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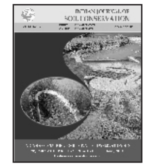

Prospects and impact of cultivating salt tolerant varieties of cotton and wheat in coastal saline soils of Gujarat

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ABSTRACT

Management of saline Vertisols has been serious concern for agriculture in Southern and Saurashtra regions of Gujarat, India. Cultivation of salt tolerant cotton and wheat varieties is ecologically and economically viable option to overcome the salinity stress. Efforts were made along with various NGO partners to study the prospects and impacts of salt tolerant cotton genotypes and wheat varieties in Southern, Central and Saurashtra regions of coastal Gujarat. It was observed that *desi* cotton was more suitable and profitable to farmers in rainfed saline conditions. *Desi* cotton accessions '*G. Cot. 23*' gave cotton seed yield ranging from 1.6 to 1.9 t ha^{-1} under the average soil salinity of 7.6 dS m^{-1} where traditional varieties like *Gheti* and *Dhummad* gave seed cotton yield in the range of 1.3 to 1.4 t ha^{-1}. In saline areas with soil EC ranging from 5.9 to 7.2 dS m^{-1}, salt tolerant wheat varieties '*KRL 210*' and '*KRL 19*' yielded in the range of 3.60 to 3.95 t ha^{-1} where traditional variety yields less than 2.5 t ha^{-1}.

1. INTRODUCTION

Sustainability of an eco-system rests on the scientific management based on a sound database. Managing the coastal agricultural eco-system is more complex when it is affected by natural causes like sea water ingress and introduction of large scale human interventions. Such situation is prevailing in the coastal districts of Gujarat state where soil salinity is constantly increasing due to sea water ingress (Gururaja Rao *et al*., 2012). The problem of environmental degradation in Gujarat is as diverse and complex as the ecological fabric of the state. Vast areas are in imminent danger of turning barren; production and productivity have declined due to secondary salinisation through excessive irrigations in canal command areas or use of saline groundwater in coastal areas due to sea water ingress. High soil salinity reduces agricultural productivity in many regions of the world (Rozema and Flowers, 2008). It is estimated that 397 m ha of land throughout the world are affected by salinity (FAO, 2005). The soil salinity problem in arid and semiarid areas is exacerbated due to low rainfall and poor quality of irrigation water (Pasternak and Malach, 1994; Villa-Castorena *et al.,* 2003).

About 6.73 m ha of land is salt affected in India, of which 2.22 m ha is in Gujarat state. Of this, about 60% area is affected by coastal soil salinity problems with highly saline groundwater. Water, being the critical component particularly in the coastal areas, its conservation and proper utilization helps in boosting the agricultural production in the region. Excessive withdrawal of groundwater for irrigation in the coastal area resulted in sea water ingress and thus makes the problem further worse. Salt sensitive crops like pulses and oilseeds do suffer because of high soil salinity and saline groundwater, and more so due to non-availability of good quality water for irrigation (Gururaja Rao *et al.,* 2013d). The erratic nature of monsoon tapering down at the critical stages of crop growth results in crop losses. Conservation of limited fresh water and its use in conjunction with saline groundwater provides an alternative for growing salt tolerant crops as well as some non-food crops.

Soil salinity either before sowing or that occurs during growing period is detrimental to crop growth and productivity. Unlike salt loving plants *i.e.,* halophytes, salt sensitive glycophytes which comprises crop plants are severely affected by salinity of soil and irrigation waters. Thus, identifying salt tolerant crops/varieties and their cultivation on saline soils holds promise in an attempt to maximize production. Cotton is classified as one of the most salt-tolerant crop and considered as a pioneer crop in reclamation of saline soils (Maas, 1986). However, its tolerance to salinity is far from that of halophytes (Dong, 2012). Therefore, growth and yield reduction is inevitable under high salinity conditions, which often reduces vegetative growth of cotton plants to a great degree with more reduction in shoots than roots (Ashraf, 2002; Dong, 2012).

