Insect Resistance in Vegetable and Tofu Soybeans[1]

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Abstract Ten tofu and 14 green-vegetable soybean, *Glycine max* (L.) Merrill, genotypes were evaluated over 3 yrs for resistance to defoliation by the corn earworm, *Helicoverpa zea* (Boddie), and seed damage by a hemipteran complex. Petri-dish assays were used to determine foliar antibiosis to corn earworm. Larvae were weighed after feeding for 10 d on excised soybean leaves. Hemipteran damage was determined at harvest by individually rating 300 randomly sampled seeds from each subplot for severity of damage and calculating a weighted damage index. The specialty soybeans most resistant to corn earworm defoliation were Tousan 122, Guanyun da hei dun, and Enrei; whereas, those with the least seed damage were Barc-8 and Houjaku. There was no significant (F = 1.193; df = 1, 300; P < 0.276) correlation of larval weight with seed damage index. It is likely that different mechanisms are responsible for seed and foliage resistance. There was a small but significant correlation (F = 40; df = 1,300); P < 0.001, R^2 = 0.12) of seed damage index with maturity group that may be related to the phenology of soybean seed development and insect populations.

Key Words Insect resistance, vegetable soybean, tofu, stink bug, corn earworm

Soybean, *Glycine max* (L.) Merrill, long a staple in Asian diets, is gaining advocates in the West. There is growing evidence that soybean consumption lowers cholesterol, reduces the risk of heart disease and certain cancers, and may play a role in moderating menopausal symptoms (Carroll and Kurowska 1994, Jing et al. 1993, Messina et al. 1994, Oakenfull et al. 1984). In October 1999, the U.S. Food and Drug Administration authorized cholesterol reduction health claims on food labels for products containing at least 6.25 g of soy protein. Although many soybean-based products are available in Asia, Americans are generally only familiar with soy sauce and tofu, a high-protein curd. Soybean can also be consumed as a roasted nut, various fermented products, sprouts, and as a vegetable harvested in the green pod stage. Vegetable types often have unusually large seeds, higher sugar content, and favorable flavor, taste, visual, and texture characteristics. Insect damage, particularly to the pod and seed, can have a major effect on consumer acceptance and marketing.

The most serious soybean pod feeders in the U.S. are corn earworm, *Helicoverpa zea* (Boddie), and the stink bug (Pentatomidae) complex (Turnipseed and Kogan 1976). Corn earworm moths are attracted to soybean at the time of flowering (Johnson et al. 1975) where they prefer to oviposit on developing new foliage (Eckel et al. 1992). Later-instar larvae often migrate to developing pods, severely affecting

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yield. Stink bugs penetrate pod walls with their stylets and feed by injecting digestive juices directly into the seeds. This results in seeds with sunken areas that are often discolored by secondary decay organisms. Protein, oil, and fatty acid composition are also affected (Todd and Turnipseed 1974, Todd et al. 1973). Stink bug damage is not always apparent from observing the pods. Because vegetable soybeans are usually marketed in the pod and sometimes consumed directly from the pod, stink bug damage must be minimal. Despite a premium of several times the market price for grain type soybeans, an early attempt in Georgia to produce a large-seeded vegetable soybean failed due to heavy stink bug damage (Carter 1987).

Tofu soybeans are harvested when mature. Although tofu may be made from just about any soybean variety, there are preferred genotypes. These have a higher percentage of protein and important protein fractions in a specific ratio that enhances the textural qualities of tofu (Saio and Watanabe 1977). Because tofu is a processed product, pod and seed damage is not quite as important as for vegetable soybeans. Still, byproducts from decay or insect feeding could result in off-flavors or colors.

The objective of this study was to evaluate specialty soybeans for resistance to corn earworm defoliation and hemipteran seed damage as part of a larger regional soybean project of 1890 Land Grant Colleges and Universities. These pests are among the most serious threats to soybean in the region covered by the participating institutions, the southeastern U.S. from Maryland to Mississippi. Our soybean selections included 10 tofu and 14 vegetable genotypes.

