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Arresting Seawater Ingress and Increasing Agricultural Production through Water Resource Development and Management in Gujarat

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Gujarat is having the longest coastline in India. Owing to rapid industrial development, over-exploitation of ground water and erratic nature of rainfall, the Gujarat coast is facing major problems of seawater ingress and declined agricultural productivity. Gujarat government has largely adopted engineering approach and created number of physical structures to prevent tidal water ingress, to harvest rainwater, and to recharge ground water. NGOs have adopted water resource development and management approaches such as rainwater harvesting structures and interlinking of ponds with rivers, etc. This sustainable water resource development and management have not only helped arresting the seawater ingress but also increased agricultural production and income. It is urged that there is a need to invest adequate financial resources to intensify such interventions at a larger scale.

*(**Key words:** Seawater ingress, Water resource development & management, Impact on agriculture)*

Gujarat occupies the longest coastline of about 1600 km in the country. Commercial activities such as mining, salt pan, and other industrial development, changing rainfall pattern from low intensity rainfall spread over many days to high intensity rainfall occurring in a few days (Sakthivadivel and Talati, 2004), deforestation, and excessive withdrawal of ground water have invited seawater intrusion in the Saurashtra coast. The seawater intrusion and ingress are widespread in the entire coastal Saurashtra of Gujarat, which is having 765 km long coastline. Seawater ingress was maximum (observed through TDS line) up to 8.8 km landward and the area affected by salinity was 567,688 ha in the Saurashtra coast. It has deteriorated land and water quality. Few researchers have thoroughly studied the adverse impact of increasing coastal salinity in the Saurashtra coast (Golakiya *et al.*, 1999, Khunt *et al.*, 2003). These studies clearly came out with results that declined agricultural productivity, migration, drinking water problem, income inequality, reduction in livelihood options are major consequences of salinity intrusion.

On the recommendations of the two High Level Committees (HLC-I, HLC-II) set up by the Government of Gujarat in 1976 and 1978, respectively, Government of Gujarat established Salinity Ingress Prevention Circle (SIPC) for development of the coastal areas of Saurashtra and Kachchh regions affected due to salinity. These committees also recommended three-pronged strategy, viz. salinity control, ground water recharge, and crop diversification with ground water regulation to address the problem. The SIPC is engaged in implementation of salinity control and development of recharge techniques. Besides, efforts made by other non-governmental organizations, such as Aga Khan Rural Support Programme (India) (AKRSP-I), Ambuja Cement Foundation (ACF), Gramya Vikas Trust (GVT), Tata Chemical Society for Rural Development (TCSRD), and ORPAT Chritable Trust are remarkable in solving the problem through water resource development and management. The joint efforts of government and non-government organizations improved water level and water quality and also increased agricultural production and productivity in their project villages.

MATERIALS AND METHODS

The paper is largely based on secondary information collected from different organizations working in the coastal areas. Annual reports and project documents were other sources of information. Informal discussion was held with key informers, such as NGO leaders and government officials followed by field visits. Trend analysis for water quality and water level fluctuations was applied. The study incorporated few case studies from some of the organizations, especially ACF, SIPC and ORPAT to illustrate the impact and importance of water resource development and management.

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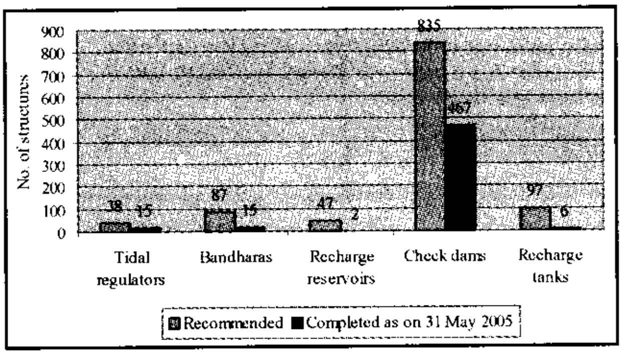
RESULTS AND DISCUSSION

Tidal regulators and *bandharas*

SIPC has constructed numerous tidal regulators and *bandharas* as salinity control structures, and check dams, recharge reservoirs and recharge tanks as ground water recharge structures at a cost of Rs. 2,200 million (Fig. 1). However, the achievement was far below the recommended quantity of structures owing to lack of fund. A total water storage capacity of these structural interventions was 243.90 MCM. It improved 132,432 ha land out of 700,120 ha salinity affected land and has created irrigation potential in 29,987 ha land.



Source: SIPC, Rajkot

Fig. 1. Structural interventions in Gujarat coast

An example of a *bandhara* was constructed on Mahuva coast, Bhavnagar in the year 1998 at a cost of Rs. 130.5 million. It has the storage capacity of 21.22 million cubic meters (MCM). The created irrigation potential was 1500 hectare. Table 1 reveals that agricultural productivity of different crops increased from 8 percent in pearl millet to 83 percent in wheat. It has generated per hectare incremental income of INR 2,660 to 111,900 under different crops at 2001 market price.

Rainwater harvesting structures (RWHS)

ORPAT charitable trust constructed 263 RWHS in six coastal villages of Maliya *taluka*, Rajkot district at a cost of Rs. 11.47 million. The intervention has brought 5,750 ha land of 1581 farmers under irrigation. These villages did not have any irrigation facility prior to RWHS and were fully dependent on rainfed agriculture. However, after construction of RWHS, there was an annual increment in agricultural crop production, i.e. 17,915 q worth of Rs. 31 million (Table 2). Satellite images of 1996-97 and 2003-04 clearly show that green cover increased in coastal villages where watershed development work has been intensified.

Interlinking village ponds with rivers

ACF constructed eight link channels in Kodinar *taluka* of Junagadh district. A link water channel was constructed at a cost of Rs. 1.17 million to connect ponds of five villages located adjacent to the Goma River in Kodinar *taluka* of Junagadh district in the year 1999-2000. The village ponds were deepened at the cost of Rs. 1.5 million to increase water holding/storage capacity to capture maximum surface runoff water. A total storage capacity of 0.35 MCM was thus created. Resultantly, it benefited 339 wells, and 1161 hectare land belonging to 316 farmers is now under irrigation. Table 3 illustrates a case study of one of the interlinked villages, i.e. Pipli. The case study indicated that there was a reduction in seed application rate from 60 to 33 percent and on the contrary the agricultural productivity increased from 50 to 100 percent because of increased availability of fresh water (Table 3).

In the second case, ACF linked Goma River with a village pond of Panadar by constructing a 1.5 km

Table 1. *Impact of Nikol* bandhara *on agriculture*

Crop	Yield (q/ha)		% change	Per hectare incremental Income (Rs)
	Before (1996-97)	After (2001)		
Bajara	107.00	116.00	8.41	4198
Cotton	66.93	83.00	24.01	33565
Groundnut	68.00	77.00	13.23	11835
Onion	860.00	1233.00	43.37	111900
Wheat	55.00	101.00	83.63	37490
Til	13.00	15.75	21.15	4592
Jowar	31.00	35.00	12.90	2660

Source: Bhammar, 2001

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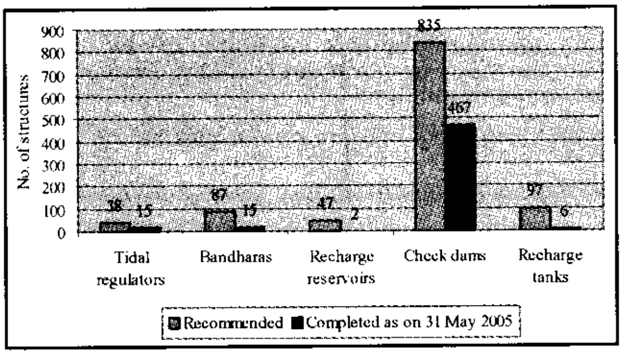

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Crop	Yield (q/ha)		% change	Per hectare incremental Income (Rs)
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Groundnut	68.00	77.00	13.23	11835
Onion	860.00	1233.00	43.37	111900
Wheat	55.00	101.00	83.63	37490
Til	13.00	15.75	21.15	4592
Jowar	31.00	35.00	12.90	2660

Source: Bhammar, 2001

Table 2. *Impact of rainwater harvesting on coastal villages of Maliya* Taluka, *Rajkot*

Name of Village	No. of RWHS in building RWHS	Total invest-ment farmers (Rs)	No of beneficiary	Irrigated land (ha)	Additional agricultural production (q)					Additional Income Rs.
					Groundnut	Til	Cotton	Wheat	Cumin	
Juna Ghantila	35	1,800,000	184	650	1000	380	400	1200	300	5,850,000
Vejalpar	42	1,800,000	284	540	950	300	375	950	200	4,860,000
Kumbhariya	57	1,800,000	298	560	1000	400	425	1100	105	5,040,000
Khakhrechi	43	1,800,000	220	580	900	375	500	1100	170	5,220,000
Rohishada	54	1,800,000	415	610	900	400	400	1050	220	5,490,000
Hajnadi	32	2,475,000	180	510	1000	250	300	1100	165	4,590,000
Total	263	11,475,000	1581	3450	5750	2105	2400	6500	1160	31,050,000

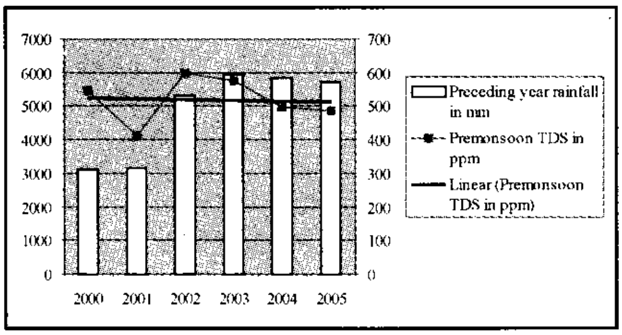
Source: ORPAT Charitable Trust, Morbi

Table 3. *Impact of interlinking ponds on agriculture*

Crop	Seed requirement (kg/acre)[1]			Yield (kg /acre)		
	Before	After	% change	Before	After	% change
Pearl millet	4	2.5	37.50	525	1050	100
Groundnut	70	40	42.86	700	1050	50
Sugarcane	NA	NA	NA	35000	53000	51.43
Lucern	30	12	60.00	30	60	100
Wheat	75	50	33.33	1050	1750	66.67
Jowar	70	30	57.14	NA	NA	NA

[1]ha = 2.52 acre, Source: ACF, 2004

long water channel in May 2002 in order to transport surplus river water into the pond. Farmers excavated five water channels of 100 meters, each from this link channel, to irrigate their farms. A total water storage capacity of the link channel was 0.05 MCM. It started providing irrigation benefit to 30 farmers covering 105 hectare land. Water level of 30 wells improved. Resultantly, agricultural productivity of major crops also improved (Fig. 2).



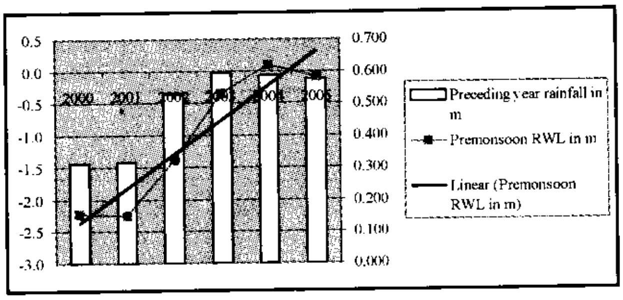
Source: SIPC, Rajkot

Fig. 2. Improvement in wells' water quality surrounding Nikol *bandhara*

Liking a river with a *bandhara* (Tidal regulator)

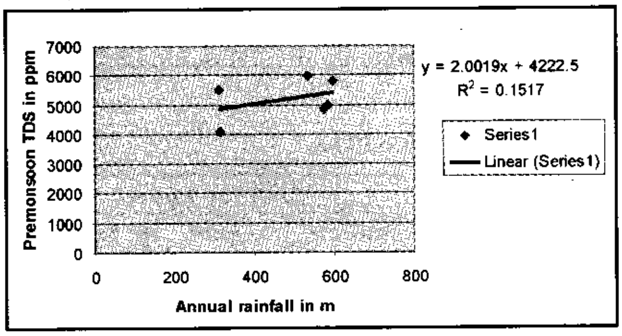
In 2002, ACF laid a pipeline, which was having a length of one km, connecting Singoda River with Barda-bandhara (tidal regulator) mainly to divert surplus water from the river to *bandhara*. A total water storage capacity of the *bandhara* was 4.67 MCM which was not fully utilized before. However, after installation of the pipeline, water table in 180 wells improved and approximately 900 ha land belonging to 180 farmers was brought under irrigation.

Sustainable water resource development approach of ACF brought the water quality changes in its project villages. Figs. 3 and 4 reveal that water levels (TDS line) in observation wells in Devli village dropped down while water level of almost all observation wells improved during similar period because of the intervention of ACT activities. It clearly indicates that there may be further improvement in the well water level and quality in future.



Source: SIPC, Rajkot

Fig. 3. Rise in wells' water level surrounding Nikol *bandhara*



Source: SIPC, Rajkot

Fig. 4. Correlation between rainfall and TDS, Nikol *bandhara*

CONCLUSION

The study result indicates that there is a need to scale up the above mentioned water resources development and management activities in other parts of the Gujarat coast as well as in other coast of the country having similar kind of topographical and geohydrological conditions. Lack of adequate fund is a major constraint to go for further development of water resource, especially in coastal areas. Thus, it attracts immediate attention of bureaucrats and policy makers to make adequate financial provisions to intensify the aforesaid activities. The defined activities and financial allocation under the new watershed guideline (Hariyali) may not be able to fulfil the requirement of coastal areas because of the topographical and geohydrological constraints. Therefore, there is a need to change the watershed guideline in favour of coastal areas.

ACKNOWLEDGMENT

The author acknowledges financial assistance provided by Sir Ratan Tata Trust, Mumbai for the study. He is also thankful to SIPC, ACF, ORPAT and other organizations for providing secondary information.

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Effect of Moisture Conservation Practices and Nutrient Management on Quality and Yield of Rainfed Groundnut (*Arachis Hypogaea* L.)

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An experiment was conducted during *kharif* 1999 and 2000 to study the influence of moisture conservation practices and nutrient management on the quality and yield of rainfed groundnut. The moisture conservation practices involving alternate furrow and bed, ridges and furrows and use of plastic and straw mulches had marked influence on protein and oil content over control. Similar positive significant results were also recorded by the moisture conservation practices in terms of protein, oil and pod yield over control. Full recommended dose of fertilizer (100% RDF) + IBA @ 50 ppm + Urea @ 1% spray at 40 and 60 DAS recorded significantly higher protein content (21.43%), protein yield (268 kg ha^{-1}) and pod yield (1724 kg ha^{-1}) over control (no nitrogen).

(***Key words:*** *Moisture conservation, Quality, Land configuration, Mulching, Nutrient management, Rainfed groundnut*).

Groundnut, mostly grown in India during *kharif* season, is primarily rainfed. Water is the most vital resource in crop production especially in arid and semiarid regions. The major area in India including Gujarat state remains under rainfed conditions where groundnut cultivation is done on varying types of soil under different fertility levels, many of which are low in organic matter and poor in water holding capacity. Further, the Saurashtra region of Gujarat is highly influenced by vagaries of monsoon, which results in lower and unstable yields. The region also faces problems of poor fertility and insufficient moisture supply for successful crop production that results in partial or total failure of crop with occurrence of mild to severe drought. The most effective and cheapest way of conserving rainwater is to hold *in-situ*. Land configurations and use of mulches are appropriate measures to conserve rainwater and sustain crop production (Singh and Das, 1988). It is also well established that fertilizer management is one of the important components of several crop and soil management practices required for high and sustainable productivity under rainfed conditions. Balanced application of nutrients through organic and inorganic sources besides biofertilizers and growth harmones may supply all the nutrients in suitable proportions, thereby enhance the groundnut yield under rainfed condition. Keeping in view the above situation the present investigation was undertaken to find an optimum combination of moisture conservation and nutrient practice for quality and yield improvement in rainfed groundnut.

MATERIALS AND METHODS

An experiment was conducted at the Instructional Farm, Gujarat Agricultural University, Junagadh during 1999 and 2000. The soils were clayey in texture, slightly alkaline in reaction and low in phosphorus. Thirty-six treatment combinations in total were evaluated in split-plot design with three replications taking combination of three levels of land configurations (L_0= Flat bed, L_1= Ridges and furrows, L_2= Alternate furrows and beds) and three treatments of mulches (M_0= Control, M_1= Wheat straw @ 5 t ha^{-1} and M_2= Plastic mulch 8μ thick) as main treatments, and four levels of nutrient management (N_0= Control, N_1= Recommended dose of fertilizer (RDF), i.e. 12.5 N + 25.0 P_2O_5 kg ha^{-1}, N_2= 50% RDF + 5t ha^{-1} FYM + Rhizobium + Phosphorus solubulizing mycorrhiza (PSM), N_3= 100% RDF + Indole Butric Acid (IBA) @ 50 ppm + Urea @ 1% at 40 and 60 days after sowing (DAS) as sub-treatments. GG-20, semi spreading variety of groundnut, was sown at a spacing of 60 x 10 cm (Table 1).

Nitrogen and phosphorus were applied as basal before sowing. Land configurations and mulches were applied as per treatments at 20 days after sowing. Indole Butric Acid (IBA) and Urea were

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Table 1. *Effect of different treatments on oil content, oil yield, protein content, protein yield and pod yield of rainfed groundnut*

Treatment	Oil content			Oil yield (kg ha^{-1})			Protein content (%)			Protein yield (kg ha^{-1})			Pod yield (kg ha^{-1})		
	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled	1999	2000	Pooled
Land configuration															
L_0= Flat bed	49.55	49.83	49.69	440	575	508	20.90	21.15	21.02	187	245	216	1246	1606	1426
L_1= Ridges & Furrows	49.87	49.88	49.87	500	663	582	21.01	21.26	21.03	210	283	247	1387	1800	1594
L_2= Alternate Furrow & Bed	49.87	49.92	49.89	528	679	604	21.13	21.32	21.22	224	291	258	1463	1866	1665
SEM±	0.33	0.47	0.29	11	14	9	0.11	0.11	0.08	4	8	4	30.88	34.45	23.13
CD (p=0.05)	NS	NS	NS	34	41	26	NS	NS	NS	13	23	13	92.61	103.29	66.67
Mulch															
M_0= Control	49.57	49.77	49.67	457	586	522	20.88	21.10	20.99	193	249	221	1280	1649	1464
M_1= Wheat straw @ 5 t ha^{-1}	49.83	49.92	49.88	508	661	585	21.08	21.32	21.20	216	283	250	1419	1830	1624
M_2= Plastic mulch 8 μ	49.88	49.94	49.91	503	671	587	21.07	21.31	21.19	213	287	250	1398	1794	1596
SEM±	0.33	0.47	0.29	11	14	9	0.11	0.11	0.08	4	8	4	30.88	34.45	23.13
CD (p=0.05)	NS	NS	NS	34	41	26	NS	NS	NS	13	23	13	92.61	92.61	66.67
Nutrient management															
N_0= Control	49.41	49.70	49.56	404	538	471	20.42	20.68	20.55	167	224	196	1147	1446	1297
N_1= 100% RDF (12.5 N + 25.0 P_2O_5 kg ha^{-1})	49.93	49.91	49.92	508	667	588	21.22	21.44	21.33	217	287	252	1416	1847	1631
N_2= 50% RDF + 5 t ha^{-1} FYM + Rhizobium + PSM	49.71	49.82	49.76	499	648	573	21.09	21.31	21.20	212	278	245	1392	1796	1594
N_3= 100% RDF + IBA @ 50 ppm + Urea 1% spray at 40 & 60 DAS	50.00	50.08	50.04	547	704	625	21.31	21.54	21.43	233	303	268	1507	1941	1724
SEM±	0.26	0.42	0.25	13	15	10	0.08	0.10	0.07	5	6	4	34.69	36.92	25.33
CD (p=0.05)	NS	NS	NS	36	44	28	0.23	0.30	0.19	13	18	11	94.40	104.72	71.08

NS-Non-significant

together sprayed as per the treatments twice at 40 and 60 DAS, respectively. Oil content in kernel was determined by NMR as per the method suggested by Tiwari *et al.* (1974), while protein content was estimated as per method described by Angelo and Mann (1973).

RESULTS AND DISCUSSION

Effect of moisture conservation practices

The data (Table 1) revealed that the oil and protein yield were influenced significantly by changing land configurations. Alternate furrow and bed registered higher oil (604 kg ha^{-1}) and protein (258 kg ha^{-1}) yield in pooled data which was significantly at par with ridges and furrows and significantly superior to flat bed method. Further, alternate furrow and bed resulted in significantly higher pod yield (1665 kg ha^{-1}) in pooled results over other treatments, while it was at par with ridges and furrows in individual years. The higher yield under modified land configurations would be attributed to favourable soil physical environment, increased soil moisture regime coupled with higher nutrient availability, which finally helped in higher photosynthetic activity with favourable yield attributes and yield. Consequent to higher pod yield, the oil and protein yields were also higher with modified land configurations. Similar results were also reported by Kadam *et al.* (2000).

Wheat straw followed by plastic mulch produced significantly higher oil and protein yield over control. Further, wheat straw resulted in 12.06 and 13.12 percent more oil and protein yield, respectively over control in pooled results. Wheat straw also produced maximum pod yield (1419, 1830 and 1624 kg ha^{-1} in 1999, 2000 and pooled results, respectively) but it was at par with plastic mulch though significantly superior to control. Owing to higher pod yield the oil and protein yields were significantly higher under mulches over control. The mulch application might have resulted in increased microbial acitivity, reduced thermal radiation and optimum soil temperature, conserving more moisture and higher uptake of nutrient and finally higher yield. These results are in conformity with those reported by Khistaria *et al.* (1994) and Shinde *et al.* (2000).

Effect of nutrient management

Perusal of data (Table 1) would indicate that different nutrient management treatments had significant effect on oil yield, protein content and protein yield and also on pod yield in both the years and in pooled results. While, oil content in kernel remained unaffected during the same period. Full Recommended Fertilizer Dose (100% RDF) + IBA @ 50 ppm + Urea @ 1% spray at 40 and 60 DAS (N_3) resulted in significantly higher oil yield (625 kg ha^{-1}) and protein yield (268 kg ha^{-1}) in pooled data as compared to other treatments. Further, N_3 recorded higher pod yield (1724 kg ha^{-1}) in pooled results while it was at par with 100% RDF (N_1) in individual years. Fifty percent RDF + 5 t ha^{-1} FYM + Rhizobium + PSM (N_2) also recorded at par pod yield with N_1 though significantly superior to control. The percent increase in pod yield with N_3, N_1 and N_2 over control was 39.92, 25.75 and 22.89, respectively. The increase in pod yield with nutrient management could be attributed to synergistic effect of combined application of different sources and levels of nutrients coupled with more soil moisture that helped the plant for optimum growth, partitioning of photosynthates, finally resulting in higher yield. Further, nitrogen being an integral part of protein, application of fertilizers at N_3, N_1 and N_2 level resulted in higher protein content as compared to control (N_0). The increase in oil and protein yield could be attributed to cumulative effect of pod yields. Mehata *et al.* (1996), Shinde *et al.* (2000) and Patra *et al.* (1995) also reported similar findings. The amount and distribution of rainfall was good in 2000 (529.8 mm) as compared to 1999 (394.5 mm), hence the growth, yield attributes and yield level were better in 2000.

From the results it could be concluded that combined use of modified land configurations, such as alternate furrow and bed, ridges and furrows with wheat straw or plastic straw mulch and 100% RDF + IBA @ 50 ppm + Urea @ 1% spray at 40 and 60 DAS would help in increasing the quality and productivity of rainfed groundnut.

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Evaluation of Microirrigation Systems for Summer Pumpkin (*Cucurbita moschata*) Production

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The field trial was conducted to study performance of drip and microjet irrigation systems with the varying irrigation schedules, based on evaporation values, on the yield attributes and fruit yield of pumpkin variety Ankur Vishal on lateritic soil of coastal Konkan during summer season. The surface irrigation treatment recorded significantly superior average weight of fruit, while the significantly superior values for number of fruits per hill and fruit yield (32.48 t ha^{-1}) was recorded by microjet irrigation system with irrigation scheduled at 100% of ET. Latter treatment saved about 22.56% irrigation water over surface irrigation with water use efficiency of 654.96 kg ha^{-1} cm^{-1}. Microject irrigation scheduled at 100% ET registered a net profit of Rs. 42,304 ha^{-1} with B:C ratio of 1.48. Under water shortage in the summer season, it could be advisable to adopt microjet irrigation at 80% ET with 37.88% saving in irrigation water over surface irrigation.

(***Key words:*** *Microirrigation, Water use efficiency, Economics)*

In microirrigation systems irrigation water is applied frequently as per the need of crop without creating water stress in soil. In drip irrigation system water is applied only on 25-60% of the total area with considerable water saving. In case of microjet water is sprinkled over the plant canopy and soil surface. Soils having low moisture retention give better response to sprinkling of irrigation water over the surface. Limited data regarding saving of water are available under microirrigation system on lateratic soils. Pumpkin (*Cucurbita moschata*) occupies a prominent place among vegetables owing to its high productivity, nutritive values, good storability, long period of availability, better transport qualities, and extensive cultivation in tropical and subtropical parts of the world. Considering the advantages of microirrigation and importance of their scheduling, the present study was conducted on pumpkin to quantify advantages of various microirrigation systems along with their optimum scheduling.

