

BROCCOLI YIELD RESPONSE TO CABBAGE LOOPER  
AND  
VARIETAL PREFERENCES OF LEPIDOPTEROUS PESTS OF BROCCOLI

by

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ABSTRACT

Respondents of the 1986 Broccoli Growers Survey grew an average of 6.2 acres of broccoli in Fall 1986; popular varieties were Green Valiant (87.5% of respondents), Packman and Emperor (62.5%). Less than 5% of tobacco land was converted to broccoli production by 62.5% of the growers. Before heading, 2.4 insecticidal sprays were applied for worms at \$20.51/acre. During heading, 2.4 insecticidal sprays were applied for worms at \$19.40/acre.

Under normal growing conditions, a nine-day mean of 8.4 and a 15-day mean of 12.1 cabbage looper larvae/plant did not significantly reduce yield in the Spring and Fall respectively. However, means of 7.4 and 11.1 cabbage looper larvae/plant reduced yield (head weight) under drought conditions. Harvest date was not affected by the above

cabbage looper levels. In Fall 1986, a reduction in yield occurred when plants had 50% or more defoliation and harvest date was significantly delayed at 100% defoliation. In the drought stressed Spring 1987 planting, a stimulation in yield occurred at 25% defoliation and 75% defoliation was needed to significantly reduce yield, but there was no difference in harvest date.

The imported cabbageworm was the most abundant pest of broccoli in Montgomery Co., VA. Based on counts of all immature stages of the insects for three seasons, Packman and Southern Comet varieties were less preferred compared to Green Defender.

Laboratory studies indicated that imported cabbageworm larvae developed faster to the fifth instar on Packman broccoli than those reared on Green Defender, Southern Comet or Emperor. Difference in amount consumed between varieties was not detected. Pupae reared on Southern Comet weighed significantly more than those reared on Packman.

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## INTRODUCTION

Due to a projected decrease in tobacco markets in the early 1980's, tobacco growers in Southside Virginia considered several crops to supplement their tobacco crop. After observing national trends of increased broccoli consumption, popularity and production, an expedition of growers was undertaken to observe commercial broccoli production in California, the nation's leading broccoli producer. In 1983, commercial broccoli production in Southside Virginia (Halifax and eight surrounding counties) started with 20 acres. Their harvest was marketed through the Southside Virginia Produce Cooperative. The acreage devoted to broccoli production has steadily increased from 1984 to 1986, doubling annually. In 1984, 1985, and 1986, 200, 400, and 800 acres, respectively were used for broccoli production in this region. Unfortunately, a hot and dry July/August prevented a large broccoli crop from being seeded in 1987.

Introduction of broccoli production into an area traditionally devoted to tobacco meant that pest management strategies were lacking in this region. Of the three major broccoli pests, the cabbage looper, Trichoplusia ni (Hubner); the imported cabbageworm, Pieris rapae (L.); and the diamondback moth, Plutella xylostella (L.), the former was the

most important pest of Fall broccoli in Southside Virginia in 1985 (McAvoy et al. 1986). The cabbage looper (Creighton 1984) and the diamondback moth (Sun et al. 1978 and Liu et al. 1981) were already known to be resistant to certain insecticidal compounds and pest management strategies would have to take this into account. Prophylactic sprays consisting of a tankmix of Bacillus thuringiensis, a synthetic pyrethroid and a fungicide were recommended at 7-10 day intervals (O'Dell 1984) for the imported cabbageworm, cabbage looper, and diamondback moth. The Virginia Cooperative Extension Service (1986) recommended treating Cole crops for lepidopterous pests when there is an average of 0.5 cabbage looper or imported cabbageworm larva, or 1 diamondback moth larva/plant. O'Dell and Ramsey (1986) still recommended spraying weekly when insects threaten through harvest. In the following paragraphs I will discuss some of the changes which should be made in these recommendations.

