thane, Raigad, Ratnagiri and Sindhudurg. The total area of coastal saline in five districts of konkan is estimated to be 65,465 ha. The coastal saline soils appear in these districts due to periodical inundation of cultivable land by sea/ creek water during high tide, which has become unfit for cultivation on account of unproductivity of the soil mainly due to salinity. These periodical inundations render the land progressively saline and in time make it completely unfit for growing any crop. The salinity is causing significant losses in agriculture and adversely affecting the farmers economy due to poor understanding and management. There is urgent need to execution of integrated farming system approach in konkan coastal belt which will help the farmers from losses due to salinity.

The scientific community engaged in reclamation and management of coastal salt affected soils, and as part of this, the Khar Land Research Station, Panvel established in 1943, which is the only research Station in the university and state of the Maharashtra dealing with reclamation and management of coastal saline soils particularly in protective embankment, provision of sluice gate on the embankment, levelling of lands, storing of excess rain water for irrigation, improved salt tolerant crop varieties etc.

I hope this technical bulletin will provide information on the coastal research and opportunity to the researchers to review the present status and focus on important issues to provide future strategy to develop productivity of coastal ecosystem of konkan region. I congratulate Ex. Khar Land Scientists, present Khar Land Scientist and his team for their efforts in bringing this research bulletin.

U. V. Mahadkar

Place : Panvel
Date : 15th June 2016

(U. V. Mahadkar)
Director of Research

Preface

Maharashtra is endowed with 720 km of sea coast with 54 creeks and their tributaries with an area of about 65,500 ha under coastal saline soils. These soils are very fertile except that those are saline in nature. Since time immemorial the farmers are practicing farming in these soils with their own method. However, if the scientific knowledge is use for cultivation of the coastal saline lands they would be become the most productive under the given set of resources.

Present bulletin "Coastal Saline Soils of Maharashtra" embodies the research efforts in soil characterization, hydrology, reclamation practices, crop improved, soil and fertility management, integrated farming system and pisciculture under coastal saline soils.

Retrospection of glorious past is always a matter of great satisfaction, especially when the activities during the said period could largely accomplish its objectives. The synchrony of ever evolving challenges in coastal agriculture and its mitigation through development of suitable technologies has been priority for Khar Land Research Station, Panvel for fostering the cause of farmers.

Efforts made by Ex-Khar Land Scientists, similarly past and present scientists and present staff of the Khar Land Research Station whole incessant work in gathering the scientific information enabled the publication of this bulletin also deserve a mention.

Panvel
June 08, 2016

K. D. Patil
Khar Land Scientist
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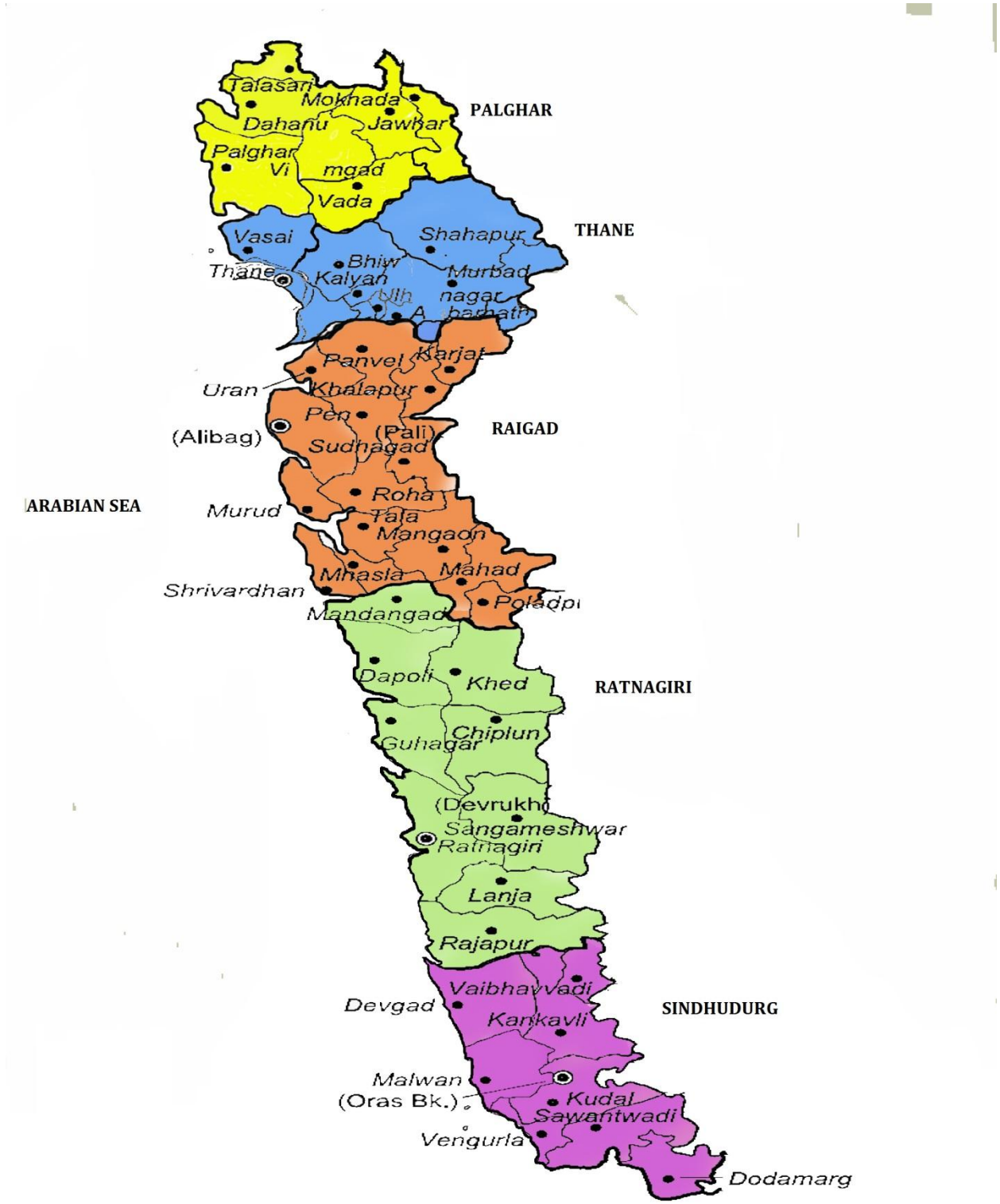

Fig 1: Location Map of Konkan Region

INTRODUCTION

1.1 Coastal saline soils :

The Maharashtra state has 720 km of coastal length with 54 creeks (Fig 1). It comprises the districts of Palghar, Thane, Raigad, Ratnagiri and Sindhudurg. The coastal saline soils occur in these districts due to periodical inundation of cultivable land by creek/sea water during high tides. Such periodical inundation render the otherwise fertile soils progressively saline and in time make it completely unfit for growing any crop. These coastal saline soils are locally called as *khar* or *khajan* soils. Even when encroachment of saline creek water is checked by putting an embankment, the brackish water from shallow water table rises through the capillaries due to evaporation, enriching the upper crust of the soil with salts and thus the salinity problem persists. As per the master plan of development of coastal saline soils of Maharashtra the total area under saline soils in five districts of Konkan is estimated to be 65,465 ha (Anonymous, 1990 a) the breakup of which is given Table 1.

Table 1 : Area under coastal saline soils in the Maharashtra state

Districts	No. of creeks	Area (ha)
Palghar	07	11,626
Thane	05	9,169
Raigad	07	31,800
Ratnagiri	18	5,770
Sindhudurg	17	7,100
Total	**54**	**65,465**

The Navi Mumbai project began in 1971 with formation of city and industrial development corporation (GoM) in the coastal Konkan. The area covered under the project had about 17,000 hectares of private land out of that 7,000 ha salt affected land is not under cultivation.

1.2 Agro-climatic zones and topography :

The coastal saline soils are spread over two agro-climatic zones of the state (Fig. 2). The very high rainfall non lateritic soil zone (VRNL) comprises the whole of Thane district and Northern part of Raigad district where the soils are derived from the basalt parent material, while very high rainfall lateritic soil zone (VRL) covers the southern portion of Raigad and the whole of Ratnagiri and Sindhudurg districts. Topographically the coastal area is almost flat and has elevation less than 10 m above mean sea level. The major rivers flow from Sahyadri ranges towards Arabian sea and influenced by the tidal water.

1.3 Climate :

Rains received from the south-west monsoon are spread over June to October with the peak period between July and August. The total annual rainfall varies between 3000 to 4000 mm. In spite of heavy rainfall, occurrence of dry spells are common and changing climate has significance in the management of coastal soils (Sahu *et al*., 1982).

