Article

Variability of morphological characters and dry matter content in the hybrid progenies of sweet potato (Ipomoea batatas (L) Lam).

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Abstract

The morphological variability in 250 hybrid progenies of sweet potato (Ipomoea batatas (L) Lam) from a biparental cross involving a white flesh (S-1) and an orange flesh clone (ST-14) were evaluated. The study aimed to assess the range of variability and segregation pattern for the different morphological characters as well as the inheritance pattern of high value carotenoids in hybrid progenies. The characters recorded from the progenies were four vine, four storage root, two each of cooking qualities and dry matter. The existence of continuous and overlapping variation for all the characters indicates the quantitative nature for all the studied morphological characters. The results revealed that the selection of a number of superior F1 clones for yield and other attributes would provide a large gene pool for the recombination to generate the promising variety of considerable value.

Key words: Sweet potato, hybridization, morphology, variability, dry matter, pollination.

Introduction:

Sweet potato (Ipomoea batatas (L) Lam), an important vegetable cum food crop is grown in the tropics, sub-tropics and warm temperate regions of the world for its edible tubers. In addition to its importance as human food it is also used as an animal feed besides serving as a raw material for various industrial purposes (Woolfe, 1992). Sweet potato is a cross-pollinated and hexaploid (2n=6x) crop with 90 chromosomes (Jones, 1965). 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; Jones et al., 1969). Studies on the entire spectrum of the variability are therefore necessary to acquire knowledge on the inheritance pattern (Vimala, 1993). The heterozygous nature of sweet potato clones and the virtually obligatory out crossing breeding systems together allow a 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 (Wang 1964; Charles et al., 1973). The production of seeds from controlled crosses forms the basis for sweet potato breeding (Stout, 1926). Most sweet potato cultivars are self and cross- incompatible which makes the plant incapable of producing viable seeds on self as well as cross- pollination. The major problems in sexual reproduction of sweet potato are non-flowering and low fertility of the seeds. The open and cross-pollinated seedlings often behave as different genotypes and hence, selection from such heterogeneous population sometimes lead to isolation of superior clones (Ghosh et al., 1999; Nayar et al., 1984; Varma, 1984). The objective of the present work was to find out the range of variability and segregation pattern for the different morphological characters and the inheritance pattern of the carotenoids in the hybrid progenies developed from a cross between an orange-flesh and white-flesh clone.

Materials and methods:

The materials for the study were selected from the sweet potato germplasm maintained at Central Tuber Crops Research Institute, Trivandrum, Kerala, India. Two accessions selected for the controlled hybridization programe were ‘ST-14’ with dark orange flesh colour as female parent and ‘S-1’ with white flesh colour as male parent. ‘ST-14’ is a moderately flowering and seed setting clone while ‘S-1’ a good male parent which flowers profusely but with very low seed setting. Plant type of ‘ST-14’ is semi erect type with mostly dark purple vine with green emerging leaf colour. Leaves are triangular and tubers are ovate type with pale orange skin and dark orange flesh colour. The dry matter content of the tuber is 22% with moist tuber texture and slightly sweet. On the Contrary, ‘S-1’ is a spreading type with green coloured vine and green emerging leaf. Leaves are narrowly 5 lobed and tubers are long elliptical in shape with purple skin and white flesh colour. The dry matter content of the tuber is 28% and cooked tubers possess moist flesh with sweetness.

The vine cuttings of both the parents were planted on raised beds. After two months, the flowering branches which were selected on the previous day were emasculated and covered with butter paper cover in order to avoid contamination by pollen grains. The flower buds from the male parent were also covered with butter paper cover. The following day, pollination was carried out between 5.00 and 6.00 am and the butter paper covers were replaced. On the fourth day the upper portion of the paper cover was tore up for the aeration of the developing fruit. The fruits matured within 25-30 days after pollination and from the successful crosses seeds were collected. About 1000 hybrid seeds collected from the cross were scarified with concentrated sulphuric acid for 5-7 min, washed thoroughly and sown in polythene bags containing potting mixture. Of the 900 seeds germinated, 250 seedlings were selected randomly for the present studies. Five vine cuttings per seedling were transplanted to the field at a spacing of 60 x 20 cm and the recommended packages of practices were adopted. Morphological traits of all the progenies were recorded as per CIP, IBPGR descriptor by Huaman (1991) and the segregation pattern were analyzed.

