BREEDING TECHNIQUES, HERITABILITIES, INSECT RESISTANCE AND OTHER FACTORS AFFECTING SWEET POTATO BREEDING

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SUMMARY

A substantially higher percentage of progenies was within the acceptable range for most horticultural characters in crosses of parents which themselves have desirable phenotype. Selection pressure for skin and flesh colour can be made at an early selection stage of seedling growth. The honeybee and the bumblebee were the most efficient pollinating insects in a polycross nursery and showed preferences for profusely flowering cultivars. The flowers of breeding parents could be grouped on the basis of flower colour, size of corolla and position of stamens in relation to flower stigma. Centennial and ten other cultivars have their stamens below the stigma and cross pollination is necessary for seed set. Centennial was poorly compatible with ten new breeding parents used in breeding at Baton Rouge.

RESUME

On rencontre un pourcentage nettement plus élevé de descendants dans la série acceptable pour la plupart des caractéristiques d'horticulture dans des croisements de parents qui eux mêmes possèdent un phénotype désirable. La pression de sélection pour la peau et la carnation peut être faite très tôt au moment de la sélection de croissance des plantules. Les abeilles domestiques et les bourdons sont des insectes de pollinisation les plus efficaces dans une pépinière de croisements multiples et sont plus attirés par les cultivars qui fleurissent abondamment. On peut grouper les fleurs des parents en cours de sélection en fonction de la couleur des fleurs, de la dimension de la corolle et de la position des étamines par rapport au stigmate. Le Centennial et six autres cultivars ont leurs étamines en dessous du stigmate, ce qui rend la pollinisation croisée nécessaire pour la formation des graines. Le Centennial est peu compatible avec dix parents nouveaux en cours de sélection à Baton Rouge.

RESUMEN

Un porcentaje substancialmente más alto de progenies estuvo dentro del rango aceptable de la mayoría de los caracteres hortícolas de cruzas de padres con fenotipo deseable. La selección por color de la cáscara y de la pulpa se pueded hacer en etapas tempranas del desarrollo de las plántulas. Las abejas y los abejorros fueron los insectos polinizadores mas eficientes en un vivero para policruzas, mostrando preferencia por los cultivares que florearon mas profusamente. Las flores de los padres hibridados pudieron ser agrupadas sobre la base de: color, tamaño de la corola y posición de los estambres en relación al estigma, lo que hace necesaria la polinización cruzada para la producción de semilla. Centennial fué poco compatible con diez nuevos padres híbridos.

INTRODUCTION

The polycross system[3] of breeding as employed at Louisiana State University utilized additive gene effects by recurrent selection as well as employing the concept of homeostasis in assessing adaptation. Use is also made of epistasis and of the inheritance of major genes. As broad a gene base as possible is maintained.

Genetic characters for good horticultural traits have been selected since the inception of the sweet potato breeding programme in 1937, and most parental material is of such improved type. Only selected genotypes are used in the breeding nurseries for crossing by insects. Consideration is given to incompatibility groups in the establishment of nursery planting plans. *Ad hoc* nurseries have been used in the polycross system to breed for resistance to soil rot, soil insects, rootknot nematodes, other diseases and good horticultural characters[3,7,8]. For genetic studies controlled crosses have been used[1,2,3].

It would be possible even with a low level of compatibility to obtain seed populations of sweet potato from known parents provided that the resources existed to make a large number of hand crosses. The polycross system on the other hand, using highly mobile insects as pollinators, affords the chance to obtain seed populations much more easily, but crosses are all of uncertain parentage.

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MATERIALS AND METHODS

In this study pollinating insects were classified by their efficacy as pollinators and the effects of temperature on insect activity were studied. Floral colours were classified following Maerz and Paul[4]. Colours were assessed at the midpoint of the throat and on the external corolla.

Measurements were taken of corolla length and maximum width. The mean data for 10 fully opened flowers of each cultivar were calculated for flowers produced on plants growing at 80° F.

Ten flowers of each parent were classified for stamen position. If two or more flowers differed, the average condition was recorded, followed by an indication of variation.