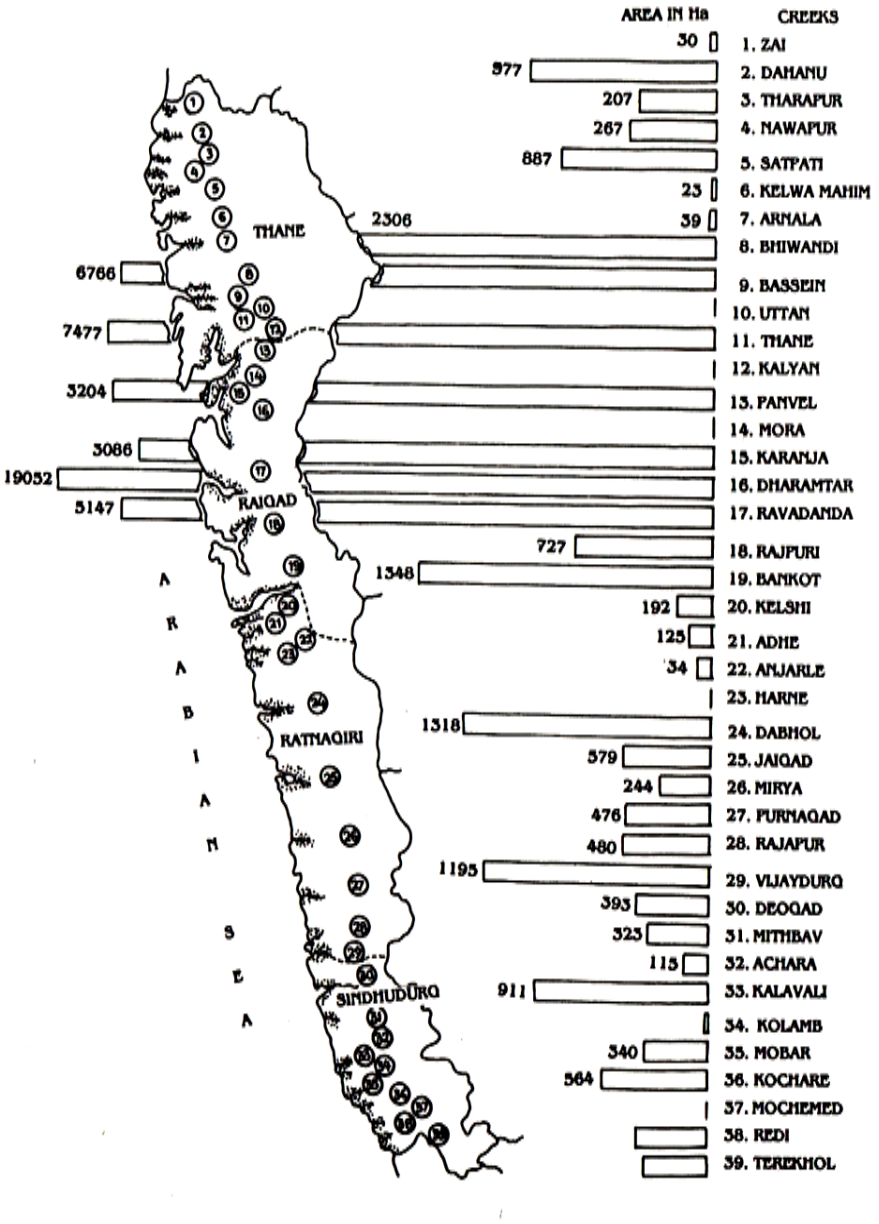

Fig 2.Main creeks in Maharashtra state

The maximum dry spells of 13, 17 and 31 days, which occur in the month of August, September and October, respectively. 20 years return period coincides with the important physiological growth stages of rice crop such as maximum tillering, panicle initiation, dough and grain filling stages during which the water requirement of rice is very high. The data reveals the need for protective irrigations in such soils. The relative humidity ranges between 75 to 80 percent. Month of May is the hottest and has mean temperature of 35.5^{o}c. The diurnal range of temperature is less than 7^{o}c during May to December and increase slightly from 8^{o}c to 10^{o}c from January to March i.e. during winter period (Sahu *et al.*, 1981).

Distribution of rainfall and dry spells:

The rainfalls in the coastal belt of Maharashtra is contributed mainly by south-west monsoon, which starts in first week of June and get established in first week of July through out the coastal belt. It starts withdrawing by the last week of September and decreases gradually towards the end of October.

Table 2: Distribution of rainfall (June-October), number of rainy days and dry spells during 2001 -2015 :

Month	Rainfall		Rainy days		Maximum dry spells in days
	Mm	%	No. of rainy days	%	
June	544.16	16.07	16.40	16.16	11
July	1045.40	30.88	24.07	23.72	4
August	833.84	24.63	24.40	24.05	5
September	369.34	10.91	16.00	15.77	11
October	88.94	2.62	5.42	5.34	24
Total of five months	**2881.68**	**85.11**	**86.29**	**85.04**	
Annual	**3384.88**	**100**	**101.45**	**100**	

Last 15 years data (Table 2)revealed that average annual rainfall at Panvel is 3384.88 mm. Out of which, 2881.68 mm *i.e.* 85.11% is received in five months from June to October. The number of rainy days are also concentrated in five months from June to October and constitutes about 85.04% of rainy days. The highest rainfall was received in the month of July *i.e* 1045.40 mm, which is 30.88 % of the annual rainfall. The rainfall declines from September onwards and it was lowest in October. The more number of rainy days were observed in month of august *i.e*. 24.40 days, which is 24.05% of total annual rainy days.

Occurrence of dry spells is very significant event for coastal saline soils. In the absence of good quality water, salinity of stagnated water in the rice field increases, which adversely affect the standing rice crop. The occurrence of dry spell in the month of June has significant adverse effect on growth of rice seedlings that ultimately reduces the yield of rice in coastal belt. The maximum duration of dry spell *i.e.* 35 days was recorded during September – October.

About Research Station:

Agricultural Research Station is situated on the bank of *gadi* creek, Bandar road at the western side of Panvel city. Station was established in the year 1943 with the objective to evolve salt tolerant and high yielding rice varieties suitable for cultivation under coastal

saline soil conditions and for agricultural extension activities in the region. Although attempts were made since very ancient times by the cultivators to reclaim these lands by putting embankment, no scientific approach was taken to evolve scientific technology for its reclamation. Hence, Khar Land Research Station Panvel was established in the year 1959 with an objective to conduct research on reclamation and management practices of coastal saline soils to increase the productivity. The station is under the control of the Dr. B.S Konkan Krishi Vidyapeeth, Dapoli since May 1972. The station was strengthened under National Agricultural Research Project phase (I) in 1984 and phase (II) in 1990 by providing scientific staff for need based research. This station is working in collaboration with Rice Specialist (MS), ICAR-IIRR, Hyderabad, IRRI Philippines and Bhabha Atomic Research Center, Mumbai. The centre is recipient of volunteer centre for salt affected soils and Use of Saline water by ICAR–CSSRI, Karnal. Some of the research and extension related activities are carried out with the financial support from DPDC and ATMA Raigad (M.S.). Transgenic rice lines from M/s. Mahyco, Jalana (M.S) were screened for salinity tolerance in the field. The centre is taking exorbitant efforts in solving needs of farming community. The results of the research carried out on various aspects like soil research, hydrological features, reclamation measures, rice breeding aspects, cropping system, fisheries aspects are embodied in the following pages.

The developed technologies were disseminated through organizing farmer rallies and training programmes. The seed of salt tolerant rice varieties, Urea-DAP briquettes, coconut saplings and seed of Indian Major Carps is produced every year to benefit farmers.

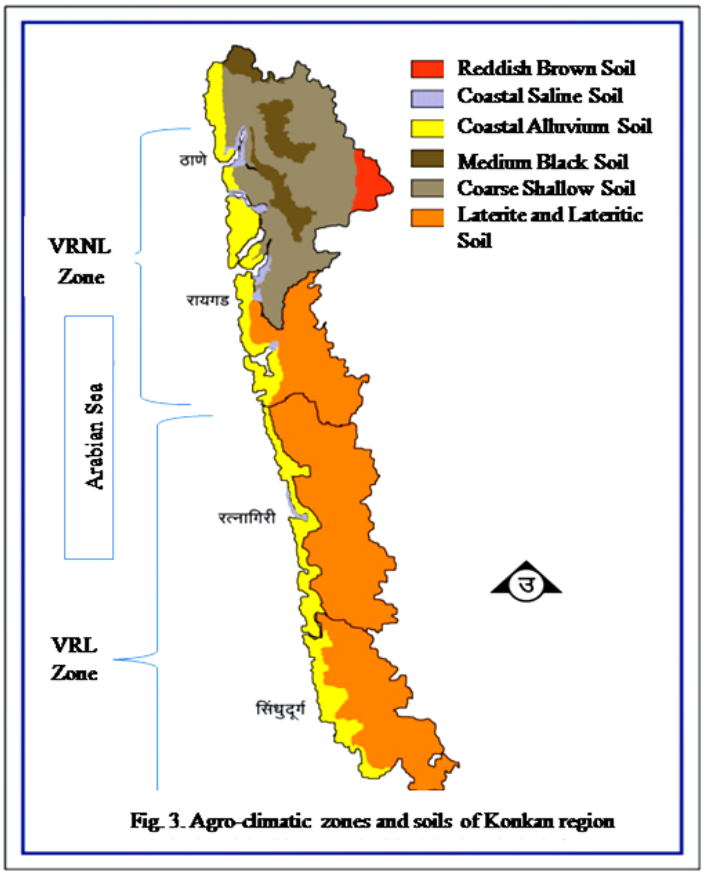

Fig. 3. Agro-climatic zones and soils of Konkan region

2. SOILS

2.1 Physio-chemical properties :

The physico-chemical properties of some typical coastal salt affected soils in the Konkan region were studied by Joshi (1985). The soils in general showed wide variations in their properties (Table 3). The soils in VRNL zone had fine texture and very poor hydraulic conductivity, while that from VRL zone had coarse texture and moderate conductivity. The soil pH ranged from slightly acidic to slightly alkaline in VRNL zone as against moderately acidic to strongly acidic in VRL zone. Due to relatively low rainfall coupled with shallow saline water table and impeded drainage the average value of ECe of the soils in VRNL zone was significantly higher (25.40dSm^{-1}). All the profile soil samples collected from VRNL zone indicated strongly saline nature of soils throughout the depth. The ECe increased gradually from surface downwards.

The concentration of Na^{++}, Mg^{++} and Ca^{++} in the surface as well as in the lower depths soils of VRNL zone was relatively high (Table 3). The K^{+} was within a narrow range. NaCl was the dominant salt present in these soils, the order being Na^{+}>Mg^{++}>Ca^{++}>K+ for cations and Cl> SO_4^{--}>HCO_3> CO_3 for anions (Joshi and Kadrekar, 1988). The average values of SAR were 28.14 and 20.07 for VRNL zone, respectively.

