Insect Resistance in Sweetpotato Plant Introductions

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Abstract. One hundred U.S. sweetpotato [*Ipomoea batatas* (L.) Lam.] plant introductions (PIs) and four control cultivars were screened for insect injury in 1993. Of the least injured by insects, 56 and 31 were tested again in 1994 and 1995, respectively. Among control cultivars, the most highly resistant was 'Regal' (moderately resistant), followed by 'Beauregard' (susceptible), 'Centennial' (susceptible), and 'Jewel' (susceptible). Stem and root injury by the sweetpotato weevil (SPW) [*Cylas formicarius elegantulus* (Summers)] and root injury by the wireworm (*Conoderus* sp.)–*Diabrotica* sp. (cucumber beetle)–*Systema* sp. (flea beetle) (WDS) complex were measured. SPW stem injury was less severe ($P \leq 0.05$) in 1994 and 1995 in PIs 508523, 531116, and 564107 than in control cultivars. PIs 508523 and 531116 also suffered less SPW root injury than did 'Regal'. In the six PIs with least SPW root injury, PIs 538354, 564149, 508523, 538286, 531116, and 564103, 70% to 85% of the roots were not injured compared with 36% in 'Regal' and 6% in 'Jewel'. SPW root injury scores (0 = no injury; 5 = severe injury) in those PIs averaged 0.5 vs. 2.3 for 'Regal'. Only in PI 538286 was WDS injury to roots less than in 'Regal' over 2 years. However, eight additional accessions suffered less WDS injury than 'Regal' in 1995 and four of those were among the six with least SPW injury. The lower levels of combined insect injury found in these four PIs (compared to 'Regal') show that PIs have potential use for increasing insect resistance in sweetpotato improvement programs.

The sweetpotato weevil (SPW) is the most destructive pest of sweetpotato worldwide (Chalfant et al., 1990). The only pandemic *Cylas* species is *C. formicarius*; it is the only species occurring in the United States (Wolfe, 1991). Greatest losses from SPW injury in the United States occur in the southernmost production areas of the southeastern states (Sorensen, 1984). Losses are avoided in northern areas by state-administered quarantines to restrict movement of the insect. However, many losses continue to occur in previously weevil-free locations because of spread of the insect from infested areas.

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Adult SPW feed on above- and below-ground plant parts and oviposit in stems and storage roots. Larvae feed and develop inside the root and render it inedible. Insecticidal control is difficult because of inaccessibility of immature stages of the insect within the root. In addition, the host range of the SPW, including sweetpotatoes and related *Ipomoea* sp., and possible movement of the weevil in commercial sweetpotatoes contribute to the difficulty of control.

Low levels of SPW resistance have been found and can be increased by breeding (Hahn and Leuschner, 1981; Mullen et al., 1985). Hahn and Leuschner (1981) initiated a program in 1971 to breed for resistance to the African SPW (*Cylas puncticollis* Boh.). Resistance to stem and root injury was increased by selection, and a highly significant correlation of 0.74 between root and shoot injury was observed.

Mullen et al. (1985) evaluated breeding lines developed for increased insect resistance, and found severity of root injury by the SPW to the susceptible check 'Centennial' over 2.5

times as great as injury to the breeding line released as 'Regal' (Jones et al., 1985).

Other soil-inhabiting insects, including those in the wireworm (*Conoderus* sp.)–*Diabrotica* sp. (cucumber beetle)–*Systema* sp. (flea beetle) (WDS) complex are also injurious to sweetpotato storage roots and are serious sweetpotato pests in the United States. Injury caused by larvae of the WDS complex is primarily to the surface of storage roots, affecting their appearance and grade. Insecticidal control is often ineffective in preventing injury by these insects and considerable losses are often incurred. The cultivars Resisto, Southern Delite, and Regal (Jones et al., 1987) were reported to have resistance to WDS injury. An integrated pest management (IPM) program would be the most effective insect control measure for SPW and the WDS complex, but increased host-plant resistance to these insects is needed for such a program to be effective.

We began a breeding program for insect resistance in 1990, using the most advanced plant materials from the aforementioned programs, and determined that a moderate rate of gain in resistance levels is possible through intermating and selection (Thompson et al., 1994). Although these materials are useful, additional insect-resistant sweetpotato sources must be identified so that the genetic base and range of resistance levels can be increased more rapidly. The objective of this research was to identify additional sources of resistance to the SPW and the WDS insect complex by evaluating germplasm from the U.S. Plant Introduction collection.

Table 1. U.S. sweetpotato plant introductions (PI) evaluated for insect resistance and their countries of origin.

