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High Starch, Beta Carotene and Anthocyanin Rich Sweet Potato: Ascent to Future Food and Nutrition Security in Coastal and Backward Areas

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ABSTRACT: *Sweet potato (Ipomoea batatas L.), a short duration creeper seems to be most suitable to grow in fragile zones and check soil erosion in degrading wet lands as eco-friendly crop. This crop can cater food (194 MJ/ha/day) feed, industrial (16-20% starch) and nutritional (Vitamin C - 23 mg/100g and Vitamin E - 4.6 mg/100g) demands. Orange flesh rich in β-carotene and purple flesh rich in anthocyanin can further fortify its nutritional value. Visibility of sweet potato as rescue crop in coastal Odisha during post super cyclone was enhanced as paddy and other vegetables failed to grow. These valued traits of sweet potato revalidated its importance across the globe as source for food-nutrition and processing. In India, at Central Tuber Crops Research Institute, sweet potato breeding has been undertaken to redesign it to meet the consumer needs. To satisfy the demands, the targeted objectives were- higher yield (more than 17 t/h), starch (more than 18%), β-carotene (more than 14 mg/100g) and anthocyanin (more than 1g/100g) with reduced crop growth cycle (75-90 days) and weevil resistance (infestation less than 10%). A stock of 265 sweet potato genotypes comprising of exotic, indigenous and their breeding lines were evaluated for such valued traits. Evaluation of germplasm lines resulted in selecting 16 lines. On the other hand breeding and evaluation resulted in developing 35 lines with targeted valued traits. 75 days maturity was recorded for 1 orange and 2 white flesh, whereas 90 days maturity recorded for 15 white, 5 orange and 5 purple flesh sweet potatoes. Yield ranged from 18-25 t/ha, β-carotene 14-16 mg/100g and anthocyanin more than 1g/100g. The high starch, β-carotene and anthocyanin rich sweet potato also found to perform better in hilly backward areas as well as coastal belts having salt stress (6-8 dSm^{-1}) across Odisha. These results have immense agricultural implications not only for coastal, backward areas of Odisha but also for other coastal wet lands prone to frequent cyclone and flood owing to climatic adversities. The high starch, anti-oxidants (β-carotene, anthocyanin) rich, short duration, weevil tolerant sweet potato is also the demand for food-nutrition and processing.*

Key words: *sweet potato, starch, beta-carotene, anthocyanin, food, nutrition security*

INTRODUCTION

Sweet potato (*Ipomoea batatus* L) is a herbaceous dicotyledonous species of the family *convolvulaceae*, grown in the tropics of the world. It is the fifth most important food staple of many developing nations. Tubers of this crop are rich in carbohydrate and minerals. The orange and purple flesh tubers are cheap source of β- carotene and anthocyanin. Despite its wider adaptability to diverse agro ecological conditions and calorie yield the productivity of sweet potato is affected to a greater extent due to salinity stress.

Stress is nothing but the perceived threat to the continued functioning of the body or life according to the current state. Salt stress is referred as incapability of a plant to grow on high salt medium. As per the statistics nearly equal 800 Mha areas are affected by salinity and sodicity worldwide, which accounts for 20% of agricultural land and 50% of crop land. This is alarming both for environmental concern as well as food security.

Soil salinity is caused by presence of soluble salts, originating from breakage and dissolution of rocks and salinity is further concentrated by evaporation and transpiration. In semi arid region the problem of salinity is further aggravated due to scarcity of water, hot and dry climate. Poor drainage in agricultural

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field also increases salinity by raising water table near the surface. Reclamation, drainage and water control can minimize the extent and spread of saline soils. However, increasing cost of water management accents the need for new strategies. In this regard, breeding of salt tolerant crop can prove to be a promising energy efficient strategy, that can be coupled with water and land management alternatives. For achieving salt tolerant breeding lines, growing of crops in high salt concentration and determination of growth or yield response under saline condition is the primary selection criteria. By this, the crop can acclimatize with stress condition by maintaining osmotic balance, removal of reactive oxygen species and homeostasis of various ion pumps.