2.2 Soil fertility:

The soils from the VRL zone showed varying contents and pattern of distribution of organic carbon throughout the soil depth while, in the VRNL zone it was in the range of low to very low in the profile. The available P was more in the soils from VRL zone than VRNL zone, while the soils from both the zones were well supplied with available K.

The micronutrient status of the coastal saline soils was studied by Patil and Meisheri (2004). They observed that these soils contain adequate available Mn and Cu (Table 3.) however deficiency of B, Zn and Fe was found in some soils both in VRNL and VRL zones, which is likely to pose problems in rice cultivation in these soils.

2.3 Salinity variations:

The variation in the soil salinity according to the season is a common feature of coastal saline soils. Mehta (1991a) observed that the salt content reduced considerably with the rainy season, while it increased again in large quantities during dry season. He further observed that the salinity of the soil gradually reduced with time after the construction of embankment, which might be due to desalinization by rain water. It was also observed that during pre monsoon period the lower soil layer was enriched with salt. Chavan *et al.*,(1984a) observed similar trend for NaCl content in the soils during the period from the year 1960 to 1981.

Though rainfall is effective in reducing soil salinity, it was revealed that it is not the total rainfall but its distribution which matters in reducing the soil salinity (Chavan *et al.*, 1984a). With the onset of monsoon the surface salts are either washed, diluted or leached and the soils become fit for growing rice crop. However, variations in soil salinity do occur during monsoon season if the dry spells prevail from the month of November the salinity starts building up again.

Table 3 : Physico-chemical properties of coastal saline soils of Maharashtra

Sr. No.	Soil property	Very high rainfall non lateritic soil zone (VRNL)	Very high rainfall lateritic soil zone (VRL)
I.	**Physical properties**		
1.	Sand (%)	18.10	51.46
2.	Silt (%)	38.23	22.91
3.	Clay (%)	43.67	25.63
4.	Bulk density ($g\ cc^{-1}$)	1.26	1.29
5.	Hydraulic conductivity ($cm\ day^{-1}$)	0.65	1.26
6.	Total porosity (%)	48.48	50.60
7.	Available moisture (%)	17.93	13.62
II.	**Chemical properties**		
1.	pHs	6.80	5.60
2.	ECe ($dS\ m^{-1}$)	25.40	11.90
3.	Soluble $Ca^{++} + Mg^{++}$($me\ l^{-1}$)	145.40	59.40
4.	Soluble Na^{+} ($me\ l^{-1}$)	243.30	117.60
5.	Soluble K^{+} ($me\ l^{-1}$)	2.90	2.00
6.	Soluble Cl^{--} ($me\ l^{-1}$)	319.80	127.2
7.	Soluble SO_4^{--} ($me\ l^{-1}$)	74.50	31.90
8.	Soluble HCO_3^{-}($me\ l^{-1}$)	12.60	15.70
9.	SAR	28.14	20.07
10.	CEC (me/100 g)	43.37	26.60
11.	Exchangeable Na (me/100 g)	11.15	5.20
12.	ESP (%)	25.70	25.14
13.	Organic carbon ($g\ kg^{-1}$)	4.80	7.70
14.	Available P_2O_5 ($kg\ ha^{-1}$)	75.10	53.97
15.	Available K_2O ($kg\ ha^{-1}$)	2533.60	1072.83
16.	$CaCO_3$ (%)	5.00	2.70
17.	DTPA extractable Zn (ppm)	2.24	2.07
18.	DTPA extractable Fe (ppm	48.70	44.47
19.	DTPA extractable Cu (ppm)	7.19	6.35
20.	DTPA extractable Mn (ppm)	55.17	51.30
21.	DTPA extractable B (ppm)	1.39	0.98

Table 4. Characteristics of typical (VRNL Zone) coastal saline soils of Maharashtra (Location : Shahabaj, Alibag, Dist- Raigad)

Soil depth (cm)	Textural composition			Hydraulic conductivity (cm/hr)	pHs	ECe (dSm^{-1})	Composition of the saturation extract (me/l)					SAR	CEC (me/100g)	ESP	Organic Carbon (%)	Available P_2O_5 ($kg\ ha^{-1}$)	Available K_2O ($kgha^{-1}$)	$CaCO_3$ (%)
	Sand (%)	Salt (%)	Clay (%)				$Ca^{++} + Mg^{++}$	Na^{+}	K^{+}	Cl^{-}	$So4^{-}$							
0-20	0.51	29.05	70.44	0.001	6.6	22.6	137.8	217.5	2.5	251.0	104.0	26.21	52.50	25.31	0.42	97.6	2997.0	5.5
20-40	3.91	53.83	42.26	0.003	6.4	27.2	169.6	252.5	3.5	293.0	136.0	27.42	50.00	36.92	0.45	127.8	2941.5	5.0
40-70	8.13	22.48	69.39	0.001	4.3	41.0	254.4	392.5	4.7	525.0	148.0	34.80	55.00	70.27	0.73	74.5	2775.0	4.5
70-100	34.73	51.98	13.29	0.750	3.5	64.7	418.7	685.0	8.5	1162.0	180.0	47.34	52.50	46.29	1.74	51.5	3219.0	4.5
100-130	34.36	47.73	17.29	2.469	2.7	71.7	651.9	785.0	0.7	1184.0	675.0	43.48	53.00	49.19	2.62	23.0	222.0	3.0
130-150	25.27	54.55	20.18	1.688	2.9	78.7	810.9	960.0	5.0	1280.0	600.0	47.68	53.00	55.96	2.73	46.1	1221.0	2.5

Table 5 : Properties of acid sulphate low land soils of coastal region of Konkan.

Sr. No	Properties	Name of villages in Konkan region				
		Ubhadanda	Waghesh-warwadi	Tar	Ubhadandi-wadi	Mean
1	Class	Entic chromusters	Entic chromusters	Entic chromusters	Entic chromusters	Entic chromusters
2	Sand (%)	71.64	74.64	72.04	70.04	72.09
3	Silt (%)	07.00	06.00	7.30	07.30	06.90
4	Clay (%)	21.36	19.36	20.66	22.66	21.11
5	Textural class	sandy clay loam	sandy clay loam	sandy clay loam	sandy clay loam	sandy clay loam
6	Clay minerals	Kaolinite, Chlorite and Mica	Kaolinite, Chlorite and Mica	Kaolinite, Chlorite and Mica	Kaolinite, Chlorite and Mica	Kaolinite, Chlorite and Mica
7	pH (1:2.5)	4.10	4.28	3.90	4.16	4.11
8	EC dSm^{-1}	0.61	0.32	0.52	0.65	0.53
9	$CaCO_3$(%)	0.50	0.50	0.25	0.50	0.44
10	Organic Carbon g kg^{-1}	0.63	0.39	0.35	0.75	0.53
11	Av. P_2O_5 kg ha^{-1}	25.39	33.20	44.38	59.24	40.55
12	Av. K_2O kg ha^{-1}	53.76	80.64	73.92	73.92	70.56
13	CEC(CMol (P^+)	16.16	17.06	15.74	18.34	16.83
DTPA Extractable micronutrients (ppm)						
14	Zn	0.46	0.85	0.46	0.60	0.59
15	Cu	2.51	1.50	1.40	2.63	2.26
16	Mn	1.29	2.74	1.05	1.44	1.63
17	Fe	26.68	66.10	85.37	108.90	71.76

Table 6 : IRRI strains of rice tested in acid sulphate soils of Konkan (q ha^{-1}).

Year	Variety		
	IRRI strain No. 39	IRRI strain No. 4	Damga (Local check)
1^{st} year	16.57	14.49	15.90
2^{nd} year	32.55	44.00	24.50
3^{rd} year	44.90	38.14	18.90
4^{th} year	14.70	6.80	22.00
Mean	**27.18**	**25.86**	**20.32**

Patil *et al*. (2002) analysed and classified acid sulphate soils in the class of Entic chromusters with dominant clay minerals Kaolinite, Chlorite and Mica (Table 5). The data on particle size distribution indicated that the soil samples fall in sandy clay loam in texture. The pH of soils was very acidic in range varied from 3.90 to 4.28 with mean of 4.11, however

electrical conductivity ranged from 0.32 to 0.65dSm^{-1}. The organic carbon content in the soil was relatively low to medium, varied from 0.35 to 0.75 g Kg^{-1} with average value of 0.53 g Kg^{-1}. The organic carbon content in this soil is observed to low, may be because of high content of sand particles. The available major nutrients, P_2O_5 ranged from 25.39 to 59.24 and K_2O ranged from 53.76 to 80.64 kg ha^{-1} with mean value of 40.55 and 70.56 kg ha^{-1} indicating medium in phosphorus and low in potassium content. The DTPA extract of Zn was varied from 0.46 to 0.85, Cu varied from 1.40 to 3.51, Mn varied from 1.05 to 2.74 and Fe was from 26.68 to 108.90 ppm indicating deficiency of Zn in the soil. Bandopadhyay and Sarkar, 1982 identified coastal area of Sundarbans as potential acid sulphate indication properties as similar under study. Acid sulphate soils occupy approximately 2000 ha area in Sindhudurg district of Konkan. These soils have extremely poor productivity due to high acidity, toxicity of aluminum, iron besides salinity and acidity induced phosphorus deficiency.

Amongst the 78 IRRI strains of rice tested, No 39 and No. 4 were selected with local check Damga in acid sulphate soil of Konkan on large scale basis to conduct trial on farmers field (Table 6). The trial was conducted for successive four years and grain yield data is presented in Table 2. The yield data showed that IRRI No. 39 and IRRI No. 4 from a set of acid sulphate soil gave 27.18 q ha^{-1} and 25.86 q ha^{-1}yield over local check Damga (20.32 q ha^{-1}). The IRRI strain No 39 and No. 4 showed 33.76 and 27.26 per cent increased the yield over local check Damga, hence suggested for cultivation in the tested area.

