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Variation in Morphological Characters and Storage Root Yield among Exotic Orange-Fleshed Sweet Potato Clones and their Seedling Population

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Abstract

Clonal evaluation was carried out with 1630 orange-fleshed sweet potato seedlings from controlled crosses of 'Jewel' population introduced from International Potato Centre (CIP), Lima, Peru. Morphological observations like leaf shape, emerging leaf colour, skin colour and flesh colour of storage root, weight of vine and storage root yield per plant were recorded. Wide variation was observed for all the qualitative and quantitative characters. Three types of leaf shapes were exhibited by the clones (cordate-81.65%, slightly lobed-16.69% and narrowly lobed-1.66%), while emerging leaf colour ranged between green (92.5%) to purple (7.5%). Four shades were observed in skin colour of storage roots varying from pink (35.21%), green (22.39%), purple (19.69%) to light pink colour (13.74%). The flesh colour of storage roots were observed to range from orange (37.48%), light orange (28.71%), dark orange (6.38%), cream (15.46%) to yellow (0.55%). The vine weight and root weight, being a quantitative character, varied according to the clone and environmental conditions (0.17 to 1.3 kg per plant). The vine weights of all the clones were higher in the lowland conditions than the upland conditions. Based on the evaluation of 1630 clones for tuber yield, tuber shape, β-carotene content and other agronomic characters, 224 clones were selected as superior progenies for recombination and sib-mating from which promising orange-fleshed varieties of considerable value can be generated.

Key words: Sweet potato, organge-flesh, seedling population, leaf shape, emerging leaf colour, skin colour, flesh colour, storage root yield

Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam), a member of the morning glory family, is an important vegetable cum food crop grown in the tropics, sub-tropics and warm temperate regions of the world for its edible storage roots. The leaves and storage roots are used as a potential source of carbohydrates, proteins, minerals and vitamins. The top portions of the plant, including the leaves contain moisture, crude protein, fibre and ash along with vitamin A and calcium. The dietary fibre content of the storage roots are reported to increase with the age of the plant, although at present it is not used for human consumption (Woolfe, 1992). In addition to its importance as human food, it also provides raw material for industrial purposes and animal feed. The flesh colour of the root varies from white to dark-orange depending upon the pigment present. Orange-fleshed sweet potato roots contain significant amounts of β-carotene, starch, dietary fibre, minerals, vitamins (especially vitamin C, B6 and folate) as well as antioxidants such as phenolics and tocopherol (Woolfe, 1992). The composition and contents of nutrients in sweet potato vary greatly depending upon genetic and environmental factors (Bovell-Benjamin, 2007). In the orange-fleshed storage root, the major carotenoid pigment is the β-carotene, which is a precursor of vitamin A. Consumption of carotenoid-rich foods has been related to prevention of cancer, cardiovascular diseases and other degenerative processes involving oxidative stress (Willet, 1990; Sies and Stahl, 2003).

The efficacy of β-carotene rich orange-fleshed variety compared with a white-fleshed variety in preventing vitamin A deficiency has been demonstrated among primary school children from South Africa (Jaarsveld et al., 2005) and Sub–Saharan Africa (Low et al., 2001). The incorporation of orange-fleshed sweet potato in the meals of 3-6 year old Indonesian children, who were marginally deficient in vitamin A showed an increased serum retinol concentration (Jalal et al., 1996). Also, one of the most important health problems in developing countries like India is the prevalence of vitamin A deficiency in young children and adults. Hence, it is important to supplement a diet which can combat vitamin A deficiency of the poorer mass. Generally, orange-fleshed sweet potatoes possess low dry matter content (Simonne et al., 1993). In sweet potato, orange-flesh colour and dry matter content is negatively correlated, while most of the farmers prefer sweet potato with high dry matter content. This paper deals with the studies on the variability for the morphological characters and storage root yield of 1630 sweet potato seedling population raised from seeds received from International Potato Centre (CIP), Lima, Peru.

