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Morphological variability and tuber productivity in exotic orange-fleshed sweet potato *(Ipomoea batatas*)

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Abstract

A preliminary yield trial was conducted with 230 clones selected from the clonal evaluation of the 1600 orange-fleshed clones in upland and lowland conditions. Morphological observations like leaf shape, emerging leaf colour, skin colour, flesh colour, weight of vine (kg) and weight of storage root (kg) were recorded. The existence of continuous and overlapping variation for all the characters indicated the quantitative nature for all the morphological characters studied. The study showed that the selection of a number of superior hybrid clones for yield and other attributes would provide a large gene pool for the recombination from which the promising variety of considerable value could be generated. The carotenoid rich clones also indicates the possibility of significantly improving the nutritive value by making more acceptable products to the consumers whereas storage roots with high dry matter and starch content are more suitable for secondary processed foods. Orange-fleshed clones with high yield can be popularized as an excellent source of β-carotene to control vit A deficiency which affects millions of children in the developing countries since β-carotene is a precursor of vit A.

Key words: Tuber yield, Morphology, Sweet potato, Clonal propagation, Vitamin A, β-carotene

1. Introduction

Sweet potato (*Ipomoea batatas* (L) Lam), an important vegetable cum food crop is grown in the tropics, subtropics and warm temperate regions of the world for its edible storage roots. It is a cross-pollinated and hexaploid (2n=6x) crop with 90 chromosomes (Jones, 1965). The roots are used as a source of carbohydrate and dietary fibre. The crop is also a rich source of provitamin A, vitamin B1 (Thiamin) and vitamin C (Huang, 1999). Dietary fibre has the potential to reduce the incidence of a variety of diseases in man including colon cancer, diabetes, heart diseases and digestive disturbances (Palmer, 1982; Pavio and Russel, 1999). In addition to its importance as human food, it is also used as an animal feed besides serving as a raw material for the production of alcohol. The flesh colour of the root varies from various shades of white, cream, yellow to dark-orange depending upon the pigment present. In the orange-fleshed sweet potato the major carotenoid present is β-carotene. Carotenoids have been linked with the enhancement of immune system and decreased risk of degenerative diseases such as cardiovascular problems, age-related macular degeneration and cataract formation (Byers and Perry, 1992). Hence, orange-fleshed sweet potato storage roots are a cheaper and complementary source of pro-vitamin A for the rural poor families who are the most vulnerable to vitamin A deficiency (VAD) (Beena et al., 2009; Binu et al., 2009; Binu Hariprakash et al., 2011a). VAD is also one of the most prevalent nutritional health problems leading to night blindness and high mortality rate in infants in the developing countries. Various studies relating to retention of carotene content after processing have promoted the use of orange-fleshed sweet potato against VAD (Vimala et al., 2011b).

The genetics of sweet potato is little understood and the inheritance pattern is quite complex one. Genetic information on many traits of direct economic importance in sweet potato are not available and most published information are from the clones of similar genetic back ground (Jones, 1966, 1969; Jones et al., 1969). Studies on the entire spectrum of the variability are therefore necessary to acquire knowledge on the inheritance pattern. The heterozygous nature of sweet potato clones and the virtually obligatory out crossing breeding systems together allow a

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wide range of genetic recombination with natural seed production (Nayar et al., 1984). However, cross-and self-incompatibilities in sweet potato cultivars are serious problem in breeding especially when many of the desirable parents belong to the same incompatible group. Most sweet potato cultivars are self and cross-incompatible which makes the plant incapable of producing viable seeds on self-pollination as well as cross pollination.

