Laboratory and Field Evaluations of Virginia-type Peanut (*Arachis hypogea* L.) Cultivars for Resistance to *Diabrotica undecimpunctata howardi* Barber

by

William J. Petka Jr.

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTERS OF SCIENCE

IN

ENTOMOLOGY

APPROVED:

Dr. Ames Herbert, Jr., Chair

Dr. Robert L. Pienkowski

Dr. Terry Coffelt

December 1995

Blacksburg, Virginia

Key words: Diabrotica, Rootworm, Arachis, Peanut, Resistance, Groundnut

CONTENTS

LABORATORY AND FIELD EVALUATIONS OF VIRGINIA-TYPE PEANUT (*ARACHIS HYPOGAEA* L.) CULTIVARS FOR RESISTANCE TO *DIABROTICA UNDECIMPUNCTATA HOWARDI* BARBER

by

William J. Petka Jr.

Dr. Ames Herbert Jr.

Department of Entomology

ABSTRACT

The southern corn rootworm (*Diabrotica undecimpunctata howardi* Barber) is the primary soil insect pest to peanut (*Arachis hypogaea* L.) in Virginia and North Carolina. The newer cultivars, which are planted on the majority of acreage, have not been extensively screened for rootworm resistance. The objective of this study was to evaluate 5 new virginia-type cultivars (NC-V 11, VA-C 92R, VA 93B, NC 10C and AgraTech VC-1) and 18 breeding lines (N90013E, VA 861101, VA 9211920, VA 9211289, VA 891438, VA 901072, VA 9010343, VA 8911115, VA 9109213, VA 9109235, VA 9109237, VA 9111309, N93007L, N92066L, N92074L, PI 121067, GP-NC 343, N92064L and N93003L) for resistance to southern corn rootworm in the laboratory and in the field. NC 7 and NC 9 were used as susceptible checks. NC 6 was used as a known resistant check. Rootworm mortality and feeding were measured from bioassays in the lab. Pod damage data were obtained from field plots.

NC 6 caused some significant differences with more rootworm mortality at both

the pupal and adult stages than NC 7, NC 9, NC 10C, NC-V11, N90013E, PI 121067, AgraTech VC-1, VA 93B, VA 861101 and VA 9211290 when feeding on peanut seedlings. In addition, NC 6 also caused significantly higher mortality at pupa and adult stages than NC 7, AgraTech VC-1, VA 861101 and VA 93B when larvae fed on peg and immature pod tissue from field plantings. NC 6 also had less total pod damage than NC 7 in natural infestations of southern corn rootworm. Results from this study indicate that NC 6 is still the only cultivar that demonstrates resistance to rootworm.

ACKNOWLEDGMENTS

I would like to thank Ames Herbert, Terry Coffelt and Robert Pienkowski for their advice and support throughout this project. I would also like to thank the following people for their technical assistance: Mike Arrington, Linda Masters-Byrd, Lee Blanchard, and Paul Wyatt.

CHAPTER 1

Introduction

About 88% of the total United States peanut acreage is planted in the southeast with over 250,000 acres planted in Virginia and North Carolina. The United States is a major exporter of peanuts, and the annual cash value is more than $ 1.36 billion. In Virginia, peanut usually ranks third in farm value among all crops. In 1990, approximately 97,000 acres were planted in Virginia (Phipps et al., 1990) with an average of aproximately 92,000 acres planted in the last 10 years.

The southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, has long been considered a major pest of peanuts grown in Virginia and North Carolina and is now considered a major soil pest in some areas of South Carolina, Georgia, Alabama and Texas. Current management is based solely on preventive applications of soil insecticides (chlopyrifos, phorate, fonofos, ethoprop) (Herbert, 1995). In 1990, approximately 90.4% and 50.6% of the total peanut acreage in Virginia and North Carolina, respectively, was preventively treated with soil incorporated insecticides to control southern corn rootworm. These preventive treatments from both states represented 158 tons of active ingredient at a cost of over $3 million (Phipps et al., 1990, Toth et al., 1991). A similar unpublished study in 1991 showed an increasing trend in acreage (92%) preventively treated in Virginia. The proportion of acreage subject to preventive insecticide treatment for southern corn rootworm can be reduced if a reliable means of predicting damage potential

can be developed and alternative management strategies can be offered to growers. Recent surveys by Troost et al. (1992) suggest that IPM practices can eliminate preventive chemical treatment on at least 40% of peanut acreage.

Southern corn rootworm is found in almost all parts of the United States east of the Rocky Mountains, but is most abundant in the southern United States. The southern corn rootworm feeds on over 300 species of plants, but is especially attracted to winter legumes, cucurbits, tomatoes, ornamental plants and fruit crops (Sell, 1916). In general the larval stage of this insect is much more destructive than the adult since a majority of adult feeding causes minimal foliage damage. Injury to peanut pods was first reported by Fink (1916). Larvae injure peanuts by feeding on developing pods causing direct yield loss or cause indirect yield loss by allowing entry of secondary pathogenic microorganisms. Also, they feed on pegs which prevents pod development. With direct yield loss, the rate of damage gradually increases with increase in larval size (Arant, 1929). In addition, external scaring, even superficial, can reduce the value of the crop since virginia-type peanuts grown in this area are primarily for in shell use (Brandenburg and Herbert, 1991).

Southern Corn Rootworm Biology

Southern corn rootworm was observed in the laboratory and in the field to complete three generations every year in Virginia (Grayson and Poos, 1947). Other states

have reported from one to four generations. The southern corn rootworm overwinters as an adult. Most adults overwinter in organic debris, and during this time very few or no eggs are deposited and activity is limited to warm days (Hays and Morgan, 1965). Egg deposition begins in March but peak oviposition for the third generation does not occur until the middle of May. Overwintering females prefer shady moist soil for oviposition (Campbell and Emery, 1967). The first generation adult emergence occurs from late May to early June. The second generation emerges in late July and the third generation in September (Grayson and Poos, 1947).

Female southern corn rootworm copulate only once, while the males will copulate several times. Copulation usually occurs when female beetles are aproximately 5 to 18 days old (Arant, 1929). After copulation, eggs are deposited in crevices of the soil. The female will lay a few eggs in one location then will move a short distance and deposit eggs in another location. The third generation lays more eggs than the first or second. The maximum number of eggs laid per female was 1198 (Arant, 1929).

Eggs usually require 6-13 days to hatch but development time is obviously highly dependent on environmental conditions. One hundred percent relative humidity is critical between 24 and 72 hr of egg development (Krysan, 1976). The larval stage consists of three instars. The larval stage has an active period and an inactive period. The active period is the time of feeding, growth and molting which involves the first two instars and first part of the third. This usually lasts approximately 10 days under laboratory conditions of 27°C and 60-70% relative humidity (Hays and Morgan, 1965).

The inactive period occurs in the latter part of the third instar and is primarily a resting stage, also known as the prepupal stage. The third stadium is the longest, with the second the shortest, and the first intermediate, regardless of generation. Following the prepupal stage, larvae molt and enter the pupal stage. The prepupal and pupal stage combined last about 10 days under laboratory conditions.

Total development period of individuals at a certain time of year is fairly constant but it is quite variable at different times of the year. The lifecycle is completed in an average of 27 days under a constant temperature of 27°C (Isley, 1929). The approximate duration for developmental stages of the first generation is 9 weeks, and the second and third generations about 5 weeks. The adult longevity varies tremendously, with third generation overwintering adults living about 200 days. When comparing duration periods of adult females and males, females live for a longer period of time. This also is seen in the overwintering adults where Arant (1929) showed that seventy percent of adults collected in the field the following spring were females.

