Evaluation of Flower Yield, Seed Production and Effect of Time on the Genetic Recombination of Sweetpotato Parents in the Rainforest Agro-Eco-Zone of Umudike Southeastern Nigeria

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Abstract

A hybridization experiment was conducted at the National Root Crops Research Institute, Umudike, Nigeria with the aim to select : parents that are high flowering, parents with high compatibility, parents with high number of good seeds and to know the best time for genetic recombination. The treatment consisted of 14 parents. Seven of the parents were planted each in a plot at a planting space of 30cm by 100cm within plants and inter row spacing. There were spacing of 1.0m between plots, giving a plant population of 30 plants per plot and laid out in a randomized complete block design replicated three times. The other seven parents were maintained in different plots for pollen collection. Data were collected from 3.0pm to 5.0pm for emerged flowers which were counted and recorded, number of flowers covered, number of flowers pollinated, number of capsules formed, number of flowers aborted, number of seeds obtained from crosses, number of good seeds, number of unfilled seeds and percentage of good seeds. Data collected were statistically analyzed using ANOVA while means separation was done using LSD at 5% probability. Results obtained showed that the variety Tio-joe gave the highest flower production of 2334. The relatively high number of capsules of 347obtained from the cross between UMUSPO/3 and NRSP/2 indicated high compatibility between the two parents suggesting that the two parents could be used for further recombination. The seedling progenies resulting from the good seeds produces a remixing or reshuffling of genetic material and phenotype variability on which selection could be based. Time of pollen fertility and stigma receptivity in sweetpotato plants was highest between the hours of 7.00 to 9.00am. Families with heavier seeds weights have more energy reserves for germination and seedling growth and produce larger, more established seedlings after germination.

Keywords - *Parents, recombination, flowers, time and seeds.*

I. INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L.) Lam) is a security food for mans, feed for livestock, raw material for industries and income for farmers and traders especially in the developing world. Sweetpotatoes can be put into many uses and value additions to various food forms for income generation. Sweetpotato does not require very fertile soil like yam and Cocoyam and could be produced with minimal input requirements. Sweetpotato crop is regarded as the most affordable sources of carbohydrates, vitamin A, vitamin C, fiber, protein and minerals [13] [18] and [19]. Sweetpotato is a powerhouse for Vitamin A [12] and as [3] stated, the crop could be used to combat vitamin A deficiency (VAD) and related diseases which account for 1.8% of deaths globally and especially in the developing world. In the face of this food related problem, farmers in Nigeria continued to grow low yielding, white- or cream- fleshed less nutritious sweetpotato landraces ([17] for food. However, as [6] reported, the average storage root yield in farmers field is less than 3.0 metric tons/ha as against globally average storage root yield of 13.3 metric tons/ha.

Reference [10] observed that sweetpotato improvement has generally been carried out by clonal selection. This method, has not been effective for the improvement of complex traits of sweetpotato crop. The development of new sweetpotato genotypes should be facilitated through genetic recombination. This method is used in sweetpotato improvement which enable breeders to overcome some of the inherent genetic barriers to sweetpotato breeding. Genetic improvement of sweetpotato for storage root yield, root dry matter content, starch content, β-carotene content and resistant to sweetpotato diseases has been difficult in flowering varieties and this is partly attributed to the complex genome of sweetpotato, which makes breeding very difficult [5] . According to [4] this is because sweetpotato is a highly heterozygous auto hexaploid (2n = 6× = 90) crop with high self-incompatibility [9]. Reference [9] also reported that high levels of cross-incompatibility occur in sweetpotato and this limits the rate of genetic recombination that can be exploited for sweetpotato improvement.

Reference [4] observed that there are other things also militating against attainment to genetic gains in sweetpotato as yield, dry matter, starch and β-carotene content plus other important agronomic traits that are quantitatively inherited. These quantitative traits are controlled by polygenes with high levels of genotype by environment interactions that further complicated variety development of the sweetpotato crop. Reference [1] and [8] reported another difficulty in genotype selection which is storage root dry matter and β-carotene content, and that these are negatively correlated, making it difficult to select for high levels of both traits in the same locus.