Materials and Methods

Soybean genotypes were selected from recent U.S. Department of Agriculture plant introductions (PIs) originating in China, Taiwan, and Japan, and a few U.S. cultivars and lines with specialty traits. One genotype, N8806, collected through a USDA/OICD sponsored visit to China in 1991 has not yet been assigned a PI number. Cultivars are identified as such, or by single quotation marks the first time mentioned. These selections ranged in maturity from group III (early maturing) through VIII (late maturing), appropriate to the southeastern region. Resistant and susceptible controls, one each from maturity groups IV, V, and VI, were selected from previous field and laboratory evaluations for foliar resistance to defoliating insects. The cultivar 'Lamar', and breeding lines L76-0049 and HC83-46-1, were developed for resistance to a wide range of foliar feeding insects (Hartwig et al. 1990, Rufener et al. 1986, Cooper and Hammond 1988) and are among the most resistant in their respective maturity groups. Plant introductions 201422 (Wu King), 399055 (Kangwon), and 407820 are highly susceptible to Mexican bean beetle, *Epilachna varivestis* Mulsant, in the field (Kraemer et al. 1988, 1990) and corn earworm in Petri-dish bioassays (Kraemer et al. 1994, 1997). Also included were three grain-type cultivars ('Hutcheson', 'Ware', and 'Essex') and 'Kunitz', whose seeds lack a major trypsin inhibitor, an anti-nutritional protein that may contribute to resistance (Bernard et al. 1991).

The field site was located at Randolph Research Farm, near Petersburg, VA, and the same experimental design was used in 1995, 1996, and 1997. The field was prepared in the manner recommended for grain-type soybeans. The selected 34 genotypes were planted in late May in 1.8 m rows, 28 seeds/m, separated from other rows by 1.2 m between genotypes and 1.5 m between furrows. Three replicates were arranged in a randomized complete block design. An electric fence was used to reduce deer and groundhog damage. Mid-season weeds were controlled manually.

Corn earworm assay. Terminal trifoliate leaves (8-10) were excised from plants in the center 1.2 m section of each plot after soybeans began flowering in late July to early August. The leaves for each replicate were collected on the same day with no more than 5 d separating the first and last replicate each year of the study. These leaves were placed in plastic zip-lock bags and transported to the laboratory in a cooler. The trifoliate leaves were separated into leaflets with petioles removed and placed in plastic Petri dishes (150 × 15 mm) lined with moistened Whatman #2 filter paper. Leaves sufficient to cover the filter paper were added to each dish. Four Petri dishes were used for each of the three replicated field plots of each genotype, a total of 12 Petri dishes per genotype. Two neonate corn earworm larvae were placed onto the foliage in each Petri dish to allow for possible first-instar mortality unrelated to leaf antibiosis. The Petri dishes were then held in an environmental chamber at 25°C and a 14:10 (L:D) photoperiod. Although relative humidity within the environmental chamber was not controlled, the filter paper within each Petri dish was kept moist with approximately 1 ml of water every other day. The number of larvae per Petri dish was reduced to one after 4 d because late-instar larvae often cannibalize each other. The larvae were weighed after 10 d.

Hemipteran seed damage. Seed damage from stink bugs was determined at harvest. Soybean plants in the center 1 m section of each 1.8-m row were cut and placed into brown paper bags to air dry. When dry, seeds from each bag were shelled by hand to avoid loss of small damaged seeds. Random samples of 300 seeds from each row-plot were individually classified according to the degree of damage from stink bugs: none, light, moderate, and heavy, as defined by McPherson et al. (1979). Seeds with light damage have punctures but no shriveling of the seed coat. Moderately-damaged seeds have punctures with some shriveling or areas of discoloration; whereas, heavily-damaged seeds have extensive shriveling. A damage index (DI) was computed according to McPherson et al. (1979) as follows: DI = 0 (% none) + 1 (% light) + 2 (% moderate) + 3 (% heavy).

Hemipteran species were collected for identification with no attempt to quantify populations. The species present were identified by comparison with specimens from our collection or by the Virginia Tech Insect Identification Laboratory. The hemipteran species observed feeding on soybean pods were the green stink bug, *Acrosternum hilare* (Say), the brown stink bug, *Euschistus servus* (Say), and an ant mimic, *Alydus pilosulus* (Herrich-Schaeffer) (Alydidae). Voucher specimens were kept at Virginia State University. No attempt was made to quantify the damage from individual hemipteran species.

