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Canopy architecture and root yield of seedlings developed from controlled pollinated sweetpotato varieties in Umudike Southeastern Nigeria

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Sweetpotato botanical seeds obtained from controlled hybridization was raised in the screen house and was later transferred to the Eastern experimental field of National Root Crops Research Institute Umudike, Umuahia- Abia State, Nigeria with the objectives to investigate the seedling canopy architecture and to determine the root yield potential of the seedlings for selection for further evaluation. Data were collected on vine length, vine diameter, number of primary and secondary branches, and number of leaves, 60 days after field transplanting. The study indicated that variability exists among the seedlings in the various families as regards the number of roots, weight of roots and high percentage of dry matter content which should be selected for further evaluation. However, out of 27 families, 13 families representing 48.1% are high yielding genotypes (18-30 t/ha) and 6 families which represented 22.2% as moderately yielding genotypes (11-17 t/ha) were selected for further evaluation. The result also indicated that the seedlings from the two families: TIS8164 X TIS87/0087 had the highest number of average vine length of 194.7 cm, the highest average number of leaves of 179.7 and average number of branches of 19.3 followed by the seedlings in the family of Local x MUSG11002-26 with average vine length of 184.7 cm; average number of leaves of 159.7 while the average number of branches was 27.3. The result indicated that variation in canopy architecture could be utilized in the varied farming systems in terms of inter cropping. The erect canopy growing ones should be for inter cropping with other crops while the spreading canopy genotypes should be for sole cropping where they should be used for weeds suppression and erosion control in erosion prone areas. The high number of roots per stand is an indication of high yielding genotypes which could be selected for high root yield.

Key words: Controlled pollination, sweetpotato seedlings, canopy architecture, root yield, family.

INTRODUCTION

Sweetpotato (Ipomoea batatas (L.) Lam), is consumed in more than one hundred countries in the World. It is a member of convolvulaceae family, although a perennial crop but usually grown as an annual. It is a starchy staple food crop in the tropical, sub-tropical and frost-free temperate climatic zones of the world (Onwueme and Sinha, 1991). It ranks fifth as the most important food crop after rice, wheat, maize and cassava in developing countries (Som, 2007). The crop is known as a highly tolerant tuberous root crop to high temperatures, poor
soils, floods and exhibits some resistance to pests and diseases. Sweetpotato plays a major part in the farming systems of the people. It is usually planted sole or intercropped with other staples such as maize, cassava, yam or okra in West African countries where it is effective in suppressing weed growth in such fields (Eneji et al., 1995). The potential of sweet potato to guarantee food security is under-estimated as its use is often limited to a substitute food in African countries. Sweetpotato is valued for its roots which are boiled, fried, baked or roasted for humans or boiled and fed to livestock as a source of energy. The roots can also be processed into flour for bread making, starch for noodles as well as used as raw material for industrial starch and alcohol (Ukom et al., 2009). The flour is utilized also in sweetening local beverages like Kunu-zaki, burukutu, and for fortifying baby foods and fufu/pounded yam in Nigeria (Tewe et al., 2003). The leaves are used as vegetables in yam and cocoyam porridge and are rich in proteins, vitamins and various minerals. Sweetpotato roots are rich in vitamins A, B, and C; and minerals such as K, Na, Cl, P and Ca (Onwueme & Sinha, 1991). Sweetpotatoes can be put into many uses and value additions to various food forms. However, there is need to develop varieties that are high yielding, resistant to various pests and diseases attacking sweetpotato in the field, income generation and can fit into the farming systems of the people. Existing varieties are degenerating as a result of pests and diseases problem. Climatic change is also affecting the performance of existing varieties. The natural way of developing new varieties is by hybridization. Hybridization is one of the ways to generate variability in sweetpotatoes, and according to Nwankwo et al. (2011) it is one of the revolutionary tools which tend to create genetic novelty. Hybridization generates raw materials for selection. It is one of the methods used to improve on the existing local varieties and other cultivars in the germplasm. At the intra-specific level, hybridization is referred to as inter-varietal crossing (Sharma, 1980). According to Sharma (1980), hybridization is generally resorted to when introduction and/or selection fails to attain a tangible crop improvement. In developing a new variety one of the parents which should be the female parent is preferably the local best variety. This will confer the requisite adaptive capacity on the new variety to immediately acquire adaptation to the local environment. The second parent which is supposed to be the desired male parent may be imported or obtained from the germplasm. The required attribute(s) of the male to be transferred should be possessed in their intense form. After hybridization, that attribute(s) can be concentrated by backcrossing to the desired male variety. The offspring so obtained would be adaptive to the local environment having combined the qualities of both parents.