There has not been much research on pest management of broccoli (Kennedy and Oatman 1976, Wyman and Oatman 1977, Chalfant and Young 1984, and Cranshaw and Default 1985), although there has been much research performed on cabbage pest management, especially action thresholds (Greene 1972, Shepard 1973, Simonet and Morisak 1982, Chalfant 1979, Chalfant et al. 1979, Workman et al. 1980, Shelton et al. 1982, and Kirby and Slosser 1984). Action thresholds recommended by the Virginia Cooperative Extension Service must

have been based on those action thresholds of cabbage. The cabbage plant is different from the broccoli plant. Leaves of the cabbage plant are wrapped around the primordium to form a head. Any pests present feed on these leaves which (except for the wrapper leaves which are discarded) form the marketable product. Holes in these leaves and pest presence reduce the marketability of the head. Thus pests have a direct impact on fresh market cabbage throughout most of the growing season. Broccoli, however, produces leaves that are not a part of the end product sent to market. Rather these leaves aid in growth of the plant. When the plant is mature, it produces an inflorescence or a head consisting of immature flower buds. Before heading, lepidopterous pests are indirect pests because they are not feeding on the marketable product. During heading, these lepidopterous pests may become direct pests. This direct pest status is based mostly on aesthetics rather than consumption of the head and action thresholds based on research on cabbage pests are more useful for broccoli during heading than at preheading.

Prophylactic sprays could have several negative effects. Eliminating unnecessary sprays, especially preheading sprays, reduces the cost of production, decreases the rate at which the pest insect will develop resistance to that insecticide, decreases any harmful effects on beneficial insects, as well as, decreases the amount of insecticides released into the environment.

Another strategy which could reduce the number of insecticidal spray is the use of resistant varieties. Although much research has been performed on screening crucifers for resistance to insect pests (Radcliffe and Chapman 1965a, 1965b, 1966a, 1966b; Harrison and Brubaker 1943, Pimentel 1961, Brett and Sullivan 1974, Chalfant and Brett 1967), none, to my knowledge, has been performed exclusively on broccoli varieties.

Broccoli production in Virginia is in a transition stage and any contribution to the management practices could have a strong impact on the future success of this crop. A sound, ecologically balanced program at this stage could prevent growers from relying on prophylactic sprays. It is possible that pesticide applications prior to head formation may be unnecessary in Virginia because the damage caused by larval feeding during the preheading stage may not reduce yield. Use of a resistant broccoli variety could have the same effect. Therefore, the objectives of this study were to:

- 1) determine the current broccoli pest management strategies of growers in Southside Virginia, such as the number and type of preheading/heading insecticide sprays and their associated costs.

- 2) determine the yield response in Spring and Fall grown broccoli subjected to cabbage looper and artificial defoliation at preheading stages.

3) Evaluate selected broccoli varieties for resistance to lepidopterous pests in the field.

4) determine the differences in feeding, development, and oviposition of the imported cabbageworm on broccoli varieties in the laboratory.

## CHAPTER 1 - LITERATURE REVIEW

Broccoli belongs to the family Cruciferae or the mustard family. The cole crops, kale, cauliflower, cabbage, brussel sprouts and broccoli, belong to the same species, Brassica oleracea. These plants share a common ancestry with a thick-leaved, blue-gray plant that grows along the Mediterranean and northwest coast of Europe. Broccoli, Brassica oleracea (Italica Group) means little sprouts in Italian (Proulx 1981).

The Italians were the first to bring broccoli to the USA in the late 1800's and it was not until 1923 that broccoli was grown for profit. Broccoli has increased in popularity since then. In 1973, the area devoted to broccoli production was 50,000 acres and in 1983 the acreage increased to 90,000. Broccoli had climbed from 22nd to eighth in acreage devoted to vegetable production (USDA 1973 and 1983).