PI	Country of origin
304088	Mexico
315342	Philippines
318858	Peru
399163	Guatemala
439749	Mexico
508506	Japan
508508	Japan
508509	Japan
508510	Korea
508511	Australia
508513	Brazil
508514	PR China
508515	PR China
508517	PR China
508519	PR China
508520	PR China
508521	PR China
508523	Guatemala
508525	Puerto Rico
508528	United States
508529	Puerto Rico
508530	Venezuela
508531	Venezuela
531096	Guatemala
531107	Peru
531116	Nigeria

continued on next page

Table 1. Continued.

PI	Country of origin
531118	Peru
531121	Peru
531122	United States
531123	Peru
531124	Peru
531125	Peru
531130	Peru
531133	Peru
531134	Costa Rica
531135	Costa Rica
531136	Mexico
531137	Mexico
531139	Costa Rica
531140	Costa Rica
531141	Taiwan
531144	Taiwan
531145	Taiwan
531146	Taiwan
531147	Taiwan
531149	Peru
531150	Peru
531152	Peru
531154	Peru
531156	Peru
531159	Peru
531166	Peru
531168	Peru
531169	Peru
538286	Peru
538288	Peru
538289	Peru
538291	Peru
538305	Peru
538307	Guatemala
538308	Guatemala
538309	Guatemala
538343	Puerto Rico
538344	Puerto Rico
538345	Puerto Rico
538348	Puerto Rico
538351	Puerto Rico
538352	Puerto Rico
538354	Puerto Rico
556936	Taiwan
564095	Peru
564096	Peru
564097	Peru
564098	Peru
564099	Peru
564100	Peru
564101	Peru
564102	Peru
564103	Peru
564104	Peru
564105	Peru
564106	Peru
564107	Peru
564108	Peru
564110	Peru
564111	Peru
564112	Peru
564113	Peru
564114	Peru
564115	Peru
564116	Taiwan
564117	Taiwan
564118	Taiwan
564119	Taiwan
564120	Taiwan
564121	Nigeria
564122	Tonga
564123	Tonga
564124	Western Samoa
564125	Western Samoa

continued

Table 1. Continued.

PI	Country of origin
564127	Western Samoa
564128	Solomon Islands
564129	Solomon Islands
564130	Solomon Islands
564131	Solomon Islands
564132	Papua New Guinea
564133	Papua New Guinea
564137	Papua New Guinea
564138	Papua New Guinea
564140	Papua New Guinea
564143	Papua New Guinea
564144	Papua New Guinea
564145	Papua New Guinea
564146	Papua New Guinea
564147	Papua New Guinea
564148	Papua New Guinea
564149	Papua New Guinea
564150	Papua New Guinea
564151	Papua New Guinea
564154	Papua New Guinea
564155	Papua New Guinea
564156	Philippines
564158	Puerto Rico
564161	Puerto Rico
564162	Puerto Rico

Materials and Methods

Plant materials. One hundred sweetpotato plant introductions (PIs) of diverse origins were selected based on availability from the U.S. germplasm collection at Experiment, Ga. (Table 1). These and four control cultivars were field evaluated for SPW and WDS injury in preliminary trials in 1993 (data not presented). Based on the percentage of uninjured roots, severity of insect injury, and a minimum storage root yield, 56 of those PIs were retested in 1994. Thirty-one of those PIs were tested again in 1995, along with 25 PIs not previously tested (Tables 2 and 3). Results from accessions included in 1994 and 1995 are reported here. The controls and their previously determined resistance levels to SPW, based on the percentage of weevil-infested roots and crown injury (Mullen et al., 1985), and to the WDS complex, based on percentage of injury-free roots and a severity index (Jones et al., 1987), were 'Centennial' (susceptible), 'Jewel' (susceptible), and 'Regal' (moderately susceptible/resistant).

Insects. During the winter before each evaluation, SPW were collected from storage roots infested the previous season in producers' fields at four to six Mississippi locations. They were cultured on storage roots in 1.1-L glass jars. Wild SPW were increased separately by location of origin over three generations, after which 20 males were placed with 20 females from a different location in each of a series of jars. The insects were allowed to oviposit in roots for a 7-d period. Adults that emerged from those roots for a period of 7-d were used for field infestation. Therefore, adult SPW 1 to 7 d old were used for infestation. Evaluation of WDS injury was based on naturally occurring insects.

Resistance evaluation. Field evaluations were conducted at the South Mississippi Branch Experiment Station in Beaumont, Miss., which

is in a SPW-infested area, but SPW weevil populations were low. Injury appeared to be exclusively from applied weevils, since few weevils were caught in pheromone traps before releases were made at the beginning of sweetpotato storage root enlargement. Consistently high WDS injury was observed on sweetpotatoes grown in previous years at the test site and naturally occurring insect levels were considered adequate for evaluations.