The seeds so obtained by controlled (hand) crosses offer greater variability within the sweetpotato families can be expressed in contrasting environments (Oleghe, 1998). According to Luka (2012), breeding is a process for adapting a crop to human needs. An important component of breeding is the selection of new varieties. The selection of better varieties requires a good understanding of what is needed by farmers and societies, and it requires good biological and statistical knowledge. A variety is always characterized by several traits. A better variety must have good performance over all traits and at least in one important trait it must be clearly superior to all other varieties, which are so far available in a region. Wolfgang et al. (2008) reported that “In early breeding stages, plants are raised from true seeds. Selection of single true seedling plants may not be advisable, because measurements on single plants have an extremely high error and plants grown from seeds are very different from those grown from cuttings with respect to storage root formation. For this reason, evaluations of true seed plants are limited to a few highly heritable traits such as susceptibility to pathogens or storage root flesh color. Genotypes selected among true seed plants enter observation trials (OTS)”. This work was carried out to investigate the variations in the seedling canopy architecture for the varied farming systems and to determine the root yield potential of the seedlings for selection for further evaluation.

MATERIALS AND METHODS

The nursery establishment was carried out in the screen house and in the field at the Eastern experimental field of National Root Crops Research Institute Umudike, Umuahia- Abia State, Nigeria.

Screen house

The seeds were soaked in solution of water containing Omo detergent. This allowed all bad and light floating seeds to be discarded by pouring off part of the solution. The seeds that settled at the bottom of the plastic container were collected and sown immediately into the filled black polybags measuring 4 by 6cm. The polybags were laid out in a completely randomized design in three replications. Thirty days after sowing, the seedlings were transplanted to the field for field evaluation.

Field layout

The seedlings were transplanted to the field 30 days after sowing in the screen house. The area for the experiment
was slashed, ploughed, harrowed and ridged. The ridges were spaced 1.0m apart. Planting was on the crest of the ridges at 1.0 x 0.3m apart in a plot size of 9.0m². The seedlings in the 27 families were laid out in a Randomized Complete Block Design (RCBD) with 30 seedlings per family per plot, 810 seedlings per block and replicated 3 times resulting to 2,430 seedlings that were evaluated in the field. Fertilizer application was N P K 15: 15:15, applied 6 weeks after being transplanted and 9cm round the base of each seedling in the field. The whole plots were kept weed-free throughout the growth of the sweetpotato seedlings with hand-hoe. Hand rouging was done toward harvesting which took place at 16 weeks after transplanting.

### Data collection

Data were collected from the sweetpotato seedlings 60 days after field establishment on 20 competitive sweetpotato seedlings from each plot. The following data were collected: number of Seedlings establishment, Vine length (this was determine from the soil level at the plant base to the tip of the vine), Scoring was as follows 3= erect (<75 cm), 5= semi-erect (75 - 150cm), 7= spreading (151-250cm), and 9 = extremely spreading (>250 cm). Vine diameter (this was measured at the middle of the vine with vernier caliper) 1= very thin (<4 mm), 3= thin (4-6 mm), 5 = intermediate (7-9 mm), 7= thick (10 – 12 mm), 9 = very thick (>12 mm). Number of primary and secondary branches, Number of leaves (this was determined by counting the number of leaves on the plants) and number of seedlings in the families that bloomed. All samples were taken from 20 most competitive plants from each plot and averaged on per plant bases. Estimated percentage of ground cover recorded 90 days after planting as: 3= low (<50%), 5 = medium (50 - 74%), 7= high (75-90%), 9= (>90%) (IBPGR, 1999).