2. Materials and methods

Preliminary yield trial was conducted with 230 clones selected from the clonal evaluation trial of 1600 orange-fleshed clones in the upland and lowland conditions. Each clone was planted on 4 mounds with 4 vine cuttings each. The spacing within and between the rows were 90 x 90 cm. The recommended dose of 5t/ha farmyard manure was broadcasted in the field before the preparation of mounds. Half the dose of N and full dose of P and K was applied on the mounds at the time of planting and half N was applied one month after planting. Intercultural operations like weeding and earthing up were also carried out during the application of second dose of fertilizer. Both the trials were harvested at 90 days after planting. Morphological observations like weight of vine (kg), weight of storage root (kg), leaf shape, emerging leaf colour, skin colour and flesh colour of storage root were recorded at the time of harvest as per IBPGR descriptor by Huaman (1991). All the quantitative observations were recorded 6 plants /clone/replication. β-carotene value was recorded as per the RHS colour chart developed by Burgos et al (2009) from CIP, Lima, Peru. The frequency of all traits in the selected progenies was classified and segregation pattern was analyzed.

3. Results

Estimation of genetic diversity of a particular crop is prerequisite for making any effective breeding programme. Morphological characterization has been used for various purposes including identification of duplicates, variability patterns and correlation with characteristics of agronomic importance (CIAT, 1993). Here, the hybrid orange-fleshed sweet potato clones from CIP exhibited high morphological variability for the shoot and storage root characters which have been summarized in figures 1 and 2.

3.1. Leaf shape

Only three types of leaf shapes were observed in the hybrid clones- cordate, 3 lobed and 5 lobed. Frequency distribution for leaf shape showed that cordate type had the maximum frequency (95.65%) which was followed by 5 lobed (3.04%) and the occurrence of 3 lobed leaf was the lowest (1.30%). In the present study, the parents were found to have cordate leaf shape, which was expressed at a maximum in the hybrid population. Sweet potato leaves are reported to be variable in size and shape even within the same plant, but lines can be divided into two basic groups from the view point of leaf shape- lines with deeply lobed leaves and the other with entire margin. Within these two basic groups exists a variety of leaf forms.

3.2. Emerging leaf colour

The emerging leaf colour variation was broadly classified as green, purple, and light purple. Majority of the clones had green emerging leaf colour (99.13%) which was followed by purple (0.43%) and light purple (0.43%). Previous studies on the leaf colour of sweet potato are reported to be green but may also contain a considerable amount of purple pigmentation, especially along the vein (Vimala and Nair, 1988).

3.3. Root skin colour

The OFSP clones possessed a variety of root skin colour varying from cream, pink, light pink to purple. In the present study, it was observed that the pink (34.35%) and cream skin colour (33.48%) of the storage root was almost in equal frequencies which was followed by purple (24.78%) and light pink colour (7.39%). Similar results were obtained by Hernandez et al (1967) in the studies of controlled crosses between parents of rose & copper, rose & purple, as well as cream & copper reported that coloured skin is incompletely dominant over white or cream skin colour. Appearance of white colour in the progeny may be due to transgressive segregation. Characters controlled by two pair of genes include root formation, colour of root skin, colour of root flesh and nature of leaf margin (Poole, 1952). Constantin (1965) and Hernandez et al (1965, 1967) have reported skin colour as a quantitative character which was controlled by several genes in complementary action. High heritability for root shape and flesh colour was observed by Jones et al (1969, 1976) and Jones (1977, 1988).

3.4. Flesh colour

The 230 clones under study showed varying intensities of orange-flesh colour. The maximum frequency of dark orange flesh colour (48.70%) was predominant in the collection followed by intermediate orange (30.0%) and pale

