PRODUCTION OF SWEET POTATO (*IPOMOEA BATATUS* (L.) LAM) POLYCROSS HYBRIDS

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ABSTRACT

A poly-cross nursery was established at the Agriculture Farm of the Papua New Guinea University of Technology to develop the poly-cross hybrids of sweet potato with high yield and superior agronomic characters. Twenty five segregating poly-cross hybrids developed from 20 selected sweet potato parental clones showed high variability in terms of tuber shape, tuber skin colour, tuber flesh colour, yield and yield components. Poly-cross hybrids showed vigorous growth and tuber yield increase ranging from 6.5% to 15.6% with higher tuber biomass ratio compared to parental clones. The hybrids showed significantly higher vine length, tuber number, tuber weight and tuber biomass ratio. However, the average vine weight was significantly higher ($p \leq 0.01$) in case of parental clones compared to the hybrids. About 65% ($r^2 = 0.649^{**}$) of the yield variability in hybrids were accounted for by the yield in parental clones. The hybrids showed significant positive correlations between tuber weight and tuber biomass ratio (0.39), tuber weight and tuber number (0.51**), but a very strong negative correlation (-0.89**) between vine weight and tuber biomass ratio.*

Key words: *Sweet potato, poly-cross hybrids*

INTRODUCTION

Sweet potato is one of the major staple food crops in Papua New Guinea (PNG). Breeding and improvement of sweet potato plant in major growing regions had been based on germplasm introduction, induced mutation, hybridization and selection. Hybridization through natural crossing of genetically variable parental clones in poly-cross nurseries has been the common method practiced in PNG and other tropical regions (Tumana and Kessavan, 1987). Poly-crossing is done to generate better hybrids that are superior in terms of tuber yielding ability as well as resistant and/or tolerant to varying ranges of abiotic and biotic stresses. Hybrids are also selected based on other superior agronomic, physiological and horticultural characters, including tuber: biomass ratio, high tuber dry matter and early maturity. Due to large number of hybrids generated through hybridization by poly-crossing, an efficient method of selection to handle these segregating progenies in their F_1 generation is necessary to select desirable hybrids (i.e. clonal selection) which can be maintained vegetatively. It is noted that due to long exposure of current parental clones to pest and diseases; producing clean poly-cross hybrids from true seeds at early generation is vital (Tumana and Kessavan, 1987). Keeping this in view, an experiment was conducted to produce hybrid seedling progenies with superior agronomic characters.

MATERIALS AND METHODS

Sweet Potato Germplasm Collection

Twenty clones originally from National Agricultural Research Institute (NARI) were selected based on improved tuber yield and other agronomic performances, including leaf scab and sweet potato weevil resistance for inclusion in the poly-cross nursery to produce seedling progenies.

A total of 350 seeds were collected from maternal parents. Due to constraints and difficulties in handling many seedlings, only 60 seedlings were raised and the rest of the seeds were reserved and stored as germplasm collection in the seed form for future sweet potato improvement programs. Seeds were scarified with concentrated sulphuric acid (H_2SO_4) for 20 minutes for softening the seed coat to improve germination (Steinbauer, 1937). The scarified seeds were sown in September 2005 in seed trays containing sterilized organic soil. The seedlings derived from each of the clones at F_1CG_1 were further multiplied to obtain more planting materials for further evaluation at clonal generation two (F_1CG_2).

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Experimental Site

The poly-cross nursery was established at the Agriculture Department Farm of the PNG University of Technology, Lae, during May to August 2004 and April 2005. The farm is situated in the north central coast of PNG mainland at an elevation of 65 m.a.s.l and between latitude 6° 41' South and a longitude of 146° 98' East. The site is classified as lowland per humid climate (McAlpine and Keig, 1983) with an annual rainfall of 4,700 mm and the minimum and maximum temperatures of 23° C and 30° C.