However, there is need to develop varieties that are high yielding, resistant to various pests and diseases attacking sweetpotato in the field. 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 for the perpetuation of sweetpotato varieties is by hybridization. Hybridization is one of the ways to generate variability in sweetpotatoes and according to [15], it is one of the re-evolutionary 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 both the intra-specific and inter-varietal crosses is referred to as , hybridization [17]. It is one method of genetic improvement in clonaly propagated crops According to [17], 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 which can be expressed in contrasting environments [16]. According to [14], 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 at large, and it requires good biological and statistical knowledge. A variety is always characterized by several traits which are unique to that variety. Varieties of a species have distinguishing characteristics such as leaf shape, vine length, root shape, flower color and may arise naturally or through deliberate hybridization. As [3] noted, 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. The parents in the hybridization blocks were crossed with the following specific objectives: to select parents that are high flowering, to select parents with high compatibility, to select parents with high number of good seeds and to know the best time for the genetic recombination of sweetpotato parents for progeny production and evaluation.

II. MATERIALS AND METHODS

The experiment was conducted in the rainforest agro-eco-zone of Southeastern Nigeria under rain fed condition. The sweetpotato breeding ground of National Root Crops Research Institute, Umudike, Nigeria was used. The area was slashed, ploughed, harrowed and ridged before being marked into plots and the plots grouped into blocks. The plot size was 3m x3m or 9m^2 and demarcated 1.0m from another plot. Each block had a distance of 1.0m. The treatment which consisted of 14 parents. The bi-parental crossing was laid out in a randomized complete block design replicated three times. Seven of the parents were planted each in a plot at a planting space of 30cm by 100cm within plants and inter row spacing. There were spacing of 1.0m between plots, giving a plant population of 30 plants per plot and seven parents per block and replicated three times. The other seven parents were maintained in different plots for pollen collection.

Before planting, the area was sprayed with primextra a pre-emergence herbicide to delay weed emergence which may seriously interfere with the early growth of the sweetpotato crop. Further weeding was complemented with manual hoe weeding throughout the duration of the experiment. The crossing block was established at the first week of August to make sure that blossoming took place toward dry period. Again to further enhance flowering and ease of pollination, the sweetpotato plants in all the plots were staked using pyramidal type of staking. No fertilizer or organic manure was applied so that the sweetpotato plants do not grow luxuriantly which may delay flowering. The following data were collected from 3.0pm to 5.0pm: all emerged flowers were counted and recorded, total number of flowers covered, total number of flowers pollinated, total number of capsules formed, total number of flowers aborted, total number of seeds obtained from crosses, number of good seeds, number of unfilled seeds, percentage of good seeds, Data collected were statistically analyzed using ANOVA while means separation was done using LSD at 5% probability. The soil and climatic data of the experimental plots were also taken.

III. RESULTS AND DISCUSSION

Environmental Factors such as the climatic data on rainfall, sunshine, relative humidity and air temperature during the cropping seasons indicated that the total rainfall for 2017 was 2060.80mm distributed over 127 days. Rainfall decreased in 2018. The total rainfall in 2018 was 1916.10mm distributed over 137 days. Monthly average maximum air temperature and relative humidity in 2018 were 32^{0}C and 80.6% respectively while the monthly average minimum air temperature and relative humidity were 31.8^{0}C and 81.67% respectively. In 2017 there was more sunshine (59.70 hours) than in 2018 (56.20 hours). This indicated that climate variation for the two years might had strong influence on flower production of the sweetptato parents evaluated. There were longer hours of sunshine hours compared with other months in both years, however, there was no rainfall throughout the days of the month of December in 2017 and in 2018 the month of December received minimal rainfall of 6.4mm. This might strongly affected flower production of the sweetpotato parents and the general sweetpotato crop performance.