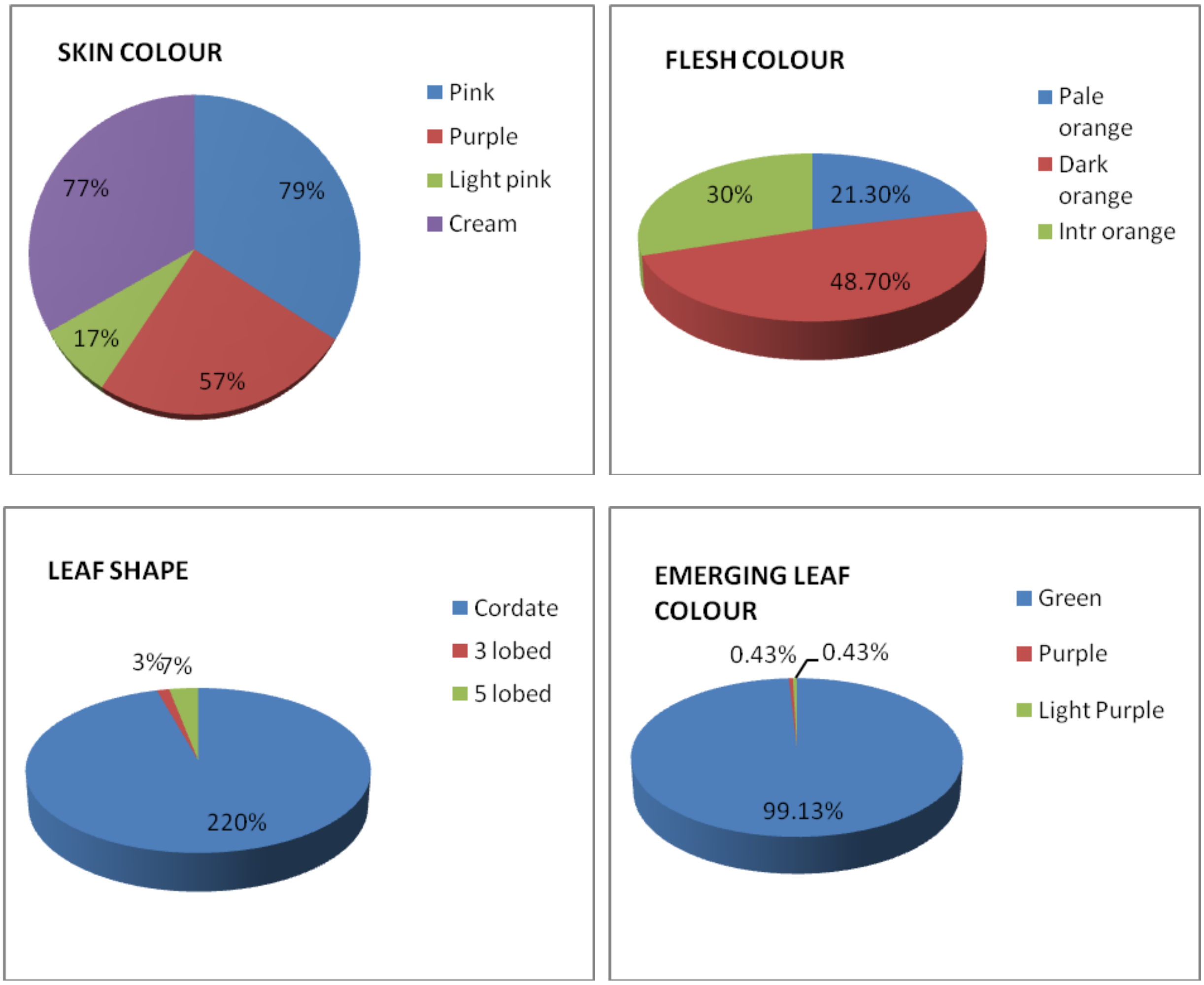

Figure 1. Frequency data for different morphological characters of OFSP hybrids

orange (21.30%) respectively. In a previous study by Hernandez et al (1965) it was found that white flesh colour was incompletely dominant over orange and total carotenoid pigments appeared to be controlled by several genes, possibly 6 that are additives. This observation was evaluated based on the inheritance of 18 flesh colour of sweet potato and found that crosses between parents possessing medium to high total carotenoids produced seedlings having mean total pigment content.