Statistical analysis. Data were analyzed using SAS/STAT software (SAS Institute 1990). The general linear model procedure (PROC GLM) was used for analysis of variance of larval weight and stink bug damage. Data were omitted from the corn earworm weight analysis if the larva failed to establish feeding or later died. Percent seed damage was converted by the inverse sine transformation before analysis. The three years of data were combined for analysis because the error variances were relatively homogeneous; 2085, 1562, and 2616 for larval weights and 386, 154 and 408 for stink bug damage indexes. Treatment means were separated using Duncan's multiple range test (DMRT) when F values were significant ($P = 0.05$). Simple linear correlation (PROC CORR) was used to determine the correlation coefficients of corn earworm larval weight and stink bug damage, and stink bug damage and soybean maturity group. The maturity group identification used in the analysis and reported in the tables, and pubescence traits were provided by the Germplasm Resources Information Network through the USDA-ARS National Plant Germplasm System (http://www.ars-grin.gov/npgs).

Results and Discussion

Corn earworm assay. Overall, larval mortality was 5% with most (90%) occurring the first year. The high mortality in 1995 was probably related to the quality of corn earworm eggs used to obtain larvae. Shortly after this bioassay the rearing facility shut down production because of increasing incidence of a microsporidium disease that affected reproduction (G. Hartley, USDA/ARS, Stoneville, MS, pers. comm.). The greatest mortality occurred in the resistant controls HC-83-46-1 (19%) and Lamar (17%). Mean larval weights were 101 ± 25 mg in 1995, 170 ± 17 mg in 1996, and 119 ± 33 mg in 1997. When data for all 3 yrs were combined, significant differences (F = 19.18; df = 37,1114; P < 0.001) were found among mean larval weights of larvae reared on foliage of the different soybean genotypes (Table 1). Larvae reared on the 3 resistant controls and the cultivar 'Ware' exhibited the lowest mean weights (63 to 71 mg). Low mean larval weight suggests antibiosis type resistance (Painter 1951) in the foliage. The most resistant vegetable types were Tousan 122 (99 ± 58 mg) and Guanyn da hei dun (102 ± 62 mg) and the most resistant tofu-types were Enrei (104 ± 66 mg) and V71-370 (106 ± 71 mg). Many of the specialty soybean genotypes showed levels of resistance not significantly different from the susceptible controls. Larvae reared on the vegetable types Tousan 140 and 'Guelph' had the greatest weights, 178 ± 79 mg and 174 ± 92 mg, respectively, and were significantly more susceptible to corn earworm than the high-yielding grain-type cultivar 'Hutcheson.'

Hemipteran seed damage. Green stink bug and brown stink bug were the major pentatomid species present in the field. No other stink bugs were observed feeding on soybean pods. *Alydus pilosus* was also observed feeding on the pods. The nymphs of this species mimic large ants and are easily mistaken for them. I reared adults from nymphs collected in the field, by providing only fresh green soybean pods once a week. Ant mimics have not been reported to be major pests of soybean but can be easily overlooked.

There was a significant year effect on percent hemipteran seed damage (F = 185; df = 2, 267; P < 0.001) and damage ratings (F = 185; df = 2, 267; P < 0.001). Mean percent damage to seeds from hemipterans was 22%, 18%, and 54% and the mean damage index was 53, 29, and 80 in 1995, 1996, and 1997, respectively. There was no significant year x genotype effect (F = 0.12; df = 66, 201; P < 0.726) in the damage index. The 3-yr mean percent damage to soybean genotypes ranged from 15% in HC-83-46-1 to 63% in 'Kanrich' (Table 2). The range of the damage index was greater, from 21 (HC-83-46-1) to 131 (Kanrich) and reflected the greater severity of damage to the more susceptible genotypes. The five most susceptible genotypes were vegetable types: Kanrich (63%, DI 131), Guelph (52%, DI 114), Mian yan (48%, DI 98), Tousan 140 (48%, DI 91), and Ryokkoh-B (48%, DI 88). However, many other vegetable genotypes had significantly less damage than these most susceptible genotypes, especially Houjaku (22%, DI 33), Tambagura (22%, DI 39), and Akiyoshi (25%, DI 39). The tofu genotypes with the least damage were Barc-8 (21%, DI 31), Barc-9 (25%, DI 38), and MD86-5788 (26%, DI 38).