Materials and Methods

The study was conducted at Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala, India, during 2008-2009 with about 8000 seeds of orange-fleshed sweet potato received from CIP, Lima, Peru. These seeds were raised from specific controlled crossess of 'Jewel' population. The seeds were treated with concentrated sulphuric acid for 7-8 minutes, washed repeatedly with running tap water till the acid residues were removed completely. The treated seeds were kept in water for 2-3 hours and then the water was drained off completely. These seeds were kept overnight on a moist filter paper in petri dishes. Out of the 8000 seeds sown, only 1650 germinated. The germinated seeds were transferred to the trays filled with sand and watering was done periodically. After 15 days, the seedlings were transplanted in polythene bags (36 x 24 cm size) which were filled with potting mixture (soil: sand: farmyard manure in 1:1:1 ratio). In each bag, two seedlings were planted. Out of 1650 seedlings planted only 1630 established. After one month, a supporting stick was allowed for each seedling and the vine was tied up on to the stick for quick growth of the vine and for easy identification. More than 80% of the transplanted seedlings started flowering one month after planting. It was observed in earlier experiments, that the storage root yield of seedlings and vine cuttings were not correlated and some of the seedlings did not even produce storage roots. However, it produced very good yield when it was clonally propagated. MacDonald (1969) had also previously reported poor agreement on the storage root development of the original seedlings and their respective vegetative progeny. Hence, clonal evaluation was adopted in this experiment. The materials selected were vine cuttings from 1630 hybrid seedlings which belonged to 147 specific cross combinations.

Twelve vine cuttings of 20-25 cm size were taken from each seedling after three months for clonal evaluation. They were planted on the ridges (three plants/clone/location) in two locations (upland and lowland). The spacing between and within the rows were 60 x 20 cm. All the clones were planted continuously on the ridges and the number of seedlings/cross combinations varied from 1 to 72. After planting the vine cuttings of one cross combination, 1m area was left before planting the seedlings of another hybrid combination. The crop was raised as per the package of practices standardized by CTCRI (CTCRI, 2004). The recommended dose of NPK @ 50:25:50 kg ha^{-1} was applied 25 days after planting the clones and the earthing up operations were carried out. Both the trials (upland and lowland) were planted during September under irrigated condition and harvested at 90 days after planting. Observations were recorded from all the 1630 clones for both qualitative and quantitative characters. Morphological observations like leaf shape, emerging leaf colour, skin and flesh colour of storage root, vine weight and storage root weight (fresh weight) were recorded at the time of harvest as per IBPGR descriptor by Huaman (1991). The β-carotene value was recorded as per the RHS colour chart developed by Burgos et al. (2009) from CIP, Lima, Peru. The frequencies of all the traits recorded from 1630 hybrid progenies were classified and segregation pattern for each character was analyzed.

Results and Discussion

Breeding programme involving large populations are necessary to make effective selection for a desired trait as each seedling represents an independent genotype which could possibly become a variety. Hence, each seedling has to be evaluated for the economic traits and better ones are to be promoted for subsequent testing and selection, while the rest are rejected in each cycle of evaluation. In the present study, wide range of variation was observed for leaf shape, emerging leaf colour, skin and flesh colour of storage root, storage root weight and vine weight in 1630 clones under upland and lowland conditions.

Leaf shape

In the present study various shapes of leaves (Fig. 1) were identified in sweet potato which ranged from round, reniform, cordate, triangular, hastate to lobed as reported by Huaman (1991). The frequency distribution for leaf shape of 1630 sweet potato clones showed that the maximum frequency was observed in cordate shape (81.65%) followed by the lobed leaves. The lobed leaves included slightly 3-lobed, 5-lobed and narrowly 3-lobed and 5-lobed. The slightly lobed (16.69%) and narrowly lobed (1.66%) leaf types were in low frequencies. Majority of clones possessed varying degrees of cordate leaf shape which may be due to the involvement of cordate leaf shaped parents in the cross combinations.