Broccoli is an emerging commercial crop in Southside Virginia. Growers decided to experiment with other, supplemental crops such as broccoli and cantaloupe, because of predicted decreasing tobacco markets. Over the past four years, broccoli has been grown in Halifax and eight surrounding counties for Fall production and in 1986, growers began experimentation with a Spring planting. In 1983, an estimated 20 acres were used for broccoli production in this

area. In 1984 and 1985, broccoli production increased to 200 and 400 acres, respectively and in 1986, about 800 acres were grown. National trends show that broccoli production and consumption are on the increase, indicating that broccoli is an excellent choice for a supplemental crop to tobacco in Southside Virginia. Because broccoli production is at a formative stage and growers are still adjusting to management practices which differ from tobacco, this provides an excellent time to establish an ecologically sound pest management program before growers become too dependent on prophylactic insecticidal sprays.

#### Pests and Their Description

The major pests of broccoli in Virginia are three lepidoptera: the imported cabbageworm (ICW), Pieris rapae (L.); the cabbage looper (CL), Trichoplusia ni (Hubner); and the diamondback moth (DBM), Plutella xylostella (L.). Other pests I have noted during three seasons of broccoli production in Virginia include flea beetles; cabbage maggot Delia radicum (L.); harlequin bug, Murgantia histrionica (Hahn); cabbage webworm, Hellula rogatalis (Hulst); corn earworm, Heliothis zea (Boddie); cutworms, armyworms, cross-stripe cabbageworm, Evergestis rimosalis (Guenee), rabbits, deer and others. A description of the three major pests follows.

The ICW egg is yellow and has been described as bullet shaped with ridges. The egg turns darker just before

hatching. Larvae pass through five instars. The head and body are pale green and cylindrically shaped with five pairs of prolegs. A yellow stripe runs down the dorsum and sides. Black and white hairs give this larva a velvety appearance. The chrysalid is a paler green than the larva, often with brown markings. The beaked head extends toward a wider, angular thorax which tapers toward the abdomen. The abdomen ends with a hooked cremaster (Harcourt 1963). The adult ICW has a hairy gray abdomen with wings whose colors range from white to yellow. The males and females are easily distinguished by the number of black dots on the forewings. Males have one dot and females have two dots on the forewing. Both sexes have one black dot on the hind wing. The ICW overwinters in Virginia as pupae, often on buildings or other structures (Lasota 1985).

The CL egg is white and round. White stripes are present above the spiracles and along the mid dorsal line of this light green CL larvae. Three pairs of hind prolegs, plus the anterior thoracic legs, allow this species to move in a looping fashion (Harcourt 1963). Pupae are brown and enclosed in a silken cocoon. The sexes are easily distinguished at this stage. The males have two bumps on the posterior segments of the abdomen, while females have a slit and a bump on the posterior end of the abdomen (Shorey et al. 1962). Adults are a mottled brown with a silver marking on the forewing which resembles a figure eight. CL adults do not

overwinter in Virginia, but usually migrate north from areas near the Gulf Coast. The farthest north the CL is reported to overwinter is coastal NC (Elsey and Rabb 1970).

The DBM egg is oval, scale-like and light green to yellow. The egg is covered with small raised areas. The larva is green, has very few hairs and has five pairs of prolegs including a distinct pair of anal prolegs. Another distinction of this larva is its wriggling motion when disturbed. Pupae are pale green and change to a light brown as they age. The pupa is enclosed in a loose netted cocoon. The DBM gets its name from a design that appears when its wings are folded at rest. The forewings, when close to the sides of the body, have a creamy band resembling three diamonds (Harcourt 1957, 1960, and 1963).

### Seasonal Abundance

Abundance of cruciferous pests seems to depend on geographic location. The most abundant pest species in Minnesota are the ICW and CL (Weires and Chang 1973). A report from California also indicates the ICW and CL as abundant pest species with six generations with peaks occurring in July and September, respectively (Oatman 1966). Pimentel (1961) found ICW and DBM to be the major cabbage defoliators in Ithaca, New York, while Andaloro et al. (1982) also found these species plus the CL at harvest in New York. Further north in Ontario, the ICW and DBM were reported as the

major cabbage pests (Harcourt et al. 1955). On cabbage grown in Hastings, Florida the CL was the only major cabbage caterpillar (Greene 1972), but in Sandford, Florida, small populations of the ICW and DBM were found (Wilson 1957).