Survival of the southern corn rootworm under different environmental conditions was studied by Campbell and Emery (1967) where they observed the effects of food, light, humidity and temperature on feeding, oviposition and survival. They found a significant effect of humidity on adult survival, oviposition and egg hatch, with a minimum of 75% relative humidity required. Longevity of the adult rootworm was greatest at 18.3°C. Over a three-day period of exposure, 35°C was shown to be detrimental. Oviposition was highest above 18.3°C with an optimum level at 29.4°C.

Average number of eggs deposited at 29.4°C was 284.5.

Peanut Biology

Arachis hypogaea L. development is generally characterized by a vegetative and reproductive stage in spite of its indeterminate growth pattern. The vegetative stage begins with emergence of cotyledons near the soil surface. For the first 2-3 weeks of seedling development, all leaves and above-ground parts are contained within the dormant seed itself. Following emergence, node development occurs which is defined when the tetrafoliolate is unfolded and the leaflets become flat (Boote, 1982).

The reproductive stages are events related to flowering, pegging, pod growth, seed growth and maturity. The first reproductive stage involves the flowering of the plant, followed by self-pollination when the pod of the plant begins to develop. A gynophore, or peg, then emerges between the floral bracts and grows downward toward the soil. After pegs have penetrated the soil, peg tips begin to swell horizontally, also known as the beginning pod stage (Gregory et al., 1973). The swelling occurs continually until full pod size is reached. Following full pod development, seeds are produced within the pod cavity. Pods reach full maturity when seeds reach full size and brown to black coloration of the inner pod wall is observed.

Peanut Resistance to Southern Corn Rootworm

Many factors can play a role in peanut resistance to southern corn rootworm. The most widely accepted classification of resistant mechanisms used by plants is defined by Painter (1951). The major classifications include antibiosis, non-preference and tolerance. Antibiosis is by far the most sought after mechanism for resistance. This type of resistance usually impairs an insect's metabolic processes which can result in a number of negative effects such as death, reduced growth rate, reduced fecundity, abnormal behavior and morphological malformations. This type of resistance is very important in a monoculture where the female has little choice of an oviposition site. Non-preference, or antixenosis (Kogan and Ortman, 1978), is a type of resistance that involves a certain characteristic of a plant that deters an insect away from a particular host. This type of resistance involves either allelochemic or morphological characteristics of the plant. The last type of resistance is tolerance, where the plant has the ability to produce sufficient yield even in the presence of high numbers of pests that would normally debilitate nonresistant cultivars.

Peanuts were first tested for resistance by Fronk (1950) when he screened five cultivars in soils where peanuts had previously suffered from rootworm damage. He observed yields and percentages of injured pods for each cultivar. Results showed some resistance in spanish- and valencia-type cultivars. Resistance factors were thought to be a type of antixenosis expressed in the firmer nut quality of the spanish- and valencia-types. Also, the habit of growth and seasonal development in relation to the seasonal history of the southern corn rootworm could have resulted in a type of pseudoresistance

or reduced synchronization, which occurs when a plant is in a growth stage that is less susceptible to pest damage when a pest is most abundant. Spanish- and valencia-types mature more quickly than other cultivars with pods developing to firm, non-susceptible stages before larvae caused significant damage.

Bousch and Alexander (1965) screened approximately 2,500 peanut lines for resistance to southern corn rootworm by observing rootworm feeding in the field. They used a 0 to 4 scale as follows: 0, those showing no pod penetration; 1, up to 10 percent pod damage; 2, up to 25 percent pod damage ; 3, up to 50 percent pod damage; and 4, over 50 percent pod damage. Results indicated least rootworm injury to the pods of the spanish lines and most injury to pods of the virginia lines tested. The type of resistance observed was not determined but was viewed as pseudoresistance since spanish lines possessed earlier maturing pods which would have been more mature and less susceptible to feeding by larvae.

Chalfant and Mitchell (1967a) evaluated several peanut cultivars by subjecting two germinating seeds to newly hatched larvae and recording the number of surviving larvae after 10 days exposure. Significant differences in larval survival were observed between cultivars. They assigned a provisional classification of "resistant cultivar" to any line expressing a 10 percent or less larval survival rate, and applied this classification in future evaluations of peanut lines. Resistance type was viewed as antibiosis since survival of the larvae was inhibited. The cultivars that did express resistance were re-evaluated by planting them in the field under both natural and induced adult infestations (Chalfant and

Mitchell, 1970). Results showed that cultivar differences in percent pod infestation and production of undamaged pods can be a consequence of rate of pod maturity and peg formation rather than a function of true resistance. However, these field tests did show some good correlation with laboratory seedling injury results, thus providing a more thorough evaluation of resistance. None of the entries tested are used in production today, except the cultivar Starr (Simpson, 1972), a spanish-type peanut which is still planted on limited acreage in the southwest. Two of the cultivars, GA 119-20 (Hammons, 1971) and VA 61R (Alexander and Allison, 1970) were used in the breeding of current commercially available cultivars VA 81B (Coffelt et al., 1982), NC 6 (Wynne et al., 1977) and VA 93B (Coffelt et al., 1994).

Smith (1970) tested peanut lines in the greenhouse by subjecting each cultivar to a known number of larvae, this way eliminating the high variation in intensity of field infestations which occurs under natural conditions. Significant differences were found between certain cultivars when determining percent damage of immature, mature, and total fruit. From this experiment, nine virginia-type cultivars viewed as possibly showing some resistance were selected then re-evaluated with three commercially grown cultivars (Smith and Porter, 1971). Testing was done using three levels of larval infestation in the greenhouse and applying the same analysis as the previous experiment, but also monitoring percent maturity between cultivars by calculating the number of mature fruit divided by the total number of fruit, under the three infestation levels. The authors concluded that no cultivars exhibited high enough resistance to be practical for com-

mercial applications. None of the nine entries are currently grown, but two of the cultivars tested, GP-NC 343 (Campbell et al., 1977a) and VA 61R, are parents of the resistant cultivar NC 6.

In 1976, NC 6 was released as a southern corn rootworm-resistant virginia-type cultivar by the North Carolina Agricultural Experiment Station (Campbell et al., 1977b, Wynne et al., 1977). NC 6 produced a higher yield (353-694 kg/ha) than Florigant (Carver, 1969) the most popular cultivar at that time, in soils with high levels of rootworm infestation. Percent pod damage in the field for NC 6 and Florigant was 12.5% and 83.7%, respectively. The authors concluded that even though NC 6 was not found to be completely resistant to rootworm damage, it was considered to be resistant enough to eliminate preventive insecticide applications to many Virginia and North Carolina peanut fields. Higher yielding and earlier maturing cultivars have since been released and farmers are choosing the higher yielding cultivars over NC 6. The currently popular cultivars are either known to be susceptible to southern corn rootworm, or the level of resistance has not been determined.

In field screening of three virginia-type cultivars, NC-V 11 (Wynne et al., 1991), VA-C 92R (Mozingo et al., 1994) and AgraTech VC-1, and an advanced breeding line VA 861101, Coffelt and Herbert (1994) suggested that VA 861101 may be an acceptable replacement for NC 6 based on yield and rootworm damage performance.

Rationale and Significance

Each year the southern corn rootworm causes significant damage to the peanut crop of Virginia and North Carolina, which results in large management expenses and extensive preventive application of soil applied insecticides. As well as being an economic expense, the widespread preventive use of insecticides is counter to the IPM philosophy and constitutes a possible risk to human health, water and soil resources. Because of this and the concern for food safety, it is critical to investigate all management methods that could result in reduced pesticide usage. One of the most effective and economic means of control would be to develop a peanut cultivar resistant to southern corn rootworm.