To overcome the effect of soil salinity and saline groundwater, three approaches can be used *viz.*, changes in natural resource management, changes in technology used and development of salt tolerant varieties of the crops. Among these, use of salt tolerant varieties is an effective, economical and eco-friendly approach in management of salt affected Vertisols.

Research conducted in this direction resulted in identification of ideal herbaceum cotton cultivars like '*G. Cot. 23', 'G. Cot. DH 7',* and arboreum *'G.Bav 109'* and *'G. Bav 120'* (Gururaja Rao *et al*., 2013a,b,c). ICAR-Central Soil Salinity Research Institute, Karnal has developed salt tolerant wheat varieties ('*KRL 1-4', 'KRL 210', 'KRL 213' and 'KRL 19'*), which are popular in parts of north India. These varieties also form successful alternatives to traditional varieties with a yield increase in the range of 26 to 27% (Singh *et al*., 2009). During the decade of 2000-01 to 2010-11, the estimated area coverage by these salt tolerant wheat varieties was 193 thousand hectares, and national level wheat production from these varieties was 0.48 M t. During demonstrations of '*KRL 210*' and '*KRL 213*', the yield was 3.2 to 6.3 t ha^{-1} even at pH 8.5 to 9.2 and EC range from 0.18 to 0.44 dS m^{-1} (Tripathi *et al.,* 2011).

Impact studies play a pivotal role in assessing the overall output of any plan scheme and provide sufficient feedback from the beneficiaries. This evaluation plays an important role in ensuring the benefits of technology to reach the end users. In order to understand farmers' response and strategies to cope with changes in the environment and to analyse the interface between changes in the natural resource base and in the socio-economic environment, studies were conducted by giving primacy to interventions developed *i.e.,* cultivation of food and high value crops like wheat and cotton, in different farm units in the coastal areas of Gujarat.

2. MATERIALS AND METHODS

Characterization of Study Area

The study area covered parts of Bara tract, Bhal area and coastal Saurashtra areas of Gujarat state of India, having different physiographic featues. The Bara tract with coastal taluks of Jambusar, Vagra and Amod do experience coastal salinity problems due to their proximity to the sea. The Bara tract in coastal Gujarat has by and large flat topography, with salinity problems confined to below 60-90 cm soil layer and the ground water is saline and thus its use as such for irrigation forms a major constraint. The soils are Vertisol and associated with high clay content. The area is having number of artificial drains, salinity ingress prevention bunds and coastal roads. The region experiences erratic nature of onset of monsoon which normally affects seeding operations, further germination and seedling establishment. The coastal areas of the Bara tract are severely degraded and pose serious problems due to salinity ingress, saline ground water and with inadequate irrigation facilities.

The Bhal area is an alluvial coastal plain situated at 22.0° to 23.2° N latitude and 72.1° to 73.2° E longitude covers parts of Anand, Ahmedabad and Bhavnagar districts is distinct by high salinity problems, high ground water table with saline ground water with sparse native vegetation. Due to its marine origin, large parts of the area is saline and only the least saline lands are being used for agriculture. Physiographically, the area comprises of the recent and old flood plains with mudflats along the tidal inlets. Water being the main constraint in the region, identification of low water requiring and salt tolerant crops thus assumes significance.

In Saurasthra region, the climate is hot and arid in nature. The summer spans from March to June and the average temperature during this period varies between 24°C and 46°C. The rainy season spans from July to September, which brings an average rainfall of 509 mm within 30 average rainy days. Continued abstraction of groundwater for irrigation led to sea water ingress resulting in salinity of groundwater and farm lands in the coastal region which warrants going for salt tolerant crops.

Field Units

Field units measuring 0.4 ha area were selected varying in soil salinity. Surface soil samples (0-15cm) were collected during crop growth and analysed for salinity status. Crop cutting experiments were carried out during 2011-12 and 2012-13 to record seed/grain yield and productivity of different crops on per unit area basis. Increase in number of units over the years, rate of adoption of salt tolerant lines and the impact of these crops was analysed. The reported results were based on year wise observations and cumulative crop performance. Performance of crops in farmers' field conditions with different salinity levels was compered to the crop yields obtained under well managed conditions (Gururaja Rao *et al*., 2013c).