A. Flower production: The result on the total number of flowers and number of flowers produced by each variety per month are presented in Table 1.

Table 1: Total number of flowers and Number of flowers produced by each variety per month

Parents	1st month Sept.	2nd month Oct.	3rd month Nov.	4th month Dec.	5th month Jan.	Total number of flowers produced
Solo 1	28	205	430	910	687	2260
Tio-joe	46	213	422	1048	605	2334
Umuspo/3	58	308	570	717	611	2204
NRSP/4	32	294	462	712	589	2089
NRSP/45	21	241	301	775	481	1819
TIS87/0087	44	296	283	603	401	1627
NRSP/1	69	332	338	926	522	2187
Total	298	1889	2746	5691	3896	14520
Mean	42.6	269.9	392.3	813.0	556.6	2074.3
Range	28-69	205-332	283-510	603-1048	401-687	1627-2334
Sig.level	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	=
LSD(0.05)	7.0	17.4	21.4	30.8	25.5	=

Statistically, high significant (P<0.01) variance was observed for the number of flower buds produced by each of the sweetpotato parents selected for the hybridization trial. Total number of sweetpotato buds produced by the parents ranged from 1627 by the parent TIS87/0087 to as high as 2334 produced by Tio-jeo giving a total of 14520 flowers produced by all the parents with mean of 2074.3. This showed that if all the flowers produced were converted into capsules and well filled seeds, there would be huge number of seed production. The result showed the mean number of flowers collected per month. Reference [15] reported that crop improvement depends on the ability of the crop to flower and produce seeds and the understanding of the flowering pattern. Few sweetpotato accessions that flowered sparsely could provide a challenge in accessing their genes through conventional breeding. Reference [7] noted that flowering ability is an important aspect of sweetpotato breeding since it determines the potential of improving certain cultivars through breeding.

The mean number of flowers collected six weeks after planting at the first month ranged from 42.6 per parent giving a total of 298 flowers at the first month, the flowering increased linearly up to a total of 5691 flower buds with mean of 813.0 flower buds per plant. Flower production by all the parents decreased to 3896 flower buds with mean of 556.6 flower buds per plant. The decrease may be as a result drastic reduction in soil moisture content. The soil water stress affected the health of the flowering parents resulting into gradual senescence and death of the sweetpotato plant and which invariably affected flower production.

B. Number of flower and capsules produced: The total number of flowers produced, number covered, number aborted and number of capsules formed are presented in Table 2.

Table 2: total number of flowers produced, number covered, number aborted and number of capsules formed

Parents	Total number of flowers produced	Number of flowers covered	Number of flowers pollinated	Number of flowers aborted	Total number of capsules formed	Total number of seeds
Solo 1xTio-joe	2260	482	415	67	310	615
Tio-joe x NRSP/1	2334	422	312	110	300	909
Umuspo/3x NRSP/2	2204	417	382	35	347	695
NRSP/4 x Tio-joe	2089	329	220	109	210	395
NRSP/45 x UMUSPO/3	1819	318	200	118	196	498
TIS87/0087 x Tio-joe	1627	510	445	65	316	718
NRSP/1 x Tio-joe	2187	386	312	74	248	529
Total	14520	2864	2291	573	1927	4359
Mean	2074.2	409.1	377.3	81.9	275.3	622.7
Range	1627-2334	318-510	200-445	35-118	196-347	395-909
Sig.level	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01
LSD(0.05)	49.2	21.8	19.5	9.8	17.9	=

The result presented in Table 2 is the total number of flowers produced, number of flowers covered, number of flowers pollinated and total number of capsules formed after crossing the sweetpotato parents. The result obtained indicated that out of the 14520 flowers produced, a total of 2864 flowers were covered to prevent natural pollination by insects, while 2291 flowers were hand pollinated. However, 573 flowers aborted after hand pollination while 1927 flowers developed into capsules. The total number of botanical seeds that resulted from the crosses was 4359 seeds. This number of seeds would be used for seedling evaluation to select genotypes for enhanced micronutrient content and dry matter content.