3.5. Vine weight

The vine weight was found to vary considerably between the clones as well as between the two sites- upland and lowland. The vine weight (kg) was recorded from 6 plants/clone/replication. In the lowland, it ranged from 0.5 – 5 kg. Majority of the clones was found to possess 0.5 – 1.0 (47.83%) followed by 1.0 – 1.5 (35.22%). 32% of the clones showed a vine weight of 1.5 – 2.0 t/ha whereas 2.17% had 2.0 – 2.5 t/ha. Few clones (0.43%) exhibited a very high shoot yield of 3.5 – 4.0 and 4.5 – 5.0 kg respectively. In the lowland the available soil moisture was higher than the upland conditions. Hence majority of the clones possessed higher vine weight than the upland. In the upland, highest shoot yield was found to fall between 0.5g – 1.0 kg but the percentage of clones was compared to be high (87.39%) followed by 1 – 1.5 kg (12.07%). In the upland, the maximum shoot yield of 2.0 – 2.5 kg was observed to be constituted by only 0.43% of clonal population.

3.6. Root yield

The root yield was found to vary between the clones as well as between the two locations - lowland and upland. In the lowland, it ranged from 0.5 – 5.0 kg whereas in the upland the storage root yield varied between 0.5 – 2.0 kg and in one clone the yield ranged between 3.5 – 4.0 kg. In lowland, 46.52% clones indicated a root yield of 0.5 – 1.0 kg followed by 1.0 – 1.5 kg (23.48%) of the clones whereas 18.69% clones had 1.5 – 2.0 kg root yield. However, few clones possessed a very high root yield of 2.0 – 2.5 (3.91%), 2.5 – 3.0 (4.35%), 3.0 – 3.5 (0.86%), 3.5 – 4.0 (0.86) and 4.5 – 5.0 (0.43%) kg respectively. In the upland, majority (92.17%) of clones produced yield between 1.0 – 1.5 kg whereas 6.96% of hybrid clones showed 2.5 – 3.0 kg root yield. Compared to the low land yield, the clones with high storage yield was low in the upland. Only 0.43% of clones produced root yield between 0.5 – 1.0 and 3.5 – 4.0 kg. Root yield is said to be a variable character and studies have indicated that heritability estimates for root yield was low indicating non additive genetic variance (Jones et al., 1969; Jones, 1977; Vimala, 1993; Vimala et al., 2011c; Binu Hariprakash et al., 2011b).

3.7. β-carotene

The β-carotene values of the 230 clones at both locations ranged between 1.32 – 14.37mg/100g fresh weight (f.w.). Hence, the β-carotene values were broadly classified into 3 groups: <5mg/100g.f.w., 6 – 11.0mg/100g.f.w. and 11.1-15mg/100g.f.w. About 40% of clones were found to possess less than 5mg/100g.f.w. β-carotene whereas majority of the clones (44.35%) had values between 6 - 10 mg/100g.f.w. The maximum β-carotene content (11 - 15 mg/100g) was observed in 21.74% of the clone. It was observed that even though little difference was noticed in the β-carotene values of the orange-fleshed clones cultivated in the lowland and upland there was no significant / drastic difference in this character. Orange fleshed clones evaluated at different locations of Orissa also indicated that there was not much difference in the total and β-carotene content (Vimala et al., 2011a). Similarly, effect of seasonal variation in carotene content from orange-fleshed sweet potato was found to have same result (Vimala et al., 2009). These studies showed that carotenoids in the orange-fleshed sweet potato is a stable character and is not affected by any environmental parameters.

