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SWEET POTATO AND TARO RESILIENT TO STRESSES: SUSTAINABLE LIVELIHOOD IN FRAGILE ZONES VULNERABLE TO CLIMATE CHANGES

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ABSTRACT

Sweet potato (*Ipomoea batatas* L.) and taro [*Colocasia esculenta* (L.) Schott] are the important tuber crops used as staple or subsistence food by millions of people in developing nations. Both tubers and leaves of these crops are an alternative source of dietary energy. Visibility of these crops as life support crops species has been enhanced during post super cyclone in Odisha and Tsunami in coastal states of India. Genetic diversity of these crops, and their wide distribution and potential to adapt in harsh environmental condition advocate for their further exploitation to develop stress tolerant crops with valued traits. Gene flow through conventional breeding is hindered owing to flowering behaviours, cytogenetical anomalies in taro and hexaploidy coupled with self incompatibility in sweet potato.

To make these crops more resilient, an extensive study was taken up integrating conventional and non conventional methods to tap the vast potential of genetic diversity in isolating the stress tolerant sweet potato and taro genotypes. The varietal gene bank of sweet potato maintained at the Regional Centre farm of the Central Tuber Crops Research Institute (CTCRI) were also tested under *in situ* to study tolerance to environmental stresses. Under such conditions, percentage of leaf damage and vine weight were recorded to identify the varieties to cope with unfavorable agro-climatic conditions. Results to isolate and develop stress tolerant sweet potato and taro and, their impact on livelihood security under climatic adversities are discussed.

Key words: *Sweet potato, taro, stress, tolerance, food security*

INTRODUCTION

The report of Intergovernmental Panel on Climate Change (IPCC) and Convention of CoP-8 (the eighth session of the Conference of the Parties to the United Nations

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Framework Convention on Climate Change) affirmed that developing nations including India are more vulnerable to climatic changes. More than sixty percent of the people of India directly or indirectly depend on land, water and marine natural resources. India, having more than 6000 km of coastline and many islands, is highly vulnerable to climate change and are prone to frequent cyclones and floods. About 23.8 million hectares of land is already affected by salinity. The total water logged area is reported to be 11.6 million ha (ICAR, 2006) and expected to increase steadily due to global warming. Indian subcontinent depends on rain-fed agriculture for its livelihood. Food-insecure vast coastal wetlands will be affected severely by consequences of climatic changes like irregular monsoon, flood, salinity and drought affecting the food security chain. All these factors compounding to wide spread poverty and accounting for malnutrition and high infant mortality rate. To mitigate hunger and nutrition 'climate proofing of crops is thus burning environmental issue'. In this context, the horticultural tropical tuber crops like sweet potato (*Ipomoea batatas* L.) and taro [*Colocasia esculenta* (L.) Schott] can play significant role (Mukherjee *et al.,* 2011; Mukherjee and Naskar, 2012).

Plant genetic resources of agri horticultural crops provide the base material for food, feed and industrial products to support the livelihood of every person on earth. These resources are depleted either by natural or man made causes. A number of studies covering developed and developing countries have shown greater concerns about the loss of genetic diversity of major crop species like rice. In India, just ten rice varieties (modern breeding lines) will soon cover three quarters of total area where once 30,000 (natural variability) types were grown. The genetic diversity of important food cum vegetables crops, *viz.*, sweet potato and taro are also diminishing (Russell, 2007). Genetic diversity is the key source of any crop improvement program and causing more concern to conserve all the races not only to cater present food demand but also to secure food for future even on climatic adversities.

Until now the major thrust of agri horticultural research in India was on improving yields. However, in the context of climate changes leading to frequent cyclone, flooding increasing pests and diseases as well as increasing demand for food with increasing population growth necessitates climate resilient crops with value addition, which could grow in vast fragile land facing frequent water logging or submergence stresses, salinity and drought. Diversity in species, varieties and practices has permitted agriculture to withstand moderate change in climate over the past 10,000 years. One of the most effective ways to overcome stress problems is the biological approach to identify and grow stress tolerant plants (Mukherjee *et al*., 2009a, b). Such approach would help to develop hardier crops including sweet potato and taro. The climatic resilience of these crops as life support species have already been evident during super cyclone in 1999 in Odisha. These crops survived the harsh environmental conditions when paddy and other vegetables failed to grow in coastal Odisha prone to cyclones and floods. The impact of these crops as food security crops was evident under ICAR contingent action plan during post super cyclone period in rehabilitating cyclone affected farm families (Mukherjee *et al*., 2002). Further, Tsunami in 2004 in coastal Andhra and Tamil Nadu States in India and other countries led to revive and rethink the potential of these third world crops for livelihood security especially under awakening threats of global warming (Mukherjee *et al.,* 2013).

