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Title: Resistance in Snap Beans, Phaseolus vulgaris L., to Adult Western Spotted Cucumber Beetle, Diabrotica u. undecimpunctata Mann.

Abstract Approved Redacted for privacy

Dr. Ralph E. Berry

Studies to evaluate resistance in snap beans, Phaseolus vulgaris L. to adult western spotted cucumber beetles, Diabrotica u. undecimpunctata Mann. were conducted in greenhouse cages, field cages, field plots, and in temperature controlled cabinet in the laboratory. Results showed that there were differences in susceptibility to adult feeding injury between 12 selected snap bean cultivars. Spartan Arrow, Green Isle, Resistant Cherokee Wax, Itasca, and Oregon 1604 showed a higher level of resistance, whereas Blue Crop, Blue Max, Green Ruler, Bush Blue Lake, and Bush Hort. #4 were most susceptible. Beetle injury affected bean grades and damage by beetles exceeded the one percent level accepted by processors for grade A beans in all cultivars tested. Adult beetles preferred young succulent leaves of the cotyledonous stage. In all cultivars studied more than 50% of the seedlings were damaged, however damage during the cotyledonous stage had the least effect on yield except when complete defoliation and death of seedling occurred.

# Resistance in Snap Beans, *Phaseolus vulgaris* L. to Adult Western Spotted Cucumber Beetle, *Diabrotica u. undecimpunctata* Mann.

by

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Typed by Sharon Mosley for Elameen M. A. Eltoum

DEDICATION

To Wala, Khadoum, and Friends

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## INTRODUCTION

A study was conducted to evaluate resistance in 12 commonly grown snap bean cultivars, *Phaseolus vulgaris* L., to adult western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata* Mannerhiem.

Snap bean growers are concerned with the yield and quality of beans, particularly for processing. Accordingly, this study was designed to evaluate the effect of adult beetles on different stages of snap bean growth, with particular emphasis on yield and quality of beans.

The western spotted cucumber beetle is considered one of the most destructive native pests in California, and it is a common pest in the Willamette Valley of Western Oregon (Rockwood and Chamberlin 1943, Michelbacher *et al.* 1943).

Adults feed on numerous cultivated and wild host plants. As the plants on which beetles are feeding senesce or are harvested the beetles move to other hosts. This migration causes them to be especially troublesome in gardens and other crops which remain green throughout the summer. The population of the western spotted cucumber beetle in the Willamette Valley begins increasing in mid-June and reaches a peak during July and August. Snap beans are normally planted from mid-April to early July and harvested from mid-July to mid-September. Thus, the population of western spotted cucumber beetle

coincides with the major growing period of snap beans in Western Oregon. This contributed to this beetle being a key pest on beans.

Snap beans produced for canning and freezing have become a major crop in Oregon. Between 1973 and 1977 an average of 36,000 acres were grown in Oregon annually. The majority of snap beans are grown in the Willamette Valley, with smaller acreages in the Milton-Freewater and Roseburg areas.

The western spotted cucumber beetle feeds on the foliage, the flowers and the developing beans. The small feeding punctures cause the beans to be downgraded and when the infestation is severe the entire crop may be unsuitable for canning.

Among the various alternatives to using insecticides for controlling this pest, the use of insect resistant plants, in combination with good cultural practices, would perhaps be the most effective, convenient, economical and environmentally acceptable method of insect control. In addition, using insect-resistant plants is a method that is completely compatible with chemical and other biological control measures (Waiss et al. 1977).

Hopefully, the results of this study will provide information leading to further studies on the mechanism of resistance in snap beans to this pest, and breeding for resistance to improve yield and quality of the cultivars grown in the Willamette Valley.

# LITERATURE REVIEW

## Nomenclature

The genus Diabrotica is one of the largest genera in the family chrysomelidae and many species are economically important (Crowell 1955).

The western spotted cucumber beetle, Diabrotica undecimpunctata was first determined as D. 12-punctata (Fabr.). However, Eschseholtz called it Galleruca 11-punctata. Later Mannerheim (1843) clearly distinguished this species, and considered it a variety (var. b.) of D. 12-punctata and recorded it from California. Leconte (1865) described D. Soror, which was commonly used in the literature for the western spotted cucumber beetle. However, Michelbacher (1941) noted that E. G. Linsley considered D. undecimpunctata (Mann.) as an earlier available name for D. Soror (Lec.).

Apparently the name was later attributed to Mannerheim (1843), who also noted that it was the same as Galleruca 11-punctata of Eschseholtz.

## Distribution

The genus Diabrotica is widely distributed from Canada to Argentina (Smith 1966). However, the western spotted cucumber beetle, D. u. undecimpunctata is confined to the Pacific Coast states, i.e., California, Oregon and Washington (Dickason 1955) (Figure 1).

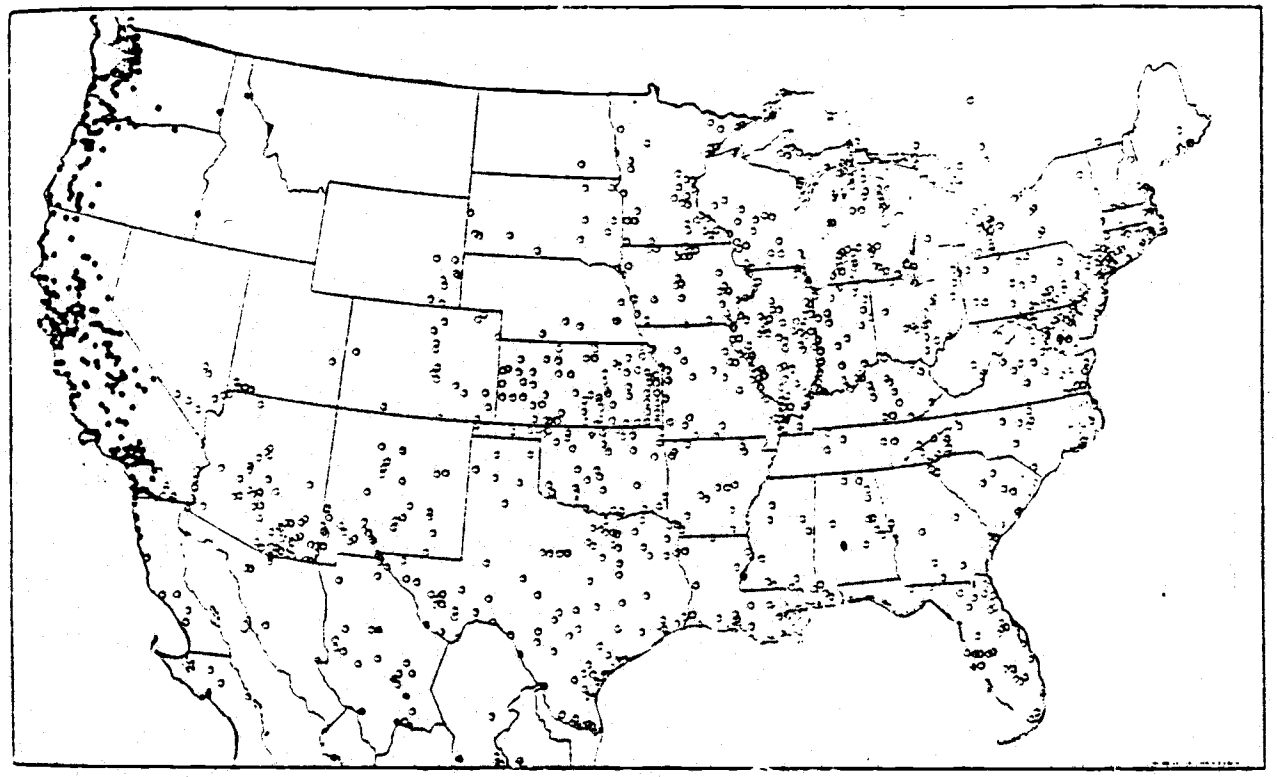

Figure 1. The distribution of the subspecies of Diabrotica undecimpunctata in the United States.

- • D. u. undecimpunctata
- o D. u. howardi
- • D. u. duodecimpunctata

In Oregon, the western spotted cucumber beetle is most serious in the Williamette Valley and does not extend east of the Cascade Mountains (Crowell 1955, Dickason 1955).

The western spotted cucumber beetle has the potential for seasonal spread into the Great Basin area, but evidently the pattern of prevailing winds may not permit it to cross the Cascade Mountains and Sierra Nevada (Smith 1966).

## Description

Adults of western spotted cucumber beetle are about 6 mm long, yellowish green with distinct black spots on their elytera (Figure 2). Mature larvae of this subspecies are 14 to 17 mm long and white in color except the head and the last abdominal segments which are brown (Berry 1978) (Figure 2). Michelbacher et al. (1943) reported that the larvae are tan in color and covered with a scattering of rather long hairs.

Males possess an extra sclerite at the abdominal apex that females do not have. This supra anal plate of the male gives the abdomen a blunter appearance in side view than the female abdomen, which appears more pointed (Smith and Allen 1931, and White 1977).