Experimental Design

A randomized complete block design was used with 20 sweet potato parental clones planted randomly in four replicated blocks. The total land area of 465 m² (15m × 31m) was further divided into four blocks, each measuring 31 m × 3 m. Each variety was planted on a raised bed of 3 m × 1 m width × 0.2 m height. In each plot, seven cuttings (30 cm of apical portion) from each of the 20 selected parental clones were planted 50cm apart between rows and within plants. Similarly, 25 selected progenies were also grown alongside the parents in a progeny row selection manner. The selected progenies were given the accession code names as MUIB (MAIA UNITECH IPOMOEA BATATAS) with the accession number.

Data Collection

Data were collected on plant vine and tuber characteristics, including leaf color, shapes, margins, leaf area and tuber textural characteristics for each of the seedling progeny. The above ground parts including vines and leaves were weighed and recorded. Tuberous roots and pencil like roots were washed, counted and weighed. The tubers were dried in an oven for six days and the dry weights taken. Leaf area for the progenies were measured using the Leaf Area meter, while vine and leaf texture were examined morphologically by observing the leaf colors of both mature and young leaves. Tuber skin colors were also examined by observing the outer skin color and inner tuber flesh color by cutting the flesh of each progeny. Vine length for each progeny was measured using a meter ruler, while vine fresh weight was weighed using an electronic balance. Tuber Biomass partition for each clone was determined using the following formula:

$$\text{TUBER BIOMASS RATIO} = \frac{\text{TOTAL TUBER WEIGHT}}{\text{TOTAL TUBER WEIGHT} + \text{TOTAL TOP WEIGHT}}$$

Data Analysis

The data collected on different parameters were analyzed using analysis of variance (ANOVA) with the MINITAB 15 Software Package and Microsoft Excel. Tuber weight of the offsprings were regressed on the corresponding parameter of the parental clones to determine the effect of parental clones on the offspring. Simple correlation coefficients were also calculated between the pairs of values for tuber number, tuber weight, vine length, vine weights and tuber biomass ratio for the offspring and the parents. Standard statistical procedures including pair mean comparison using the Duncan Multiple Range Test (DMRT) was also used to compare differences between treatment means as applicable.

RESULTS

The details of tuberous roots and other horticultural characteristics of the progenies selected from the parent in the progeny row selection are presented in Table 1. Progenies differ greatly in tuber shapes ranging from round to long/round and long. The progenies fall into three more or less distinct groups: MUIB 007, 009, 015, 016, 026, 035, 037 and 049 with round tuber; MUIB 001, 005, 011, 013, 014, 028, 031, 033, 034, 044, 045, 047, 048, 057, 058 and 059 with long/round tubers; and MUIB 004 as long tuber.

There were also wide variations for tuber skin color and tuber flesh color. Majority of the progenies have white tuber skin color and the rest were of yellow, red, pink, brown, orange and the combination of light to reddish pink color. The tuber flesh color varied widely among the progenies and the majority of the progenies fall into yellow and white color followed by yellow/purple.

The placement of tubers was either compact or spreading type (Table 1). A great majority (60%) of the tubers were of compact type, while the rests were spreading type. Results on vine length of the parents and offspring are presented in Table 2. The vine length of the parental clones ranged from 300 cm to 550 cm. The vine lengths in the case of offspring ranged from 350 cm in MUIB 013 to 650 cm in MUIB 034. All the offsprings had longer vines compared to their corresponding parental clones. On the average, the offsprings had longer vines (478 cm) than the parental clones (319.2) and the mean vine length difference was significant at $p \leq 0.01$ (LSD).

The tuber numbers for both the parents and offspring varied widely. The tuber numbers for the parental clones ranged from three to five. However, the tuber numbers for the offspring ranged from the lowest of three in MUIB 0016 and 037 to the highest of six in MUIB 004, 011, 013, 015, 033, 034 and 057 (Table 2). In most of the cases, the tuber numbers for the offspring were higher than the corresponding parental clones except MUIB 016, 026, 031, 037, 0.44 and 059, where the tuber numbers were equal for both the offspring and the parental clones; and for MUIB 009 had four tubers compared to five for the corresponding parent. The mean tuber number for the offspring (4.92) was higher than the corresponding mean tuber numbers of parental clones (3.96) and the difference in mean was significant at $p \leq 0.05$ (LSD).