WHY SWEET POTATO AND TARO ?

Sweet potato

'Sweet potato' (*Ipomoea batatas* L.), the fifth most important food crop, is a short duration creeper (90-110 days). This crop seems to be most suitable to grow and check soil erosion in degrading and fragile lands as ecofriendly crop to cater food (194 MJ/ ha/day), feed, nutritional [vitamin C (23 mg/100g), + vitamin E (4.56 mg/100g)] and industrial demands (16-20% starch). Orange-flesh genotypes rich in *b*-carotene (5-16 mg/ 100g) and purple flesh rich in anthocyanin (85-90 mg/100g) are source of healthy foods. These biofortified sweet potato can combat malnutrition in many developing nations. Despite its wide adaptive nature, productivity is affected due to salinity, drought and submergence stresses (Mukherjee, 2005; Mukherjee *et al*., 2009a, b).

Taro

Taro [*Colocasia esculenta* (L.) Schott] is one of the important tuber crop used as staple or subsistence food by millions of people in developing countries. It ranks fourteenth among staple/vegetable crops worldwide. It is grown in most of the states of India in a wide range of agro ecological conditions. Both tubers and leaves of these crops are an alternative source of dietary energy. Taro starch is easily digested and used in baby food. Productivity of taro (5.4 t ha^{-1}) is reasonably higher as compared to rice (4.2 t ha^{-1}). Cultivation of taro often causes yield loss in the range of 25% to 90% due to biotic (*Phytophthora colocasiae* Raciborski) and abiotic stresses (drought, salinity, *etc.*) pronounced under erratic climatic conditions.

India is said to be the secondary centre of origin of taro endowed with diverse genetic resources. This has been further conformed with wide variations in isozyme profiles of Asian taro from India, Indonesia and Japan (Lebot and Aradhya, 1992). Some of the land races of this ancient crop are found to have desirable stress tolerant traits but are not acceptable by consumers.

Diversity within its genotypes, and its wide distribution and potential to adapt in harsh environmental condition advocate for their further exploitation to develop stress tolerant sweet potato and taro. However, gene flow through conventional breeding is hindered owing to flowering behaviours, cytogenetical anomalies in taro and hexaploidy coupled with self incompatibility in sweet potato (Mukherjee *et al.*, 2004; Mukherjee *et al*., 2009a, b). To make these crops more resilient, an extensive study was taken up integrating conventional and non conventional methods to tap the vast potential of genetic diversity in isolating the salt stress tolerant sweet potato genotypes under AP Cess fund and biotic (blight) and abiotic (drought, salinity) stress tolerant taro under Competitive Grant Programme of NATP of Indian Council of Agricultural Research during 2002 and 2005. The results of *in vitro* and *in vivo* screening and evaluations have been validated further through All India Coordinated recommended trials under *in situ* on farm stress during 2005-2010.

Development of stress tolerant sweet potato, taro and their impact on livelihood security under climatic adversities are discussed.

EXPERIMENTAL

Plant sources

Genetic resources of sweet potato (171 genotypes) and taro (174 genotypes) maintained at Regional Centre farm of Central Tuber Crops Research Institute (CTCRI) located at Bhubaneswar in Odisha, India were used for screening.

Screening for biotic stress in taro

Artificial inoculation techniques with spore suspension of *Phytophthora colocasiae* Raciborski *in vivo* and with elicitor on detached leaves were used for screening following the methodologies described earlier (Mukherjee 2004; Mukherjee *et al.,* 2004).

Screening for abiotic stresses (salinity, drought and submergence)

Sweet potato and taro genotypes were screened *in vitro* in NaCl and artificial sea water mediated stress conditions (EC. 4.0 - 24.0 dSm^{-1}). Growth parameters like rooting response, sprouting and percentage necrosis of leaves were recorded. *In vivo* stressed conditions were created by amending the soil with different doses of NaCl and artificial seawater maintaining EC. 4.0- 16.0 dSm^{-1}. PEG-6000 was used for *in vitro* screening for drought tolerance in taro as explained by Mukherjee (2004) and Mukherjee *et al.,* (2004). Induced flooding (Mukherjee *et al.,* 2009b) and *in situ* water logging areas were use for submergence tolerance study.