## Life History

Western spotted cucumber beetle overwinters as fertilized females. Adults are active during mild periods in the winter, but do not begin

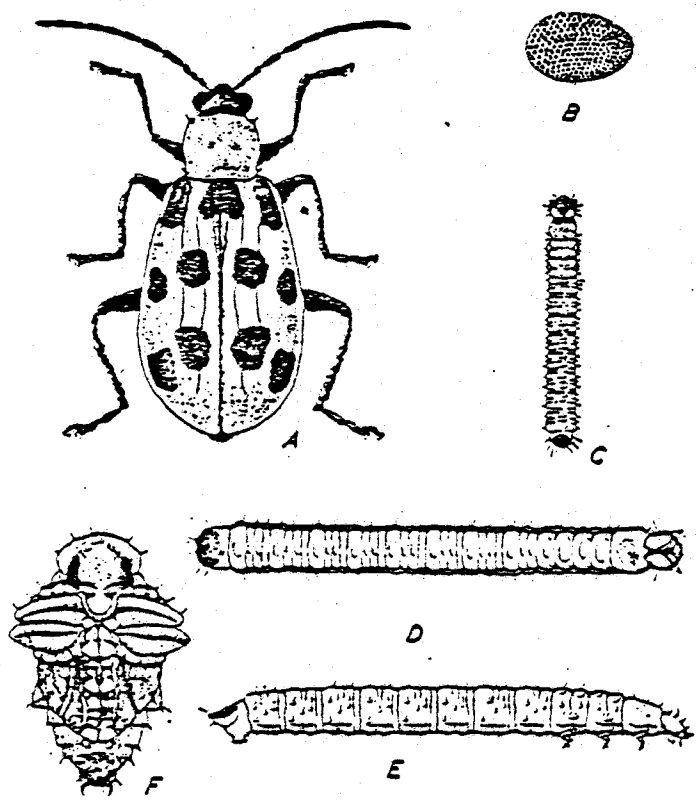


Fig. 2.—Life cycle of *Diabrotica 11-punctata* Mann.: *A*, Adult; *B*, egg; *C*, first instar larva; *D*, dorsal view of last instar larva; *E*, lateral view of last instar larva; *F*, ventral view of pupa. (All × 7, except the egg which is × 30.)

laying eggs until early spring (Berry 1978, Rockwood and Chamberlin 1943).

Males and females undergo multiple copulations, each lasting from about 30 minutes to several hours. Copulation takes place at any time of the day and even at temperatures of 11°C, however, egg production is favorable at 24 to 25°C (Leo et al. 1966). Females lay an oval, yellowish egg around the bases of plants, just beneath the surface of the soil. Eggs may become dingy in color just before hatching (Michelbacher et al. 1943). Eggs may also be laid in crevices, or under plant debris in moist situations and even scattered or in groups of four to five between stems and petiols of dense vegetations (Rockwood 1941).[1] Rockwood reported that over 1800 eggs may be depoisted by a single female over a period of five months.

The soil temperature greatly influences egg development and hatching. Michelbacher et al. (1943) showed that at 16°C eggs hatch in 20 to 30 days, but at 29°C eggs hatch in as little as five to seven days. After hatching, the larvae begin feeding on roots of their host plants.

There are three larval instars before the pupal stage, with the greatest increase in weight occurring during the third instar, which when fully grown measures between 14 to 17 mm (Fisher and Shanks 1979, Berry 1978). However, Rockwood and Chamberlin (1943) reported finding third instar larvae larger than 17 mm.

[1]Rockwood, L. P. 1941. Tentative program on D. Soror. Cereal and forage insect investigations, Forest Grove, Oregon.

Pupation takes place in an earthen cell (Michelbacher et al. 1943). Larvae reared in the laboratory showed higher mortality in the absence of these cells (Michelbacher et al. 1943). Duration of the pupal stage also depends on soil temperature, being most rapid at higher temperatures. A range of 15 to 24 days is required at 16°C while at 29°C only three to six days are sufficient for complete pupal development (Rockwood and Chamberlin 1943). Emergence of adults also depends on soil temperature and emergence is rapid at higher temperatures. The newly emerged adults are fragile and inactive, but after a short time they start to feed. It requires about three days for the lemon yellow luster of the elytera to appear, after which the beetles disperse, mate, and begin laying eggs in about ten days depending on the temperature (Leo et al. 1966).

The time required for complete development from egg to adult is strongly influenced by temperature. About 27 days at 29°C, 101 days at 16°C, and 56 days at 20°C (Michelbacher et al. 1943). However, Leo et al. (1966) reported that at 27°C and 50 ± 5% RH the average rate of development was 6.4 days for eggs, 13.2 for larvae, 3.6 for prepupae, and 6.5 for pupae, or a total of 29.7 days from egg to adult.

This beetle is reported to have two generations each year in the Northwest and three in California (Berry 1978, Fisher and Shanks 1979). However, Rockwood and Chamberlin (1943) and Smith and Michelbacher (1949) reported that this subspecies has one generation in the Pacific

Northwest and three in California. Crowell (1953 unpublished),[2] showed that there are two full generations and a partial third in the Pacific Northwest. He also indicated that increased use of sprinkler irrigation in the Willamette Valley produced conditions more favorable for a second generation of this beetle.

## Economic Importance

Adults and larvae of the western spotted cucumber beetle are general feeders. Larvae complete development in the soil on the roots of the following host plants: corn, wheat, barley, melon, cucumber, squash, gourds, alfalfa, beans and peas (Michelbacher et al. 1943). Fisher and Shanks (1979) reported that the most important larval damage in the Willamette Valley is on corn. Larvae feed in and on germinating seeds, developing crowns, roots and rootlets causing stunting, distortions and death of the plants. Larval injury, however, varies tremendously with the area and the season (Crowell 1955). On potatoes, larvae cause blemishes on tubers, similar to damage by larvae of the tuber flea beetle. In Western Oregon as much as 60% of the tuber injury usually attributed to flea beetles maybe caused by larvae of the western spotted cucumber beetle (Crowell 1955).

Adults feed on many crop plants including: snap beans, corn, artichokes, sugarbeets, lettuce, alfalfa, sunflower, apricot, peaches,

[2]Crowell, H. H. 1953. Investigation of the life habits and control of the western spotted cucumber beetle, Project #61-1 Oregon Agr. Exp. Sta., Corvallis, Oregon.

nectarine, almonds, squash, melons, cucumbers and gourds (Michelbacher et al. 1943). Elmore and Campbell (1936) reported that ground buffalo-gourd is strikingly attractive to this beetle. Many weeds also serve as hosts including: mayweed, manroot, and varieties of wild grasses and flowers (Michelbacher et al. 1943). Wilcox (1977) added common peanut, cabbage, rue, coffee, cauliflower, cantaloupe, potato, spinach, hops, clover and zinnia as hosts of the adults.

The western spotted cucumber beetle has been reported as one of the most serious pests in Guayule nurseries, especially when nurseries are adjacent to bean fields. The adults prefer the flowers to the leaves (Lange 1944). Glandless cotton has also been reported to be a host of adults of this beetle. On cotton, adults feed on the foliage, petals, and pollen of open blossoms (Thomas et al. 1971).

The beetles are especially injurious to snap beans, because adults feed on foliage, flowers, and the developing beans. Beetle damage to the foliage, stems, and young seedlings reduces the stand, and damage to the flowers causes inadequate pollination and poor seed set (Berry 1978). The most critical damage is caused by adults feeding on the developing green pods, causing irregular feeding punctures which may result in complete deformation of the whole pod under severe attack. This damage results in lowering the grade of beans for processing and reducing the amount paid to farmers. Grading of processed beans is based on the number of serious and minor blemishes in which the aggregate area affected exceeds the area of a circle 3.2 mm in diameter or

the appearance or eating quality of the bean is materially affected (Reinhold unpublished).[3] Reinhold also reported that beetle bites usually cause serious blemishes.

Initially beans are separated according to their largest diameter into sieve sizes. Sieve size one and smaller are undersize and discarded before processing. Sieve sizes, two, three, and four are acceptable for cut green beans. Sieve sizes five and six are discarded or are made into french cut beans, i.e., they are cut several times along the long axis of the bean. Sieve size seven and above are discarded as oversize beans. Sieve sizes two, three, and four are cut into 2.54 cm segments and stems and ends are discarded.

For frozen beans a 283.75 grams sample which contains about 220 pieces, must not have more than three serious and seven minor blemishes to be graded "A". For grade "A" canned beans no more than one percent serious and two percent minor blemishes (by drained weight) are permitted. Grade "A: beans receive 100% of the wholesale price while grade "B" beans receive 70% and grade "C" receive 40% (Reinhold unpublished).[3]

Berry (1978) reported that one percent of the beans with feeding punctures is the maximum level of damage accepted by processors. Accordingly, he considers the western spotted cucumber beetle as the key insect pest on snap beans in the Willamette Valley.

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[3]Reinhold, John. 1979. An assessment of carbaryl (Sevin) usage on snap beans in the Willamette Valley. Dept. of Ent., OSU, Corvallis, Oregon.

## Control Strategies

### Natural Control

Physical Conditions. The most critical factor affecting the western spotted cucumber beetle is insufficient precipitation in the spring since larvae are very dependent on moisture in the soil (Smith and Michelbacher 1949). Additionally Rockwood and Chamberlin (1943) reported that many beetles were killed in their hibernating caches at -15°C without a snow cover, during cold winter conditions.

Birds. Bobwhite, Calinus virginianus virginianus, the valley quail, Lophortyx Californica vallicola, and the western flicker, as well as Chinese pheasant, Phasianus torquatus were found to play a role in lowering beetle populations (Thompson unpublished).[4]

Parasites. The tachinid fly, Celatoria diabroticae (Shim), is probably the most effective parasite on adult beetles (Michelbacher et al. 1943, Crowell 1953[2], Rockwood and Chamberlin 1943). C. diabroticae probably lays its eggs in the abdomen of the host while in flight. After completion of development within the abdomen, the mature parasite larva breaks away the larger portion of the beetle's abdomen, falls to the ground and probably pupates in the soil (Michelbacher et al. 1943).