In areas closer to Virginia, Elsey and Rabb (1970) reported six generations of CL in N.C. Heavy populations of CL were present in Eastern Shore, VA in late summer (Hofmaster 1961). In 1981 and 1982, larvae of ICW and CL were present in damaging numbers, but the DBM was present in low numbers and caused no damage to cabbage in Montgomery Co., VA (Chamberlin 1986). Commercial cabbage fields in Carroll Co. had only low populations of CL and no ICW, although high populations of CL were found in a field sprayed 2-3 weeks earlier. Lasota (1985) found high populations of ICW, and lower populations of DBM and CL on cabbage in Montgomery Co., VA. On other Brassicas (collard, kale, mustard, and turnip), in Chesterfield Co., VA, ICW and DBM were the major pests in the Spring and CL and the cabbage webworm, Hellula rogatalis (Hulst), were present in the Fall (Latheef and Irwin 1983).

Several studies have observed seasonal abundance of lepidopterous pests on broccoli. In Halifax Co., VA the CL was the dominant species in a 1985 Fall broccoli planting (McAvoy et al. 1986), while the ICW was the dominant species on broccoli grown in Montgomery Co. In southern California, CL was the predominant species in Spring, Summer, and Fall 'deCicco' broccoli plantings. DBM and ICW were present at low

levels at all plantings and Spodoptera exigua (Hubner) occurred in the Spring and Fall only (Wyman and Oatman 1977). Kennedy and Oatman (1977) while evaluating selective insecticides in Riverside, California for the CL, ICW, DBM, and two aphids, found the DBM to be the most abundant species and Brevicoryne brassicae, cabbage aphid, to be the major head contaminant. However, in Orange Co., CL was the most abundant species followed by DBM and ICW.

#### Oviposition and Varietal Preferences

(a) Pieris rapae (L.) oviposits on plants in the Cruciferae Family and a few others - cabbage, cauliflower, kale, collards, kohlrabi, Brussel sprouts, mustard, radish, turnip, horseradish, related weeds, and sweet alyssum, nasturtium, mignonette, and lettuce (Metcalf et al. 1962). The ovipositing female is responsible for host selection since only the late fifth instars are known to wander (Lasota 1985). Factors thought to influence oviposition include tarsal contact with the host plant (Traynier 1979) , learning (Traynier 1986), color (Hovanitz and Chang 1964), mainly nonvolatile, but possibly volatile constituents of hosts (Renwicke and Radke 1981, 1983, and 1985), age and maturity of the plant (Harrison and Brubaker 1943), previous damage to the host plant (Radcliffe and Chapman 1966b), as well as others.

Tarsal contact, rather than ovipositor contact, was important to cause an ovipositional response (Traynier 1979).

Learning of the appearance of a chemical contact can alter the oviposition preference (Traynier 1986). White, blue, and yellow caused a searching response in the ICW, but females preferred green for oviposition (Hovanitz and Chang 1964). Although Sinigrin, a mustard oil glucoside, is known to stimulate oviposition (Tranyier 1984) , Renwicke and Radke (1983) indicated this stimulation had little effect on the spatial distribution of the eggs. They suggested that probably more than one nonvolatile chemical was responsible for the selection of an exact oviposition site. Upon further study, Renwicke and Radke (1985) discovered that cabbage extract sprayed on cabbage plants resulted in less eggs being laid. This drop in oviposition was not as dramatic a drop in oviposition as the CL had under the same conditions (Renwicke and Radke 1981). Under normal conditions, ICW populations would not be high enough to elicit such an ovipositional deterrent response. Plants that were an accepted host also contained non-polar deterrents, as well as a water soluble oviposition stimulant. Nonhost crucifers or unacceptable hosts, Capsella bursa-pastoris and Erysimum cheiranthoides, contained both polar and nonpolar deterrents. Oviposition deterrence from these hosts could either have been due to the deterrent constituents or to a lack of stimulant. Oviposition can be affected by stimulants and deterrents (Renwicke and Radke 1985).