To study the effect of drought stress on sweet potato varieties, *in situ* study was simultaneously conducted during dry period. The temperature during the day time was between 35-42°C. The water holding capacity of the sandy soil of the farm at Regional Centre of Central Tuber Crops Research Institute (CTCRI) is low, coupled with declining water table. Twentysix varieties were maintained in the stress condition, with rain fed irrigation for six weeks (42 days) after reaching maturity (3 weeks after planting). The survival potential of the varieties under drought stress thus induced were measured in terms of morphological characters. The percentage of leaf retention, vine weight after full maturity indicated the survival potentials of the varieties.

Biochemical and molecular marker studies

Biochemical parameters like reducing sugar (RS), total soluble sugar (TSS), protein, proline content and nitrate reductase activity were assessed. Isozyme and RAPD studies were carried out as followed earlier (Mukherjee, 2002; Mukherjee *et al*., 2003; Mukherjee *et al*., 2009a).

Yield evaluation

Yield was evaluated by standard techniques with experimental designs using RBD/SPD. Tuber qualities (starch, carotene, anthocyanin, *etc*.) were assessed with the methodologies followed by Mukherjee *et al*. (2009a) and Mukherjee (2010).

RESULTS

Screening genetic resources for stress tolerance

The 174 taro and 171 sweet potato genotypes with wide variability comprising of indigenous and exotic stocks were screened for tolerance to taro leaf blight disease (biotic stress) and also for abiotic stresses like drought, salinity and submergence.

Biotic stress (Phytopthora leaf blight in taro)

Based on the pooled data on hypersensitive reactions (Fig. 1) *in vitro*, *in vivo* and percentage leaf infection of 174 germplasm lines, six lines were selected for further evaluation under integrated stress conditions to isolate the tolerant genotypes in taro.

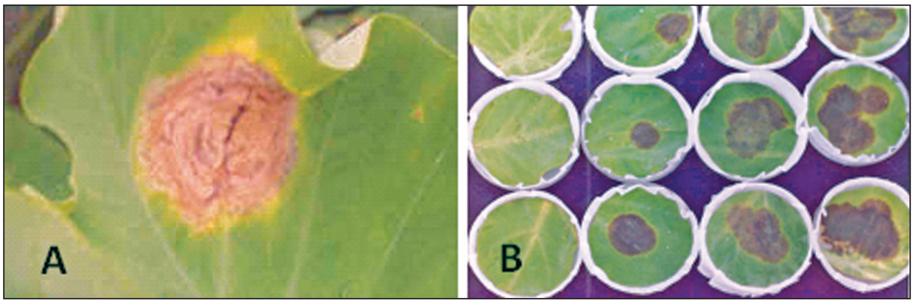

Fig. 1. *In vitro* evaluation under epiphytic conditions for tolerance to biotic stress (leaf blight disease reactions in taro). A. Source of inoculum; B. Reactions in resistant and susceptible lines

Abiotic stress

Drought and salinity tolerance in taro

Of the 174 lines screened under NaCl mediated salinity and PEG mediated moisture stresses, based on growth response, minimum necrosis (Fig. 2), sprouting behavior and other physiological parameters, six lines each for moisture and salinity

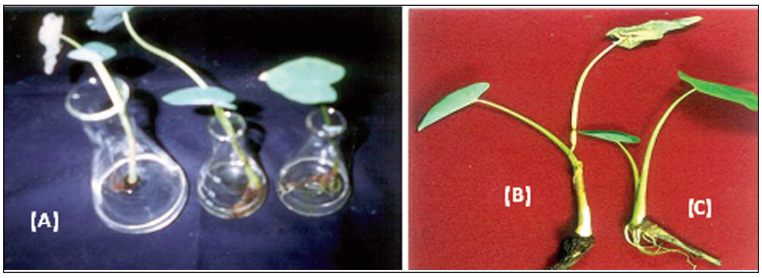

Fig. 2. Screening genetic resources of taro for abiotic stresses (drought and salinity). A. Taro lines grown in hydroponic cultures with stress chemicals like NaCl and PEG; B. Necrosis in susceptible lines; C. No necrosis in tolerant lines

stress were selected for further evaluation under integrated biotic and abiotic stress trials in taro.