Since there maybe two and a partial third generation of this beetle each year and probably several of the fly, the effects of this parasite

[4]Thompson, B. G. 1930-1933. Report of project on D. Soror on beans. Oregon Agric. Exp. Sta., Corvallis, Oregon.

could be cumulative. It may be of considerable importance in the natural control of this beetle. However, the percentage of parasitized beetles may not be high at any one time (Rockwood unpublished).[1]

Nematodes. A considerable percentage of this beetle is parasitized by mermithid nematodes which not only sterilizes the parasitized females but eventually kills them. Parasitzation by these nematodes is likely to vary with location. Sometimes it may occur simultaneously with C. diabroticae on the same beetle, in which case their effect is considerable (Rockwood unpublished).[1]

Predators. Staphylinid beetles kill western spotted cucumber beetles by feeding on hibernating beetles in their caches (Rockwood and Chamberlin 1943).

Fungi. The fungus Beauvena globulifera (Speg.) may also be an important factor in natural control of hibernating beetles (Michelbacher et al. 1943). Rockwood (1951) indicated that this fungus has strains that are more virulent to some insects. He found a strain of B. globulifera from staphylinid beetles that was distinctly less virulent to D. u. undecimpunctata than a strain from carabid beetles.

Other Natural Controls. Rodents, probably field mice, and spiders may also feed on this beetle (Michelbacher et al. 1943).

## Cultural Controls

The beetles overwinter as gravid females among weeds and other vegetation. Therefore the elimination of such overwintering sites

could reduce the overwintering population (Berry 1978). However, this practice is limited because of the migratory habit of adult beetles.

Destruction of the beetles in their hibernating caches or in drift, after floods, was found to be very effective in most cases (Rockwood unpublished).[1] Rockwood and Chamberlin (1943) reported that late seeding of clover, alfalfa and corn could help avoid most of the damage caused by the larvae and adults.

## Chemical Controls

Insecticides have been the most widely used method to control larvae and adults of the western spotted cucumber beetle. The most commonly used insecticides in the past were DDT (Robinson 1947, Jones 1947, Michelbacher et al. 1950), BHC (Crowell 1948), parathion (Schoenfeld 1950), and aldrin, dieldrin and heptachlor (Michaelbacher et al. 1952, Crowell 1955, Morrison and Crowell 1955). In spite of their effectiveness to control this pest, none of these insecticides are currently registered because of their impact on the environment.

The currently used insecticides include: Carbaryl, Diazinon, Azinophosmethyl, Malathion, Methoxychlor and Naled. Carbaryl is the most widely used because it is inexpensive and more effective.

# MATERIALS AND METHODS

## Laboratory Cultures

Adult western spotted cucumber beetles were collected from the entomology farm and the vegetable crop research farm near Corvallis, Oregon. A culture was maintained at room temperature in a rearing cage (3.6 x 1.8 x 1.8 m). Fresh bean leaves, supplemented from time to time with leaves and flowers of various weed plants were added regularly to the rearing cage. Two small petri dishes with folded pieces of dampened cotton cloth were placed in the rearing cage to supply water for the beetles. The rearing cage was cleaned regularly to remove dead and parasitized beetles.

## Snap Bean Cultivars

Twenty snap bean cultivars were evaluated in a preliminary field test. Cultivars were grown in field cages (3.6 x 1.8 x 1.8 m) at the entomology farm and each was infested with 200 adult western spotted cucumber beetles. Twelve cultivars were then selected to evaluate resistance of snap beans to damage caused by adult western spotted cucumber beetles. This selection was based on the average number of undamaged green pods from a preliminary field study.

The cultivars Green Isle, Itasca, Resistant Cherokee Wax, and Spartan Arrow were selected as least susceptible; Bush Blue Lake 274,

Green Ruler, Blue Max, and Blue Crop as most susceptible; and Oregon 1604, Bush Hort. #4, Early Gallatin and Galamor as intermediate in their susceptibility to adult damage.

## Preliminary Field Study

This study was conducted in Lumite[R] cages (3.6 x 1.8 x 1.8 m) at the entomology farm during 1978. The snap bean cultivars which were evaluated included: Green Isle, Itasca, Resistant Cherokee Wax, Spartan Arrow, Oregon 1604, Bush Hort. #4, Blue Max, Blue Crop, Bush Blue Lake 274, Green Ruler, Early Gallatin, Galamor, Sungold, Provider, Tendercrop, Harvester, Astro, Eastern Butterwax, Asgrow 290, and Del Rey. Two plants of each cultivar were grown in each cage in a randomized block design with six replications. Each cage was infested with 200 adult beetles during the early flowering stage of the beans. Six screen cages (1 x 1 x 1 m) arranged in the same randomized design were used as uninfested controls.

Results of this study indicated that the yield of some cultivars was reduced by adult feeding. Variations between cultivars in response to beetle injury on the green pods provided evidence that some cultivars were less susceptible to adult injury.

## Greenhouse Studies

Studies were conducted in Lumite cages (3.6 x 1.8 x 1.8 m) in the greenhouse. Two plants of each of the 12 selected cultivars were

grown in each of four pots (20 cm in diameter). Fertilizer[5] and lime were incorporated with greenhouse soil at the rate of about nine grams of each per pot of soil prior to planting. Pots were arranged in a completely randomized design in each of four cages. Pots were placed in a layer of vermiculite and watered from below.

During the first trifoliate growth stage, three cages were each infested with 200 field collected beetles. No beetles were released in the fourth cage. At the beginning of the flowering stage, all pots in the four cages were removed and replaced, using the same randomization with an equal number of plants all in the flowering stage. A density of 200 beetles was also used to evaluate injury on flowers and the pods which subsequently developed.

Plants which had been exposed to beetles during the first trifoliate stage and the flower and pod development stages were harvested separately. Cultivars were evaluated by assessing yield reduction relative to that of the control, the number of feeding punctures on the green pods, and the grades of the beans.

## Laboratory Studies

### Foliar Damage

Two methods were used to evaluate beetle injury on foliage. In the first experiment, three leaves from each of four field plots were collected from each of ten cultivars in each plot. The leaf area was

[5]Webfoot 15-5-10. Webfoot Fertilizer Company, Inc., Portland, Oregon.

measured using a Licor area meter.[6] Masking tape was used to cover the beetle feeding injury on the leaves, and each was re-measured using the area meter. The amount of feeding injury was estimated by subtracting the area of the untaped leaves from that of the taped leaves.

In the second experiment, two leaves from each of the 12 selected cultivars were randomly removed from plants in the greenhouse. The leaf area of each was measured with the Licor area meter. Then one leaf of the pair was infested with one adult beetle in a covered petri dish, and the other leaf was left as an uninfested control in a covered petri dish. All petri dishes were placed in a temperature controlled cabinet at 20°C for 24 hours. Fresh leaves were replaced daily. Percent leaf consumption by beetles was adjusted using the following formula:

$$100 \quad \left( \frac{I_1 - I_2}{I_1} - \frac{C_1 - C_2}{C_1} \right)$$

Where $I_1$ and $I_2$ are the measurement of the infested leaf before and after infestation, respectively. $C_1$ and $C_2$ are the first and second leaf area measurements of the uninfested leaf.

Damage to Green Pods

Two fresh pods from each of ten snap bean cultivars were placed at random in each of five screen cages (0.25 x 0.25 x 0.5 m). Each

[6]Model LI-3000 portable area meter. Lambda Instrument Corporation, Lincoln, Nebraska.

cage was infested with 20 adult beetles which were allowed to feed for 24, 48, and 72 hours in three separate tests.

Feeding injury was evaluated by counting the number of feeding punctures on each pod after 24, 48, and 72 hours of beetle feeding.

## Field Studies

### Damage to Flowers and Developing Pods

Ten snap bean cultivars were evaluated in the field. Three plants of each cultivar were caged in (1 x 1 x 1 m) screen cages. Three cages were infested with 12 adult beetles, and the fourth cage was used as an uninfested control. Cages were infested during the flowering stage, and beetles were allowed to feed 20 days before harvest. Beans were individually picked from each plant at harvest.

Evaluation of the damage was based on yield reduction, number of damaged pods, and bean grades.

### Damage to Seedlings

Beetle damage to seedlings was determined for 20 snap bean cultivars in six naturally infested field plots at the vegetable crop research farm. Evaluation was conducted first by counting the number of seedlings damaged by beetles in each cultivar. Additionally a visual rating of adult damage on the foliage of the seedlings was performed. A rating system from one to four was used to estimate the injury (1 ≡ 0 to 3 holes, 2 ≡ 4 to 6, 3 ≡ 7 to 10, 4 ≡ > 10).

# RESULTS AND DISCUSSION

## Preliminary Field Study

Differences among the cultivars in this experiment were evaluated by determining the yield of each cultivar, the number of feeding punctures on green pods, and the percent of damaged pods.

Results showed that there were differences in feeding injury among the cultivars (Table 1). Twelve cultivars were selected from the preliminary study for further evaluation in the field and greenhouse. The 12 cultivars were selected based on the percent damaged pods and the average number of undamaged pods. The cultivars Resistant Cherokee Wax, Green Isle, Itasca, and Spartan Arrow were least susceptible; Blue Crop, Blue Bush Lake, Green Ruler, and Blue Max were highly susceptible and Bush Hort. #4, Oregon 1604, Early Gallatin, and Galamor were selected as intermediate in resistance to beetle injury.