A total of 11 characters (4 shoot, 4 storage root, 2 each of cooking qualities as well as dry matter) were evaluated for each genotype. The shoot characters recorded for the vines were plant type, vine colour, leaf shape, emerging leaf colour, while those recorded for storage root were tuber shape, tuber skin colour, flesh colour and tuber yield. The two cooking quality characters were texture after boiling and sweetness. For the determination of dry matter, 20 gm of fresh tuber was cut into small pieces and dried to a constant weight in a hot air oven at 500C and percentage of dry matter was calculated.

Results and discussion:

Morphological characterization is the basic of any crop improvement programme including a crop like sweet potato. Such characterization has been used for various purposes like identification of duplicates, variability patterns and correlation with characteristics of agronomic importance (CIAT, 1993). In the present study, the exhibited high morphological variability for the shoot and storage root characters (Figs 1, 2 & 3) of the hybrid progenies are presented as follows.

Plant type:

Four types of plant types were observed ie., erect type (<75 cm), semi erect (75-150 cm, spreading (151–250 cm) and extremely spreading (>250 cm). The frequency distribution for plant type indicated that majority of the clones belonged to spreading type (72%) showing an affinity to the male parent where as 26% belonged to semi erect type directed towards the maternal side. The extremely spreading type and erect habit was found to be very low (1.2% and 0.8%). Sweet potato has long thin stem which trail along the soil surface, anchoring the soil with roots from the nodes. Stem length varies with cultivars from 1m to over 6m which are circular or slightly angular in cross section and also possess minute hairs on young stem which tend to disappear when it ages (Jones, 1966).

Vine colour:

High variability was observed in vine colour ranging from green to purple. It was observed that the progenies possessed a preponderance of purple (42.8%) colour like ‘ST-14’ closely followed by green (40%) which was nearly equal in frequency. The other vine colour observed in the progenies were green with few purple spots (5.2%), green with many purple spots (1.6%), green with many dark purple spots(0.4%), most dark purple (2.8%), totally purple

(5.2%) and total dark purple (2%) colouration. Stem colour is reported to be predominantly green in sweet potato, though purple pigmentation is also present. Similar results showing some what equal distribution of green and purple vine colour of sweet potato progenies have been demonstrated by Vimala and Nair (1988). However, the purple vines have no correlation with emerging leaf colour. Dominance of red stem over green was reported by Poole (1952).

Leaf shape:

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. Frequency distribution for leaf shape showed that lobed type had the maximum frequency (49.2%) which showed an affinity towards the male parent. This was followed by triangular (27.2%) and cordate leaf (23.2%). The occurrence of hastate type leaf was the lowest (0.4%).

Emerging leaf colour:

The emerging leaf colour variation was broadly classified as green, slightly purple, mostly purple and purple on both surfaces. Both the male and female parents possess green emerging leaf colour and majority of the hybrid progenies also had green emerging leaf colour (71.2%). The progenies had predominantly green colour in emerging leaves indicating that it may be an incompletely dominant trait which was followed by slightly purple (17.6%), mostly purple (10.8%) and purple both surface (0.4%). 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).