Salinity tolerance in sweet potato

To isolate tolerant lines to salt stress, a stock of 171 carotene, anthocyanin and starch rich genotypes of sweet potato were screened in NaCl and artificial seawater mediated salt stress conditions (Fig. 3). Based on minimum necrosis (< 25%), rooting response and minimum reduction of photosynthetic rate under *in vitro* and *in vivo,* 23 genotypes were selected for yield and biochemical evaluation under *in situ* salt stress conditions.

Fig. 3. Screening in hydroponics

Drought tolerance in sweet potato

Progressive screening, evaluation of sweet potato genetic resources and selective breeding programme resulted in release of more than thirty varieties in India. The Regional Centre of CTCRI maintaining all the released varieties and pre-released lines as varietal gene bank under DUS programme. During summer the temperature of the farm of RC, CTCRI reaches up to 45° to 48°C during April and May. To maintain varietal gene bank, plants are usually transferred to shaded place to overcome the dry spell with frequent irrigation. Simultaneously a set was also maintained in open field to evaluate the survivable of the varieties, their growth response, *etc*. Of the various morpho-physiological responses under dry spell, considerable leaf damage and lean growth of the vine were found to be more significant among the twenty six varieties. The percentage of leaf damage per plant varied between 14.8% (Pusa Red) and 40.6% (Gouri). The varieties with minimum leaf damage were Pusa Red (14.8%), Sree kanaka (15.9%), Sankar (17.3%) and Samrat (19.1%). During the stress conditions the overall growth of the plant was affected, vine weight reflected the retardation in growth and stress susceptibility. Vine weight varied between 0.146 (ST-14) and 0.468 (Kanjakanad) kg per plant. Pusa Safed (0.356 kg/plant), VLS-6 (0.370 kg/plant), Co-2 (0.405 kg/plant) and Sree Varsha (0.392 kg/plant) showed comparatively higher vine weight percent among the varieties exposed to dry spell (Table 1).

Table 1. Response of sweet potato varieties to drought stress

Variety	% Damaged leaf/plant	Vine weight/ plant (in kg)
ST-14	21.9	0.146
Tirupaty	27.1	0.225
Sankar	17.3	0.194
VLS-6	20.6	0.370

Table 1. contd.

Variety	% Damaged leaf/plant	Vine weight/ plant (in kg)
Sree Vardhini	32.5	0.276
Goutam	22.0	0.241
Samrat	19.1	0.162
Sree Arun	25.0	0.226
Sree Varsha	33.0	0.392
Sree Bhadra	22.5	0.220
Sree kanaka	15.9	0.18
Kanaka Aswini	28.2	0.245
Kishan	28.8	0.386
COCIP-1	37.9	0.27
Sree Nandini	25.8	0.20
Pusa Red	14.8	0.280
Co-2	27.0	0.405
Co-3	29.4	0.311
Co-1	22.5	0.342
Rethna	28.5	0.37
Kanjakanad	20.4	0.468
Sourin	28.5	0.218
Kalinga	24.3	0.295
Pusa Safed	22.4	0.356
Gouri	40.6	0.150
Sree Varun	30.9	0.153

Interpolating the two parameters, percentage of damaged leaf and weight of overall foliage, the varieties, *viz.*, Pusa Safed, Kanjakanad, Kishan, Kalinga, Sree Varsha were found to have better adaptability under stress than the other varieties.

Submergence tolerance in taro and sweet potato

The progressive screening and evaluation under induced flooding and *in situ* water logged coastal and flood prone areas resulted in identifying two taro genotypes. Those genotypes were released as varieties, *viz.*, Pani Saru-1 and Pani Saru-2 (Fig. 4) in 2005 for commercial cultivation in water logged/submerged swampy conditions

Fig. 4. Submergence tolerant taro (Pani Saru- 1, Pani Saru -2) and sweet potato (Kalinga)

in Odisha. Such studies in sweet potato resulted in identifying 12 to 16 days submergence tolerant three genotypes (cv. Kalinga, Pusa safed and Samrat). The genotype Kalinga (Fig. 4) gave reasonably good yield with quality tubers when grown under submergence stress (Mukherjee, 2010).