NC 6 was introduced as a rootworm resistant virginia-type peanut cultivar in 1977 (Campbell et al., 1977; Wynne et al., 1977). Although NC 6 does confer resistance to rootworm and has been grown on as much as 20% of Virginia acreage, it is not grown as widely now because it does not compete well with newer cultivars that have higher yield potential, earlier maturity and/or disease resistance. The newer cultivars, which are planted on the majority of acreage, have never been screened for rootworm resistance. Without knowledge of resistance, these cultivars must be treated as if they do not have resistance in order to insure minimal losses. This does not allow for judicious use of pesticides or other appropriate pest management alternatives. Plant resistance is a management tool that is well worth developing by peanut breeders and entomologists, since many of the pesticides that farmers rely on currently are expensive, may pose environmental risks, and may not be reregistered under the current stringent EPA rulings.

Southern Corn Rootworm Culture Maintenance

Adult beetles were stored in wooden framed, aluminum screened cages with a 45 x 45-cm base and a 60-cm height. Each cage was designed to maintain up to 1500 beetles. A cloth sleeve was attached to one of the screen sides to allow for easy access to beetles. Temperature was maintained near 25^0 C and at a relative humidity of 30 to 60%, which would prevent disease problems and increase egg production and survival (Jackson, 1986). A photoperiod of 10:14 (L:D) hr was used.

The adult diet consisted of a number of different vegetable items, including lettuce (Mendoza and Peters, 1963), sliced sweet potatoes (Cuthbert et al., 1968), string beans, and yellow squash slices (Chalfant and Mitchell, 1968).

The oviposition media consisted of 0.05 x 8.00 cm strips of 2 ml black plastic piled 7 cm thick in a styrofoam cup (with upper half cut off), on top of a cotton ball wetted to saturation with distilled water. The plastic was lightly moistened to provide females with tight crevices for adequate oviposition sites. A piece of 5.5-cm diameter qualitative filter paper (Whatman, Maidstone, England) was placed between the plastic and the cotton to prevent any eggs from falling into the porus cotton, where eggs would be impossible to remove without inflicting damage. In addition, a small piece of aluminum foil was placed over the cup with small openings to allow for beetle entry and to simulate a natural dark medium that most females prefer for oviposition sites (Chalfant and Mitchell, 1967b).

Eggs were recovered by washing all plastic strips in a 20-mesh sieve which

allowed eggs to pass into a collection beaker. This was done every day in order to obtain 24 hr old eggs. The water temperature used for washing eggs was equal to the egg temperature (25^0 C) to prevent thermal shock. If eggs were not used for bioassay or field studies, they were stored at 10^0C in distilled water. To minimize disease and contamination, all eggs were sterilized in a 1% sodium hypochlorite solution (Oloumi-Sadeghi and Levine, 1989), after being washed from plastic media .

Larval rearing required high maintenance and sufficient environmental conditions to allow larvae to develop and survive. Temperature was maintained at 25^0C in a growth chamber with a photoperiod of 14:10 (L:D) hr. Larval diet consisted of corn seed (Pioneer, Hybrid 3140) spread evenly on the bottom of a plastic shoe box (9.4 x 8.2 x 33.6-cm) and covered with a 2-cm thick layer of horticultural vermiculite (Palmetto Vermiculite Co., Arcadia, La.). Distilled water, 700 ml, was put into each box to cause germination of corn and provide adequate moisture for larvae. Moisture was also very critical in order for larvae to survive. Approximately 1000 eggs were suspended in 30 ml of distilled water which was poured evenly along the longitudinal axis of the box.

After 15 days, all of the corn and developing larvae were moved to a new plastic shoe box and placed on top of a 4-cm thick layer of fresh, moist vermiculitte. At 18 days, germinated corn (2-3 days old) was placed between the old corn and the layer of vermiculite. This attracted the larvae out of the old corn mat and created a more suitable environment for pupation. At 20 days, the old corn mat was removed and any larvae that were still in it were collected. Also, any molded corn was removed and replaced with

fresh corn if larvae appeared to be feeding. Then at 23 days, all corn was removed to prevent corn roots from breaking any pupal cells that would be formed in the future.

After 35 to 48 days, all boxes were checked daily for adult emergence. Adults were collected with an aspirator and moved into the screen cages described above. Temperature, moisture levels and the quality and quantity of food throughout the larval stage was critical to successfully rearing this insect.

CHAPTER 2

Seedling Bioassay

Objective - To bioassay seedlings of 24 selected virginia-type peanut cultivars and breeding lines for resistance to southern corn rootworm.

Materials and Methods

A two-year laboratory study (1994-1995) was conducted at the Virginia Tech Tidewater Agricultural Research and Extension Center, Suffolk, VA, to determine the resistance of five newly or previously released virginia-type cultivars (NC-V 11, VA-C 92R, VA 93B, NC 10C (Wynne et al., 1991a) and AgraTech VC-1) and 19 breeding lines (N93007L, N92066L, N92074L, N92064L, N93003L, N90013E, VA 861101, VA

9211920, VA 9211289, VA 891438, VA 901072, VA 9010343, VA 8911115, VA 9109213, VA 9109235, VA 9109237, VA 9111309, PI 121067 and GP-NC 343) to southern corn rootworm. NC 6 was used as a known resistant standard, and NC 7 (Wynne et al., 1979) and NC 9 (Wynne et al., 1986) as known susceptible cultivars.

In 1994, the following lines and cultivars were tested: NC 6, NC 7, NC 9, NC-V 11, NC 10C, AgraTech VC-1, VA-C 92R, VA 93B, VA 861101, VA 9211290, VA 9211289, VA 891438, VA 901072, VA 9010343, VA 8911115, VA 9109213, VA 9109235, VA 9109237, VA 9111309 and N90013E. In 1995, all previously released cultivars were again re-evaluated, except NC 10C, along with a new group of breeding lines (N93007L, N92066L, N92074L, N92064L, N93003L, PI 121067 and GP-NC 343). Testing procedures were conducted at 25 $\pm$ 1°C and at 50-80% relative humidity. All test peanuts were treated with Vitavax (Gustafson, McKinney, Texas) seed protectant to prevent any seed decay or seedling disease, and placed in a moist paper towel to induce germination.

When primary roots on seedlings were approximately 3.5 to 4.0 cm long, three seedlings of each cultivar or breeding line were placed in moist vermiculite within a 411 ml clear plastic cup. Each cup contained 175 ml of vermiculite and 45 ml of distilled water to provide sufficient moisture for survival of seedlings and larvae. Ten neonates (newly hatched larvae), were put into each cup and allowed to feed on roots. Cups were maintained in growth chambers (Photo 1) using a photoperiod of 10:14 (L:D) hr to germinate seedlings for the duration of the study.

Cups were monitored every other day for molded seedlings and replaced if any mold was detected. Larvae were monitored for survival at 18 days after initiation of bioassay and adult emergence was monitored from day 35 to 45. Percent mortality was determined for each stage and each cultivar. Tests were set up in units containing each of the 27 cultivars/lines tested, each unit was replicated 10 times in a completely randomized design. Data were analyzed by analysis of variance (PROC ANOVA) and means separated by Tukey's test (SAS, 1985).

Results

In 1994, analysis of variance showed significant differences among cultivars with respect to mortality during development from neonate to pupal ($P = 0.0096$) and neonate to the adult stage ($P = 0.0035$) (Table 1). NC 6 caused significantly higher rootworm mortality compared with NC 10C, N90013E, NC 9, VA 93B and VA 921190 at the neonate to pupal stage and total mortality from neonate to the adult stage. The percent mortality that occurred between the pupal and adult stage ranged from 0 to 8 percent among all entries. VA 9109235 caused significantly higher mortality compared with all other entries except VA 861101, NC 7 and NC 9 between the pupal and adult stage (Table 1).

In 1995, analysis of variance showed significant differences among cultivars with respect to mortality during development from neonate to pupal and neonate to adult stages (Table 2). NC 6 caused significantly ($P = 0.0002$) higher rootworm mortality compared with NC-V 11, PI 121067, AgraTech VC-1 and VA 93B at the neonate to pupal stage.