The resistant controls HC-83-46-1 (15%, DI 21) and Lamar (19%, DI 26) had the least seed damage. However, two of the "susceptible" controls also had very low damage, PI 407820 (22%, DI 29) and Wu King (21%, DI 29). The resistant and

Table 1. Mean (± SE) weight of corn earworm larvae reared for 10 days on terminal foliage of selected soybean introductions and cultivars

Genotype	Name/cultivar	Type*	MG**	N†	Weight (mg)‡
PI 561398	Tousan 140	V	V	33	178.2 ± 79.0 a
PI 548335	Guelph	V	III	34	174.3 ± 91.6 ab
PI 407820	PI 407820	S	IV	35	174.0 ± 92.1 abc
MD86-5788	MD86-5788	T	V	35	171.2 ± 90.9 abcd
V81-1603	V81-1603	T	V	35	169.6 ± 74.2 abcde
PI 187154	Tambagura	V	VII	35	166.7 ± 80.4 abcdef
PI 399055	Kangwon	S	V	36	166.6 ± 73.2 abcdef
PI 507079	Nakasennari	T	V	34	162.0 ± 86.8 abcdefg
PI 548667	Essex	G	V	36	154.3 ± 74.3 abcdefgh
PI 561339	Mian yan	V	III	31	150.7 ± 93.3 abcdefgh
PI 201422	Wu Kung	S	VI	34	148.9 ± 65.8 abcdefgh
PI 542044	Kunitz	K	III	34	148.5 ± 75.7 abcdefgh
PI 548552	Kanrich	V	III	35	141.3 ± 87.6 bcdefghij
PI 518664	Hutcheson	G	V	34	138.7 ± 70.3 cdefghij
PI 555399	Barc-9	T	IV	36	137.7 ± 65.5 defghij
PI 561382	Shangrao wan qingsi	V	V	34	136.5 ± 74.2 defghijk
S90-1056	S90-1056	T	V	35	135.0 ± 66.0 efghijk
PI 561391	Tomahomare	V	V	34	134.1 ± 74.9 efghijkl
PI 423908	Houjaku	V	VIII	32	132.5 ± 70.0 fghijkl
N8806	N8806	V	V	34	131.5 ± 76.4 fghijkl
PI 536547B	Ryokkoh-B	V	III	34	129.2 ± 74.4 ghijkl
PI 555398	Barc-8	T	V	33	128.1 ± 67.8 ghijkl
PI 553038	York	T	V	36	124.8 ± 58.4 hijkl
PI 561383	Akiyoshi	V	V	32	123.8 ± 59.2 hijkl
PI 561395	Suzuyutaka	T	V	35	120.4 ± 63.4 hijkl
PI 536547A	Ryokkoh-A	V	III	35	111.2 ± 53.1 ijkl
V71-370	V71-370	T	V	34	106.3 ± 70.9 ijkl
PI 423903	Enrei	T	IV	34	103.8 ± 66.4 jkl
PI 561378	Guanyun da hei dun	V	V	31	101.6 ± 61.7 klm
PI 561397	Tousan 122	V	V	36	98.6 ± 58.1 lm
L76-0049	L76-0049	R	V	34	70.8 ± 57.9 mn
PI 533604	Lamar	R	VI	30	64.4 ± 46.0 n
PI 548627	Ware	G	IV	33	63.2 ± 40.5 n
HC-83-46-I	HC-83-46-I	R	IV	29	63.1 ± 50.5 n

* V = vegetable-type, T = tofu-type, S = susceptible control, R = resistant control, G = grain-type, K = Lacks Kunitz trypsin inhibitor.

** Maturity Group.

† Number of larvae alive after 10 days out of 36 total.

‡ Means not followed by the same letter are significantly different (DMRT, $P < 0.05$).