Biochemical and yield response under stress

Taro

To isolate tolerant lines biochemical and yield parameters were studied for the selected 18 lines under integrated stresses like diseases, drought and salinity in taro. Percent increase in reducing sugar was below 20% in tolerant whereas in susceptible lines it was more than 90%. Protein content decreased less than 15% in tolerant lines. Proline accumulation was much higher in tolerant (>70%) than sensitive lines (<20%) under abiotic stresses.

Evaluation of both biochemical and yield parameters of the selected 18 lines under integrated stress condition showed that the 3 lines DP-25, Jhankri and Duradim (Fig. 5) are tolerant to both biotic and abiotic stresses. Reduction in yield was observed to be less than 20% in these genotypes when evaluated under integrated stress (Fig. 6). These genotypes under on farm *in situ* stress gave reasonable yield of 11-18 t ha^{-1}.

Fig. 5. Biotic and abiotic stress tolerant taro. (DP-25, Duradim and Jhankri)

Sweet potato

Percentage decrease in biochemical constituents like reducing sugar, total soluble sugar and protein was significantly less (< 15%) in tolerant genotypes. However, all these genotypes showed accumulation of higher amount (>78%) of proline in contrast to less than 60% proline accumulation in rest of the genotypes. Yield reduction was also minimum (<20%) in tolerant genotypes. Such evaluations resulted in identification of 11 salt tolerant genotypes with good yield (16-21 t ha^{-1}), five of which rich in carotene and 1 rich in anthocyanin (Table 2 & Fig. 7).

Isozymes and RAPD

Higher antioxidant and pronounced isozymes activities were recorded in tolerant

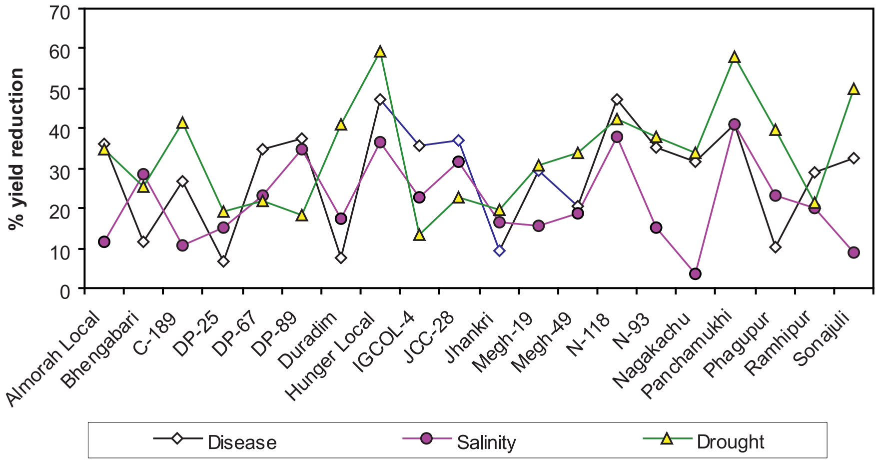

Fig. 6. Percentage reduction in yield due to leaf blight, salinity and drought stress in taro

Fig. 7. Promising orange and purple flesh sweet potato genotypes tolerant to salt stress (EC 6.0 - 8.0 dSm^{-1})

genotypes under stress in both the crops (Mukherjee *et al.*, 2009a, b). Variations in RAPD profiles (Fig. 8) among tolerant and sensitive lines and cluster analysis revealed that tolerant lines share the same node (Fig. 9).

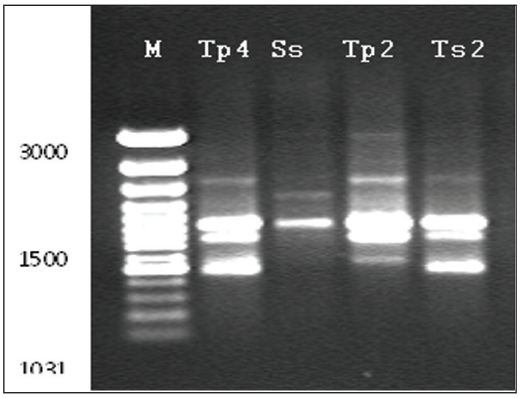

Fig. 8. RAPD variations among tolerant (T) and sensitive lines (S) in taro M-Marker (100 bp Gene Ruler, Genetix)

Table 2. Average tuber yield (t ha^{-1}), carotene, anthocyanin and starch contents of sweet potato grown at five different coastal areas of Odisha during 2008-2009