There were wide variations among the parents and offspring for total tuber weight (Table 2). The tuber weights for the parents ranged from 460 g in Kabakaba to 1780 g in SI 172. On the other hand, the tuber weights for the offspring ranged from 430 g in MUIB 001 to 2110 g in MUIB 011. The tuber weights were always higher for the offspring than their corresponding parental clones with the exceptions of MUIB 001, 004, 016, and 028, where the tuber weights were slightly higher for the parental clones. The mean tuber weight of the offspring (1354 g) was much higher than the parental mean tuber weight (1108 g) and the difference was significant at $p \leq 0.01$ (LSD).

Table 3 shows the treatment mean comparisons for the tuber weights among the offspring. The results indicate that wide variations exist in the yielding abilities of the offspring. The highest yield (2110 g) was observed in the case of MUIB 011 and the lowest yield being 430 g in MUIB 001 and they differ significantly at $p \leq 0.05$ (DMRT). The tuber weights of MUIB 011, 013, 031 and 058 did not differ significantly at $p \leq 0.05$ (DMRT), but were significantly higher than MUIB 001, 004, 014, 016 and 026. However, the mean tuber weights of MUIB 001, 016 and 026 did not differ significantly.

The results for the vine weights for both the parents and offspring are presented in Table 2. Large variations exist both in the parental clones and the offspring in terms of vine weight. The vine weight of the parents ranged from 2440 g to 6300 g; whereas the vine weights of the offspring's ranged from 145 g in MUIB 026 to 3690 g in MUIB 001. In all the cases, the offspring had lower vine weights than the corresponding parental clones. The mean vine weight of the offspring's (907.89 g) was much lower than the mean vine weight of the parents (4600 g) and the difference of the means is significant at $p \leq 0.01$ (LSD).

Table 1: Tuberous root characteristics of the selected hybrid progenies

Progeny	Tuber shape	Tuber skin color	Tuber flesh color	Placement of tubers
MUIB 001	Long/round	Yellow	Yellow	Compact
MUIB 004	Long	Red	White	Compact
MUIB 005	Long/round	Copper color	Light yellow	Compact
MUIB 007	Round	White	Yellow/Purple	Spreading
MUIB 009	Round	Pink	Yellow	Spreading
MUIB 011	Long/round	White	White	Spreading
MUIB 013	Long/round	Light pink	Orange	Spreading
MUIB 014	Long/round	White	Orange	Compact
MUIB 015	Round	Brown	White	Compact
MUIB 016	Round	Yellow	Orange	Compact
MUIB 026	Round	White	Yellow/Purple	Spreading
MUIB 028	Long/round	White	White	Spreading
MUIB 031	Long/round	Pink	White	Compact
MUIB 033	Long/round	Orange	Orange	Compact
MUIB 034	Long/round	White	White	Spreading
MUIB 035	Round	Pink	Yellow	Compact
MUIB 037	Round	White	Yellow	Compact
MUIB 044	Long/round	Light pink	Yellow	Spreading
MUIB 045	Long/round	Pink	White	Spreading
MUIB 047	Long/round	White	Yellow	Compact
MUIB 048	Long/round	Reddish pink	Yellow	Spreading
MUIB 049	Round	White	White	Compact
MUIB 057	Long/round	Light pink	Orange	Compact
MUIB 058	Long/round	Brown/Yellow	Orange	Compact
MUIB 059	Long/round	Pinkish	Yellow	Compact

The tuber biomass ratio of the parental clones ranged from 0.071 to 0.311; however, the biomass ratio for the offspring ranged from 0.104 in MUIB 001 to 0.788 in MUIB 026 (Table 2). The tuber biomass ratios of the offspring were always higher than the corresponding parental clones except for MUIB 001. Overall, the mean of the tuber biomass ratio for the offspring (0.624) was much bigger than the mean of the parental clones (0.197) and the difference of the means was significant at $p \leq 0.05$ (LSD).