It was observed by [2] that crosses between parents with maximum genetic divergence are generally the most responsive for genetic improvement. However, [14] and [11] acknowledged that genetic diversity resulting from the crosses made is pre-requisite for any crop improvement programme as it helps in the development of superior recombinants and the quantitative estimation of the genetic diversity assist the plant breeder for rapid progress of the breeding process. The selection of agronomically suitable diverse parents for hybridization is important for getting desired recombinants in segregating generations.

C. ***Number of capsules collected per unit time of pollination***: The mean number of capsules collected per unit time of pollination for the selected sweepotato parents are presented in Table 3.

Table 3: Mean number of capsules collected per time of pollination for the selected sweepotato parents

Parents	Mean number of capsules collected from 7.am to 8.am	Mean number of capsules collected from 8.am to 9.am	Mean number of capsules collected from 9.am to 10.am	Mean number of capsules collected from 10.am to 11.am	Mean number of capsules collected from 11.am to 12.noon	Total number of capsules produced
Solo 1xTio-joe	158	121	22	9	0	310
Tio-joe x NRSP/1	171	112	13	3	1	300
Umuspo/3x NRSP/2	217	96	26	9	5	347
NRSP/4 x Tio-joe	177	19	8	3	8	210
NRSP/45 x UMUSPO/3	99	81	13	1	2	196
TIS87/0087 x Tio-joe	212	76	17	5	2	316
NRSP/1 x Tio-joe	219	18	7	2	2	248
Total	1253	523	106	32	15	1927
Mean	476	74.7	15.1	4.6	2.1	275.3
Range	99-219	19-121	8-26	1-9	0-8	310-248
Sig.level	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01	P<0.01
LSD(0.05)	14.5	9.3	4.2	2.3	1.6	17.9

D. Number of capsules fertilized per unit time:

The result in Table 3 is the mean number of capsules collected per time of pollination for the selected sweepotato parents evaluated. Number of capsules produced per time of pollination differ significantly (P<0.01) and varied from family to family. For instance, mean number of capsules collected from each crossed parent ranged from 99 capsules collected from the cross between NRSP/45 and UMUSPO/3 to as high as 219 for capsules collected from the cross between the parents NRSP/1 and Tio-joe. The total number of capsules collected from crosses made between the hours of 7.00am to 8.00am was 1253 capsules with mean of 476 capsules per plant. However, number of capsules collected from the crosses made between the hours of 8.00am to 9.00am was 523 with mean of 74.7 capsules per plant. The number of capsules however, decreased to 106 capsules from the cross pollination made between the hours of 9.00am to 10.00am with mean of 15.1 capsules per plant. Number of capsules collected from crosses made further decreased to 32 with mean of 4.6 capsules from the hours of 10.00am to 11.00am while the least was the number of capsules collected from cross pollination made between the hours of 11.00am to 12 noon which was 15 capsules with mean of 2.1 capsules per plant. This indicated that stigma receptivity of the sweetpotato flowers decrease as the day progresses. The same could be said of pollen fertility which also deteriorate as the day progresses. This showed that hand pollination should be done as soon as flowers open in the early hours of the morning to pollinate as many flowers as possible before the flower sexual parts become inactive leading to flower abortion if natural pollination by insects did not take place. The time when pollen fertility and stigma receptivity is high in sweetpotato is diagrammatically represented in the figure 1 below.