Table 2. Mean (± SE) hemipteran damage to soybean over 3 yrs expressed as percent of seeds damaged and the severity of the damage

Genotype	Name/cultivar	Type*	MG**	Percent damage†	Damage index†
PI 548552	Kanrich	V	III	63.4 ± 27.0 a	131.2 ± 80.0 a
PI 548335	Guelph	V	III	52.0 ± 21.6 b	114.1 ± 58.6 ab
PI 561339	Mian yan	V	III	47.8 ± 18.3 bc	97.7 ± 53.4 bc
PI 561398	Tousan 140	V	V	48.5 ± 22.4 bc	90.7 ± 54.2 bcd
PI 536547B	Ryokkoh-B	V	III	47.9 ± 20.3 bc	88.3 ± 60.0 bcde
PI 399055	Kangwon	S	V	39.4 ± 22.3 cdef	83.5 ± 44.6 cdef
PI 423903	Enrei	T	IV	42.8 ± 24.2 bcd	79.6 ± 46.8 cdefg
PI 542044	Kunitz	K	III	41.7 ± 22.1 bcde	79.4 ± 37.3 cdefg
PI 561397	Tousan 122	V	V	34.9 ± 16.5 defg	66.1 ± 22.0 defgh
PI 548627	Ware	G	IV	34.3 ± 24.4 defgh	62.7 ± 43.0 defghi
S90-1056	S90-1056	T	V	33.4 ± 24.3 defgh	58.0 ± 47.8 efghij
V71-370	V71-370	T	V	32.6 ± 14.6 defghi	53.9 ± 20.0 fghijk
PI 561391	Tomahomare	V	V	30.5 ± 23.4 defghi	49.6 ± 34.7 ghijk
N8806	N8806	V	V	32.7 ± 18.9 defghi	49.2 ± 26.7 ghijk
PI 548667	Essex	G	V	27.3 ± 11.9 fghijk	46.5 ± 16.8 hijk
PI 561395	Suzuyutaka	T	V	27.9 ± 17.7 fghijk	46.3 ± 24.9 hijk
PI 536547A	Ryokkoh-A	V	III	27.8 ± 22.6 fghijk	45.7 ± 35.4 hijk
PI 561382	Shangrao wan qingsi	V	V	29.2 ± 27.7 efghij	44.2 ± 44.2 ghijk
PI 561378	Guanyun da hei dun	V	V	26.2 ± 24.9 fghijk	44.0 ± 39.6 hijk
V81-1603	V81-1603	T	V	29.6 ± 20.3 efghij	43.4 24.1 hijk
PI 507079	Nakasennari	T	V	26.1 ± 14.4 fghijk	41.3 ± 21.6 hijk
PI 553038	York	T	V	27.1 ± 16.3 fghijk	40.9 ± 21.4 hijk
PI 561383	Akiyoshi	V	V	25.0 ± 20.7 ghijk	39.3 ± 29.5 hijk
PI 187154	Tambagura	V	VII	22.3 ± 25.3 ghijk	38.7 ± 45.9 hijk
PI 555399	Barc-9	T	IV	24.7 ± 18.8 ghijk	38.3 ± 25.7 hijk
MD86-5788	MD86-5788	T	V	26.0 ± 19.3 ghijk	38.0 ± 25.9 hijk
L76-0049	L76-0049	R	V	24.5 ± 19.3 ghijk	37.0 25.9 hijk
PI 423908	Houjaku	V	VIII	22.0 ± 20.5 ghijk	33.2 ± 29.2 hijk
PI 555398	Barc-8	T	V	21.1 ± 20.0 hijk	31.4 ± 25.3 ijk
PI 201422	Wu King	S	VI	20.8 ± 17.4 hijk	29.0 19.5 ijk
PI 407820	PI 407820	S	IV	21.6 ± 19.1 ghijk	28.7 ± 23.8 ijk
PI 518664	Hutcheson	G	V	19.2 ± 14.2 ijk	26.2 ± 17.3 jk
PI 533604	Lamar	R	VI	19.0 ± 20.0 jk	26.1 ± 26.9 jk
HC-83-46-1	HC-83-46-1	R	IV	15.4 ± 17.7 k	20.9 ± 21.5 k

* V = vegetable-type, T = tofu-type, S = susceptible control, R = resistant control, G = grain-type, K = Lacks Kunitz trypsin inhibitor.