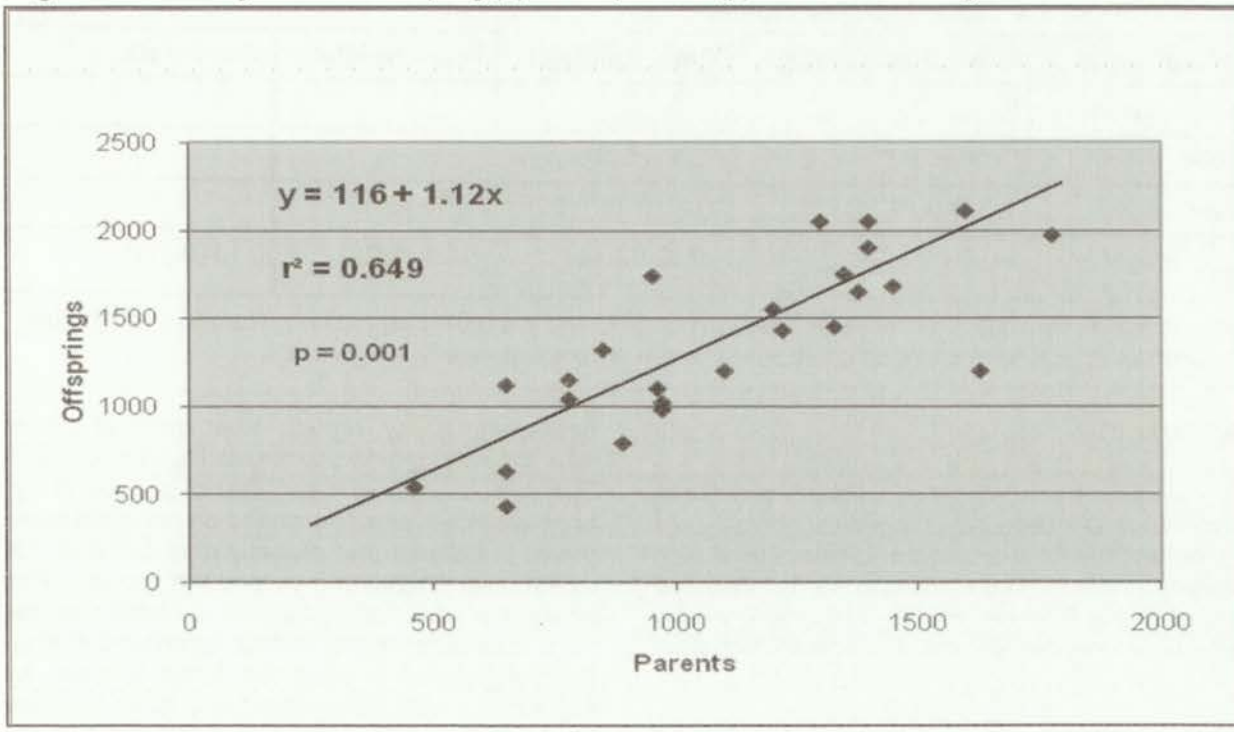
Table 2: Tuber weight, tuber number, vine length, vine weight and tuber: biomass ratio of parental clones and offspring

