A STUDY OF *Ipomea trifida* F_1 HYBRIDS, AND

BACKCROSSES BETWEEN

I. trifida x *I. batatas*

By

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
LITERATURE REVIEW	2
MATERIALS AND METHODS	6
RESULTS	14
DISCUSSION AND CONCLUSION	28
SUMMARY	31
REFERENCES CITED	33
APPENDIX	35

LIST OF TABLES

Table — Page

I. Number of Polinated Flowers, Per Cent Fruit Set, and Seeds per 100 Pollinated Flowers for Certain *I. trifida* Clones when Selfed or Intercrossed, 1964-65 15

II. Number of Pollinated Flowers, Per Cent Fruit Set, and Seeds per 100 Pollinated Flowers for Certain *I. trifida* Clones when Crossed with Certain *I. batatas* Clones, 1964-65 16

III. Number of Pollinated Flowers, Per Cent Fruit Set, and Seeds per 100 Pollinated Flowers for Certain *I. trifida* Clones when Crossed with Certain *I. batatas* Clones, 1964-65 17

IV. Number of Pollinated Flowers, Per Cent Fruit Set, and Seeds per 100 Pollinated Flowers for Certain *I. batatas* Clones when Selfed or Intercrossed, 1964-65 19

V. Leaf Shape of Seedling Plants of *I. trifida*, *I. batatas* and Their Hybrids 20

VI. Root Enlargement of *I. trifida*, *I. batatas* and Their Hybrids 23

VII. Skin and Flesh Color of Roots of *I. trifida*, *I. batatas*, and Their Hybrids 25

VIII. Reaction of F_1 Plants of *I. trifida* x *I. batatas* to Fusarium Stem Rot and Southern Root-Knot Nematode . . . 27

IX. Leaf Shape and Root Enlargement of Seedling Plants of *I. trifida* and *I. batatas* 36

X. Leaf Shape and Root Enlargement of F_1 Hybrid Seedling Plants of *I. trifida* x *I. batatas* 37

XI. Leaf Shape and Root Enlargement of F_1 Hybrid Seedling Plants of *I. batatas* x *I. trifida* 38

XII. Leaf Shape and Root Enlargement of Backcross Seedling Plants from F_1 Hybrid x *I. trifida* and *I. batatas* . . . 39

Table		Page

XIII. Skin and Flesh Color Ratings of Roots of Seedling Plants of *I. trifida* and *I. batatas*. 41

XIV. Skin and Flesh Color Ratings of Roots of F_1 Hybrid Seedling Plants of *I. trifida* x *I. batatas*. 42

XV. Skin and Flesh Color Ratings of Roots of F_1 Hybrid Seedling Plants of *I. batatas* x *I. trifida*. 43

XVI. Skin and Flesh Color Ratings of Roots of Backcross Seedling Plants from F_1 Hybrid x *I. trifida* and *I. batatas*. 44

XVII. Reaction of Seedling Plants in Crosses of *I. trifida* x *I. batatas* to Fusarium Stem Rot and Southern Root-Knot Nematode. 45

LIST OF FIGURES

Figure		Page
1.	Vines of *I. trifida* Parent Lines in Greenhouse X1-1 (top) and X2-3 (bottom), December 21, 1964	7
2.	Seedling Plants in Greenhouse.	9
3.	Unthickened Roots of *I. trifida* Seedling (X2-3) Parent Line at Harvest Time, October 23, 1965	11
4.	Thickened Storage Roots of *I. batatas* Seedling (106 x 185) Parent Lines at Harvest Time, October 23, 1965	11
5.	Thickened Storage Roots of Backcrosses of Sweet Potato P-Lines to K-Line Hybrids.	12
6.	Classes of Leaf Shape Used to Record Field Data at Harvest Time, October 23, 1965	12
7.	Root Size and Morphology of Hills of *I. trifida*, F_1 Hybrid and Backcross Seedlings of Harvest Time, October 23, 1965	22

INTRODUCTION

The production and use of the sweet potato, Ipomea batatas, Lam. for food is widespread, but the origin is unknown. Sweet potato breeders have searched the genis Ipomea for the ancestral plant, but were unable to locate wild plants in the original or adapted habitat.

The objectives of this study were to evaluate the characteristics of Ipomea trifida (H.B.K.) G. Don, a close relative of the cultivated sweet potato, to compare the wild species, I. trifida, with the cultivated sweet potato, and to determine the possible value of I. trifida for use in sweet potato breeding.

Specifically, it was the designs of this experiment to establish compatibility relationships between the two species, to observe growth habits, and to define the major characteristics of the wild species, the F_1 hybrids, and the backcrosses to the parent species. The characteristics considered were: (1) leaf shape; (2) root enlargement; (3) external root color; (4) internal root color: and (5) reaction to the pathogens causing stem rot (Fusarium oxysporium f. batatas) (Wollenweber) Snyder and Hansen, and Southern root-knot nematode (Meloidogyne incognita acrita), Chitwood.

LITERATURE REVIEW

Botanically the sweet potato, Ipomea batatas, belongs to the Convolvulaceae or morning-glory family (1). Most of the species of the genus Ipomea are ornamentals with only a few species used for food. The sweet potato is the only member of the family of commercial value consumed by man (1). It is a widely variable plant with respect to morphological characteristics, both vine growth habit and leaf type variants are numerous. Generally, the stems are long and trailing but in certain instances they are short, the vines are either non-twining or twining, depending on the variety, usually glabrous, but erect bunch and pubescent stem types are known to occur. The flowers are borne in cymes in axils of leaves with a funnel-shaped corolla, tinged rose, violet or pink. The edible part is the much enlarged "tuberous roots," varying in shape from fusiform to oblong or pointed oval. Internal root color ranges from white through cream to orange and infrequently purple; and external root color ranges from white, light buff (tan) to brown or rose-copper and purple (red) (2). The nutrient composition of the flesh of the roots consists largely of carbohydrates including starch, and the orange-fleshed varieties are high in carotene (1).

Although unknown to the European and Mediterranean people before 1492 A. D., the sweet potato had been cultivated in tropical America for some time. Four or five generations prior to 1350 A.D., the plant was introduced into Asia by the Polynesian traders. The Maorias of

New Zealand developed crude methods of cultivation and storage of the "Kumara" or sweet potato (4).

A study conducted by King and Bamford (11) indicated that most Ipomea species are diploids (2n=30) e.g., I. pandurata, G. F. W. Mey.; I. purpurea, (L.) Roth.; and I. hederacea, (L.) Jacq. Two species with high chromosome numbers are I. ramoni, Choisy (4n=60) and I. batatas (6n=90). The sweet potato is a hexaploid with 90 chromosomes in a genus where n=15.

Ting and Kehr (15) advanced the hypothesis that the sweet potato originated from the genus Ipomea through inter-species crosses and chromosome duplication. The cross of a tetraploid species with a diploid species produced a sterile triploid hybrid (45n). Subsequent doubling of the chromosome numbers gave the sweet potato (2n=90). A genome make-up of such an origin would produce a plant of low fertility.

Stout (13) conducted a survey concerning sexual reproduction in the sweet potato. He noted that few of the plants flowered and that those seldom produced capsules and seeds. A type of sterility existed, similar to that of other cultivated species propagated vegetatively. In regions of unfavorable environment, the plant flowered sparingly. Stout obtained only eight mature capsules from four successful cross-combinations and none of the plants were self-compatible. He concluded that the low capsular and seed set was the result of inherited incompatibility factors that in some way prevented fertilization.

Much later, Wang (16) reported that the incompatibility problem was apparently genetic. Self- and cross-compatibility studies revealed that most sweet potato varieties are self-sterile. Fertility or incompatibility was due to the presence of a fertility factor "S_f" or conversely the presence of one or more sterility genes of the allemorphic series, e.g., S_1, S_2, S_3, etc.