Table 7. Average soil salinity (dSm^{-1}) at Khar Land Research Station, Pargaon

Year	Pre Monsoon (May)		Post Monsoon (Nov.)	
	0-22.5 cm	22.5 - 45 cm	0-22.5 cm	22.5 - 45 cm
1st	23.37	21.72	19.57	20.54
2nd	21.00	18.10	15.92	16.04
3rd	16.24	14.79	12.40	13.00
4th	12.98	11.00	11.10	11.65
5th	11.35	10.73	9.98	10.28
6th	9.90	8.96	8.65	8.91
7th	11.46	11.56	8.94	10.47
8th	11.47	11.07	6.06	6.64
9th	9.68	9.36	7.34	7.99

The data indicate that there is reduction of soil salinity after construction of embankment and maintenance of sluice gate (Table 7).

Correlation of EC_e with EC_2:

Coefficient and co-relation was established for EC_2 (X) and EC_e (Y). The correlation was observed to be statistically significant and 'r' value was 0.83. The linear regression equation EC_e was Y=0.54+1.72X (Anon., 1989).

3. HYDROLOGY

The reliable and systematic information regarding hydrological characteristics of coastal saline soils is essential to develop reclamation techniques.

3.1 Infiltration rate :

The studies on infiltration characteristics of these soils were carried out under the two covers i.e. 1) dry, stirred surface soil (10 cm) without surface cracks and 2) with small surface cracks but no crop residue. When the infiltration rate and accumulated infiltration were plotted against time (Sahu *et al.,* 1981) the equation Y= a $t^{o}C$ + b was found adequate to represent accumulated infiltration data. The following two equations were developed for the two soil cover conditions.

i) Y = 0.5630 t0.3674 – 0.3013

ii) Y = 1.1618 t 0.2926 – 1.0288

Where Y = infiltration rate in cm and T = time in minutes.

The infiltration rate for surface cover condition (i) above as found to be 7.84 cm/day and for cover condition (ii) it was 8.73 cm/day. In general the infiltration rate is observed to be very low due to heavy texture of the soil.

3.2 Hydraulic conductivity :

The Hydraulic conductivity in situ is an important soil characteristics required for computation of drain spacing. The hydraulic conductivity of soils from Panvel and Pargaon location was measured by auger hole method (Sahu *et al*., 1981). The average value for hydraulic conductivity for soil at Pargaon is observed to be 0.62 cm/day and in Panvel location it was found to be 1.05 cm/day. As per USDA classification these values are treated as low and soils need efficient drainage system.

Excess sodium in exchangeable complex is known to exert an adverse effect on the soil properties, Prabhu *et al*. (1987) observed that the degree of dispersion and the saturated hydraulic conductivity showed negative and positive relationship, respectively with the salinity levels. The deleterious effect of high SAR status of saline soils were due to poor transmissibility of water as a result of displacement and dispersion of finer soil particles clogging the macropores.

3.3 . Ground water characteristics :

The brackish ground water of coastal saline soils is a constant source of soil salinity. The degree of salinization depends on the capillary conductivity of the soil and the evaporation rate. The critical depth of mineralised ground water is the depth of water table above which the salt solution can ascend by capillary action to the soil surface causing salinization. The critical depth of mineralised ground water was found to be 407.3 ± 15 cm at Panvel (Sahu *et al*., 1982)

The water table depth and its salinity were measured through the observation wells installed at Pargaon (Panvel) (Mehta, 1991b). The ground water table rose to 0.17 m in the month of September and dropped from October onwards. It reached the average salinity of groundwater ranged from 29 dSm^{-1} in the month of July to 75 dSm^{-1} in the month of May.

3.4 Tidal data :

Sea water rises above the normal level up to 4 to 5 m during high tides and recedes to the same extent during low tides. The effect is manifested in the rise and fall of water level of the estuarine channels and creeks. High tides and low tides occur twice a day. Period between these two tides is generally 24 hours and 50 minutes, which is counted between these two ditches. The tidal data were recorded in the month of July for the three consecutive years *viz;* 1960, 1961 and 1962 and their fluctuations are shown in fig.6 (Kadrekar *et al*., 1981). It would be seen that the period between two consecutive high tides is about 15 days. Similarly, the period between two consecutive low tides is also about 15 days. Month wise average data on highest and lowest tides along the Konkan coast are shown in fig. 7 (Kadrekar *et al*., 1981).

3.5 Surface water characteristics :

The salinity of surface water is important for growth of the rice. The correlation between the percent NaCl of surface water and subsurface water was worked out (Chavan *et al*., 1984a) and it was observed that a strong positive correlation (r=+0.702) exists between these parameters.

Fig 4.: Seasonal variations in ground water salinity

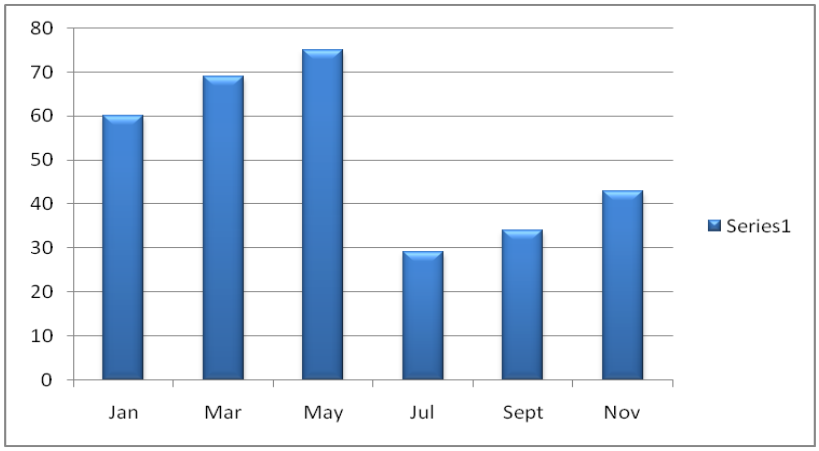

Fig.5:Seasonal variations in water table depth and salinity of ground water

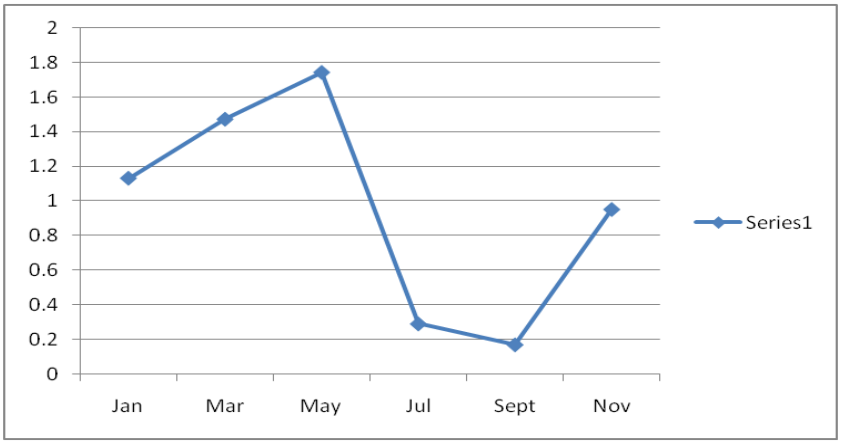

Table 8 : Seasonal variations in ground water salinity.

Sr. No.	piezometer No.	Distance from creek(m)	Salinity (dSm^{-1})						Average
			Jan	Mar	May	Jul	Sept	Nov	
1	A1	425	60	74	71	42	24	35	**49**
2	B1	470	62	67	78	10	23	31	**45**
3	B2	370	69	74	73	28	32	39	**52**
4	B3	270	68	71	72	41	37	55	**56**
5	B4	170	68	72	75	33	58	64	**61**
6	B5	70	89	91	99	39	37	49	**68**
7	C1	525	59	73	75	20	19	20	**42**
8	C2	425	58	67	71	28	29	29	**49**
9	C3	325	63	73	79	29	46	51	**55**
10	C4	225	72	83	72	34	51	50	**60**
11	C5	125	61	68	85	58	64	60	**65**
12	D1	730	62	65	65	20	39	40	**39**
13	D2	630	48	73	68	10	6	29	**41**
14	D3	530	64	72	70	8	5	39	**41**
15	D4	430	58	65	76	23	16	45	**46**
16	D5	330	61	74	74	34	46	40	**54**
17	D6	230	69	76	74	33	45	53	**58**
	Average		**60**	**69**	**75**	**29**	**34**	**43**	**52**

Table 9. : Average monthly fluctuations in groundwater table depth (m) from ground surface

Sr. No.	Piezometer No.	Distance from creek (m)	Month						Average
			Jan	Mar	May	Jul	Sept	Nov	
1	A1	425	1.18	1.53	1.88	0.20	0.88	0.70	**0.95**
2	B1	470	1.24	1.68	2.01	0.22	0.11	0.97	**1.02**
3	B2	370	1.18	1.51	1.78	0.20	0.11	0.86	**0.94**
4	B3	270	1.07	1.39	1.63	0.35	0.10	1.04	**0.91**
5	B4	170	0.65	1.16	1.33	0.44	0.25	0.85	**0.80**
6	B5	70	0.78	1.07	1.50	0.05	0.04	0.64	**0.67**
7	C1	525	1.24	1.56	1.79	0.37	0.31	1.19	**1.04**
8	C2	425	1.13	1.55	1.78	0.29	0.17	1.09	**1.00**
9	C3	325	1.10	1.45	1.72	0.14	0.14	0.85	**0.91**
10	C4	225	1.03	1.41	1.61	0.24	0.16	0.94	**0.81**
11	C5	125	0.89	1.19	1.41	0.23	0.23	0.85	**0.80**
12	D1	730	1.39	1.82	2.19	0.42	0.12	1.13	**1.20**
13	D2	630	1.40	1.76	2.13	0.50	0.15	1.11	**1.16**
14	D3	530	1.47	1.65	1.78	0.52	0.21	1.07	**1.12**
15	D4	430	1.12	1.46	1.67	0.38	0.29	1.07	**1.01**
16	D5	330	1.17	1.51	1.72	0.30	0.12	0.94	**0.94**
17	D6	230	1.11	1.35	1.72	0.04	0.33	0.76	**0.85**
	Average		**1.13**	**1.47**	**1.74**	**0.29**	**0.17**	**0.95**	**0.94**

From the data presented on salinity (EC) of observation wells (Piezometers) it was evident that variation in EC values of high tide water intrusion in observation wells (Piezometers) was mainly caused by intrusion of ground water and seasonal variation (Table 8). Depth of ground water observed to be shallow during monsoon season whereas, ground water depth was high during summer months (Table 9).