Total mortality for NC 6 was significantly (P = 0.0001) higher compared with NC- V11, PI 121067, AgraTech VC-1, VA 93B, VA 861101, NC 9 and NC 7. Mortality from pupal to adult stage was much more evident in 1995, with a range of 7 to 42 percent among entries (Table 2).

Discussion

NC 6 caused consistently higher levels of mortality at the neonate to pupal stages in both 1994 and 1995. Total percent mortality caused by NC 6 was 48 and 81% in 1994 and 1995, respectively. In both years, NC 6 caused significantly higher mortality compared with NC 9 and VA 93B.

In 1994, once larvae reached the pupal stage of development, most survived to the adult stage. Results in 1995 were different with a larger percentage of mortality occurring between the pupal and adult stages. Without this late stage mortality, total mortality in the two study years would have been similar. One possible explanation for this difference in mortality was that seedling bioassays were conducted in different growth chambers in 1994 and 1995. Although conditions (temperature, relative humidity, photoperiod) were not detectably different, the chamber environment in the two years must have been different, with the 1995 chamber being less suitable for pupal development.

The type of resistance expressed within this study appears to be antibiosis, as defined by Painter (1951), since mortality occurred from larvae feeding on seedling tissue. A similar method of determining preliminary resistance using seedlings was also reported by Chalfant and Mitchell (1967a) to support evidence of cultivar resistance apparent in

field studies. However, mortality of rootworm larvae after feeding on seedlings in bioassay is not a complete indication of rootworm resistance. A large majority of larval feeding in the field occurs at a much later stage of peanut development. As reported by Grayson and Poos (1947), substantial feeding on pod tissue occurs which results in crop losses. Also, seedling roots could have a different effect on rootworm survival, and level of resistance, than larvae reared on reproductive field tissue. However, seedling tissue bioassay is a valid technique to obtain preliminary indications of cultivar resistance, and to substantiate data from field plantings.

CHAPTER 3

Field-Grown Peg and Pod Tissue Bioassay

Objective - To determine the effect of feeding on pegs and pods of selected virginia-type peanut cultivars on southern corn rootworm development, and to evaluate the extent of peg and pod damage:

Materials and Methods

A two-year laboratory and field study (1994-1995) was conducted at the Virginia Tech Tidewater Agricultural Research and Extension Center, Suffolk, VA, to determine the resistance of four recently released virginia-type peanut cultivars (NC-V 11, VA-C 92R, VA 93B, and AgraTech VC-1) and an advanced breeding line (VA 861101) to

southern corn rootworm. NC 6 was used as a known resistant standard, and NC 7 and NC 9 as known susceptibles. Each cultivar was planted on 16 May in 1994 and in 6 May in 1995, in plots of two 11-m rows (Photo 2) to provide sufficient amounts of tissue for each cultivar bioassay. In both years, plots of each cultivar or breeding line were replicated eight times in a completely randomized design.

Peg or pod tissue was bioassayed during the growing season as follows: 1) when peanut plants were pegging, 2) had immature pods, and 3) had mature pods. Tissue was removed by lifting the vines of the plants and cutting and removing enough tissue from all entries. After tissue was removed, soil and debris were washed off and tissue sterilized in 1% sodium hypochlorite solution for 5 minutes. Tissue was bioassayed by placing 10 rootworm, neonate and third instars individually, into 411 ml clear plastic cups as in the seedling bioassay (Fig 3). Comparable amounts of tissue for each cultivar were placed into cups. Peg tissue bioassay required 2 to 5 grams of tissue which consisted of aproximately 8 to 15 individual pegs. When immature and mature pods were bioassayed, 3 pods were used in each cup, with a range in weights of 7 to 21 grams of tissue. Each cup contained aproximately 100 ml of distilled water and 50 ml of vermiculite. Both the larvae and tissue were covered in vermiculite to simulate a natural larval feeding environment. Each tissue type was replaced three times during the course of the bioassay to provide larvae with sufficient amounts of tissue to feed on and also to prevent any mold from occurring. Each tissue type, of each cultivar, was bioassayed using eight replicates arranged in a completely randomized design within the growth chamber. A

photoperiod of 10:14 (L:D) hr was maintained.

Insects were monitored for mortality from neonate to the pupal stage at 18 days after initiation of the bioassay and from the pupal to the adult stage at 35 to 40 days. Evaluation of larval feeding was made by determining number of punctures to immature and mature pods and weight of peg and pod tissue consumed. Weight was determined by subtracting weight from moisture loss from dry weight after consumption. Moisture loss was found by determining the weight difference in comparable amounts (5 replicates) of peg and pod tissue before and after drying at 98^{0}C for 24 hr. Data were analyzed by analysis of variance (PROC ANOVA) and means separated by Tukey's test (SAS, 1985).

Results

Peg Tissue -

In 1994, NC 9 caused significantly greater neonate to pupal (P = 0.0078) mortality compared with VA 93B (Table 3). Also, larvae feeding on NC 6 and NC 9 caused significantly greater mortality in the neonate to adult stage (P = 0.0050) compared with VA 93B. Percent mortality that occurred between the pupal and adult stage ranged from 1.2 to 13.7 with no significant differences among entries. In addition, no significant differences in mortality were observed at the adult stage when third instar was introduced to bioassay tissue. Tissue consumed by larvae was not analyzed due to very little variation between cultivars. This was a result of insufficient weight measurements when recording grams to the 0.0 level which was not low enough to detect any larval consumption.

In 1995, NC 6 resulted in the greatest neonate to pupal and neonate to adult mortality (Table 4). NC 6 caused significantly (P = 0.0546) greater neonate to pupal mortality compared with AgraTech VC-1, and significantly greater total (P = 0.0032) mortality compared with NC 7, VA 93 B, VA 861101, and AgraTech VC-1. The percent mortality that occurred between the pupal and adult stage was again minimal with a range of 1.2 to 7.5 percent and no significant differences among entries. Third instars were not evaluated in 1995 because of the insignificant amount of feeding that occurred within and among all entries in 1994. Total peg tissue consumed throughout the bioassay showed that NC 6 was fed upon more (P = 0.0839) than VA 861101 (Table 5).

Immature pod tissue -

In 1994, feeding on NC 6 again resulted in the greatest neonate to pupal and neonate to adult mortality, and significantly (P = 0.0174) greater neonate to pupal mortality compared with VA 93B and NC 7 (Table 6). Mortality at the adult stage after development from neonate or third instar showed no significant differences among entries. The percent mortality that occurred between the pupal and adult stage ranged from 3.7 to 22.5 percent among entries.

NC 9 had a significantly (P = 0.0169) higher number of punctures due to rootworm feeding compared with either VA 93B or VA-C 92R in the bioassay of neonate to the pupal stage (Table 7). Introduction of third instars showed no significant differences in feeding with respect to the number of punctures to pods.

In 1995, NC 6 caused significantly higher rootworm mortality compared with

AgraTech VC-1, from neonate to pupal stage (P = 0.008) and significantly higher compared with NC 7, VA 93B, VA 861101 and AgraTech VC-1 from neonate to the adult stage (P = 0.0005). The percent mortality that occurred between the pupal and adult stage was again minimal with a range of 0.0 to 16.2 percent among entries. NC 6 caused significantly higher mortality compared with NC 9, NC-V 11, NC 7 and VA 93B between the pupal and adult stage (Table 8). Third instars were not evaluated in 1995 because of the insignificant amount of feeding that occurred within and among all entries in 1994. VA 93B had a significantly (P =0.0112) higher number of punctures on immature pod tissue due to rootworm feeding compared with NC 6 in the bioassay of neonate to pupae. In addition, total immature pod tissue consumed was significantly (P = 0.001) higher on cultivars VA 93B, VA 861101 and NC 9 compared with AgraTech VC-1 (Table 9).