Emerging leaf colour

In sweet potato, in addition to the storage root characters, leaf shape and emerging leaf colour are two important traits which are used to identify a particular clone. Depending on the sweet potato cultivar, the emerging leaf colour varies from green to varying shades of purple colour. Frequency distribution graphs for the different variates are given in Fig. 1. In the present study, 92.5% of the clones had predominantly green colour indicating

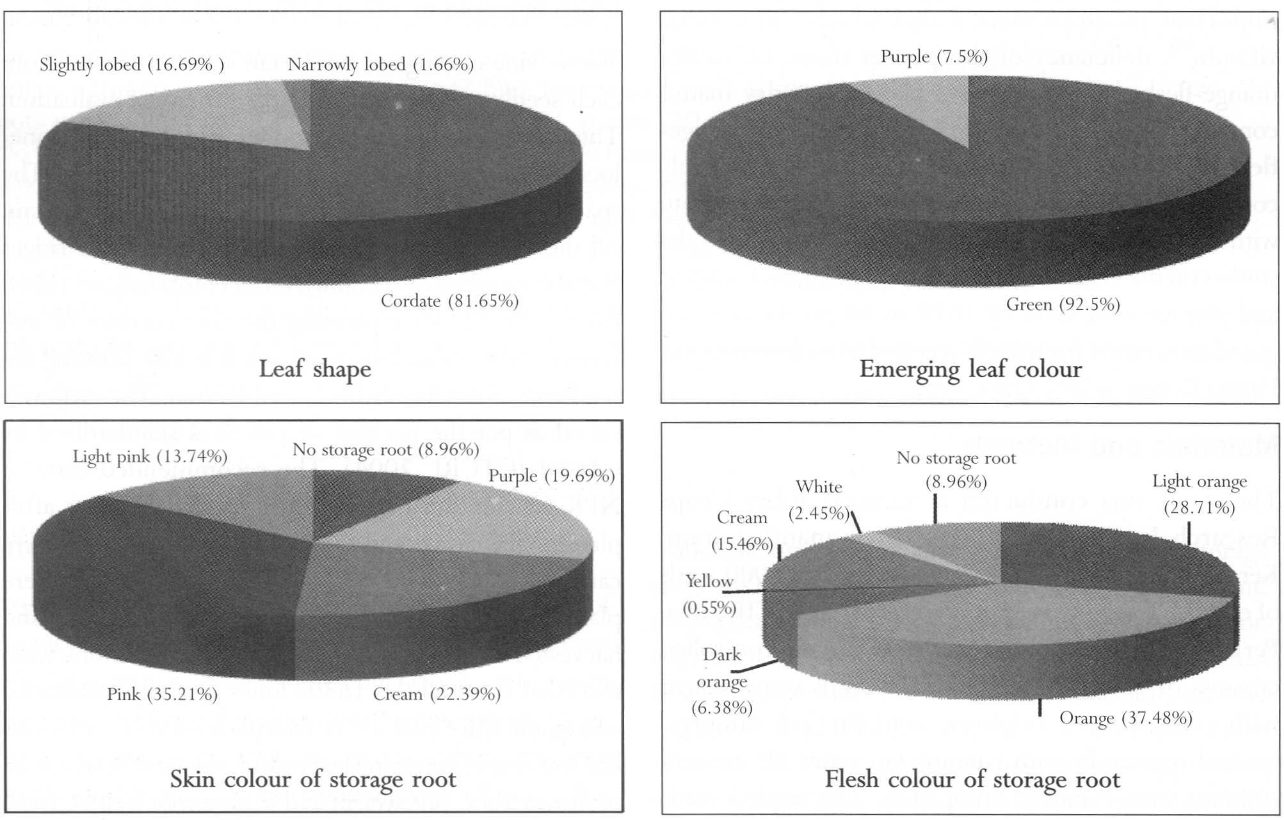

Fig. 1. Frequency distribution for vegetative shoot descriptors such as leaf shape, emerging leaf colour, skin colour and flesh colour of storage root

that green colour may be an incompletely dominant trait which was followed by different shades of purple colour (7.5%). The above results are in confirmation to that by Vimala and Nair (1988).