As Odisha shares a major chunk of the eastern coastline of India, considerable part of the cultivable land of this state falls in coastal area. Further the land under cultivation is gradually and steadily encroached by saline water. This, leads to significant change in agro-climatic conditions of coastal regions. Sweet potato being a short duration crop with climate resilient adaptability (Mukherjee and Naskar 2012, Mukherjee 2013), can help in reclamation of agriculture lands in coastal regions. NaCl mediated tolerance to salt stress in sweet potato genotypes has been reported by Mukherjee (1999, 2001 & 2002) both *in vivo* and *in vitro* conditions. In the present study, white orange and purple flesh genotypes which performed well under institutional trials were grown in coastal belts of Odisha. Breeding and progressive evaluation including All India Coordinated Research Project (AICRP) on tuber crops recommended multilocations and on farm tests (MLT, OFT) for breeding lines resulted in developing salt tolerant β-carotene rich ST-14, anthocyanin rich ST-13 and high starch varieties ST-10 (Mukherjee and Naskar 2012, Moorthy *et al*., 2010). Those recently developed β-carotene rich (14mg/100g), orange flesh ST-14 and anthocyanin rich purple flesh ST13 (90mg/100g) and high starch (>18%) white flesh ST-10 were used for poly cross for further enhancement of targeted valued traits like β-carotene more than 14mg, anthocyanin more than 1g and starch 15-20% with shorter crop growth cycle and weevil tolerance.

The results on shorter crop growth (75-90 days) with higher starch (18-20%), β-carotene (>14mg/100g), anthocyanin (> 90mg/100g) and weevil tolerant (<10% infestation) sweet potatoes are reported in this communication.

MATERIALS AND METHODS

Central Tuber Crops Research Institute harbours a sizeable collection of sweet potato germplasm at its Regional Centre, Bhubaneswar farm, Odisha, India.

Germplasm is the source of variability for valued traits. Collection and evaluation is a continuous process to identify source of desirable traits. A stock of 180 genetic resources of sweet potato evaluated during 2004 – 2005 under APCess scheme.

Based on the results of APCess fund scheme entitled "Integrated approach for selection, introduction and characterization for development of salt tolerant sweet potato", the orange and purple flesh genotypes which showed salinity tolerance were forwarded to onfarm trials in coastal areas having EC of 6-8 dsm^{-1} (Mukherjee, 2005).

The genotypes which performed well under onfarm were also forwarded to Uniform Regional Trial (URT), MLT as per the recommendation of AICRP on tuber crops (TC). Better yielded genotypes were then recommended to release (Mukherjee and Naskar 2012) for commercial cultivation.

Such studies resulted in developing high β-carotene rich orange flesh ST-14, anthocyanin rich purple flesh ST-13, starch rich white flesh ST-10. Those evolved varieties along with other released varieties used for further enhancement of β-carotene, anthocyanin and starch contents. Methodologies followed were as described earlier (Mukherjee 2009, Moorthy *et al.* 2010 and Mukherjee 2013).

Progressive screening and evaluation of 1st clonal generation of seedling progenies for yield and other attributes were evaluated as explained by Mukherjee and Naskar 2012. Based on targeted attributes of higher yield, β-carotene, anthocyanin and starch contents evolved 35 lines. Of the 35 breeding lines, 29 comprising of 11 orange, 10 purple and 8 white fleshes were tested in coastal Kendrapara having 6-8 dsm^{-1} EC, Odisha, India.

Simultaneously a stock of 265 genetic resources also evaluated for early maturity and weevil tolerance. Yield and other attributes were also evaluated following the methodologies of Mukherjee *et al* (2009).

RESULTS AND DISCUSSION

The results on evaluation of genetic resources and breeding lines are presented as follows.

Evaluation of Genetic Resources

The evaluation of 265 genetic resources revealed more than 16t/ha yields in 16 accessions. Of the 16, the accessions with higher yield and other attributes are presented in Table 1.The accessions viz. S30/16, S30/15, Baster-45 found to have 75 days early maturity. Rest found to have 90 to110 days maturity, few of them observed to be nutrient efficient and responded to half doses of N and K (Table 1).