Besides plant constituents, pheromones can also deter oviposition. Larval feeding of Pieris brassicae (L.) was thought to deter P. brassicae (L.) from ovipositing. Thus resulting in prevention of overcrowding a limited food source (Rothschild and Schoonhoven 1977). An oviposition pheromone was later detected to retain its activity for seven weeks and plants treated with the deterrent extract deterred oviposition by P. brassicae for at least 14 days (Schoonhoven et al. 1981). This oviposition deterrent pheromone of P. brassicae also deterred P. rapae oviposition for up to eight days. Although not conclusive, ICW appeared to lack any oviposition deterring pheromone or an intraspecific egg load assessment (Klijnstra 1985).

Results of oviposition preferences of ICW on cruciferous crops, including varieties, has been conflicting. Host selection was not correlated to cabbage plant size (Radcliffe and Chapman 1966a), yet Ives (1978) found that larger and older leaves of wild plants were preferred. Red cabbage varieties were less susceptible for oviposition than the green varieties, although this appeared to be influenced by season. Red varieties less susceptible early in the season became more susceptible later in the season. They concluded that the varieties least injured by the first generation were more likely to be chosen as a site for oviposition by the next generation. Although plant size determined the number of insects that a plant could support, seasonal shifts or prior

damage were more important in influencing oviposition site choice (Radcliffe and Chapman 1966b).

Amount of foliage present, maturity, plant height, and physical condition influenced caterpillar abundance rather than host preference of eight types of plants (green cabbage, red cabbage, collards, cauliflower, kale, broccoli, brussel sprouts, and kohlrabi) (Harrison and Brubaker 1943).

They also stated red cabbage were more heavily infested than green, a contradiction to Radcliffe and Chapman (1966b).

Broccoli and Brussel sprouts supported the largest populations of cabbage caterpillars. Pimentel (1961) found open leaf plants, collards and kale, had lower ICW populations than the heading plants, cabbage and Brussel sprouts, due to parasitism. Even though Brussel sprouts supported higher populations of ICW in the two studies mentioned, a red foliated Rubin Brussel sprout was found to be less susceptible to ICW than green varieties (Dunn and Kempton 1976).

(b) CL preferred collard and cotton to broccoli, cauliflower or cabbage for oviposition (Boling and Pitre 1971). Mammoth Red Rock cabbage had more eggs and small larvae, but less feeding damage and large larvae than other varieties indicating a possible antibiosis (Chalfant and Brett 1967). Frass, produced by normal populations of CL was thought to be an ovipositional deterrent (Renwicke and Radke 1980). The frass was not releasing a pheromone, but an ovipositional

deterrent was being released by the disrupted plant tissue caused by the feeding larvae (Renwicke and Radke 1981). These deterrent compounds were volatile (a one day deterrent) and nonvolatile (ether soluble) compounds (Renwicke and Radke 1982). Benepal and Hall (1967) found amino acids and total soluble Nitrogen differed in susceptible and resistant varieties. In the resistant varieties 'Savoy Chieftain' and PI 245000, free amino acids pipecolic and tyrosine were detected respectively, but were not detected in susceptible varieties. Free amino acids and total soluble Nitrogen were higher in the susceptible variety 'Green Acre' than in the resistant varieties.

(c) Three sensory modes are important in controlling oviposition by the DBM. These included vision, chemoreception (olfaction and gustation) and mechanoreception (Tabashnik 1985). Two compounds, coumarin and rutin, not found in large quantities in the cruciferae, but found in higher quantities in other herbs, were tested for oviposition response by DBM. Coumarin elicited an ovipositional deterrence in the dark indicating it acted as a volatile, while rutin gave a strong deterrence in the light, probably acting as a nonvolatile compound (Tabashnik 1985).