4. Discussion

Sweet potato exhibits hexasomic or tetra-disomic inheritance (Kumagai et al., 1990). A wide range of variation exists among the sweet potato cultivars for the morphological as well as root characters. They differ from one another in the shape of roots, depth of rooting, time of maturity, resistance to disease and several other vegetative characters. Most of the important characters including yield are highly influenced by environment, since they are polygenically controlled (Amin and Singla, 2010). The possibility of improvement in any crop is dependent on the variability available in the crop, wider the genetic variability in the traits, better the chances of improvement through selection (Jindal et al., 2010). In sweet potato, the skin as well as the flesh contains carotenoids and anthocyanin pigments which determines its colour. The combination and intensity of these pigments vary to produce varying intensities of cream, yellow, orange, pink or purple skin and flesh colour. Attempts to demonstrate clear relationship between yield and morphological characteristics have been unsuccessful (Jones, 1966). However, with the advent of molecular markers and development of various DNA isolation protocols these problems have been solved to an extent (Binu Hariprakash et al., 2011c). Previous reports on the characterization of morphological diversity in sweet potato have been restricted to germplasm bank collections which revealed high phenotypical variability (Ritschell & Huaman, 2002; Daros et al., 2002; Mok & Schmiediche, 1999; Contreras et al., 1995). Das and Naskar (2008) have pointed out that analysis of varieties in genetic level throws more light on their genetic relationships along with morphological traits which will be of immense help in guiding the breeding programme in sweet potato for their improvement. Earlier reports showed that extensive studies have been made on the inheritance of various characters of sweet potato (Poole, 1952) while Harmon (1960) have demonstrated the quantitative inheritance of morphological characters such as leaf type, stem colour and vine length and found that deeply cleft leaf type was dominant and several genes influence the degree and pattern of purple colouration in stem. In another study, from the reciprocally intercrossed 19 sweet potato parents selected for early blooming varieties, wide variation was recorded for all the character studied (Jones, 1966). Similar results were observed in another study by Vimala and Binu Hariprakash (2011) while evaluating the morphological characters of 250 hybrid progenies generated from a controlled cross. All these studies showed that no clear cut demarcation was visible for any of the morphological traits and all the characters showed continuous variation (Vimala and Lakshmi, 1990; Vimala and Nair, 1988). From evaluating 14 sweet potato accessions, Daros et al. (2002) observed high morphological variability, concluding that the most informative descriptors were the vine tip pubescence, the abaxial leaf vein pigmentation and the shape of the roots. The traits that most contributed to the diversity were distribution of secondary flesh color, root shape, storage root surface defects and predominant storage root flesh color. Orange flesh colour is reported to be a typical quantitative character with large number of recessive alleles as several genes are involved in controlling the carotenoid pigment (Harmon, 1960). Hernandez (1963) has reported that a significant positive correlation between skin colour and carotenoid pigments while a negative correlation existed between dry matter and carotene content. The range of variation observed for all the traits makes it difficult to classify into discrete classes as both additive and non genetic variance are involved for all the characters. The existence of continuous and overlapping variation points towards the quantitative nature of all the characters studied (Vimala and Nair, 1988). Most of the morphological characters do not have any stable corelation with the root yield or yield components.