MATERIALS AND METHODS

The investigation was conducted at Agronomy Farm, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (M.S.) during summer season of the year 2003 on pumpkin var. Ankur Vishal on lateritic soil. The treatments comprised of surface irrigation method (T_1) along with recommended package of practices. The treatments T_2, T_3, T_4 and T_5 were supplied with drip irrigation applied at 100%, 80%, 60% and 40% of ET, respectively. While, the treatments T_6, T_7, T_8 and T_9 comprised of supply of irrigation water through microjet applied at 100%, 80%, 60% and 40% of ET, respectively. The surface irrigation treatment was supplied with 5 cm water per irrigation. Paddy straw at the rate of 5 t ha^{-1} was applied as mulch after 12 days of sowing uniformly to all the treatments. The microjets were installed in the field at a spacing of 2.24 m with a stake height of 75 cm. The discharge of microjet was 35 lph at an operating pressure of 1.25 kg cm^{-1}. In drip irrigation treatment online drippers were placed at a distance of 112 cm and lateral spacing was maintained at 150 cm. The discharge of dripper was 4 lph with one dripper per hill. The crop was sown with 1.12 m x 0.75 x 1.5 m spacing following the paired row planting pattern. Crop was supplied with 5 t ha^{-1} of poultry manure and 100 kg N, 50 kg P_2O_5 and 50 kg K_2O per ha in each. The poultry manure and quantity of P and K were supplied while preparing hills. N was applied in three splits at 12, 30 and 60 days after sowing. The crop was sown during second week of February and harvested in three pickings. The trial was conducted in randomized block design and each treatment was replicated thrice. For check basin, irrigation was scheduled after 4-5 days as per recommendation. The experimental site was clay loam in texture, slightly acidic in reaction with pH 6.2. The field capacity and wilting point values were 28% and 15%,

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Table 1. *Yield attributes, yield, irrigation water applied, saving of irrigation water, water use efficiency and economics of pumpkin as influenced by irrigation system and scheduling*

Treatment		Number of fruits per hill	Average weight of fruit (kg)	Fruit yield (t ha^{-1})	Irrigation water applied (cm)	Saving of irrigation over T_1	Water use efficiency (kg $ha^{-1} cm^{-1}$)	Total cost (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1	Surface irrigation with recommended practice	1.42	2.52	28.10	64.00	-	439.00	71,675	1,12,400	40,725	1.57
T_2	Drip irrigation 100% of ET	1.72	1.87	25.45	49.00	23.43	519.39	80,243	1,01,920	21,677	1.27
T_3	Drip irrigation 80% of ET	1.50	1.56	18.41	39.20	38.75	469.64	75,540	73,640	-1,900	0.97
T_4	Drip irrigation 60% of ET	1.37	1.62	17.55	29.40	54.06	596.94	74,968	70,200	-4,768	0.94
T_5	Drip irrigation 40% of ET	1.18	1.47	13.82	19.60	69.38	705.10	72,481	55,280	-17,201	0.76
T_6	Microjet irrigation 100% ET	1.86	2.16	32.48	49.56	22.56	654.96	87,536	1,29,840	42,304	1.48
T_7	Microjet irrigation 80% ET	1.82	2.18	31.98	39.76	37.88	804.32	86,715	1,27,920	41,205	1.47
T_8	Microjet irrigation 60% ET	1.72	2.10	28.83	29.96	53.19	962.28	84,628	1,15,400	30,672	1.36
T_9	Microjet irrigation 40% ET	1.83	1.94	28.04	20.10	68.50	1090.87	84,088	1,12,160	28,072	1.33
SE ±		0.14	0.15	3.20							
CD at p=0.05		0.41	0.44	9.58							

respectively. The data on yield attributes and yield were recorded at harvest and economics of the treatments were studied.

RESULTS AND DISCUSSION

The yield attributes, viz. number of fruits per hill and average weight of fruits (kg) was statistically influenced by the irrigation systems and irrigation schedule (Table 1). The treatment T_6, microjet irrigation at 100% of ET recorded significantly superior number of fruits per hill (1.86 fruits per hill) over the treatments T_1, T_4 and T_5. The treatment T_6 was at par with treatments T_2, T_3, T_7, T_8 and T_9. The significantly superior values for average weight of fruits (2.52 kg fruit per hill) were recorded by the treatment T_1, surface irrigation with recommended practice, over the treatments T_2, T_3, T_4, T_5 and T_9. The treatment T_1 was at par with T_6, T_7 and T_8. The bigger size of fruits were observed in surface irrigation method and microjet irrigation treatments. This may be due to higher availability of moisture in case of check basin and better distribution of soil moisture within root zone in case of microjet irrigation treatments. The significantly superior fruit yield (32.48 t ha^{-1}) was recorded by the treatment T_6, viz. microjet irrigation at 100% ET over the treatments, T_3, T_4 and T_5. The treatments, viz. T_6, T_1, T_2, T_7, T_8 and T_9 produced statistically similar yield. The higher pumpkin fruit yield was associated with higher moisture availability within the root zone in case of microjet irrigation considering the succulent foliage of crop (Firake and Shinde, 2000). The treatment T_6 was supplied within 49.56 cm irrigation water while the treatment T_1 was supplied 64 cm of water, which involved 22.56% saving of irrigation water over the surface irrigation method. The highest water use efficiency was recorded by the treatment T_9, i.e. microjet irrigation at 40% ET (1090.87 kg ha^{-1} cm^{-1}) followed by the treatment T_8 (962.28 kg ha^{-1} cm^{-1}). The higher water use efficiency in case of treatments T_8 and T_9 was associated with substantial increase in yield with minimum quantum of water required to produce it. The highest total cost of production was recorded by the treatment T_6 (Rs. 87,536 ha^{-1}) which was closely followed by treatment T_7 (Rs. 86,715 ha^{-1}). The highest gross return Rs. 1,29,840 ha^{-1} and net returns of Rs. 42,304 ha^{-1} were recorded by the treatment T_6 (microjet irrigation at 100% ET) over rest of the treatments. The treatments T_3, T_4 and T_5 recorded negative net returns, which might be due to a poor fruit yield and higher investment in irrigation system. The highest B:C ratio was recorded by the treatment T_1 (1.57) which was closely followed by the treatment T_6 (1.48). The treatment T_6 saved about 22.56% irrigation water and considerable amount of labours for cultivation of the crop which have been reflected in high net return and B:C ratio. The lateritic soils are having low moisture retention and lateral movement of moisture due to which the sprinkling of water through microjets within the entire crop root zone have resulted into better growth and yield (Shinde *et al.*, 2002).

In comparison between two irrigation systems, i.e. drip and microjet irrigation with same quantity of irrigation water applied, the microjet irrigation performed better in respect of the fruit yield production on lateritic soil of Konkan. The treatment T_7, i.e. microjet irrigation with 80% of ET was at par with former best treatment, viz. T_6. For the treatment T_7, 39.76 cm of irrigation water was applied with a saving over surface irrigation to the tune of 37.88%. Marginal difference was observed in net profit and B:C ratio under the treatments T_6 and T_7. Under water shortage situations in the summer season it could be advisable to adopt irrigation schedule at 80% of ET using microjet irrigation.

Therefore, it could be concluded, considering the net profit, the pumpkin var. Ankur Vishal in summer season may be provided with irrigation water through microjet system at 100% ET.

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Performance Evaluation of a Bullock Drawn Groundnut Digger for East and South Eastern Coastal Plain Agroclimatic Zone of Orissa

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A bullock drawn groundnut digger with V-shaped digging blade was developed and tested for power requirement, effective field capacity, field efficiency, labour requirement, pod losses, digging efficiency, performance index and economics of digging in the sandy loam soils of Khurda district of east and south eastern coastal plain agroclimatic zone of Orissa. The average draft was 66.8 kgf and power requirement was 0.43 HP, which were within the capacity of an average pair of bullock. The maximum digging efficiency of 82.0 % was found under an optimum speed of 1.77 km h^{-1}. The performance index was observed as 0.094 considering the quality and quantity of digging alongwith power requirement for its operation. As compared to manual uprooting the performance of this bullock drawn groundnut digger was satisfactory and economical. The use of the digger is within the reach of small and marginal farmers growing groundnut crop on a commercial basis.

(***Key words:*** *Groundnut digger, Power requirement, Field efficiency, Pod losses, Digging efficiency*)

In Orissa, groundnut (*Arachis hypogea* L.) was cultivated over an area of 3.96 lakh ha area with a production of 3.33 lakh tons during 1990-91, which has been reduced to an area of 2.33 lakh ha with a production of 2.17 lakh tons during the year 2002-03, with the productivity however remaining almost the same (1410 kg ha^{-1}). Major cultivation of groundnut is in the districts of Cuttack, Khurda, Dhenkanal, Jajpur, Ganjam, Sambalpur and Kalahandi (Anon., 2004). The Govt. of Orissa is giving emphasis on increasing the area of oilseeds and particularly groundnut through oilseed mission programme. Harvesting of groundnut is carried out at a moisture content of 12 to 15 percent. If the moisture content falls below the above range, there is possibility of drying of the vines which get detached or decomposed, leaving the pods uncollected, and finally resulting in low yield. Similar is the problem if the moisture content increases, when the germination of kernel may take place. Keeping the soil moisture content in mind, harvesting has to be completed within a limited period of time. Traditional method of harvesting groundnut is by manual uprooting or by digging the ridges with the help of hand hoes, either of which is much labour intensive and time consuming. Also, the socioeconomic conditions of farmers of Orissa do not permit them to use tractor, power tillers, etc. The production constraint of groundnut crop is non-availability of suitable cultural practices including the implements recommended by OUAT (Anon., 1996). Keeping these problems in view, a bullock drawn groundnut digger with V-shaped cutting blade was developed and tested in the farmers' fields at village Paniora of Khurda district in east and south eastern coastal plain agroclimatic zone of Orissa.

MATERIALS AND METHODS

The bullock operated groundnut digger with the V-shaped digging blade has the following components as shown in Fig. 1.

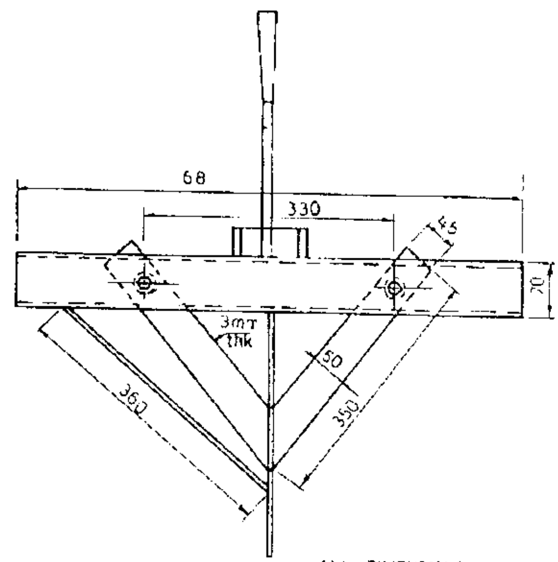

Fig. 1. Groundnut digger ('V' shaped digging blade type)

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Main frame: The main frame has 4 nos. of mild steel: plates of size 67 cm x 6 cm x 5 mm which are welded together. This frame has number of holes at required distances. The cutting tool is tightly fixed with the frame by two numbers of nut and bolts of 0.19 cm sizes using two mild steel pipes. Over the frame, the handle is fixed with the support of two iron flats.

Digging tool: The V-shaped digging blade consists of two 34 cm long 45 mm x 10 mm mild steel flat. This is designed with an internal angle of 85°. This is fitted with the main frame. The blade is tempered to withstand additional strength.

Hitching arrangement: The beam is fitted to the frame with nuts and bolts. The required holes are made suiting the requirement of different sizes of bullocks. The beam is made up of *sal* wood of size 65 x 45 x 2.5 cm.

The groundnut digger was evaluated in the farmers' fields at village Paniora of Khurda district, Orissa, using AK-12-24 as test variety of the crop, for the estimation of power requirement, effective field capacity, field efficiency, labour requirement, pod losses, digging efficiency, performance index, and economics of digging. The moisture content of pod, vine and soil were determined on oven dry weight basis. The draft, power requirement, and effective field capacity were measured during the test. The pods left on the surface, within the soil and those damaged were collected separately from the specified area to determine the losses.

Percentage of exposed pod loss, $L_a = \frac{G}{A} \times 100$

Percentage of unexposed pod loss, $L_b = \frac{H}{A} \times 100$, and

Percentage of undug pod loss, $L_c = \frac{K}{A} \times 100$

where, G = quantity of detached pods lying exposed on the surface, H = quantity of detached pods which remained inside the soil in the sampled area, K = quantity of pods remained undetached from the undug plants in the sampled area, and A = total quantity of pods collected from the plants in the samples area.

Total percentage of pod loss = percentage of (exposed + unexposed + undug) pod loss,

Digging efficiency = 100 – total percentage of pod loss, and

Draft, $D = P \cos\theta$

where, D = draft in kgf, P = pull in kgf, and θ = angle between line of pull and horizontal plane.

Power requirement,

$$\text{H.P.} = (\text{Draft in kgf} \times \text{speed in m/s}) / 75$$

Effective field capacity: It is the actual rate of coverage. It includes the time lost while making adjustment, unclogging the blades, etc. It is expressed in hectares per hour.

Field efficiency: It is the ratio of effective field capacity to theoretical field capacity and is expressed in percentage.

Labour requirement: It is the number of labourers required for one ha area for digging groundnut.

$$\text{Performance Index} = \frac{(1-L_a)(1-L_b)(1-L_c) \times W_d \times b_D \times 75}{R_L \times D_D}$$

where, W_d = total weight of groundnut dug in kg, b_D = width of cut of groundnut digger in meter,

R_L = length of run in meter, and D_D = draft of groundnut digger in kgf.

RESULTS AND DISCUSSION

The average values of power requirement, field capacity, field efficiency, losses, digging efficiency, performance index and cost of operation of the digger were computed from the test and are presented in Table 1. The draft required to run the digger varied from 59.4 to 73.1 kgf with an average value of 66.8 kgf and the power requirement from 0.34 to 0.51 HP with an average value of 0.43 hp. The average theoretical and effective field capacities were found to be 0.078 ha h^{-1} and 0.06 ha h^{-1}, respectively. The effect of speed on effective field capacity of the digger is presented in Fig. 2. The average field efficiency was found to be 76.71 percent. The optimum operating speed to achieve maximum digging efficiency of 82.0 % was 1.77 km h^{-1}. The

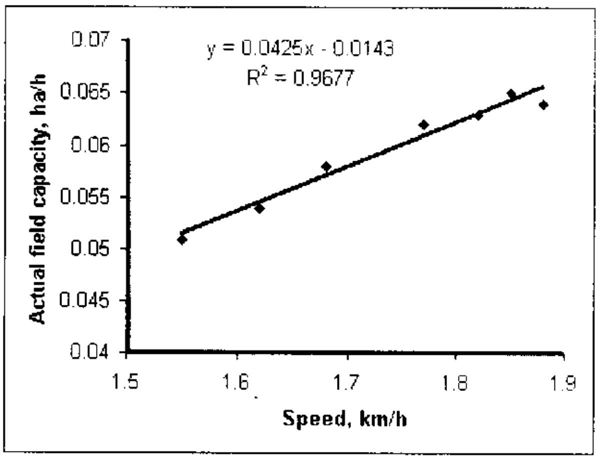

Fig 2. Effect of speed on actual field capacity

Table 1. *Average values of power requirement, losses, field efficiency, digging efficiency, performance index and cost of operation of groundnut digger*

Speed, km h^{-1}	1.74	Exposed pod loss, percent	7.6
Draft, kgf	66.8	Unexposed pod loss, percent	10.9
HP	0.43	Undug loss, percent	1.3
Effective field capacity, ha h^{-1}	0.06	Total loss, percent	19.8
Theoretical field capacity, ha h^{-1}	0.078	Digging efficiency, percent	80.2
Field efficiency, percent	76.71	Width of cut, cm	45.0
Labour requirement, man-ha h^{-1}	50.73	Performance Index	0.094
		Cost of operation, Rs ha^{-1}	647.00

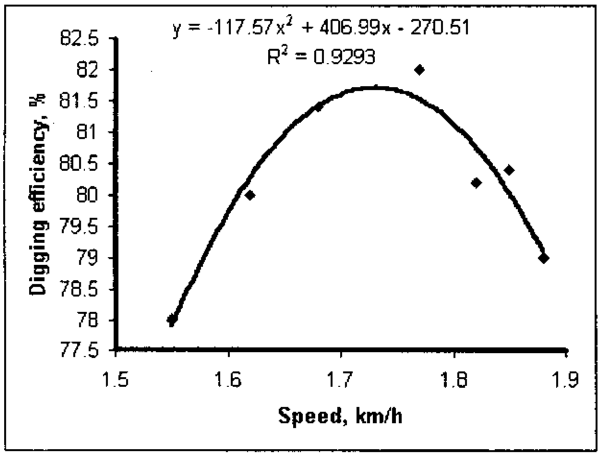

Fig 3. Effect of speed on digging efficiency

average digging efficiency was found to be 80.2 %. The variation of digging efficiency with respect to speed of operation of the digger is shown in Fig. 3. The performance index of the groundnut digger was found to be 0.094 considering the quality of digging, quantity of digging and power requirement for the operation. The cost of operation in case of manual digging method was found to be Rs. 1100.00 per ha, as compared to which for riding type digger it was Rs.647.00 per ha, thus the effective field capacity of the said digger (0.06 ha h^{-1}) was much higher than manual method (0.0075 ha h^{-1}).

CONCLUSION

The performance of the developed groundnut digger was satisfactory and found to be suitable for harvesting of groundnut in sandy loam soil of east and south eastern coastal plain agroclimatic zone of Orissa. The use of the digger is within the reach of small and marginal farmers of the state of Orissa.

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Response of Okra to Fertigation

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An experiment was conducted on coastal lateritic soil of Konkan with different irrigation systems and fertigation to study the effect on yield attributes, yield and economics of okra cultivation during hot weather season. Drip irrigation with 125% dose through soluble fertilizer recorded significantly higher values of most of the yield attributes, viz. weight of fruit per plant (g) and average weight of fruit (g) over the remaining treatment combinations of fertilizer with drip and microsprinkler. Drip with 125% dose through soluble fertilizer (T_3) recorded significantly superior fruit yield (22.43 t ha^{-1}), highest gross and net returns with consumption of 58.44 ha-cm of irrigation water. The irrigation water saved by this treatment over the check basin was 38.48% with a highest water use efficiency of 383.81 kg ha^{-1} cm^{-1}. While, the highest B:C ratio was, however, recorded by check basin with recommended dose of common fertilizers.

(**Key words:** *Drip, Microsprinkler, Fertigation, Water use efficiency, Economics*)

The total area under irrigation in Maharashtra is only 16.2% and it is estimated that after full development of water resources, the irrigated area in the state may not exceed 30% with the adoption of conventional surface irrigation method. Bringing more area under irrigation will largely depend on the effieincy in water use. In this context, microirrigation has to play a significant role to achieve not only higher productivity and water use efficiency but also sustainability of its use. The microirrigation system permits the use of fertilizers, pesticides and other soluble chemicals along with irrigation water and has potential to improve input use efficiency which becomes major components in adoption of precision farming. In Maharashtra, area under pressurized irrigation system is showing increasing trend every year. The work so far carried out on fertigation through microirrigation system indicated that fertigation leads to efficient utilization of fertilizers (Nakayma and Buck, 1986). The fertilizer use efficiency of conventional method of fertilizer application is low because of various reasons like leaching and volatilization losses, as well as due to fixing of nutrient after their application in the soil. A very meagre amount of work has been carried out on fertigation under lateritic soil conditions. Thus an attempt was made to evaluate the response of okra crop to fertilixation under different microirrigation systems.

MATERIALS AND METHODS

A field experiment on okra, var. Varsha Uphar was conducted during summer season of 2003 at Agronomy Farm, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The soil was clay loam with pH 6.3, available nitrogen 356.23 kg ha^{-1}, available phosphorus 16.28 kg ha^{-1}, and available potash 201.84 kg ha^{-1}. The trial consisted of three irrigation systems, viz. drip, microsprinkler, with check basin as a control. Recommended dose of common fertilizers (RDCF) @ 150:50:50 NPK kg ha^{-1} was applied in soil through urea, single superphosphate, murate of potash, respectively in check basin (T_1), with drip irrigation (T_2), and with microsprinkler irrigation (T_7). The treatments T_3, T_4, T_5 and T_6 represented drip irrigation with 125%, 100%, 75%, 50% of RDCF, respectively in soluble form. Similarly treatments T_8 to T_{11} supplied irrigation through microsprinklers with 125%, 100%, 75%, 50% of RDCF, respectively in soluble form.

The trial was conducted in randomized block design and each treatment replicated thrice. The plot size was 6 m x 3.6 m. Normal planting pattern was followed for check basin and microsprinkler irrigation treatment with 45 x 30 cm spacing. Paired row planting pattern at 30 x 30 x 60 cm spacing was used in drip irrigation system for okra. The crop was sown on 1st February, 2003. A common dose of 7 t ha^{-1} of poultry manure was applied at the time of sowing. The paddy straw mulch at the rate of 7 t ha^{-1} was applied 12 days after sowing. For check basin (T_1), drip irrigation with RDCF (T_2), microsprinkler with RDCF (T_7) alongwith fertilizers through band placement were applied as per recommendation. The treatment-wise soluble fertilizers were applied in four splits at 10 day interval through 19:19:19 grade complex fertilizer starting from 10 days after sowing and the remaining

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Table 1. *Yield and growth attributes, water use efficiency and economics of okra influenced by different treatments*

	Treatment	Weight of fruits per plant (g)	Number of fruits per plant	Average weight of fruit (g)	Fruit yield (t ha^{-1})	Irrigation water applied (ha-cm)	Saving of irrigation water over check basin (%)	Water use efficiency (kg ha^{-1} cm^{-1})	Total cost (Rs.ha^{-1})	Gross income (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
T_1	Check basin with RDCF	406.00	34.27	11.83	17.70	95.00	-	186.32	90896	141600	50704	1.56
T_2	Drip with RDCF	383.67	31.07	12.32	18.24	58.44	38.48	312.11	113111	145920	32809	1.29
T_3	Drip with 125% dose through soluble fertilizer	402.00	31.93	12.59	22.43	58.44	38.48	383.81	125604	179400	53836	1.43
T_4	Drip with 100% dose through soluble fertilizer	396.00	31.47	12.78	21.77	58.44	38.48	372.52	122970	174160	51190	1.42
T_5	Drip with 75% dose through soluble fertilizer	364.00	30.33	12.00	18.94	58.44	38.48	324.09	114995	151520	36525	1.30
T_6	Drip with 50% dose through soluble fertilizer	374.67	29.87	12.56	17.40	58.44	38.48	297.74	108742	139200	30458	1.28
T_7	Microsprinkler with RDCF	292.67	25.07	11.72	11.57	56.00	41.05	206.61	98905	92500	-6345	0.93
T_8	Microsprinkler with 125% dose through soluble fertilizer	331.33	28.67	11.59	14.42	56.00	41.05	257.70	112059	115360	3301	1.03
T_9	Microsprinkler with 100% dose through soluble fertilizer	302.67	27.47	11.01	12.05	56.00	41.05	215.18	104698	96400	-8298	0.92
T_{10}	Microsprinkler with 75% dose through soluble fertilizer	258.33	23.93	10.72	12.68	56.00	41.05	226.43	101336	101440	104	1.00
T_{11}	Microsprinkler with 50% dose through soluble fertilizer	282.33	26.60	11.59	12.47	56.00	41.05	222.68	96856	99760	2904	1.03
SE ±		23.69	2.07	0.25	0.93	-	-	-	-	-	-	-
CD at p=0.05		69.86	N.S.	0.73	2.74	-	-	-	-	-	-	-

RDFC, Recommended dose of common fertilizer; NS, Non-significant quantity of N was applied through urea in four splits at an interval of ten days. For check basin irrigation was scheduled as per recommendations, i.e. after 4-5 days during February-May. Irrigation through microsprinkler and drip was scheduled at alternate days and at 80% E.T. The discharge of dripper and microprinkler used for experimentation was 4 and 25 lph, respectively at a pressure of 1.25 kg cm^{-2}. The crop was harvested in 30 pickings. Yield attributes were recorded while harvesting and economics of treatments were studied by calculating the benefit : cost ratio.

RESULTS AND DISCUSSION

Yield attributes and fruit yield

Both yield attributes, viz. weight of fruits per plant (g) and average weights of fruits (g) were significantly influenced by the different treatments (Table 1). Treatment T_4 (drip irrigation with 100% fertilizer dose in soluble form) recorded significantly superior value for average weight of fruit over rest of the treatments. However, the former treatment was statistically at par with the treatments T_2, T_3 and T_6. The statistically superior weight of fruit per plant was recorded by treatment T_1, i.e. check basin with RDCF over the rest of treatments, except T_2, T_3, T_4, T_5 and T_6. The number of fruits per plant was not influenced statistically. The treatment T_3, viz. drip irrigation with 125% dose through soluble fertilizer recorded significantly superior values of fruit yeld (22.43 t ha^{-1}) over rest of the treatments, however, the former treatment was at par with the treatment T_4, i.e. drip irrigation with 100% dose through soluble fertilizers. The quantity of water supplied for the check basin, drip and microsprinkler treatment was 95.00, 58.44 and 56.00 ha-cm, respectively. The drip and microsprinkler irrigation treatments saved about 38.48 and 41.05 perecnt irrigation water, respectively over check basin. The lower fruit yield was recorded in case of microsprinkler treatment which may be due to interference by tall foliage of okra and non-uniform application of irrigation water due to sprinkling at late growth stage.

The highest water use efficiency (383.81 kg ha^{-1} cm^{-1}) was recorded by the treatment T_3, i.e. drip irrigation with 125% dose through soluble fertilizer. The lowest water use efficiency (186.32 kg ha^{-1} cm^{-1}) was recorded by the treatment T_1, i.e. check basin with RDCF. This lowest water use efficiency for check basin irrigation was due to the use of large quantity of irrigation, significant amount of which might have been lost through deep percolation, run off, etc.