** Maturity Group.

† Means not followed by the same letter are significantly different (DMRT, $P < 0.05$).

susceptible controls were selected with regard to foliar antibiosis, not stink bug resistance. Although some genotypes were susceptible to both corn earworm defoliation and hemipteran damage (Guelph, Tousan 140) and others were resistant to both (Lamar, HC-83-46-1), there was no overall correlation ($F = 1.193$; df = 1, 300; $P < 0.276$) between these two types of resistance.

Maturity group. Genotypes belonging to different maturity groups were mixed in the same block because the number of lines in several maturity groups was too few to create meaningful individual blocks. Because of the small plot size and mixed maturity groups, antizenosis was a major factor in the observed difference in seed damage. It is possible that different results could have been obtained if lines were planted in blocks containing a single maturity group. Much larger plots of single genotypes are needed to evaluate antibiosis-type resistance in the field. The mixed maturity group experimental design resulted in a small but significant correlation between seed damage index and maturity group. Simple linear correlation analysis indicated genotypes belonging to earlier maturity groups tended to have slightly more damage than later maturity groups ($F = 40$; df = 1, 300; $P < 0.001$; $R^2 = 0.12$). Several of the more recent germplasm accessions appeared to belong to later maturity groups than that listed in the National Plant Germplasm System. Shangrao wan qingsi, Guanyun da hei dun, and Akiyoshi flowered 2 wks later than the other maturity group V genotypes, which is more consistent with the maturity group VI genotypes planted nearby. The date of seed maturity was also consistent with a later maturity group. Statistical analysis using these more appropriate maturity group classifications did not significantly change the correlation with seed damage.

Effects related to maturity group are important and are likely related to pod development times and stink bug population dynamics. In this study, the later maturity groups had slightly less damage than the early ones. In Georgia, McPherson (1996) found just the opposite relationship of stink bug damage to soybeans of maturity groups IV through VIII. In that study, high populations of stink bug occur in late summer when the seeds of maturity groups VII and VIII are young and tender and most vulnerable to severe damage. In Virginia, this stage of pod development in these maturity groups occurs in early fall. One of our less damaged genotypes, Tambagura (22%, DI 39) in maturity group VII, had been heavily damaged by stink bugs in Georgia (Carter 1987). We planted all maturity groups at the same time, late May, and the early groups, III and IV, were the first to flower. Many had green pods from early to late summer and were thus exposed to stink bug attack for a long period of time. This long period of green pod availability may be related to a longer pod filling period in large-seeded genotypes and/or less uniformity in pod maturity than in grain-type cultivars. Traditional Asian methods of harvesting were by hand and did not require uniform maturity. The Georgia study (McPherson 1996) involved grain-type soybeans. In a similar study in eastern Virginia, McPherson et al. (1988) found that green stink bug was more abundant on early maturing varieties, in accordance with our results.

Multiple insect resistance. Both green vegetable and tofu type soybeans had a wide range of response to insect attack with significant differences between the most susceptible and resistant genotypes. In addition to identification of resistant genotypes, the identification of susceptible varieties is important to avoid excessive reliance on pesticides. The results of the Petri dish bioassays has been shown to correspond with field performance. Both susceptible and resistant controls were selected from previous field evaluations and performed as expected. In addition, previous Petri dish evaluations were correlated ($P < 0.01$, $r = 0.39$ to 0.84) with percent defoliation by Mexican bean beetle, *Epilachna varivestis* Mulsant, in the field (Kraemer et al. 1997). The Petri dish bioassay measures antibiosis-type resistance and is generally considered a good indicator of resistance in the field.

The factors responsible for soybean resistance to defoliating insects affect multiple pest species, lepidopteran and coleopteran. However, with the exceptions of Lamar and HC-83-46-1, this resistance did not generally extend to hemipteran seed damage. The resistant and susceptible controls were not necessarily expected to serve as controls for hemipteran seed damage because they were selected solely for their response to defoliating insects. Yet, all three resistant controls were developed from genotypes that exhibited some resistance to stink bugs (Jones and Sullivan 1979). The small amount of damage to two of the susceptible controls and overall lack of correlation with corn earworm resistance ratings indicates that although there may be some common mechanisms of resistance, other factors are involved.