Vine weight

The vine weight is a quantitative character which varies according to the clone and environmental conditions. It was found to range considerably among the clones as well as between upland and lowland conditions (Fig. 2). The vine weights of all the clones were higher in the lowland condition than the upland which could be due to the availability of high moisture in the lowland. The vine weight ranged from 0.17 to 1.30 kg per plant. Majority of the clones were found to possess less than 0.17 kg (62.09%) followed by 0.17 – 0.33 kg (27.61%). The clones which possessed 0.33 – 0.50 kg and 0.53 – 0.67 kg vine was in low frequencies (6.13% and 3.68% respectively). In the lowland, only seven clones (0.49%) exhibited a very high shoot weight of above 0.67 kg. In the upland conditions, the highest shoot yield was found to fall under the category of less than 0.17 kg (51.84%) followed by 0.17 – 0.33 kg (37.91%). The clones which produced a vine weight of 0.33 – 0.50 kg and 0.50 – 0.67 kg constituted about 7.55% and 2.58% respectively. The highest vine yield of above 0.67 kg was exhibited by 20 clones (0.12%).

Skin colour of storage root

As sweet potato is a polyploid species and a number of allelles controls each single character, the segregation of genes allows the expression of a wide range of colours (Constantin, 1965; Hernandez et al. 1965; 1967). Of the 1630 clones, 8.96% did not produce storage roots. A wide variety of skin colours of the storage root ranging from purple, cream, pink and light pink were observed in the present study (Fig. 1). Maximum percentage (35.21%) of hybrids possessed pink skin followed by cream (22.39%), purple (19.69%) and light pink colour (13.74%). Earlier reports (Hernandez et al., 1965; 1967) indicated that coloured skin is incompletely dominant over white or cream skin colour in sweet potato. High heritability for tuber shape and flesh colour was reported by Jones et al. (1969, 1976) and Jones (1977, 1988).

Flesh colour of storage root

Flesh colour of storage root of sweet potato is controlled by the presence or absence, type and amount of pigments present in the internal tissue. Generally observed flesh colours of sweet potato are white, cream, yellow, orange (carotenoids) and purple (anthocyanin) with light, intermediate and dark shades of each. However, some cultivars show red-purple pigmentation in the flesh in very few scattered spots, pigmented rings or, in some cases, throughout the entire flesh of the root. As the study was conducted using vine cuttings from seedlings, numerous combination of alleles from the parents would have occurred, resulting in the expression of wide variety of morphology. Analysis of the data showed that 8.96% of the clones did not produce any storage root. The flesh colour showed different intensities of white to dark-orange colour. Orange flesh colour was found to be predominant (37.48%) followed by light orange (28.71%) and dark orange (6.38%) depending upon the carotenoid pigment present. In the present study, 15.46% of the hybrids possessed cream flesh colour followed by 2.45% white flesh colour and only nine hybrids (0.55%) had yellow pigmentation. Maximum frequency of clones showed different intensities of light to dark orange-flesh colour since the parents involved in the biparental crosses possessed orange-flesh colour. According to Hernandez et al. (1965; 1967) orange colour behaved as a typical character and several additive genes were involved in controlling the carotenoid pigment.

Storage root weight

The storage root weight was also found to vary among the clones as well as in the upland and lowland conditions (Fig. 2). It was observed that the storage root yield of all the clones under lowland were higher than the upland. At both sites, it ranged from 0.17 to 1.3 kg per plant. In the lowland, no tuberisation was observed in 9% of the clones. However, 63.5% clones had a root weight of < 0.17 kg. The clones which possessed 0.33 – 0.50 kg and 0.53 – 0.67 kg root yield were 15.28% and 10.55% respectively. Very low frequency (1.72%) of clones had above 0.67 kg root weight. In the upland conditions, out of the total 1630 clones, 15.40% did not produce storage roots, while majority (75.09%) of clones produced < 0.17 kg. Low frequency of hybrids (6.2% and 2.9%) produced 0.33 – 0.50 kg and 0.53 – 0.67 kg root yield. Only seven hybrids produced a root yield of 0.70 - 1.30 kg. Compared to the upland conditions, the clones which produced above 0.67 kg storage root yield was more in the lowland (1.72%). Root yield is said to