Compatibility studies made by East and Mangelsdorf (7) on Nicotiana sanderae, Hort. Sander, suggest a series of sterility genes similar to those speculated by Wang in the sweet potato. The gametophytic system gives rise to three main types of pollinations: (1) fully incompatible (S_1S_2 x S_1S_2) in which both alleles are common; (2) half the pollen is compatible (S_1S_2 x S_1S_3) in which one allele is different; and (3) all the pollen is compatible (S_1S_2 x S_3S_4) in which both alleles differ. At times, normally incompatible combinations set fruits. Aside from the "fertility gene" hypothesis, some physiological limitations might be present (7).

In 1954, Nishiyama (12) found a hexaploid species of Ipomea in the wild in southern Mexico, I. trifida (H.B.K.) G. Don, also reported to be present in Venezuela. The exact origin of this species is unknown, but the plant appears to be closely related to the sweet potato. Nishiyama described I. trifida as having long, slender, twining vines; leaves shaped comparable to those of the sweet potato; and as being cross-fertile with the sweet potato. No pronounced amount of pigmentation of the skin and flesh of the roots was observed. Furthermore, the plants failed to develop the thickened, "tuberous-like" roots similar to the sweet potato.

By far, the most pertinent clue to the genetic relationship of this wild Ipomea and the sweet potato was the cross-compatibility of the two species. True, the two species possess the same genome composition (n=45, 2n=90). Nishiyama crossed I. trifida with oriental lines of sweet potato and produced fertile F_1 hybrids. He grouped the clones of *I. trifida* into seven incompatibility classes. One clone of *I. trifida* appeared to possess the same incompatibility genes found within certain sweet potato lines.

Recently, Jones and Deonier (10) made a number of crosses between *I. trifida* and *I. batatas*. Hybrids from the crosses were backcrossed to parent sweet potato breeding lines. They reported a higher level of flowering and fertility in the hybrids than that which existed in their sweet potato breeding stock. The current hybridization program was designed to incorporate new or existing fertility genes into desirable sweet potato breeding lines.

MATERIALS AND METHODS

Two species were used to study compatibility relationships and morphological similarities and differences during the winter of 1964-65 and the following summer. Plants of the wild species (_I. trifida_) were grown from seeds received from Nishiyama of Japan. Four free blooming clones were selected. The sweet potato (_I. batatas_) parent lines were those currently in use in breeding programs at Oklahoma State University.

The plants of _I. trifida_ and _I. batatas_ were grown in the horticulture greenhouse according to growh conditions outlined by Sorenson's research (14). The plants of _I. trifida_ were grown in beds of low nutrient fertility sand secured from the Horticulture Farm at Perkins, Oklahoma. Some of the sweet potato parent lines were grown in adjacent beds of similar sand. Other sweet potato parent lines were grown in gravel culture in the same greenhouse. No photoperiod regulation was made. Daytime temperatures were maintained at 80° to 85°F. and night time temperatures were kept at 65°F.

Each plant was pruned so three or four main laterals developed and the vine was trained onto a 6-foot wire trellis (Figure 1). A moderate degree of pruning was done so the vines remained in full blossom from September 15, 1964 until April 15, 1965.

The nutrient requirement of the plants was kept at the desired level by a regular fertilizer program. The beds were fertilized at

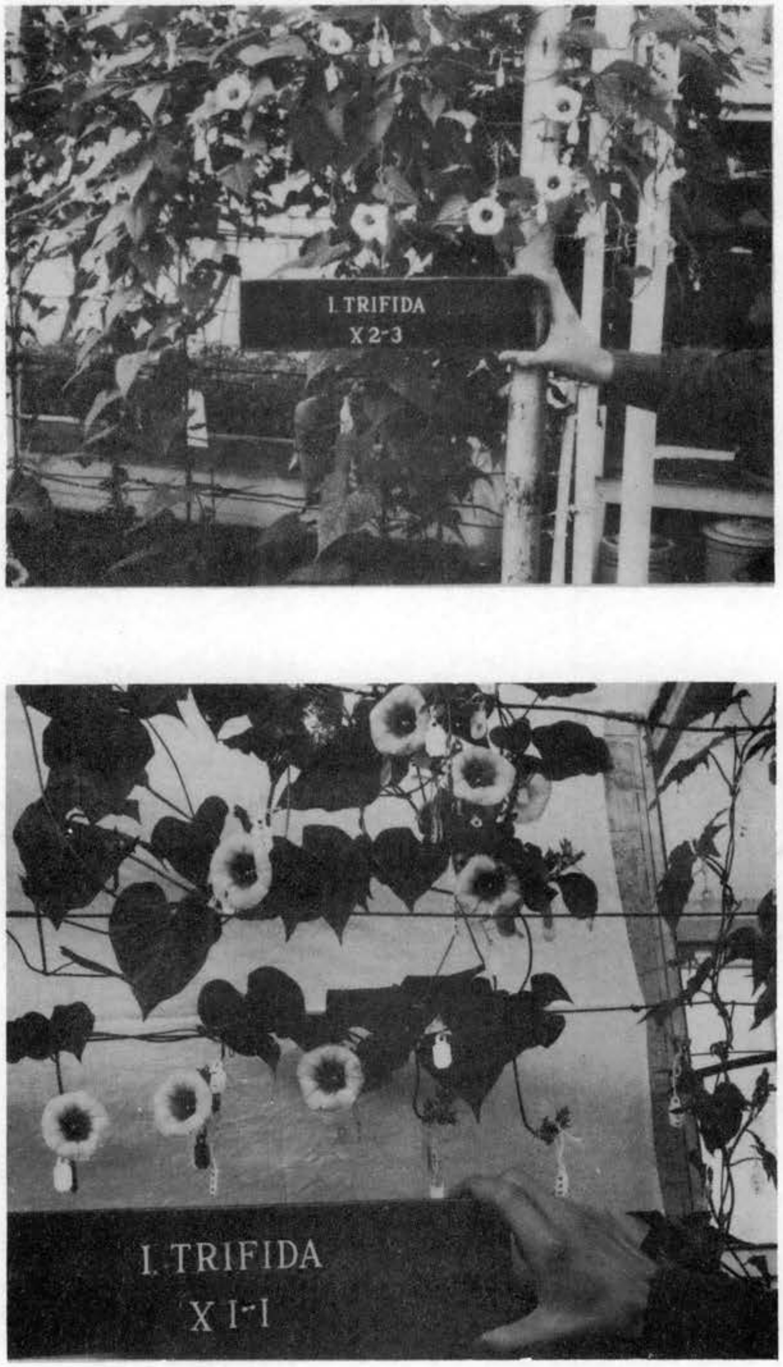

Figure 1. Vines of I. trifida Parent Lines in Greenhouse, X1-1 (top) and X2-3 (bottom), December 21, 1964.

two-week intervals with one pound of dry fertilizer consisting of three parts K_2SO_4, two parts $MgSO_4$, and one part $MnSO_4$. Peter's Special, a 20-20-20 analysis fertilizer dissolved at the rate of one ounce per three gallons of H_2O was used in place of watering at two-week intervals.

Pollinated flowers were tagged to indicate the pollen parent and the number pollinated each day was recorded. Ripened capsules were harvested, separated according to parentage, counted, and the number of seeds ascertained. From this datum the number of pollinations, per cent set, and seeds per 100 pollinations were obtained. By combining the per cent set and seeds per capsule, compatibility was expressed in a single statistic-seeds per 100 pollinations.

As soon as mature seeds of the early crosses were available, they were planted to secure F_1 plants. These F_1 hybrids were designated as "K" lines. Due to the lateness in obtaining these F_1 plants in a blooming condition, only a limited number of backcrosses were obtained involving both the wild species and the sweet potato.

After scarification of the seeds by means of a needle, seedling progenies were started in the greenhouse for field plantings (Figure 2). The seeds were planted in sterilized soil in greenhouse flats, but in a core of vermiculite to avoid damping-off.