Mature pod tissue -

In 1994, when neonates were subjected to mature pods, 100 percent mortality resulted before the pupal stage, for all cultivars (Table 10). Third instar bioassays showed no significant differences in mortality among cultivars. No punctures were observed for either neonate or third instar bioassays. No tests were conducted on mature pods in 1995 since no feeding appears to occur when the peanut pod reaches this stage, as determined in 1994.

Discussion

Field tissue bioassays appear to be a valid way to determine rootworm resistance. By using actual plant tissue that is grown under natural conditions and that is available

to the pest at the time of field infestation, assays more nearly resemble what occurs in the field setting. Some cultivars in the field have a high percentage of pegs present at time of infestation, as a result damage or whole peg removal by rootworms can cause substantial yield losses. In addition, cultivars that have a high percentage of immature pods may experience pod damage and mature pods may escape damage altogether. Laboratory bioassays can avoid this problem of cultivar differences in rate of maturity at time of infestation. These bioassays could prevent a false reading compared to field screening if cultivars have reached a stage in the field, at time of infestation, which is not suitable for larval feeding.

This experiment tested all the reproductive peanut plant stages including peg, immature pod, and mature pod against survival of rootworm larvae feeding on these tissues. Both newly hatched larvae and third instars were tested individually. The results showed that when third instars were introduced, very little feeding occurred. This resulted in no significant differences in rootworm mortality among cultivars. For this reason, third instar bioassays were discontinued in 1995. In addition, when neonates were exposed to mature pods, no feeding occurred and no larvae survived to the pupal stage. This stage of plant maturity apparently is too tough for larvae to penetrate and feed upon and is therefore not suitable for development. Neonate bioassays on peg and immature pod tissue showed that NC 6 was the only cultivar that consistently caused higher mortality at both pupal and adult stages with significant differences among some cultivars, especially VA 93B.

Observation of rootworm feeding, with respect to total tissue consumed and number of punctures, was very inconsistent. Number of punctures to immature pods in 1994 ranged from 1.7 to 5.0 in each test unit but in 1995, the range was 6.0 to 12.0. In 1994, NC 6 had the second highest number of punctures but the lowest number of punctures the following year. In regards to the amount of peg tissue consumed among cultivars, NC 6 was the highest and significantly higher compared with VA 861101. When immature pods were evaluated for tissue consumption, NC 6 was not ranked as high which would be expected since NC 6 is a known resistant cultivar. This technique of measuring peanut resistance to rootworm, which produced inconsistent results, needs to be re-evaluated. This also points out the need to improve on the current system of assessing pod damage to determine resistance.

Pod maturity played a major role in the amount of rootworm feeding sustained, with less damage occurring to the more mature pods regardless of cultivar. Because peanut cultivars mature at different rates in the field, it is difficult to determine if antibiosis, non-preference or pseudoresistance is taking place. In future evaluations, more emphasis should be placed on the time of infestation in relation to the maturity of the peanut plant. Planting at different dates in order to escape peak rootworm populations could be one way to avoid or minimize pod damage. Planting cultivars that do not have an abundance of susceptible pegs and immature pods at time of infestation could also minimize pod damage. A better understanding of ideal conditions for rootworm damage and which generations are causing the majority of damage would be helpful in developing

a better prediction of damage and would be helpful in developing better management strategies.

CHAPTER 4

Field Study

Objective - To evaluate peanut cultivar resistance at induced and natural levels of rootworm infestation in the field:

Materials and Methods

These experiments were conducted at the Virginia Tech Tidewater Agricultural Research and Extension Center in Suffolk, VA, and at a grower's field in Greensville County, Virginia in 1994-1995. The cultivars used in this study were as follows: NC 6, NC 7, VA 861101 and AgraTech VC-1. NC 6 was used as a known resistant standard and NC 7 as a known susceptible.

In 1994, cylindrical microplots (30.5 cm diam.) constructed of fiberglass sheets (Photo 4) were placed in the soil at a depth of 20 cm over a row of three peanut plants immediately after seed was planted. The microplots were designed to keep emerging larvae within the experimental area. An aluminum screen cage, with a 60 x 45-cm base and 55-cm height (Photo 5), was placed over the microplot to prevent any immigration or emigration of adult beetles. Each replicate for each cultivar consisted of four 30-m

rows. Two microplots were placed in each replicate. Each cultivar was set up in six replicates in a completely randomized design in the field (Photo 6). The soil type was a Yemmassee fine sandy loam (Fine-loamy, siliceous, thermic Aeric Ochraquults).

Four hundred 24-hr old rootworm eggs suspended in an agar solution, were placed around the base of the plants in each microplot at a depth of 8 cm one week after both the first and second peak emergence of local adult southern corn rootworms. Adult peaks were determined by using southern corn rootworm sex pheromone (10-methyl-2-tridecanone) (Guss et al., 1983) baited traps (Photo 7) placed near the experiment (Brandenburg et al., 1992). Random samples of eggs from agar solutions were maintained in the laboratory at 25°C to determine viability. Percent pod damage of immature and mature pods was determined by digging all pods within each microplot two weeks prior to harvest (mid September). Pod damage by natural infestation was assessed by sampling pods from five plants outside of the cages. Percent pod damage was determined from 100 pods randomly selected from each 5-plant sample. If any pods in the samples were punctured or showed signs of external scarification they were considered damaged. Percentage of eggs that developed into adults was determined by trapping emerging adults. Adults were trapped by placing a 470 ml yellow plastic cup into each microplot baited with a small piece of sponge soaked with 3 ml of SLAM™ (BASF, Research Triangle Park, NC), an adult feeding stimulant and toxicant dissolved in olive oil (Lampman and Metcalf, 1987).

In 1995, the induced rootworm infestation portion of the experiment was

eliminated due to the very low survival rate of larvae in the previous year. The four entries were planted in two fields that had a history of southern corn rootworm infestation. One field was located at the Tidewater Agricultural Research and Extension Center in Suffolk, the other in Greensville County. Each cultivar was planted in four 11.5-m rows. A completely randomized design was used with four replicates. Soil types were a Yemmassee fine sandy loam (Fine-loamy, siliceous, thermic Aeric Ochraquults) in Suffolk and a Varina fine sandy loam (Clayey, Kaolinitic, thermic Plinthic Paleudults) in Greensville.

Five plants of each cultivar were selected randomly in each replication, just before harvest to determine southern corn rootworm damage. Peanuts were harvested on 20 September 1994 and 10 October 1995. Percent pod damage was determined by randomly selecting 100 pods from each five-plant sample. Data were analyzed by analysis of variance (PROC ANOVA) and means separated by Tukey's test (SAS, 1985).

Results

In 1994, no pod damage was recorded in the field cage study. No larvae within microplots survived to the adult stage. The egg samples maintained in the laboratory had a mean hatch of 45.4 percent, indicating no problems with the viability of artificially infested eggs. The environmental conditions in the field most likely accounted for poor egg and larval development. Significant differences were found among cultivars in percent total pod damage caused by natural infestations. NC 6 sustained the least amount of pod damage (5.0%) and significantly ($P = 0.0025$) less compared with NC 7 (27.0%)

(Table 11).

In 1995, NC 6 again sustained the least amount of pod damage from natural infestations at both the Suffolk and Greensville sites (Table 11). At the Suffolk site, NC 6 showed significantly (P = 0.0426) less percent pod damage compared with NC 7. In Greensville, NC 6 (6.0%) was significantly (P = 0.0004) lower in percent pod damage compared with NC 7 (24.5%).

Discussion

When evaluating cultivars in the laboratory, potential resistance may be overlooked because of reasons not related to survival of larvae in the field and environmental conditions associated with plant maturity. Cultivar resistance based on percent pod damage may be influenced by factors other than those associated with true resistance such as cultivar differences in rate of maturity, time of infestation and soil conditions for rootworm survival.