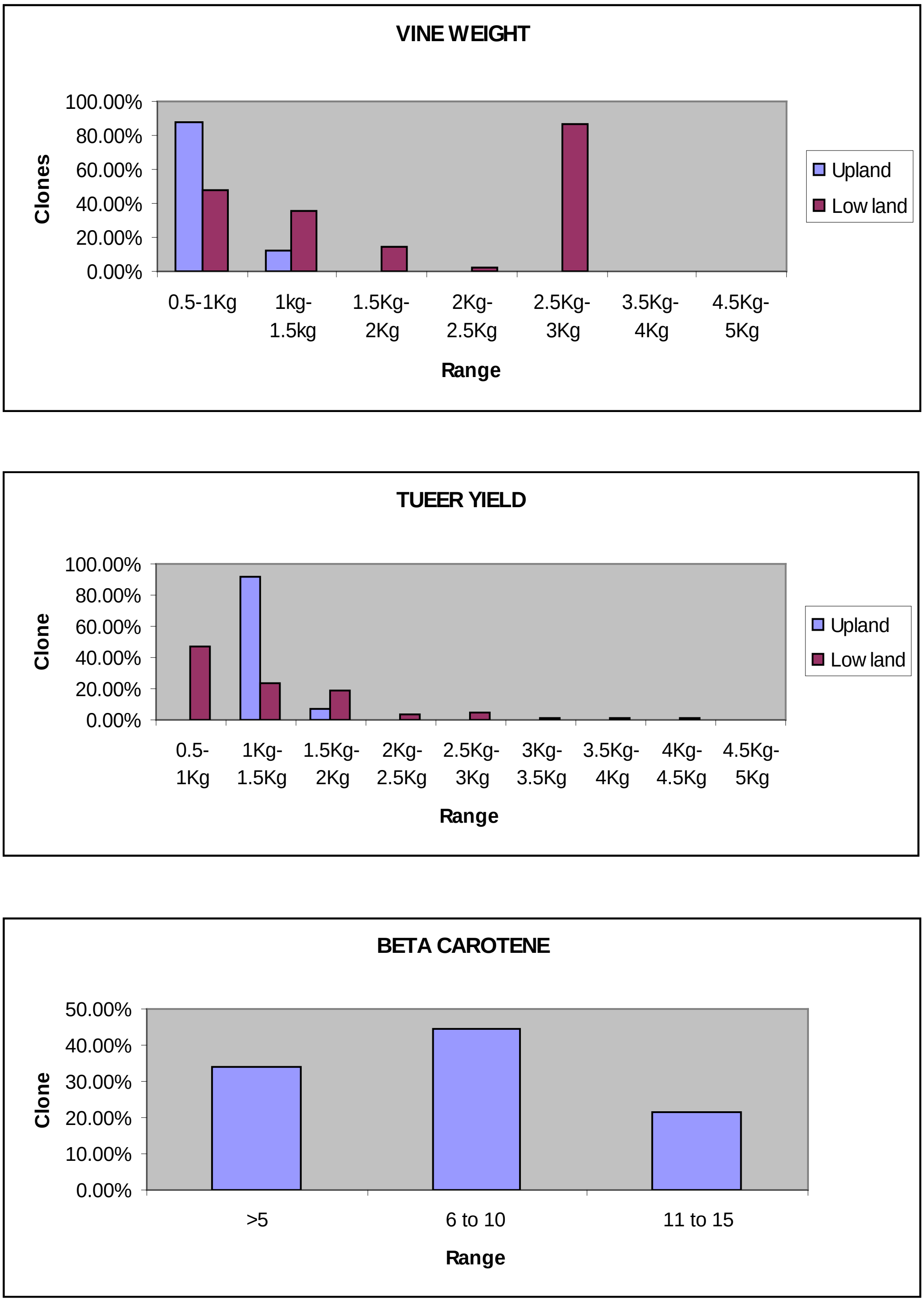

Figure 2. Frequency data for different quantitative characters of OFSP hybrids

5. Conclusion

In the present study, some of the hybrid clones exhibited superior seedling habit for yield and other desirable agronomic traits like flesh colour and β-carotene content. The range of variation observed for all the traits makes it difficult to classify into discrete classes, since considerable variation existed in between the classes. The existence and continuous overlapping variation points towards the quantitative nature for all morphological characters studied. The study indicated that the selection of a number of superior hybrid clones for yield and other attributes would provide a large gene pool for the recombination from which the promising variety of considerable value could be generated. The carotenoid rich clones also indicates the possibility of significantly improving the nutritive value by making more acceptable products such as ice creams (Vimala and Bala Nambisan, 2010) to the consumers whereas storage roots with high dry matter and starch content are more suitable for secondary processed foods. Orange-fleshed clones with high yield can be popularized as an excellent source of β-carotene to control vit A deficiency which affects millions of children in the developing countries since β-carotene is a precursor of vit A.

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