The seedling progenies were transplanted to a field of Norge sandy loam soil May 14, 1965 on the Oklahoma State University Research Farm near Perkins. The soil and plant beds were prepared as is usual for sweet potatoes. A 10-20-10 analysis fertilizer was applied in the row at the rate of 300 pounds per acre. The plants were spaced about 18 inches apart in rows on the center of beds 3-1/2 feet apart. The field was cultivated and hoed twice. Rainfall was adequate in May and June

Figure 2. Seedling Plants in Greenhouse. Back Row, F_1 Hybrids (*I. trifida* x *I. batatas*); and Front Row, *I. batatas* x *I. batatas*), December 21, 1964.

with 2.82 inches after May 15 and 4.28 inches in June, but irrigation was needed in July and August with 1.69 inches and 3.39 inches of rainfall, respectively. Moisture provided by rainfall was adequate for the remainder of the season (8.62 inches in September). The plants were dug October 16, 1965 in the usual fashion for harvesting sweet potatoes. After undercutting, the hills were lifted by hand for observation. The roots of some typical individuals representing the parents, F_1's and backcrosses were selected and photographed (Figures 3, 4, and 5). Others were selected for future research studies.

Data were taken on individual plants at harvest time in regard to leaf shape, root formation, root enlargement, as well as skin and flesh color of the roots. Six classes of leaf shape were established to cover the anticipated range, e.g. (1) entire, (2) shouldered, (3) trilobed, (4) sub-pentalobed, (5) pentalobed, and (6) sub-heptalobed. A visual guide to these classes is represented by Figure 6. Root enlargement was expressed by four classes, e.g. (1) no enlargement (less than 1/4-inch in diameter), (2) some enlargement (1/4-3/4 inch in diameter), (3) considerable thickening (3/4-1-1/2 inches in diameter), and (4) enlargement equal to an acceptable sweet potato variety (greater than 1-1/2 inches in diameter). The roots were classified into three groups according to external and internal color designations. External chroma classes were: (1) white (no pigmentation), (2) tan to orange (some pigmentation), and (3) light rose-red, red or purple (intense pigmentation). The internal chroma classes were: (1) white or cream (no appreciable amount of carotene present), (2) lemon, light orange or faint red (moderate carotene content), and (3) deep orange, intense red and sometimes purple (much carotene and other pigments present).

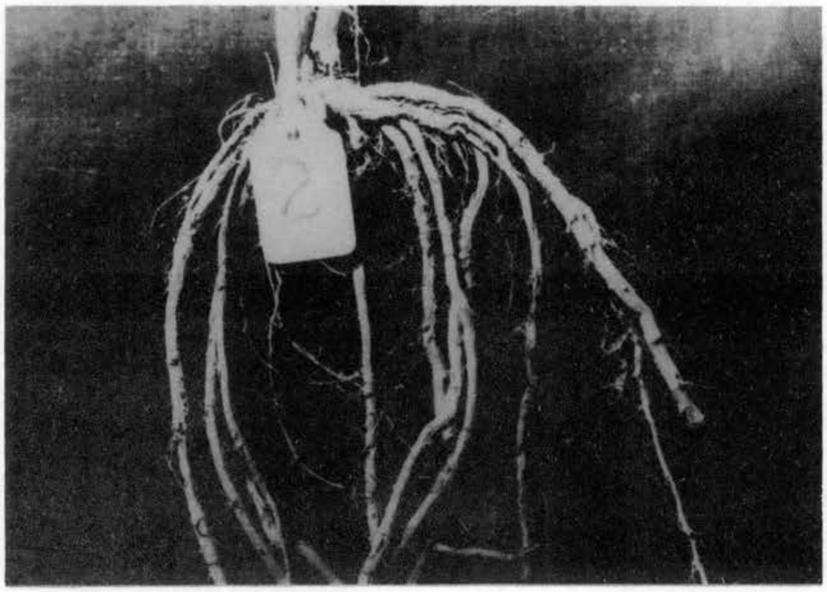

Figure 3. Unthickened Roots of I. trifida Seedling (X2-3) Parent Line at Harvest Time, October 23, 1965.

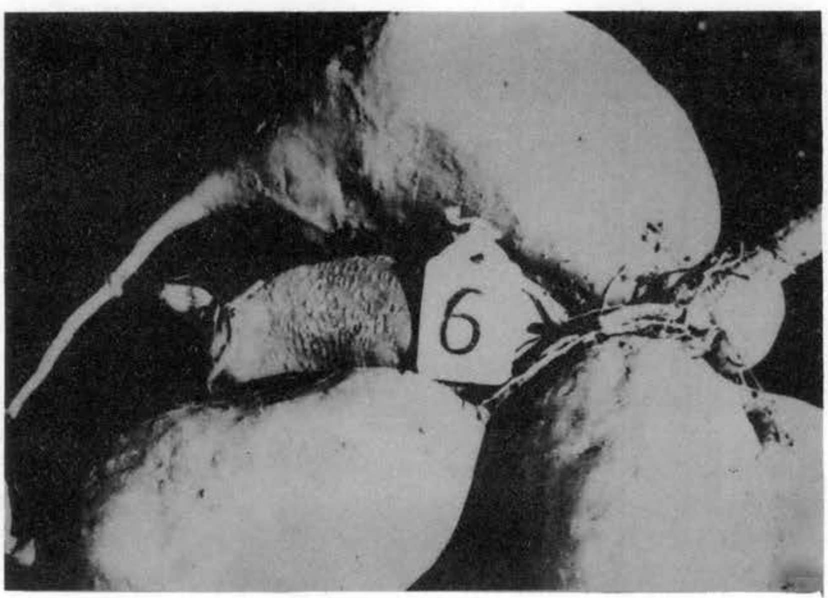

Figure 4. Thickened Storage Roots of I. batatas Seedling (106 x 185) Parent Lines at Harvest Time, October 23, 1965.

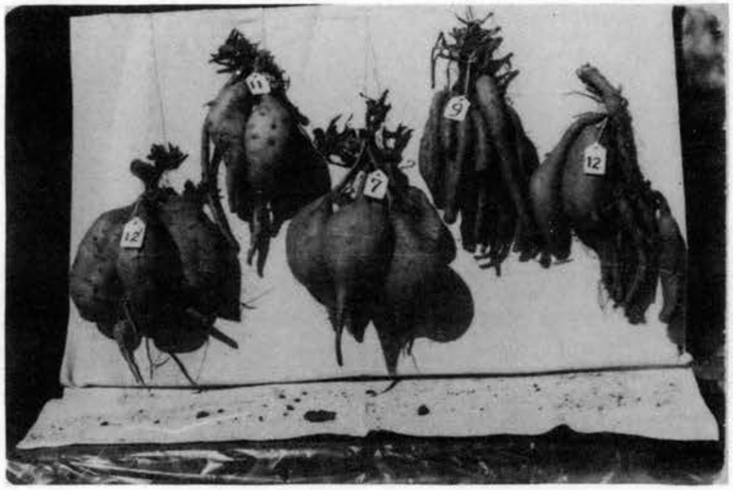

Figure 5. Thickened Storage Roots of Backcrosses of Sweet Potato P-Lines to K-Line Hybrids. The Parentage of the Above Seedlings is Number 12, 185 x K_2; Number 11, 184 x K_3; Number 7, 182 x K_1; Number 9, 183 x K_1; and Number 12, 185 x K_2 at Harvest Time, October 23, 1965.

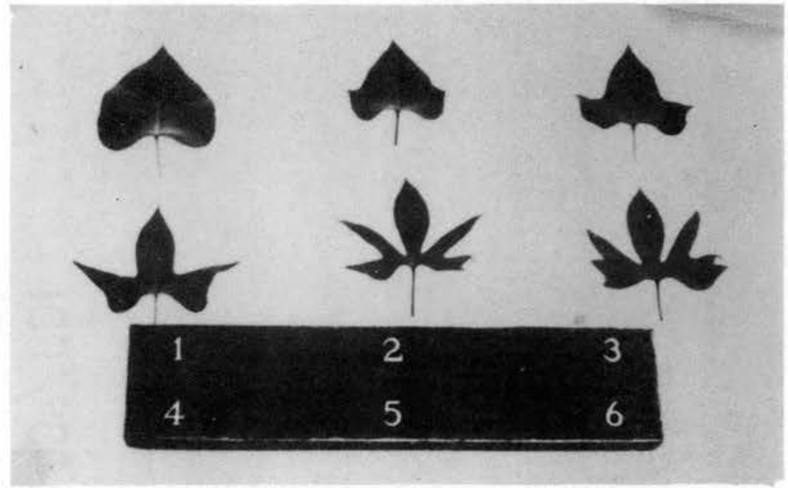

Figure 6. Classes of Leaf Shape Used to Record Field Data at Harvest Time, October 23, 1965.