Economics

The highest total cost of production of okra crop (Rs. 1,25,604 ha^{-1}) was recorded by the treatment T_3, i.e. drip irrigation with 125% dose through soluble fertilizers which was closely followed by the treatment T_4 (Rs. 1,22,970 ha^{-1}), i.e. drip irrigation with 100% dose through soluble fertilizer. The higher total cost of production was observed in case of soluble fertilizers treatments due to 5-6 fold higher cost of soluble fertilizer. Similarly, the highest gross income (Rs. 1,79,400 ha^{-1}) was recorded by the treatment T_3 which was closely followed by the treatment T_4 (Rs. 1,74,160 ha^{-1}). The higher cost of production in case of drip and microsprinkler treatments was due to depreciation on materials used in irrigation system and highest initial investment. The highest net income (Rs. 53,836 ha^{-1}) was recorded by the treatment T_3, i.e. drip irrigation with 125% dose through soluble fertilizer. This was closely followed by the treatment T_4, i.e. drip irrigation with 100% dose through soluble fertilizer (Rs. 51,190 ha^{-1}). Considering the marginal difference in net profit and B:C ratio between the treatments T_3 and T_4, fertigation at 150:50:50 dose is advisable. Similar results were also reported by Deolankar and Firake (1999). The treatment T_7 (microsprinkler with RDCF) and T_9 (microsprinkler with 100% dose through soluble fertilizer) recorded negative profit. The highest B:C ratio (1.56) was recorded in case of T_1 (check basin with RDCF) followed by treatment T_3 (1.43). The treatments T_3 and T_4 involved about 38.48% saving of water over the check basin. The high cost of soluble fertilizer significantly reduced the net profit and B:C ratio (Shinde *et al.*, 1999). The fruit yield produced by treatment T_2, i.e. drip irrigation with RDCF (18.24 t ha^{-1}) was compared with fertigation treatment and it was observed that the former treatment (T_2) was at par with T_5 (drip with 75% dose through soluble fertilizer) and T_6 (drip with 50% dose through soluble fertilizer). This indicated that 50 percent fertilizer dose could be saved through fertigation. Similar trend was observed in economics. The net profit reported by the treatment T_2 and T_5 were Rs. 32,809 ha^{-1} and Rs. 36,525 ha^{-1}, respectively. Treatment T_5 saved about 25% nutrient, when these were added through fertigation.

Therefore, it could be concluded from above discussion that considering the limited availability of water in summer season and for obtaining the higher net income from okra crop, in lateritic soils of Konkan, drip irrigation and major nutrients (150 kg N, 50 kg P_2O_5, 50 kg K_2O) must be supplied through fertigation.

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Inhibition of Urea Hydrolysis and Temperature Stability of Urease in Coastal Saline Inceptisol

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Incubation study was conducted to study the urease activity under variable temperatures (37°C, 47°C, 57°C and 67°C) and transformation of applied urea under different moisture regimes, viz. 50 percent (M_1) and 100 perent (M_2) of maximum water holding capacity (MWHC) in major soil types of Konkan, i.e. lateritic, medium black and coastal saline soils. Results showed that the urease activity (μg Urea-N hydrolysed g^{-1} soil h^{-1}) was highest in medium black (13.230 to 30.647) followed by lateritic (8.893 to 12.453) and coastal saline (6.673 to 9.340) soils at 37°C. It correlated positively with silt, silt + clay, organic carbon and pH of soils and negatively with sand and MWHC of soils. The temperature had profound influence on soil urease activity. It increased significantly with increase in temperature from 37°C to 57°C and the increase was highest in case of medium black soil (425%), followed by lateritic soil (222%) and was least in coastal saline soil (101%). But at a temperature of 67°C there was significant reduction in urease activity of soils. The hydrolysis of applied urea was complete within 2 and 4 days in medium black and lateritic soils, respectively and the period was much longer, i.e. 21 to 35 days in case of coastal saline soils. The content of NH_4-N in soils increased gradually from ½ to 4 days and it attained the peak within 2 to 4 days in most of the soils. The concentration of NH_4-N markedly declined after 7 days onwards and there was gradual increase in NO_3-N concentration with time. The highest NO_3-N content was observed during 28th to 35th day of incubation in almost all soils.

(***Key words:*** *Urease activity, Temperature effect, Urea hydrolysis*)

Urease is unique among soil enzymes, and this affects the rate and transformation of applied urea, and its activity in soils provides a good index about the ability of soil to hydrolyse urea. The urease activity (UA) in soil is influenced by several factors, viz. pH, organic matter, soil types, moisture regime, rhizosphere, substrate concentration (McGarity and Myer, 1967, Kumar and Wagenet, 1984, Savant *et al.*, 1985), salinity and sodicity (Nitant, 1974, Singh and Bajwa, 1986, Sharma and Chauhan, 1994) and temperature (Dalal, 1975, Zantua and Bremner, 1977, Dash *et al.*, 1981). A rapid urea hydrolysis results in high loss if nitrogen from soil and even its slow rate may increase leaching loss of urea. These aspects are very important in coastal region like Konkan, which represents very high rainfall zone of Maharashtra. Different crops grown here show very good response to urea application, but nitrogen use efficiency is low due to nitrogen losses during rainy season. In the present investigation attempt has been made to assay the urease activity in major soils of Konkan, temperature stability of UA, and urea hydrolysis.

MATERIALS AND METHODS

Twelve surface soil samples (0-22.5 cm) representing three major soil types of Konkan region, viz: lateritic (S_1 to S_4), medium black (S_5 to S_8) and coastal saline Inceptisol (S_9 to S_{12}) were collected in May, 2001 from the University Research Farms, Dapoli, Karjat and Panvel (Table 1). The soil samples passed through 2 mm sieve were used for study. The urease activity in different soils was assayed by non-buffer method (Zantua and Bremner, 1975). For this purpose, 10.0 g soil sample was transferred into 125 ml plastic container (4.5 dia and 8.5 cm height) in triplicate. Distilled water @ 2.0 ml and urea solution (1000 mg urea N L^{-1}) @ 1.0 ml, i.e. 10 mg urea N per 10 g soil was applied uniformly to soil in each container. The moisture content was maintained at 30 percent by weight. After fixing the lid, the containers were incubated at 37°C for 5 h. Then soils were extracted with 50 ml of 2M KCl containing 5 ppm phenyl mercuric acetate (PMA), and urea N was determined calorimetrically (Watts and Chrisp, 1954). To study the effect of different temperatures on urease stability the soils were incubated separately at varied temperatures, viz. 37, 47, 57 and 67°C.

The urea hydrolysis in two soils, each of lateritic (S_2 & S_3), medium black (S_6 & S_8) and coastal saline (S_{10} to S_{11}) type, was further studied under two moisture regimes, viz. 50 and 100 percent maximum water holding capacity (MWHC). The 10 g soil was

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***Table 1.** Relevant physicochemical characteristics of the different soils used and their urease activity*

Soil No.	Soil	MWHC (%)	Particle Size Analysis (%)			Textural Class	pH (1:2.5)	EC[1]	Org. C. (%)	Av. N[2]	Urease activity[3]
			Sand	Silt	Clay						
S_1	Lateritic soil	54.80	25.6	34.7	39.7	Clay loam	5.09	0.06	0.955	304	12.453
S_2	Lateritic soil	51.16	28.2	34.7	37.0	Clay loam	5.25	0.07	1.112	292	8.893
S_3	Lateritic soil	58.20	25.6	38.7	35.7	Clay loam	5.60	0.06	1.072	307	12.453
S_4	Lateritic soil	60.04	28.2	30.7	41.0	Clay	4.95	0.08	1.423	386	10.780
S_5	Medium black soil	56.20	25.0	38.4	36.2	Clay loam	7.09	0.16	0.565	282	14.010
S_6	Medium black soil	52.46	20.0	41.0	38.8	Silt Clay loam	6.84	0.29	0.838	298	30.647
S_7	Medium black soil	53.12	22.1	45.0	32.4	Silt Clay loam	6.87	0.38	0.780	285	17.670
S_8	Medium black soil	61.15	21.1	34.4	44.4	Clay loam	7.14	0.15	0.604	295	13.230
S_9	Coastal saline soil	64.87	15.5	26.9	57.5	Clay	7.97	11.5	0.370	229	8.007
S_{10}	Coastal saline soil	59.26	24.5	29.5	42.8	Clay	7.13	8.8	0.312	238	9.340
S_{11}	Coastal saline soil	58.09	31.6	39.1	29.1	Clay loam	7.15	18.1	0.409	232	6.673
S_{12}	Coastal saline soil	62.20	28.8	41.5	29.5	Clay loam	6.86	1.35	0.546	251	8.560
CD (p=0.05) 2.39											

[1]EC, dSm^{-1}; [2]Ave. N, kg ha^{-1}; [3]Urease activity, μg urea N hydrolysed g^{-1} soil h^{-1} at 37°C

taken in plastic container in triplicate, and 1 ml urea N solution (2000 mg L^{-1}), i.e. 2 mg urea N per 10 g soil was added uniformly and one control (no urea N treated) was simultaneously incubated at room temperature (30°C ± 2°C). The soils were periodically extracted with 50 ml of 2M KCl containing 5 ppm phenyl mercuric acetate (PMA) and the extracts were analysed for urea N (Watts and Chrisp, 1954). NH_4-N (Prasad, 1998) and NH_4-N + NO_3-N (by microdistillation method). The data on urea hydrolysis in soils over moisture regimes have been presented in this paper.

RESULTS AND DISCUSSION

Temperature stability of urease

Data in Table 1 show that the urease activity (μg urea N hydrolysed g^{-1} soil h^{-1}) was highest in medium black soil (13.23 to 30.65), followed by lateritic soil (8.89 to 12.45) and was lowest in coastal saline soil (6.67 to 9.34). Saraswathi and Balachandran (1993), Nagaraja *et al.* (1998) and Singh and Bajwa (1986) also reported similar result. There was significant increase in urease activity with increase in temperature from 37°C to 57°C which thereafter showed significant reduction at 67°C compared to that at 57°C (Table 2). The enhancement in urease activity caused by temperature (57°C) was variable among different soils being highest in medium black (425%), followed by lateritic (222%), and was least in coastal saline soil (101%). Similarly, the reduction at 67°C over 57°C also differed appreciably among different soil types. The mean percent retardation in urease activity was highest in coastal saline soil (-51.44 to -70.24, mean 63.80), closely followed by lateritic soil (-11.77 to -77.92, mean 54.30), and was lowest in medium black soil (+ 10.30 to -58.51, mean 21.53) indicating relatively higher urease stability in medium black soil. These results are in agreement with those reported by Dalal (1975), Zantua and Bremner (1977) and Dash *et al.* (1981) who showed considerable dependence of urease activity in soils on temperature. Positive effect of temperature on urease activity upto 47°C in sandy soils was reported by Dash *et al.* (1981), and upto 70°C, followed by decline thereafter, in Iowa soils by Zantua and Bremner (1977). Bremner and Mulvaney (1978) opined that the urease activity is partially inactivated at higher tempeatures (65°C to 90°C), and thereafter there was complete inactivation at 105°C.

Urea transformation

Urea hydrolysis: Coastal saline soil (S_{10}, S_{11}) showed higher values of urea-N as compared to lateritic and medium black soils. In all, the highest concentration of urea-N was at half day of incubation which declined sharply thereafter (Fig. 1) due to hydrolysis. No urea-N was observed in medium black and lateritic soils on 2nd and 4th day of incubation, respectively (Fig. 2) indicating its complete hydrolysis after 1 to 2 days in medium black soil and in 2 to 4 days in lateritic soil after urea application. However, in coastal salt affected soil, it

Table 2. *Effect of temperature on urease activity of different soils*

Soil No.	Soil	Urease activity (μg urea N hydrolysed g^{-1} soil h^{-1}) Temperature °C				Mean
		37	47	57	67	
S_1	Lateritic soil	12.45	27.34	35.34	9.33	21.12
S_2	Lateritic soil	8.89	24.33	30.66	6.77	17.64
S_3	Lateritic soil	12.45	38.01	47.23	41.67	34.84
S_4	Lateritic soil	10.78	19.68	30.33	13.99	18.70
S_5	Medium black soil	14.01	55.33	111.69	90.99	67.98
S_6	Medium black soil	30.65	59.65	159.30	66.89	79.12
S_7	Medium black soil	17.67	35.34	56.33	40.89	37.56
S_8	Medium black soil	12.23	40.34	64.34	70.96	47.22
S_9	Coastal saline soil	8.01	11.34	15.66	4.66	9.92
S_{10}	Coastal saline soil	9.34	13.34	16.33	7.93	11.74
S_{11}	Coastal saline soil	6.67	10.01	14.32	3.63	8.66
S_{12}	Coastal saline soil	8.54	15.65	19.37	7.96	12.89
Mean		12.73	29.19	50.07.	30.47	—
CD (p=0.05)		Soil		Temperature		Interaction
		1.80		1.02		3.57

was markedly delayed to more than two weeks. The urea-N on 7th day of incubation in these soils, i.e. S_{10} and S_{11}, was much higher, i.e. 41.2 and 74.7 percent of applied N, respectively indicating very slow rate of urea hydrolysis and the inhibition was higher in S_{11} than in S_{10}. The urea hydrolysis was complete during 3rd week in S_{10} whereas it was incomplete in S_{11} even upto 5th week of incubation.

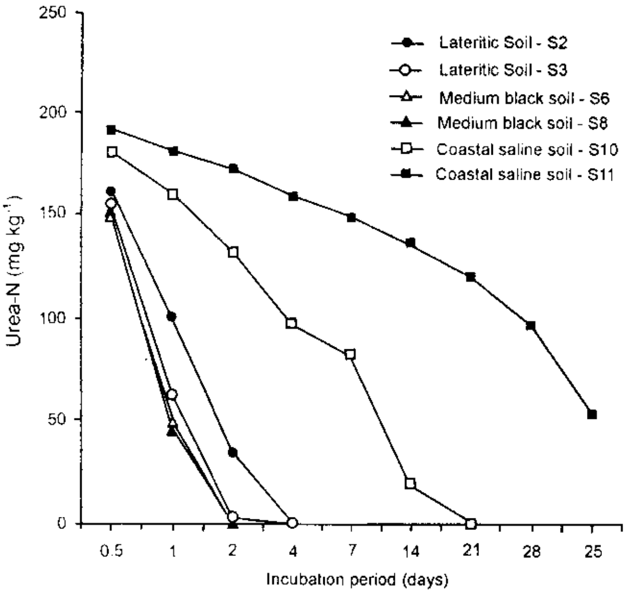

Fig. 1. Periodical content of unhydrolysed Urea-N in different soils

Thus the urea hydrolysis was most rapid in medium black soil, followed by lateritic soil (Sannigrahi and Mandal, 1987, Sahrawat, 1992) and was most delayed in coastal salt affected soil. Such retardation was also reported by Nitant (1974), Singh and Bajwa (1986) and Shrama and Chauhan (1994) in saline, saline sodic and sodic soils, but the rate and period of retardation observed in present study was considerably higher. Coastal salt affected soils in Konkan (M.S.), formed by ingress of brackish creekwater, are diagnosed either as saline or saline sodic (Joshi, 1985) and there was a dominance of sodium in soluble cations. The dominant anions were Cl^{-1} and SO_4^- followed by HCO_3^-. The high quantity of Na salts of chloride, sulphate and bicarbonate type had depressive effect on urease and urea hydrolysis (Nitant, 1974, Singh and Bajwa, 1986). The excessive concentration of Cl^- and SO_4^-, followed by HCO_3^- and Na^+, may result in specific ion toxicities and hence may adversely affect microbial growth (Frankenberger and Bingham, 1982). Similarly, delayed urea hydrolysis could also be ascribed partly to their low organic carbon status since organic constituents protect urease against microbial degradation and other processes leading to decomposition or inactivation of enzymes (Dalal, 1975, Zantua and Bremner, 1977, Singh *et al.*, 1991).

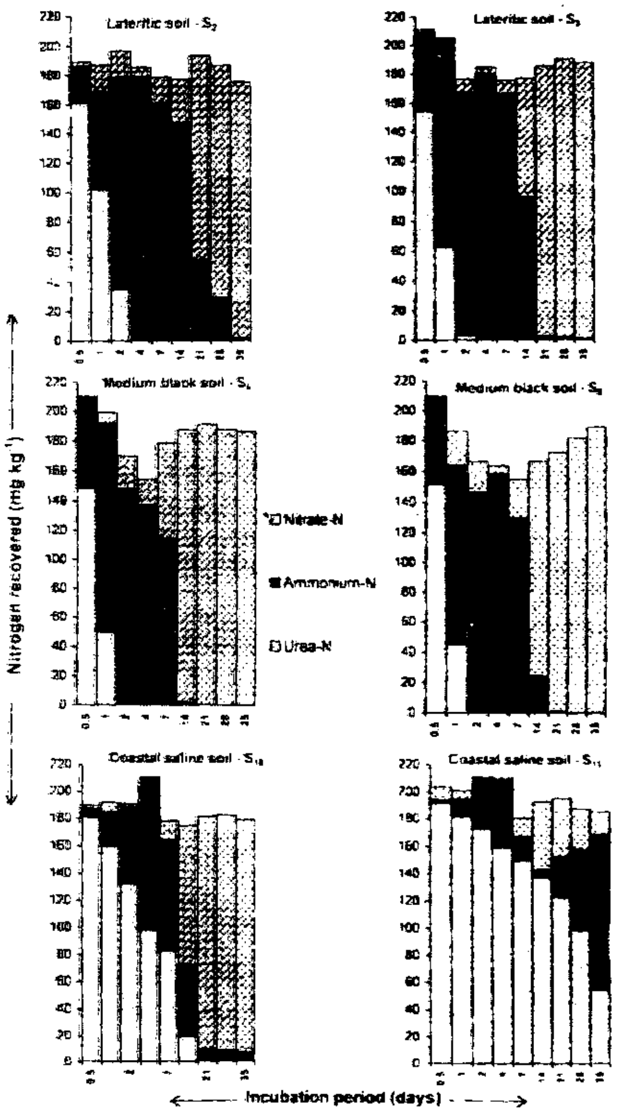

Fig. 2. Periodical changes in the content of Urea-N, NH_4-N and NO_3-N in three different soils due to urea application

Ammonification and Nitrification: The NH_4^- concentration in almost all soils showed gradual increase with time and attained a peak at 4th day after urea application, and it accounted for 89.49 to 90.15, 68.65 to 79.21 and 56.5 percent of applied urea N in lateritic, medium black and coastal saline (S_{10}) soils, respectively. Then there was sharp decline in NH_4^-N concentration from 7th day onward till 35th day due to nitrification except in the coastal saline soil S_{11} wherein its content increased gradually after 14th day of incubation recording 2nd peak of NH_4^- N at 35th day of incubation due to delayed urea hydrolysis in this soil (Fig. 2).

The content of NO_3^-N in all soils during first 2 to 4 days was low (4.3 to 20.1 mg kg^{-1}) showing very slow nitrification rate which increased slightly up to the end of first week (8.8 to 65.0 mg kg^{-1}), followed by rapid increase during the second week (29.0 to 184.6 mg kg^{-1}), in general attained a peak in the third week in medium black and coastal saline soil and in the fourth week in latertitic soil (Fig. 2). The conversion of NH_4 N to NO_3^-N was quicker in medium black soil followed by lateritic soil and coastal saline soils. These results are in agreement with Sannigrahi and Mandal (1987), Sahrawat (1992) and Sharma and Chauhan (1994). At 35th day of incubation the NO_3^-N represented 86.3 to 94.15 percent of the applied urea-N in all soils except S_{11} where the concentration of urea N, NH_4^-N and NO_3^-N were 27.12, 57.3 and 8.6 percent of the applied N, respectively.

The results thus showed that the urease activity (UA) in coastal saline soil was lowest, whereas it was highest in medium black soil. The urease activity markedly increased with increasing temperature from 37°C to 57°C which then declined at 67°C. Temperature stability of urease was higher in medium black soil, The rate of urea hydrolysis was retarded in coastal saline soil and required more than 3 to 5 weeks for complete hydrolysis of applied urea-N.

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Forms of Phosphorus in Some Soils of Coastal Ecosystem of West Bengal

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A study was conducted to develop knowledge regarding the distribution of total and inorganic P fractions, and their relationship with physicochemical properties of some soils of coastal ecosystem of West Bengal. Surface soil contained higher amount of total P, available P and mineral P as well as its different fractions than the subsurface soil. Ca-P content was found to be higher in subsurface soil and was the dominant fraction of mineral P. The average contribution of different fractions of inorganic P expressed as the percentage of total P were in the order: Ca-P (15.7%) > RS-P (11.8%) > A1-P (10.5%) > Occl-P (8.6%) > Fe-P (7.3%). On the basis of available P status soils were in high category. Soil pH had a significant positive relation with Ca-P (r=0.587) but negative with A1-P (r= -0.496) and Fe-P (r= -0.477). Major variability in total P, total inorganic P and total active P could be explained by organic carbon content of this ecosystem soils. RS-P and A1-P collectively could explain 80.9 percent variation in available P status of soils.

(***Key words:*** *Forms of soil P, pH, Organic carbon*)

The amount of total P has little or no relationship to availability of P to plants. Plant availability of inorganic P can be limited by formation of sparingly soluble Ca-P, particularly in alkaline and calcareous soil, due to adsorption to Fe and A1 oxide surfaces in acid soils, and due to formation of Fe/A1-P complexes with humic acids (Gerke, 1992). The knowledge of nature and distribution of various forms of soil P provides useful information for assessing the available P status of soil and estimating the degree of chemical weathering of the soil (Gupta and Lattoo, 1999). Estimation of available P indicates only the amount of P present in soil, which is available to plants, but it does not indicate about the relative contribution of different fractions of P towards available P. The present study was undertaken to develop some knowledge regarding the distribution of various forms of P and their relationship with different physicochemical properties of soils of coastal ecosystem in West Bengal.

MATERIALS AND METHODS

Surface (0-15 cm) and subsurface (15-30 cm) soil samples were collected from eight different locations in coastal ecosystem of West Bengal, namely Kakdwip, Paschim Dandirhat, Jaynagar, Gurudaspur, Canning, Ramkrishnapur, Kantalberia and Ghateswar. Taxonomic classification of the samples selected for this study was received from NBSS & LUP, Kolkata centre.

Processed (>2 mm) soil samples were analyzed for physicochemical properties by standard methods as described by Jackson (1967) and Piper (1950). Available P was determined by chlorostanous reduced molybdophosphoric blue colour method after extracting the soil samples by Olsen extractant. Total P was extracted by idgestion in triacid mixture (HNO_3: H_2SO_4: HCl::5:2:1 v/v) and estimated colorimetrically by vanadomolybdic phosphoric yellow colour method (Jackson, 1967). Fractionation of soil inorganic P was done by the modified procedure of Chang and Jackson (1957) and Peterson and Corey (1966), as outlined by Hesse (1998). Organic P was computed as the difference between total P and total inorganic P, while total active P was computed by summing up of all active inorganic P fractions, namely A1-P, Fe-P and Ca-P (Sharma and Tripathi, 1992).

RESULTS AND DISCUSSION

The soils under study were neutral to slightly alkaline (6.2 to 7.5) in reaction and soluble salt content in general was of medium to low category (Table 1).

Total P, total mineral P, its different fractions and available P content of the soils of eight different locations are presented in Table 2. Except Ca-P,

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Table 1. *Physicochemical properties of the soils*

Location	Depth (cm)	Organic C (g kg^{-1})	CEC [cmol(p+) kg^{-1}]	pH	EC (dSm^{-1})	Clay (%)	Silt (%)	Textural class
Kakdwip	0-15	3.8	21.1	6.7	0.89	37.1	30.8	cl
	15-30	3.1	24.3	7.0	0.96	30.9	36.9	cl
Paschim Dandirhat	0-15	4.1	26.1	6.5	1.10	38.3	18.3	scl
	15-30	3.5	24.0	6.9	1.25	34.0	20.0	scl
Jaynagar	0-15	3.7	20.8	6.7	0.78	36.6	23.4	cl
	15-30	3.0	23.3	6.8	1.00	30.5	32.9	cl
Gurudaspur	0-15	3.9	23.2	6.2	1.70	37.9	33.1	cl
	15-30	3.2	19.8	6.8	0.98	31.8	40.3	cl
Canning	0-15	3.9	21.0	6.4	1.10	40.8	30.9	c
	15-30	3.3	20.8	5.9	1.20	33.2	38.3	c
Ramkrishnapur	0-15	3.6	18.1	7.0	1.07	35.8	31.9	cl
	15-30	3.4	19.6	7.5	1.03	33.5	30.7	cl
Kantalberia	0-15	3.3	22.0	6.5	1.05	34.1	30.1	cl
	15-30	2.9	22.6	7.0	1.15	30.8	30.0	cl
Ghateswar	0-15	3.8	24.2	6.2	1.26	37.0	35.3	cl
	15-30	3.1	22.8	6.5	0.97	31.9	36.8	cl

Table 2. *Different forms of phosphorus (mg kg^{-1}) in both surface and subsurface soil samples*

Location	Depth (cm)	Al-P	Fe-P	Ca-P	RS-P	Occl-P	Total inorganic P	Total active P	Total P	Avail. P
Kakdwip	0-15	28.4	20.7	48.2	33.1	24.1	154.5	97.3	285.3	11.2
	15-30	20.8	14.1	53.1	25.2	15.3	128.5	88.0	233.1	8.5
Paschim Dandirhat	0-15	32.2	22.1	44.2	36.1	25.5	160.1	98.5	307.4	11.1
	15-30	24.1	16.3	52.3	28.3	20.1	141.1	92.7	263.5	8.5
Jaynagar	0-15	28.2	20.3	45.3	32.6	23.8	150.2	93.8	278.5	9.9
	15-30	20.1	10.2	56.4	24.3	14.5	125.5	86.7	231.3	7.8
Gurudaspur	0-15	32.3	24.1	40.5	35.3	27.9	160.1	96.8	269.3	9.2
	15-30	21.2	14.5	50.2	25.1	18.2	130.2	86.9	243.8	7.1
Canning	0-15	33.1	24.1	45.4	35.8	26.8	165.5	102.6	239.1	10.9
	15-30	23.4	16.7	50.1	26.3	17.0	133.5	90.2	247.5	7.5
Ramkrishnapur	0-15	26.1	18.3	50.4	30.2	21.2	146.2	94.8	270.2	10.6
	15-30	23.5	13.5	56.8	27.1	18.6	139.5	93.8	258.2	8.1
Kantalberia	0-15	25.3	14.5	40.3	30.9	19.6	130.6	80.1	251.2	11.3
	15-30	20.5	8.2	48.1	26.4	12.0	115.2	76.8	220.6	9.4
Ghateswar	0-15	32.1	21.2	41.0	34.3	25.5	154.1	94.3	288.2	10.7
	15-30	21.2	12.1	55.2	25.1	14.6	128.2	88.5	237.3	8.3
Average	0-15	29.7	20.6	44.4	33.5	24.3	152.5	94.7	283.8	10.6
	15-30	22.0	13.2	52.8	27.0	17.0	132.0	88.0	241.9	8.1

contents of all inorganic forms of P in surface samples were higher than in subsurface counterpart. Higher amount of clay and organic carbon in the surface soil, the actual site for soil P, than in the subsurface sample justified the findings. Highly significant positive correlation coefficient values were also in support of the findings. On the other hand, higher Ca-P content in the subsurface layer was attributed to higher pH value than in surface layer. The results were in agreement with Hsu and Jackson (1960) and Syers *et al.* (1970). According to them, Ca-P is the most stable fraction in neutral to alkaline soil reaction, while Al-P and Fe-P are the dominant fractions in acidic soil reaction.