Varieties found to be susceptible to flea beetles were resistant to DBM and vice versa. Also a variety of kale was less susceptible than other kale varieties because of densely

compact cells. These cells could have acted as barriers to the early instar DBM by preventing them from mining the leaf (Rudder and Brett 1967).

Another effect on oviposition was investigated by Tabashnik and Mau (1986). DBM's peak oviposition time was found to be between 2000 and 2300 hours. Irrigation of watercress, Nasturtium officinale (R. Br.) was applied intermittently through the day and night. Oviposition was deterred during the night by the overhead irrigation.

#### Current Controls of Lepidopterous pests on cruciferous crops

O'Dell (1984) recommended sprays every 7-10 days for Fall cabbageworm complex using Bacillus thuringiensis tank mixed with a synthetic pyrethroid, plus a fungicide, such as Bravo. He also recommended consulting the extension agent for current control recommendations. Control recommendations for 1986 for lepidopteran pests of broccoli in VA uses an action threshold of 0.5 CL or ICW, and 1 DBM larva/plant. Insecticides recommended were the following : Bacillus thuringiensis (applied with a sticker when the ICW and CL larvae first appear and weekly thereafter), Guthion, methomyl, Monitor, Pydrin, or permethrin. All the above pesticides should be mixed with a sticker and sprayed with side and downward directed nozzles for complete coverage. They should be applied every five to seven days (Virginia Cooperative

Extension Service 1986). Fall 1986 recommendations included spraying weekly, when insects threaten, until harvest by using Ambush, Pydrin, or Pounce (O'Dell and Ramsey 1986). Weekly spray use was finally questioned, and recommendations for Spring 1987 were to begin spray programs using Ambush, Pydrin and Pounce when broccoli starts heading or when at least 30% leaf damage exists before heading (O'Dell and Ramsey 1987).

Selective insecticides for Lepidoptera and aphid pests of broccoli were tested for their selectiveness and effectiveness. Dipel and pirimicarb, and Methomyl were applied at various concentrations to control the three lepidoptera: CL, ICW, DBM, as well as the two aphids, B. brassicae and Myzus persicae, respectively (Kennedy and Oatman 1976). Dipel 0.45 kg and pirimicarb 0.28 kg/ha, suppressed lepidopterous larvae and aphids, but was not as consistent as methomyl during the preheading stage. B. brassicae, the most serious head contaminant, was as effectively controlled by Dipel and pirimicarb as with methomyl applied at half the original rate. Dipel and pirimicarb were more selective at seven days post spray because they interfered less with parasitism. Fourteen days post treatment, Dipel and pirimicarb as well as methomyl had a negligible effect on parasitism of CL and DBM.

Bacillus thuringiensis Berliner var kurstaki was applied to 'DeCicco' broccoli grown in Orange County California to maintain larval populations below 0-1, 2 and 5 larvae/plant to

find an economic threshold (Wyman and Oatman 1977). Chalfant and Young (1984) used fenvalerate applied through center pivot irrigation to control CL, ICW and DBM on broccoli.

Research on control of lepidoptera on other cruciferous crops has been extensive. The CL is difficult to control and Creighton (1984) listed chemicals that are ineffective. Workman et al. (1980) found permethrin provided better control of loopers than B.t. or B.t. plus methomyl or methamidiphos, even though the latter provided adequate control. Eckenrode et al. (1981) found methamidiphos and permethrin to be the most consistent insecticides applied for lepidoptera larvae in commercial sauerkraut cabbage fields in New York. They also commented on the wide variety of chemicals used for lepidoptera control and the number of combinations of chemicals used -- Parathion and B.t. in combination were the most common insecticides used. Andaloro et al. (1983) found methamidiphos and the pyrethroids most effective for control of lepidoptera in commercial cabbage fields. Pathogens shown to reduce looper populations alone or in conjunction with chemical insecticides were reported by Browning et al. (1982), Jacques and Laing (1978), Vail et al. (1980), and Young et al. (1980).