Classes of Leaf Shape Were Number 1, Entire; Number 2, Shouldered; Number 3, Trilobed; Number 4, Sub-pentalobed; Number 5, Pentalobed; Number 6, Sub-heptalobed.

A selected number of hybrid seedlings of I. trifida x I. batatas were evaluated in the field for resistance to stem rot and Southern root-knot nematode. The plants were inoculated with the stem rot organism, Fusarium oxysporum f. batatas before planting. Stand counts were made to establish the degree of resistance to stem rot. At harvest time, the hills were lifted and the roots sliced to determine the extent of vascular discoloration due to stem rot. Plants used in the Southern root-knot nematode trials were planted in a field known to be infested with the nematode, Meloidogyne incognita acrita. Roots of the plants in the nematode trials were examined at harvest time with the degree of injury based upon the extent of root damage, lesions, and gall formation. Plants with a high degree of disease injury were classified as (S) susceptible, and no injury as (R) resistant. The field work was conducted in cooperation with Dr. F. Ben Struble and Professor Lou Morrison, Plant Pathologists at Oklahoma State University.

RESULTS

Flowering: Four classes of I. trifida (X-1, X2-1, X2-2, and X2-3) developed numerous blossoms during the fall of 1964 and spring of 1965. The sweet potato P-lines (106, 161, 178, 184, 185, 188, 189, and 190) also bloomed freely. Only the P-183 sweet potato line produced a limited amount of blooms due to limited vine growth. Several K-lines (K_1, K_2, and K_3) bloomed sparingly during the spring of 1965.

I. trifida crosses: A total of 1,110 pollinations were made during the season. Fruit set from the crosses varied from two per cent in X2-2 combinations to 19 per cent in the X2-1 line crosses. The number of individual pollinations, per cent fruit set, and seed per 100 pollinations are given in Table I. The combinations are listed to show the relative fertilities both as male and female parents.

Hybrid crosses: Over 6,247 interspecies pollinations were made between I. trifida and I. batatas. From the results shown in Table II, the I. trifida x I. batatas cross (excluding P-190) produced an average seed set of 25 to 47 per cent and seed per 100 pollinations range from 35 to 83. The reciprocal cross, I. batatas x I. trifida, had an average seed set of 34 per cent in X1-1 and 16 per cent in X2-3. The number of seed per 100 pollinations ranged from 22 to 52 in I. batatas female classes. No seeds were set in X2-1 x 106, X2-1 x 161, and X2-2 x 184 cross combinations. Only one cross with 183 as a female parent was made, due to a lack of blooms on the 183 plants. These data are given in Table III.

TABLE I

NUMBER OF POLLINATED FLOWERS, PER CENT FRUIT SET, AND SEEDS PER 100 POLLINATED FLOWERS FOR CERTAIN *I. trifida* CLONES WHEN SELFED OR INTERCROSSED, 1964-65

I. trifida Clones ♀	*I. trifida* Clones ♂			
	X1-1	X2-1	X2-2	X2-3
X1-1				
Number of pollinations	368	144	107	36
Per cent fruit set	14	31	5	78
Seed per 100 pollinations	17	42	6	132
X2-1				
Number of pollinations	10	54	12	
Per cent fruit set	33	0	0	
Seed per 100 pollinations	8	0	0	
X2-2				
Number of pollinations	6		151	2
Per cent fruit set	33		0	0
Seed per 100 pollinations	8		0	0
X2-3				
Number of pollinations	15	14	19	162
Per cent fruit set	0	0	0	0
Seed per 100 pollinations	0	0	0	0
Total pollinations	399	212	289	200
Average per cent fruit set	15	19	2	22
Average seed per 100 pollinations	19	28	2	37

TABLE II

NUMBER OF POLLINATED FLOWERS, PER CENT FRUIT SET, AND SEEDS PER 100 POLLINATED FLOWERS FOR CERTAIN *I. trifida* CLONES WHEN CROSSED WITH CERTAIN *I. batatas* CLONES, 1964-65

I. trifida Clones ♀	*I. batatas* Clones ♂						
	106	161	178	183	184	185	190
X1-1							
Number of pollinations	141	389	256	749	369	466	647
Per cent fruit set	29	36	34	50	44	26	7
Seed per 100 pollinations	57	54	52	84	67	36	10
X2-1							
Number of pollinations	24	42	7	73	44	46	46
Per cent fruit set	0	0	14	41	9	17	22
Seed per 100 pollinations	0	0	14	78	9	24	22
X2-2							
Number of pollinations	24	113	28	150	168	52	98
Per cent fruit set	83	33	43	47	0	29	22
Seed per 100 pollinations	125	55	46	62	0	43	29
X2-3							
Number of pollinations	50	124	68	232	123	73	85
Per cent fruit set	70	45	43	39	33	21	26
Seed per 100 pollinations	128	78	83	71	52	31	34
Total pollinations	239	668	359	1204	704	637	876
Average per cent fruit set	40	35	36	47	26	25	11
Average seed per 100 pollinations	74	56	60	83	40	35	15

TABLE III

NUMBER OF POLLINATED FLOWERS, PER CENT FRUIT SET, AND SEEDS PER 100 POLLINATED FLOWERS FOR CERTAIN *I. trifida* CLONES WHEN CROSSED WITH CERTAIN *I. batatas* CLONES, 1964-65

I. batatas Clones ♀	*I. trifida* Clones ♂			
	X1-1	X2-1	X2-2	X2-3
183				
Number of pollinations	56			
Per cent fruit set	61			
Seed per 100 pollinations	70			
184				
Number of pollinations	7			2
Per cent fruit set	43			50
Seed per 100 pollinations	43			50
185				
Number of pollinations	80	30		45
Per cent fruit set	55	57		33
Seed per 100 pollinations	97	67		42
188				
Number of pollinations	125	74	86	178
Per cent fruit set	30	16	16	12
Seed per 100 pollinations	51	25	24	16
189				
Number of pollinations	63	34	23	47
Per cent fruit set	56	15	30	30
Seed per 100 pollinations	71	15	34	36
190				
Number of pollinations	352	98		254
Per cent fruit set	22	26		13
Seed per 100 pollinations	36	58		21
Total pollinations	683	236	109	526
Average per cent fruit set	34	25	19	16
Average seed per 100 pollinations	52	43	26	22

_I_. _batatas_ crosses: Data are reported in Table IV on 6,563 pollinations of sweet potato lines. Average fruit set ranged from 20 per cent in P-161 and P-178 to 51 per cent in P-185. Few seeds were obtained in the 183 x 161 and 185 x 178 crosses, three per cent and eight per cent, respectively.

Backcrosses: Only a limited number of crosses could be made. Data were inadequate to report.

Vegetative characters: General observations were made on the vine types and growth rate of seedlings. Leaf shape data are recorded in Table V.

_I_. _trifida_ seedlings: The plants grew profusely, e.g. long, thin, twining vines often 20-30 feet long. The leaves of some plants were quite pubescent and many plants had corrugated or ruffled leaves. There were a large number of plants (53%) with entire leaves and a sizeable number (23%) with shouldered leaves. No plants had sub-heptalobed leaves.

Hybrid seedlings: The F_1 hybrids were very prolific with long vines, thickened stems, and large leaves. The basal ends of the vines close to the hill were often more thickened than those of sweet potato seedlings. The _I_. _trifida_ x _I_. _batatas_ combination, as well as the reciprocal cross, produced plants which had 77 and 68 per cent of the individuals with entire leaves. Most of the hybrids (99%) had entire, shouldered, or trilobed leaves.

Sweet potato seedlings: Data were reported on two sweet potato crosses (185 x 106 and 185 x 178). Although 51 per cent of the plants had entire leaves, 13 per cent developed pentalobed leaves and three per cent had sub-pentalobed and sub-heptalobed leaves.