The total P content of the surface soil samples varied from 251 to 307 mg kg^{-1} with an average of 284 mg kg^{-1}. Total mineral P content of the surface soils ranged between 131 and 160 mg kg^{-1} and constituted 52 to 54% of total P. The average contribution of Al-P, Fe-P, Ca-P, Reductant Soluble-P (RS-P) and Occluded P (Occl-P) expressed as the percentage of total P followed the order: Ca-P (15.7%) > RS-P (11.8%) > Al-P (10.5%) > Occl-P (8.6%) > Fe-P (7.3%).

In general, Ca-P was dominant among the different fractions of inorganic P. Ca-P and RS-P together constituted about one-half of total inorganic P (Table 2). On an average, 62.0% of total inorganic P in the surface soil was in active state and Ca-P, the major contributor, accounted for nearly 50% of total active P in surface and 57.6% in subsurface soils. In order of amounts of different active P fractions, Ca-P was highest, followed by Al-P and Fe-P in both surface and subsurface soils. The results suggested that the soil was in the initial stage of weathering, i.e. it was young soil. Ca-P and Al-P were the dominant fractions at the initial stage of weathering and with advancement, phosphate as Ca-P and Al-P in soil was gradually transformed into Fe-P form (Hsu and Jackson. 1960, Syers *et al.*, 1970). The study area was developed from deltaic alluvial deposits of the river Ganges and delineated as new alluvial zone. Moreover, the soils are taxonomically classified under the order Inceptisols and Entisols which thus conformed the results. Olsen extracted available P content in the surface soils varied from 9.2 to 11.3 mg kg^{-1} with an average of 10.6 mg kg^{-1}. Based on available P status soils were rated as high (>20 kg ha^{-1}).

Table 3. *Simple correlation coefficient (r) between soil properties and forms of phosphorus*

Soil property	Forms of P							Total P
	Al-P	Fe-P	Ca-P	RS-P	Occl-P	Total active P	Total inorganic P	
pH	-0.477	-0.496	0.587*	-0.411	-0.396	-0.210	-0.340	-0.358
Organic C	0.954**	0.952**	-0.601*	0.934**	0.966**	0.856**	0.979**	0.998**
EC	0.374	0.326	-0.411	0.315	0.337	0.154	0.274	0.299
CEC	0.160	0.049	-0.211	0.171	0.052	-0.035	0.050	0.118
Clay	0.969**	0.941**	-0.649**	0.955**	0.950**	0.818**	0.964**	0.952**
Silt	-0.371	-0.269	0.204	-0.466	-0.352	-0.273	-0.374	-0.459

* and ** indicate significant at p=0.05 and 0.01, respectively

Table 4. *Stepwise regression (R^2) between total P, total inorganic P, total active P and available P with soil properties and inorganic P fractions*

	Equation	R^2	ΔR^2	Eqn. No.
Total active P	= 36.76 + 15.71 Org.C	0.732	-	1
	= -16.84 + 21.74 Org.C + 0.67 Ca-P	0.923	0.191	2
	= 5.70 + 8.10 Org.C + 0.78 Ca-P + 1.16 FeP	0.983	0.060	3
	= 1.75 + 0.47 Org.C + 0.98 Ca-P + 1.04 Fe-P + 0.89 Al-P	0.999	0.006	4
	= 2.15 + 0.98 Ca-P + 1.06 Fe-P + 0.92 Al-P	0.999	-	5
Total inorganic P	= 3.59 + 39.67 Org.C	0.958	-	1
	= 33.43 + 25.67 Org.C + 1.11 Fe-P	0.970	0.012	2
	= 11.76 + 25.22 Org.C + 1.41 Fe-P + 0.37 Ca-P	0.981	0.009	3
	= 4.03 + 10.30 Org.C + 1.18 Fe-P + 0.76 Ca-P + 1.74 Al-P	0.994	0.013	4
	= 10.31 + 4.54 Org.C + 0.76 Fe-P + 0.83 Ca-P + 1.55Al-P + 1.09 Occl-P	0.998	0.004	5
Total P	= 11.75 + 72.26 Org.C	0.996	-	1
Available P	= 1.30 + 0.27 RS-P	0.648	-	1
	= -2.06 + 0.95 RS-P – 0.63 Al-P	0.809	0.161	2

Soil pH bears a highly significant positive correlation with Ca-P (r= 0.587*) and negative with Al-P (r= -0.477) and Fe-P (r= -0.496) (Table 3). The results were in conformity with Mondal *et al.* (2002). On the other hand, clay and organic carbon contents had significantly and positively been related with Al-P (r= 0.969 & 0.954), Fe-P (r= 0.941 & 0.952), RS-P (r= 0.955 & 0.934), Occl-P (r= 0.950 & 0.966), but negatively with Ca-P (r= -0.649 and -0.601), respectively. Total active P, total inorganic P and total P were also eventually significantly related with clay and organic carbon content of soils.

Stepwise regression analysis between physicochemical properties and fractions of inorganic P with total P, total inorganic P and total active P showed that organic carbon player a very important role in explaining their variability (Table 4). Organic carbon alone could explain 95.8, 73.2 and 99.6 percent variability in total inorganic P, total active P and total P content of these soils, respectively and this indicated that phosphate ions were adsorbed on organic colloids through metal bridging or co-adsorption (Tan, 1998). Inclusion of Fe-P and Ca-P with organic carbon improved R^2 values of total inorganic P and total active P to 0.984 and 0.983, respectively. Fe-P, Al-P and Ca-P along with organic carbon explained 99.4 and 99.9 percent variation in total inorganic and total active P content of these soils, respectively. In explaining the variability of available P content (80.9%) in this ecosystem soils, RS-P and Al-P were the indicators.

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Effect of Different Sources of Sulphur on Uptake of Nutrients and Sulphur Use Efficiency : 1. Sunflower Genotypes Grown in Red Soils

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An experiment was conducted to study the effect of different sources of sulphur (elemental sulphur, gypsum and pyrites) on the uptake of nutrients by sunflower genotypes. The uptake of N, P, K, S and sulphur use efficiency by shoot at 45 DAS, harvest stage and by seed was significantly more with the gypsum > pyrites > elemental sulphur. The genotypes also significantly differed in the uptake. More nutrient uptake was observed in Ganga Kalyani-2002 than 6460 PH-1.

***(Key words:** Sulphur, Gypsum, Pyrites, Elemental sulphur, Sunflower, Nutrient uptake & SUE, Red soil)*

Oilseed crops constitute the second largest agricultural produce in India next to food grains and are important source of our economy. Among oilseed crops, groundnut and sunflower are the most promising crops from economic point of view. Sunflower is currently preferred by farmers of Andhra Pradesh owing to its superior quality of oil. The area under sunflower crop in the state is spreading fast and it is replacing the traditionally grown groundnut in some districts.

Sulphur requirement of oilseed crops is very high. On an average, 12 kg S is required to produce 1 ton of oilseeds. The importance of fertilizer application in crop is being gradually established among farmers and lot of attention and investments are now centered on NPK fertilization to achieve immediate high returns without much of organic recycling which accentuates the deficiency of secondary nutrients particularly sulphur in oilseed crops. Hence, the present study was taken up on the effect of indigenous sources such as gypsum, elemental sulphur and pyrites on the uptake of nutrients by sunflower.

MATERIALS AND METHODS

This experiment was conducted using two genotypes (Ganga Kalyani-2002 and 6460 PH-1) in red soils having pH 7.5 and E.C 0.26 dSm^{-1}. The soil is low in organic carbon (0.4%) and has initial content of 195.52 kg ha^{-1} of available nitrogen, 16.20 kg ha^{-1} of phosphorus, 300.29 kg ha^{-1} of potassium and 17.85 kg ha^{-1} of sulphur. The experimental design adopted was factorial RBD. Recommended dose of nitrogen @ 30 kg ha^{-1} in the form of urea, phosphorus @ 60 kg ha^{-1} P_2O_5 ha^{-1} in the form of DAP and potassium @ 30 kg K_2O ha^{-1} in the form of muriate of potash were applied as basal dose. Nitrogen @ 35 kg ha^{-1} was top-dressed in two splits in the form of urea. Sulphur was applied @ 40 kg ha^{-1} through the above three sources. Treatments were replicated six times.

Elemental sulphur and pyrites were applied one month before sowing while gypsum was applied before sowing of seeds. Plants were harvested from three replications at 45 DAS and plants from the remaining three replications were harvested at maturity stage. They were dried, powdered and were digested with diacid mixture (9:4). They were analyzed for N, P, K and S both in shoot and seed by microjeldahl method, vanadomolybdo phosphoric yellow colour method, flame photometer and turbidity method, respectively. Uptake of various nutrients was computed by using the following formula:

$$\text{Uptake of nutrient per pot (mg per pot)} = \frac{\text{Percent concentration of nutrient} \times \text{dry weight of plant per pot}}{100} \times 1000$$

Sulphur use efficiency was calculated using the formula :

$$\text{SUE} = \frac{\text{Uptake of sulphur in treatment} - \text{uptake of sulphur in control}}{\text{Quantity of sulphur added}} \times 100$$

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Table 1. *Effect of different sources of sulphur on the uptake of major nutrients by sunflower grown in red soils*

Treatment	Dry matter (g per pot)		Seed yield g per pot)	N Uptake (mg per pot)			P Uptake (mg per pot)			K Uptake (mg per pot)		
	At 45 DAS	At harvest		At 45 DAS	At harvest		At 45 DAS	At harvest DAS		At 45	At harvest	
				Stalk	Stalk	Seed	Stalk	Stalk	Seed	Stalk	Stalk	Seed
Source												
Control (T1)	5.24	7.22	4.55	105.68	113.64	129.56	9.99	8.62	11.43	67.71	129.01	33.30
Elemental sulphur (T2)	6.21	8.82	5.45	139.72	158.98	160.91	13.94	13.65	17.48	95.93	173.44	42.01
Pyrites (T3)	6.92	9.74	6.21	154.96	186.60	198.42	16.12	16.82	22.41	112.71	200.22	48.66
Gypsum (T4)	8.17	11.85	7.65	202.07	260.70	261.10	21.72	23.32	31.34	146.17	262.85	62.60
S.Em±	0.22	0.30	0.23	4.90	7.76	8.98	0.69	0.94	1.50	5.09	8.37	2.06
C.D (p=0.05)	0.67	0.9	0.72	14.85	23.51	27.22	2.09	2.86	4.56	15.43	25.36	6.26
Genotypes												
6460 PH-1(V1)	6.22	9.02	5.41	139.30	170.72	167.98	12.00	12.18	18.18	93.07	176.97	41.87
Ganga Kalyani-2002 (V2)	7.06	9.73	6.51	161.92	189.24	207.01	18.88	19.02	23.16	118.19	205.82	51.47
S.Em±	0.15	0.21	0.16	3.46	5.48	6.35	0.48	0.66	1.06	3.60	5.91	1.46
C.D (p=0.05)	0.48	0.65	0.51	10.50	16.63	19.25	1.47	2.02	3.23	10.91	17.93	4.42
Interaction												
T1V1	4.92	7.03	4.05	98.09	108.41	113.40	7.57	7.18	9.72	58.94	119.80	29.16
T1V2	5.57	7.41	5.06	113.28	118.88	145.72	12.42	10.06	13.15	76.48	138.38	37.44
T2V1	5.82	8.25	5.00	129.45	150.69	146.00	10.91	10.19	15.50	84.32	160.16	38.00
T2V2	6.66	9.12	5.90	149.99	167.27	175.82	16.98	17.11	19.47	107.54	186.72	46.02
T3V1	6.47	9.25	5.80	142.19	174.59	182.70	12.62	12.64	20.30	98.82	181.70	45.24
T3V2	7.37	10.24	6.63	167.74	198.62	214.14	19.62	21.00	24.53	126.60	218.75	52.08
T4V1	7.69	11.55	6.80	187.48	249.20	229.84	16.92	18.71	27.20	130.20	246.25	55.08
T4V2	8.65	12.15	8.45	216.67	272.20	292.37	26.53	27.94	35.49	162.14	279.45	70.13
S.Em±	0.31	0.43	0.32	6.92	10.96	12.70	0.97	1.33	2.13	7.20	11.83	2.92
C.D (p=0.05)	0.96	1.30	0.97	20.96	33.20	38.49	2.94	4.04	6.46	21.82	35.86	8.85

The quantity of sulphur added was 40 kg ha^{-1}, i.e recommended dose of sulphur to sunflower. The data were statistically analyzed following the analysis of variance method described by Panse and Sukatme (1978). Statistical significance was tested by applying F-test at 0.05 level of probability.

RESULTS AND DISCUSSION

It is evident from the data (Table 1) that the application of different sources of sulphur increased the uptake of N, P, K and S by sunflower shoot and seed. Significant increase in the uptake of nutrients by shoot and seed over control had its cumulative effect leading to higher yield along with higher content of nutrients.

A profuse vegetative growth and higher yield due to S application increased nitrogen uptake (Das and Das, 1994). Increased uptake of phosphorus by plants was because of increased P absorption in the presence of sulphur. The favourable effect of S on the absorption of P could be due to ability of S to mobilize P into available form. Increased uptake of K was mainly because of increase in K concentration and dry matter. Similar results on increase in uptake of N, P and K by sulphur application were also reported by Gangwar and Parameswaran (1977), Sagare *et al.* (1990) in sunflower, and Singh and Bairathi (1980), Singh *et al.* (1986) in mustard.

Sulphur uptake and sulphur use efficiency also increased with its application irrespective of sources (Table 2). This may be due to higher availability of sulphur on its application to soils and also may be due to rapid absorption and translocation by the plant with adequate supply through different sources. This was also reported by Gangadhara *et al.* (1990) and Sreemannarayana *et al.* (1994).

Table 2. *Effect of different sources of sulphur on sulphur uptake and sulphur use efficiency by sunflower grown in red soils*

Treatment	S uptake (mg per pot)			Sulphur use efficiency (%)	
	At 45 DAS	At harvest		At 45 DAS	At harvest
	Stalk	Stalk	Seed		
Source					
Control (T1)	8.56	9.83	9.61	0.00	0.00
Elemental sulphur (T2)	12.24	15.08	14.21	8.52 (2.26)	13.87 (5.78)
Pyrites (T3)	14.81	18.35	17.44	11.15 (3.80)	17.94 (9.55)
Gypsum (T4)	19.47	25.27	22.95	14.93 (6.67)	24.14 (16.79)
S.Em±	0.79	1.02	1.05	0.81	0.93
C.D (p=0.05)	2.42	3.10	3.18	2.47	2.82
Genotypes					
6460 PH-1(V1)	12.30	15.76	13.99	11.02 (3.86)	17.91 (9.87)
Ganga Kalyani-2002(V2)	15.24	18.51	18.11	12.05 (4.62)	19.39 (11.55)
S.Em±	0.26	0.72	0.74	0.57	0.66
C.D (p=0.05)	1.71	2.19	2.24	NS	NS
Interaction					
T1V1	7.57	8.98	8.10	0.00	0.00
T1V2	9.56	10.69	11.13	0.00	0.00
T2V1	10.91	13.83	12.50	8.13 (2.05)	13.44 (5.43)
T2V2	13.58	16.33	15.93	8.91 (2.47)	14.30 (6.14)
T3V1	13.17	16.59	15.66	10.63 (3.43)	17.26 (8.84)
T3V2	16.45	20.12	19.22	11.68 (4.18)	18.63 (10.27)
T4V1	17.57	23.64	19.72	14.30 (6.12)	23.03 (15.34)
T4V2	21.37	26.91	26.19	15.56 (7.23)	25.26 (18.25)
S.Em±	1.12	1.44	1.48	1.14	1.32
C.D (p=0.05)	3.42	4.38	4.49	3.45	3.99

Note : Values in parentheses are original values and without parenthesis are Transformed Arc Sin Percentage values

Gypsum resulted in higher nutrient uptake and sulphur use efficiency followed by pyrites and elemental sulphur. This was due to quick availability of sulphate sulphur present in gypsum than the other two sources. Pyrites because of its associated micronutrients either in composition or as impurities helped better performance of crop over elemental sulphur. Superiority of gypsum over other sources was also reported by Sreemannarayana *et al.* (1993) in sunflower. Subbiah and Singh (1970) in groundnut. mustard and soybean.

Regarding the nutrient uptake and SUE at different stages of crop growth, more uptake of nutrients were recorded at harvest than at 45 DAS. More uptake of N at harvest was because of more biomass production (Sreemannarayana *et al.*, 1998). However, P uptake was high in shoot at 45 DAS even though increase in dry matter was observed at harvest. This was because of more translocation of P to seed as compared to other nutrients (Peter *et al.*, 1983). Unlike P, K uptake by shoot at harvest was much more than at 45 DAS and this was probably due to poor translocation of K to seed when compared to N and P. Peter *et al.* (1983) and Aulakh *et al.* (1985) also reported higher concentration of K in vegetative portion of plant.

Uptake of sulphur by shoot at harvest was not more than by shoot at 45 DAS even though increase in dry matter was recorded like phosphorus. This was because of reduction in sulphur content from flowering to maturity stage which can be attributed to higher quantity of sulphur activity at earlier stages (Sreemennarayana *et al.*, 1994).

Sulphur use efficiency was more at harvest than at 45 DAS. Seed recorded higher sulphur content than straw, which may be due to mobility of sulphur from straw to seed due to high demand resulting in more uptake and more sulphur use efficiency at later stages. Higher use efficiency corresponding with high sulphur uptake was also reported by Raju and Sreemannarayana (1997) in castor which was more at maturity than at flowering.

Sunflower genotypes showed significant variation in nutrient uptake. Ganga Kalyani-2002 proved superior to 6460 PH-1. Differential response by genotypes may be due to their genetic variation and also due to variable sulphur requirements (Tripathi and Sharma, 1993).

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Effect of Integration of Flyash with Fertilizers on Soil Properties and Yield of Groundnut in Alfisols

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A field experiment was conducted for four seasons from *kharif*, 2004 to *rabi*, 2005 on red sandy loam soils (Udic haplustalf) to study the effect of flyash alone and in integration with fertilizers on soil physical, physicochemical, chemical properties and groundnut yield. The results showed that the application of flyash either alone or integrated with fertilizers improved the physical condition and nutrient status of the soil and also increased the pod and haulm yield of groundnut significantly. Flyash @ 25 t ha^{-1} along with fertilizers can be used as an amendment for improving physical condition of the soil and as a source of plant nutrients for groundnut grown in *Alfisols* for maintaining sustainability in terms of both fertility and productivity of the soil.

(***Key words:*** *Flyash, Fertilizers, Alfisols, Physicochemical properties, Nutrient availability, Groundnut yield*)

Modern intensive system of agriculture has brought marked changes in the soil fertility under increased cropping intensity with high yielding varieties and high levels of nutrient input. When the inherent fertility of the soil is depleted, remunerative farming becomes difficult. In Rayalaseema region of Andhra Pradesh, farmers are growing groundnut in both seasons since many years in light soils (Alfisols and Inceptisols). Many farmers of the region do not afford to apply recommended dose of fertilizers. However, their cost and constraints otherwise frequently deter farmers from using recommended quantities of fertilizers and in balanced proportions. Complementary use of plant nutrients from waste materials along with mineral fertilizers is of great importance for enhancing soil productivity by improving soil aggregation and water holding capacity particularly in light soils (Ray, 1994).

Huge amount of flyash, a byproduct of thermal power station, contains some essential plant nutrients such as P, K, Ca, Mg, S and micronutrients. Hence, the present investigation was undertaken to explore the feasibility of using flyash as a component of integrated plant nutrient supply system for sustaining soil productivity and crop yield in an Alfisol.

MATERIALS AND METHODS

Field experiments were conducted for four seasons from *kharif* 2004 to *rabi* 2005 on red sandy loam soil (*Udic Haplustalf*) at Regional Agricultural Research Station, Tirupati (Andhra Pradesh). The flyash collected from RTPP, (Rayalaseema Thermal Power Plant), Muddanur (Kadapa district) was used for the study. The properties of experimental soil and flyash are furnished in Table 1.

The experiment was laid out in randomized block design replicated three times with eight treatments, viz. Absolute control (T_1); Flyash @ 15.0 t ha^{-1} (T_2); Flyash @ 20.0 t ha^{-1} (T_3); Flyash @ 25.0 t ha^{-1}(T_4); NPK (20 : 40 : 50 N, P_2O_5, K_2O) as RDF (T_5); NPK + Flyash @ 15.0 t ha^{-1}(T_6); NPK + Flyash @ 20.0 t ha^{-1} (T_7); NPK + Flyash @ 25.0 t ha^{-1}(T_8). First crop of groundnut was raised during *kharif* 2004 as per treatments and subsequent *rabi* crop was raised on residual fertility level with 75% recommended dose of fertilizers. The post-harvest soil samples were collected after four seasons and analyzed for various physicochemical properties as per the standard procedures outlined by Tandon (1997). The pod and haulm yield and analytical data of soils were statistically analyzed as per the methods described by Nigam and Gupta (1978).

RESULTS AND DISCUSSION

Physicochemical changes

Application of flyash significantly influenced pH of the soil over four seasons of crop (Table 2). pH of the soil increased in all the treatments except in control and was highest with 25 t ha^{-1} of flyash application (pH 7.47), followed by that under flyash @ 20 t ha^{-1} and 15 t ha^{-1}. Pandey *et al.* (1994) reported increased soil pH with increasing rate of flyash. Application of flyash @ 25 t ha^{-1} along with fertilizers maintained neutral soil pH. Maiti *et al.*

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***Table 1.** Properties of experimental soil and flyash*

Parameter	Soil	Flyash
Bulk density (Mgm^{-3})	1.58	1.29
Pore space (%)	39.5	43.6
MWHC (%)	22.8	42.6
pH	6.91	8.90
EC (dSm^{-1})	0.09	0.69
Organic carbon ($g\ kg^{-1}$)	2. 8	6.5
N ($kg\ ha^{-1}$)	230.15	37.64
P ($kg\ ha^{-1}$)	10.5	7.54
K ($kg\ ha^{-1}$)	125.1	89.0
Ca [c mol (p+) kg^{-1}]	2.29	7.20
Mg [c mol (p+) kg^{-1}]	12.61	2.00
S ($mg\ kg^{-1}$)	24.31	30.21
Fe ($mg\ kg^{-1}$)	9.68	17.86
Mn ($mg\ kg^{-1}$)	8.27	1.62
Zn ($mg\ kg^{-1}$)	5.12	2.64
Cu ($mg\ kg^{-1}$)	3.09	2.19

(1990) found that application of flyash to acid soils is likely to neutralize acidity. Application of flyash alone or in combination with fertilizers to groundnut crop brought about significant changes in soil pH in all the treatments but the differences were narrow. Such marginal decrease or increase may not reflect in the growth and yield of the crop. This was in agreement with the findings of Abdullah Taufig and Sudaryano (1998) who found no noticeable differences in pH of Alfisol with the application of organic and inorganic fertilizers application to groundnut crop on a long run. The electrical conductivity of the soil was not influenced by the treatments. This was contrary to the findings of Selvakumari *et al.* (1999) who revealed increased electrical conductivity of the soil with continuous addition of flyash.

The organic carbon content of the post-harvest soil was significantly influenced by the treatments. Higher organic carbon content was recorded with the application of flyash alone or in combination with fertilizers which was due to considerable amount of organic carbon present in flyash itself. The treatment which received flyash @ 25 t ha^{-1} along with RDF was recorded highest (4.2 g kg^{-1}) in organic carbon followed by flyash @ 20 and 15 t ha^{-1}. A study on increase of organic carbon with the application of flyash alone or in combination with fertilizers was reported earlier by Malewar *et al.* (2000).

Application of flyash alone or in combination with fertilizers to the soil significantly influenced the physical properties like bulk density, porosity and MWHC of the soil but the soil strength was not influenced by the treatments. However, lower soil strength values were observed with the application of flyash alone or in integration with fertilizers compared with control. The lower bulk density (1.56 Mg m^{-3}) and higher porosity (45.81%) with high MWHC (26.07%) was observed with application of flyash @ 25 t ha^{-1} along with fertilizers followed by those recorded under flyash @ 20 and 15 t ha^{-1}. Improved physical properties with the application of flyash alone or in combination with fertilizers were reported earlier by Matte *et al.* (1996).

Nutrient availability

The available nitrogen content of the soil was markedly increased with the application of flyash alone or integrated with fertilizers. The addition of flyash @ 15, 20 and 25 t ha^{-1} increased the available nitrogen status of the soil to 176.6, 181.2 and 179.6 kg ha^{-1}, respectively. The combined application of flyash @ 25 t ha^{-1} with fertilizers recorded the highest value of 271.9 kg ha^{-1} of available nitrogen. The contribution of nitrogen through flyash as well as its influence on availability of N in the post-harvest soils might have resulted in such values (Selvakumari *et al.*, 1999).

The combined application of flyash @ 25 t ha^{-1} along with fertilizers recorded highest (38.7 kg ha^{-1}) available P_2O_5 content in the post-harvest soil which was significantly superior to other treatments. In Alfisols, the rise in pH, consequent to addition of silica through flyash, may be responsible for the solubilization and release of soil P due to replacement of adsorbed phosphate ions by silicate ions. This suggests the build-up of soil available P_2O_5 by the use of flyash either alone or in combination with fertilizers in Alfisols. The synergistic effect of combined application of flyash might have resulted in the marked enhancement of P availability in post-harvest soils. Such results were reported earlier by Jambagi *et al.* (1995).