Plant introductions were received as plants derived from nodal explants in Dec. 1992 and increased by stem cuttings for field evaluations in 1993. Most plants were propagated from storage roots in 1994 and 1995, with a few clones being increased from plants maintained in a greenhouse. On 10–13 May 1994 and 17–19 May 1995, plants were transplanted to five plant field plots in a randomized block design with eight replications. Plants were spaced 36 cm apart in rows 1 m apart.

Field infestation of SPW was repeated for two infestation times in 1994 and 1995. The SPW increase was timed to coincide with storage root enlargement based on 1993 results. The first infestation was completed when all accessions had started storage root enlargement (64 d after transplanting in both years) as determined by examining plants outside the experimental area. Therefore, storage roots of all entries were available for infestation at the time of SPW release. Seven days after first SPW emergence from roots used for increase (15 July and 15 Aug. 1994, and 20 July and 10 Aug. 1995) roots were placed in containers with open bottoms and suspended from rods 1.3 m high in sweetpotato plots. Containers with closed tops were suspended above the plots to prevent storage root destruction by contact with soil, rainwater, and rodents. One container was centrally placed between every two plots. Since SPW were released the same distance from all PIs, distance from the source should not have influenced differences in injury among PIs. Nearly equal quantities (by weight) of roots were placed in each container. Random samples of containerized roots were monitored to determine numbers of SPW. Based on those observations, an average of 16 SPW per plant was applied.

On 26–28 Oct. 1994, and again on 14–16 Nov. 1995, stems were cut 25 cm above the soil surface and plants with storage roots attached were dug and placed in bags. Stem and storage root WDS and SPW injury evaluations were completed 31 Oct. to 10 Nov. 1994 and 27 Nov. to 6 Dec. 1995. Measurements taken were root numbers, root weights, numbers of WDS, and SPW-injured roots, SPW-injured stems, and scores for WDS root injury and SPW stem and storage root injury. SPW stem injury was scored by observing injury from the point of first storage root attachment to a point 10 cm above the soil surface. Stem injury ratings were: 0 = no injury, 1 = 1% to 20% injured tissue, 2 = 21% to 40%, 3 = 41% to 60%, 4 = 61% to 80%, and 5 = 81% to 100%, and root injury ratings were: 0 = no injury, 1 = larval tunnels 0.1–5 mm deep and 0.1% to 6% internal tissue injury, 2 = tunnels 5.1–10 mm deep and 6.1% to 12% tissue injury, 3 =

Table 2. SPW injury to sweetpotato plant introductions (PI) and to four commercial cultivars in 1994 and 1995.

PI/cultivar	Roots not injured (%) ^y	Injury score ^z		
		Stem		Root ^y
		1994	1995	
538354	85 a ^x	2.0 a-c	3.8 e-h	0.4 ab
564149	84 a	2.6 d-g	3.6 c-f	0.6 a-c
508523	84 a	1.7 ab	3.5 b-e	0.6 a-c
538286	77 ab	1.5 a	4.3 jk	0.3 a
531116	76 a-c	1.6 ab	3.3 bc	0.6 a-c
564103	70 a-d	2.8 e-h	4.3 jk	0.3 a
531133	69 a-d	3.2 g-i	3.8 e-h	0.9 a-e
531118	65 a-d	2.7 d-g	4.5 k	1.0 a-f
564138	62 b-e	2.6 d-g	3.9 f-i	2.1 f-j
531159	58 b-f	3.2 g-i	4.1 h-k	1.3 b-g
315342	56 c-g	2.1 a-d	4.0 g-j	0.7 a-d
531130	56 c-g	2.7 d-g	4.0 g-j	1.6 c-i
564145	56 c-g	2.4 c-f	4.2 i-k	1.1 a-f
531135	55 d-h	3.4 hi	3.9 f-i	1.1 a-f
564115	55 d-h	2.2 b-e	4.0 g-j	0.9 a-e
508511	53 d-h	2.1 a-d	3.9 f-i	1.3 b-g
508525	53 d-h	2.7 d-g	3.9 f-i	1.7 c-i
564106	51 d-h	2.7 d-g	3.4 b-d	0.9 a-e
531122	44 e-i	2.8 e-h	3.5 b-e	1.8 d-i
538345	42 e-i	2.2 b-e	3.6 c-f	1.4 b-h
531149	42 e-i	2.2 b-e	3.2 b	1.1 a-f
531139	39 f-j	2.7 d-g	4.0 g-j	1.6 c-i
Regal	36 g-j	2.7 d-g	4.1 h-k	2.3 g-k
531147	36 g-j	3.1 g-i	3.8 e-h	1.5 b-h
531123	35 h-j	2.0 a-c	4.0 g-j	1.9 e-i
564133	29 i-k	3.4 hi	4.2 i-k	2.7 i-l
564107	29 i-k	1.8 a-c	3.7 d-g	2.5 h-l
531134	27 i-l	2.6 d-g	4.0 g-j	2.5 h-l
304088	26 i-m	3.2 g-i	4.0 g-j	3.2 j-l
531136	21 j-m	2.6 d-g	4.2 i-k	3.3 kl
531146	20 j-m	3.1 g-i	4.2 i-k	2.3 g-k
531168	12 k-m	2.8 e-h	2.7 a	1.9 e-i
Centennial	12 k-m	3.7 i	4.1 h-k	3.4 kl
Beauregard	8 lm	3.4 hi	4.2 i-k	3.5 l
Jewel	6 m	3.0 f-h	4.2 i-k	3.6 l
PI × year	NS	*	*	NS