Several tofu type soybeans had low hemipteran damage despite having early to mid maturities (Barc-8, Barc-9, and MD86-5788), as did Hutcheson, a high yielding grain-type soybean popular in our area. The susceptibility of many of the vegetable genotypes to hemipteran damage may be related to the higher sugar content found in many of these genotypes. A sweeter taste is desired by most consumers, both human and arthropod. Thus, it could be difficult for plant breeders to develop greater stink bug resistance in vegetable soybeans. Higher levels of most anti-nutritional or bitter components are not desired, and physical barriers such as tougher pod walls, if possible, are unlikely to prevent stylet penetration of green pods. Pod pubescence could be effective. However, some traditional Asian uses of large-seeded vegetable soybean discourage pubescence. Erect and dense pubescence is not desired when placing the entire pod in the mouth to extract the seeds. Consequently, vegetable soybean genotypes often have reduced or appressed pubescence. Unfortunately, this makes them more susceptible to potato leafhopper, *Empoasca fabae* (Harris), damage (Broersma et al. 1972). The one genotype in our study with glabrous pubescence, N8806, had severe hopper burn each year of the study. Five other genotypes had appressed and/or semi-sparse pubescence and exhibited some degree of hopper burn: Enrei, Guanyun da kei dun, Suzuyataka, Tousan 140, and Tomahomare.

Kester et al. (1984) reviewed the results of previous attempts to identify stink bug-resistant soybean germplasm and found only limited success. They attributed a major part of the resistance in the best performing entry in the largest study (Gilman et al. 1982) to phenological effects associated with late flowering and a short reproductive stage. This genotype, PI 171444, also has very small seeds, 7 g per 100-seed weight. Vegetable soybeans often have unusually large seeds and may require longer pod-filling periods. In addition, each damaged seed of a large-seeded genotype represents a larger fraction of the total yield than for a small-seeded genotype.

Because of the high quality requirements, stink bug damage is likely to be the greatest insect threat to commercial production of vegetable soybean in the mid-Atlantic and southern states. Vegetable soybeans appear to be more susceptible to hemipteran damage than tofu or grain-type soybeans. Planting time and maturity group choices can help to avoid pest population peaks. However, with fresh market sales it is often desirable to have an extended harvest period through multiple plantings and/or maturity groups. Susceptible genotypes such as Kanrich or Guelph should probably be avoided, except as trap crops. Although pyrethroid insecticides can be effective against stink bugs (McPherson et al. 1995), they are also hard on beneficial insects. The development of cultural or biologically-based control methods would enhance product value for some health conscious consumers.

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References Cited

Bernard, R. L., T. Hymowitz and C. R. Cremeens. 1991. Registration of 'Kunitz' soybean. Crop Sci. 31: 232-233.

Broersma, D. B., R. L. Bernard and W. H. Luckmann. 1972. Some effects of soybean pubescence on populations of the potato leafhopper (*Empoasca fabae*). J. Econ. Entomol. 65: 78-82.

Carroll, K. K. and E. M. Kurowska. 1994. Soy consumption and cholesterol reduction: Review of animal and human studies. Proc. First International Symposium on the Role of Soy in Preventing and Treating Chronic Disease. February 20-23, Mesa Pavilion Hilton, Mesa, AZ, P 7.

Carter, T. E. 1987. Genetic alteration of seed size: breeding strategies and market potential. USDA Report.

Cooper, R. L. and R. B. Hammond. 1988. Registration of Mexican bean beetle soybean Germplasm line HC83-123-9. Crop Sci. 28: 1037-1038.

Eckel, C. S., L. I. Terry, J. R. Bradley, Jr. and J. W. Van Duyn. 1992. Changes in within-plant distribution of *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) on soybeans. Environ. Entomol. 21: 287-293.

Gilman, D. R., R. M. McPherson, L. D. Newsom, D. C. Herzog and C. Williams. 1982. Resistance in soybeans to the southern green stink bug. Crop Sci. 22: 573-576.

Hartwig, E. E., L. Lambert and T. C. Kilen. 1990. Registration of 'Lamar' soybean. Crop Sci. 30:231.

Jing, Y., K. Nakaya and K. Han. 1993. Differentiation of promyelocytic leukemia cell HL-60 induced by daidzein in vitro and in vivo. Anti-Cancer Res. 13: 1049-1084.