At harvest the following data were collected on root yield: (a) Number of storage roots and weight of storage roots from 20 most competitive plants from each plot and averaged on per plant bases. Dry matter content: One fresh storage root from each of the 20 most competitive sweetpotato seedlings from each plot representing each family were collected, sliced and mixed. Two hundred grammes were collected and dried in the oven until constant weight was obtained and then used to calculate the estimated dry matter content of the seedlings from each family.

### RESULT

#### Field establishment

The sweetpotato seedlings in all the families had high significant ($P<0.01$) variability in seedling field establishment. The highest field establishment (97%) was obtained from the family of Local x 105141-8, while the least 64% was from the family of MUSG0621-07 x 107038-3. However, the field establishment from all the families was very high with overall mean percentage of 82.5% (Table 1).

### Seedling canopy indices

#### Vine length

There was high significant ($P<0.01$) variability in vine length among the sweetpotato seedlings. The result revealed that the seedlings in the family of TIS164 X TIS87/0087 had the longest vine length of 194.7 cm far less than the general mean of 129.3 cm. However, the least vine length was obtained from the seedlings in the family of Local x 105268 -10 with vine length of 11.6 cm which was far less than the general mean of 129.3 cm. The coefficient of variation of 55.6% showed wide range of variation of vine length among the sweetpotato seedlings which indicated wide genetic variability in the genes expressing the vine length.

#### Plant types

The result in Table 1 shows that there were no sweetpotato seedling genotypes with extremely spreading habit (>250 cm) in all the families evaluated. However, the families of Local x MUSG11002-26 and TIS8164 x TIS87/0087 had seedlings with spreading habit (Score 7) that is vine length of 151-250 cm. The family with this type of canopy structure constituted 7.4% of all the families evaluated. The seedlings in the families of Local x 10526807 and Local x 105268-10 were erect (<75 cm) in their growth habit (Score rate 3). This constituted 7.4% of the families evaluated while 85.2% of the seedlings in the various families were semi-erect (75 – 150 cm) in growth habit (Score 5).

#### Number of leaves

High significant ($P<0.01$) variability existed among the number of leaves of the sweetpotato seedlings in the families. The seedlings in the family Local x 107007 - 12 gave the highest number of leaves with mean leaf of 184.0 per plant even higher than the general mean of which was 160.1 leaves. However, the least mean number of leaves was from the sweetpotato seedlings in the family of Local x MUSG11015-34 which was 142.7 leaves per plant which was less than the general mean of 160.1 number of leaves per seedling plant. The coefficient of variation of 47.8% indicated that very wide
genetic variation in the leaves existed among the sweetpotato seedlings in the families.

**Ground cover**

The canopy cover of the soil surface of the seedlings in the family of Local x MUSG11002-26 with score rate of 9 indicated that the ground cover was 'very high' up to 90% ground coverage. This constituted 3.7% of all the families evaluated. This was followed by the seedlings in the family of TIS8164 x TIS87/0087 with score rate of 7 which indicated that the canopy cover was 'high' up to 75 - 90% soil surface coverage. Two families Local x 10526807 and Local x 105268-10 which constituted 7.4% of the families evaluated had ground coverage score rate of 3 which indicated that the canopy cover was low that is below 50% (<50%) of the soil surface.

**Vine diameter**

The ANOVA results indicated very high significant (P<0.01) variation in the vine diameter of the sweetpotato seedlings in the families. The vine diameter ranged from 0.2mm from the seedlings in the families of Local x MUSG11005-14, Local x 105141-8 and MUSG0621-07 x 105793-4 to as high as 5.0mm (Table 1). The general mean was 3.9 mm. However, the coefficient of variation of 42.6% indicated a very wide genetic variation among the seedlings within the families evaluated. Over eighteen percent (18.5%) of the families had seedlings with vine diameter less than 4.0mm which indicated that vine thickness were very thin (Score 1), while 81.5% of the seedlings in the various families had vine diameter with score 3 which is thin (4-6 mm).