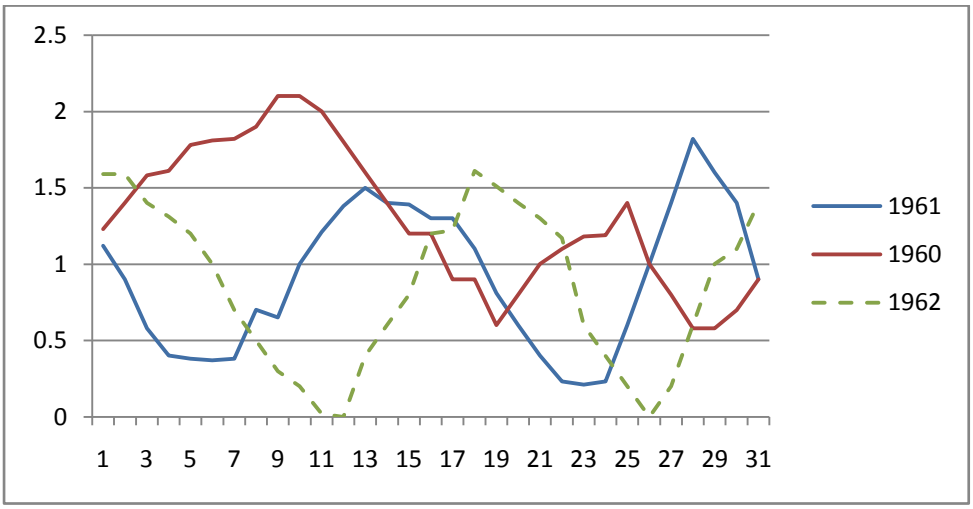

Fig. 6. Fluctuations of tide water in the month of July.

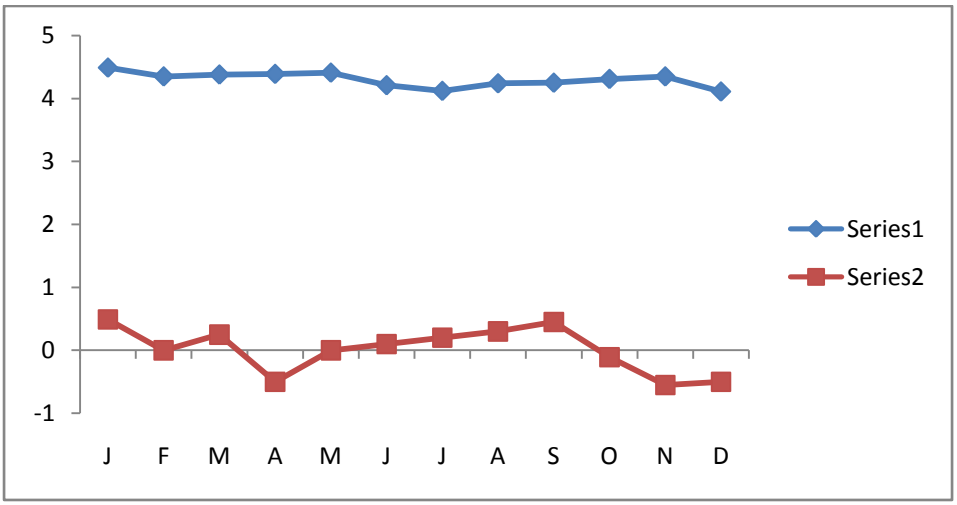

Fig. 7. Tide height along Konkan coast

4. RECLAMATION MEASURES

4.1 Ingress control :

A strong embankment is required to construct at least to height greater than the height of maximum tide to stop ingress of sea water. Side slopes of 2:1 with stone pitching towards creek side and 1:1 towards land side with grass cover is found to be optimum (Kadrekar *et al.,* 1981). Conservation of mangroves on creek side of the embankment helps in stabilization of embankment and reducing erosion due to waves of sea water. Timely control of marine creatures like Nivata (*Boteophthalmus dussumieri*), eel fish locally called Muner (*Angulla angulla*) and brackish water crab (*Scylla serrata*) is essential to increase the longetivity of bund as these creatures make holes which get widened due to ingress of sea water and the embankment is damaged. Construction of intercepting drain (cut off drain) 10 to 15 m inside, parallel to outer embankment is found effective in checking the seepage of saline creek water (Fig.8).

4.2 Drainage and desalinization :

In order to remove excess salts by run off without causing erosion of soil deep drains of 1.5 to 2.0 m depth are found effective. For soil of low hydraulic conductivity (0.62 cm/day) 100 m drain distance was found optimum, which showed 85 per cent reduction in soil salinity (Sahu *et al*., 1982).

Closed spaced drains of 20 m spacing were more efficient in reducing soil salinity than 30 m spacing drains (Bhuibhar *et al*., 1990). Open drains and backfilled drains were observed to be equally effective in reducing soil salinity.

Very low hydraulic conductivity of the soil poses problem in the speedy reclamation by downward movement of salts. However, horizontal desalinization by flushing out of salts into the salt drains with the help of rain water is considered to be temporary measures, which removes the salts from surface soil and makes it suitable for growing rice in *kharif* season. The age old practice of ploughing the field in summer and by impounding 20 cm water depth on the surface of soil and periodic flushing of such water was carried out (Anon. *et al*., 1991a). It was observed that the soil salinity decreased gradually after each flushing in both the treatments. However, the decrease was more in surface layer (10 cm) only with the treatment of ploughing (10.17dSm^{-1}) than *Ulkatni* (2.15 dSm^{-1}) at the end of fourth flushing.

Surface drainage farm pond showed added advantage of reclaiming an area up to a radial distance of 27 m by periodical pumping of saline water into the drain and flushing it out (Chavan *et al*., 1985). The periodicity of pumping intensity and distribution of rainfall were then major factors governing the leaching and recharging processes in such ponds.

Fig. 8. Map of Khar Land Research Station, Pargaon (Panvel) farm showing locations of reclamation measures

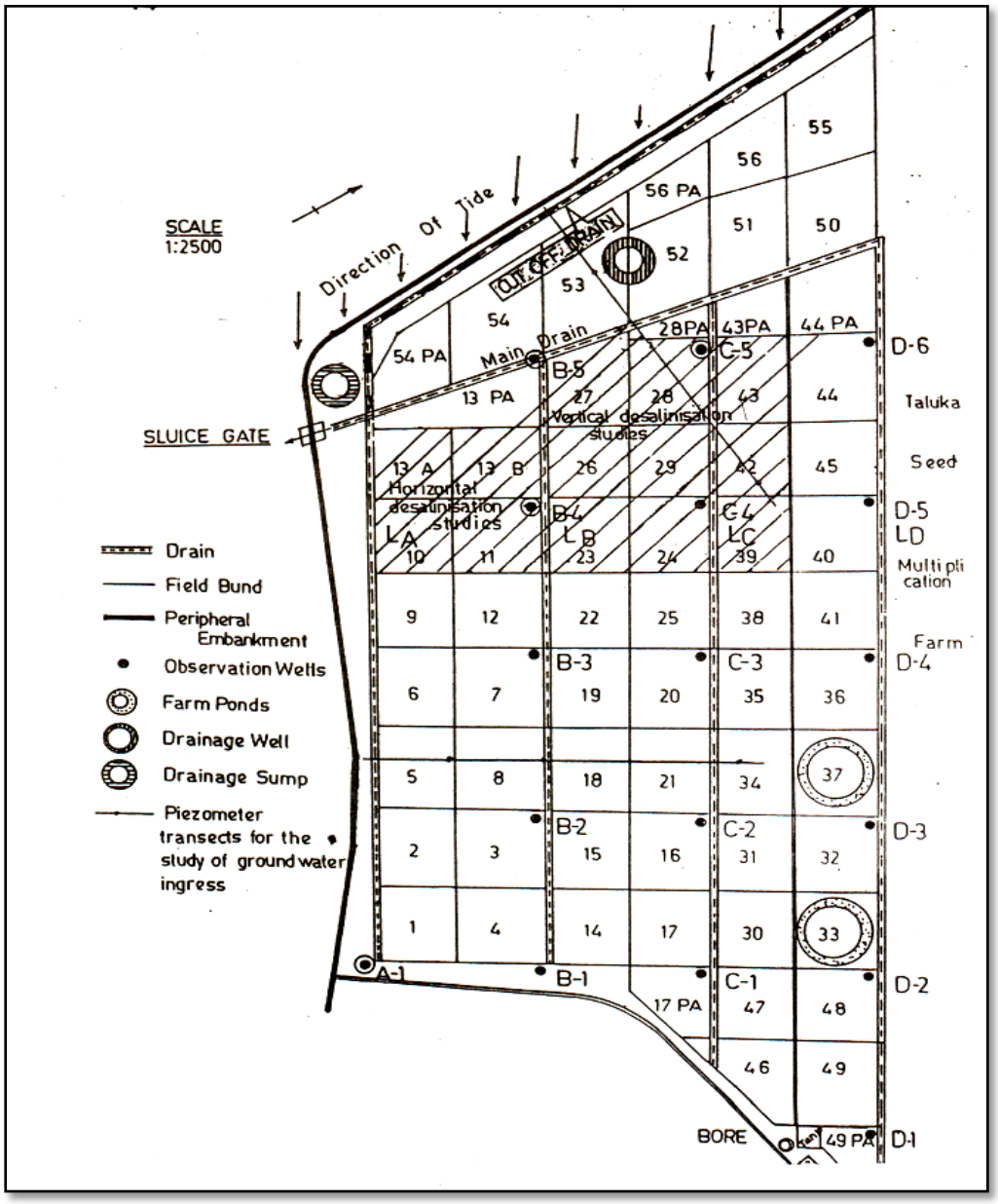

Table 10: Effect of rain water storage in farm pond on desalinization (EC_2 dSm^{-1}).