Crosses were made between P.I. 343721 x W15-2, W15-2 x Centennial, and W51 x Centennial, to study the distribution among seedlings of skin and root colours. P.I. 343721 is a parental line introduced from East Africa and has a purple skin and a white flesh colour. W15-2 and W51 were received from the U.S. Breeding Laboratory, Charleston, South Carolina, and they contain carotenoid pigments. W-15-2 has a rose skin colour and W51 has a tan skin colour. Centennial is a cultivar released by Louisiana[9].

Segregating seedling progenies from hand crosses between P.I. 343721 x W15-2 and W15-2 x Centennial were compared for genetical performance in seedlings with good horticultural characters.

The pollination technique used was similar to that used by Hernandez *et al.*[3] Horticultural characters of seedlings in the above progenies were scored as follows: skin colour 1–6, representing the range white to purple, respectively; leaf shape 1–5, representing entire to deeply lobed; flesh colour 1–5, representing zero to very high carotenoid pigments; yield 1–5, representing very low to very high; root shape 1–5, representing very rough to very smooth; vine length 1–5, representing dwarf to very long; vine thickness 1–5, representing very small to very large; plant production 1–5, representing very poor to very good; storage ability 1–5, representing very poor to very high; and vine terminal colour 1–5, representing green to dark purple. Baking quality was determined using an average of several ratings in a scale of 1–10 with 10 representing the most favourable expression of characters for flesh colour, flavour, texture and fiber content. Parental cultivars were rated concurrently with seedlings.

The technique of handling polycrossed seedlings was similar to that for seedlings from hand crosses.

Fifteen breeding parents and other cultivars were planted in 8 replicated tests in 1971 using 10 plants per plot. Bedding roots of Centennial inoculated with sweet potato weevils were planted in rows on either side of each plot in this test. At harvest time roots of each cultivar were rated for horticultural characters and weevil infestation.

All data were analyzed in accordance with Stansfield[12].

RESULTS AND DISCUSSION

Insect pollinators of sweet potato flowers in Louisiana include an assemblage of leaf eaters, nectar feeding and predatory insects. Insects identified as pollen vectors were: (1) bumblebees (*Bombus* spp.); (2)honeybees (*Apis mellifera*); (3) digger bees (*Melissodes* spp.); (4) vespid wasps (*polistes* spp.); (5) bee killer wasp (*Philanthus ventrilabrus*); (6) brush footed butterfly (*Agraulis vanillae niger*); (4) skippers (*Leremia accivus*); (8) swallow tail butterfly (*Battus philenor philenor*); (9) sulfur butterfly (*Phoebus sennal ebule*); (10) milkweed butterfly (*Danaus blexippus*); (11) cucumber beetle (*Diabrotica balteata*); (12) soldier beetle (*Chauliognathus margenatus fabricatus*); (13) assassin bug (*Zebis bilobus*). All these insects had pollen on their bodies and moved from flower to flower to obtain nectar or to prey on others. Data for 8 consecutive weeks in September and October 1971 on each breeding parent showed that honeybees and bumblebees were the predominant visitors. The highest insect counts were associated with parents that bloomed most profusely. Thus, parents that flower profusely are flavoured with respect to crossing. Average daily body pollen count per insect was 130 on bumblebees, 397 on honeybees. The average daily pollen count on the bodies of other insects ranged from 3 to 28.

The mean number of pollen grains found on the stigmas of emasculated flowers was greatest at temperatures between 70 and 86° F when bumblebee and honeybee population and activity were at their highest.

W15-2, W51, and L6-5 were found to be compatible with Centennial, but L3-66, L3-64, L3-217, L9-23, L8-343, L9-192, L9-190 and L9-163 had low compatibility or were completely incompatible with it. Other workers[5,6,13] have reported on incompatibility in the sweet potato. In this study a new form of incompatibility was found in which seed with normal endosperms but lacking embryos, arose in the cross between W51 x Centennial.