Tuber shape:

The nine key characters were identified for tuber shape in the hybrid progenies namely, round, round elliptic, elliptic, ovate, oblong, long oblong, long elliptic and long irregular. Ovate (28%) tubers were the prevalent type followed by round (20.4%) and elliptic type (19.6%). The frequency of other tuber shapes were round elliptic (2%), oblong (5.2%), long oblong (13.6%), long elliptic (5.2%) and long irregular (6%) respectively. The presence of so many intermediate characters clearly demonstrates the incomplete dominance as well as the occurrence of multiple alleles for a particular character in sweet potato. Hammett (1966) have reported that tuber shape was controlled by additive effect in the absence of dominant genes and the female parent was found to exert a greater influence than the male parent. High heritability for tuber shape was reported by Jones et al., (1969, 1976) and Jones (1977, 1988) and the uniformity of tuber colour was controlled by a few genes with partial dominance.

Tuber skin colour:

The clones possessed a variety of tuber skin colour varying from white, cream, yellow, orange, pink to purple and the intensity varied from pale, intermediate to dark colour for each shades. In the present investigation the hybrid progenies was predominantly red colour (24.4%) followed by purple red (21.6%), cream (19.6%) and pink colour (12.4%). 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. They 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 tuber formation, colour of tuber skin, colour of tuber flesh and nature of leaf margin in complementary action (Poole, 1952). The uniformity of tuber colour was controlled by a few genes with partial dominance (Hammett 1966). Constantin (1965) and Hernandez et al (1965, 1967) observed skin colour as a quantitative character which was controlled by several genes in complementary action. High heritability for tuber shape and flesh colour was reported by Jones et al (1969, 1976) and Jones (1977, 1988).

Flesh colour:

Attractive flesh colours were exhibited by the clones such as white, cream, dark cream, pale yellow, dark yellow, pale orange, intermediate orange, dark orange and those pigmented with anthocyanin. Orange colour, the female parent character, was predominant in the progeny with pale orange (24.8 %), intermediate orange (22.4 %) and dark orange (11.6 %) colour respectively which constituted to about 58.8% of the total progeny status whereas white colour constituted to about 8.4% only. Cream colour was noticed in 15.2 % of seedlings while all the other colours were below 10%. However, pink pigmentation which showed the presence of anthocyanin (6.4 %) was also noticed in this progeny. Previous study by Hernandez et al (1965) reported 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. Jones et al (1969, 1976) and Jones (1977, 1988) reported high heritability for flesh colour.

Yield:

The yield ranged from 50g to 5 kg per 5 plants in the 250 clones during the present study. Only 7 clones were found to give lowest yield of 50g, and the highest yield of 5 kg was recorded in one clone. 23 clones produced yield below 100g, while 95, 69, 45 and 10 clones yielded 500g, 1kg, 2kg and 3kg of tuber respectively. Frequency distribution for tuber yield showed that 38% of the progeny produced only upto 500 g, while 27.6% yielded upto 1kg and 18% upto 2kg tubers. The maximum yield, ie., 5kg was observed only in 0.4% of the progenies while 2.8% showed lowest yield of 50 g.

The mature storage root ranged from spherical to spindle shape, in length from a few cm to more than 40 cm and in weight from 0.1kg to several kg Hernandez et al (1965). Tuber yield is said to be a variable character and studies have indicated that heritability estimates for tuber yield was low indicating non additive genetic variance (Jones et al., 1969; Jones, 1977).

Texture after boiling:

Storage roots can be classified according to their texture when cooked. ie., cultivars with firm or dry flesh or cultivar with soft or moist flesh. Three key characters were identified for starch content like dry, intermediate, moist and very moist. Out of the 250 hybrids, 16.8% were identified as dry tubers with good eating quality, while 18.8% were intermediate. Moist type tubers contributed to about 46% while 18.4% were of very moist type with high amount of water content. The dry texture in sweet potato is dependent on starch swelling pressure, causing cell separation to predominate over cell rupture when tissue is disrupted, and thus preventing the release of intracellular fluid (Watson and Jarvis, 1995).