On-farm trials were taken for three years (2011 to 2013) in South Gujarat (Bara tract in Bharuch, Jambusar taluka), Central Gujarat (Bhal area covering Dholera taluka in Ahmedabad district) and Saurasthra (Covering Junagadh and Amreli districts). Field units at different places along the Gujarat coast were taken in a cluster approach replicated at different famers fields with varying soil salinity level (Table 1) in collaboration with Coastal Salinity Prevention Cell (NGO) as the Nodal Agency and it's partner organisations VIKAS/SAVE and ATAAPI (in Jambusar), MAHITI (in Dholka), TCSRD, GHCL, VRTI and SSKK (in Saurasthra).

Crops and Varieties

Desi Cotton varieties, herbaceum, '*G.Cot. 23*' and arboreum '*G.Bav 120*' were selected based on studies conducted at Bharuch on screening of cotton varieties for salt tolernce (Gururaja Rao *et al.,* 2013c). Experiments carried out at CSSRI (both Karnal and Bharuch) under the All India Coordinated Research Program on salt tolerance of wheat, has clearly indicated that the cultivars '*KRL 19*' and '*KRL 210*' are suitable for cultivation on saline soils with yield potential of 3.6-3.9 t ha^{-1}. Accordingly, these wheat accessions were taken as second intervention for cultivation on coastal saline soils of Bara tract, Bhal area and Coastal Saurashtra areas.

3. RESULTS AND DISCUSSION

Field Trials with Salt Tolerant Desi Cottons

Studies with cotton clearly indicated that on saline soils of Bara tract and Bhal area, herbaceum cottons showed better adaptability and good yield under rainfed conditions thus indicating their suitability for this region. The yield ranged between 1.68 to 1.91 t ha^{-1} grown at soil salinity level of 7.8 to 9.2 dS m^{-1} (Table 2). Seed cotton yield obtained from the farmers' fields was found to be at par with that of experimental yield while traditional varieties like *Gheti* and *Dhummad* used to give seed cotton yield in the range of 1.3 to 1.4 t ha^{-1} (Gururaja Rao *et al*., 2013c). These accessions had been found performing well in Saurashtra also (Table 2).

In Jambusar, where high sub-surface soil salinity exists (Nayak *et al*., 2003), studies indicated that herbaceums and arboreums showed seed cotton yields like that of yields obtained at CSSRI Research farm (Samni) suggesting the possibility of their expansion in other saline areas (Fig. 1). The farmers desire to go for desi lines, in view of their low water requirements, minimum/no pest problems (Gururaja Rao *et al*., 2013c) and their satisfacory yields. Across the farm units, the soil salinity at harvest ranged from 7.4 to 8.8 dS m^{-1}. Seed cotton yield of herbaceum '*G.Cot. 23*' and arboreum '*G. Bav 120*' ranged between 1.35 to 1.92 t ha^{-1} where '*G. Cot. 23*' performed better at sites. A strong negatiave relation (R^2 = 0.882) between soil salinity and seed cotton yield was noticed. Seed cotton yield dropped below 1.7 t ha^{-1} only at soil salinity of >9 dS m^{-1} (Fig. 2). As compared to hybrids and Bt lines, desi cottons possesed

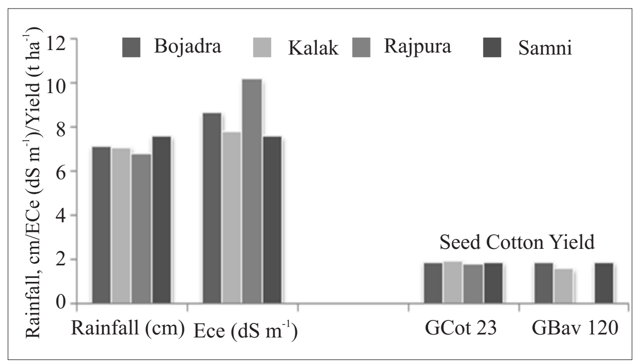

Fig. 1. Rainfall (cm), soil salinity (ECe) and seed cotton yield in South Gujarat