TABLE IV

NUMBER OF POLLINATED FLOWERS, PER CENT FRUIT SET, AND SEEDS PER 100 POLLINATED FLOWERS FOR CERTAIN I. batatas CLONES WHEN SELFED OR INTERCROSSED, 1964-65

I. batatas clones ♀	I. batatas Clones ♂					
	106	161	178	183	184	185
161						
Number of pollinations	231		161	108	136	151
Per cent fruit set	55		55	24	46	55
Seed per 100 pollinations	84		82	29	64	77
183						
Number of pollinations	356	63	208		273	25
Per cent fruit set	44	3	38		27	4
Seed per 100 pollinations	71	5	57		38	4
185						
Number of pollinations	1268	279	1311	195	869	
Per cent fruit set	29	19	8	41	18	
Seed per 100 pollinations	41	27	11	53	22	
190						
Number of pollinations	153	132	231	180	107	121
Per cent fruit set	57	32	45	53	47	55
Seed per 100 pollinations	97	46	75	88	71	85
Total pollinations	2008	474	1911	483	1385	297
Average per cent fruit set	40	20	20	41	25	51
Average seed per 100 pollinations	56	29	30	60	33	74

TABLE V

LEAF SHAPE OF SEEDLING PLANTS OF *I. trifida*, *I. batatas* AND THEIR HYBRIDS

Parentage	Leaf Shape[a]					
	1	2	3	4	5	6
I. trifida						
Number per class	74	32	25	6	2	0
Per cent of total	53.0	23.0	18.0	4.5	1.5	0
F_1 Hybrids						
I. trifida x *I. batatas*						
Number per class	246	50	23	1	3	0
Per cent of total	77.0	15.0	7.0	0.0	1.0	0
I. batatas x *I. trifida*						
Number per class	279	72	44	2	10	2
Per cent of total	68.0	18.0	11.0	.5	2.0	.5
Total Number per class	525	122	67	3	13	2
Per cent of total	73.0	17.0	9.0	0.0	1.0	0.0
Backcrosses						
I. trifida x F_1						
Number per class	14	20	10	2	0	0
Per cent of total	30.0	44.0	22.0	4.0	0.0	0.0
I. batatas x F_1						
Number per class	18	66	31	29	27	7
Per cent of total	10.0	37.0	18.0	16.0	15.0	4.0
Total Number per class	32	86	41	31	27	7
Per cent of total	14.0	39.0	18.0	14.0	12.0	3.0
I. batatas						
Number per class	38	13	10	2	10	2
Per cent of total	51.0	17.0	13.0	3.0	13.0	3.0

[a] Classes of leaf shape are (1) entire, (2) shouldered, (3) trilobed, (4) sub-pentalobed, (5) pentalobled, and (6) sub-heptalobed.

Backcrosses: Plants of backcrosses to I. trifida produced vines which developed similarly to the "wild type" observed in I. trifida crosses; whereas backcrosses to the sweet potato developed shortened vines, rarely over 6-8 feet long with both thickened stems and petioles; also, the leaves and petioles were glabrous, e.g. similar to sweet potato lines. Backcrosses to I. trifida developed 30 per cent of the plants with entire leaves and only four per cent of the plants with leaves more parted than trilobed. The reciprocal backcross, F_1 hybrid x sweet potato, produced only a modest number of plants (10%) with entire leaves and many plants (35%) with sub-pentalobed, pentalobed, and sub-heptalobed leaves.

Root enlargement and morphology: Data are summarized in Table VI for 1,202 seedlings of I. trifida, F_1 hybrids, I. batatas, and backcrosses to each species. The roots were grouped into their respective class according to the degree of root enlargement. Figure 7 presents a visual image of the relative size and morphological appearance of representative individuals of the species, F_1 hybrids, and backcrosses.

I. trifida seedlings: The species developed mature roots similar to those described by Nishiyama (9), i.e. no secondary thickening of the roots. A distinctive vascular tissue composed of thick-walled vessels and fibers were present. The roots were long, cylindrical, and often quite crooked and with a tough skin or epidermal layer.

Hybrid seedlings: The F_1 hybrids produced individuals with a wide range of root size. A small number (4%) produced roots of a size comparable to acceptable sweet potato seedlings, whereas almost half of the population (48%) produced roots similar to those of I. trifida.

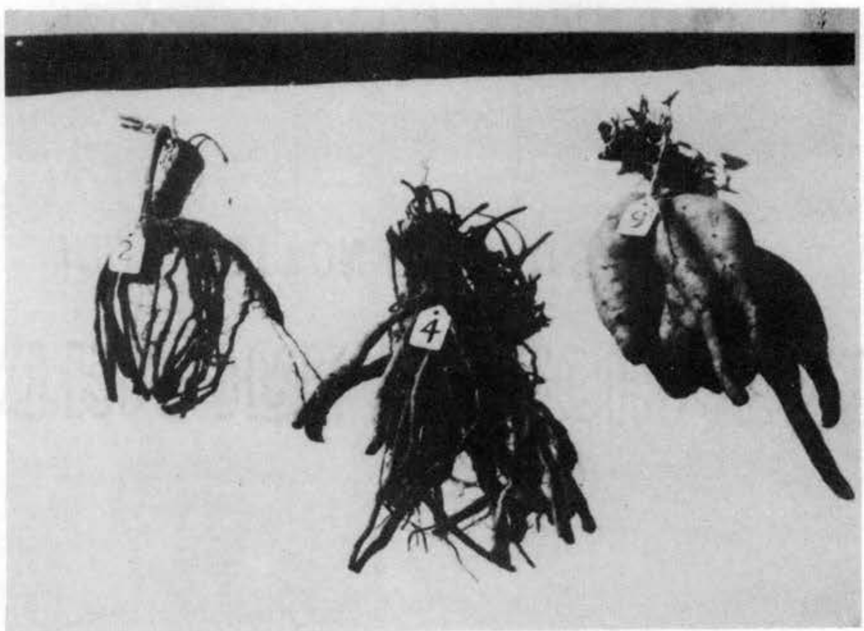

Figure 7. Root Size and Morphology of Hills of *I. trifida*, F_1 Hybrid and Backcross Seedlings. At Harvest Time, October 23, 1965. The Parentage of the Above Plants is Number 2, *I. trifida* (X2-3); Number 4, F_1 Hybrid, *I. trifida* x *I. batatas* (K_{123} x 183); Number 9, Backcross, *I. batatas* x F_1 Hybrid (183 x K_1).

TABLE VI

ROOT ENLARGEMENT OF I. trifida, I. batatas AND THEIR HYBRIDS

Parentage	Root Enlargement[a/]			
	1	2	3	4
I. trifida				
Number per class	141	0	0	0
Per cent of total	100.0	0.0	0.0	0.0
F_1 Hybrids				
I. trifida x I. batatas				
Number per class	174	125	32	5
Per cent of total	52.0	37.0	9.5	1.5
I. batatas x I. trifida				
Number per class	190	174	40	24
Per cent of total	44.0	41.0	9.0	6.0
Total Number per class	364	299	72	29
Per cent of total	48.0	39.0	9.0	4.0
Backcrosses				
I. trifida x F_1's				
Number per class	44	2	0	0
Per cent of total	96.0	4.0	0.0	0.0
I. batatas x F_1's				
Number per class	22	66	49	38
Per cent of total	13.0	38.0	27.0	22.0
Total Number per class	66	68	49	38
Per cent of total	30.0	31.0	22.0	17.0
I. batatas				
Number per class	18	8	7	43
Per cent of total	24.0	10.0	9.0	57.0

[a/] Classes of root enlargement are (1) no enlargement (< ¼" in diameter), (2) some enlargement (1/4-3/4" in diameter), (3) considerable thickening (3/4-1½" in diameter), and (4) enlargement equal to an acceptable sweet potato variety (> 1½" in diameter).

Root shape ranged from spindle shape to oblong, ellipsoidal, and cylindrical. There was a low level of cracked roots in the F_1 hybrids. Many of the roots did have russeted skins.