Sweetness:

Palatability being an important factor for the acceptance of sweet potato, 3 characters such as sweet, medium sweet and non sweet type were scored for all the hybrids. Out of the 250 hybrids, only 30 found to be in the category of sweet type while 99 were of medium sweetness and 121 were non sweet type. The flesh colour, sweetness and flavour were positively corelated and showed a high heritability estimate indicating additive genetic variance according to Constanin et al (1966).

The dry matter of the progenies ranged between 15.8 -37.2%. A stock of 44.8% hybrids possessed 25 – 30%. dry matter content. Almost equal proportion of the progenies (25.2% and 24.4%) possessed 20 – 25% and 30 – 35% respectively. 0nly 4% of the progenies had less than 20% while 1.6% had more than 35% dry matter. Compared to other tuber crops, the sweet potato has high moisture content resulting in relatively low dry matter content. The average dry matter content in sweet potato is approximately 30% but are also found to vary widely depending on the factors such as cultivar, location, climate, day length, soil type, incidence of pests, diseases and cultivation practices (Bradbury and Holloway 1988). Hamilton et al (1986) observed a positive correlation with the light flesh colour of the tuber and the dry matter content while Dai et al (1988) suggested an additive gene effect for the starch content and dry matter.

Sweet potato exhibits hexasomic or tetra-disomic inheritance (Kumagai et al., 1990). Previous reports suggest the occurrence of wide range of variation among the sweet potato cultivars for the morphological as well as tuber characters. They differ from one another in the shape of tubers, depth of rooting, time of maturity, resistance to disease and several other vegetative characters. The colour of the skin as well as flesh is determined by pigments such as carotenoids and anthocyanins the combination of which vary to produce skin and flesh of a whitish, yellow, orange, pink or purple colour, depending on the cultivar under consideration (Hernandez et al., 1965). However, attempts to demonstrate clear relationship between yield and morphological characteristics has been found unsuccessful (Jones, 1966). Previous reports on the characterization of morphological diversity in sweet potato have been restricted to duplicate identification of germplasm bank collections revealed high phenotypical variability (Contreras et al., 1995; Huaman et al., 1999; Mok & Schmiediche, 1999; Ritschel & Huaman, 2002; Daros et al., 2002). Extensive studies have been made on the inheritance of various characters of sweet potato (Poole, 1952). Harmon (1960) have demonstrated the quantitative inheritance of morphological characters such as leaf type, stem colour and vine length. They found that deeply cleft leaf type was dominant and several genes influence the degree and pattern of purple colouration in stem. In another study, wide variation was recorded for all the characters studied by Jones (1966) in reciprocally intercrossed 19 sweet potato parents selected for early blooming.

All these studies showed lack of distinct demarcation for any of the morphological traits and all the characters exhibited continuous variation (Vimala and Lakshmi, 1991; Vimala and Nair, 1988). Daros et al. (2002) observed high morphological variability, while evaluating 14 sweet potato accessions. They concluded that the most informative descriptors might be the vine tip pubescence the abaxial leaf vein pigmentation and the shape of the roots. The traits that mostly contributed to the diversity were found to be the 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 flesh colour and carotenoid pigments while a negative correlation existed between dry matter and carotenoid.

Biparental breeding is rarely attempted in sweet potato because of the hard labour of emasculation, bagging and pollination involved. The main advantage of the hybridization programe is the use of well tested parents for specific traits in breeding and hence chances of getting a desirable combination was much higher than from open pollination. 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 indicated the quantitative nature of inheritance for all studied characters (Vimala and Nair, 1988). However, most of the morphological characters do not have any stable correlation with the tuber yield or yield components.

In the present study, some of the progenies exhibited superior seedling habit for yield and other desirable agronomic traits as the parents involved have high frequency of superior genotypes. It will increase the selection efficacy when there is a high mean and variance for the attributes. In the present study distinct demarcation was not visible for any of the studied characters. The range of variation observed for all the traits makes it difficult to classify into discrete classes owing to considerable variation existed in between the classes. The existence of continuous overlapping variation for all the studied characters reflects their quantitative nature of inheritance. Hence, the results of the present study revealed a suitable breeding strategy through selection of superior F1 clones for yield and other value added attributes. This would provide a large gene pool for effective recombination to raise promising sweet potato variety of considerable agri-horticultural importance.