The method of handling polycross seed from the breeding nurseries was similar to that described by Hernandez *et al.*[3] In this study, seedlings grown in the greenhouse from true seed were planted in January, 1971, and harvested and scored for flesh and skin colour in May, 1972, when the fleshy roots were one to two inches in diameter. Each seedling was transplanted into the field and again rated for flesh and skin colour in September. The frequency distribution for these characteristics was essentially the same for the ratings on May 5, 1972 and September 5, 1972, as shown in Table 1. This indicates that early selection is practicable. In 10 years an average of approximately 90 percent of the seedlings have been discarded as phenotypically inferior in the first selection screening.

Progenies of two crosses, P.I. 343721 x W15-2 and W15-2 x Centennial, were grown and evaluated. Each seedling was vegetatively propagated and planted into a replicated test. Heritability values were computed for each of 11 genetic characters comparing crosses of W15-2 and P.I. 343721 with Centennial (Table 2,3).

Heritability in this study was in the broad sense involving all types of gene action[10,11].

In the cross of P.I. 343721 x W15-2, flesh colour, root shape and fleshy root exterior had low heritability, whereas in the cross W15-2 x Centennial heritability was medium to high as shown in Table 2. Skin colour, leaf shape, number of fleshy roots, vine length, storage ability, baking index, and vine colour were all medium to highly heritable in both progenies.

Fifteen cultivars were grown in an eight replicated test using 10 foot plots. These were exposed to heavy insect pest pressure, especially sweet potato weevil (*Cylas formicarius elegantulus*) in cooperation with Dr. Edmon Kantack, entomologist. Data in Table 4 show that the cultivars L3-64, Heartogold, P.I. 343851, P.I. 343721, W15-2, W19-2 and W51 have varying levels of resistance to sweet potato weevil.

The cultivars were grouped on the basis of colour and size of corolla of flowers and position of stamen in relation to stigma of flowers. Centennial, L0-240, L3-92, L3-217, L4-89, L8-67, L8-71, L9-159, L9-190, L9-219, and L9-47 have their anthers below the stigma, and hand pollination is a virtual necessity. Forty-seven other cultivars were classified as having anthers with stamens superior, equal of slightly sub-equal in relation to the stigma of the flowers. The corolla width of the flowers of the breeding parents varied from 5.6 cm for W15-2 to the smallest of 3.3 cm for L7-177.

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TABLE 1

A comparison of selection techniques of polycrossed seedling progenies at two time periods, May 5, 1972 and September 5, 1972

Maternal Parent	Skin colour (% seedlings) White	Cream	Tan	Copper	Rose	Purple	Flesh colour* (% seedlings) 1	2	3	4
			May 5, 1972					May 5, 1972		
P.I. 343721	41.3	7.2	7.9	38.5	5.0	0	77.5	19.6	2.9	0
W15-2	34.7	13.9	11.1	30.5	9.8	0	66.6	11.1	19.4	0
Centennial (L3-77)	0	24.3	28.9	45.8	1.0	0	7.9	37.8	37.1	18.0
L8-343	0	45.1	15.8	39.0	0	0	0	14.8	80.4	4.7
L3-66	0	24.5	17.2	54.3	0	0	26.3	12.9	55.3	5.3
			Reclassified September 5, 1972							
P.I. 343721	47.1	7.2	7.9	38.5	5.0	0	76.8	20.2	2.9	0
W15-2	38.8	16.6	4.1	30.5	9.8	0	73.6	6.9	19.4	0
Centennial (L3-77)	0	26.4	27.0	45.8	1.0	0	6.9	34.0	37.1	21.9
L8-343	0	46.3	14.6	39.0	0	0	0	14.8	79.2	6.0
L3-66	0	27.9	17.7	54.3	0	0	25.0	12.8	56.4	5.8

* Flesh colour: 1 is white and 4 is high total carotenoids.