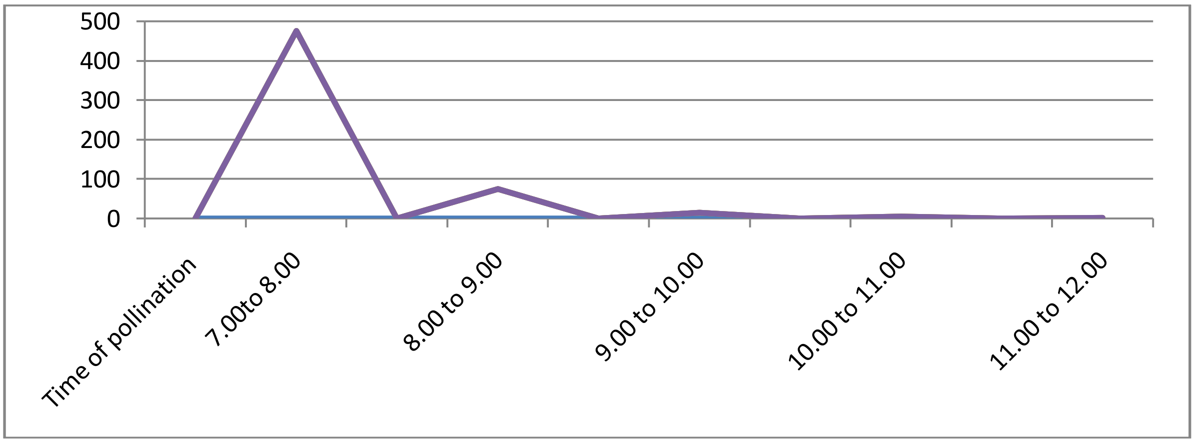

Fig. 1:Time of pollen fertility and stigma receptivity in sweetpotato plants

The time for pollen fertility and stigma receptivity in sweetpotato is high early in the morning between the hours of 7.00am to 8.00am and decreases as the days progressed. This decrease may be attributed mainly due to short duration of the pollen fertility and stigma receptivity which may be caused as a result of increase in temperature due to the intensity of the sun as the day progress.

E. Seed production: The result of the total number of seeds, number of good seeds, number of unfilled seeds, percentage of good seeds and weight of 100 seeds from hand pollinated flowers are presented in Table 4.

Table 4: Total number of seeds, number of good seeds, number of unfilled seeds, percentage of good seeds and weight of 100 seeds from hand pollinated flowers

Parents	Total number of seeds produced	Number of good seeds	Number of unfilled seeds	Percentage good seeds	Total number of seeds	Weight of 100 seeds
Solo 1xTio-joe	615	411	204	67.0	615	550.0
Tio-joe x NRSP/1	909	439	470	48.2	909	500.6
Umuspo/3x NRSP/2	695	317	378	52.0	695	655.0
NRSP/4 x Tio-joe	395	212	183	54.0	395	687.9
NRSP/45 x UMUSPO/3	498	319	129	64.0	498	558.4
TIS87/0087 x Tio-joe	718	425	293	59.0	718	698.0
NRSP/1 x Tio-joe	529	402	127	76.0	529	601.6
Total	4359	2525	1834	-	4359	=
Mean	622.7	360.7	262	60.0	622.7	607.4
Range	395-909	212-439	127-470	48-76	395-909	500-698
Sig.level	P<0.01	P<0.01	P<0.01	-	P<0.01	
LSD(0.05)	27.0	20.5	17.5	-	=	

The results of the total number of seeds produced, number of good seeds, number of unfilled seeds, percentage of good seeds and weight of 100 seeds from each of the parents crossed are presented in Table 4. The result indicated high significant (P<0.01) variability in the number of seeds produced by the sweetpotato parents hand pollinated. Total number of seeds produced by the parents varied from 395 seeds (NRSP/4 x Tio-joe) to 909 seeds produced by the cross between Tio-joe and NRSP/1. A total number of 4359 seeds were produced with grand mean of 622.7 seeds.