The available potassium status in the post-harvest soil was significantly increased with the addition of flyash either alone or in combination with fertilizers @ 15, 20 and 25 t ha^{-1}, and these were found to be 175.2, 174, 191 kg ha^{-1}, respectively. This increase might be due to addition of potassium through flyash to the soil (Grewal *et al.*, 1998). Results showed that flyash either alone or integrated with fertilizers might have left residual P and K

Table 2. *Effect of flyash on physical and chemical properties of soil after harvest of (after four seasons) groundnut*

Treatment	Physical Property				Chemical Property					
								Available nutrients (kg ha^{-1})		
	BD (Mgm^{-3})	Porosity (%)	MWHC (%)	Soil strength $kgcm^{-2}$	pH	EC $d Sm^{-1}$	O.C. $g kg^{-1}$	N	P_2O_5	K_2O
Control (T_1)	1.68	39.04	19.10	2.3	6.17	0.10	3.1	133.8	20.7	155
Flyash @ 15 t ha^{-1} (T_2)	1.61	40.38	22.58	2.0	7.25	0.08	3.4	176.6	21.9	175
Flyash @ 20 t ha^{-1} (T_3)	1.60	40.58	24.38	2.1	7.33	0.07	3.8	181.2	22.6	174
Flyash @ 25 t ha^{-1} (T_4)	1.64	43.48	23.65	2.0	7.47	0.07	3.8	179.6	23.1	191
NPK as RDF (T_5)	1.58	40.36	25.22	2.1	6.73	0.10	3.9	236.7	31.4	197
NPK+ flyash @ 15 t ha^{-1} (T_6)	1.56	40.90	25.41	2.1	7.06	0.09	4.0	241.7	33.7	203
NPK+ flyash @ 20 t ha^{-1} (T_7)	1.56	44.95	25.34	2.0	6.92	0.11	4.1	258.6	36.1	200
NPK+ flyash @ 25 t ha^{-1} (T_8)	1.56	45.81	26.07	1.9	7.0	0.10	4.2	271.9	38.7	213
C.D (p= 0.05)	0.04	4.36	3.66	NS	0.23	NS	0.4	5.5	6.9	13.5

Table 3. *Effect of flyash on pod and haulm yields of groundnut*

Treatment	Pod yield q ha^{-1}						Haulm yield q ha^{-1}					
	Kharif			*Rabi*			*Kharif*			*Rabi*		
	2004	2005	Pooled	2004	2005	Pooled	2004	2005	Pooled	2004	2005	Pooled
Control (T_1)	13.0	17.2	15.1	27.7	24.7	26.2	32.7	36.9	34.8	24.9	29.8	27.3
Flyash @ 15 t ha^{-1}(T_2)	15.4	23.2	19.3	30.7	27.5	29.1	34.5	37.7	36.1	33.5	34.5	34.7
Flyash @ 20 t ha^{-1}(T_3)	15.8	23.3	19.6	29.8	27.3	28.5	38.7	41.8	40.2	33.0	34.5	33.7
Flyash @ 25 t ha^{-1}(T_4)	16.7	23.7	20.2	32.9	29.2	31.1	40.4	43.6	42.0	36.7	38.1	37.4
NPK as RDF (T_5)	16.8	24.6	20.7	36.8	30.8	33.9	44.5	49.1	46.8	42.6	38.1	40.3
NPK+ flyash @ 15 t ha^{-1}(T_6)	16.6	26.9	21.8	37.4	31.0	34.2	44.0	44.8	44.4	35.7	38.6	37.1
NPK+ flyash @ 20 t ha^{-1}(T_7)	17.1	28.3	22.7	36.8	30.7	33.8	43.8	48.0	45.9	37.8	40.5	39.2
NPK+ flyash @ 25 t ha^{-1}(T_8)	17.7	32.3	25.0	38.7	31.7	35.2	45.5	50.7	48.1	41.8	46.4	38.2
C.D (p= 0.05)	1.2	6.1	2.9	8.7	2.9	2.3	5.0	3.3	1.6	4.8	5.8	5.5

thereby building up their availability in the post-harvest soil. The presence of phosphorous and potassium in flyash and the fineness of the material benefit crop growth by increasing the availability of these nutrients (Selvakumari *et al.*, 1999).

Pod and haulm yield

Application of flyash along with fertilizers to the groundnut crop grown in Alfisols significantly increased yield in both seasons (Table 3). Highest pod and haulm yield was recorded with application of flyash @ 25 t ha^{-1} along with fertilizers in *kharif* and *rabi* in both the years. An increase of 23.7 and 13.4 percent of pod yield and 14.4 and 18 percent of haulm yield with application of flyash @ 25 t ha^{-1} along with RDF over flyash alone applied at the same level was recorded during *kharif* and *rabi*, respectively. This suggests the combined application of flyash with fertilizers to realize higher yields. Selvekumari *et al.*, (1999) have reported such results earlier.

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Intercropping Groundnut and Sweet Corn at Different Fertility Levels and Row Proportions

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A field experiment was conducted during *rabi*-cum-hot weather season of 2004-05 at Dapoli to study the productivity, land-equivalent ratio (LER) and economics of groundnut (*Arachis hypogaea*) + sweet corn (*Zea mays saccharata*) intercropping system at different fertility levels and row proportions. The dry pod yield, haulm yield of groundnut, green cob yield and green biomass yield of sweet corn were highest in case of sole planting and application of 125% RDF. In case of intercropping situation groundnut + sweet corn in the ratio of 3:1 and supplemented with 125% RDF recorded higher dry pod yield while higher green cob yield was recorded at 1:1 row proportion. The maximum value of LER was recorded due to intercropping at 3:1 ratio and supplied with 100% RDF. The net return and B:C ratio were highest due to sole planting of sweet corn growth with 125% RDF followed by groundnut + sweet corn in the ratio of 1:1 and supplemented with 125% RDF.

(**Key words:** *Groundnut, Sweet corn, Intercropping, Fertility level, Row proportion, Growth attributes, Economics*)

Most of the research works and approaches to develop production technologies in the past have been confined to individual crops, but now there is need to work with cropping systems that farmers can practise to exploit location specific agroclimatic conditions for enhanced production. Considering the limited net sown area, it will be necessary to raise the cropping intensity so as to grow more crops on the same piece of land. In Konkan region, groundnut is gaining popularity due to its high yield potential. Similarly, this crop suits into different cropping systems also. Similarly, there is rising demand from the urban people for sweet corn. Taking into account good yield potential and short duration, it could be very well suited either in sequential cropping or intercropping. Since water was not limiting upto March due to well irrigation resources experiment was conducted to study the performance of sweet corn intercropped with groundnut under varying fertility levels and row proportions.

MATERIALS AND METHODS

A field experiment was conducted at Agronomy Farm, College of Agriculture, Dapoli during *rabi* season of 2004-05. The soil of experimental plot was clay loam with slightly acidic reaction (pH 6.51), very high in organic carbon (1.60%), medium in available N (342.6 kg ha^{-1}), and low on P_2O_5 (16.1 kg ha^{-1}) and K_2O (297.4 kg ha^{-1}). The experiment was laid in RBD consisting of fifteen treatments with three replications. The treatments comprised of sole crops, intercropping between sweet corn and groundnut at 1:1, 2:1 and 3:1 row proportions, and supplemented with 75% RDF, 100% RDF and 125% RDF to each crop. The recommended fertilizer dose for groundnut and sweet corn was 25:50:50 and 150:50:150 kg NPK per ha, respectively. Groundnut cv. TG-26 and sweet corn hybrid 'Sumadhur' were grown. For sole planting of groundnut and sweet corn, 30 x 10 cm and 45 x 20 cm spacing were adopted. Two seeds were dibbled at each hill and covered with moist soil. The yield was recorded and considering the present market prices economics were worked out.

RESULTS AND DISCUSSION

Yield and growth attributes

The data recorded on yield components of groundnut and sweet corn are given in Table 1. Intercropping system did not influence 100-kernel weight of groundnut, however, number of pods per hill, weight of pods per hill and percent shelling were significantly influenced due to different treatments. In case of sole planting of groundnut, application of 125% RDF resulted in significantly higher number of pods per hill, weight of pods per hill and percent shelling than the application of 75% RDF did. All these yield components were improved due to intercropping and were highest under the treatment groundnut + sweet corn in 3:1 ratio and provided with 125% RDF. The yield components like length of cob and average weight of cob were significantly higher when groundnut + sweet corn were intercropped at 3:1 ratio and provided with 125%

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Table 1. *Effect of different treatments on yield components of groundnut and sweet corn*

Treatment	Yield components of groundnut				Yield components of sweet corn		
	No. of pods/hill	Wt. of pods/hill (g)	100-kernel wt(g)	Shelling (%)	Length of cob (cm)	Girth of cob (cm)	Av. wt. of cob
T_1 Groundnut (G) 75%RDF	19.60	18.56	44.15	66.35	-	-	-
T_2 Groundnut (G) 100%RDF	21.73	19.61	45.63	66.56	-	-	-
T_3 Groundnut (G) 125%RDF	22.93	21.18	46.40	68.87	-	-	-
T_4 Sweet corn (S) 75%RDF	-	-	-	-	14.35	12.87	159.66
T_5 Sweet corn (S) 100%RDF	-	-	-	-	15.80	13.47	165.89
T_6 Sweet corn (S) 125%RDF	-	-	-	-	17.88	13.93	183.19
T_7 G+S (1:1), 75%RDF	20.67	18.46	45.03	67.49	14.66	12.29	157.53
T_8 G+S (1:1), 100%RDF	22.07	20.18	46.10	67.14	16.51	13.81	170.47
T_9 G+S (1:1), 125%RDF	23.33	21.95	46.63	69.95	17.53	13.86	181.69
T_{10} G+S (2:1), 75%RDF	20.47	18.58	45.10	66.74	14.71	12.99	156.94
T_{11} G+S (2:1), 100%RDF	20.67	20.95	46.13	68.97	15.71	13.26	177.63
T_{12} G+S (2:1), 125%RDF	23.60	22.56	46.07	69.60	17.83	14.63	187.18
T_{13} G+S (3:1), 75%RDF	19.87	19.09	44.27	66.70	14.67	13.29	157.61
T_{14} G+S (3:1), 100%RDF	19.27	21.61	46.10	69.55	16.59	13.67	175.49
T_{15} G+S (3:1), 125%RDF	24.87	24.47	47.47	71.79	18.47	14.85	192.85
SE±	0.61	0.67	0.77	0.63	0.51	0.48	3.98
CD (p=0.05)	1.78	1.97	NS	1.86	1.51	NS	11.66

Table 2. *Groundnut dry pod and haulm yield, sweet corn green cob and stover yield, LER and economics oj intercropping system*

Treatment	Yield (q/ha)		Yield (q/ha)		Net return (Rs/ha)	B:C ratio
	Dry pod	Haulm	Green cob	Stover		
T_1 Groundnut (G), 75%RDF	28.22	36.09	-	-	18582	1.78
T_2 Groundnut (G), 100%RDF	28.74	37.38	-	-	18820	1.77
T_3 Groundnut (G), 125%RDF	31.04	38.93	-	-	21265	1.84
T_4 Sweet corn (S), 75%RDF	-	-	127.25	83.83	37788	1.98
T_5 Sweet corn (S), 100%RDF	-	-	135.32	89.88	63613	2.42
T_6 Sweet corn (S), 125%RDF	-	-	150.44	101.29	98001	2.87
T_7 G+S (1:1), 75%RDF	16.40	20.28	66.75	44.51	32617	2.02
T_8 G+S (1:1), 100%RDF	17.29	22.14	69.75	47.84	46253	2.30
T_9 G+S (1:1), 125%RDF	18.69	23.89	77.60	52.59	65585	2.64
T_{10} G+S (2:1), 75%RDF	19.11	25.07	53.24	35.99	30770	2.03
T_{11} G+S (2:1), 100%RDF	20.05	26.02	54.67	36.60	41234	2.27
T_{12} G+S (2:1), 125%RDF	21.95	28.22	57.58	38.39	54610	2.52
T_{13} G+S (3:1), 75%RDF	25.40	32.12	42.68	28.45	34115	2.15
T_{14} G+S (3:1), 100%RDF	26.28	33.63	43.61	29.51	42439	2.33
T_{15} G+S (3:1), 125%RDF	26.34	34.96	44.83	31.01	50289	2.48
SE±	0.73	0.69	3.12	1.44		
CD (p=0.05)	2.15	2.03	9.75	4.23		

RDF. Though girth of cob was not influenced significantly, it was highest with the intercropping at 3:1 ratio and application of 125% RDF. Similar findings were also reported by Singh *et al.* (2000).

The data recorded on yield of groundnut and sweet corn are presented in Table 2. Sole crop of groundnut provided with 125% RDF gave higher dry pod and haulm yield than when grown as intercrop. The increase in yields was mainly due to higher plant density under the sole cropping compared with that under intercropping combinations. Similar trend was also observed in case of sweet corn. Under intercropping conditions, green cob and biomass yields of sweet corn were significantly higher due to intercropping at 1:1 ratio and application of 125% RDF as compared to those at 2:1 and 3:1 ratio combined with different fertilizers levels. The improvement in yield components of sweet corn was observed in intercropping which might be due to the more availability of symbiotically fixed nitrogen by the groundnut crop, increasing with increasing proportion of groundnut. Sweet corn being the short duration crop (85-90 days) was harvested 40-45 days earlier resulting in least competition with groundnut. This ultimately resulted in improved performance of both the crops considering their total productivity in intercropping system. Such type of results were also observed by Singh and Singh (1993), Kaushik *et al.* (1998) and Singh *et al.* (2000).

Economics

Sole sweet corn when supplied with 125% RDF gave the highest net returns followed by the intercropping of groundnut + sweet corn at 1:1 ratio and supplied with 125% RDF. The higher returns were the result of high total produce and higher prices of green sweet corn cobs. The lowest net returns were recorded under sole groundnut supplied with 75% RDF. Sweet corn gave the higher net returns than groundnut either as sole crop or as an intercrop with groundnut. The higher gross and net returns were, however, observed due to the treatments where sweet corn replaced maximum proportion of groundnut area. The highest benefit:cost ratio was obtained under sole sweet corn supplemented with 125% RDF, which was followed by groundnut + sweet corn at 1:1 ratio and provided with 125% RDF.

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Screening and Evaluation of Rice Varieties for Salinity and Tissue Tolerance

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Some screening procedures are essential to identify the salt tolerant genotypes for direct use or use in the breeding programme. Once such programme was undertaken at the Salinity Lab, University of Sussex, UK under the Indo-UK (CSSRI-Sussex) Collaborative Programme on "Salt-affected soils and breeding for salt resistant crops". Ten rice varieties were used and coastal saline situation including temperature, humidity, etc. was simulated in the green house. The resistant check varieties used were SR26B, CSR10, Pokkali, CSR1, Panvel, etc. and the sensitive check was M1-48. The germinated seeds placed on floats were filled with Yoshida's Culture solution kept in a green house under controlled environment. An amount of 50 mM Nacl was added and pH at 6.5 was maintained all along the test period. At both 20 and 35 day-old stages contents of Na, K and Cl in shoots and roots were, in general, low comparatively in the traditional varieties, viz. SR 26B, Pokkali and CSR1, etc. Those varieties exercise transportation of Na salts in the roots and shoots keeping the amount low, whereas those were almost same in the roots and shoots in M1-48, which is a sensitive variety. Most interesting was Cl content of shoots and roots at 35 day-old stage, which showed lower amount in the tolerant varieties and appreciably higher in the sensitive variety (M1-48). Similar was the response to K at the same stage of growth. After studies on responses to various salts at different stages and recording of the final survival counts at 35 day-old stage the varieties were categorized as: Highly tolerant: SR 26B, IET 1444, Pokkali and IR 16294 CS9-1-30; Moderately tolerant: Panvel 1, CSR 1, and CSR 10; Low tolerant: M1-48. Tissue tolerance studied on four varieties, viz. IR 16294 CS9-1-30, SR 26B, IET 1444 and CSR1 using toxic effect of Na and Cl on chlorophyll showed those varieties quite tolerant and hence are usable in breeding programme for crop improvement.

(**Key words:** *Rice varieties, Stress tolerance, Tissue tolerance*)

MATERIALS AND METHODS

Eight rice varieties grown in the coastal saline soils of India were screened with the check varieties CSR 10 and M 1-48 (Table 1). The coastal saline ecosystem was simulated in growing plants on the floats in tanks filled with 250 litres of Yoshida's culture solution in the Green house with control on temperature and humidity. Fifty seeds of each variety were transplanted on the floats with replications. Regular flow of culture solution was maintained with the pump. At 10 day-old stage 50mM NaCl and at 14 day-old stage another 25 m M Nacl was added to the tanks and pH at about 6.5 was maintained during the entire period of study.

Ten plants were harvested from each of first and second replications at 20 day-old and 35 day-old stage, respectively, shoots and roots were separated, dried, and both were assessed for Na, K and Cl contents (mmol per 10 plants). The third replication was used for recording shoot length, root length, stress symptoms and survival counts, etc. The dried root and shoot samples treated with 5 ml of 100mM acetic acid were digested in hot water bath for 2 hours. Na and K were determined by atomic absorption spectroscopy (Unicam SP 919[3]) and chloride was determined by sensor with a chloride meter. In the study for tissue tolerance four varieties, viz. IR 16294 CS9-1-30, SR 26B, IET 1444 and CSR 1 were used. Seven day-old seedlings were transplanted in the boxes filled with Yoshida's culture solution and kept in Growth chamber. At 15 day-old stage the boxes were salinized with 50mM NaCl. The third leaves were harvested at 30 day-old stage when apparent symptoms of salinity damages appeared. The leaves were heated at 80°C for 10 minutes in 80% ethanol. Optical density was measured (Pye Unicam[3]) and chlorophyll content were estimated. Five ml of 300mM acetic acid was subsequently added to the ethanol extract. Na and K were determined by atomic absorption spectroscopy (Unicam SP 919[3]). Chloride was estimated by chloride meter. Then the leaves were dried and weighed for taking ethanol-insoluble dry weight.

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RESULTS AND DISCUSSION

At both 20 and 35 day-old stages contents of Na, K and Cl in shoots and roots were, in general, low comparatively in the traditional varieties, viz. SR 26B, Pokkali and CSR 1, etc. and Na contents in the shoots were less than those in the roots, in general, but reverse were the contents of K and Cl. The varieties tested were mostly tolerant (Tables 1 & 2). Contents of Na in shoots (mmol per 10 plants) was maximum in Pokkali (0.713) and minimum was in SR 26B (0.1494), whereas that in case of roots was maximum in IR 30864 (1.032) and minimum in SR 26B (0.3901). Almost same amount of Na was present in shoot and root (0.2860 and 0.2999) in M 1-48. It is supported by Kannan (1987), who reported from a solution culture with NaCl (10mM), that Na uptake and transport in roots were lower in the salt tolerant rice variety, Bhura Rata and suggested an 'ion-exclusion' mechanism.

Similarly, at 35 day-old stage Na content of shoots was highest in M 1-48 (4.03) and lowest in Pokkali (1.24) and SR 26B (1.68). The roots contained lower amount of Na than shoots, in general, but the roots of the comparatively tolerant varieties showed higher amount of Na than the shoots (SR-26B 2.79, Pokkali 2.27), whereas M 1-48 had lower amount of the salt in roots (2.60).

So far as chloride content of the shoots at 20 day-old stage was concerned there was no definite pattern of difference among the varieties observed, whereas that in case of roots was comparatively clear. Kannan (1987) observed that Cl uptake in the shoots did not appear to indicate anything on the salt tolerance, which might be due to the study conducted at the early stage by him. Most interesting was Cl (mmol per 10 plants) content of the shoots and roots at 35 day-old stage which indicated the

Table 1. Salt content (m mol) of 10 plants at 20 day-old stage

Variety	Shoot			Root		
	Na	K	Cl	Na	K	Cl
CS 9-1-30	0.22	0.65	0.27	0.36	0.53	0.15
CSR 10	0.21	0.72	0.36	0.43	0.38	0.15
Panvel 1	0.57	0.81	0.49	0.47	0.35	0.12
M 1-48	0.29	0.61	0.25	0.30	0.40	0.16
Jaya	0.34	0.58	0.31	0.43	0.22	0.11
SR 26 B	0.15	0.68	0.22	0.39	0.33	0.13
IET 1444	0.31	0.68	0.26	0.67	0.50	0.18
IR 30864	0.29	0.68	0.26	0.03	0.50	0.18
CSR 1	0.26	0.72	0.25	0.64	0.67	0.14
Pokkali	0.71	0.55	0.20	0.61	0.42	0.12

Table 2. *Salt content (m mol) of 10 plants at 35 day-old stage*

Variety	Shoot			Root		
	Na	K	Cl	Na	K	Cl
CS 9-1-30	1.69	1.57	1.28	2.83	1.11	1.07
CSR 10	3.36	1.89	3.18	3.14	1.05	1.27
Panvel 1	2.90	1.23	2.47	3.04	0.98	0.96
M 1-48	4.03	1.92	3.46	2.60	1.03	1.22
Jaya	3.46	1.11	3.08	2.78	0.84	1.17
SR 26 B	1.68	1.31	1.55	2.22	0.80	0.94
IET 1444	2.96	1.24	2.70	2.79	1.02	0.93
IR 30864	2.52	1.21	2.73	3.18	0.90	1.15
CSR 1	2.17	1.45	2.35	2.61	1.00	0.98
Pokkali	1.24	1.36	1.35	2.27	0.94	0.74

status of the rice varieties. It showed the shoots of M1-48 (3.46) having maximum amount, while others had lower content, viz. CS 9-1-30 (1.28), SR 26B (1.55), Pokkali (1.35), etc. Similar was the picture in case of Cl content in the roots at 35 day-old stage.

K content of shoots and roots at different stages the study at 35 day-old stage may be helpful in getting a clear pattern of status of the varieties. M 1-48 contained maximum amount of K in both shoots (1.92) and roots (1.22), whereas SR-26B had moderate content (1.3 and 0.80, respectively).

Apart from salt dynamics, the observations on seedling height at different stages after salinization showed slower rate of growth, in general, and the root length at 8 days after salinization (DAS) was more affected than shoot length. The shoot length: root length ratio at 8 DAS dropped to 2.0 (1.75 to 2.16) which indicated tolerance as root elongation was affected due to salinization (Table 3). The check variety M 1-48 exhibited a shoot length of 216% (percentage of length attained at non-saline stage of 10 days after which salinization started) at 8 DAS, whereas the other eight varieties ranged between 127 to 151%. The same trend was expressed at 16 DAS, where M 1-48 exhibited 283% elongation and the other varieties were below 200%, but SR-26B expressed 235% elongation. This supports the observation of Kannan (1987) that growth of seedlings in early stages of salinization was not affected which differs from the observation of Flowers and Yeo (1986) stating NaCl at 50mM was so toxic to many dwarf rice cultivars that they died at about two weeks.

Table 3. *Shoot and root length (cm) at 8 days after salinization (DAS) and their ratio*

Variety	Shoot length (cm) at 10 day-age under non-saline condition	Shoot length (cm) at 8 DAS	Root length (cm) at 8 DAS	Shoot length/ Root length at 8 DAS
CS 9-1-30	15.92	24.00	13.10	1.83
CSR 10	15.92	21.56	13.49	1.60
Panvel 1	15.82	20.81	11.69	1.75
M 1-48	11.08	23.73	7.70	3.08
Jaya	17.58	22.42	12.03	1.86
SR 26 B	20.68	26.57	13.41	2.13
IET 1444	15.90	23.67	10.95	2.16
IR 30864	17.71	23.91	11.99	1.99
CSR 1	17.79	26.68	13.67	1.95
Pokkali	23.55	32.31	15.87	2.04

Table 4. *Effect of salinization on seedling elongation (cm) at different (day-old) stages and survival count*

		Percentile increase over non-saline condition					
Variety	Shoot length(cm) at 10 day-old non-saline stage	8 DAS	16 DAS	23 DAS	33 DAS	Survival (%) 34 DAS	Rank
CS 9-1-30	15.92	151	153	171	185	56	4
CSR 10	15.92	135	160	177	185	34	5
Panvel 1	15.82	132	176	215	216	32	7
M 1-48	11.08	216	283	378	314	-	10
Jaya	17.58	127	166	177	178	24	8
SR 26 B	20.68	138	235	242	253	86	1
IET 1444	15.90	149	184	209	205	68	2
IR 30864	17.71	135	168	190	188	16	9
CSR 1	17.79	150	189	214	221	34	6
Pokkali	23.55	137	168	182	198	62	3

The seedling height at 33 DAS was almost stable after 23 DAS in case of Panvel 1 and Jaya but had 32 and 24 percent survival, respectively. IR 30864 had reduced height during the same period with only 16% survival, whereas IET 1444 had reduced elongation, which exhibited 68% survival (Table 4). It indicated that those varieties had potentiality to adapt still under the existing stresses with reduced plant height and those were capable of restoring provided there was improvement of stress situation. Mandal (1998) has reported the variety IR30864 performing well under moderate soil salinity in the coastal areas.

Most interesting was M1-48 which had been showing highest shoot elongation till 23 DAS, reduced elongation thereafter, and at 33 DAS there was no survival which means it had failed to survive under prolonged salinity stress (upto 33 DAS). It was observed that the traditional varieties, viz. SR 26B, Pokkali, CS 9-1-30 with tall stature were found to be tolerant. It corroborates with the report of Garcia *et al.* (1977) stating salt tolerance as a complex character comprising number of component traits (including sodium uptake and compartmentalization), vigour (diluting salt uptake through vegetative growth) that can have a larger effect when diverse germplasm is included.

Considering all these aspects the status of the rice varieties under prolonged salinity stress (upto 33 DAS) may be categorised as:

Highly tolerant : SR26B, IET1444, Pokkali and IR16294 CS9-1-30

Moderately tolerant : Panvel 1, CSR 1 and CSR 10.

Fairly tolerant : Jaya and IR 30864

Low tolerant : M 1-48.