Month	Distance from pond (mt)					
	0	**10**	**20**	**30**	**40**	**50**
Sept,14	1.27	1.45	1.83	3.08	3.62	4.24
Oct ,14	1.24	1.38	1.85	3.33	4.93	5.48
Nov, 14	1.76	1.86	2.08	3.48	4.98	5.72
Dec,14	1.38	2.10	2.21	4.02	5.71	6.80

Farm pond is one of the ways of finding reclamation and increasing production potential of coastal saline soils. The observations were recorded around pond up to 50 meters away from pond. Soil salinity at surface was observed as 1.5, 1.92, 2.96, 3.97, 4.39 and 5.31 dSm^{-1} for 0, 10, 20, 30, 40 and 50 meters distance from pond, respectively. However sub-surface soil salinity were found to 2.25, 2.66, 3.32, 5.12, 6.26 and 6.62 dSm^{-1} for a distance 0 , 10, 20, 30, 40 and 50 meters away from pond, respectively. It was evident that stored rainwater in fish pond had shown influence on reduction in soil salinity. Salinity seems to be gradually increases as distance from fish pond increases. It was lowest at 0 meter and maximum at 50 meters (Patil *et al.*, 2016). The rainwater stored in the pond during rainy season was used for fish culture, getting benefit to cost ratio of 1.53. The water can be used as source of irrigation for production of salt tolerant vegetable crops such as palak, radish, spinach, beet root etc.

5. CROP AND SOIL MANAGEMENT

Coastal saline soils are mostly monocropped. Rice is grown during *kharif* season. Along with the reclamation practices of coastal saline soils it is necessary to grow salt tolerant high yielding and multiple resistant rice varieties. With this view, the rice breeding work was undertaken at the Khar land Research Station, Panvel since 1943 to evolve suitable varieties.

5.1 Salt tolerant rice varieties :

During early years Bhura rata 4-10 and Kala rata 1-24 varieties were evolved through extensive selections and released during the year 1953 and 1958, respectively. Both the varieties are highly salt tolerant, early in duration red grained and yield 20 to 25 q/ha. Efforts were also made to improve grain quality and yield levels of these varieties. As a result, MK 47-22 and SR 3-9 varieties were evolved and released during the years 1962 and 1965, respectively. In order to increase yield potential the work was further intensified and the varieties Panvel 1 and Panvel 2 having yield potentials of 44 q/ha and 38 q/ha were evolved and released during the years 1984 and 1988, respectively. The former variety is coarse grained while the later is fine and translucent. Panvel 3 salt tolerant rice variety with long bold grains and midlate duration has been released for commercial cultivation in the year 2000. The details of these varieties are given in Table 11.

5.2 Tillage practices :

The local tillage practices *viz*; *Ulkatni*, *Vindhani* and excavation of *chali* are generally followed in coastal saline soils (Kadrekar *et al.*, 1981). In *Ulkatani*, the field is dug with crowbar or pick axe and big clods are turned upside down during the months of April, May to accelerate the process of desalinization with the first showers. In *Vindhani* small pits of about 25 cm deep are dug at a distance of 30-45 cm apart. With the onset of monsoon the rain water accumulates in these pits and leach the salts. *Chali* is a practice of excavation of peripheral drains of 60 cm wide and 30 cm deep along the bunds of plots. *Chali* functions as an internal drains as well as water storage.

When the practice *Ulkatni* was compared with the usual practice of shallow ploughing yield differences between two methods was found to be non significant (Anonymous, 1985). However, *Ulkatni* is a laborious process. Hence, the practice of ploughing the field immediately after the harvest of rice crop at proper moisture conditions is recommended. As reclamation of coastal saline land progresses shallow ploughing (22.5 cm depth) was found beneficial over deep ploughing (45 cm) (Kadrekar *et al.*, 1981).

Table 11. Salt tolerant rice varieties evolved at Panvel

Sr. No.	Variety	Year	Parentage	Maturity (Days)	Grain yield (q/ha)	Grain quality
1.	BR 4 - 10	1953	Selection from local *rata*	110	22.00	Red Kernel, coarse
2.	KR 1 – 24	1958	Selection from *rata*	120	21.00	Red Kernel, coarse
3.	MK 47 – 22	1962	Mulkudai x KR 1-24	125	28.00	White Kernel, coarse
4.	SR 3 – 9	1965	KR 1-24 x Zinia 149	145	21.00	Translucent Kernel, fine
5.	Panvel - 1	1984	IR 8 x BR 4-10	125	44.00	White kernel, coarse, short bold
6.	Panvel - 2	1988	BR 4-10 x IR 8	119	38.00	Translucent kernel, fine
7.	Panvel - 3	2000	Damodar x Pankaj	125	48.00	Long bold

5.3 Planting practices :

In *Kharif*, *rahu* method of sowing the rice is followed. Proper water management in this method is essential. Seed rate of 60 to 80 kg/ha is found to be optimum to compensate mortality and maintain proper plant population (Anonymous, 1987). *Awatni* i.e. superficial planting of seedlings along with mud ball is an another method followed in coastal saline area. In this method circular or rectangular mounds are prepared in the field for rice nursery. Seedlings when ready for transplanting are uprooted keeping mud balls intact are thrown in the field. This method of planting avoids direct contact of roots of seedlings with the saline soils and thus minimizes seedling mortality. Hence, a*watni* was found to be superior over the method of transplanting (Anonymous, 1985) in increasing the yield by 10 per cent over the later method.

Chali (peripheral drains) *Ulkatni (turning of clods upside down)*

Mounts (Used as seed bed)

Fig. 9. The local tillage practices for reclamation.

Age of rice seedlings at transplanting is an important factor in determining the yield of rice crop. It was observed (Anonymous, 1990b) that 25 days old seedlings of Panvel 1 rice variety with four seedlings per hill and 100 kg N/ha gave the optimum yield (36.45 q/ha). If the transplanting is delayed 35 days old seedlings with six seedlings of 15 x 20 cm for Panvel 1 variety and 15 x 15 cm for Panvel 2 variety were found to be optimum (Anonymous, 1986)

In north konkan coastal zone of saline soil, under direct seeded method, it was observed that, during *kharif* season the salt tolerant rice variety Panvel-3 with recommended dose of fertilizers recorded higher grain yield and profit (Borse *et. al,* 2016).

5.4 Nutrition Management :

Addition of organic material either in the form of FYM, compost or green manure reduces the adverse effects of salinity on rice crop. Dhaincha (*Sesbania cannabina*), Shevari (*Sesbania aegyptica*) and leaves of bhend (*Thespesia populanea*) are found to be useful in increasing the yield of rice crop (Kadrekar *et al*., 1981) . Linear response was observed with increasing doses of FYM upto 15 t/ha along with recommended dose of fertilizers (Chavan *et al*., 1990). The fertilizers like ammonium sulphate, calcium ammonium and ammonium sulphate nitrate were found equally effective to rice crop (Kadrekar *et al*., 1981). The response of rice varieties to nitrogen was found to be quadratic (Rajput and Mehta, 1990). The response to the application of potassic fertilizers was nonsignificant. Similarly application of $ZnSO_4$ (Anonymous 1991b) did not increase the yield of rice. In north Konkan coastal zone of saline soil, under direct seeded method, the seed rate @ 100 $kgha^{-1}$ of rice variety panvel-1 with application of 100 kg N ha^{-1} along with basal dose of 50 kg P_2O_5 and 50 kg K_2O ha^{-1} is recommended. (Borse *et al.,*2015).

5.5 Pests and diseases :

Pests like stem borer, army worm. leaf folder, brown pant hopper, land crab and diseases like bacterial leaf blight and blasts are the major pests and diseases observed in coastal saline soils. *Har* weed (*Ceratophyllum sp*.) which is aquatic in nature is most widely found in coastal saline soils. It was observed that its growth can be suppressed by spraying stamp 34 and 2-4D Na salt (Kadrekar *et al*., 1981). The tool developed by the Khar Land Research Station, Panvel to collect the *har* weed manually has been found to be effective in collecting the weed successfully.

5.6 Rabi cropping :

There is no source of good quality irrigation water during *rabi* season in the coastal belt of Maharashtra. The underground water is brackish and not suitable for irrigation. However, this area receives very high rainfall. The rain water can be harvested by excavating shallow farm ponds and construction of check dams (Sahu *et al.,* 1981). This stored water can be used for growing certain crops with protective irrigations.

Many pulses, oilseeds and vegetable crops and their varieties were screened for salt tolerance at Panvel location. The following crops (Table 12) performed satisfactorily (Anonymous 1986). The Ramonskaya variety of sugar beet also performed well and yielded up to 28 t/ha (Anonymous, 1986).

Table 12. Crops suitable for rabi cultivation in coastal saline soils

Sr. No	Crop/Variety	Duration (days)	No. of protective irrigations	Salinity range EC_2 (dSm^{-1})	Yield (q/ha)
1	Radish *(Pusa Reshmi)*	55-60	5 to 6	4 to 7	190 to 200
2	Spinach *(All green)*	80-90	6 to 7	3 to 5	140 to 150
3	Tomato *(Pusa Rubi)*	130-150	8 to 10	3 to 7	180 to 190
4	Mustard *(Pusa Bold)*	110-120	3	2 to 7	2.5 to 3.0
5	Linseed (AKL-10)	110-120	3	3 to 5	3.0 to 3.5

The nitrogen requirement of spinach (var. All green) (Rajput *et al*., 1989) and radish (var. Pusa Reshmi) was found to be 120 kg N/ha for getting optimum yields. Cultivation of various cucurbitaceous crops on field bunds were tested. The Okra, cucumber, ridge gourd, sponge gourd and bitter gourd performed well on field bunds with an average yield of 0.485, 0.750, 2.030, 1.490 and 1.500 kg per plant, respectively (Anonymous, 1990c).