## Greenhouse Experiment

Resistance of snap beans to adult western spotted cucumber beetle was evaluated during two snap bean growth stages.

The first experiment was conducted on plants in the leaf stage. This experiment was evaluated by comparing the yield of snap beans in infested cages with yield in uninfested cages and computing the yield ratio (infested/uninfested) of each cultivar. Results of this experiment showed a highly significant difference in yield among the cultivars ($P < 0.01$)(Table 2). However, differences in yield ratio

Table 1. Preliminary field evaluation of resistance in snap beans to adult western spotted cucumber beetle.

| Cultivars | Total No. Pods | No. Damaged Pods | No. Undamaged Pods | % Damage | Rank |
|---|---|---|---|---|---|
| Resistant Cherokee Wax | 616 | 86 | 530 | 14.0 | 1* |
| Green Isle | 538 | 110 | 428 | 20.4 | 2* |
| Itasca | 309 | 74 | 235 | 23.9 | 3* |
| Spartan Arrow | 472 | 114 | 352 | 24.2 | 4* |
| Bush Hort. #4 | 327 | 88 | 239 | 26.9 | 5* |
| Sungold | 346 | 98 | 248 | 28.3 | 6 |
| Provider | 304 | 91 | 213 | 29.9 | 7 |
| Eastern Butterwax | 337 | 109 | 228 | 32.3 | 8 |
| Oregon 1604 | 379 | 123 | 256 | 32.5 | 9* |
| Asgrow 290 | 394 | 136 | 258 | 34.5 | 10 |
| Harvester | 358 | 126 | 232 | 35.2 | 11 |
| Early Gallatin | 389 | 138 | 251 | 35.5 | 12* |
| Del Rey | 443 | 163 | 280 | 36.8 | 13 |
| Tender Crop | 333 | 124 | 209 | 37.2 | 14 |
| Astro | 314 | 123 | 191 | 39.2 | 15 |
| Galamor | 413 | 176 | 237 | 42.6 | 16* |
| Blue Crop | 206 | 92 | 114 | 44.7 | 17* |
| Bush Blue Lake | 432 | 201 | 231 | 46.5 | 18* |
| Green Ruler | 238 | 121 | 117 | 50.8 | 19* |
| Blue Max | 332 | 184 | 148 | 55.4 | 20* |

*Cultivars selected for further study.

Table 2. Yield ratio (infested/uninfested) of snap bean cultivars infested with adult western spotted cucumber beetle during leaf stage and flower and pot stages.

| Cultivars | Reps | Leaf Stage $\bar{X}$ Yield Ratio (Infested/Uninfested) I | II | III | $\bar{X}$[1/] |
|---|---|---|---|---|---|
| Spartan Arrow | | 1.30 | 1.74 | 1.66 | 1.56a |
| Oregon 1604 | | 1.29 | 1.27 | 1.77 | 1.44ab |
| Green Ruler | | 1.17 | 1.26 | 1.50 | 1.31abc |
| Green Isle | | 1.24 | 1.48 | 1.07 | 1.26abcd |
| Resistant Cherokee Wax | | 0.63 | 1.58 | 1.31 | 1.17bcd |
| Itasca | | 1.15 | 0.99 | 1.10 | 1.98cde |
| Early Gallatin | | 0.86 | 0.79 | 1.31 | 0.99cdef |
| Galamor | | 0.89 | 0.74 | 1.19 | 0.94def |
| Bush Hort. #4 | | 0.90 | 0.72 | 0.73 | 0.78efg |
| Bush Blue Lake | | 1.00 | 0.61 | 0.70 | 0.77efg |
| Blue Max | | 0.60 | 0.54 | 0.91 | 0.68fg |
| Blue Crop | | 0.56 | 0.62 | 0.63 | 0.60g |

| Cultivars | Reps | Flower and Pod Stages $\bar{X}$ Yield Ratio (Infested/Uninfested) I | II | III | $\bar{X}$[1/] |
|---|---|---|---|---|---|
| Oregon 1604 | | 1.01 | 1.21 | 1.26 | 1.16a |
| Itasca | | 1.36 | 1.01 | 1.08 | 1.15ab |
| Bush Blue Lake | | 1.04 | 1.24 | 1.06 | 1.11abc |
| Galamor | | 1.02 | 0.96 | 1.32 | 1.10abc |
| Green Isle | | 1.02 | 1.15 | 1.01 | 1.06abc |
| Early Gallatin | | 0.91 | 1.26 | 0.95 | 1.04abc |
| Spartan Arrow | | 1.09 | 0.82 | 1.09 | 1.00abc |
| Bush Hort. #4 | | 1.00 | 0.84 | 1.08 | 0.97abc |
| Blue Max | | 0.74 | 0.88 | 0.91 | 0.84abc |
| Blue Crop | | 1.06 | 0.68 | 0.73 | 0.82bc |
| Resistant Cherokee Wax | | 0.70 | 0.66 | 1.05 | 0.80c |
| Green Ruler | | 0.87 | 0.68 | 0.79 | 0.78c |

1/ means followed by the same letter are not significantly different (DNMRT)($P < 0.05$).

Analysis of Variance (Appendix Table 3)

| Source of Variation | df | F | Significance |
|---|---|---|---|
| Stages | 1 | 3.268 | NS |
| Cultivars | 11 | 5.093 | $P < 0.01$ |
| Error | 22 | | |

within each cultivar could be attributed to genetic variations among cultivars or to the effect of moving plants from the cages at the end of the leaf stage to an adjacent greenhouse where the plants were allowed to mature.

The second experiment was designed to evaluate beetle injury during the flower and pod stages. Field collected adults were introduced into the cages when floral buds first firmed. This experiment was evaluated using analysis of variance to compare yield ratios (infested/uninfested) to test differences among the cultivars. Results showed a significant difference in yield among the cultivars ($P < 0.01$) (Table 2).

Beetle feeding injury during the flower and pod stages was expected to have a greater impact on yield reduction than during the leaf stage. A comparison between the yield of infested cages indicated a highly significant difference between snap bean cultivars within each growth stage ($P < 0.01$)(Table 2). However, there were no significant differences in the yield of individual cultivars between the leaf stage and the flower and pod stages.

The results also indicated that there was a highly significant difference in the number of damaged pods among the cultivars ($P < 0.01$) (Table 3). Results showed that Blue Max was the most susceptible to beetle injury, followed by Galamor, Bush Hort. #4, Green Ruler, and Blue Crop. Green Isle, Resistant Cherokee Wax, Spartan Arrow, Oregon 1604, and Itasca were least susceptible to beetle injury.

Table 3. Resistance to adult western spotted cucumber beetle in snap beans during flower and pod growth stages.

| Cultivars | % Damaged Pods Replications I | II | III | $\bar{X}$[1/] |
|---|---|---|---|---|
| Green Isle | 7.12 | 9.80 | 14.07 | 10.33a |
| Resistant Cherokee Wax | 8.70 | 11.76 | 16.67 | 12.38ab |
| Spartan Arrow | 13.33 | 12.50 | 12.07 | 12.63ab |
| Oregon 1604 | 12.50 | 9.72 | 16.46 | 12.89ab |
| Itasca | 17.65 | 9.09 | 12.72 | 13.15ab |
| Early Gallatin | 15.00 | 6.25 | 25.93 | 15.73ab |
| Bush Blue Lake | 23.81 | 15.38 | 11.11 | 16.77ab |
| Blue Crop | 15.00 | 20.00 | 18.18 | 17.73ab |
| Green Ruler | 21.82 | 12.70 | 18.97 | 17.83ab |
| Bush Hort. #4 | 15.38 | 17.14 | 21.86 | 18.13ab |
| Galamor | 16.97 | 20.88 | 19.12 | 18.99b |
| Blue Max | 27.27 | 31.82 | 26.09 | 28.39c |

1/means followed by the same letter are not signifivantly different (DNMRT) ($P < 0.05$)

Analysis of Variance (Appendix Table 4)

| Source of Variations | df | F | Significance |
|---|---|---|---|
| Cultivars | 11 | 3.2059 | $P < 0.01$ |
| Error | 22 | | |

Snap beans were graded with sieves into sizes one through six. Snap beans in sieve sizes two, three, and four were combined to make grade A. Beans in sieve sizes five and six were combined to make grade B. The beans in grade C were oversized (> 6) and undersized (≤ 1). Grades A and B were computed as a percentage of the total yield in each infested cage. Results showed that Green Isle, Early Gallatin, and Spartan Arrow produced the highest percentage of Grade A beans, whereas Blue Max, Green Ruler, and Bush Hort. #4 produced the lowest percentage of grade A beans (Figure 3). All cultivars produced higher percentages of grade B beans than grade A beans except for Green Isle and Early Gallatin. Oregon 1604 produced the highest percentage of grade B beans, whereas Early Gallatin produced the lowest percentage of grade B beans.

Beetle feeding injury on beans in grades A and B is shown in Figure 4. Blue Max, Bush Hort. #4, and Green Ruler were most severely damaged. Oregon 1604, Green Isle, and Itasca were the least damaged as well as Spartan Arrow which had the lowest percentage of damaged beans in grade B (Figure 4).

## Damage on the Foliage

The first experiment was designed to evaluate injury on leaves collected from field plots. Results showed that there were highly significant difference in damage to foliage among the cultivars ($P < 0.01$)(Table 4). Itasca, Oregon 1604, and Spartan Arrow were least damaged and Blue Crop was the most severely damaged.