In the experiment for tissue tolerance four rice varieties, viz. IR 16294 CS 9-1-30, SR 26B, IET 1444 and CSR I were tested. Toxicity of chloride was quantified as the concentration in the leaves bringing about reduction in chlorophyll contents in case of first two varieties. The varieties appeared to be tolerant appreciably. The varieties tested here may be used in the breeding programmes for crop improvement. Biswas and Mandal (1999) have reported that the variety IR 16294 CS 9-1-30 performed well under coastal waterlogged situation.

CONCLUSION

The potentiality of the existing rice varieties in the coastal saline soils is refelected in their adaptation over years but the degree of tolerance to the soil salinity stress varies depending on the intensity of stress in the location and the genotypic constitution. The study of rice varieties under saline environment and analysing the plants for the individual salt content quantitatively and co-ordinating those with the growth and survivality parameters helps for identifying suitable varieties either for direct use or for utilizing in a hybridization programme for evolving an improved salt tolerant variety. Here in the study it is observed that SR 26 B, IET 1444, Pokkali, CS 9-1-30, Panvel 1, CSR 1 are quit salt tolerant, which is well supported by the fact that some of those have been used as\donors for evolving salt tolerant high yielding varieties by the breeders earlier. Among those varieties four were tested for tissue tolerance and were found quite promising. Hopefully, the tolerant varieties would be used for production enhancement with better management practices in the coastal ecosystem.

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Variability for Flower Traits in Rice

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The variability in floral structure and floral biology was studied in 15 strains of rice. The spikelet of rice consisted of two sterile glumes, the rachilla and the floret. The number of spikelets per plant ranged from 646.0 to 1470.0. There was a wide range of variation in filament length, angle of floret opening and duration of floret opening. There was also a wide range of variation in days to panicle emergence, days to blooming and blooming duration. The peak period of blooming was between 10.00 AM and 11.00 AM. The grain setting percentage ranged from 55.10 to 82.20 % and yield per plant ranged from 7.58 to 23.80 g.

***(Key words:** Rice, Floral attributes, Flowering behaviour, Variability)*

The knowledge of floral biology is a prerequisite in formulating more efficient crossing programme in self-pollinated crop like rice. Floral attributes and flowering behaviour are very important for commercial exploitation of heterosis. The flowering behaviour also greatly influences yielding ability of genotypes. The grain setting percentage depends upon the blooming characters in spikelets. In view of this, the present investigation was undertaken to obtain a clear picture of the floral attributes and flowering behaviour of rice in coastal salinity condition.

MATERIALS AND METHODS

The experimental material for the study consisted of 15 strains of rice (*Oryza sativa* L.) evolved by Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli (M. S.). The experiment was conducted under field condition at Khar Land Research Station, Panvel in *kharif* 2001 and 2002 by raising the nursery. Transplanting was done 21 days after sowing. Each variety was transplanted in rows with spacing of 20 x 15 cm. A distance of 50 cm was left between two successive varieties. The data were recorded on angle of floret opening, length of filament, time of opening of spikelets, number of spikelets per plant, days to panicle emergence, days to blooming, seed setting percentage and yield per plant. The data were statistically analyzed as suggested by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The detailed investigation on the spikelet revealed that the spikelets were present on the small rachillae at the ends of the branches of the panicle. The rachilla bearing a spikelet had a little bend or contortion above which there was an enlarged angular portion. On this enlarged region, two lower glumes were placed. The lemma and palea were chartaceous, obtuse or acute scaberulous on the nerves. The palea was deeply keeled, three nerved with margins overlapped by those of the lemma. The lodicules, which represented the aborted perianth, were two in number, broad and fleshy. There were six stamens having sudden exertion of growth at the time of anthesis. The ovary was tricarpellary, single celled and single ovuled. The six stamens had two celled anthers borne on slender filaments.

At the time of anthesis, the angle of lemma and palea separation ranged from 18.2 to 27.0^0 and the filament length ranged from 5.2 to 9.6 mm (Table 1). The angle of glume separation depends upon several factors. Wide opening of glumes for long interval in the male sterile parents enables the stigma to intercept with ease the air-borne pollination. It was reported that more the elongation of filaments better was exertion of anthers and hence, higher amounts of pollen dispersal in air (Anandkumar *et al.*, 1989). The spikelet required 2 to 3.5 minutes to open depending upon the atmospheric conditions (Kadam, 1933 and Parmar *et al.*, 1979). With respect to the blooming duration, the period from opening to closing of florets, the results indicated that on normal days it took, on an average, 31.04 to 65.20 minutes. It was observed that in the early strains, the duration was more (48.32 min) followed by mid-late strains (41.25 min) and less in late strains (38.37 min).

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Table 1. *Variation in days to panicle emergence and days to blooming, along with floral attributes in rice*

Strain	Days to first panicle emergence and blooming		Days to 50% panicle emergence and blooming		Days to last panicle emergence and blooming		Duration of panicle emergence and blooming (day)		Angle of floret opening (°)	Length of filament (mm)	Spikelets per plant	Grain setting %	Grain yield per plant (g)
Early	**E**	**B**	**E**	**B**	**E**	**B**	**E**	**B**					
Ratnagiri 73	69	70	72	72	78	80	10	11	19.4	6.2	646.8	73.31	7.58
Karjat 1	71	72	77	77	79	83	09	12	19.4	6.2	732.0	74.31	11.65
Karjat 184	72	73	75	75	80	83	09	12	21.2	7.2	739.6	82.20	12.16
Ratnagiri 24	77	78	81	83	85	88	09	12	22.4	5.2	1470.6	55.10	12.96
Ratnagiri 1	78	79	83	83	86	90	09	13	18.2	6.2	739.4	77.92	12.10
Ratnagiri 711	80	81	85	85	88	91	09	11	21.4	6.4	1001.6	67.31	12.80
	74.5	75	78.83	79.16	82.66	85.83	9.16	11.83	20.3	6.2	888.33	71.69	11.54
Mid-late													
Panvel 1	81	82	89	92	92	96	12	16	19.2	6.2	1106.8	73.72	21.21
Panvel 2	84	85	90	96	94	97	11	14	25.2	6.2	1431.0	77.37	23.80
Karjat 3	87	88	90	93	92	101	06	05	27.0	6.2	856.6	71.19	8.32
Palghar 1	97	98	100	101	102	108	06	02	19.0	5.0	1176.0	81.53	17.25
	87.25	87.25	92.25	95.5	95	100.5	8.75	14.25	22.6	5.9	1140.1	75.95	17.74
Late													
Karjat 14-7	101	101	105	105	108	115	08	05	26.2	9.4	1082.2	78.26	17.78
Karjat 2	108	108	110	111	115	119	08	12	22.6	9.4	685.8	77.22	10.06
Ratnagiri 2	109	109	115	116	118	121	10	13	21.8	8.4	651.4	73.65	13.67
Ratnagiri 3	109	109	115	116	117	121	09	13	22.6	9.6	973.8	68.86	18.10
Ratnagiri 68	110	110	115	116	118	122	09	13	19.0	9.6	919.0	73.89	11.56
	107.4	107.4	112	112.8	115.2	119.0	8.8	8.2	22.4	9.2	862.44	74.39	14.23
Mean	88.86	89.06	93.46	94.73	96.8	101.0	8.93	12.13	21.6	7.16	946.77	73.72	14.067
S.E. ±	3.807	3.753	3.823	3.860	3.72	3.84	0.392	0.37	0.688	0.410	66.581	1.65	0.82
Range	69 to 110	70 to 110	72 to 115	720 to 116	78 to 118	80 to 122	6 to 12	11 to 16	18.0 to 27.0	5.2 to 9.6	646 to 1470	55.10 to 82.20	7.58 to 23.8
S.D. ±	14.746	14.53	14.81	14.98	14.44	14.89	1.52	1.43	2.66	1.59	257.87	6.4038	4.47

E = Emergence

B = Blooming

Table 2. *Variation in the time of opening of spikelet and blooming durations*

Strain	No. of opening of spikelets					Time taken for floret opening (min)	Blooming duration (min)
	8.00 AM	9.00 AM	10.00 AM	11.00 AM	12.00 noon		
Early							
Ratnagiri 73	0.00	0.00	68.96	31.04	0.00	3.0	38.49
Karjat 1	0.00	7.90	72.59	16.55	2.96	3.5	63.05
Karjat 184	0.00	25.93	57.03	17.04	0.00	3.5	65.20
Ratnagiri 24	0.00	0.00	48.34	48.96	2.70	3.0	51.23
Ratnagiri 1	0.00	0.00	28.16	52.59	19.25	3.5	33.23
Ratnagiri 711	0.00	0.00	30.66	69.34	0.00	3.0	37.59
Average	**0.00**	**5.63**	**50.95**	**39.25**	**4.15**	**3.25**	**48.32**
Mid-late							
Panvel 1	0.00	0.00	2.66	74.66	22.68	3.0	44.35
Panvel 2	0.00	3.44	64.13	32.43	0.00	3.0	35.56
Karjat 3	0.00	0.00	64.14	32.42	3.44	3.5	34.22
Palghar 1	0.00	0.00	4.16	95.84	0.00	3.0	50.90
Average	**0.00**	**0.86**	**33.37**	**58.83**	**6.53**	**3.12**	**41.25**
Late							
Karjat 14-7	0.00	22.14	74.28	3.58	0.00	3.0	48.29
Karjat 2	0.00	0.68	77.94	21.38	0.00	2.0	38.00
Ratnagiri 2	0.00	10.00	90.00	0.00	0.00	2.5	35.41
Ratnagiri 3	0.00	6.66	85.34	8.00	0.00	2.0	31.04
Ratnagiri 68	0.00	7.89	66.17	13.35	12.57	2.0	37.14
Average	**0.00**	**7.89**	**66.17**	**13.35**	**.12.57**	**2.3**	**38.37**
Average (%)	**0.00**	**5.12**	**51.44**	**35.85**	**7.59**	**3.03**	**43.23**

The observations on the blooming of rice panicle showed that the upper portion began to bloom first and as the panicle emerged blooming went on downwards. The spikelets began to open from 9.00 AM onwards, the most active period being from 10.00 AM to 12.00 noon (Table 2). In 5.12 percent of the cases, the spikelets started opening at 9.00 AM, the maximum opening being at 10.00 AM (51.44%), and it came down at 11.00 AM (35.85%) to 7.59 % at noon.

The panicle emergence was continuous with the age of the crop and hence, detailed observations were recorded on different dates of panicle emergence and days to blooming (Table 1). The variation in days to panicle initiation ranged from 69.0 days (Ratnagiri 73) to 110.0 days (Ratnagiri 68). The days to last panicle emergence required 78.0-118.0 days. In the early strains, the last panicle emergence required 82.66 days, mid-late strains required 95 days, and the late strains required 115.2 days. The panicle emergence duration ranged from 6.0 to 12.0 days. It was reported that the duration ranged from 3.0 to 12.0 days, while others observed that it was completed on 4th day (Anandkumar *et al.*, 1989 and Kadam, 1933). Thus, the panicle emergence duration changed with the change in environmental conditions.

The crop blooming was also continuous with the advancement of age of the crop. The character, days to blooming has two important considerations, firstly, the days taken for blooming by the parents to enter into a cross for synchronization, and secondly, in planning and completing the hybridization programme. The variation in days to initial blooming ranged from 70.0 to 110.0 days, the days to 50 % blooming ranged from 72.0 to 116.0 days, and the days to last blooming ranged from 80 too 122 days. The blooming duration ranged from 11.0 to 16.0 days (Table 1). This means, the crossing work may be taken up immediately after blooming initiation, which may be continued for a period of about two weeks. The mid-late strains had more duration (14.25 days), followed by the late strains (13.2 days), and least in early strains (11.83 days).

If the blooming duration is less, there is a need to manage hybridization programme efficiently within a short span.

The spikelets per plant ranged from 646.0 to 1470.0 exhibiting a wide range of variation (Table 1). The spikelets were evenly distributed throughout the panicle of the plant. The maximum number of spikelets was observed in mid-late strains (192.08), medium in late strains (154.97), and minimum in early strains (129.08). The seed setting percentage mostly depends upon the number of spikelets per plant (Table 1). The seed setting percentage was maximum in mid-late strains (75.95%). The seed yield per plant was more in mid-late strains (17.74 g per plant), followed by late strains (14.23 g per plant) and early strains (11.54 g per plant).

Thus, it is evident that a wide range of genetic variability existed in respect of the floral biology, which could be utilized for systematic exploitation in rice improvement programme through hybridization.

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Identification of Parents and Hybrids on the Basis of Combining Ability in Okra [*Abelmoschus esculentus* (L.) Moench]

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Eight genotypes of okra [*Abelmoschus esculentus* (L.) Moench], namely D-40, Parbhani Kranti, Long green smooth finger, Arka Abhay, Local, Gold finger, Ankur-40 and Green gold and their crosses made in half diallel fashion were evolved to estimate the combining ability effects. The gca and sca estimates for all characters were highly significant. The estimates for δ^2s were higher than δ^2g. The proportion of δ^2s/δ^2g indicated preponderance of non-additive gene action for all characters. All parents exhibited significant estimates for gca for one or more characters. The parents, Gold finger and Parbhani Kranti were good combiners for most of the characters. Among hybrids, Parbhani Kranti x Gold finger, Long green smooth finger x Green gold, Gold finger x Arba Abhay, and Arka Abhay x Local were identified as promising hybrids. It is revealed that promising hybrids of okra had parents with high, moderate and even of low gca estimates.

(***Key words:*** *Okra, General combining ability, Specific combining ability, Hybrids, Gene action*)

Okra [*Abelmoschus esculentus* (L.) Moench] is grown as an important vegetable crop for its green and tender fruits throughout India. Torrential rains ranging between 3500-4000 mm annually during *kharif* season characterize the coastal area of Maharashtra in Konkan, but fast depletion of moisture in soil due to high percolation rate of water in lateritic soils compels farmers to cultivate crops on residual moisture in soils during *rabi* season. However, farmers require the high yielding and early maturing varieties. Okra is known by large variability in fruit yield, fruit size, duration, height, etc. The ease in emasculation and crossing due to large malavceous flower, heavy pollen load, solitary and axillary flowers arising all over stem, and number of seeds from a single crossed fruit makes okra the best choice for developing hybrids. Therefore, the purpose of this study was to identify promising parents and hybrids in okra suitable for Konkan region.

MATERIALS AND METHODS

The experimental material consisted of eight genetically divergent genotypes of okra [*Abelmoschus esculentus* (L.)], namely D-40, Parbhani Kranti, Long green smooth finger, Arka Abhay, Local, Gold finger, Ankur-40 and Green gold, crossed in half diallel fashion (excluding reciprocals) as suggested in Method-I, Model-II (Griffing, 1956). The twenty-eight F_1's along with 8 parents were grown in randomized block design with three replications during *rabi* 2000.

The experiment was conducted at the Department of Botany, College of Agriculture, Dapoli, Maharashtra. The seeds were dibbled on ridges at 45x20 cm distance between rows and plant, respectively. One vigorous seedling was retained from 2 to 3 seeds dibbled at each hill. The observations were recorded on five randomly selected plants of each genotype per replication for 15 quantitative traits, viz. days to initiation of flowering, days to initiation of fruit, days to maturity for green fruit, days to maturity for seed, plant height, leaf area, number of branches per plant, number of nodes per plant, length of fruit, breadth of fruit, fruit weight, number of fruits per plant, number of seeds per fruit, test weight and fruit yield per plant. The analysis of variance was computed as suggested by Panse and Sukhatme (1976). The combining ability analysis was carried out as per Kempthorne (1969).

RESULTS AND DISCUSSION

Analysis of variance for combining ability revealed highly significantly differences both for general combining ability and specific combining ability variance for all the 15 characters (Table 1). The mean squares for sca were more than those for gca. The ratio of gca/sca revealed the preponderance of non-additive gene action for inheritance of all the characters. Chavadhal and Malkhandale (1994) have also reported similar non-additive gene action of high magnitude for various characters.

The general combining ability (gca) effects of parents are presented in Table 2. The results revealed that none of the parents was good general combiner for all the characters. The high yielding

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Table 1. *Analysis of combining ability for 15 characters in a 8 x 8 diallel of okra* [Abelmoschus esculentus *(L.) Moench*]

Character	Mean sum of square					
	gca (d.f.=7)	sca (d.f.)	Error (d.f.=70)	δ^2g	δ^2s	δ^2g/ δ^2s
Days to initiation of flowering	4.6185**	106.27**	0.1592	0.4459	106.11	0.0042
Days to initiation of fruit	1.1934**	5.99**	0.3412	0.0852	5.648	0.1508
Days to maturity for green fruit	1.1711**	3.344**	0.3457	0.08254	2.998	0.0275
Days to maturity for seed	4.0571**	4.3064**	0.277	0.3780	4.029	0.0938
Plant height	145.98**	70.84**	4.825**	14.11	66.015	0.2137
Leaf area	24.51**	33.24**	0.7835	2.372	34.456	0.0688
Number of branches per plant	0.5631**	0.1762**	0.7712	0.0485	0.09908	0.4895
Number of nodes per plant	18.27**	38.860**	9.975	0.8295	28.885	0.0287
Breadth of fruit	0.07249**	0.02303**	0.01371	0.0058	0.0093	0.6236
Length of fruit	4.5951**	2.6125**	0.720	0.38751	1.262	0.3070
Fruit weight	2.572**	2.083**	0.0295	0.2542	2.0635	0.1231
Number of fruits per plant	20.85**	25.192**	1.924	1.892	23.268	0.813
Number of seeds per fruit	73.244**	68.14**	3.32	6.992	64.82	0.1078
Test weight	0.3621**	2.109**	0.0066	0.0355	2.1024	0.0168
Fruit yield per plant	8890.78**	5161.51**	464.45	842.63	4697.06	0.1793

**Significant at 1 percent level of significance

parent Gold finger was found to be good general combiner for yield per plant, plant height, breadth of fruit, fruit weight, leaf area, and length of fruit. Another parent, Ankur-40 showed desirable general combining ability effect for the characters, viz. initiation of flowering, number of fruits per plant, test weight, and fruit yield per plant. The parent Long green smooth finger showed desirable general combining ability effects for days to maturity for green fruit and maturity for seeds, fruit weight, number of fruits per plant, and fruit yield per plant. The parent Parbhani Kranti also showed desirable general combining ability effects for the characters, days to maturity for seed, length of fruit, breadth of fruit, fruit weight, number of seeds per fruit, and test weight. The early flowering Local parent was good general combiner for test weight. Arka Abhay was good general combiner for initiation of flowering and fruit yield per plant. The parent D-40 was good general combiner for initiation of flowering (-0.389) and number of seeds per fruit (3.289). Pathak *et al.* (1998) have also reported such negative as well as positive gca effects exhibited by parents for different characters in okra.

The specific combining ability (gca) effects of hybrid are presented in Table 3. The results indicated that no hybrid combination was consistently good for all the characters. The highest yielding hybrid combination was consistently good for all the characters. The highest yielding hybrid Parbhani Kranti x Gold finger recorded highest significantly positive specific combining ability effect for fruit yield per plant (272.138). This hybrid also recorded significant specific combining ability effects of high magnitude for plant height, number of nodes per plant, number of fruits per plant, and number of branches per plant. The second high yielding hybrid Long green smooth finger x Green gold exhibited highest significant specific combining ability effect for fruit yield per plant (124.86), plant height (33.09), number of seeds per fruit (14.55), number of nodes per plant (13.82), leaf area (11.87), number of fruits per plant (9.92), number of branches per plant (0.780), and days to maturity for seed (-1.769). The cross Gold finger x Arka Abhay exhibited significant specific combining ability effect in desired direction for yield per plant, leaf area, number of seeds per fruit, number of nodes per plant, number of fruits per plant, number of branches per plant, days to maturity for green fruit, initiation of flowering, and days to maturity for seed. These results signifying a single hybrid exhibiting desirable sca effects for more than on character are in conformity with the findings of Sundhari *et al.* (1992) and Rewale *et al.* (2003).

Present investigation revealed that, on the basis of gca estimates, none of the parents was good combiner for all characters. However, the parents

Table 2. *Estimation of general combining ability of parents for 15 characters in okra [*Abelmoschus esculentus *(L.) Moench]*

Character	D-40	Parbhani Kranti	Long green smooth finger	Gold finger	Arka Abhay	Local	Green gold	Ankur-40	S.E. (gi)	S.E. (gi-gi)
Days to initiation of flowering	-0.389**	-0.224*	-0.164	0.482**	1.138**	-0.451**	-0.102	-0.278*	0.1180	0.1784
Days to initiation of fruit	-0.274	0.192	0.125	0.432**	-0.681**	-0.029	0.238	-0.001	0.1727	0.0923
Days to maturity for green fruit	-0.037	-0.179	-0.414*	0.095	0.970**	0.485**	0.601**	-0.311	0.1739	0.0929
Days to maturity for seed	-0.711**	-0.888**	-0.452**	0.515**	0.014	0.394*	0.288	-0.58	0.1556	0.0832
Plant height	-0.551	-1.231	-1.358*	4.009**	-3.519**	-2.358**	-2.592**	-7.602**	0.6497	0.9823
Leaf area	-0.547*	-2.428**	0.394	2.783**	-0.888**	0.143	0.084	0.551*	0.2618	0.3958
Number of branches per plant	-0.030	-0.109	0.103	-0.145	0.085	-0.115	-0.089	0.144	0.0821	0.1241
Number of nodes per plant	-1.355	0.617	0.399	0.394	-1.602	-1.246	-1.236	0.323	0.9342	1.4124
Breadth of fruit	-0.065**	0.133**	-0.031**	0.107**	0.041**	-0.073**	-0.014**	-0.096**	0.00119	0.0523
Length of fruit	-0.530*	1.062**	-0.939**	0.738**	-0.418	0.272	0.155	-0.345	0.2509	0.379
Fruit weight	-0.083	0.618**	0.136**	1.783**	0.057	0.09	-0.543**	-0.381**	0.508	0.0768
Number of fruits per plant	-1.1317**	-1.783**	1.413**	0.113	-0.809*	-0.503	0.563	2.359**	0.4103	0.62032
Number of seeds per fruit	3.289**	2.562**	-0.913	-3.432**	-1.024	2.188	1.102*	-3.772**	0.05389	0.8148
Test weight	-0.124**	0.310**	-0.089**	-0.124**	-0.107**	0.213**	-0.211**	0.132**	0.02403	0.0363
Fruit yield per plant	-54.328**	-11.136	14.11*	31.018*	14.068*	-20.149*	2.436	23.97*	6.374	9.637

* and ** represent significance at 5 and 1% level, respectively

Table 3. *Estimation of specific combining ability effect for 15 characters in hybrids of okra [*Abelmoschus esculentus *(L.) Moench]*

Hybrid	Days to initiation of flowering	Days to initiation of fruit	Days to maturity for fruit	Days to maturity for seed	Plant height	Leaf area	Number of branches per plant	Number of nodes per plant	Breadth of fruit	Length of fruit	Fruit weight	Number of fruit per plant	Number of seeds per fruit	Test weight	Fruit yield per plant
D-40 x Parbhani Kranti	0.870*	-0.554	-1.29*	0.059	0.598	0.610	0.25	1.73	0.160	-0.390	-0.65**	2.80	10.00**	0.834**	15.18
D-40 x Long green smooth finger	-0.790	-0.017	0.423	0.423	6.795*	0.191	0.121	5.74*	0.126	-0.197	-0.071	3.20**	11.74**	0.103	43.76*
D-40 x Gold finger	-0.509	-0.124	-0.016	-1.314**	1.244	-2.458**	-0.281	-4.525	0.038	1.966**	-0.118	-5.30**	1.19	0.51**	-47.36**
D-40 x Arka Abhay	-0.495	0.259	0.429	-1.43*	-8.514**	-5.137**	-0.461	-1.799	-0.006	0.022	-0.372**	-1.778	-7.28**	1.221	-27.18
D-40 x Local	1.894**	0.607	0.244	0.907	-0.075	-4.538**	0.079	-0.895	-0.132	-0.968	-0.715**	0.316	-5.633**	0.741**	-22.37
D-40 x Green gold	1.345**	1.000*	1.666*	-0.917	2.689	3.799**	0.113	2.876	-0.031	0.579	0.618**	2.45*	-7.407**	0.455**	12.32
D-40 x Ankur-40	-0.819*	-0.561	-0.09*	-1.641**	-3.365	11.67**	0.02	2.405	-0.069	-0.563	0.526**	2.054**	-2.673	0.462**	28.09
Parbhani Kranti x Long green smooth finer	0.498	0.047	0.15	5.80**	20.925**	3.858**	0.40	7.571**	0.262*	1.608**	0.562**	2.53**	9.735**	1.629**	64.029**
Parbhani Kranti x Gold finger	-0.544	-0.32	0.306	0.033	51.839**	3.263**	0.698**	15.573	-0.01	-0.105	-3.746**	10.97**	3.31*	0.734**	272.138**
Parbhani Kranti x Arka Abhay	-1.33**	0.593	-0.429	-0.766	3.967*	-0.866	-0.112	1.369	0.076	3.11	1.957**	1.688	-7.024**	0.797**	41.027**
Parbhani Kranti x Local	-0.541	-0.999*	-1.814**	-0.716	9.120**	-1.907	-0.242	-4.59	-0.07	-4.479*	-1.386**	-2.618	1.134	1.237**	-49.189
Parbhani Kranti x Green gold	0.58	0.004	0.548	-1.01**	-2.49	0.042	-0.068	-1.826	0.021	-0.452	-9.093**	-1.684	3.25*	1.591**	-3.829
Parbhani Kranti x Ankur -40	0.616	1.043*	1.452*	-1.534**	-12.429**	1.965	-0.241	-4.036	0.173	1.336	-0.055	0.32	15.92**	-0.362**	-167.132
Long green smooth finger x Gold finger	-0.464	-0.723	0.211	-1.743**	-20.90**	-1.799	-0.784**	-2.878	0.094	1.365	-0.817	-4.23**	-10.47**	0.663**	-93.422**
Long green smooth finger x Arka Abhay	0.280	2.26**	0.936	4.058*	4.563**	-1.708	0.206	-1.412	-0.16	-1.489**	-1.529	0.492	.32**	0.566**	23.54
Long green smooth finger x Local	0.129	-0.626	0.351	-4.452**	13.602**	6.521**	0.346	7.092**	0.361	0.116	3.986**	0.79	-0.214**	-0.046	71.554**
Long green smooth finger x Green gold	-0.02	-0.399	1.113**	-1.179**	33.09**	11.87**	0.780**	13.823**	0.828	0.139	9.92**	14.544**	0.62**	0.035	124.864*
Long green smooth finger x Ankur -40	0.356	0.380	0.747	1.70**	-11.29**	-5.767**	0.017	-0.747	-0.794	-0.243**	3.324**	-6.331**	1.687**	-0.023	-8.138
Gold finger x Arka Abhay	1.636**	1.42**	-1.303**	-1.769**	7.456**	15.46**	1.564**	0.852*	-4.706**	-0.018	6.592**	10.90**	0.121	-0.218*	5.368**
Gold finger x Local	0.023	0.631	0.15	1.551**	-6.635**	-4.55**	-0.166	-0.974	-1.236	-0.141	-2.114	-9.442**	0.200**	-0.024	85.921**
Gold finger x Green gold	0.674*	0.364*	0.804	2.257**	-12.801**	-6.479**	-0.522*	-2.603	-1.119	-0.138	0.580	3.774*	0.052	-0.123	-43.739
Gold finger x Ankur-40	0.11	-0.267	1.238**	2.063**	1.275	0.494	-0.095	-2.657	1.109	-0.81**	3.024*	0.718	0.562**	0.009	31.679
Arka Abhay x Local	-2.633**	-10.656**	-0.93	0.282**	0.823	-2.51**	-0.036	0.882	-2.15**	0.505**	1.408	5.42**	0.454**	0.162	-112.41**
Arka Abhay x Green gold	0.018	1.407**	-1.001	4.618**	2.397	-0.508	-0.132	-1.077	0.827	-1.102**	-2.658	-6.764**	0.628**	-0.067	-27.76
Arka Abhay x Ankur-40	0.994**	1.446**	0.563	-0.266	-7.067**	-3.52**	-0.295	-2.077	-0.965	0.04	-1.654	-3.96	0.425**	-0.045	-23.332
Local x Green gold	-0.393	-0.045	-5.956**	-1.092	8.766**	12.02**	0.468	6.827*	0.357	-1.775**	7.036**	12.29**	0.138	-0.363**	26.874
Local x Ankur-40	0.643	-0.806	-1.812**	2.054**	1.572	-3.66**	-0.235	1.957	1.625*	0.913**	1.24	6.968**	0.365**	0.199**	51.052**
Green gold x Ankur-40	-0.766	-1.133**	0.88	-0.51	8.476	-0.697	0.079	4.958	1.442*	0.556**	3.574**	-3.886	0.969*	0.170	62.322**
S.E. (sij)	0.3442	0.5039	0.5073	0.4541	1.895	0.7637	0.2396	2.7250	0.7321	0.1481	1.196	1.5721	0.0700	0.1010	18.594
S.E. (sij - sik)	0.5353	0.7836	0.7883	0.7061	2.9470	1.1875	0.3725	4.2373	1.1381	0.2304	1.860	3.5476	0.1089	0.1570	28.913
S.E. (sij - ski)	0.5046	0.7388	0.7437	0.6657	2.778	1.1196	0.35127	3.994	1.073	0.7368	1.754	2.304	0.10276	0.1481	27.26

* and ** Significant at 5 and 1 percent level of significance, respectively

Gold finger and Parbhani Kranti were identified as good general combiners for most of the characters in okra. The sca estimates revealed that no cross combination was good for all the characters. However, the hybrids Parbhani Kranti x Gold finger, Long green smooth finger x Green gold, Gold finger x Arka Abhay and Arka Abhay x Local exhibiting high sca effects were identified as good specific combiners for yield contributing characters.