Table: 1
Farm units selected at different locations of coastal Gujarat

Region	Selected places for trials	Crop (s)	Number of farm units
South Gujarat	Bharuch - Jambusar (Magnad, Kalak, Bojadra)	Desi cotton and Wheat	10
Central Gujarat	Ahmedabad - Dholera (Rajpura)	Desi Cotton	09
Saurashtra	Junagadh - Jafrabad (Balana, Vadhera, Kadiyali); Veraval (Vadodara, Navapara, Adri, Dari) and Una (Moto Moli, Kakdi Moli, Vankiya); Amreli (Kodinar, Sutrpada)	Wheat	32

Table: 2
Performance of desi cotton in Bara tract area of Coastal Gujarat

District/Taluka	Village	Cotton variety	Mean yield (t ha^{-1})	Soil salinity (dS m^{-1})
Bharuch/Jambusar	Kalak	*G. Cot. 23*	1.78	9.20
	Magnad	*G. Cot. 23* (*Herbaceum*)	1.89	8.40
		G. Bav 120 (*Arboreum*)	1.68	8.45
	Bojadara	*G. Cot. 23*	1.84	8.82
		G. Bav 120	1.76	8.75
CSSRI farm	Samni	*G. Cot. 23*	1.91	7.86
		G. Bav 120	1.80	8.02
		Total Average	1.81	8.50
		Standard deviation	0.08	0.46
		Sem ±	0.03	0.17

higher salt tolerance and showed lowered yield drop at salinity more than 6 dS m^{-1} (Gururaja Rao *et al*., 2013a). Akhtar *et al*. (2010) also reported that yield of salt tolerant cotton genotypes decline at higher NaCl stress in solution and soil culture. Unlike hirsutums/hybrids which have shallow root system and shorter duration (July to October) with high water requirement, desi cottons have deep root system and longer duration (July to March). The low amount of water requirement by desi cottons rendered them as ideal ones for rainfed saline situations (Gururaja Rao *et al*., 2013b,c).

In Saurashtra, cultivation of desi cotton (*G. Cot. 23*) had been taken at 4 different locations (Fig. 3) in Junagarh. Soil salinity in this region was lower than that observed in South Gujarat and Bhal area. Seed cotton yield ranged from 1.62 to 1.78 t ha^{-1} grown on coastal saline soils having salinity in the range of 6.2 to 7.2 dS m^{-1} (Fig. 3) and the groundwater salinity ranged between 5.6 to 6.8 dS m^{-1}. When compared to the soils of South Gujarat or Bhal area, the soils of Junagadh are clay-loam type and needed more irrigation, which however, has not resulted in higher root zone salinity.

Based on the on-farm trials and the feedback from the farmers, the impact on cultivation of desi cottons noticed in the above areas is given below:

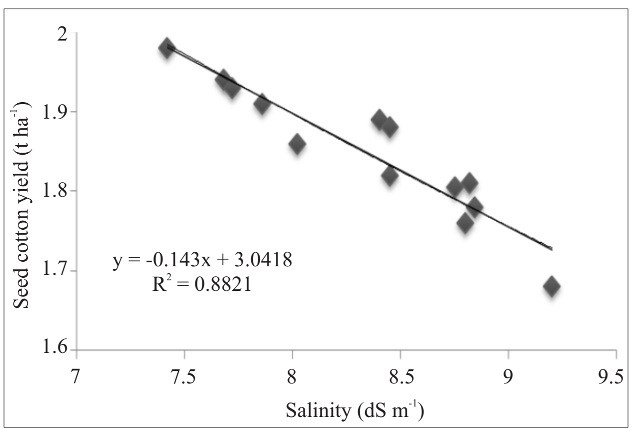

Fig. 2. Relation between soil salinity and seed cotton yield

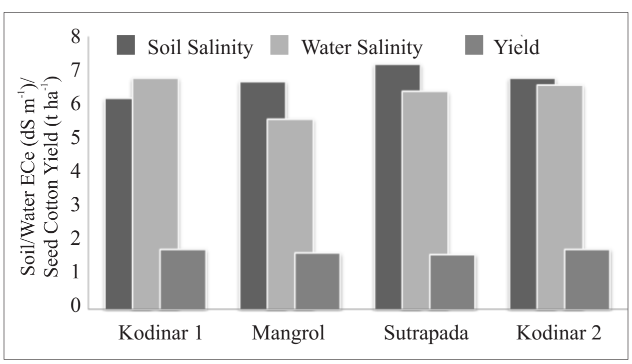

Fig. 3. Performance of cotton (*G. Cot. 23*) in Junagadh district (NGO Partner: VRTI, Rajula)

Physical Impacts

The continued efforts through various NGO partners resulted in expanding the cultivation of salt tolerant herbaceum cotton (*G. Cot. 23*) in coastal areas of Bharuch, Anand, Ahmedabad and Junagadh districts. Since the performance of salt tolerant cultivars was found remunerative, more number of farm units/farmers (Fig. 4) had adopted this intervention as evident from increase in number of demonstrations in succeeding years. The adoption rate during the study period and afterwards has increased from 20 to 30% across the coastal saline area. Farmers were also getting the improvement in seed cotton yields under all the NGO clusters. It was observed that at different locations in coastal Gujarat, the seed cotton yield of desi cotton was significantly higher than in Bara Tract (VIKAS and ATAAPI) compared to Saurashtra (VRTI) in the year 2012 and 2013 (Table 3). This is mainly because of the cultivar being less prone to diseases, which had become a centre point for their further adoption. Also, the input costs in desi cotton were much less (30 to 35% less) when compared to hybrids or Bt lines mainly due to low cost of seed, lesser pesticide use and reduced irrigation, and also due to their response to saline water irrigation, the desi cotton lines were gaining momentum in the region.

Economic Impact

Saline lands having soil salinity of 8 to 10 dS m^{-1} had been profitably brought under cultivation with herbaceum

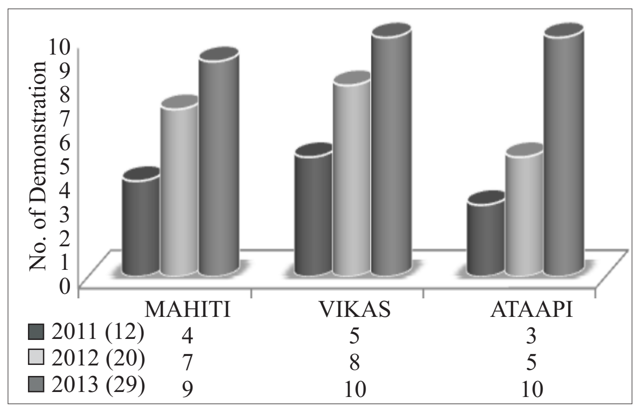

Fig. 4. Demonstrations with *G. Cot. 23* in Bhal area and Bara Tract during 2011-13

Table: 3
Seed cotton yield in South Gujarat and Saurashtra during 2011-13

Site (NGO)	Cotton seed yield (t ha^{-1})		
	2011	2012	2013
VIKAS	1.68	1.72	1.84
ATAAPI	1.62	1.74	1.79
MAHITI	1.61	1.76	1.81
VRTI	1.56	1.59	1.68
SEm±	0.024	0.038	0.035
CD (5%)	0.053	0.062	0.058

cotton, '*G. Cot. 23*' in all the three coastal regions of the state. This had resulted in gross income in the range of ₹ 70,000/- to 75,000/- ha^{-1} and net income of ₹ 45,000/- to 50000/- ha^{-1}, particularly in South Gujarat *i.e.,* in Bojadra and Kalak with B:C ratio of 1.8 to 2.0. The lower salt tolerance coupled with less seed cotton yields of hybrids and Bt lines compared to herbaceum and arboreum (Gururaja Rao *et al.,* 2013c) formed a basis for the farmers going for desi cottons in coastal saline areas. Further, earlier studies by Gururaja Rao *et al.* (2013b) also indicated lower input costs primarily due to reduced disease incidence in desi cotton coupled with reduced number of irrigations.