The high significant (P<0.01) variation in the number of good seeds produced by the various families pollinated indicated that out of a total of 2525 good seeds produced, the highest number of 439 which represented 48.2% was from the cross between the two parents Tio-joe and NRSP/1, while the least number of good seeds totaling 212 were obtained from the cross between NRSP/4 and Tio-joe which represented 54.0%. Although the parents NRSP/4 x Tio-joe produced high percentage of good seeds (54.0%) compared with the cross between the parents Tio-joe and NRSP/1 which produced 48.2%. This may be attributed to the number of flowers produced and number of flowers that are receptive at time of pollination when compared with the number of capsules formed and number of seeds produced. Time of pollination of sweetpotato is very crucial because pollen and stigma fertility and receptivity is very high early in the morning when the weather is very cool and none windy.

Number of unfilled seeds varied from 127 from the cross between NRSP/1 and Tio-joe to as high as 470 unfilled seeds from the cross between Tio-joe and NRSP/1 giving a total of 1834 unfilled seeds with mean of 262 unfilled seeds. However, the large number of unfilled seeds may be as a result of soil water stress water due to lack of rainfall and none irrigation of the experimental site. Most of the seeds collected during those periods were not filled. Although the condition favoured flower production of the parents to a point when the soil water stress became so severe affecting the parent plants which led to flowering declined (Table 1). Plant breeders however believe that breeding new crops is important for ensuring food security by developing new varieties that are higher yielding, disease resistant, drought tolerant or regionally adapted to different environments and growing conditions. This could be achieved through cross pollination of flowering plants and other means of generating new genotypes. Reference [12] reported that hybrids seedlings showing strong heterosis are usually developed from recombinant parental lines that are diverse in relatedness, ecotype, geographic origin and other traits. The genetic diversity of the seedlings developed from the recombinant seeds can be evaluated with morphological traits, protein, isozymes and DNA markers. Conventionally, the seedlings could be estimated by analysis of variance using morphological traits.

***F. Seed weight*:** Hundred seeds were taken from each family and weighed, The cross betweenTIS87/0087and Tio-Joe had the highest seed weights of 698g followed by the cross between UMUSPO/3 and NRSP/2 which was 687g while the least seed weight was obtained from the cross between Tio-Joe and NRSP/1 with 500.6g. Seed weight is a measure of high percentage of germinability and survivability of the crop into seedlings. Plants that produce smaller seeds can generate many more seeds per flower, while plants with larger seeds invest more resources into those seeds and normally produce fewer seeds. Most insects pollinated sweetpotato flowers produces four seeds per capsule while hand pollinates flowers produces one to two seeds per capsule. So sweetpotato seeds matures within 21 days after pollination. Many annual plants such as sweetpotato produce great quantities of smaller seeds to ensure at least that a few will end in a favorable place for growth. Heavier seeds weights have more energy reserves for germination and seedling growth and produce larger, more established seedlings after germination. Heavy seed weight protect and nourish the embryo or young plant thereby giving the seedling a faster start of germination and growth because of the larger food reserves in the seed and the multicellularity of the enclosed embryo. The larger reserved food give nourishment to the embryo during dormancy period or during time of unfavourable condition. Although, seeds are products of sexual reproduction by plants, seeds produces a remixing or reshuffling of genetic material and phenotype variability on which selection take place [20]. Sweetpotato parents with light seed weight should not be prolonged before planting to avoid losing their viability. When being planted, they should be raised in a medium with high nutrient content to give the seedlings a boost of strong growth since the food reserve for the embryo is not enough to accomplish vigour growth.

IV.CONCLUSION

The variety Tio-joe gave the highest flower production of 2334. The relatively high number of capsules of 347obtained between UMUSPO/3 x NRSP/2 indicated high compatibility between the two parents suggesting that the two parents could be used for further recombination for micro-nutrient enhancement. The seedling progenies resulting from the number of good seeds produces a remixing or reshuffling of genetic material and phenotype variability on which selection take place. Time of pollen fertility and stigma receptivity in sweetpotato plants was highest between the hours of 7.00 to 8.00am. Therefore hand pollination in sweetpotato should not exceed the hour of 9.00 hours, period when stigma fertility and pollen viability is very high. Families with heavier seeds weights have more energy reserves for germination and seedling growth and produce larger, more established seedlings after germination.

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