**Number of branches**

High significant (P<0.01) variability existed in the branching of the sweetpotato seedlings in all the families evaluated. The least number of branches per seedling was 2.8 (MUSG0621-07 x 1057038-3) while the highest number of branches which was 27.3 was obtained from seedlings in the family of Local x MUSG11002-26. The general mean was 7.6 branches per family. The coefficient of variation which was 8.4% indicated that vine

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**Table 1.** Field vigour indices of the sweetpotato seedlings 60 days after planting.

<table>
<thead>
<tr>
<th>Crosses</th>
<th>Establishment %</th>
<th>Vine length (cm)</th>
<th>No of leaves</th>
<th>Vine diameter (mm)</th>
<th>No of branches</th>
<th>Ground cover rating (%)</th>
<th>Diameter rating</th>
<th>Plant habit</th>
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<tr>
<td>Local x 10526807</td>
<td>86.4</td>
<td>13.3</td>
<td>172.3</td>
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<td>4.0</td>
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<td>159.7</td>
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<td>MUSG0621-07 x 105268-5</td>
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<td>152.3</td>
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<td>19.3</td>
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<td>6.2</td>
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<td>168.5</td>
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</table>

**Key:** Ground cover: 3= low=<50%, 5= medium= 50-74%, 7= high=75-90%, 9=very high=>90%. Plant type: 3= erect=<75cm, 5= semi-erect=75-150cm, 7=spreading=250cm. Vine diameter: 1=very thin=<4mm, 3=thin=4-6mm, 5=intermediate=7-9mm, 7=thick 10-12 mm, 9=very thick=>12 mm.
branching in the seedlings in the families vary little. This indicated that there was low genetic variation among the seedlings in the families (Table 1).

Number of storage roots

The results of the number and weight of storage roots of the sweetpotato seedlings are presented in Table 2. The result reveals high significant (P<0.01) variation in the number and weight of storage roots of sweetpotato seedlings per plot. The highest mean number of storage roots was 68 per plot from the family of Local x 105141-8, while the least number of storage roots was 9.0 per plot obtained from the family of 440293 x TIS87/0087. Also, there was high significant (P<0.01) variation in the mean number of storage roots per stand of sweetpotato seedling in each family. The least mean number of storage roots per sweetpotato seedling was 9.0 (MUSG0619-6 x musg11018-3A) equivalent to 0.45 roots per plant per 1000 per hectare, while the highest mean number of storage roots per sweetpotato seedling was 3.4 (Local x 105141-8) equivalent to 3.4 roots per plant per 1000 per hectare.

Weight of Storage roots

High significant (P<0.01) variability exist in the mean storage root weight per plot and per stand of the sweetpotato seedlings evaluated. The mean storage root weight per plot ranged from 1.1kg per plot in the family of MUSG0621-07 x 105193-4 to as high as 44.42kg (MUSG0621-07 x 107038-3) per plot. However, the mean storage root weight per sweetpotato seedling stand ranged from 0.06kg equivalent to 0.99t/ha obtained from the family of MUSG0621-07 x 10593-4 to as high as 2.22kg per plant equivalent to 39.98t/ha obtained from the family of MUSG0621-07 x 107038-3.

Dry matter content

The percentage dry matter content of the tuberous root yield of the sweetpotato seedlings in the various families ranged from 21.0% (MUSG0616 x MUS11002-26) to 38.0% (Local x 105199-29).