I. batatas seedlings: The sweet potato progenies developed a wide range of root types with respect to shape, enlargement, and development. A majority of the plants (57%) had roots without secondary thickening.

Backcrosses: Plants from the backcross to I. trifida produced a large number (96%) of the plants without thickened roots; whereas in the reciprocal backcross (sweet potato x F_1 hybrids) few plants (13%) developed in the same category and a modest number (22%) in the maximum enlargement class. In general, the root development of the I. trifida backcrosses were similar in morphological qualities to the I. trifida lines; whereas the sweet potato backcrosses were in many instances indistinguishable from the roots of sweet potato seedlings.

Skin and flesh color: The roots of all crosses involving I. trifida, hybrids, sweet potatoes, and backcrosses were grouped into three classes according to the degree of skin and flesh pigmentation. The field data taken on the individuals are summarized in Table VII.

I. trifida seedlings: In general, the roots of the seedlings failed to develop recognizable carotenoid, or anthocyanin pigments in the skin or flesh. No appreciable amount of carotene was formed in 96 per cent of the roots and no discernable quantity of skin pigmentation developed in 41 per cent of the roots. However, a sizable number of seedlings (21%) did develop roots with intense skin pigmentation (deep red and even purple).

TABLE VII

SKIN AND FLESH COLOR OF ROOTS OF I. trifida, I. batatas, AND THEIR HYBRIDS

Parentage	Skin Color[a]			Flesh Color[b]		
	1	2	3	1	2	3
I. trifida						
Number per class	58	53	30	135	6	0
F_1 Hybrids						
I. trifida x I. batatas						
Number per class	90	145	101	235	61	40
Per cent of total	27.0	43.0	30.0	70.0	18.0	12.0
I. batatas x I. trifida						
Number per class	122	195	111	259	100	69
Per cent of total	28.0	46.0	26.0	61.0	23.0	16.0
Total number per class	212	340	212	494	161	109
Per cent of total	28.0	44.0	28.0	65.0	21.0	14.0
Backcrosses						
I. trifida x F_1's						
Number per class	13	24	9	40	4	2
Per cent of total	28.0	52.0	20.0	87.0	9.0	4.0
I. batatas x F_1's						
Number per class	37	79	59	54	52	69
Per cent of total	21.0	45.0	34.0	31.0	30.0	39.0
Total number per class	50	103	68	94	56	71
Per cent of total	22.5	46.5	31.0	43.0	25.0	32.0
I. batatas						
Number per class	21	37	18	43	13	20
Per cent of total	28.0	49.0	23.0	57.0	17.0	26.0

[a] Classes of skin color are (1) white; (2) tan; faint orange or light rose; and (3) orange, red, or purple.

[b] Classes of flesh color are (1) white to cream; (2) lemon to light orange, through faint red; and (3) deep orange to intense red or purple.

Hybrid seedlings: Appreciable amounts of flesh and skin pigmentation developed in the F_1 hybrids. Many seedlings (44%) had intermediate amounts of skin pigmentation and a considerable number (21%) had moderate quantities of carotene or other flesh pigments present.

Sweet potato seedlings: The 76 sweet potato seedlings from the 185 x 106 and 185 x 178 crosses produced roots with a wide range of skin and flesh pigmentation. The skin color ranged from 28 per cent non-pigmented to 23 per cent with intense pigmentation; whereas, the flesh color ranged from 57 per cent without recognizable amounts of carotene to 26 per cent with intense carotene or other pigments present.

Backcross seedlings: The population distribution of the backcross progenies were similar to the F_1 hybrids in respect to skin pigmentation; but there were no similarities in regard to flesh pigmentation. A high level of carotene and other flesh pigments developed in 39 per cent of the backcrosses to the sweet potato; whereas, only 13 per cent of the _I. trifida_ backcross progenies developed recognizable amounts of flesh pigment.

Disease trials: Data are reported in Table VIII on 243 F_1 hybrid seedlings grown on the Oklahoma State University Farm, Perkins, Oklahoma in the summer of 1965 and evaluated for disease resistance to Southern root-knot nematode and fusarium stem rot. Many of the hybrids were highly resistant to both pathogens.

TABLE VIII

REACTION OF F_1 PLANTS OF I. trifida x I. batatas TO FUSARIUM STEM ROT AND SOUTHERN ROOT-KNOT NEMATODE

Parentage	Wilt Trials[a]			Nematode Trials[a]		
	R	I	S	R	I	S
I. trifida x I. batatas						
Number per class	42	4	5	18	9	1
Per cent of total	82.0	8.0	10.0	64.0	32.0	4.0
I. batatas x I. trifida						
Number per class	51	9	22	51	28	3
Per cent of total	62.0	11.0	27.0	61.0	34.0	5.0
Total number per class	93	13	27	69	37	4
Per cent of total	71.0	10.0	19.0	63.0	33.0	4.0

[a]Classes of disease reaction of plants were: (R) Resistant, (I) Intermediate or tolerant, (S) susceptible.

Field evaluation work was conducted in cooperation with Dr. F. Ben Struble and Professor Lou Morrison, Plant Pathologists, at Oklahoma State University.

DISCUSSION AND CONCLUSION

One of the major problems in breeding polyploid plants is the low level of fertility or the degree of incompatibility present. Any source of genes to increase the level of existing fertility would reduce the cost and shorten the time required to produce a new variety by the sweet potato breeder.

The primary purpose of this experiment was to ascertain the intra-compatibility of the two species, *I. trifida* and *I. batatas*, and the amount of fertility present in the *I. trifida* lines.

The "S" genes proposed by Wang (16), possibly prevented certain intra-species crosses. A fairly high level of incompatibility exists within the *I. trifida* lines. There appears to be a fertility factor present in one line, e.g. X1-1.

Enough differences exist in morphological characteristics so that *I. trifida*, F_1 hybrids, and backcrosses to *I. trifida* were easily recognized and distinguished from the sweet potato seedlings. Certainly, *I. trifida* does possess genes that are expressed in a "wild type" phenotype similar to "variants" that occur occasionally in sweet potato seedlings.

The F_1 hybrids were very vigorous growers. Hybrid vigor or heterosis seems to manifest itself in the F_1 generation. Backcrossing to either *I. trifida* or *I. batatas* recovered the "parent type" of each species, respectively. The presence of a substantial amount of hybrid vigor leads one to conclude that the two species or sub-species are rather distantly related.

The most notable difference between I. trifida and I. batatas was the lack of root enlargement in I. trifida. In this respect, all the I. trifida selfs and crosses appeared to be genetically similar. The F_1 hybrids received enough genes from the sweet potato parent-lines so that some hybrids did form storage roots of acceptable size. Furthermore, a second increment of root enlargement genes, by back-crossing to the sweet potato, permitted plants to develop with storage roots comparable in size to a sweet potato variety.

The roots of I. trifida possessed some distinct exterior and interior features which might be heritable. In this experiment, a lower level of cracked roots was present in the F_1 hybrids and the backcrosses. The backcrosses to the sweet potato produced roots with uniform flesh texture; whereas, the I. trifida roots possessed a distinct vascular tissue.

Although the wild species, I. trifida, possessed the ability to develop plants with a wide range of skin pigmentation, the plants developed roots with less carotene and flesh pigments than the average sweet potato seedling. A significant visual increase in skin and flesh pigmentation was present in the F_1 hybrids and backcrosses. The increase in skin pigmentation was partly the result of a greater amount of carotene present in the flesh. The orange colored flesh beneath the epidermis was visible through the epidermis and resulted in the darker skin color of the roots (5).

Results of field data taken on a small population of F_1 hybrid plants indicated that the species, I. trifida, possessed some degree of natural heritable immunity against the pathogens causing damage resulting from Southern root-knot nematode and fusarium stem rot present in the trial plots.

SUMMARY

The following is a brief resume of the findings determined during the period of the research conducted at Oklahoma State University in regard to the two species, I. trifida and I. batatas, and their cross combinations.