5.7 Integrated farming system:

Integrated farming system trial was conducted in Vashi village, Tal. Pen, Dist. Raigad in coastal saline soils (Table 13). IFS components were fishpond, paddy field, vegetables, poultry, vermicompost, ornamental fish raring and horticultural crops. Water stored in pond has positive effect on desalinization of soil, which yielded better kharif rice and rabi crops. Pond water was used as protective irrigation for growing rabi crops. The vermicompost produced was used as manure to the crops. The poultry sheet was used as poultry manure to improve soil productivity. Total yield and profitability for 1 hectare area with IFS components revealed B:C ratio 1.99 at vashi farm location. High B:C ratio at this centre might be due to large area under pond (4035.75 m2).

Table 13: Total cost, Gross returns and Net returns of different enterprises in IFS (Vashi)

Sr. No.	Enterprise	Cost of production (Rs.)	Gross returns	Net returns
1	Crops/Cropping Systems (Including vegetables/flowers)	18,067.52	26,501.25	8,433.73
2	Fishery	99,895	2,50,000	1,50,105
3	Goatry	-	-	-
4	Poultry	8,149	9,040	891
5	Horticulture (Fruit crops+ Nursery)	52,763	80,350	27,587
6	Vermicompost	19,846	30,750	10,904
	Total	**1,98,720.52**	**3,96,641.25**	**1,97,920.73**

Integrated farming system trial was conducted at village Koproli, Tahasil - Uran, Dist. Raigad in coastal region (Table 14).IFS components were fish pond, paddy field, vegetables, poultry, vermicompost and horticultural crops. The poultry sheet was used as poultry manure to improve soil productivity. The fish yield was increased due to appropriate management and increase in farm produce by adopting integrated farming system. Total yield and profitability for 1 hectare area using with IFS components was B:C ratio 1.67.

Table 14: Total cost, Gross returns and Net returns of different enterprises in IFS (Koproli)

Sr. No.	Enterprise	Cost of production(Rs.)	Gross returns	Net returns
1	Crops/Cropping Systems (Including vegetables/flowers)	41,865.29	54,522.5	12,657.21
2	Fishery	59,710	1,23,000	63,290
3	Goatry		-	--
4	Poultry	8,149	9,450	1,301
3	Horticulture (Fruit crops + Nursery)	44,428.58	69,012	24,583.42
4	Vermicompost	19,846	36,000	16,154
	Total	**1,73,998.87**	**2,91,984.5**	**1,17,985.63**

6. FISH FARMING

Use of coastal saline area for agriculture alone has certain limitations. It has been estimated that out of 65,465 ha area 14,655 ha can be utilized for fish and prawn culture (Dodd, 1988). The marine fishing in Maharashtra is stagnated to near about three lakh tonnes for the last several years. Hence, it is essential to concentrate efforts on aquaculture in ponds or cages in marine, brackish as well as fresh water.

6.1 Rice-cum-fish farming :

The rice and fish farming has shown yield of *Cyprinus carpio* in the range of 138 to 286 kg/ha (Chavan *et al*., 1984b). The fish weight increased from 1.29 g at the time of release to 44 g at the time of harvest within 65 to 70 days (Shirgur *et al.*, 1986a).

6.2. Rice-cum-fish farming (Jitada) :

Paddy cum Asian sea bass (*Jitada*) culture yielded additional income of Rs. 12,000/- other than main crop Rice (Patil *et al.,* 2013) as shown in Table 15..

6.3. Fish / prawn culture is brackish water / fresh water ponds :

Jitada (*Lates calcarifer*) culture is fairly wide spread in the coastal area of the state and ranks second after Indian major carps in culture fisheries (Singh *et al*., 1990 a). After a period of 42.8 weeks with supplementary feedings it yielded an average weight of 318.4 kg/ha (Singh *et al.,* 1992) and when tilapia was used as forage fish an average growth of 570 g of *Jitada* in seven months was observed (Anonymous, 1991c). With the identical techniques of phased fertilization, the fresh water prawns *Macrobrachium rosenbergii* grew to an average weight of 60 g in 15 weeks, while the tiger prawn *Penaeus monodon* grew to an average weight of 43 g in 23 weeks (Shirgur, 1986b). In nursery ponds at paragon post larvae of *M. rosenbergii* were reared by administering different combinations of oil cake, rice bran and fish meal when the maximum growth / survival was observed with 80 per cent oil cake + 10 per cent rice bran + 10 per cent fish meal (Shirgur *et al*., 1990). The polyculture of *M. rosenbergii* with common carps resulted in an average weight gain of 125 g in a span of 25 weeks (Raje and Joshi, 1990).

These results revealed that there is a potential for the above fish and prawn species in the fresh /brackish water ponds in the coastal saline soils (Table 18). The seed of *Lates calcarifer* is in great demand on account of its potential. The spawn size seed collected from natural creeks were reared to fingerling size, which is generally preferred for stocking in ponds by giving different types of live and organic food. In this experiment continuous change in food preference in pre adult Jitada was observed (Singh *et al.,* 1990b).Organic manure in the form of Chicken Dropping (CD) and Raw Cow Dung (RCD) in 70:30 ratio instead of 100 % Raw Cow Dung (RCD) in phase fertilization technique for better production of mix zooplankton in the Khar Land ponds (Anonymous, 2014b).

Patil *et al.,* (2013) worked out the economics of fish culture in one acre pond (0.40 ha) and found 1 : 3 as cost : benefit ratio when Indian major carps and other fishes were cultivated (Table 16). The nursery management practice for IMC has shown significant role in improving economics of coastal region (Patil *et al.,* 2016)(Table 17).

Table 15. Economics of rice-cum-fish farming (Jitada).

Sr. No.	Particulars	Average Expenses in Rs. (per acre)
	Paddy cultivation	
1.	Rice Seed	750/-
2.	Fertilizers	1,000/-
3.	Ploughing	500/-
4.	Other management	2,000/-
5.	Rice sowing	2,500/-
6.	Weeding (before rice sowing)	1,000/-
7.	Rice harvesting	2,000/-
8.	Threshing	2,500/-
9.	Transport	1,500/-
	Total	13,750/-
10.	Jitada harvesting 200 nos with 150 gms / no. i.e. 30 Kgs (30 Kgs @ Rs. 400/- per Kg)	12,000/-
11.	Rice production 12 q/acre @ Rs. 1300/- per q	15,600/-

Table 16. Economics of one acre fish culture in pond.

Sr. No.	Particulars	Average Expenses in Rs. (per acre)
1.	Fertilizers	500/-
2.	Seed cost	2,500/-
3.	Pond management	10,000/-
4.	Feed cost (700 Kgs @ Rs. 33 / Kg)	23,100/-
	Total	**36,100/-**
5.	Harvested fishes - IMC & other fishes500 Kgs @ Rs. 140/- per Kg and 100 Kgs Jitada @ Rs. 400/- per Kgs	1,10,000/-

Table 17 : Details of nursery management of IMC at KLRS, Panvel

Sr. No.	Particulars	Details
1.	Area for fish nursery (m^2)	3000
2.	Duration	30 days
3.	Numbers of Catla spawn stocked	18 lakhs
4.	Numbers of Catla fry harvested	5 lakhs
5.	Survival (%)	27.77
6.	Size of Catla fry	3.0 cm
7.	Cost of spawn @RS. 3300/lakh	59400
8.	Cost of 250 kg feed required @ Rs. 45/kg	11250
9.	Cost of 150 kg lime	2250
10.	Manpower 2 nos. @ Rs. 300/person/day/ 30 days	18000
11	Total expense (Rs.)	90900
12	Income from sale of fry @ Rs. 1. Fry (Rs.)	500000
13	Profit (Rs.)	409100

6.4. New interventions in aquaculture and fish processing:

The sea bass fish *Lates calcarifer,* which is locally known as Jitada in Konkan is voracious feeder and cannibalistic. In Konkan, the seed of the sea bass is being collected from natural resources by local fisherman of Raigad district and sold to the fish farmers. (Vartak and Belsare, 2004). The farm feed was developed by incorporating Bombay duck fish meal as an attractant. This feed is low cost and acceptable by sea bass with better growth rate of fish (Vartak and Singh, 2004). The study also indicated that a proper level of dietary phosphorus is essential to maintain normal physiology, growth of Juvenile Asian sea bass, Jitada. According to results, 0.75% dietary phosphorus was required for the optimal growth and maximum tissue storage and mineralization (Anonymous, 2014a). Aquaculture of crabs was not popular along the west coast of Maharashtra despite huge demand of the crabs by local as well as international markets. There are two commercially important crabs of the genus *Scylla* known as mud crab, *Scylla serrata* and green crab, *Scylla tranquebarica*. The later was recorded for the first time on the west coast of India. (Vartak and Singh, 2002 and Singh *et al.,* 2005). The fattening of the green crab is livelihood development activity for the marginal farmers of the Konkan region. It can be carried out separately in cages, masonry tank and earthen ponds and successfully demonstrated on farmer's field (Vartak *et al*. 2006a and b).The farming of these crabs was possible after installing fencing to the pond. The plastic tarpaulin can be used as a fencing material as it's rigid, slippery and remain in good condition as compared to other material. Also crabs are unable to escape due to the slippery nature and cannot bite as they don't get grip to bite.