Cultivars that have a high percentage of pegs at time of peak infestation will possibly yield less, due to peg removal or damage. Also, any cultivar that matures earlier or later could possibly avoid infestation. Cultivars in this study were not planted according to rate of maturation which could have resulted in certain cultivars avoiding damage from rootworm infestations.

NC 6 is the only cultivar of those evaluated that exhibits significant resistance to southern corn rootworm. NC 6 showed resistance both in laboratory bioassays and against natural rootworm infestations in the field. Although NC 6 is not completely

resistant to southern corn rootworm damage, it is resistant enough to allow for reduction or elimination of some preventive insecticide applications. This corresponds to conclusions by Wynne et al. (1977). NC 6 is still a valid southern corn rootworm resistant cultivar since it was released as such in 1976. NC 6 causes substantial rootworm mortality and suffers significantly less pod damage. It should be maintained in the breeding program as a future parent to other peanut lines.

The cultivars AgraTech VC-1, NC 7 and VA 93B appear to be very susceptible to southern corn rootworm and possibly should not be planted in problem fields unless treated with insecticides. The cultivars NC 9 and NC-V11 appear to be more resistant than the former but not as resistant as NC 6. VA-C 92R in these studies caused lower rootworm mortality than NC 6, but not significantly less in any test, so may be the best choice for growers to replace NC 6.

LITERATURE CITED

Alexander, M. W., and A. H. Allison. 1970. Registration of Virginia 61R peanuts. Crop Sci. 10: 728.

Arant, F. S. 1929. Biology and control of the southern corn rootworm. Alabama Institute Agriculture Extension Bull. 230: 46 p.

Boote, K. J. 1982. Growth stages of peanut (*Arachis hypogaea* L.). Peanut Sci. 9: 35-40.

Bousch, G. M., and M. W. Alexander. 1965. The reaction of Spanish, Virginia, and Valencia type peanuts to the southern corn rootworm. Proceedings of the North Central Branch Entomol. Soc. of Amer. 20: 152-154.

Brandenburg, R. L.,J. D. Barbour, and D. A. Herbert, Jr. 1992. Pheromone trapping as an indication of southern corn rootworm damage in peanut. Peanut Sci. 19: 37-40.

Brandenburg, R. L., and D. A. Herbert, Jr. 1991. Effect of timing on prophylactic treatments for southern corn rootworm (Coleoptera: Chrysomelidae) in peanut. Econ. Entomol. 84(6): 1894-1898.

Campbell, W. V., and D. A. Emery. 1967. Some environmental factors affecting feeding, oviposition, and survival of the southern corn rootworm. Econ. Entomol. 60(6): 1675-1678.

Campbell, W. V., D. A. Emery, and W. C. Gregory. 1977a. Registration of GP-NC 343 peanut germplasm. Crop Sci. 11: 605.

Campbell, W. V., J. C. Wynne, D. A. Emery, and R. W. Mozingo. 1977b. Registration

of NC 6 Peanuts. Crop Sci. 17: 346.

Carver, W. A. 1969. Registration of Florigant peanuts. Crop Sci. 9: 849-850.

Chalfant, R. B., and E. R. Mitchell. 1967a. Laboratory evaluation of peanut cultivars for resistance to the southern corn rootworm. Econ. Entomol. 60(5): 1450-1451.

Chalfant, R. B., and E. R. Mitchell. 1967b. Some effects of food and substrate on oviposition of the spotted cucumber beetle. Econ. Entomol. 60: 1010-1012.

Chalfant, R. B., and E. R. Mitchell. 1968. Continuous rearing and notes on biology in culture of the southern corn rootworm *Diabrotica undecimpunctata howardi* (Chrysomelidae: Coleoptera). Georgia Entomol. Soc. 3: 47-50.

Chalfant, R. B., and E. R. Mitchell. 1970. Resistance of peanut cultivars to the southern corn rootworm in the field. Econ. Entomol. 63(4): 1825 -1827.

Coffelt, T. A., and D. A. Herbert. Jr. 1994. Evaluation of Virginia-type peanut cultivars for resistance to southern corn rootworm. Peanut Sci. 21: 88-91.

Coffelt, T. A., D. M. Porter, and R. W. Mozingo. 1982. Registration of Virginia 81 Bunch peanut. Crop Sci. 22: 1085-1086.

Coffelt, T. A., D. M. Porter, and R. W. Mozingo. 1994. Registration of 'VA 93B' peanut. Crop Sci. 34: 1126.

Cuthbert, F. B. Jr., C. S. Creighton, and R. B. II Cuthbert. 1968. Mass rearing banded cucumber beetles, with notes on rearing spotted and striped cucumber beetles. Econ. Entomol. 61: 288-292.

Fink, D. E. 1916. Injury to peanuts by the twelve-spotted cucumber beetle. Econ.

Entomol. 9: 366-368.

Fronk, W. D. 1950. Cultural and biological control of the southern corn rootworm in peanuts. Econ. Entomol. 43(1): 22-24

Grayson, J. M., and F. W. Poos. 1947. Southern corn rootworm as a pest of peanuts. Econ. Entomol. 40(2): 251-256.

Gregory, W. C., M. P. Gregory, A. Krapovickas, B. W. Smith, and J. A. Yarbrough. 1973. Structure and genetic resources of peanuts, pp. 47-133. *In* H. E. Pattee, and C. T. Young (eds.) Peanuts: Culture and Uses. Amer. Peanut Res. & Educ. Soc., Inc. Stillwater, OK.

Guss, P. L., J. H. Tumlinson, P. E. Sonnet, and J. R. McLaughlin. 1983. Identification of a female-produced sex pheromone from the southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber. Chem. Ecology 9(9):1363-1375.

Hammons, R. O. 1971. Registration of GA 119-20 peanuts. Crop Sci. 11: 313.

Hays, S. B., and L. W. Morgan. 1965. Observation on the biology of the southern corn rootworm and insecticidal tests for its control on peanuts in Georgia. Econ. Entomol. 58: 637-642.

Herbert, D. A. Jr. 1995. Insect control in peanut. *In* C. W. Swann (ed.): Peanut Production Guide. Virginia Cooperative Experiment Station, Tidewater Agricultural Experiment Station Information Series No. 349. Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Isley, D. 1929. The southern corn rootworm. University of Arkansas Agricultural

Experiment Station Bull. 232: 1-31.

Jackson, J. J. 1986. Rearing and handling of *Diabrotica vigifera* and *Diabrotica undecimpunctata howardi*. pp. 25-47. *In* J. L. Krysan and T. A. Miller (eds.) Methods for the Study of Pest *Diabrotica*. Springer-Verlag New York Incorporated. New York. 260 p.

Kogan, M., and E. E. Ortman. 1978. Antixenosis - a new term proposed to replace Painter's nonpreference modality of resistance. Entomol. Soc. of Amer. Bull. 24.

Krysan J. L. 1976. Moisture relationships of the egg of the southern corn rootworm, *Diabrotica undecimpunctata howardi* (Coleoptera: Chrysomelidae). Entomol. Exp. Appl. 20: 154-162.

Lampman, R. L., and R. L. Metcalf. 1987. Multicomponent kairomonal lures for the southern and western corn rootworms (Coleoptera: Chrysomelidae: Diabrotica spp.). Econ. Entomol. 80(6): 1137-1142.

Mendoza C. E., and D. C. Peters. 1963. Mass rearing southern corn rootworms. Proceedings of the North Central Branch Entomol. Soc. of Amer. 18: 92-93.

Mozingo, R. W., J. C. Wynne, D. M. Porter, T. A. Coffelt, and T. G. Isleib. 1994. Registration of 'VA-C 92R' peanut. Crop Sci. 34: 539-540.