1. The I. trifida crosses were generally self-incompatible. Incompatible combinations, e.g. X2-1 x 106 were present in intra-species crosses.
2. I. trifida seedlings and the F_1 hybrids were climbing plants with twining vines and pubescent leaves similar to the "wild variants" found occasionally in sweet potato crosses.
3. A substantial amount of hybrid vigor or heterosis was expressed in the vigor of the F_1 hybrids.
4. Thickened roots did not develop in plants of I. trifida line crosses and selfs.
5. Both species, I. trifida and I. batatas, as well as F_1 hybrid plants produced roots with a wide range of skin pigmentation.
6. The species, I. trifida, did possess genes for carotene and other flesh pigment formation.
7. From the limited number of F_1 hybrid seedlings tested in field plots there appeared to be several lines resistant to Southern root-knot nematode and fusarium stem rot.

The results of this investigation gives some support to the proposal that *I. trifida* may be the ancestral plant from which the cultivated sweet potato was propagated. Presently, there does not appear to be a more logical parent form known. The wild species, *I. trifida*, does offer a source of germ plasm to be used in breeding work.

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APPENDIX

TABLE IX

LEAF SHAPE AND ROOT ENLARGEMENT OF SEEDLING PLANTS OF *I. trifida* AND *I. batatas*

Parentage	Leaf Shape[a/]							Root Enlargement[b/]				
	1	2	3	4	5	6	Total	1	2	3	4	Total
I. trifida												
X1-1 "S_1"[c/]	3	10	8				21	22				22
X1-1 x X2-1	8	8	13	4	2		35	35				35
X1-1 x X2-3	28	1					29	30				30
X2-2 x X2-1	7	7	2	2			18	18				18
X2-3 "S"[c/]	3	1	1				5	5				5
X2-3 x X1-1	13	2	1				16	16				16
X2-3 x X2-1	6	2					8	8				8
X2-3 x X2-2	6	1					7	7				7
Total per class	74	32	25	6	2		139	141	0	0	0	141
Per cent per class	53.0	23.0	18.0	4.5	1.5	0.0	100.0	100.0	0.0	0.0	0.0	100.0
I. batatas												
185 x 106	11	8	5	2	10	2	38		3	1	35	39
185 x 178	27	5	5				37	18	5	6	8	37
Total per class	38	13	10	2	10	2	75	18	8	7	43	76
Per cent per class	51.0	17.0	13.0	3.0	13.0	3.0	100.0	24.0	10.0	9.0	57.0	100.0

a/ Leaf shape classes are defined in Table V.

b/ Root enlargement classes are defined in Table VI.

c/ The "S" indicates the selfed lines.

TABLE X

LEAF SHAPE AND ROOT ENLARGEMENT OF F_1 HYBRID SEEDLING PLANTS OF *I. trifida* x *I. batatas*

Parentage F_1 Hybrids	Leaf Shape[a/]							Root Enlargement[b/]				
	1	2	3	4	5	6	Total	1	2	3	4	Total
X1-1 x 38	38	4					42	10	32			42
X1-1 x 106	26	13	8				47	39	6	3		48
X1-1 x 178	34	5	1				40	27	9	6		42
X1-1 x 183	38	1	1				40	33	12			45
X1-1 x 185	11	5	7				23	11	9	3	1	24
X2-1 x 190	3						3	3				3
X2-2 x 161	17	6					23	6	12	4	1	23
X2-2 x 183	19	3	1				23	10	10	5		25
X2-2 x 184	12	2					14	7	3	3	2	15
X2-3 x 38	6						6	2	4			6
X2-3 x 106	14	7	3	1	2		27	11	12	3	1	27
X2-3 x 161	12						12	3	7	2		12
X2-3 x 183	3		1				4	1	2	1		4
X2-3 x 184	3						3	3				3
X2-3 x 185	2	2	1		1		6	4	1	1		6
X2-3 x 190	8	2					10	4	6	1		11
Total per class	246	50	23	1	3	0	323	174	125	32	5	336
Per cent per class	77.0	15.0	7.0	0.0	1.0	0.0	100.0	52.0	37.0	9.5	1.5	100.0

[a/] Leaf shape classes are defined in Table V.

[b/] Root enlargement classes are defined in Table VI.

TABLE XI

LEAF SHAPE AND ROOT ENLARGEMENT OF F_1 HYBRID SEEDLING PLANTS OF _I. batatas_ x _I. trifida_

Parentage F_1 Hybrids	Leaf Shape[a/]							Root Enlargement[b/]				
	1	2	3	4	5	6	Total	1	2	3	4	Total
F_{34} x X1-1	12	7	5	1	5	2	32	17	13	1	1	32
F_{34} x X2-1	7	2			2		11	6	6			12
F_{34} x X2-3	8	1	2		1		12	5	5	2		12
38 x X1-1	20	7	4				31		4	9	19	32
177 x X1-1	13	4	5				22	8	14	3		25
177 x X2-1	11	3	1	1			16	3	10	3		16
177 x X2-3	10	6	6				22	10	7	2	2	21
183 x X1-1	30	2					32	17	13	2		32
185 x X1-1	4	1	2				7	2	4	1		7
185 x K_{123}	10	2	7				19	5	10	3		18
189 x X1-1	16	4	2				22	17	5	1	1	24
189 x X2-1	6						6	3	4			7
189 x X2-3	3	1					4	2	2			4
190 x [illegible]-1	52	11	4				67	42	29	3		74
190 x X2-1	17	1					18	8	10	1		19
190 x X2-3	30	9					39	23	15	2		40
196 x X2-3	29	10	6		1		46	20	22	7	1	50
292 x X1-1	1	1			1		3	2	1			3
Total per class	279	72	44	2	10	2	409	190	174	40	24	428
Per cent per class	68.0	18.0	11.0	.5	2.0	.5	100.0	44.0	41.0	9.0	6.0	100

a/ Leaf shape classes are defined in Table V.

b/ Root enlargement classes are defined in Table VI.

TABLE XII

LEAF SHAPE AND ROOT ENLARGEMENT OF BACKCROSS SEEDLING PLANTS FROM F_1 HYBRID x _I. trifida_ AND _I. batatas_

Parentage Backcrosses	Leaf Shape[a]							Root Enlargement[b]				
	1	2	3	4	5	6	Total	1	2	3	4	Total
I. trifida x F_1's												
X1-1 x K_1[c]	6	12	4				22	19	2			21
X1-1 x K_2	4	2	2	1			9	10				10
X2-3 x K_1	4	5	3				12	12				12
X2-3 x K_2		1		1			2	2				2
K_2 x X2-3			1				1	1				1
Total per class	14	20	10	2			46	44	2			46
Per cent per class	30.0	44.0	22.0	4.0	0.0	0.0	100.0	96.0	4.0	0.0	0.0	100.0
I. batatas x F_1's												
F_{34} x K_2[c]	2	1					3	2	1			3
161 x K_1	1	4					5		1	2	2	5
161 x K_2	5	4	1				10		4	4	2	10
161 x K_3	1	5	2		3	1	12	1	2	3	6	12
177 x K_1					1		1		1			1
183 x K_2	2	5	5	3	1		16		4	7	4	15
184 x K_3		2	4	4	1		11		2	6	3	11

(continued)

TABLE XII (Continued)

Parentage Backcrosses	Leaf Shape[a] 1	2	3	4	5	6	Total	Root Enlargement[b] 1	2	3	4	Total
I. batatas x F_1's (continued)												
185 x K_1[c]	1	9	2	8	3	3	26	1	10	6	9	26
185 x K_2	5	26	12	13	15	2	73	4	35	20	11	70
190 x K_1		2					2	2				2
190 x K_2	1	4	4	1	3	1	14	12	2		1	15
K_2 x 161		2					2		2			2
K_1 x 183		2	1				3		2	1		3
Total per class	18	66	31	29	27	7	178	22	66	49	38	175
Per cent per class	10.0	37.0	18.0	16.0	15.0	4.0	100.0	12.0	38.0	28.0	22.0	100

[a] Leaf shape classes are defined in Table V.

[b] Root enlargement classes are defined in Table VI.