Feeding three times in a day was found better in terms of growth and survival of stunted catla fingerlings in ponds of Khar Land Research Station, Panvel. (Anonymous, 2011). The study on the use of floating feed mash has showed better growth and survival than traditional feed mixture (Vartak and Patil, 2016). The study on manuring the nursery ponds revealed that treating nursery ponds with fertilizer dose containing 70% chicken manure and 30% raw cow dung shows significant increase in mix zooplankton population *i.e.* 2289.75 nos./lit compared with the other treatments (Anonymous, 2014b)

Farming of All male tilapia and Pangasius fish**,** floating feed technology, use of prebiotic and probiotics in aquaculture, value addition and marketing of fish are recent arenas which are being exploited. The research work on these aspects is in pipeline.


Male Tilapia (*Tilapia niloticus*)


Green crab (*Scylla tranquebarica*)


Asian Sea bass, Jitada (*Lates calcarifer*)


Pangasius fish (*Pangasius hypophthalmus*)


Floating fish feed


Succesful green crab farmer of Panvel


Green crab fattening cages


Floating fish cage system of farm pond

Table 18: Summary results of fish and/ or prawn culture trials in coastal saline soil of Maharashtra

Sr. No.	Fish and Prawn species cultured	Culture type	Location	Culture period (weeks)	Supplementary feed given, if any	Initial average wt (g)	Final average wt (g)	Yield (kg/ha)	References
1	*C. carpio*	Paddy cum fish culture	Panvel	-	Nil	10	54-113	138-160	Chavan *et al.*, 1984b
2	*C. carpio*	-do-	Panvel	-	GOC	10	110	286	Chavan *et al.*, 1984b
3	*C. carpio*	-do-	Rice fields in Raigad district	9 to 10	Nil	1.29	44	99.15	Shirgur *et al.*, 1986a
4	*L. calcarifer*	Monoculture	Pargaon	42.8	Nil	7.5	283.4	138.4	Singh *et al.*,1992
5	*L. calcarifer*	Monoculture	Panvel	43.5	GOC+RB+FM	5	223.1	336	Singh *et al.*,1992
6	*L. calcarifer* + *O. mossambicus*	Composite culture	Pargaon	28	GOC+RB	6.25 15.0	570 100	NR	Anonymous, 1991c
7	*M. rosenbergii*	Monoculture	Pargaon	15	GOC+RB	0.6	60	NR	Shirgur *et al.*, 1986b
8	*M. rosenbergii*	Polyculture (with IMC)	Ulawe (Tal Panvel)	25	GOC+RB+TF	1.0	125	NR	Raje& Joshi, 1990
9	*P. monodon*	Monoculture	Pargaon	23	GOC+RB+Manure	0.03	43	NR	Shirgur *et al.*, 1986 b
Abbreviations: RB- Rice bran, GOC – Groundnut oil cake, FM – Fish meal, TF – Trash fish, NR – Not Reported									

6.8. Survey of natural seed resources :

The preliminary survey of natural seed resources of commercially important fish and prawn species reveals that seeds of *Lates calcarifer* is available along the Dharmtar creek in Poynad and Shahabaj area of Raigad district in large quantity and along the Naigaon and Vasai creeks in Thane district during the period from June to August. The seed of mullet (*Liza persia*) was available throughout the year in and around Ratnagiri. While, the seed of *Mugil cephalus* is available during the period from June to September. The seed stocks of *Penaeus merguiensis* was found in Zadgaon creek near Ratnagiri and Mochemad creek near Vengurla in abundance during the months of May – June while, the seed of *Penaeus monodon* was found to be limited (Table 19) (Anonymous, 1991 d).

Table 19. Penaeld shrimp seed in some creeks of south Konkan region.

Sr. No	Creek	Location	Dominant seed species	Seed availability / man/hr
1.	Bhatye	Karle	*P. merguiensis*	77
2.	Gaokhadi	Purnagad	*P. merguiensis*	131
3.	Kalavaii	Kandalgaon (Near Malwan)	*M. monoceros*	476
4.	Kalbadevi	Kalbadevi	*P. merguiensis*	523
5.	Mirya	Mirya	*P. merguiensis*	135
6.	Mochemad	Mochemad (Near Vengurla)	*P. merguiensis*	796
7.	Terekhol	Arone (Near Vengurla)	*P. merguiensis*	190
8.	Varvade	Varvade	*P. merguiensis*	69
9.	Zadgaon	Zadgaon	*P. merguiensis*	1086

SUMMARY

Soils :

The coastal saline soils locally called *Khar* lands in the Konkan are problematic soils of the region. The repeated ingress of saline creek water as well as upward rise of salts due to low ground water table during hot season make these soils unsuitable for cropping. The average ECe of the soils during pre monsoon period is 25 dSm^{-1}. Na^{+} and cl^{-} are the dominant ions on the exchange complex. The heavy texture of the soil reduces the hydraulic conductivity and infiltration rate, whichimpeded the drainage. The soils are adequate in available nutrients. However, their productivity is affected by high salt content. Acid sulphate soils are observed in Sindhudurg district of Konkan having peculiar characteristics can be brought under cultivation by proper management.

Reclamation measures :

They include primarily the construction of sea dykes and provision of sluice gates for preventing ingress of saline sea/ creek water. The embankment having height greater than the maximum tidal height of the location, stone pitching on creek side and grass cover on land side are recommended method to check soil erosion and give stability to embankment. Conservation of mangroves on creek side helps in minimizing the erosion due to waves of sea water. Deep drains of 1.5 to 2.0 m at 100 m distance coupled with other reclamation measures such as cut of drains parallel to embankment drainage wells and surface dug out ponds are found effective in lowering the soil salinity.

Crop and soil management :

During the early stages of reclamation the local tillage practice of *Ulkatni* and *Awatni* and growing of salt tolerant rice varieties such as KR 1-24 and BR 4-10 are advisable. However, as reclamation process progresses with time, ploughing and shallow transplanting were found beneficial. *Rahu* sowing is another method followed in khar lands of Konkan where sprouted rice seeds are broadcasted in the fields. The method is adopted when the seedlings in the nurseries diedas consequence of increase in salinity due to dry spells or if the rice fields are permanently under water, which makes it difficult to carry out normal tillage operations. The KR 1-24 and BR 4-10 are most suited for *rahu* sowing.

Khar lands of Konkan are monocropped with rice, which is grown in *kharif*. Six salt tolerant rice varieties have been evolved so far at the station as a result of rice breeding programme since 1953.. KR 1-24 and BR 4-10, the selections from local rata were highly salt tolerant but had low yield potential. The hybridization programme evolved MK 47-22 and SR 3-9 but compare to the high yielding rice varieties such as Jaya, IR 8, etc. they also could not satisfy the need of farmers. Recently, Panvel 1,Panvel 2 and Panvel 3, high yielding salt tolerant varieties of rice have been evolved with yield potential comparable with any of the high yielding rice varieties suitable for normal soils.

Addition of organic matter either in the form of FYM, compost or green manure reduces the adverse effect of salinity on crop. The fertilizers like ammonium sulphate, calcium ammonium nitrate, ammonium sulphate nitrate, which have residual acidity are found equally effective in these soils. A dose of 100:50:50 kg/ha of NPK is recommended

for high yielding salt tolerant rice varieties. The acquatic weed *Ceratophyllum sp.* (Har weed) becomes nuisance to paddy under certain conditions. It can be completely controlled by hand weeding and with the tool developed by the khar land research station, Panvel. No chemicals have been found effective in completely eradicating the menace of the weed.

The chances of *rabi* cultivation in *khar* lands are remote. However, stored rain water in surface dug out ponds can be used as protective irrigation for short duration and salt tolerant cropslike spinach, radish, mustard, linseed, sugar beet, tomato and cucurbitaceous vegetables besides its use for rice during dry spells in *kharif* season. Cultivation of Okra and bitter gourd on field bunds during *kharif* and *rabi* season give additional monetary returns.

Fish farming :

Simultaneous culturing of fish in the rice fields has been a practice adopted by the farmers in the rice growing area all over the world. The farmers in coastal area of Konkan also rear *Lates calcrifer* (*Jitada*) in their rice fields. However due to shortage of its seed the practice has remained with limited numbers of cultivations. The research done at Panvel and Pargaon has shown that *Cyprinus carpio* and *Lates calcarifer* with tilapia can be successfully grown in paddy fields without hampering rice yields as well as in farm ponds. External feeding to fish through dung and oil cakes have proved beneficial. Similarly, monoculture and polyculture of prawns such as *Penaeus monodon* and *Macrobrachium rosenbergii* in brackish water ponds have shown promise.

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Khar Land Research Station, Panvel, Maharashtra (Established 1959)
Name of the Incharge Officers

Name of the Officer Incharge (Dr./Shri.)		Designation	From	To
1	B.D. Kamat	Khar Land Investigator	04-06-1959	10-02-1960
2	G.N. Dixit	Khar Land Investigator	11-02-1960	08-01-1966
3	K.S. Pharande	Khar Land Investigator	09-01-1966	05-06-1968
4	G.M. Gokhale	Khar Land Investigator	08-07-1968	08-01-1970
5	G.N. Dixit	Khar Land Investigator	09-01-1970	31-05-1972
6	T.N. Patil	Khar Land Investigator	10-08-1972	11-09-1973
7	R.G. Joshi	Khar Land Investigator	12-09-1973	28-02-1981
8	K.N. Chavan	Khar Land Investigator	01-03-1981	28-07-1987
9	V.B. Mehta	Khar Land Scientist	24-09-1987	12-09-1996
10	S.S. Dhane	Khar Land Scientist	26-12-1996	31-08-2005
11	J.H. Dongale	Khar Land Scientist	01-09-2005	14-12-2005
12	S.T. Ingale	Khar Land Scientist	15-12-2005	18-05-2006
13	S.L. Powar	Khar Land Scientist	19-05-2006	31-12-2006
14	S.T. Ingale	Khar Land Scientist	01-01-2007	30-06-2007
15	T.S. Mahajan	Khar Land Scientist	26-07-2007	04-06-2012
16	K.D. Patil	Khar Land Scientist	14-06-2012	till date