DISCUSSION

The high significant (P<0.01) genetic variability that existed among sweetpotato families and within the
sweetpotato seedlings suggested that there is ample opportunity for selection of seedlings for further evaluation and for crop improvement programme. High field establishment showed high adaptability of the seedlings to the field conditions. It has been noted by Gasura et al. (2008) that parents already adaptable to the local environment should be constituted in the hybridization block and used as the female parents since sweetpotatoes have high maternal inheritance (Wilson et al., 1989). This indicated that most of the seedlings in the families will do well under harsh field conditions (Table 1). The field canopy represented in form of vine length, number of leaves, vine diameter, number of primary and secondary branches among the families were significantly high (P<0.01), indicating a very high variation in the canopy characters evaluated among the sweetpotato families. The wide coefficient of variation among the traits evaluated except for number of branches (CV 8.4%) indicated high degree of genetic variability among the traits which could lead for further selection of traits for genetic improvement in breeding objectives. According to Francis and Kannenberg (1978), low coefficient of variation and high mean is used to select cultivars in cassava with stability in character since adaphic factors within season and agro-ecological zones could significantly influenced their performance. The number of leaves is an indication of the vigour of the crop. It could however, not be an indication of high yielding genotypes as a result of environmental influence (Wilson 1982). Although the leaves assist in photosynthesis of the crop which leads to high yield, high number of leaves is also an indication of high vigour of the crop. High number of leaves leads to complete coverage of the soil surface thereby preventing soil erosion (Onwueme and Sinha, 1991). The seedlings in the family Local x 107007 - 12 gave the highest number of leaves with mean leaf of 184.0 per plant even higher than the general mean of which was 160.1 leaves. Vine length which invariably is a function of plant vigour also formed the sweetpotato plants’ canopy architecture/plant morpho - types of the sweetpotato plant. Two families Local x MUSG11002-26 and TIS8164 x TIS870087 were identified to have seedlings with spreading canopy of 184.7 and 194.7cm respectively than the rest of seedlings from other families. Vine length could be of various lengths and this gives the sweetpotato plant its characteristic canopy morpho-types such as erect, semi-erect, spreading and extremely spreading. Main Vine length of less than 75 cm is regarded as having erect canopy while main vine length of 250cm is regarded as having extremely spreading canopy. Vine length of 75 to 150cm is intermediate/semi-erect canopy (IBPGR, 1999). According to Onwueme and Sinha (1991), lengthy spreading vigorous vine genotypes with many branched vines have canopy that suppress weeds and other plants in the ecology and with many branches they produce more planting material. These ones could be used for sole sweetpotato production. Majority of lengthy spreading vine genotypes produce enlarge roots at the nodes while creeping (Huaman and Asmat 1999). Small scale or subsistence farmers that harvest piecemeal roots prefer vines that produce roots at the nodes and at planting points while commercial farmers prefer vines that produce roots at planting points for easy mechanization during harvest. Climbing vines diametre that are thin (<0.2cm) produce poor planting material. Most seedlings possess semi-erect canopy/vines, a growth habit which may be appreciated by some farmers while majority have spreading canopy/vine habit with their branches. Farmers need compact or erect vines canopy which are best for intercropping. This trait may be appreciated by farmers which are needed for combating weeds and provides enough vines for planting materials as well as for use as cover crop in erosion prone areas. However, spreading genotypes with canopy that have many branches may not be appreciated by some farmers in any intercrop farming as the spreading types may suppress the performance of some low growing crops in the mixture with their canopy (Table 1). Gomez and Gomez (1984) reported that the size difference in plant canopy character between the varieties in a mixed cropping plays an important role in determining the extent of varietal competition effects. They further observed in a study on varietal competition effects in rice that tall and high tillering canopy varieties compete better than the short and low tillering ones. Thus, short and low tillering variety would be at a disadvantage when planted adjacent to a plot with a tall and high tillering canopy variety. So the smaller the varietal difference in sweetpotato vine length the greater is the expected disadvantage if planted in a crop mixture. The vine diameter measures the thickness of the vine. Those genotypes producing vine thickness of less than 4.0mm produce poor vine diameter that may not survive long drought period. Vine thickness of between 4.0 to 6.0 mm is regarded to be acceptable (Gasura et al., 2008) since they store adequate water and dry matter and could withstand long period of drought. Sweetpotato seedlings within that diameter bracket have good canopy structure that stands erect and could subdue weeds and give appreciable yield. Gasura et al. (2008) further added that they are good planting material and most preferred by farmers because of its keeping quality and high survivability during dry periods. The sweetpotato seedlings in the families have good quality vine materials (Table 1). Vine length and vine thickness are highly heritable traits. These two traits are also maternally inherited (Wilson et al., 1989). Improvement of these two traits through breeding is easy to meet farmers’ preferences. Vines with thick stem produce strong
cuttings which establish well at planting, whereas thin stem vines produce weak canopy which may die immediately after harvest. Weevil damage thick stem vines more severely than thin stem vines thereby collapsing the plants canopy structure. However, medium stem vines establish well in the field and less susceptible to weevil damage. Stem thickness maternally inherited crosses are best made with female parents with thick vines (Wilson et al., 1989). The Breeders require breeding population that exhibit strong vine survivals to enable them use this trait adequately in population improvement.