Performance of Salt tolerant Wheat

Conducting on-farm trials and dissemination of the technical know-how to the farmers have been undertaken in collaboration with the NGO partners in different locations of coastal region of Gujarat. Farmers' field trials undertaken through the NGOs like SSKK and GHCL (Saurashtra), MAHITI (Bhal area), VIKAS and ATAAPI (Bara tract), TCSRD (Jamnagar district) indicated almost consistent yield performance (3.6 to 3.95 t ha^{-1}) of both salt tolerant wheat accessions, '*KRL 210*' and '*KRL 19*' under soil salinity of 5.9 to 7.2 dS m^{-1} (Table 4).

Similarly, field trials conducted at Una, Veraval and Jafrabad talukas (coastal areas of Junagadh district), the seed yield of '*KRL 210*' ranged from 3.4 to 3.95 t ha^{-1} across all the sites (Fig. 5). Una and Veraval (except for Adri) showed seed yield of about 3.8 t ha^{-1} at salinity ranging from 6.4 to 6.9 dS m^{-1} where as at similar salinity, the seed yields reduced by 0.2 q ha^{-1} at Jafrabad due to high clay content of the soil, since even low salinity become detrimental for crop production under clayey type of soils. However, the seed yield of the salt tolerant wheat lines were much higher than local variety 'Lok 1' which yielded about 2.5 to 3.0 t ha^{-1} indicating the superiority of these lines to saline conditions and their better suitability for saline areas of coastal Gujarat (Table 5). However, significant negative relation was noticed between wheat yield and salinity (Fig. 6).

Impact of Salt Tolerant Wheat Varieties

Fig. 7 indicates the gradual increase in number of on farm units adopting cultivation of '*KRL 19*' and '*KRL 210*' wheat varieties from 2011 to 2013 in coastal Gujarat. While desi cotton (*G. Cot. 23*) showed an increase mainly in Bara tract, salt tolerant wheat varieties ('*KRL 210*' and '*KRL 19*') have gained wider acceptability in salinity affected Central Gujarat and Saurashtra regions as evident from the findings.

4. CONCLUSIONS

The studies indicated that in coastal saline areas, Desi cottons, in view of their higher salt tolerance and better

Table: 4
Wheat yield in different clusters in coastal Gujarat taken up by NGOs

Site/NGO	Soil ECe (dS m^{-1})	Average wheat yield (t ha^{-1})*	
		KRL 19	KRL 210
SSKK	6.02-6.9 (6.49)	3.72	3.64
MAHITI	5.90-6.82 (6.38)	3.92	3.83
VIKAS	6.16-6.74 (6.39)	3.85	3.82
ATAAPI	5.88-6.32 (6.09)	3.97	3.96
TCSRD	6.34-6.63 (6.42)	3.71	3.57
GHCL	6.16-6.87 (6.46)	3.61	3.63
SEm±		0.047	0.045
CD (5%)		NS	NS