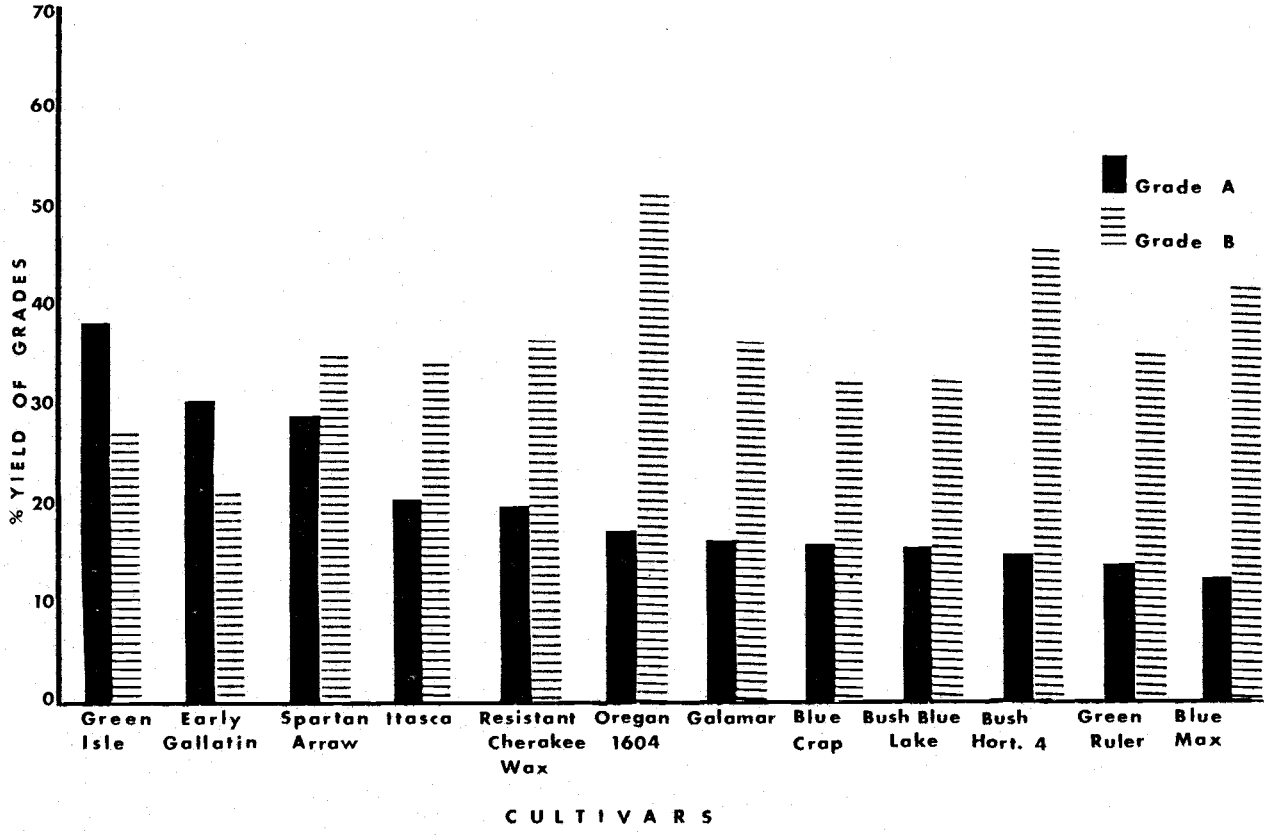


Figure 3. Effect of adult beetles on percent yield of grade A and B snap bean cultivars.

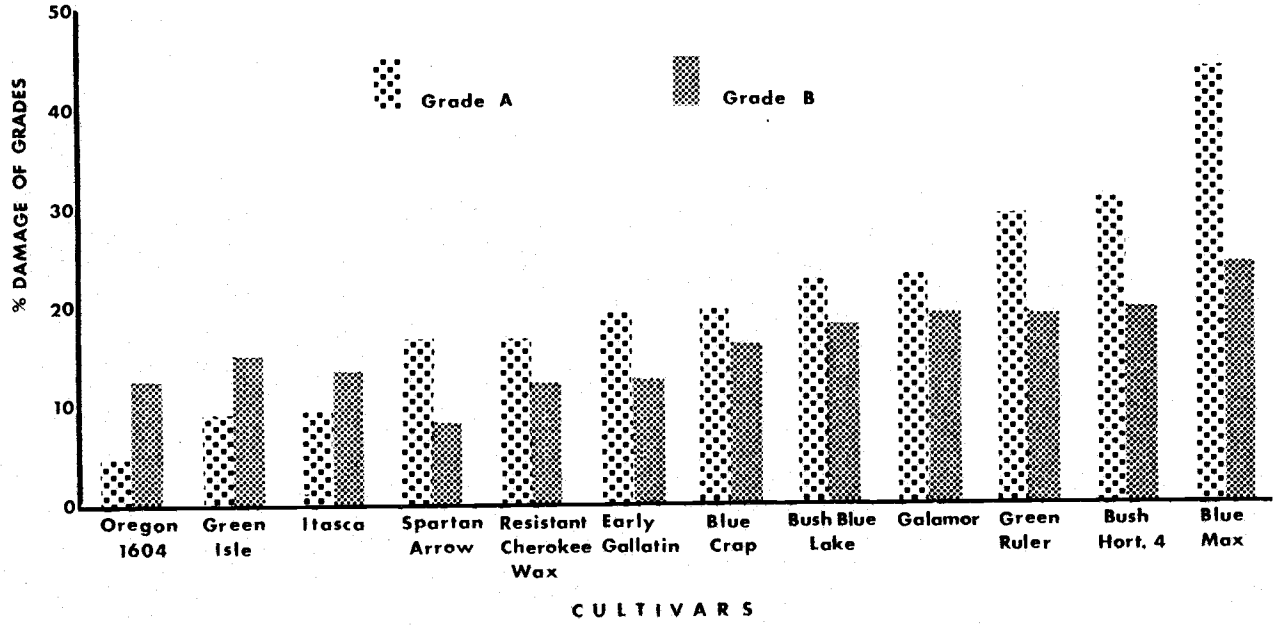


Figure 4. Percent of grade A and B beans of 12 snap bean cultivars damaged by adult feeding injury.

Results of the second experiment which was conducted in the laboratory showed a highly significant difference in leaf consumption between the cultivars ($P < 0.01$)(Table 5).

The results of both experiments clearly indicated that Spartan Arrow as well as Itasca, Resistant Cherokee Wax, Oregon 1604, and Green Isle were the least susceptible cultivars, whereas Blue Crop was the most susceptible cultivar, followed by Blue Max and Green Ruler.

A comparison of mean foliage consumed in field and laboratory studies for ten cultivars is shown in Figure 5. Foliar damage was most severe on cultivars grown in the field. This result indicates that adults had a preference for the succulent cotyledonous leaves which were attacked by beetles in the field. Randomly selected mature leaves were used in the second study and were less severely damaged. In both studies, leaf tissues of Blue Crop was the most heavily consumed particularly in the field (Figure 5).

## Damage to Green Pods

Damage on pods is the most critical type of beetle injury because snap beans with one percent feeding damage is the maximum level accepted by processors. An experiment was conducted to evaluate the effect of beetle feeding injury on green pods for one, two, and three days.

Data were collected by computing the average number of feeding punctures on the pods of each cultivar during each infestation period.

Table 4. Evaluation of adult western spotted cucumber beetle damage on foliage of the snap bean cultivars in field plots.[1/]

| Cultivars | % Leaf Damaged Replications I | II | III | IV | $\bar{X}$[2/] |
|---|---|---|---|---|---|
| Itasca | 2.19 | 2.31 | 1.94 | 3.14 | 2.4a |
| Oregon 1604 | 1.56 | 3.48 | 1.57 | 3.84 | 2.6a |
| Spartan Arrow | 3.13 | 4.40 | 2.43 | 1.07 | 2.8a |
| Resistant Cherokee Wax | 5.42 | 1.62 | 5.79 | 3.51 | 4.1ab |
| Green Isle | 7.49 | 4.00 | 6.15 | 2.37 | 5.0ab |
| Early Gallatin | 3.17 | 8.73 | 4.48 | 6.17 | 5.6ab |
| Galamor | 1.85 | 10.60 | 1.26 | 8.59 | 5.6ab |
| Blue Max | 6.94 | 4.91 | 9.21 | 6.17 | 6.8ab |
| Rush Blue Lake | 5.80 | 11.49 | 6.68 | 9.26 | 8.3b |
| Blue Crop | 18.30 | 14.03 | 20.88 | 7.67 | 15.2c |

[1/] Damaged measured in number $cm^2$ consumed.

[2/] Means followed by the same letter are not significantly different (DNMRT)($P < 0.05$).