Oloumi-Sadeghi, H., and E. Levine. 1989. Controlling fungi that colonize eggs of the western corn rootworm in the laboratory. Entomol. Exp. Appl. 50: 271-279.

Painter, R. H. 1951. Insect Resistance in Crop Plants. The MacMillan Company. New York. 520 p.

Phipps, P. M., C. W. Swann, D. A. Herbert, Jr., M. J. Weaver, and P. A. Hipkins. 1990. Virginia pesticide use survey for peanuts. Project Report -Virginia Pesticide Impact Assessment Program. Tidewater Agric. Exp. Stn. 6321 Holland Rd., Suffolk, VA 23437.

SAS Institute. 1985. SAS user's guide: statistics, version 5 ed. SAS Institute, Cary, NC.

Sell, R. A. 1916. Notes on the twelve spotted cucumber beetle. Econ. Entomol. 9: 551-556.

Simpson, C. E. 1992. Registration of Starr peanut. Crop Sci. 12: 395.

Smith, J. C. 1970. Preliminary evaluation of peanut lines for resistance to the southern corn rootworm in the greenhouse. Econ. Entomol. 63(1): 324-25.

Smith, J. C., and D. M. Porter. 1971. Evaluation of selected peanut lines for resistance to the southern corn rootworm in the greenhouse. Econ. Entomol. 64(1): 245-246.

Toth, S. J. Jr., H. M. Linker, R. L. Brandenburg, D. W. Monks, and C.W. Averre. 1991. A survey of pesticide use on apples, cucumbers and peanuts in North Carolina. Data Report Submitted to the National Agricultural Pesticide Impact Assesment Program Extension Service, USDA, June 30, 1991. Department of Entomology, North Carolina State University, Raleigh, NC.

Troost M. K., R. L. Moxley, T. Sohn, and R. Chung. 1992. Promising new IPM technology for peanut. *In* New Directions in Integrated Pest Management (IPM) Technology Transfer: Research on Peanut Farmers, Attitudes, and Socioeconomic Impacts. A report to the Management Office of the Peanut Collaborative Research

Support Program (CRSP). University of Georgia, Griffin, GA.

Wynne, J. C., M. K. Beute, J. Bailey, and R. W. Mozingo. 1991a. Registration of 'NC 10C' peanut. Crop Sci. 31: 484-485

Wynne, J. C., W. V. Campbell , D . A. Emery, and R. W. Mozingo. 1977. NC 6 A southern corn rootworm - resistant peanut cultivar. North Carolina State University Agric. Exp. Stn. Bull. 458: 15 p.

Wynne, J. C., T. A. Coffelt, R. W. Mozingo, W. F. Anderson. 1991b. Registration of 'NC-V11' peanut. Crop Sci. 31: 484-485.

Wynne, J. C., D . A. Emery, and R. W. Mozingo. 1979. Registration of 'NC 7' peanut. Crop Sci. 19: 197.

Wynne, J. C., D . A. Emery, and R. W. Mozingo. 1986. Registration of 'NC 9' peanut. Crop Sci. 26: 563.

TABLES

Table 1. Mean percent mortality of southern corn rootworm at pupal and adult stages reared on seedlings of different peanut cultivars and breeding lines (1994).

	% Mortality		
Entry	Neonate - pupa	Pupa - adult**	Total (neonate - adult)
NC 6	48.0 a*	0.0 b	48.0 a
VA 9010343	29.0 ab	0.0 b	37.0 ab
VA-C 92R	34.0 ab	0.0 b	34.0 ab
VA 861101	27.0 ab	4.0 ab	32.0 ab
AgraTech VC-1	31.0 ab	0.0 b	31.0 ab
VA 9109213	28.0 ab	0.0 b	28.0 ab
NC-V11	25.0 ab	0.0 b	25.0 ab
NC 7	21.0 ab	4.0 ab	25.0 ab
VA 9111309	24.0 ab	0.0 b	24.0 ab
VA 901072	23.0 ab	0.0 b	23.0 ab
VA 891438	20.0 ab	0.0 b	23.0 ab
VA 9109235	22.0 ab	8.0 a	22.0 ab
VA 9211289	21.0 ab	0.0 b	21.0 ab
VA 8911115	21.0 ab	0.0 b	21.0 ab
VA 9109237	19.0 ab	0.0 b	19.0 ab
NC 10C	17.0 b	0.0 b	17.0 b
N90013E	17.0 b	0.0 b	17.0 b
NC 9	11.0 b	5.0 ab	16.0 b
VA 93B	14.0 b	0.0 b	14.0 b
VA 9211290	14.0 b	0.0 b	14.0 b

* Means within columns followed by the same letter are not significantly different (df = 180, N = 200, P = 0.05) as determined by MSD.

**Based on number of individuals surviving to pupa.

Table 2. Mean percent mortality of southern corn rootworm at pupal and adult stages reared on seedlings of different peanut cultivars and breeding lines (1995).

	% Mortality		
Entry	Neonate - pupa	Pupa - adult**	Total (neonate - adult)
NC 6	59.0 a*	22.0 ab	81.0 a
GP-NC 343	50.0 ab	18.0 abc	69.0 ab
N92074L	26.0 abc	42.0 a	68.0 ab
N93003L	34.0 abc	34.0 ab	68.0 ab
N93007L	52.0 ab	14.0 bc	66.0 abc
N92064L	30.0 abc	31.0 abc	61.0 abc
N92066L	38.0 abc	21.0 abc	59.0 abc
VA-C 92R	31.0 abc	28.0 abc	59.0 abc
NC-V 11	24.0 bc	19.0 abc	43.0 bcd
VA 861101	30.0 abc	11.0 bc	41.0 bcd
NC 7	28.0 abc	10.0 bc	38.0 bcd
NC 9	29.0 bc	7.0 c	36.0 bcd
AgraTech VC-1	20.0 bc	16.0 abc	36.0 bcd
PI 121067	23.0 bc	9.0 bc	32.0 cd
VA 93B	12.0 c	14.0 bc	21.0 d

* Means within columns followed by the same letter are not significantly different (df = 135, N = 150, P = 0.05) as determined by MSD.

**Based on number of individuals surviving to pupa.

Table 3. Mean percent mortality of southern corn rootworm at pupal and adult stages reared on peg tissue of seven peanut cultivars and one advanced breeding line (1994).

Entry	% Mortality			
	Neonate -pupa[1]	Pupa - adult[1] **	Total (neonate - adult)[1]	Third instar - adult[2]
NC 9	92.5 a*	1.2.a	96.2 a	53.7 a
NC 6	86.2 ab	10.0 a	93.7 a	73.7 a
VA 861101	83.7 ab	5.0 a	88.7 ab	67.5 a
NC 7	81.2 ab	6.2 a	87.5 ab	63.7 a
NC -V11	78.7 ab	5.0 a	83.7 ab	62.5 a
AgraTechVC-1	73.7 ab	2.5 a	75.0 ab	62.5 a
VA-C 92R	72.5 ab	1.2 a	73.7 ab	51.2 a
VA 93B	56.2 b	13.7 a	67.5 b	65.0 a

[1] One bioassay observing mortality from neonate to adult stage.

[2] Second bioassay observing mortality from third instar to adult stage.

*Means within columns followed by the same letter are not significantly different (df = 56, N = 64, P = 0.05) as determined by MSD.

**Based on number of individuals surviving to pupa.

Table 4. Mean percent mortality of southern corn rootworm at pupal and adult stages reared on peg tissue of seven peanut cultivars and one advanced breeding line (1995).