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Figure1. Morphological vegetative shoot descriptors for plant type, vine colouration, leaf shape and emerging leaf colour evaluated in 250 hybrid progenies of sweet potato.

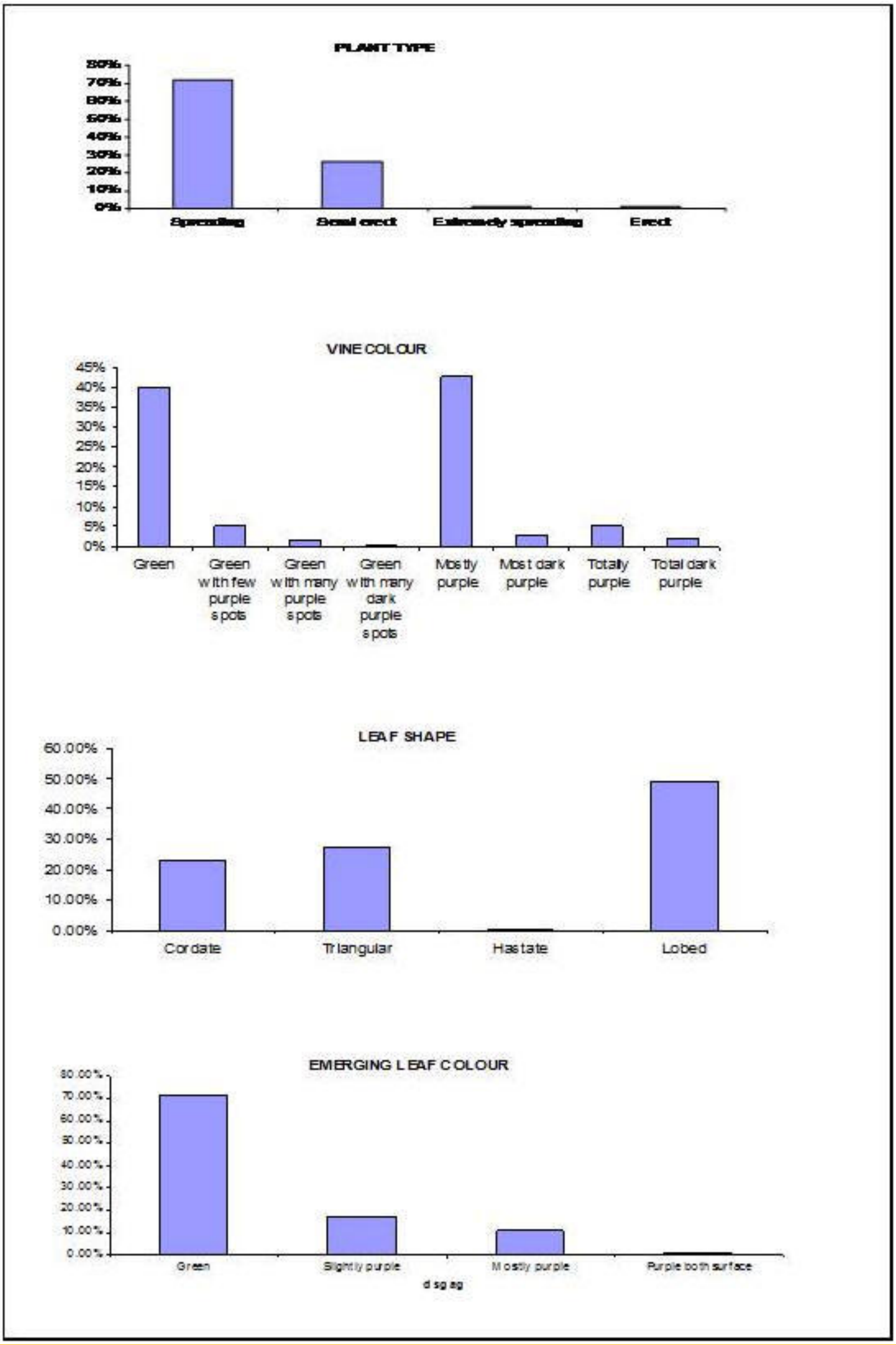


Figure2. Morphological vegetative shoot descriptors for tuber shape, tuber skin colour, flesh colour and tuber yield in the hybrid progenies.