Genotypes	Mean tuber yield (t ha^{-1})	Carotene (mg/100g)	Anthocyanin (mg /100g)	Starch (%)
CIPSWA-2	21.29	6.5	-	16.8
ST-13	17.49	-	85	20.0
ST-14	18.11	14	-	20.5
440127	19.91	6.9	-	18.3
SB 198/115	18.84	5.1	-	16.2
Gouri	16.69	5.2	-	16.5

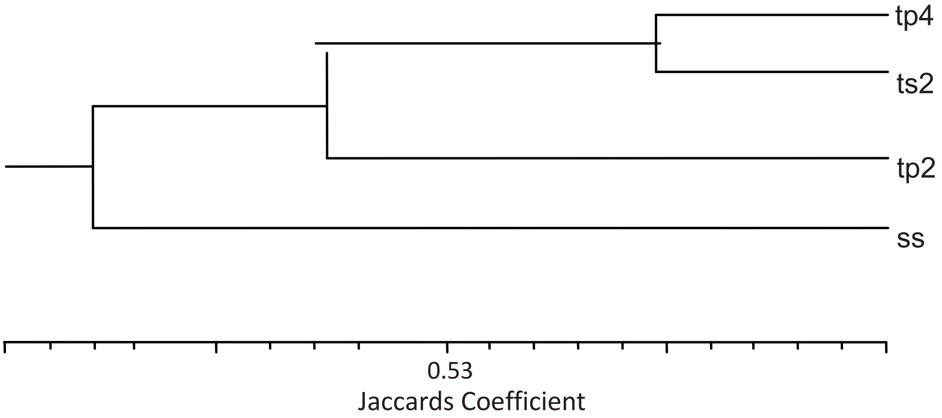

Fig. 9. Genomic relations of tolerant and sensitive as revealed by RAPD analysis in taro.

CONCLUSION

In vitro and *in vivo* screening and evaluation of 171 sweet potato genotypes and their successive evaluation under *in situ* salt stress (6.0-8.0 dSm^{-1}) in coastal Odisha and West Bengal resulted in identification of 11 salt tolerant genotypes packed with high yield (>15 t ha^{-1}), starch (16-20%), beta carotene (5-14 mg/100g) and anthocyanin (85mg/100g). Induced flooding resulted in identifying submergence tolerant 3 sweet potato genotypes. Further, the survival of some of the varieties of sweet potato over dry period reflects their tolerance to drought stress and can be adapted for cultivation in high lands, where such conditions prevail. Similarly screening of 174 taro genotypes through *in vitro-in vivo* screening, evaluation under integrated stress and validation of results under *in situ* stress resulted in identifying five stress tolerant taro including two submergence tolerant. Results on isozymes, DNA polymorphisms and cluster analysis are encouraging for gene pool enrichment for stress tolerant superior types to cope with harsh climate.

In India and other developing countries, under privileged and under nourished people live in coastal backward areas (Fig. 10). Thus, the results of the studies on stress tolerant sweet potato and taro in India are very promising.

Fig. 10. Sweet potato and taro for food, nutrition security.

The research conducted by the International Potato Centre at Peru, Kenyan Agricultural Research Institute, Uganda National Agricultural Research Organization and International Centre for Research on Women showed that the addition of small amount of orange-flesh sweet potato to the family's diet can mitigate vitamin A deficiency in both children and adults.

Of the 11 sweet potato genotypes identified with salt tolerant traits, five are orange flesh rich in b-carotene and one is purple flesh rich in anthocyanin and rest are white flesh rich in starch with yield more than 15 t ha^{-1} (Mukherjee, 2010).

Similarly the identified stress tolerant taro gave significantly higher yield (11-18 t ha^{-1}) with non acrid quality tubers which are rich in vitamins and minerals. These identified stress tolerant high energy rich biofortified sweet potato and taro have already been distributed in coastal areas across the country through All India Coordinated trials. Results under *in situ* on farm stress have immense agricultural implications towards food, nutrition security and economic sustainability of required especially under the awakening threats of climatic adversities.

FUTURE THRUST

Higher antioxidant enzyme activity linked with stress tolerance, variations in isozymes and RAPD profiles of tolerant and sensitive lines (Mukherjee *et al*., 2009a, b; Mukherjee, 2010) would facilitate *gene pyramiding* in sweet potato and taro for multiple resistances *against major stress factors* to cope with *climatic adversities* and the threats of global warming for sustenance of *life in planet earth*.

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