TABLE 2

Mean, standard deviation and broad sense heritability[12] for 14 horticultural characters of three sweet potato progenies grown 1971–72

Horticultural character	PI 343721 x W15-2 *Mean	S.D.	$h^{2\dagger}$	W15-2 x Centennial *Mean	S.D.	h^2	**W51 x Centennial *Mean	S.D.	h^2
Skin colour	3.82	.0035	.51	4.3	.00033	.68	3.5	.0025	.43
Leaf shape	1.64	.00014	.84	1.5	.00028	.97	1.4		
Flesh colour	1.75	.00058	.13	2.8	.0004	.51	2.9	.0039	.52
Yield	1.96	.00075	.08	3.1	.00014	.008	1.2	.01	0
Yield (number roots)	0.71	.00033	.32	8.7	.0005	.61	0.3	.0004	.72
Root shape	3.53	.0012	.04	3.0	.0001	.62	3.1	.0039	.27
Vine length	3.14	.0005	.42	2.8	.0003	.96	2.4	.0004	.83
Storage ability	1.41	.0005	.33	3.9	.00039	.54	3.1	.0043	.49
Baking index	1.5	.0057	.22	6.9	.00041	.71	5.9	.0036	.47
Vine colour	2.1	.000005	.96	3.3			2.2		
Vine colour terminal	1.64			3.2			1.5		
Fleshy root exterior	1.95	.0021	0	3.9	.0019	.67	3.7	.0009	49
Vine thickness	3.2			3.3			2.5		
Pubesence				0.5			0		

* The higher the digital expression, the more favourable the horticultural characters, except for root shape with the 3 rating representing the optimum.

** Data of progeny of W51 x Centennial included in this table but no in the text of paper.

† Ratio of genetic gain to selection differential ($^{\Delta G}/_{\Delta P}$),(Reference 12, p.228-9). 0.5 high, .25 medium, 0.2 low heritable biometric traits.

TABLE 3

A comparison of progenies of control crosses as to distribution of segregating seedlings for skin and flesh colour

Parental crops	No	Flesh colour* (%) 1	2	3	4
PI 343721 x W15-2	85	23.6	62.5	13.9	
W15-2 x Centennial	125		17.2	51.9	31.9

	Skin colour (%) White	Cream	Tan	Copper	Rose	Purple
PI 343721 x W15-2	38.8	17.9	4.2	8.4	25.0	5.6
W15-2 x Centennial	0	38.7	19.8	39.6	1.7	0

* Flesh colour: 1 = white; 4 = high total carotenoids

TABLE 4

A comparison of cultivars as to resistance to insects*

Cultivar	Banded cucumber beetle**	Pale striped flea beetle**	Wireworm	Sweet potato flea beetle	Sweet potato weevil	Grubs	†Baking Index
Centennial	50.63	79.12	0.00	18.88	88.75	5.00	7.00
L3-64	12.50	20.25	3.50	12.38	7.38	0.0	6.40
L4-89	27.25	41.25	0.0	20.50	83.25	0.0	6.33
Heartogold	15.00	8.50	0.0	0.0	8.50	0.0	6.05
L8-71	182.43	159.00	2.50	15.88	270.25	6.25	7.00
L8-164	77.38	61.13	3.63	20.75	88.50	7.13	5.95
L3-66	98.14	150.00	3.14	29.86	183.57	9.14	6.13
W19-2	31.00	15.25	0.0	8.13	34.38	0.0	6.03
W51	30.38	14.00	0.0	8.38	61.63	1.25	5.78
W15-2	31.38	18.38	0.0	0.0	45.13	0.0	6.23
W26-2	14.57	12.43	0.0	0.0	21.29	0.0	4.10
W2-361	6.38	5.00	2.63	0.0	19.50	0.0	2.63
PI 343851	86.25	20.63	0.0	0.0	9.63	0.0	2.35
PI 343721	11.25	39.63	7.00	10.88	12.88	0.0	2.10
NCVQ	19.38	28.13	3.50	10.25	143.00	0.0	1.70

* Cultivars rated for insect damage in each of 8 replications by Dr Edmon Kantack, Entomology Department.

** Significant at the .01 and .025 level; the lower the indices, the more resistant are the cultivars. †Baking index - 10 represents most favourable reading.