	% Mortality		
Entry	Neonate - pupa	Pupa - adult**	Total (neonate - adult)
NC 6	81.2 a*	7.5 a	88.7 a
NC 9	66.2 ab	3.7 a	70.0 ab
VA-C 92R	60.0 ab	7.5 a	67.5 ab
NC-V 11	58.7 ab	3.7 a	63.7 ab
NC 7	56.2 ab	3.7 a	60.0 b
VA 93B	53.7 ab	2.5 a	56.2 b
AgraTech VC-1	50.0 b	6.2 a	56.2 b
VA 861101	51.1 ab	1.2 a	52.5 b

* Means within columns followed by the same letter are not significantly different (df = 56, N = 64, P = 0.05) as determined by MSD.

**Based on number of individuals surviving to pupa.

Table 5. Mean peg tissue consumed by southern corn rootworm larvae reared on seven peanut cultivars and one advanced breeding line (1995).

Entry	Tissue consumed (g)
NC 6	0.6459 a*
NC-V11	0.4855 ab
NC 9	0.4574 ab
VA-C 92R	0.4096 ab
AgraTech VC-1	0.4034 ab
VA 93B	0.3709 ab
NC 7	0.3468 ab
VA 861101	0.2671 b

* Means within columns followed by the same letter are not significantly different (df = 56, N = 64, P = 0.05) as determined by MSD.

Table 6. Mean percent mortality of southern corn rootworm at pupal and adult stages reared on immature pod tissue of seven peanut cultivars and one advanced breeding line (1994).

	% Mortality			
Entry	Neonate - pupa[1]	Pupa - adult[1] **	Total (neonate-adult)[1]	Third instar - adult[2]
NC 6	86.0 a*	3.7 a	90.0 a	32.5 a
AgraTechVC-1	77.5 ab	3.7 a	80.0 a	41.2 a
VA 861101	73.7 ab	5.0 a	78.7 a	31.2 a
VA-C 92R	72.5 ab	10.0 a	82.5 a	41.2 a
NC -V11	66.2 ab	11.2 a	82.5 a	38.7 a
NC 9	67.5 ab	13.7 a	81.2 a	35.0 a
VA 93B	60.0 b	18.7 a	78.7 a	38.7 a
NC 7	56.2 b	22.5 a	78.7 a	32.5 a

[1] One bioassay observing mortality from neonate to adult stage.

[2] Second bioassay observing mortality from third instar to adult stage.

* Means within columns followed by the same letter are not significantly different (df = 56, N = 64, P = 0.05) as determined by MSD.

**Based on number of individuals surviving to pupa.

Table 7. Mean number of punctures caused by southern corn rootworm on immature pod tissue on seven peanut cultivars and onebreeding line (1994).

	Number of punctures	
Entry	Neonate - pupa[1]	Third instar - pupa[2]
NC 9	5.0 a*	0.6 a
NC 6	3.7 ab	0.8 a
VA 861101	3.1 ab	0.5 a
NC 7	2.8 ab	0.5 a
NC-V 11	2.8 ab	0.5 a
AgraTechVC-1	2.8 ab	0.3 a
VA-C 92R	2.1 b	0.2 a
VA 93B	1.7 b	0.2 a

[1] One bioassay observing punctures from neonate to pupal stage.
[2] Second bioassay observing punctures from third instar to pupal stage
* Means within columns followed by the same letter are not significantly different (df = 56, N = 64, P = 0.05) as determined by MSD.

Table 8. Mean percent mortality of southern corn rootworm at pupal and adult stages reared on immature pod tissue of seven peanut cultivars and one advanced breeding line (1995).

	% Mortality		
Entry	Neonate - pupa	Pupa - adult**	Total (neonate - adult)
NC 6	81.2 a*	16.2 a	88.7 a
NC 9	66.2 ab	2.5 b	70.0 ab
VA-C 92R	60.0 ab	6.2 ab	67.5 ab
NC-V 11	58.7 ab	0.0 b	63.7 ab
NC 7	56.2 ab	2.5 b	60.0 b
VA 93B	53.7 ab	2.5 b	56.2 b
AgraTech VC-1	50.0 b	8.7 ab	56.2 b
VA 861101	51.1 ab	7.5 ab	52.5 b

* Means within columns followed by the same letter are not significantly different (df = 56, N = 64, P = 0.05) as determined by MSD.

**Based on number of individuals surviving to pupa.

Table 9. Mean number of punctures and total tissue consumed by neonate to pupal stage on immature pod tissue of seven peanut cultivars and one advanced breeding line (1995).

Entry	# of punctures	Tissue consumed (g)
VA 93B	12.0 a*	1.4128 a
VA 861101	11.0 ab	1.3596 a
NC 9	7.5 ab	1.3120 a
NC-V 11	8.0 ab	0.9094 ab
NC 7	7.1 ab	0.9508 ab
VA-C 92R	6.6 ab	1.1086 ab
NC 6	6.0 b	1.0214 ab
AgraTech VC-1	10.1 ab	0.6606 b

* Means within columns followed by the same letter are not significantly different (df = 56, N = 64, P = 0.05) as determined by MSD.

Table 10. Mean percent mortality of southern corn rootworm reared on mature pods of seven peanut cultivars and one advanced breeding line at adult stage of development using third instars (1994).

	% Mortality
Entry	Third instar - adult
NC 7	68.7 a*
VA 861101	63.7 a
VA-C 92R	58.7 a
NC -V11	55.0 a
NC 6	45.0 a
AgraTech VC-1	38.7 a
NC 9	37.5 a
VA 93B	37.5 a

* Means within columns followed by the same letter are not significantly different (df = 56, N = 64, P = 0.05) as determined by MSD.

Table 11. Mean percentages of total pod damage by southern corn rootworm on three peanut cultivars and one advanced breeding line in natural infestations of City of Suffolk and Greensville County (1994-1995).

	Total pod damage (%)		
	1994	1995	
Entry	Suffolk site	Suffolk site	Greensville site
NC 6	5.0 a*	5.5 a	6.0 a
VA 861101	15.3 ab	9.0 ab	10.2 a
AgraTech VC-1	15.6 ab	11.0 ab	13.2 a
NC 7	27.0 b	18.0 b	24.5 b

* Means within columns followed by the same letter are not significantly different (df = 12, N = 16, P = 0.05) as determined by MSD.

PHOTOGRAPHS

Photo 1. Seedling bioassay placed in a growth chamber.

Photo 2. Peanut entries planted in two, 11-m rows in a completely randomized design

Photo 3. Peg tissue bioassay in a 411-ml cup.

Photo 4. Fiberglass cylindrical microplot surrounding three peanut plants.

Photo 5. Aluminum screen cage placed over microplot.

Photo 6. Field study set up in three replicates with two microplots each.

Photo 7. Pheromone traps placed near the experiment.

Vita
William J. Petka Jr.

Date of Birth: 11 / 6 / 69

Education:

Master of science, Entomology, December 1995.
Virginia Polytechnic Institute and State University (VPI & SU), Blacksburg, VA. Thesis: *Laboratory and Field Evaluations of Virginia-type Peanut (Arachis hypogea L.) Cultivars for Resistance to Diabrotica undecimpunctata howardi Barber.* GPA: 3.5/4.0.

Bachelor of Science, Entomology, May 1992.
University of Delaware, Newark, DE. GPA: 3.0/4.0.

Related Experience:

Research
Graduate Research Assistant, Department of Entomology, VPI & SU, 1994-95.
- Evaluated peanut cultivar resistance to southern corn rootworm
- Monitored rootworm populations along with rootworm pod damage
- Evaluated insecticides for efficacy in peanut, cotton and soybean

Extension
Interacted with peanut growers throughout southeast Virginia and educated them on southern corn rootworm management.

Teaching
Graduate Teaching Assistant for Medical Veterinary Entomology, Dept Entomology, VPI & SU, Spring 1994.

Skills:

Computer

SAS	Word Perfect	Freelance Graphics
Excel	World Wide Web	Power Point

Pesticide Applicator License
Registered Technician

Professional Societies:

Entomological Society of America
- Member, 1993-present

American Peanut Research and Education Society
- Member, 1995-present