^xRated on a scale of 0 to 5; 0 = no injury and 5 = severe injury. See text for descriptions.^yMeans for 1994 and 1995.^zMean separation within columns by LSD ($P \leq 0.05$).ns, *Nonsignificant or significant at $P \leq 0.05$, respectively.

tunnels 10.1–15 mm deep and 12.1% to 24% tissue injury, 4 = tunnels 15.1–20 mm deep and 24.1% to 48% tissue injury, and 5 = tunnels >20 mm deep and 48.1% to 100% tissue injury. Severity of WDS root injury was scored based on number of feeding scars where 0 = no scars, 1 = 1 to 5 scars, 2 = 6 to 10 scars, 3 = 11 to 15 scars, and 4 = more than 15 scars.

Results and Discussion

Stem injury by SPW was more severe in 1995 than in 1994 (Table 2). The mean stem injury scores over all entries were 2.6 and 3.9 in 1994 and 1995, respectively. The PI × year interaction for stem injury was significant. The reported resistance levels of the four control cultivars to root injury were not observed for stem injury, since few differences among the controls were found (Table 2). The PIs 508523, 531116, and 564107 had lower stem injury scores in both years than did the controls ($P \leq 0.05$).

The percentage of roots not injured by SPW was greater in the 10 least-injured PIs than in 'Regal' and greater in 24 PIs than in the susceptible control 'Centennial' (Table 2). Fifty-eight percent to 85% of the roots of those 10 PIs were not injured, compared with 36% in

'Regal' and 12% in 'Centennial'. Of the 10 PIs with less root injury than 'Regal', eight had lower SPW injury scores than did 'Regal' (Table 2). The 24 PIs with fewer injured roots than 'Centennial' also had lower injury scores than did 'Centennial'. The root injury scores ranged from 0.3 to 1.0 in the eight least-injured PIs vs. 2.3 in 'Regal' and 3.4 in 'Centennial'. Therefore, severity of root injury was 2.3 to 7.7 times greater in 'Regal' than in the least-injured PIs.

The PI × year interaction for percentage of SPW injury and injury score was nonsignificant at $P \leq 0.05$. The low genotype × environment interactions for SPW root injury in this study differed from the report by Thompson et al. (1994), who estimated genetic variances of a breeding population and found that genotype × environment interactions were significant.

The only PI that had a greater percentage of WDS-uninjured roots than 'Regal' in both years was PI 538286 ($P \leq 0.05$) (Table 3). PIs 538354 and 564107 had a greater percentage of WDS-uninjured roots than 'Regal' in 1994, but they did not differ in 1995. Several of the highest ranking PIs that did not differ from 'Regal' in 1994 had greater percentage of uninjured roots in 1995 than 'Regal'. Differences among PIs and 'Regal' in WDS injury

scores paralleled those for percentage of uninjured roots. Scores for 'Regal' were higher than those for PI 538286 in both years, for PIs 524107 and 531116 in 1994, and for several PIs in 1995. Most of those in the last category also had greater percentage of uninjured roots than did 'Regal' in 1995.

Of the six PIs with lower SPW injury levels than 'Regal', PIs 564103, 538286, and 508523 were also among the six injured least by WDS and differed from 'Regal' in percentage of WDS-uninjured roots and severity of root injury in 1995.