*Average of 4 fields at each site

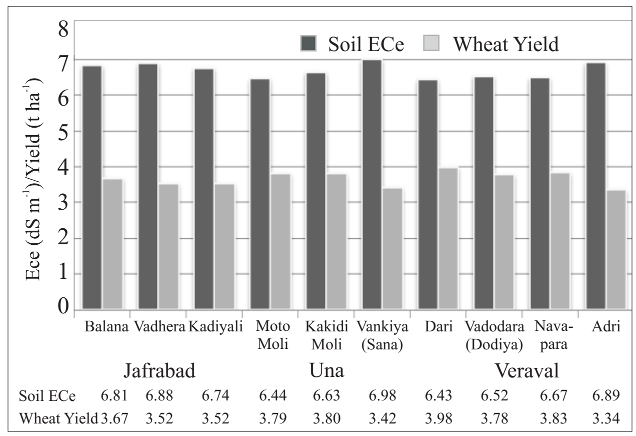

Fig. 5. Performance of wheat (KRL 210) in Junagadh district

Table: 5
Comparative performance of salt tolerant wheat varieties over local variety (Lok 1) under saline soils of coastal Gujarat

Site/NGO	Wheat yield (t ha^{-1})		
	KRL 210	KRL 19	Lok 1
SSKK	3.86	3.72	2.98
MAHITI	3.81	3.92	3.01
VIKAS	3.82	3.85	3.05
ATAAPI	3.96	3.92	2.78
TCSRD	3.57	3.71	2.56
GHCL	3.61	3.78	2.87
SEm±	0.061	0.038	0.075
SDev	0.15	0.09	0.18
CD (5%)	0.14	NS	0.16

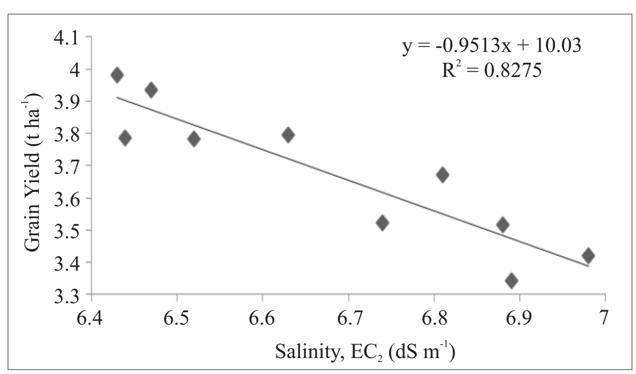

Fig. 6. Relation between soil salinity and wheat yield

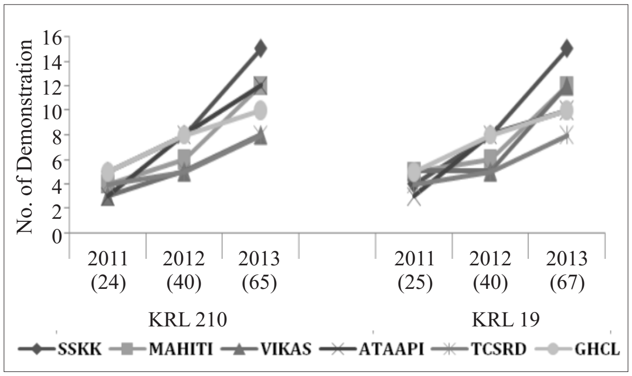

Fig. 7. Demonstrations of salt tolerant wheat varieties in different coastal areas of Gujarat taken up by different NGO partners

response to saline water (because of saline ground water) were getting an edge over Bt lines and hybrids (Gururaja Rao *et al.,* 2013a,b) which invariably need good quality water and also their salt tolerance is low. Desi cotton accessions '*G. Cot. 23*' gave 19.4 to 24.2% higher yield over traditional cotton varieties under the average salinity of 7.6 dS m^{-1}. In saline areas of southern, central and Saurashtra areas of Gujarat (EC range 5.9 to 7.2 dS m^{-1}), salt tolerant wheat varieties '*KRL 210*' and '*KRL 19*' gave yield in the range of 3.6 to 3.95 t ha^{-1}. The increase in number of farmers/user agencies going for the salt tolerant desi cottons and wheat varieties clearly indicated their impact on the agricultural scenario in the coastal Gujarat. The cultivation of salt tolerant varieties is effective biological approach by the farming community to manage salt affected lands. Cultivation of salt tolerant varieties of crops in salt affected areas is thus considered as the very prudent option with less environmental degradation.

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