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Disease Severity, Yield Loss Assessment and Control of Chilli (*Capsicum annum* Linn.) Anthracnose [C.O. *Colletotrichum capsici* (Syd.) Butler and Bisby] under Coastal Saline Zone of West Bengal

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Anthracnose disease [C.O. *Colletotrichum capsici* (Syd.) Butler and Bisby] of chilli (*Capsicum annum* Linn.) occurs regularly on green and ripe fruit in varying intensities and causes considerable crop loss in coastal saline zone of West Bengal. An experiment was conducted during 2002-03 on chilli cultivar, Beledanga with eight fungicides, viz. bavistin (carbendazim, 50%) @ 1 g, indofil M-45 (mancozeb, 75%) @ 2.5 g, saaf (carbendazim 12% + mancozeb, 64%) @ 2.0 g, cuman L (Ziram, 27%) @ 1.5 ml, captaf (captan, 50%) @ 1.5 g, bordeaux mixture (copper sulphate, 1%) @ 10 g, prochloraz 45% EC @ 0.5 ml, 0.75 ml, 1.0 ml, 1.25 ml, and blitox 50 WP (copper oxychloride, 50%) @ 4.0 g per litre of water in twelve treatments including control to assess the intensity of disease on fruit and monetary yield loss caused by the disease and work out economic gain due to reduction of disease severity by fungicide spraying. Results indicated that percent loss in fruit yield due to disease in control plots was around 12.5% when the percent of diseased fruit in the same plots ranged from 10.1 – 14.1. All treatments except saaf reduced the incidence of disease on chilli fruits and percent loss in fruit yield significantly as compared to control. The percent and yield of diseased chilli fruits per plot and percent loss in fruit yield due to disease were found lower in bordeaux mixture treated plot followed by bavistin, blitox and other fungicide treatments. Monetary loss due to production of diseased chilli was Rs. 5115 per ha in absence of fungicidal measures whereas it was reduced to Rs. 1503, Rs. 1502 and Rs. 1730 in bordeaux mixture, bavistin and blitox 50 WP treatments, respectively. Net profit due to chilli cultivation was Rs. 20525 per ha but the same due to fungicide spraying over control was Rs. 6800. Monetary advantage assessed as return-cost ratio was found higher in bordeaux mixture (1.40) followed by captaf (1.29), blitox (1.24) and others as compared to control (0.98). Considering the parameters studied, bordeaux mixture still appeared to be economically the best fungicide against the management of anthracnose disease of chilli.

(***Key words:*** *Chilli, Colletotrichum capsici, Fungicides, Crop loss, Economics*)

Anthracnose disease [*Colletotrichum capsici* (Syd.) Butler and Bisby] causing die-back and ripe fruit rot of chilli (*Capsicum annum* Linn.) occurs regularly in varying intensities, viz. 13.9 – 58% (Patil *et al.*, 1993, Hegde *et al.*, 2001, Ekbote, 2002, 2005), and causes considerable loss in yield and quality (Jeyalakshmi *et al.*, 1999).

Use of resistant genotype(s) identified is the most useful, cheap and viable tool to minimize the crop loss due to the disease (Singh *et al.*, 1997, Jeyalakshmi and Seetharaman, 1998a, Patil *et al.*, 2003). Still attempts were made to use plant products (Jeyalakshmi and Seetharaman, 1998b, Bagri *et al.*, 2004), plant growth promoting rhizobacteria (Bharathi *et al.*, 2004), antagonistic microorganisms (Jeyalakshmi and Seetharaman, 1998b, Jeyalakshmi *et al.*, 1998), organic pesticides, manures alongwith inorganic fertilizers (Fugro, 2000) and homeopathic drugs (Khare and Atri, 1997) as alternative methods for avoiding pesticidal hazards, minimizing the disease, and maximizing yield. However, management of this disease by chemical as seed treatment or spray or both (Perane and Joi, 1989) is still popular and adopted by most farmers.

Chilli is one of the most important cash crops, next to betelvine, in South 24 Parganas district under coastal saline zone of West Bengal. Out of 63.1 thousand ha area under the crop in West Bengal, the South 24-Parganas district alone has an acreage of 16.7 thousand ha. The crop is attacked each year by anthracnose disease in varying

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intensities causing considerable yield loss. The amount of yield loss caused by the disease and extent of monetary gain due to effective control of the disease by suitable fungicide spraying has yet to be assessed from this zone. For this reason field experiment was conducted with a view to assess the disease intensity and amount of loss caused by the disease as well as to screen out the effective fungicide(s) having potentiality to reduce the amount of yield loss and thereby enhancing the monetary gain.

MATERIALS AND METHODS

The field experiment was conducted during 2002-03 at Regional Research Station of Bidhan Chandra Krishi Viswavidyalaya under coastal saline zone, Kakdwip, South 24-Parganas, West Bengal with eight fungicides, viz. bavistin 50 WP (carbendazim, 50%), indofil M-45 (mancozeb, 75%), saaf (carbendazim 12% + mancozeb, 64%), cuman L (Ziram, 27% SC), captaf (captan, 50% WP), bordeaux mixture (copper sulphate, 1%), prochloraz 45% EC, and blitox 50 WP (copper oxychloride, 50%) in twelve treatments including control following randomized block design in three replications. Prochloraz 45% EC with four doses (0.50 ml, 0.75 ml, 1.00 ml and 1.25 ml per litre) constituted four treatments whereas other seven fungicides with single dose comprised of rest seven treatments besides control. Experimental plots were of 2m x 2m size which accommodated sixteen plants with spacing of 50 x 50 cm. Transplanting of seedling was done each year between 7-15th January. Well rotted farmyard manure was applied @15 t ha^{-1} and chemical fertilizers, i.e. N, P_2O_5 and K_2O @ 60:30:30 were applied as per recommended practice for the area. Irrigations, weeding and other intercultural

Table 1. *Effect of different fungicides on percent incidence of anthracnose disease infested fruits and plot yield of diseased chilli*

Treatment	Dose per litre	% of diseased fruit			Chilli yield (g) per diseased plot		
		2001-02	2002-03	Pooled	2001-02	2002-03	Pooled
Bavistin (Carbendazim, 50%)	1.0 g	3.5 (2.0)	4.0 (2.1)	3.8 (2.1)	56.5	34.0	45.3
Indofil M-45 (Mancozeb, 75%)	2.5 g	7.1 (2.7)	8.0 (2.9)	7.6 (2.8)	107.4	88.6	98.0
Saaf (Carbendazim 12% + Mancozeb 64%)	2.0 g	9.6 (3.2)	13.0 (3.7)	11.3 (3.5)	137.6	98.6	118.1
Cuman L (Ziram, 27%)	1.5 ml	3.8 (2.1)	5.4 (2.4)	4.6 (2.3)	87.5	43.0	65.3
Captaf (Captan, 50%)	1.5 g	3.9 (2.1)	5.8 (2.5)	4.9 (2.3)	73.2	38.0	55.6
Bordeaux mixture (Copper sulphate, 1%)	10.0 g	2.7 (1.8)	3.5 (2.0)	3.1 (1.9)	52.0	39.0	45.5
Prochloraj 45% EC	0.5 ml	7.2 (2.8)	8.8 (3.0)	8.0 (2.9)	72.7	80.6	76.7
Prochloraj 45% EC	0.75 ml	6.0 (2.5)	6.4 (2.6)	6.2 (2.6)	94.8	68.3	81.6
Prochloraj 45% EC	1.00 ml	6.0 (2.5)	5.0 (2.3)	5.8 (2.5)	79.8	50.3	64.9
Prochloraj 45% EC	1.25 ml	4.1 (2.1)	4.8 (2.3)	4.5 (2.2)	86.0	58.9	72.5
Blitox 50 WP (Copper oxychloride, 50%,	4.0 g	4.5 (2.2)	2.4 (1.7)	3.5 (2.0)	64.7	39.6	52.2
Control	-	10.1 (3.3)	14.1 (3.8)	12.1 (3.6)	158.1	153.3	156.0
SEm±		0.06	0.08	0.07	5.1	4.2	4.8
CD (p=0.05)		0.18	0.22	0.21	15.0	12.5	14.2

Figure within parenthesis indicates square root transformed value operations were done as and when required. Disease was found to first appear from end of March to second week of April during both years of experimentation. First spraying of fungicides was done at the onset of the disease and four sprayings were given at 12 days interval. Starthane (acephate, 75% WP) was sprayed @ 0.75 g L^{-1} of water at 15 days interval for checking the chilli thrips infestation. Data on number and weight of healthy and diseased fruits were taken per plot basis on each plucking and were statistically analyzed. Percent data were analyzed statistically after changing to square root transformed value.

The economics of disease control was judged by computation of total cost, net return, return-cost ratio as well as by the computation of monetary advantage over control. Cost of inputs including labours for different agronomic operations were also included in the total cost estimation.

RESULTS AND DISCUSSION

Results presented in Table 1 indicated that percent of anthracnose disease infested fruit in control plot ranged from 10.1 – 14.1%. The yield of diseased chilli was also the highest in control plot. But fungicide treatments except saaf reduced both diseased fruit yield and percent of diseased fruit per plot significantly. The effect of reduction was more pronounced and higher in bordeaux mixture closely followed by that in bavistin and blitox 50 WP. The fruit rot incidence due to the disease had been recorded earlier as 13.9 – 58.0% (Patil *et al.*, 1993, Hegde *et al.*, 2001) from chilli growing tracts. But application of fungicides reduced fruit infection and rot thereby increased fruit yield per unit area (Mandal and Beura, 2003, Joi *et al.*, 2004).

The disease also caused on an average 12.5% loss in fruit yield in absence of any control measure (Table 2). Such yield loss may be due to the loss of

Table 2. *Effect of different fungicides on production of healthy chilli and percent yield loss due to disease*

Treatment	Dose per litre	% of diseased fruit			% yield loss per plot		
		2001-02	2002-03	Pooled	2001-02	2002-03	Pooled
Bavistin (Carbendazim, 50%)	1.0 g	1.307	1.163	1.235	4.2 (2.2)	2.8 (1.8)	3.5 (2.0)
Indofil M-45 (Mancozeb, 75%)	2.5 g	1.185	1.168	1.176	8.3 (2.9)	7.1 (2.7)	7.7 (2.8)
Saaf (Carbendazim 12% + Mancozeb 64%)	2.0 g	1.182	1.013	1.094	10.4 (3.3)	9.0 (3.1)	9.7 (3.2)
Cuman L (Ziram, 27%)	1.5 ml	1.464	1.068	1.266	5.7 (2.5)	3.8 (2.1)	4.8 (2.3)
Captaf (Captan, 50%)	1.5 g	1.518	1.166	1.342	4.6 (2.3)	3.1 (1.9)	3.9 (2.1)
Bordeaux mixture (Copper sulphate, 1%)	10.0 g	1.558	1.253	1.405	3.3 (1.9)	3.0 (1.8)	3.2 (1.9)
Prochloraj 45% EC	0.5 ml	1.371	0.994	1.183	7.8 (2.9)	7.5 (2.8)	7.7 (2.9)
Prochloraj 45% EC	0.75 ml	1.215	1.178	1.196	7.3 (2.8)	5.6 (2.5)	6.5 (2.7)
Prochloraj 45% EC	1.00 ml	1.378	1.226	1.302	5.4 (2.4)	4.0 (2.1)	4.7 (2.3)
Prochloraj 45% EC	1.25 ml	1.381	1.189	1.285	5.8 (2.5)	4.8 (2.3)	5.3 (2.4)
Blitox 50 WP (Copper oxychloride, 50%	4.0 g	1.415	1.242	1.329	4.4 (2.2)	3.1 (1.9)	3.8 (2.1)
Control	-	1.106	1.117	1.111	12.7 (3.7)	12.2 (3.6)	12.5 (3.7)
SEm±		0.079	0.080	0.080	0.06	0.07	0.07
CD (p=0.05)		0.232	0.235	0.233	0.16	0.21	0.22

Figure within parenthesis indicates square root transformed value dry weight of fruits (Basak, 1994). Fungicide application increased healthy chilli fruit yield by reducing the percent loss in yield due to disease. Healthy chilli yield per plot was higher with bordeaux mixture followed by that under captaf, blitox 50 WP and others. Percent loss in yield due to disease was observed low in bordeaux mixture, blitox 50 WP and bavistin. Saaf, among the fungicide treatments, exhibited higher yield loss. So far as reduction of percent diseased fruit, diseased fruit yield, yield loss, and increment of fruit yield were concerned, bordeaux mixture appeared to be the promising fungicide followed by bavistin, blitox 50 WP and others. Present findings about the efficacy of

Table 3. *Monetary loss due to production of diseased chilli*

Treatment	Av. yield (g) of diseased chilli per 4m^2 plot	Yield of diseased fruit projected to healthy fruit yield (kg/ha)	Market price of the projected yield (Rs.)*	Monetary loss due to production of diseased chilli (Rs.)
Bavistin (Carbendazim, 50%)	45.3	150.2	1502	1502
Indofil M-45 (Mancozeb, 75%)	98.0	323.5	3235	3235
Saaf (Carbendazim 12% + Mancozeb 64%)	118.1	387.3	3873	3873
Cuman L (Ziram, 27%)	65.3	214.0	2140	2140
Captaf (Captan, 50%)	55.6	182.3	1823	1823
Bordeaux mixture (Copper sulphate, 1%)	45.6	150.3	1503	1503
Prochloraj 45% EC	76.7	250.5	2505	2505
Prochloraj 45% EC	81.6	264.0	2640	2640
Prochloraj 45% EC	64.9	214.0	2140	2140
Prochloraj 45% EC	72.5	236.8	2368	2368
Blitox 50 WP (Copper oxychloride, 50%)	52.2	173.0	1730	1730
Control	156.0	511.5	5115	5115

* Price of 1 kg healthy green chilli is Rs. 10.00

Table 4. *Monetary advantage due to fungicide spraying*

Treatment	Av. yield (g) of diseased chilli per 4m^2 plot	Total return from healthy chilli per ha (Rs.)*	Total cost per ha (Rs.)	Net return per ha (Rs.)	Return cost-ratio
Bavistin (Carbendazim, 50%)	1.235	30875	14790	16085	1.09
Indofil M-45 (Mancozeb, 75%)	1.176	29400	14850	14550	0.98
Saaf (Carbendazim 12% + Mancozeb 64%)	1.094	27350	15435	11915	0.77
Cuman L (Ziram, 27%)	1.266	31650	14380	17270	1.20
Captaf (Captan, 50%	1.342	33550	14680	18870	1.29
Bordeaux mixture (Copper sulphate 1%)	1.405	35125	14600	20525	1.40
Prochloraj 45% EC	1.183	29575	14300	15275	1.07
Prochloraj 45% EC	1.196	29900	14426	15474	1.07
Prochloraj 45% EC	1.302	32550	14550	18000	1.24
Prochloraj 45% EC	1.285	32125	14676	17449	1.19
Blitox 50 WP (Copper oxychloride, 50%)	1.329	33225	14850	18375	1.24
Control	1.111	27775	14050	13725	0.98

* Price of 1 kg healthy green chilli is Rs. 10.00

bordeaux mixture corroborated with the results of Sulochana *et al.* (1992), where they found 1% bordeaux mixture and 0.3% ziride (ziram) equally and more significantly effective than other treatments. The efficacy of blitox 50 WP, bavistin and prochloraz as indicated by the results had also been found effective against the disease (Jayasekhar *et al.*, 1987, Biswas, 1992, Hegde and Anahosur, 2001, Ekbote, 2003). But in the present experiment indofil M-45 and saaf were not so effective as were recorded in case of other fungicides though its effectiveness had been proved by several other workers (Malraja and Narayanaswami, 1988, Ebenezer and Alice, 1996, Singh *et al.*, 2000). Ineffectiveness of fungicide saaf against the disease may be due to the presence of lower concentration of carbendazim used in the experiment since sole fungicide at 0.1% dose was highly effective against the disease. Mancozeb which was one of the two active ingredients of saaf was also the active ingredient of indofil M-45. Since mancozeb did not perform well against the disease saaf did not perform as well up to the mark.

Disease infested fruits were not only lower in weight as compared to healthy fruits but also poor in quality and thereby fetched lower market price. So, there was substantial monetary loss due to the occurrence of anthracnose disease. Monetary loss due to the occurrence of the disease was higher in control followed by saaf, indofil M-45 and others, whereas the same was lower in bordeaux mixture, bavistin and blitox 50 WP treatments (Table 3).

Fungicide spraying reduced the infestation of disease on green chilli at the developing stage and thereby the yield of healthy chilli per unit area increased as compared to control. Computation of monetary advantage revealed that fungicide spraying except saaf gave added monetary advantage over no spraying, i.e. control (Table 4). Net monetary return was higher in bordeaux mixture followed by captaf, blitox 50 WP and others. Monetary advantage measured in terms of return-cost ratio indicated the same trend. The return-cost ratio of indofil M-45 was observed at par with control but saaf spraying against the disease lowered the return-cost ratio further as compared to control. So, use of indofil M-45 and saaf against anthracnose disease would not be economically viable. Fungicidal management of anthracnose disease would be economically feasible when the disease crossed the threshold limit. At that stage it would definitely bring higher net monetary return and return-cost ratio. The economics of disease management by chemicals had earlier been computed by several workers from other areas (Kamawat, 1997, Mandal and Beura, 2003, Hingole and Kurundkar, 2004) and they indicated net profitability of Rs. 8895 – 15479 per ha. In the present study the fungicide sprayings resulted in net profitability of Rs. 6800 over control but net profitability of chilli cultivation was Rs. 20525 per ha.

So, it is apparent from the results of the experiment that anthracnose disease on chilli fruits caused substantial yield loss affecting weight and quality of the fruits and it can be effectively and economically controlled by fungicide spraying especially by bordeaux mixture, captaf, blitox 50 WP and bavistin.

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Comparative Analysis on the Growth Response of Diatom *Skeletonema costatum* in Different Culture Media

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Nine culture media, such as Walnes, PM, SEAFDEC, TMRL, Suto, Miquels, Guillard f, f/2 and f/4 have been used to find out suitable media for successful culture of *Skeletonema costatum* which are widely used as larval food of prawns. Among the tested media, Walnes has given best multiplication (14.5 lakhs cells ml^{-1}) of this species under laboratory conditions. The study revealed that the culture has to be harvested on 3rd to 4th day in media Walnes, Guillard f, TMRL, PM, SEAFDEC and Miquels whereas algae in the media of Suto, Guillard f/2 and Guillard f/4 can be harvested on 2nd to 3rd day of culture after inoculation. The availability of nutrients such as nitrate, phosphate, iron and silicate is essential for the production of this species, and their appropriate proportions are required in the culture media to escalate the maximum cell multiplication. To keep the starter culture in good condition, *Skeletonema* culture is needed to be reinoculated on every 3rd day of its culture.

*(**Key words:** Skeletonema costatum, Microalgae, Culture media, Stock culture)*

Microalgae being the predominant component in the aquatic food chain have got immense value as aquaculture live feed, and as a result the production of unicellular algae has gained importance in several countries due to their wide use as food in the hatchery seed production of commercially important shell and fin fishes. Therefore, the microalgae are indispensable food source in commercial rearing of many cultivated species including all growth stages of bivalve molluscs, larval stages of some crustacean species and very early growth stages of some fin fishes. Microalgae are used for the mass production of zooplankton, which in turn serve as food of the larval stages of fish species. Moreover, the algae are also directly introduced into the larval rearing tanks of marine fishes as they play a vital role in stabilizing the water quality, nutrition of the larvae and microbial control. Among the microalgal species *S. costatum* belonging to the class Bacillariophyceae is the first widely used prawn larval food for *Penaeus monodon* and other prawn species in research and in commercial hatcheries (Fujinaga, 1967, Liao, 1970). Even though *S. costatum* has several advantages over the other microalgal species, the maintenance of its stock culture is always met with difficulties especially during summer season as it could not thrive under high temperature (Mock and Murphy, 1971). However this species has been extensively used for the larval rearing of shrimp (Hudinaga, 1942, Cook and Murphy, 1969). Thus, the development of stock culture of Skeletonema culture is inevitable as it holds great potential in future for breeding of marine prawns in Andaman and Nicobar Islands. In this context an experiment has been carried out to find out suitable culture media for its stock culture maintenance in Andaman waters.

MATERIALS AND METHODS

Microalgae *S. costatum* were isolated from the water samples collected form Dundus point of Bay island by micropipette method (Sournia, 1978) and maintained in 50 ml test tube in algal culture laboratory under controlled conditions of temperature, i.e. 23 to 25° C, pH 7.8 to 8.2, salinity 30 to 32 ppt and illumination provided for 12 h. These cultures were then transferred to 250 ml conical flask under the same environmental conditions of the inoculum. In order to find out befitting media for the successful maintenance of stock culture of *S.costatum*, nine different culture media Walnes (Walney, 1974), PM, SEAFDEC (Pantastico, 1977), TMRL (Tung Kong Marine Research Laboratory, Tahiti), Suto (Suto, 1959), Miquels (Miquel, 1892) Guillard f, f/2 and f/4 (Guillard and Ryther, 1962) were freshly prepared prior to the culture experiments.

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Three haufkin flasks containing one litre of sterilized seawater enriched with culture media in standard proportions were carried out to study the variability, growth rate and differentiation of the culture media along with control (without addition of nutrients). For each media and control, three replicates were maintained and to each culture flask an initial volume of 5 ml algal inoculum having cell density of 15×10^5 cells ml^{-1} was added and maintained under the controlled condition of temperature, i.e. 23 to 25°C, pH 7.8 to 8.2, salinity 32 to 34 ppt, and illumination for 12 hours (2000 lux). The flasks were swirled 3 times daily to enhance gas exchange and to avoid settlement of cells. During the experiment daily one ml of samples were taken from each flask and kept in stoppered test tubes with a few drops of Liguol's iodine solution which helped to kill and stain the cells for counting. Before counting, the samples were vigorously shaken to break up dividing cell and number of cells were counted daily at 10 hrs with the aid of an improved neubauer ruling haemocytometer as per the methodology followed by Smith *et al.* (1993). The mean value of triplicates of each media was accounted for the expression of algal growth. The relative growth rate (k) of algae in terms of cell division was calculated as suggested by Hoogenhout and Amesz (1965).