Considering the relationship between stem and root injury scores, agreement in PI rankings was apparent, but there were exceptions (Table 2). For example, of the three PIs with least stem injury, 531116 and 508523 had greater percentage of uninjured roots and lower root injury scores in both years than did 'Regal', but root injury in PI 564107 was similar to that in 'Regal'. The lack of precise agreement was reflected in the partial correlation coefficient between stem injury and root injury of 0.19 ($P \leq 0.01$), which was lower than the 0.74 reported by Hahn and Leuschner (1981). A strong relationship was observed between SPW and WDS injury levels. Partial correlations in percentage of and in injury scores were 0.46 and 0.68 ($P \leq 0.01$), respectively.

Results of this study show that additional sources of resistance to SPW and to the WDS insect complex are available in plant introductions. Eight PIs suffered less SPW injury to roots than did the most resistant cultivar ('Regal') and two of those also had lower stem injury. In addition, WDS injury was lower than in 'Regal' in four of these PIs in at least one year. Several additional PIs did not differ significantly from 'Regal' in injury, but were less severely injured than were the remaining check cultivars. Therefore, additional sources of genes for insect resistance are available, and, when combined with those presently being used, should result in more rapid progress in increasing resistance.

The high correlation between freedom from SPW and WDS injury in these PIs is beneficial since increased resistance levels to both insect groups can be obtained from the same sources. Similarly, the correlation between freedom from SPW injury to stem and to roots indicates that resistance to both types of injury is available from some of the same sources.

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Table 3. Injury to sweetpotato plant introductions (PI) and four commercial cultivars by WDS complex (*Conoderus*, *Diabrotica*, and *Systema* sp.) in 1994 and 1995.

PI	Noninjured roots (%)		Injury score ^z	
	1994	1995	1994	1995
538286	51 a ^y	47 c-e	0.4 a	0.9 b-f
564107	50 ab	0 l	0.5 ab	2.1 j-n
538354	43 a-c	29 d-i	0.9 a-d	1.2 c-i
564103	33 b-d	100 a	1.1 b-f	0.0 a
508523	32 cd	41 c-f	0.9 a-d	1.1 b-h
564149	27 c-e	26 e-k	1.2 c-g	1.4 e-j
531116	26 c-e	10 i-l	0.7 a-c	1.3 d-i
508525	20 d-f	14 h-l	1.5 d-j	1.7 g-k
564106	19 d-g	29 d-i	1.0 a-e	1.5 e-j
564115	17 d-h	50 cd	1.2 c-g	1.5 e-j
Regal	16 d-h	16 g-l	1.5 d-j	1.9 i-m
531130	14 e-h	50 cd	1.5 d-j	1.1 b-h
564138	14 e-h	20 f-l	1.3 c-h	1.5 e-j
564145	13 e-h	16 g-l	1.5 d-j	1.7 g-k
531147	13 e-h	75 b	1.6 e-j	0.4 ab
531122	12 e-h	34 c-h	1.7 f-j	0.9 b-f
315342	11 e-h	52 c	1.4 d-i	0.6 a-d
304088	11 e-h	0 l	1.9 h-l	1.0 b-g
531135	10 e-h	10 i-l	1.2 c-g	1.3 d-i
538345	7 f-h	27 e-j	1.6 e-j	1.1 b-h
508511	7 f-h	6 j-l	1.5 d-j	1.6 f-j
531123	7 f-h	13 h-l	1.4 d-i	1.4 e-j
531146	6 f-h	1 l	1.7 f-j	2.7 n
531159	6 f-h	22 f-l	1.4 d-i	1.8 h-l
531136	5 f-h	15 h-l	2.4 k-n	2.6 mn
Jewel	4 f-h	1 l	2.5 l-n	2.8 n
564133	2 gh	5 j-l	2.0 i-m	1.7 g-k
531118	1 h	18 g-l	1.3 c-h	1.4 e-j
Beauregard	1 h	6 j-l	2.6 mn	2.5 l-n
531133	0 h	51 cd	1.0 a-e	0.8 b-e
531168	0 h	50 cd	2.1 j-n	0.5 a-c
531139	0 h	16 g-l	1.8 g-k	1.4 e-j
531149	0 h	38 c-g	1.8 g-k	0.6 a-d
Centennial	0 h	4 kl	2.7 n	2.5 l-n
531134	0 h	19 f-l	1.7 f-j	2.4 k-n
PI × year	*	*	*	*

^zBased on number of feeding scars; 0 = no scars, 1 = one to five scars, 2 = six to 10 scars, 3 = 11 to 15 scars, and 4 = more than 15 scars.

^yMean separation within columns by LSD ($P \leq 0.05$).

*Interaction significant at $P \leq 0.05$.

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