Appendix of Variance (Appendix Table 5)

| Source of Variation | df | F | Significance |
|---|---|---|---|
| Cultivars | 9 | 6.4893 | $P < 0.01$ |
| Error | 27 | | |

Table 5. Laboratory evaluation of adult western spotted cucumber beetle damage on snap bean foliage.[1/]

| | % of Leaf Damaged Observation No. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | $\bar{X}$[2/] |
| Spartan Arrow | 1.88 | 1.35 | 0.92 | 1.31 | 1.48 | 1.07 | 1.29 | 1.43 | 1.25 | 1.96 | 1.39a |
| Green Isle | 0.77 | 0.41 | 1.65 | 1.26 | 3.16 | 1.39 | 2.31 | 2.92 | 1.97 | 2.41 | 1.83ab |
| Itasca | 1.40 | 1.32 | 0.54 | 1.36 | 2.31 | 1.74 | 2.10 | 4.74 | 2.54 | 2.16 | 2.02ab |
| Resistant Cherokee Wax | 0.84 | 2.30 | 2.08 | 2.41 | 4.34 | 2.94 | 1.96 | 1.53 | 1.89 | 0.95 | 2.17abc |
| Oregon 1604 | 1.38 | 2.85 | 2.12 | 3.48 | 1.88 | 2.95 | 2.58 | 2.31 | 2.13 | 1.17 | 2.29abc |
| Early Gallatin | 1.99 | 0.61 | 3.10 | 2.50 | 2.65 | 2.94 | 2.74 | 2.92 | 2.13 | 3.34 | 2.29abc |
| Galamor | 1.35 | 0.21 | 0.75 | 1.75 | 5.70 | 4.48 | 0.99 | 2.44 | 3.13 | 3.85 | 2.47abc |
| Bush Hort. #4 | 0.13 | 0.20 | 5.60 | 4.06 | 3.23 | 1.93 | 1.33 | 3.25 | 5.55 | 6.39 | 3.17bcd |
| Bush Blue Lake | 2.28 | 4.80 | 4.04 | 3.66 | 3.08 | 2.72 | 3.25 | 3.21 | 3.41 | 1.64 | 3.21bcd |
| Green Ruler | 0.77 | 4.84 | 0.99 | 7.16 | 4.53 | 3.10 | 4.63 | 2.58 | 3.91 | 2.35 | 3.49cd |
| Blue Max | 3.30 | 2.60 | 1.58 | 4.80 | 3.53 | 2.83 | 3.61 | 5.74 | 4.20 | 3.54 | 3.57cd |
| Blue Crop | 11.11 | 2.18 | 8.39 | 1.80 | 2.35 | 3.01 | 5.91 | 6.74 | 4.23 | 3.69 | 4.14d |

[1/] Damage was measured in no. $cm^2$ consumed.

[2/] Means followed by the same letter are not significantly different (DNMRT)($P < 0.05$).

Analysis of Variance (Appendix Table 6)

| Source of Variation | df | Ms | F | Significance |
|---|---|---|---|---|
| Cultivars | 11 | 6.8625 | 3.4816 | $P < 0.01$ |
| Error | 99 | 1.9710 | | |

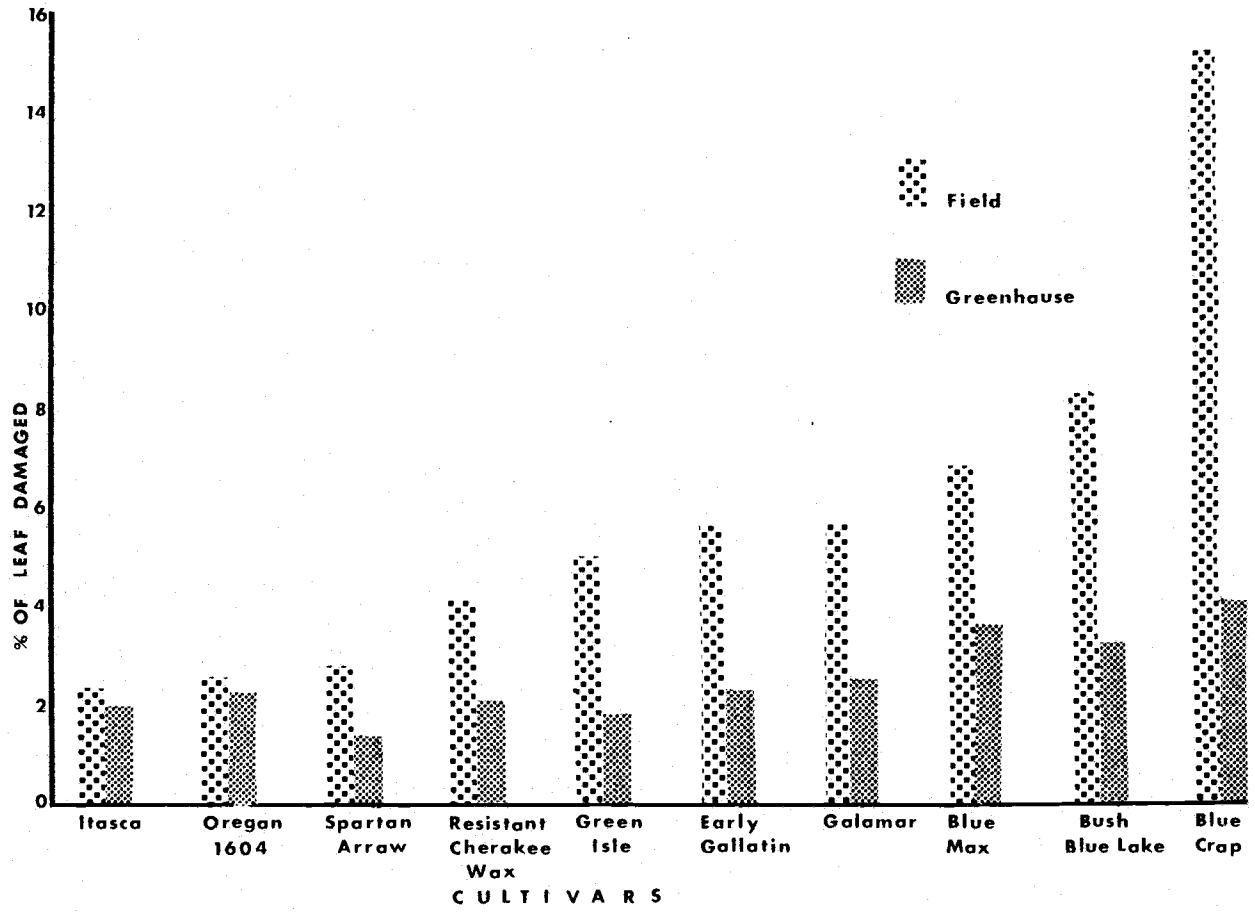


Figure 5. Comparison of adult beetle damage to foliage in field and greenhouse studies.

Results of this study showed that there was a significant difference among the cultivars ($P < 0.05$), and a highly significant difference between the three infestation periods ($P < 0.01$)(Table 6). Except for Oregon 1604, the number of feeding punctures increased as the exposure period increased. This exception could be due to differences in tenderness of the pods selected since standardization was very difficult. In most cases, beetles fed in groups of three to four on one pod, especially on the cultivar, Itasca, which was heavily damaged during the three day feeding period. Collectively, Spartan Arrow, Oregon 1604, Resistant Cherokee Wax and Green Isle were least susceptible and Bush Blue Lake, Blue Crop, and Blue Max were most susceptible (Table 6).

## Individual Field Cage Evaluations

In this experiment the effect of beetle injury on each cultivar was expressed as the percentage of damaged green pods. Results indicated that there was a highly significant difference in the percentage of damaged pods among the cultivars ($P < 0.01$)(Table 7). Spartan Arrow and Resistant Cherokee Wax were least susceptible, whereas Blue Crop and Blue Max were most damaged.

Results of this experiment confirmed the greenhouse experiment in which beetles were allowed to feed on the cultivars during flower and pod stages (Table 2).

A comparison between the greenhouse and field study is shown in Figure 6. Feeding injury was more severe in the greenhouse experiment

Table 6. Mean[1/] no. of western spotted cucumber beetle feeding punctures on green pods of ten snap bean cultivars.

| Cultivars | X No. Feeding Punctures Feeding Periods | | |
|---|---|---|---|
| | 24 hrs. | 48 hrs. | 72 hrs. |
| Itasca | 1.7a[2/] | 2.6ab[2/] | 10.0e[2/] |
| Galamor | 1.8a | 3.2bc | 5.2d |
| Spartan Arrow | 1.9a | 2.6ab | 3.0a |
| Early Gallatin | 1.9a | 2.6ab | 4.0c |
| Oregon 1604 | 2.0ab | 4.3d | 3.2ab |
| Bush Blue Lake | 2.2ab | 3.4c | 5.6d |
| Green Isle | 2.3ab | 2.3a | 3.8bc |
| Resistant Cherokee Wax | 2.6bc | 2.8abc | 3.4abc |
| Blue Max | 3.2c | 3.1bc | 5.2d |
| Blue Crop | 3.2c | 3.0bc | 5.4d |

[1/] Average of five replications.