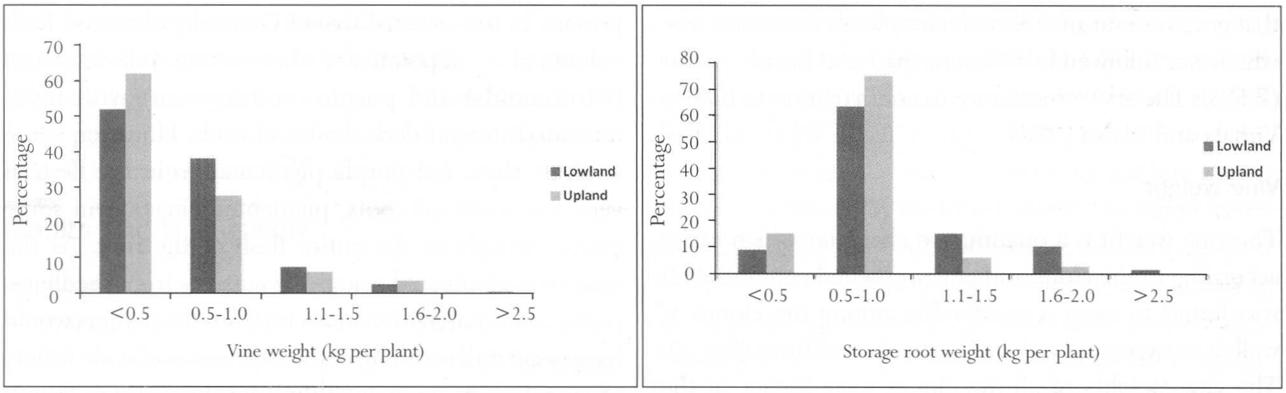

Fig.2. Frequency distribution for quantitative descriptors such as vine weight and storage root weight under upland and lowland conditions

be a variable quantitative character and studies had indicated that heritability estimates for tuber yield was low indicating non additive genetic variance (Jones, 1977). Jones et al. (1969) reported that storage root weight is an important component of yield in sweet potato and it could be expressed as differential plant vigour. Variation in storage root yield may be either due to the difference in the number of storage roots per plant or size of individual roots (Lowe and Wilson, 1975).. The present study showed that some of the crosses gave superior progenies indicating the pre-potency of some clones for superior seedling habits for yield and other agronomic characters. Similar results were also reported by Vimala and Nair (1988).

Sweet potato is a hexaploid, pollinated and vegetatively propagated crop. Though it is an important food crop, very little attention has been given for the improvement of this crop. For any crop improvement programme it is important to know the inheritance pattern of the characters. A study on the entire spectrum of variability, regardless of its commercial value is necessary to obtain the knowledge of inheritance pattern (Jones, 1966). The high morphological polymorphism exhibited by cultivated varieties of *I. batatas* has been reported by Sihachakr and Ducreux (1987) which also helped to specify their centre of origin (Austin, 1987). Estimation of genetic variability of a particular crop is a prerequisite for making any effective breeding programe. The present work has provided a preliminary morphological and agronomical characterization of orange-fleshed sweet potato. Using morphological traits, grouping of clones based on similar and shared characters provided information on the genetic base of the available orange-fleshed sweet potato. Flesh colour showed high polymorphism among the cultivars compared to other characters. It is noteworthy that upper limit of range was high in lowland conditions for most of the quantitative characters. The range of variation observed for all the traits makes it difficult to classify the clones into discrete classes, since considerable variation existed between the classes. The existence of continuous and overlapping variation points towards the quantitative nature of all morphological characters studied. The parental combinations having high frequency of superior progeny will increase the selection efficiency when there is a high mean and variance for the attribute. Based on the evaluation of 1630 clones for tuber yield, tuber shape, β-carotene content and other agronomic characters, 224 clones were selected for further evaluation. The study indicated that the selection of a number of superior progenies would provide a large gene pool for recombination and sib-mating from which promising orange-fleshed varieties of considerable value could be generated.

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