RESULTS AND DISCUSSION

During the first and second day of the experiment, the tested algae underwent the lag phase which did not show much variation among the tested media and the growth of *S. costatum* was slow during these days in all tested media. This might have been due to deactivation of enzyme or decreased level of metabolic level of inoculum. Cell size may have increased without cell division or some diffusible factors produced by the cells themselves may have been necessary for carbon fixation or introduction of inoculum into a medium containing high concentration of some particular substance. But on the second day onwards all media influenced the growth of algae to start the exponential phase. The media which showed maximum multiplication were 14.5 lakh cells ml^{-1} in Walnes media, 12.2 lakh cells ml^{-1} in Guillard f, 11.00 lakh cell ml^{-1} in TMRL, 10.8 lakh cells ml^{-1} in PM, 9.65 lakh cells ml^{-1} in SEAFDEC, and 8.8 lakh cells ml^{-1} in Miquels medium on 4th day, whereas the peak cell density in Suto, Guillard f/2 and Guillard f/4 was 11.625, 11.15, 9.5 lakh cells ml^{-1}, respectively on 3rd day (Table 1). Thereafter, it showed sudden decline in cell density which might have been due to depletion of particular materials or change in the rate of supply of carbondioxide or oxygen or change in pH. This was due to preferential absorption or with a balance formed between growth rate and limiting factor or depletion of nutrients to a level incapable of sustaining growth or build-up of metabolites to toxic level. In the experiment it was observed that cell size gradually decreased during consecutive cell division and the size of the cell became less than 7μ which accelerated the formation of auxospores, and after this the formation of course chain was repeated. The onset of decay of a Skeletonema culture was observed later in coarser chain lines and at this stage the cultures were neither suitable as food for larvae nor as inoculum for subsequent culture.

Out of the tested media, Walnes medium showed maximum cell density and the relative growth constant k (number of doubling per day) was found to be 4.393 doublings per day on fourth day, whereas other media showed comparatively less doublings on the same day (Table 2). The higher multiplication of *S. costatum* in the Walnes medium may be due to the availability of higher level of nitrate, phosphate, iron, silicate and vitamins,

Table 1. *Multiplication of* S. costatum *in different culture media*

Day	Cell density (lakh cells/ml) in different culture media									
	Walnes	Guillard f	Suto	Guillard f/2	Guillard f/4	PM	TMRL	SEAFDEC	Miquels	Control
1	0.75	0.675	0.6	0.5	0.2	0.625	0.5	0.45	0.35	0.25
2	2.05	1.875	1.7	1.4	0.8	1.45	1.25	1.05	0.95	0.875
3	8.5	7	11.625	11.15	9.5	6.3	5.95	5.65	5.25	1.2
4	14.5	12.2	10.05	10.275	7.5	10.8	11	9.65	8.8	1.95
5	11.75	10.075	4.2	3.55	3.1	9.3	9.55	7.325	7.325	1.3
6	4.575	2.725	3	2.8	2.05	2.95	3	2.9	2.75	0.8
7	1.325	1.175	1.1	1.1	0.5	0.95	1	0.875	0.6	0.375

Table 2. *Relative growth rate of* S.costatum *(division/day) in different culture media*

Day	Culture media									
	Walnes	Guillard f	Suto	Guillard f/2	Guillard f/4	PM	TMRL	SEAFDEC	Miquels	Control
1	0.909	0.818	0.727	0.606	0.242	0.757	0.606	0.545	0.424	0.303
2	1.242	1.136	1.030	0.848	0.485	0.879	0.757	0.636	0.576	0.530
3	3.431	2.828	4.696	4.504	3.838	2.545	2.404	2.282	2.121	0.485
4	4.393	3.696	3.045	3.113	2.272	3.272	3.333	2.924	2.666	0.591
5	2.848	2.442	1.018	0.860	0.751	2.254	2.315	1.775	1.775	0.315
6	0.924	0.550	0.606	0.566	0.414	0.596	0.606	0.586	0.555	0.162
7	0.229	0.203	0.190	0.190	0.087	0.164	0.173	0.152	0.104	0.065

Cyanocobalamine (B12) and Thiamine Hydrochloride (B1). The relative growth in terms of doubling per day also showed low values during the initial days of culture and the rate of growth was maximum in the exponential phase and thereafter showed a declining trend. The study also elucidated that multiplication was comparatively high in media containing silicates which indicates that an adequate level of silicate is essential for the growth of *S. costatum*. Though the Guillard f, f/2 and f/4 media are similar in composition except the quantity of nutrient added, on the reduction of quantity of the nutrient in f/2 and f/4, they showed noticeable decrease in cell density than the Guillard f. This revealed that nutrients in appropriate proportions were required in the culture media to accelerate the multiplication of cells. Thus, the higher cell density obtained in Guillard f medium is attributed to optimum quantity of minerals, trace metals and vitamins in this medium. Walney (1974), Suba Rao (1981), Wikfors (1986) and Laing (1991) also reported that the nutrients such as trace metals, nitrate and phosphate had an influence on the growth of microalgae. Smith *et al.*(1993) reported that Guillard medium is the most widely used for seawater enrichment and it would support the growth of virtually all marine microalgal species. According to the cell quota concept, the growth rate of algae decreases and growth ceases (Droop, 1975) and biochemical composition decreases (Fabregas *et al.*, 1985, Fernandez-Reiriz *et al.*, 1989) when the nutrient is in shortest supply relative to metabolic needs of the algal population, and the population enters the stationary phase of growth cycle.

In the present study though the control also showed an initial multiplication of cells, the cell density and growth rate were less compared to other media and the intensity of multiplication was less during the subsequent days of culture. This indicates that supplementation of additional nutrients, which are required for their rapid growth and multiplication, is essential for the culture of microalgae. Smith *et al.* (1993) also reported that in the natural seawater, the nutrients are available only in very limited quantity to sustain good growth under culture condition. The present study thus suggests that the natural seawater needs to be enriched with suitable media to cater to the maximum multiplication under controlled condition, and Walnes media can be considered as the suitable media for stock culture maintenance, while the culture needs to be reinoculated at every third day of culture for the maintenance of healthy starter culture of *S. costatum*.

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Short Communication

Soil and site evaluation along coastal Southern Saurashtra (Gujarat) for alternate land use options

The soil site suitability for different land use is very important for alternate and suitable land use planning. The land suitability evaluation forms a prerequisite for land use planning (Sys *et al.*, 1993). Each plant species requires specific soil and climatic conditions for its optimum growth. Suitability of the area along the coast of Southern Saurashtra in Gujarat has been evaluated for the *kharif* crops to be grown and to suggest alternate land use options for sustainable productivity.

The study was undertaken in the coastal soils of Junagadh and Amreli district of Southern Saurashtra located between 20° 44' to 20° 55' N latitude and 70° 46 to 71° 23'E longitudes at an elevation between 4 and 8 m above mean sea level. The area falls under semiarid climate with a mean annual rainfall of 592 mm. The mean annual, summer and winter temperature were 27.6°C, 30.6 °C and 22.4 °C, respectively. The temperature regime of the study area was isohyperthermic and soil moisture regime was ustic. Three representative soil profiles occurring widely in the coastal soils of Southern Saurashtra region of Gujarat were selected for the present study. The physicochemical characteristics were estimated using standard procedures. Their suitability was assessed using limitation method (Sys *et al.*, 1993). The site and characteristics of the selected soils were compared with the requirement of the crops grown in the area to adjudge their suitability for different *kharif* crops.

The coastal soils of Southern Saurashtra were situated in nearly leveled plain area and have alluvium parent material. The soils of study area were moderately deep to very deep, having very slow erosion, moderately slow to very slow permeability, and severe flooding (Table 1). The soils had sandy loam to silty clay loam texture, with imperfect to poor in drainage, are calcareous in nature, moderately to strongly alkaline in reaction, non-sodic, non-saline to slightly saline, and poor in soil fertility (low O.C.) (Kaswala *et al.*,1999). These soils had relatively higher ESP (8.92 to 12.92), which project the potential alkalinity hazard, and it was required to take appropriate amendment measures coupled with suitable drainage improvement (Table 2).

The studied soils varied in their suitability for different *kharif* crops (Table 2) according to the criteria for the determination of the land suitability classes. The soils of pedon P_1 belonged to Fluventic Ustropepts, are moderately suitable for groundnut, cotton, sorghum, maize and soybean and marginally suitable for sesame, while P_2 were moderately suitable for cotton, sorghum, maize and marginally suitable for groundnut, sesame and soybean. The soils of pedon P_3 belonged to Calcic Ustropepts, which were moderately suitable for sorghum and soybean, marginally suitable for cotton only, currently not suitable for groundnut and sesame, and unsuitable for maize. This might have been due to the limitations in the soils of Ustropepts characterized by poor drainage, texture, salinity and high ESP and with high $CaCO_3$ content and poor soil fertility status (low O.C.) (Giri *et al.*, 1999). Following are the improved management practice suggested:

1. Poor drainage: The high water table and poor soil physical condition have made coastal soils poorly drained. The fine texture and poor soil physical condition have left scope for introducing subsurface drainage.
2. High ESP: Ca can replace excessive sodium through gypsum and the salts can be subsequently leached to free the root zone of excessive sodium.
3. Salinity: The entire root zone requires to be flushed off for which availability of good quality water is essential. Also, proper subsurface drainage needs to be ascertained. Lateral ditches may however serve to drain the soils of excessive salts.

It is suggested that on severely degraded soils xerophytic, halophytic trees, shrubs and grasses may be grown, which also provide alternate means of livelihood to both human and animal population (Anon., 1990). A few of the species, viz. *Acasia*

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Table 1. *Soil physical & chemical characteristics of three pedons*

Pedon no.		Depth (m)	Clay (%)	pH (1:25)	$CaCO_3$ (%)	O.C. (%)	CEC [cmol(p+) kg^{-1}	ESP
P_1	Fluventic Ustropepts	1.45	22.2-38.0 (31.00)	7.99-8.21 (8.05)	2.5-17.5 (9.17)	0.26-0.69 (0.36)	25.60-31.52 (26.41)	3.49-22.81 (8.62)
P_2	Fluventic Ustropepts	1.45	21.4-30.1 (24.65)	8.11-8.60 (8.39)	3.0-15.0 (11.05)	0.06-0.20 (0.12)	17.02-31.83 (24.15)	10.75-17.00 (12.92)
P_3	Calcic Ustropepts	1.00	20.2-31.4 (25.27)	8.56-8.73 (8.59)	31.5-65.0 (47.05)	0.12-0.69 (0.34)	21.32-26.65 (23.27)	9.70-14.56 (12.30)

Figures in parentheses indicate the weighted means

Pedon no.	Climate (c)		Wetness (w)		Physical characteristics				Fertility characteristics (f)*			Salinity/Sodicity (n)*	
	Rainfall (mm)	Temp. (°C)	Topography (% slope)	Drainage	Texture	Soil depth (cm)	AWC* (mm/m)	$CaCO_3$* (%)	O.C. (%)	BSP	CEC [cmol(p+)kg^{-1}]	ECe (dSm^{-1})	ESP
P_1	594	27.2	0.0 - 1	Imperfect	sicl	120	293	9	0.59	91	26	2.30	8.92
P_2	594	27.2	0.0 - 1	Imperfect	sl	115	266	11	0.20	91	24	0.75	12.92
P_3	589	26.8	0.0 - 1	Poor	sicl	70	185	47	0.69	93	23	3.66	12.30

*, Weighted means; soil texture, sicl: Silty clay loam, sl: Sandy loam

Table 2. *Limitation levels of the land characteristics and land suitability classes for* kharif *crops*

Pedon no.	Village	Soil family	Groundnut	Cotton	Sesame	Sorghum	Maize	Soybean
P_1	Chauhanikhan *Tal*: Una Dist. Junagadh	Fine loamy, smectite (calcareous) Fluventic Ustropepts	$S_2w(d_2)$ $s(te_1)$ $n(oc_1)$	$S_2c(r_1)$ $w(d_1)f(oc_1)$ $n(sa_1)$	$S_3c(r_2)$ $w(d_1)s(te_1)$ $f(oc_2)$	$S_2c(r_2)$ $w(d_1)$	$S_2w(d_1)$	$S_2c(r_2)$ $w(d_1)$ $n(es_1)$
P_2	Rampara *Tal*: Una Dist. Junagadh	(do)	$S_3w(d_2)$ $s(te_1)n(es_1)$	$S_2c(r_2)$ $w(d_1)s(te_1)$ $f(oc_2)$	$S_3c(r_2)$ $w(d_1)s(te_1)$ $f(oc_2)$	$S_2c(r_2)$ $w(d_1)s(ca_1)$ $f(oc_1)n(es)$	$S_2w(d_1)$ $f(oc_2)$	$S_3c(r_2)$ $w(d_1)s(ca_1)$ $f(oc_1)n(es_1)$
P_3	Kadiyali *Tal*: Jafrabad Dist. Amreli	Fine loamy, smectite (calcareous) Calcic Ustropepts	$N_1,w(d_3)$ $s(te_1,sd_1ca_2)$ $f(oc_1)n(es_1)$	$S_3c(r_1)$ $w(d_2)$ $s(sd_1ca_2)$ $f(oc_2)n(sa_1es_1)$	$N_1c(r_2)$ $w(d_3)$ $s(te_1sd_1)$ $f(oc_2)$	$S_2c(r_2)$ $w(d_2)$ $s(sd_1ca_2)$ $n(es_1)$	$N_2w(d_2)$ $s(ca_4)$	$S_2c(r_2)$ $w(d_1)$ $s(ca_2)$ $n(sa_1es_1)$

S_1= Highly suitable, S_2= Moderately suitable and S_3= Marginally suitable; N_1= Currently not suitable, N_2= Unsuitable; c= Climate, w=Wetness, s= Physical characteristics, f= Soil fertility, n= Salinity/Sodicity hazards, te= Texture, sd= Soil depth, oc= Organic carbon, d= Drainage, Ca= $CaCO_3$, es= ESP, r= rainfall, ce= CEC, Sa=Salinity

Small figures in parentheses indicate crop requirement at different levels: slight (1), moderate (2), severe (3) and very severe (4) *catechu*, *Azadirchta indica*, *Casuarina equisetifolia*, *Cynadon dactylon*, *Eucalyptus* spp., *Prosopis juliflora*, *Pheonix sylvestris* and *Rhizophora mucronata*, etc., which can withstand the degraded condition like high salinity/alkalinity, poor drainage, etc. should be grown.

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Studies on fruit yield, foliar and soil nutrient status in Kokum (*Garcinia indica* Choisy)

Kokum (*Garcinia indica* Choisy) is the important spice crop in the Konkan region of Maharashtra State. It is popularly known as 'Ratamba" which belongs to the family Guttiferae. Kokum is mainly grown in Karnataka, Kerala, West Bengal, Goa and Gujarat states in India. In Maharashtra, it is mostly found in Ratnagiri and Sindhudurg districts. The kokum fruits are used in canning industry. The seeds of kokum yield oil, known as kokum butter, are used in the preparation of ointments and cosmetics. Kokum butter has medicinal values as nutritive, demulcent, astringent and emollient (Pruthi, 1976).

Considering the rapidly rising economic importance of this crop and tremendous scope in the international market farmers have diverted their attention towards cultivation of this crop. The climatic conditions of Konkan region are suitable for cultivation of this crop. Nutritional aspects for this crop have not been studied. Hence the present investigation was undertaken to find out correlation between the leaf and soil nutrient levels with the yield of kokum.

The present investigation was carried out at the Agricultural Research Station, Shirgaon (Ratnagiri) farm. Eleven kokum trees cv. Kokum Amruta of 25 year age were selected. The plants were receiving uniform cultural practices. The soil samples (0 to 30 cm) were collected from each tree within a radius of 1 m from the tree trunk at post-harvest stage and tested for its physicochemical properties (Jackson, 1979). Thirty leaves at full bloom from each bearing tree were collected at random covering all sides upto a workable height of the tree. The leaves were thoroughly washed, dried for 48 h at 60 ± 5°C, thereafter ground to powder, and finally analysed for nutrients following the procedures given by Jackson (1979). The correlation between leaf, soil nutrients and yield were worked out as per Snedecor and Cocharan (1967).

The physicochemical properties of soil under study are given in Table 1. The pH of the soil was acidic in nature. The organic carbon content in soil was high. The available nitrogen and phosphate were in medium range, whereas the available potash was in high range. The exchangeable Ca, Mg were at high level. The DTPA extractable micronutrients, viz. Fe, Mn, Zn and Cu were adequate in the orchard soil. The textural class of the soil was sandy clay loam.

The nutrient levels in leaf at post-harvest stage are given in Table 2. The leaf N varied from 1.05 to 1.89% with a mean value of 1.44%, and the leaf P ranged between 0.057 to 0.128% with mean value of 0.089%. The plant K ranged from 0.34 to 0.61% with an average value of 0.44%. The Ca and Mg content ranged from 1.62 to 3.04% (mean 2.30%) and 0.15 to 0.57% (mean 0.38%), respectively. The S content in leaf ranged between 0.099 to 0.234% with a mean value of 0.143%. The micronutrients, viz. Fe, Mn, Zn and Cu ranged between 95 to 395 ppm (mean 196 ppm), 30 to 90 ppm (mean 60 ppm), 40 to 94 ppm (mean 59 ppm), and 5 to 16 ppm (mean 9 ppm), respectively.

Table 1. *Physicochemical properties of soil at 0-30 cm depth under experimental trees*

Soil characteristics	Value
pH (1:2.5)	5.5
Organic carbon %	1.29
Available N [kg ha^{-1}]	393.96
Available P_2O_5 [kg ha^{-1}]	16.76
Available K_2O [kg ha^{-1}]	357.0
Exch. Ca [cmol (+) kg^{-1}]	5.59
Exch. Mg [cmol (+) kg^{-1}]	2.81
DTPA-Fe [cmol (+) kg^{-1}]	95.95
DTPA-Mn [cmol (+) kg^{-1}]	19.55
DTPA-Zn [cmol (+) kg^{-1}]	0.74
DTPA-Cu [cmol (+) kg^{-1}]	4.21
Textural class	Sandy clay loam

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Table 2. *Foliar nutritional levels in relation to kokum yield*

Yield kg/tree	Nutrient content in leaf									
	N%	P%	K%	Ca%	Mg%	S%	Fe ppm	Mn ppm	Zn ppm	Cu ppm
26.0	1.47	0.084	0.43	2.41	0.48	0.147	395	70	43	12
64.0	1.42	0.107	0.40	2.23	0.36	0.128	140	30	56	14
144.0	1.47	0.082	0.49	2.35	0.57	0.202	200	30	56	8
86.0	1.63	0.080	0.38	2.39	0.29	0.109	95	75	94	6
74.0	1.53	0.096	0.43	2.91	0.46	0.234	230	64	42	5
121.0	1.05	0.103	0.43	3.04	0.15	0.176	240	35	40	5
104.0	1.37	0.078	0.34	2.05	0.36	0.119	170	85	43	7
199.0	1.21	0.057	0.56	2.19	0.43	0.116	144	90	85	5
98.0	1.89	0.128	0.61	1.62	0.23	0.099	112	70	66	16
185.0	1.47	0.094	0.40	2.11	0.32	0.138	311	65	75	7
65.0	1.37	0.073	0.40	1.99	0.49	0.102	118	45	48	11
106.0	1.44	0.089	0.44	2.30	0.38	0.143	196	60	59	9

Table 3. *Correlation between foliar, soil nutrients and yield of kokum fruits*

Property	r
Yield vs Plant-N	-0.286
Yield vs Plant-P	-0.264
Yield vs Plant-K	+0.336
Yield vs Plant-Ca	-0.098
Yield vs Plant-Mg	-0.114
Yield vs Plant-S	-0.078
Yield vs Plant-Fe	-0.075
Yield vs Plant-Mn	+0.192
Yield vs Plant-Zn	+0.501
Yield vs Plant-Cu	-0.497

Property	r
Yield vs soil-N	+0.521
Yield vs soil-P	-0.126
Yield vs soil-K	-0.021
Yield vs soil Exch.-Ca	-0.227
Yield vs soil Exch.-Mg	+0.365
Yield vs soil DTPA-Fe	+0.117
Yield vs soil DTPA-Mn	-0.199
Yield vs soil DTPA-Zn	+0.054
Yield vs soil DTPA-Cu	-0.486

r values at p = 0.05: 0.600
at p = 0.1: 0.783

The correlation coefficient (r) between yield and nutrients are given in Table 3. From the data it is found that during the fruiting season of 1995-96 leaf Zn, K and Mn showed a positive correlation with yield (r = +0.501, +0.336, +0.192, respectively). The available nitrogen, exchangeable Mg, DTPA Fe and Zn content at the depth of 0-30 cm soil showed positive relationship with yield (r = +0.521, +0.365, +0.117 and +0.054, respectively).

The above results indicated that macro and micronutrients in soil and leaf directly play their role in the kokum yield production. The positive correlation between yield and soil available N indicated that N fertilizer application will prove beneficial to kokum yield. Thus, there is need to study in details the effect of nitrogen fertilizer and micronutrients on the yield of kokum in future.

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Estimation of leaf area through leaf characteristics in three cultivars of Mango (*Mangifera indica* L.)

Mango (*Mangifera indica* L.) is the most important fruit of the Anacardiaceae family, possessing the pride position among tropical and subtropical regions, between 23° north and south latitudes of the world. Leaves being centre of metabolic activities is important in determining the vigour and productivity of the tree. There are many methods to measure leaf area, some of which may be destructive (e.g. graphic as well as planimetric method) and some needs expensive instrument (e.g. leaf area meter). On the other hand, leaf length, breadth and length x breadth product are non-distructive and cheapest linear measurements used to estimate the area of leaves, which has been attempted in this paper with three cultivars.

The present investigation of mango (*Mangifera indica* L.) was carried out at the Regional Horticultural Research Station, Gujarat Agricultural University, Navsari Campus. The investigation was carried out on three cultivars of mango, viz. Alphonso, Dashehari and Rajapuri. Two types of shoots (flowered and non-flowered) were selected from four directions. Hundred leaf samples each of three types, i.e. immature (M_1), partially immature (M_2) and matured (M_3) were drawn at random from 18 year-old trees of Alphonso (C_1), Dashehari (C_2) and Rajapuri (C_3) mango cultivars during February, 1998. The leaves were selected from all the four main compass points of tree canopy. The samples were immediately shifted to laboratory. The length of the leaf (excluding petiole) was measured from base to top and breadth at the widest point. The product of the length x breadth was calculated. The leaf area was actually measured by using a CI-203 Portable Laser Area Meter[1]. A regression equation, viz. $Y = b.x$ was fitted for each type of leaf, where, Y = predicted leaf area, b = constant (k) and x = length x breadth. From this, factor k was calculated by formula $b = \Sigma\ xy\ /\ \Sigma\ x^2$. The unit leaf area was calculated according to Sestak *et al.* (1971) by multiplying length x breadth with constant factor k.

The data revealed that leaf area was significantly correlated with leaf length, leaf breadth as well product of leaf length and breadth (Table 1) irrespective of age of leaves, i.e. M_1 (immature), M_2 (partially immature) or M_3 (mature) in all the three cultivars, viz. C_1 (Alphonso), C_2 (Dashehari) and C_3 (Rajapuri). The constant k thus obtained (Table 1) for three types of leaves (M_1, M_2 and M_3) were averaged to get a common factor k which were 0.449 for C_1 (Alphonso), 0.553 for C_2 (Dashehari) and 0.647 for C_3 (Rajapuri). These three factors were used for leaf area estimates of sampled leaves by multiplying the factor k with the product of length and breadth (Table 1). The estimated leaf area of M_1, M_2 and M_3 leaves of C_1 (Alphonso) were 63.38 cm^2, 80.10 cm^2 and 106.89 cm^2, respectively as compared to actual leaf area of 62.86 cm^2, 78.76 cm^2 and 106.23 cm^2, respectively. The estimated leaf area of M_1, M_2 and M_3 leaves of C_2 (Dashehari) were 42.55 cm^2, 57.24 cm^2 and 64.44 cm^2, respectively as compared to actual leaf area of 42.43 cm^2, 56.30 cm^2 and 62.43 cm^2, respectively. Similarly, corresponding estimated leaf area values of C_3 (Rajapuri) were 107.74 cm^2, 118.75 cm^2 and 145.45 cm^2, respectively as compared to actual leaf area of 106.82 cm^2, 117.01 cm^2 and 144.16 cm^2, respectively. The data revealed the average estimated leaf area of 83.456 cm^2 as compared to actual leaf area of 82.616 cm^2 in C_1 (Alphonso), 54.743 cm^2 as compared to actual leaf area of 53.720 cm^2 in C_2 (Dashehari), and 123.980 cm^2 as compared to actual leaf area of 122.663 cm^2 in C_3 (Rajapuri), which were in close agreement in each case.

Leaf length, breadth and length and breadth are non-distructive and cheapest linear measurements used to estimate the area of leaves. Thus, leaf length x leaf breadth x k factor could be used in determining the leaf area of Alphonso, Dashehari and Rajapuri cultivars of mango. Similar results were obtained by Saidha and Rao (1985) in three mango cultivars, viz. Malgoa, Neelum and Bangalora. The constant factor k of 0.449 for

[1]Does not suggest preferential use of the model/manufacturer

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Table 1. *Leaf size, leaf area and other leaf parameters in Alphonso, Dashehari and Rajapuri cultivars of mango*

Character	C_1 (Alphonso) Type of leaves			C_2 (Dashehari) Type of leaves			C_3 (Rajapuri) Type of leaves		
	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3
Length (cm) (L)	24.28	28.33	33.74	15.83	19.35	20.95	22.43	24.22	26.00
Maximum breadth (cm) (B)	5.57	6.33	7.24	4.73	5.27	5.88	7.12	7.70	8.80
Length x Breadth (sq cm) (L x B)	135.72	179.20	246.30	75.05	101.50	121.82	161.78	185.84	227.90
Actual leaf area (sq cm)	62.86	78.76	106.23	42.43	56.30	62.43	106.82	117.01	144.16
k value of L x B	0.467	0.447	0.434	0.567	0.564	0.529	0.666	0.639	0.638
Average k value of L x B	0.449			0.553			0.647		
Estimated leaf area (sq cm)	63.38	80.10	106.89	42.55	57.24	64.44	107.74	118.75	145.45

Type of leaves : M_1, Immature; M_2, Partially immature; M_3, Mature

Alphonso, 0.553 for Dashehari and 0.647 for Rajapuri obtained in the present study may be employed efficiently for quick estimation of leaf area even with intact leaves.

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