[2/] Means followed by the same letter are not significantly different (DNMRT)(P < 0.05)

Analysis of Variance (Appendix Table 7)

| Source of Variations | df | F | Significance |
|---|---|---|---|
| Cultivars | 9 | 2.359 | P < 0.05 |
| Feeding Periods | 2 | 43.693 | P < 0.01 |
| Error | 72 | | |

Table 7. Evaluation of resistance in snap beans to adult western cucumber beetles in field cages.

| | % No. Damaged Pods Cultivars | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant No. | Spartan Arrow | Resistant Cherokee Wax | Green Isle | Early Gallatin | Itasca | Bush Blue Lake | Oregon 1604 | Galamor | Blue Max | Blue Crop |
| 1 | 3.64 | 8.33 | 6.06 | 5.88 | 3.70 | 4.69 | 10.67 | 6.78 | 13.92 | 24.14 |
| 2 | 4.11 | 7.41 | 7.52 | 6.25 | 7.27 | 9.09 | 12.16 | 10.91 | 14.04 | 4.76 |
| 3 | 3.51 | 2.56 | 6.12 | 5.41 | 13.64 | 14.75 | 16.39 | 7.84 | 22.97 | 12.12 |
| 4 | 4.05 | 3.53 | 4.69 | 9.68 | 7.41 | 9.72 | 11.76 | 8.82 | 5.38 | 45.45 |
| 5 | 7.14 | 7.84 | 8.86 | 5.63 | 5.26 | 9.46 | 3.16 | 12.50 | 10.49 | 8.00 |
| 6 | 4.35 | 8.33 | 6.94 | 8.06 | 3.49 | 6.49 | 6.82 | 18.92 | 9.09 | 8.33 |
| 7 | 4.69 | 3.61 | 6.38 | 7.41 | 7.14 | 4.11 | 7.58 | 9.30 | 5.56 | 10.34 |
| 8 | 2.13 | 7.46 | 10.64 | 10.81 | 7.27 | 9.80 | 3.39 | 9.30 | 4.48 | 16.00 |
| 9 | 2.56 | 3.54 | 4.00 | 5.56 | 10.53 | 5.77 | 6.67 | 8.55 | 12.26 | 14.29 |
| $\bar{X}$[1/] | 4.58a | 5.83ab | 6.80ab | 7.19ab | 7.3ab | 8.21ab | 8.73ab | 10.32b | 10.90b | 15.94c |

[1/] Means followed by the same letter are not significantly different (DNMRT) ($P < 0.05$)

Analysis of Variance (Appendix Table 8)

| Source of Variations | df | MS | F | Significance |
|---|---|---|---|---|
| Cultivars | 9 | 93.0311 | 3.5845 | $P < 0.01$ |
| Error | 72 | 25.9535 | | |

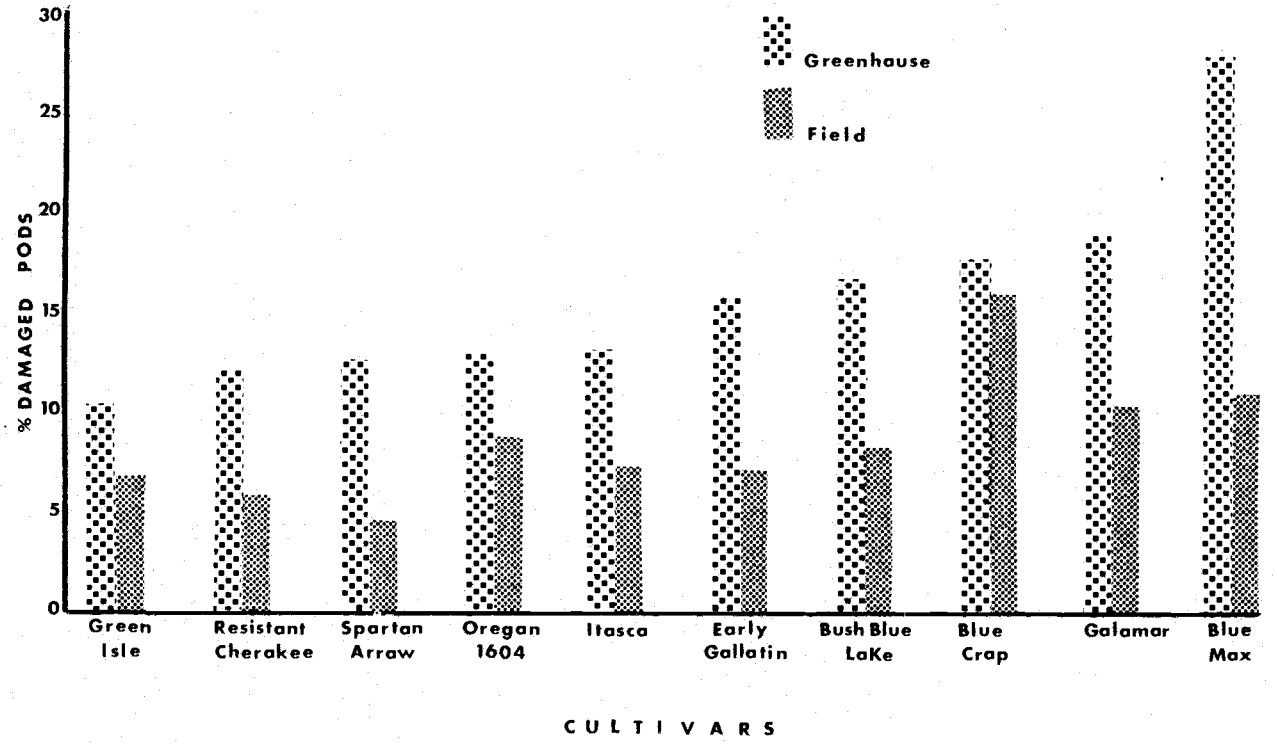


Figure 6. Percent of pods damaged in greenhouse and field experiments.

because plants were exposed to a larger number of beetles per cage area. Also, the potted plants in the greenhouse appeared less vigorous and were grown under lower light intensity than plants grown in the field. However, the same pattern of susceptibility to beetle injury was evident in both experiments. Spartan Arrow, Resistant Cherokee Wax, Green Isle, Early Gallatin, Oregon 1604, and Itasca were least susceptible while Galamor, Blue Max, and Blue Crop were most susceptible (Table 7)(Figure 6).

## Effect of Beetle Injury on Seedlings

A visual rating of beetle injury on seedlings of each cultivar in each plot is summarized in Table 8. An analysis of variance applied to averages of the visual ratings indicated that there were no significant differences among the cultivars. All cultivars were injured during early stages of growth. However, feeding injury was particularly severe in all six plots of Blue Crop confirming its high susceptibility to beetle injury. Green Isle was least susceptible to beetle injury during the seedling stage.

The number and percent of damaged seedlings of each cultivar was also analyzed (Table 9). Results indicated a significant difference in percent damaged seedlings between the cultivars ($P < 0.05$). Blue Crop was the most susceptible and Green Isle was the least susceptible cultivar as in the previous study (Table 8).

In all cultivars evaluated more than fifty percent of the seedlings were damaged, however all cultivars recovered from this

Table 8. Ratings of adult western spotted cucumber beetle damage on foliage of snap bean seedlings in field plots.

| Cultivars | Damage Rating[1/] Replications | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | X |
| Green Isle | 1 | 2 | 3 | 1 | 3 | 2 | 2.0 |
| Provider | 2 | 1 | 2 | 4 | 2 | 2 | 2.2 |
| Resistant Cherokee Wax | 1 | 2 | 3 | 4 | 1 | 3 | 2.3 |
| Tender Crop | 2 | 1 | 4 | 3 | 2 | 2 | 2.3 |
| Itasca | 2 | 3 | 2 | 4 | 3 | 1 | 2.5 |
| Oregon 1604 | 1 | 4 | 4 | 3 | 1 | 2 | 2.5 |
| Early Gallatin | 4 | 2 | 2 | 2 | 2 | 3 | 2.5 |
| Blue Max | 2 | 4 | 3 | 3 | 2 | 1 | 2.5 |
| Del Rey | 3 | 3 | 2 | 4 | 2 | 1 | 2.5 |
| Asgrow 290 | 3 | 3 | 2 | 3 | 2 | 2 | 2.5 |
| Green Ruler | 4 | 4 | 2 | 3 | 2 | 1 | 2.7 |
| Sungold | 4 | 4 | 2 | 3 | 2 | 1 | 2.7 |
| Spartan Arrow | 2 | 3 | 3 | 3 | 3 | 3 | 2.8 |
| Galamor | 3 | 4 | 3 | 3 | 2 | 3 | 3.0 |
| Bush Blue Lake | 4 | 4 | 2 | 4 | 2 | 3 | 3.2 |
| Astro | 2 | 4 | 4 | 3 | 2 | 4 | 3.2 |
| Eastern Butterwax | 3 | 3 | 3 | 3 | 4 | 3 | 3.2 |
| Bush Hort. #4 | 4 | 4 | 2 | 4 | 3 | 3 | 3.3 |
| Harvester | 4 | 3 | 3 | 4 | 3 | 3 | 3.3 |
| Blue Crop | 4 | 4 | 3 | 4 | 4 | 4 | 3.9 |

[1/] 1 = 0 to 3 holes
2 = 4 to 7 holes
3 = 8 to 10 holes
4 = > 10 holes

Analysis of Variance (Appendix Table 9)

| Source of Variation | df | F | Significance |
|---|---|---|---|
| Cultivars | 19 | 1.3722 | NS |
| Error | 95 | | |

Table 9. Effect of adult western spotted cucumber beetle on seedlings of 12 snap bean cultivars in field plots.

| Cultivars | % Seedlings Damaged Replications I | II | III | IV | V | VI | $\bar{X}$[1/] |
|---|---|---|---|---|---|---|---|
| Green Isle | 50 | 40 | 50 | 89 | 67 | 63 | 61.5a |
| Green Ruler | 70 | 75 | 56 | 67 | 50 | 67 | 64.2a |
| Bush Hort. #4 | 56 | 86 | 30 | 71 | 89 | 63 | 65.8a |
| Spartan Arrow | 80 | 57 | 88 | 70 | 50 | 57 | 67.0a |
| Resistant Cherokee Wax | 83 | 89 | 60 | 70 | 57 | 60 | 69.2a |
| Oregon 1604 | 33 | 100 | 57 | 100 | 89 | 50 | 71.5a |
| Itasca | 100 | 88 | 86 | 60 | 67 | 38 | 72.8a |
| Early Gallatin | 88 | 90 | 80 | 60 | 89 | 38 | 74.2a |
| Galamor | 89 | 86 | 70 | 67 | 70 | 78 | 76.7a |
| Bush Blue Lake | 80 | 89 | 75 | 67 | 75 | 78 | 77.3a |
| Blue Max | 80 | 89 | 88 | 80 | 90 | 40 | 77.8a |
| Blue Crop | 89 | 100 | 100 | 100 | 100 | 100 | 98.2b |

[1/] Means followed by the same letter are not significantly different (DNMRT)($P < 0.05$).