Evaluation of Breeding Lines

Progressive evaluation of breeding lines generated from high starch white flesh, β-carotene rich orange and anthocyanin rich purple flesh lines revealed 12-24 t/ha yield at Institutional farm. Of the 55 breeding lines, 35 lines recorded more than 16t/ha yield. Clonal generation of such twenty nine high yielding lines with high starch β-carotene and anthocyanin were tested onfarm in coastal Kendrapada having 6-8 dsm[1] salt stress. Yield performance of orange, white and purple flesh breeding lines presented in tables 2,3 & 4. Of the 11 orange flesh breeding lines, yield ranged between 19.46 to 21.84t/ha (Table 2). Of the 10 purple flesh, VABP-19 line recorded highest yield of 22.45 t/ha and lowest was by VAP-9 with yield of 18.24 t/ha (Table 3). Among the white flesh, yield ranged between 22.3 to 25.3 t/ha. The highest yield was recorded by VAW-8. Besides yield, the targeted valued traits like starch, β-carotene and anthocyanin observed to be higher in all those lines.

Evaluation for Valued Traits

Overall assessment for valued traits of germplasm and other breeding lines revealed 75 days maturity for three germplasm lines of which one was orange and 2 with white flesh. Among the breeding lines, 90days maturity recorded for 15-white, 5-orange and 5-purple flesh sweet potato (Table 5).

Starch contents observed to be 16-20.8% among those improved lines. β-carotene contents in orange flesh recorded as 12-16mg/100g and anthocyanin contents observed to be 90mg to 1.2g/100g (FigsA.-G). All those have recorded weevil infestation within 2-10% (Table 5).

DISCUSSION

Importance of biofortified salt tolerant sweet potato has been well explained by Mukherjee et al (2009). Performance of sweet potato as life support crop in post supercylone period in coastal Odisha has enhanced visibility of this neglected food crop. The high β-carotene rich ST-14 and anthocyanin rich ST-13 now gaining popularity not only in coastal backward areas of Odisha but also across the country for their high nutritional values. Results of present study on higher starch, β-carotene and anthocyanin contents with weevil tolerance traits will have immense agricultural importance towards food, nutrition and livelihood security.

Table 1
The identified sweet potato germplasm lines with early maturity and nutrient efficiency

Accessions No.	*IC No.*	*Attribute*
S30/16	590246	75 days
S30/15	590194	
Baster-45	590174	
SB72 / 7	590263	90 days
196	590252	
SBOP5/63	590240	
527	590206	
811	590205	
27	590270	
B X 24	590276	
SB 72/7	590263	Responded to half
Megh-2	590250	doses of Nitrogen
S30/15	590194	and Potassium

Table 2
Onfarm trial of orange flesh sweet potato in coastal (6-8dsm[1]) Kendrapada, Odisha, India

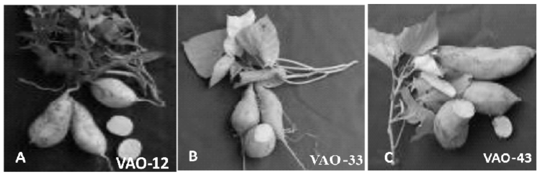
Sl. No.	*Genotypes*	*Yield(t/ha)*
1	VABO-22	21.57
2	VAO-19	20.55
3	VAO-8	20.17
4	VAO-23	20.93
5	VAO-12	20.11
6	VAO-33	19.46
7	VAO-16	21.15
8	VAO-43	20.86
9	VAO-17	19.6
10	VAO-22	21.84
11	VAO-14	20.33

CD=1.51

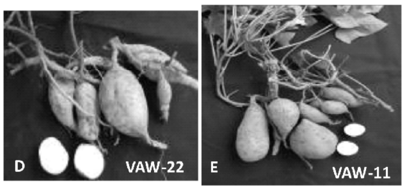
Table 3
Onfarm trial of purple flesh sweet potato in coastal (6-8dsm[1]) Kendrapada, Odisha, India