Branches in sweetpotato contribute to the vigour and maintain the plants canopy architecture. The branches however, hold the leaves and keep them in place for photosynthesis using the sun energy. Farmers may prefer few branches in the intercropping, whereas the spreading branches are needed in combating weeds and in addition provide more planting material. The variation in the number of branches per plant and length of the vines indicated the sweetpotato canopy morpho-types and are the bases for farmers' choice in incorporating the sweetpotato genotypes in their farming systems. Canopy structure characteristics of the sweetpotato seedlings could be used in genotype discrimination such as such as erect, semi-erect, spreading and extremely spreading (IBPGR, 1999). Canopy structure characteristics of the sweetpotato seedlings could be used for selection of plants that has favourable traits whose genes could be used for genetic improvement. Canopy structure characteristics of the sweetpotato seedlings are of importance to the farmer. The farmer is interested in including them in his crop mixture / farming system for root yield, for food and in leaf production as vegetable or as fodder for the animals such as sheep, goats, cattle and pigs. Canopy structure characteristics of sweetpotato genotypes are of great asset to the plant breeder for the genetic improvement of the sweetpotato crop.

The highly significant (P<0.01) variation in the percentage of dry matter, number and weight of storage roots per plot and per plant indicated that variability existed among the seedlings in the families of the sweetpotato. These variation suggested basis for selection. Seedlings in the families with high number of roots, weight of roots and high percentage of dry matter content should be selected for further evaluation. Number of roots is also a function of yield (Nwankwo, 2012). According to Wolfgang et al. (2008) lowly heritable traits (traits which are strongly affected by the environment) such as yield, yield stability and adaptability, are evaluated in later stages, when more planting material is available, on the basis of plots, plot replications and information across several environments. Such a multistage selection program can take up to five years or more.

However, according to NARO (National Agricultural Research Organization) sweetpotato yield classification criteria, genotypes were grouped into three root tuber yield classes: high yielding (18-30t/ha), moderate yielding (11-17t/ha) and low yielding genotypes (<11t/ha) (Wilson et al., 1989). The seedlings in the family MUSG 0608-61 were in the top group (high yielding). Based on this result, the families could be selected and distinguished into genotypes. The result in Table 2 indicated that out of 27 families evaluated, 13 families representing 48.1% fall into the class of high yielding genotypes (that is 11-17), while 8 families representing 29.6% were classified as low yielding genotypes (<11t/ha).

Conclusion

The study suggested that variability exist in the seedlings in the various families as regards the number of roots, weight of roots and high percentage of dry matter content. Superior traits in the seedlings of the various sweetpotato families should be selected for further evaluation. However, 13 families representing 48.1% were selected as high yielding genotypes (ie. 18 -30t/ha) and 6 families representing 22.2% as moderately yielding genotypes (that is, 11-17) were selected for further evaluation. The study also indicated that variability in canopy architecture and number of roots per stand could be generated through controlled crosses in sweetpotato improvement strategy and the considerable variation in the sweetpotato families evaluated suggested that there is ample opportunity for selection of seedlings for further evaluation. The variation in canopy architecture could be utilized in the varied farming systems in terms of intercropping. The erect canopy growing ones should be for inter cropping with other crops while the spreading canopy genotypes should be used for sole cropping where they should be used for weeds suppression and erosion control in erosion prone areas. The high number of roots per stand is an indication of high yielding genotypes which could be selected for high root yield.

REFERENCES