Maternal parental clones	Selected progeny (offspring (O)	Vine length (cm)		Tuber number		Tuber weight (g)		Vine weight g)		Tuber: biomass ratio	
		P	O	P	O	P	O	P	O	P	O
RAB 32	MUIB 001	400	540	3	4	650	430	4250	3690	0.133	0.104
K9	MUIB 004	350	400	4	6	890	790	3340	875	0.210	0.474
K9	MUIB 005	300	450	4	5	780	1150	5045	750	0.134	0.605
L676	MUIB 007	450	500	3	5	1400	1900	6300	2200	0.182	0.463
L676	MUIB 009	400	430	5	4	1200	1550	4340	890	0.217	0.635
L676	MUIB 011	350	400	4	6	1600	2110	5980	1200	0.211	0.637
L676	MUIB 013	300	350	4	6	1400	2050	4990	750	0.219	0.732
L676	MUIB 014	450	500	4	5	970	980	4780	690	0.169	0.587
L676	MUIB 015	400	540	5	6	1350	1750	5050	950	0.211	0.648
L676	MUIB 016	550	500	3	3	650	630	4680	340	0.122	0.649
Kabakaba	MUIB 026	350	430	4	4	460	540	5995	145	0.071	0.788
L43	MUIB 028	300	400	4	5	1630	1200	6070	750	0.212	0.615
SI-172	MUIB 031	400	450	5	5	1780	1970	4050	685	0.305	0.742
RAB 36	MUIB 033	450	500	5	6	1330	1450	4140	855	0.243	0.629
RAB36	MUIB 034	500	650	5	6	1450	1680	5990	550	0.195	0.753
RAB 36	MUIB 035	430	560	4	5	970	1020	4970	995	0.163	0.506
RAB 36	MUIB 037	450	500	3	3	850	1320	5220	980	0.140	0.574
KAV 57	MUIB 044	500	550	4	4	960	1100	5240	540	0.155	0.671
KAV 57	MUIB 045	450	550	3	4	1220	1430	4500	450	0.213	0.761
L696	MUIB 047	300	400	3	5	1380	1650	3985	560	0.257	0.747
L696	MUIB 048	400	500	4	4	650	1120	3030	755	0.177	0.597
L696	MUIB 049	300	450	4	5	780	1040	2980	525	0.207	0.665
NUG 5	MUIB 057	350	400	4	6	950	1740	4035	890	0.191	0.662
L329	MUIB 058	450	500	3	5	1300	2050	3600	1200	0.265	0.631
L329	MUIB 059	400	500	5	5	1100	1200	2440	480	0.311	0.714
Mean		**319.2**	**478****	**3.96**	**4.92***	**1108**	**1354****	**4600**	**907.8****	**0.197**	**0.624***

P = parent, O = offspring

*, **, offspring means are significantly different at $p \leq 0.05$ and $p \leq 0.01$ (LSD), respectively from the corresponding parental means.

Figure 1: Linear regression for offspring (o) on the parental (p) tuberous root weight



The result of the linear regression of the tuber weight of the offspring on the tuber weight of parental clones is presented in Fig 1. The parental clones accounted for 65% of the tuber yield variability of the offspring (r^2 = 0.649**).

The correlation coefficients for tuber weight, tuber number, vine length, vine weight and tuber biomass ratio both for the parental clones and offspring are presented in Table 4. In the case of offspring, tuber number was positively correlated to tuber biomass ratio (0.13) and tuber weight (0.51**) but negatively to vine length and vine weight; and was significant only for tuber weight. Vine length was negatively correlated to tuber number, tuber weight and tuber biomass ratio, though none of them was significant. Tuber weight also had a significant (0.39*) correlation with tuber biomass ratio. Vine weight had a negative correlation (-0.89**) with the tuber biomass ratio, tuber number (-0.02) and tuber weight (-0.06) but was positively correlated to vine length (0.15). Similar was the trend with the parental clones except that the correlation coefficients between tuber number and tuber biomass ratio was much higher; and it was much smaller (0.49*), but was positive between vine weight and tuber biomass ratio compared to their corresponding offspring values.

Table 3: Treatment means comparison for offspring tuber weight.