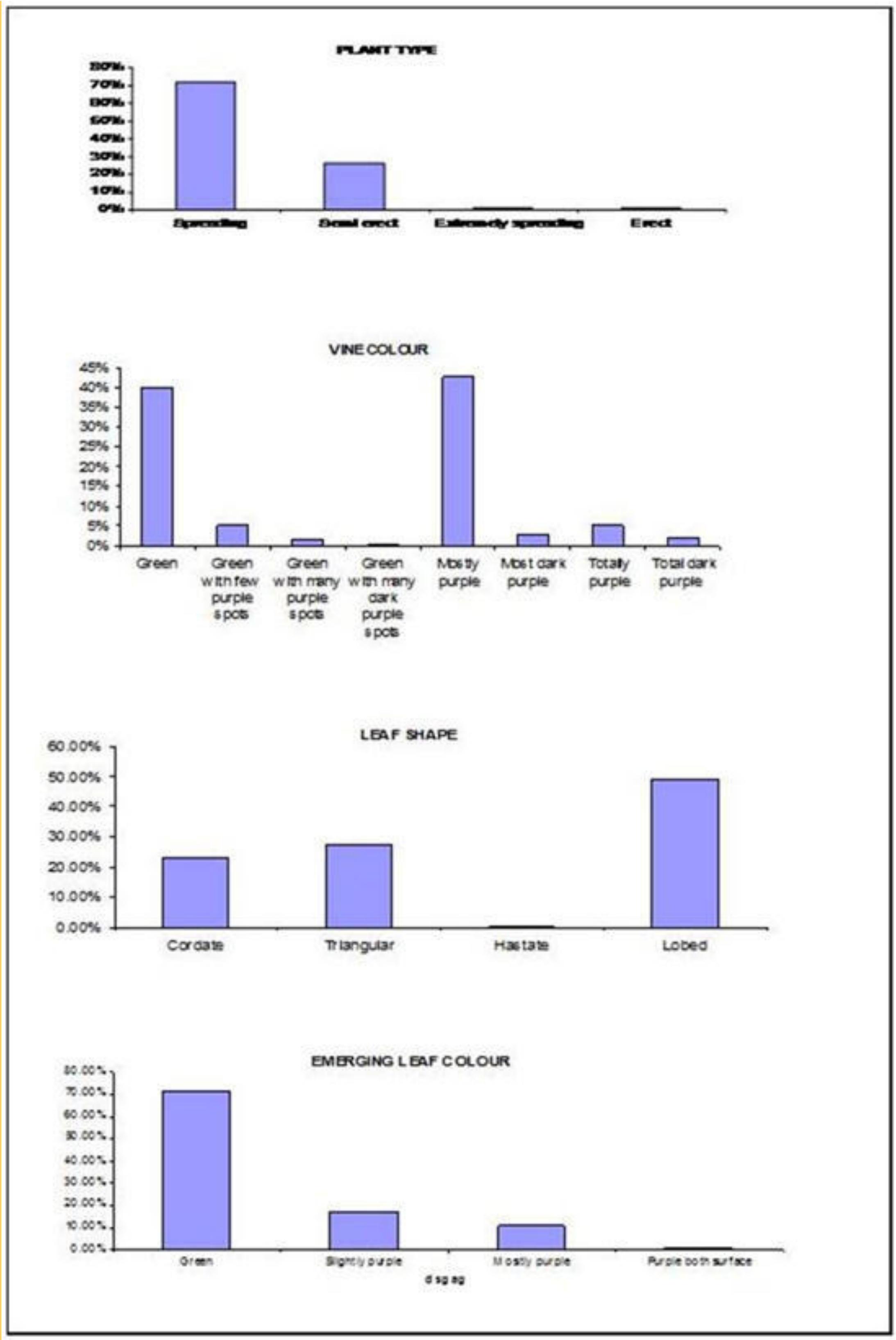
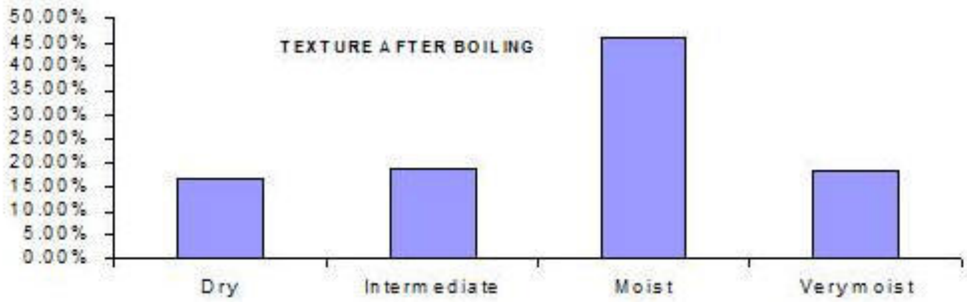
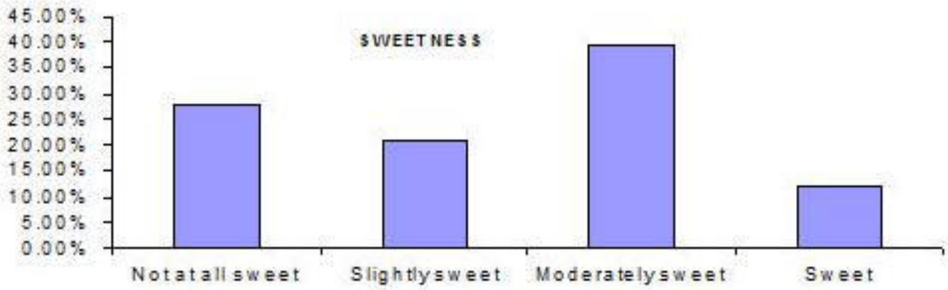
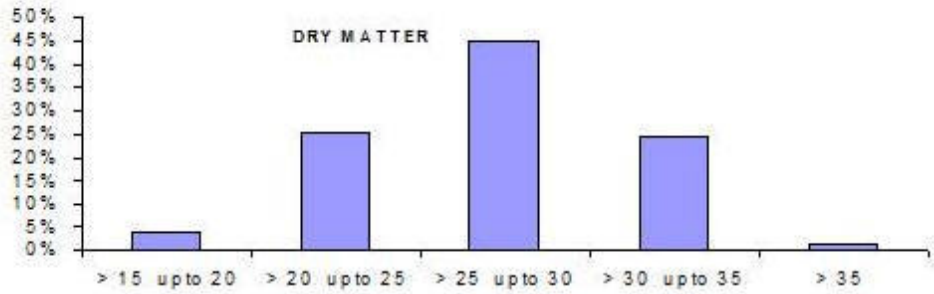


Figure3. Sensory and quantitative descriptors for texture after boiling, sweetness and dry matter content.


TEXTURE AFTER BOILING
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Dry
Intermediate
Moist
Very moist


SWEETNESS
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
Not at all sweet
Slightly sweet
Moderately sweet
Sweet


DRY MATTER
50%
45%
40%
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