[c] K's are K-lines so: $K_1 = K_{123}$ x 161; $K_2 = K_{123}$ x 185; $K_3 = K_{123}$ x 183.

TABLE XIII

SKIN AND FLESH COLOR RATINGS OF ROOTS OF SEEDLING PLANTS OF *I. trifida* AND *I. batatas*

Parentage	Skin Color[a/]				Flesh Color[b/]			
	1	2	3	Total	1	2	3	Total
X1-1"S_1"[c/]	5	10	7	22	16	5		22
X1-1 x X2-1	11	10	14	35	35			35
X1-1 x X2-3	21	8	1	30	30			30
X2-2 x X2-1	14	4		18	18			18
X2-3"S"[c/]	2	3		5	5			5
X2-3 x X1-1		11	5	16	16			16
X2-3 x X2-1	1	4	3	8	8			8
X2-3 x X2-2	4	3		7	7			7
Total per class	58	53	30	141	135	6		141
Per cent per class	41.0	38.0	21.0	100.0	96.0	4.0	0.0	100.0
I. batatas								
185 x 106	9	25	5	39	21	6	12	39
185 x 178	12	12	13	37	22	7	8	37

[a/] Skin color classes are defined in Table VII.

[b/] Flesh color classes are defined in Table VII.

[c/] The "S" indicates the selfed lines.

TABLE XIV

SKIN AND FLESH COLOR RATINGS OF ROOTS OF F_1 HYBRID SEEDLING PLANTS OF I. trifida x I. batatas

Parentage F_1 Hybrids	Skin Color[a]				Flesh Color[b]			
	1	2	3	Total	1	2	3	Total
X1-1 x 38	6	19	17	42	39	3		42
X1-1 x 106	3	10	35	48	44	3	1	48
X1-1 x 178	12	24	6	42	18	8	16	42
X1-1 x 183	17	21	7	45	34	8	3	45
X1-1 x 185	7	14	3	24	14	2	8	24
X2-1 x 190	1	1	1	3	2	1		3
X2-2 x 161	4	8	11	23	14	8	1	23
X2-2 x 183	7	11	7	25	15	7	3	25
X2-2 x 184	7	7	1	15	12	3		15
X2-3 x 38	3		3	6	5	1		6
X2-3 x 106	11	12	4	27	17	6	4	27
X2-3 x 161	3	5	4	12	9	2	1	12
X2-3 x 183	1	2	1	4	2	2		4
X2-3 x 184	1	1	1	3	2	1		3
X2-3 x 185	1	5		6	3	1	2	6
X2-3 x 190	6	5		11	5	5	1	11
Total per class	90	145	101	336	235	61	40	336
Per cent per class	27.0	43.0	30.0	100.0	70.0	18.0	12.0	100.0

a/ Skin color classes are defined in Table VII.

b/ Flesh color classes are defined in Table VII.

TABLE XV

SKIN AND FLESH COLOR RATINGS OF ROOTS OF F_1 HYBRID SEEDLING PLANTS OF I. batatas x I. trifida

Parentage F_1 Hybrids	Skin Color[a/]				Flesh Color[b/]			
	1	2	3	Total	1	2	3	Total
F_{34} x X1-1	18	14		32	26	4	2	32
F_{34} x X2-1	9	2	1	12	11	1		12
F_{34} x X2-3	11	1		12	11	1		12
38 x X1-1	4	16	12	32	6	6	20	32
177 x X1-1			25	25	25			25
177 x X2-1	1	2	13	16	16			16
177 x X2-3	1	5	15	21	19	2		21
183 x X1-1	9	20	3	32	20	7	5	32
185 x X1-1		7		7	1		6	7
185 x K123	5	7	6	18	9	2	7	18
189 x X1-1	10	10	4	24	23	1		24
189 x X2-1		4	3	7	3	2	2	7
189 x X2-3	4			4	4			4
190 x X1-1	15	49	10	74	29	31	14	74
190 x X2-1	3	10	6	19	7	10	2	19
190 x X2-3	15	25		40	14	24	2	40
196 x X2-3	15	22	13	50	32	9	9	50
292 x X1-1	2	1		3	3			3
Total per class	122	195	111	428	259	100	69	428
Per cent per class	28.0	46.0	26.0	100.0	61.0	23.0	16.0	100.0

[a/] Skin color classes are defined in Table VII.
[b/] Flesh color classes are defined in Table VII.

TABLE XVI

SKIN AND FLESH COLOR RATINGS OF ROOTS OF BACKCROSS SEEDLING PLANTS FROM F_1 HYBRID x *I. trifida* AND *I. batatas*

Parentage Backcrosses	Skin Color[a] 1	2	3	Total	Flesh Color[b] 1	2	3	Total
I. trifida x F_1's								
X1-1 x K_1[c]	8	10	3	21	19		2	21
X1-1 x K_2	3	4	3	10	10			10
X2-3 x K_1		10	2	12	8	4		12
X2-3 x K_2	2			2	2			2
K_2 x X2-3			1	1	1			1
Total per class	13	24	9	46	40	4	2	46
Per cent per class	28.0	52.0	20.0	100.0	87.0	9.0	4.0	100.0
I. batatas x F_1's								
F_{34} x K_2[c]	1	2		3	1	1	1	3
161 x K_1		4	1	5	1	3	1	5
161 x K_2	4	2	4	10	6		4	10
161 x K_3	3	7	2	12	6	1	5	12
177 x K_1			1	1			1	1
183 x K_2	6	6	3	15	7	4	4	8
184 x K_3	7	2	2	11	9		2	11
185 x K_1	2	18	6	26	5	6	15	26
185 x K_2	13	28	29	70	19	24	27	70
190 x K_1		1	1	2		2		2
190 x K_2	1	5	9	15		9	6	15
K_2 x 161		1	1	2		1	1	2
K_1 x 183		3		3		1	2	3
Total per class	37	79	59	175	54	52	69	175
Per cent per class	21.0	45.0	34.0	100.0	31.0	30.0	39.0	100.0

[a] Skin color classes are defined in Table VII.

[b] Flesh color classes are defined in Table VII.

[c] K's are K-lines so: $K_1=K_{123}$x161; $K_2=K_{123}$x 185; $K_3=K_{123}$x 183.

TABLE XVII

REACTION OF SEEDLING PLANTS IN CROSSES OF I. trifida x I. batatas TO FUSARIUM STEM ROT AND SOUTHERN ROOT-KNOT NEMATODE

Parentage	Wilt Trial[a/]				Nematode Trial[a/]			
	R	I	S	Total	R	I	S	Total
I. trifida x I. batatas								
X1-1 x 185	6	1	1	8	4	1	1	5
X2-1 x 106	9		1	10	3	2		5
X2-1 x 161	8	1	1	10		3	1	4
X2-2 x 183	8		1	9	7	2		9
X2-3 x 106	8	1		9	4	1		5
X2-3 x 185	3	1	1	5				
Total per class	42	4	5	51	18	9	1	28
Per cent per class	82.0	8.0	10.0	100.0	64.0	32.0	4.0	100.0
I. batatas x I. batatas								
F_3 x K_{123}					2	1		3
149 x X1-1	4		2	6	5			5
161 x K_{123}	4		3	7				
177 x X1-1	9			9	7	3		10
183 x K_{123}					1	4	1	6
184 x X1-1					5	3		8
184 x X2-1	3	1	3	7				
185 x X1-1	2	3	4	9	9			9
185 x X2-3	5		2	7	2	1		3
190 x X1-1	14	3	4	21	12	3	1	16
190 x X2-1	6		2	8	1	3	1	5
190 x X2-3						1		1
196 x X1-1	4	2	2	8	7	9		16
Total per class	51	9	22	82	51	28	3	82
Per cent per class	62.0	11.0	27.0	100.0	62.0	34.0	4.0	100.0

[a/] Classes of disease reaction of plants were: (R) Resistant; (I) Intermediate or tolerant; (S) Susceptible.

VITA

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Master of Science

Thesis: A STUDY OF *Ipomea trifida* F_1 HYBRIDS AND BACKCROSSES BETWEEN *I. trifida* x *I. batatas*

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