Offspring	Tuber weight (g)
MUIB011	2110 a
MUIB013	2050 ab
MUIB058	2050 ab
MUIB031	1970 abc
MUIB007	1900 bcde
MUIB015	1750 cde
MUIB057	1740 cdef
MUIB034	1680 defg
MUIB047	1650 efgh
MUIB009	1550 fghi
MUIB033	1450 ghij
MUIB045	1430 hijk
MUIB037	1320 ijkl
MUIB059	1200 jklm
MUIB028	1200 jklm
MUIB005	1150 klmn
MUIB048	1120 lmno
MUIB044	1100 mnop
MUIB049	1040 nopq
MUIB035	1020 opq
MUIB014	980 qr
MUIB004	790 qrs
MUIB016	630 rst
MUIB026	540 stu
MUIB001	430 tuv

Means followed by the same letters in a column do not differ significantly at p ≤ 0.05 (DMRT).

Table 4: Correlations among tuber number, tuber weight, tuber biomass ratio, vine length and vine weights for the offspring and parental clones

Components	Tuber biomass ratio	Tuber number	Tuber weight	Vine length
Tuber number	0.13(0.37)			
Tuber weight	0.39*(0.71)**	0.51**(0.30)		
Vine length	-0.16(-0.15)	-0.21(0.17(0.08)	- 0.17 (0.08)	
Vine weight	- 0.89**(0.49**)	- 0.02 (-0.10)	-0.06 (0.24)	0.15 (0.12)

*, **, correlation coefficients are significant at $p \leq 0.05$ and $p \leq 0.01$, respectively. Numbers within the parentheses are the correlation coefficients for the parental clones.

DISCUSSION

In sweet potato crop improvement programs, screening of seedling progenies from poly-crosses is the first step towards selection of high yielding cultivars. The seedlings are first selected based on the tuberous root formation followed by selection for other desirable agronomic characters.

Highly significant differences were observed for tuber yield and related vine characters on the poly-cross hybrids (off-springs) as compared to parental clones. The selected sweet potato genotypes raised through poly-crossing showed wide variations in plant vine and tuberous root characteristics indicating that progenies were highly segregating and assortment in F_1 generation since parents of sweet potato are highly heterozygous. This confirmed the findings of Tumana and Kessavan (1987), Bang (1987) and Anders (1983).

Tuber numbers for the off-springs were significantly higher with an average of 4.9 (≈ 5.0), while parental clones produced an average tuber number of 3.9 (≈ 4.0). The increase in tuber number in off-springs could be attributed to clean seedlings without virus originating from the true seeds. Tumana and Kessavan (1987) reported that increase in tuber yield from the poly-cross hybrids is due to clean seedlings without virus originating from the true seeds. It was also noted by the same authors that the parental clones have been long exposed to wide ranges of virus strains and other pathogenic organism contributing to low tuber yield.

High Tuber: biomass ratio indicates partitioning ability (Tumana and Kessavan, 1987; Bang, 1987), i.e. the portion of total biomass which assimiates sources is highly converted to edible tuberous roots. Partitioning was the highest in the poly-cross hybrids compared to parental clones. It does appear that many poly-cross hybrids generated from poly-cross mating process have high partitioning ability, though other parental clones also showed high partitioning ability (Bang, 1987). The comparisons of tuber yield of poly-cross hybrids with their parental clones on per plant basis grown in parents and progeny rows showed that hybrids significantly out-yielded the parents. This allows the selection of the hybrids based on the tuber bearing ability for further agronomic evaluations. Significant positive correlation between tuber number with tuber weight and tuber biomass ratio indicated that high tuber yielding clones are related to high tuber number and weight with less vine weight. This study also revealed that sweet potato improvement adapted for wide range of environment through poly-crossing is feasible. Tumana and Kessavan (1987) also reported similar feasibility for improving sweet potato performance under lowland conditions.

CONCLUSION

Twenty five hybrids were produced from 20 selected parental clones through poly-crossing. Wide morphological variation was observed in all selected progenies on the vine characteristics especially on leaf textures ranging from purple to green leaves. Leaf shapes also ranged from deeply lobed, slightly lobed to simple leaf shapes. All the poly-cross hybrids out yielded the parents raising the feasibility of sweet potato improvement through poly-crossing. The selected clones were also noted for high tuber partitioning ratio which was related to production of bigger tubers with less vine weight and biomass.

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