Sl. No.	*Genotypes*	*Yield(t/ha)*
1	VAP-9	18.24
2	VAP-22	21.37
3	VABP-19	22.45
4	VAP-19	20.29
5	VAP-34	18.9
6	VAP-12	20.95
7	VAP-14	19.1
8	VAP-2	20.62
9	VAP-27	21.33
10	VAP-39	18.5

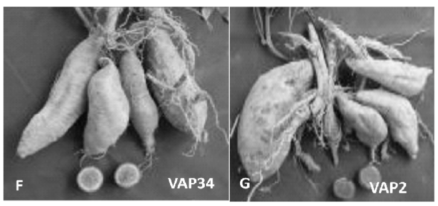
CD= 1.72



Orange flesh sweet potato (A-C) with β-carotene 14-16mg/100g



White flesh sweet potato (D&E) with high starch 16-20.8%



Purple flesh sweet potato (F&G) with anthocyanin 90mg-1.2g/100g

Figs. (A-G): Improved white, orange and purple flesh sweet potato evolved through breeding

Table 4
Onfarm trial of white flesh sweet potato in coastal (6-8dsm[1]) Kendrapada, Odisha, India

Sl no	*Genotypes*	*Yield(t/ha)*
1	VAW-6	22.89
2	VAW-24	22.54
3	VAW-8	25.3
4	VAW-11	23.3
5	VAW-17	23.49
6	VAW-22	22.87
7	VAW-9	24.75
8	VABW-6	22.28

CD=2.05

Table 5
Valued traits of improved sweet potato

Maturity of germplasm / breeding lines (Days)	*Starch contents (%)*	*β-carotene contents (mg/100g)*	*Anthocyanin contents (mg-g/100g)*	*Weevil infestation (%)*
75 days (Germplasm)				
1 orange	16	12	–	3.8
2 white	16-17.3	-	–	2-2.4
90 days (Breeding lines)				
15 white	18-20.8	-	-	3.2-6.5
5 orange	16-18.5	14-16	-	7-10
5 purple	18-20.5	-	90mg-1.2g	2.6-4.7

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REFERENCES

Mukherjee A. (1999), Tuber crops. In: *Biotechnology and its application in Horticulture*, Ed. (S P Ghosh), Narosha Publishing House, New Delhi, pp. 267-294.

Mukherjee A (2001), Effect of NaCl on axillary shoot proliferation in sweet potato. *Ann Trop Res*, 23:1-10.

Mukherjee A (2002), Effect of NaCl on *in vitro* propagation of sweet potato. *Applied Biochemistry and Biotechnology*, 102: 431-441.

Mukherjee A (2005), Integrated approach for selection, induction and characterization for development of salt tolerant sweet potato. In: Final report (May 2002-April2005), Code No. 303073652(F. No. 8(46)/ 2002-Hort.II dated 10th January, 2002, ICAR Cess Fund Scheme.

Mukherjee A., Naskar S K, Poddar A., Dasgupta M., Sahoo M. R. and Chand P. K. (2009), Submergence and Salinity tolerance in sweet potato (*Ipomoea batatus* L.): progress and prospects. *Plant Science Research*, vol. 31 (1 &2): 1-9.

Mukherjee A and Naskar S K (2012), Performance of orange and purple flesh sweet potato genotypes in coastal belts of Odisha, *Journal of root crops*, 38 : pp 71-76.

Mukherjee A. (2013), Climatic resilience and salinity cum submergence stresses tolerance of sweet potato (*Ipomoea batatas* L.) genotypes. In: Climate change and Environment. Eds. J. Sundaresan, S. Sreekesh, A.L. Ramanathan, Leonard Sonnenschein, Ramboojh. Scientific publisher, Jodhpur, India, pp: 89-99.

Moorthy S. N., Naskar S.K., Shanavas S., Radhika G.S. and Mukherjee A. (2010), Physicochemical characterization of selected sweet potato cultivars and their starches. *International Journal of Food Properties*, 13: 1280-1289.