Jones, W. A., Jr. and M. J. Sullivan. 1979. Soybean resistance to the southern green stink bug, *Nezara viridula*. J. Econ. Entomol. 72: 628-632.

Johnson, M. W., R. E. Stinner and R. L. Rabb. 1975. Ovipositional response of *Heliothis zea* (Boddie) to its major hosts in North Carolina. Environ. Entomol. 4: 291-297.

Kester, K. M., C. M. Smith and D. Frank Gilman. 1984. Mechanisms of resistance in soybean (*Glycine max* [L.] Merrill) genotype PI 171444 to the southern green stink bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae). Environ. Entomol. 13: 1208-1215.

Kraemer, M. E., M. Rangappa, P. S. Benepal and T. Mebrahtu. 1988. Field evaluation of soybeans for Mexican bean beetle resistance. I. Maturity groups VI, VII, and VIII. Crop Sci. 28: 497-499.

Kraemer, M. E., M. Rangappa, T. Mebrahtu and P. S. Benepal. 1990. Field evaluation of soybeans for Mexican bean beetle resistance. II. Maturity groups III, IV, and V. Crop Sci. 30: 374-377.

Kraemer, M. E., T. Mebrahtu and M. Rangappa. 1994. Evaluation of vegetable soybean genotypes for resistance to Mexican bean beetle (Coleoptera: Coccinellidae). J. Econ. Entomol. 87(1): 252-257.

Kraemer, M. E., M. Rangappa and A. I. Mohamed. 1997. Evaluation of vegetable soybean genotypes for resistance to corn earworm (Lepidoptera: Noctuidae). J. Entomol. Sci. 32:25-36.

McPherson, R. M. 1996. Relationship between soybean maturity group and the phenology and abundance of stink bugs (Heteroptera: Pentatomidae): impact on yield and quality. J. Entomol. Sci. 31: 199-208.

McPherson, R. M., L. D. Newsom and B. F. Farthing. 1979. Evaluation of four stink bug species from three genera affecting soybean yield and quality in Louisiana. J. Econ. Entomol. 72: 188-194.

McPherson, R. M., G. W. Zehnder and J. C. Smith. 1988. Influence of cultivar, planting date, and row width on abundance of green cloverworms (Lepidoptera: Noctuidae) and green stink bugs (Heteroptera: Pentatomidae) in soybean. J. Entomol. Sci. 23: 305-313.

McPherson, R. M., D. J. Boethel, J. E. Funderburk and A. T. Wier. 1995. The effect of alternative southern green stink bug (Heteroptera: Pentatomidae) insecticide controls on soybean pest management, quality and yield. J. Entomol. Sci. 30: 216-236.

Messina, M., V. Messina and K. D. R. Setchell. 1994. The simple soybean and your health. Avery Pub. Group, 260p. Garden City Park, NY.

Painter, R. H. 1951. Insect resistance in crop plants. MacMillan, NY.

Oakenfull, D. G., D. L. Topping, R. J. Almoign and D. E. Fenwick. 1984. Prevention of dietary hypercholesterolemia in the rat by soya bean and quillaja saponins. Nutr. Rep. Inter. 29: 1039.

Rufener, G. K. II, R. B. Hammond, R. L. Cooper and S. K. St. Martin. 1986. Mexican bean beetle (Coleoptera: Coccinellidae) development on resistant and susceptible soybean lines in the laboratory and relationship to field selection. J. Econ. Entomol. 79: 1354-1358.

Saio, K. and T. Watanabe. 1977. Differences in functional properties of 7S and 11S soybean proteins. J. of Texture Studies 9: 135-157.

SAS Institute. 1990. SAS/STAT User's Guide, version 6, 4th ed. SAS Institute, Cary, NC.

Todd, J. W. and S. G. Turnipseed. 1974. Effects of southern green stink bug damage on yield and quality of soybeans, J. Econ. Entomol. 67: 421-426.

Todd, J. W., M. D. Jellum and D. B. Leuch. 1973. Effects of southern green stink bug damage on fatty acid composition of soybean oil. Environ. Entomol. 2: 685-689.

Turnipseed, S. G. and M. Kogan. 1976. Soybean entomology. Ann. Rev. of Entomol. 21: 247-282.