Analysis of Variance (Appendix Table 10)

| Source of Variation | df | F | Significance |
|---|---|---|---|
| Cultivars | 11 | 2.2056 | $P < 0.05$ |
| Error | 55 | | |

damage after one week when more leaves developed and plants became vigorous. Accordingly, beetle injury to seedlings may be assumed to have its drastic effect on yield only when complete defoliation and death of seedlings occurs.

# CONCLUSIONS

Studies were conducted to evaluate resistance in snap beans to adult western spotted cucumber beetles. The cultivars Green Isle, Resistant Cherokee Wax, Spartan Arrow, Itasca, Early Gallatin, Galamor, Bush Hort. #4, Oregon 1604, Bush Blue Lake, Green Ruler, Blue Max, and Blue Crop were selected because they showed various levels of susceptibility to adult feeding injury in preliminary experiments.

Greenhouse experiments showed that there were highly significant differences in yield ratios (infested/uninfested) among the cultivars when exposed to adult beetles during the leaf, flower, and pod stages ($P < 0.01$). However, there were no significant differences in yield ratios for the cultivars between the growth stages.

Results also showed that there were significant differences in percent of pods damaged in the flower and pod stages among the cultivars ($P < 0.01$). Green Isle, Resistant Cherokee Wax, Spartan Arrow, and Oregon 1604 were least damaged, whereas Blue Crop, Green Ruler, Bush Hort. #4, Galamor, and Blue Max were most susceptible.

Green Isle, Early Gallatin and Spartan Arrow produced the highest percentage of grade A beans, and Bush Hort. #4, Green Ruler and Blue Max produced the lowest percentage of grade A beans.

The cultivars Oregon 1604, Green Isle, Itasca, and Spartan Arrow showed less beetle damage on grade A and B beans, whereas Green Ruler, Bush Hort. #4, and Blue Max showed the highest percentage of damage in grade A and B beans.

There were highly significant differences in beetle damage to foliage among the cultivars in the field and laboratory ($P < 0.01$). Itasca and Spartan Arrow were least susceptible, and Blue Max and Blue Crop were most susceptible.

Results also indicated that there were significant differences in the average number of feeding punctures on pods among the cultivars ($P < 0.05$), and highly significant differences between periods of exposure of the pods to beetles ($P < 0.01$). Spartan Arrow was least susceptible, whereas Blue Max and Blue Crop were most susceptible.

Field experiments also showed that there were significant differences in percentage of pods damaged among the cultivars ($P < 0.01$). Spartan Arrow was least damaged and Blue Crop was most severely damaged.

Results showed that there were significant differences in percent number of seedlings damaged among the cultivars ($P < 0.05$). Green Isle, Green Ruler, Bush Hort. #4, and Spartan Arrow were least susceptible, whereas Galamor, Bush Blue Lake, Blue Max, and Blue Crop were most susceptible.

The results of greenhouse experiments confirmed the field experiments and showed that there were differences in resistance among the cultivars to beetle injury. Spartan Arrow, Green Isle, Itasca, Resistant Cherokee Wax, and Oregon 1604 were more resistant than Green Ruler, Bush Blue Lake, Bush Hort. #4, Blue Max and Blue Crop.

Results of my study have shown that the cultivars Spartan Arrow, Green Isle and Resistant Cherokee Wax were consistently less

susceptible to beetle injury. Blue Crop and Blue Max were shown to be most susceptible to injury. Hopefully, these results can be used by plant breeders to study the mechanism of resistance and breed for more resistant cultivars to improve yield and quality of snap beans in the Willamette Valley.

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# APPENDIX

Appendix Table 1. Analysis of variance for yield ratios of 12 snap bean cultivars infested during leaf growth stage.

| Source of Variation | df | SS | MS | F |
|---|---|---|---|---|
| Replication | 2 | 2321.77 | 1160.88 | 2.2449 |
| Cultivars | 11 | 31304.08 | 2845.82 | 5.5033** |
| Error | 22 | 11376.46 | 517.11 | |
| Total | 35 | 45002.31 | | |

**Significant at 0.01 level of probability.

Appendix Table 2. Analysis of variance for yield ratio of 12 snap bean cultivars infested during flower and pod growth stages.

| Source of Variation | df | SS | MS | F |
|---|---|---|---|---|
| Replication | 2 | 372.60 | 136.30 | 0.7377 |
| Cultivar | 11 | 6590.42 | 599.12 | 2.3723* |
| Error | 22 | 5556.21 | 252.55 | |
| Total | 35 | 12519.23 | | |

* Significant at 0.05 level of probability.

Appendix Table 3. Analysis of variance for comparison between yield ratios of 12 snap bean cultivars infested during leaf stage and flower and pod growth stages.

| Source of Variation | df | SS | MS | F |
|---|---|---|---|---|
| Stage | 1 | 1070.53 | 1070.53 | 3.268 |
| Cultivar | 11 | 18353.27 | 1668.47 | 5.093** |
| Replication | 2 | 1649.57 | 824.78 | 2.518 |
| Stage x Cultivar | 11 | 22795.81 | 2072.34 | 5.326 |
| Cultivar x Replication | 22 | 10651.59 | 484.16 | 1.478 |
| Stages x Cultivar x Replication | 22 | 7207.15 | 327.59 | |
| Total | 71 | 62076.72 | | |

**Significant at 0101 level of probability.

Appendix Table 4. Analysis of variance for number of pods damaged during flower and pod growth stages in the greenhouse.

| Source of Variation | df | SS | MS | F |
|---|---|---|---|---|
| Replication | 2 | 54.66 | 29.83 | 1.5328 |
| Cultivar | 11 | 682.33 | 52.39 | 3.2059** |
| Error | 22 | 428.16 | 19.46 | |
| Total | 35 | 1174.15 | | |

** Significant at 0.01 level of probability.

Appendix Table 5. Analysis of variance for beetle damage on foliage in field plots.

| Source of Variation | df | SS | MS | F |
|---|---|---|---|---|
| Cultivars | 9 | 522.80 | 48.08 | 6.4893** |
| Replications | 3 | 10.56 | 3.52 | 0.3932 |
| Error | 27 | 241.65 | 8.95 | |
| Total | 39 | 775.01 | | |

** Significant at 0.01 level of probability.

Appendix Table 6. Analysis of variance for beetle damage on foilage of snap bean cultivars in the greenhouse.

| Source of Variations | df | SS | MS | F |
|---|---|---|---|---|
| Cultivars | 11 | 75.48 | 6.86 | 3.4816** |
| Error | 108 | 212.87 | 1.97 | |
| Total | 119 | 288.36 | | |

LSd 0.05 = 1.24443
0.01 = 1.64815

** Significant at 0.01 level of probability.

Appendix Table 7. Analysis of variance for mean number of beetle feeding punctures on green pods of snap beans.

| Source of Variations | df | SS | MS | F |
|---|---|---|---|---|
| Time | 2 | 179.47 | 98.73 | 43.693** |
| Cultivars | 9 | 47.97 | 5.33 | 2.359* |
| Replications | 4 | 6.35 | 1.58 | 0.703 |
| Time x Cultivars | 18 | 148.69 | 8.26 | 3.656 |
| Time x Replications | 8 | 8.46 | 1.05 | 0.468 |
| Cultivar x Replications | 36 | 70.87 | 1.96 | 0.871 |
| Time x Cultivars x Replications | 72 | 162.70 | 2.25 | |
| Total | 149 | 642.51 | | |

* Significant of 0.05 level of probability.

** Significant of 0.01 level of probability.

Appendix Table 8. Analysis of variance for number of pods damaged during flower and pod stages.

| Source of Variation | df | SS | MS | F |
|---|---|---|---|---|
| Cultivars | 9 | 337.28 | 93.03 | 3.5845** |
| Error | 80 | 2076.31 | 25.95 | |
| Total | 89 | 2913.59 | | |

** Significant at 0.01 level of probability.

Appendix Table 9. Analysis of variance for rate of damage on seedlings in field plots.

| Source of Variations | df | SS | MS | F |
|---|---|---|---|---|
| Replication | 5 | 13.07 | 2.61 | 3.3379** |
| Cultivar | 19 | 20.92 | 1.07 | 1.3722 |
| Error | 95 | 74.42 | 7.83 | |
| Total | 119 | 107.91 | | |

** Significant at 0.01 level of probability.

Appendix Table 10. Analysis of variance on percent number of seedlings damaged in field plots.

| Source of Variations | df | SS | MS | F |
|---|---|---|---|---|
| Replication | 11 | 6991.5 | 635.59 | 2.2056* |
| Cultivar | 5 | 1753.25 | 350.65 | 1.2168 |
| Error | 55 | 15849.25 | 288.18 | |
| Total | 71 | 24594 | | |

* Significant at 0.05 level of probability.