#### ACTION THRESHOLDS

Action thresholds have been developed to reduce the number of insecticide applications to cabbage. Greene (1972) recommended a level of 0.1 looper larva/plant for insecticide applications in central Florida that would produce damage free, marketable cabbage. The 0.1-0.3 looper/plant level was used by Shepard (1973) in Florida with a sequential sampling plan to reduce the number of insecticide applications without a loss in marketable cabbage heads. Thresholds of 0.5 total larva/plant were used for insecticide screening for lepidopterous pests of cabbage throughout the growing season (Simonet and Morisak 1982). Action thresholds for lepidopterous larval pests of cabbage in Georgia were between 0.1 and 0.3 larva/plant. Insecticide applications were reduced by up to four sprays without a significant loss in marketability in the heads when action thresholds were used instead of the weekly scheduled sprays (Chalfant 1979).

Greene (1972), Shepard (1973), Simonet and Morisak (1982) and Chalfant (1979) did not relate spraying with host phenology (precupping and cupping or heading), but applied insecticides whenever thresholds were equalled or exceeded. Host phenology was used in the following studies to develop action thresholds. Cabbage grown in Georgia and Florida were sprayed with permethrin according to visual thresholds of 1, 1-2, 3-5, 6-10, and >11 holes/plant and action thresholds of 0.1 larva/plant. These thresholds were combined with management programs of sampling through the growing season,

sampling before cupping and spraying on schedule thereafter, and spraying precupping and sampling after cupping.

Permethrin was also sprayed on a weekly schedule. Less sprays were used with the sampling program. The visual threshold of 1-2 holes/plant was as effective as larval thresholds and took less time. Chalfant et al. (1979) also concluded that there was no loss in marketability due to cabbage feeding before cupping.

Workman et al. (1980) found visual damage thresholds of >1 window (damage caused by larvae that left the upper cuticle intact)/plant to be more effective in detecting the presence of loopers than the >1 hole/plant threshold. Both of these thresholds reduced the number of sprays for the cabbage grown in Georgia and Florida, but also reduced the percentage of marketable heads. When precupping sprays were eliminated and permethrin was used postcupping, no significant difference in percent marketability was found when compared to the full season sprays.

Shelton et al. (1982) stated that no loss in head weight or marketability occurred when larvae were allowed to feed prior to heading, as long as effective insecticides were used once heading started and when cabbage looper equivalents equalled or exceeded 0.5/plant. Head weight was not accurately predicted by larval counts. A multiple regression model for fresh market cabbage included the following variables as a function of percent marketable yield (Kirby and

Slosser 1984): mean number of all larvae (ICW, CL, DBM) per plant, percent CL larvae > 13 mm prior to cupping, mean seasonal temperature and their interactions. The model, although dynamic, indicated 0.3 larva/plant as a static threshold to produce 80% marketable heads. This procedure saved 4.5 times as many sprays as compared to a 5-6 day spray schedule.

Very few action thresholds studies have included broccoli as the host. Wyman and Oatman (1977) used Dipel to maintain, from thinning to heading, levels of 0-1, 2, and 5 larvae/plant in California. While larval counts/plant reached 4.6 and 9.1 (Summer and Fall) in the untreated plots, no yields differed in any of the treatments. This indicated that preheading sprays would be unnecessary when larvae remain below 9 per plant. In 1985, the highest larval count/plant was 3.5 on broccoli grown in Halifax Co., VA. This larval level did not reduce yield (McAvoy pers. comm.).

When Premium Crop and Southern Comet broccoli varieties were artificially defoliated 25, 50 and 100 % of their leaf tissue at 20, 31 and 45 days post transplanting (using 6 week transplants), yield loss of Premium crop occurred only when they were defoliated 100% (Cranshaw and Default 1985). Fifty percent defoliation at 45 days post transplanting resulted in yield loss for the Southern Comet variety. However, defoliation of even 25% is rare in Minnesota and they concluded that preheading sprays could be eliminated. Wyman

and Oatman (1977) and Kennedy and Oatman (1976) also questioned the use of preheading insecticide applications for broccoli. However, because no pests can be tolerated in the broccoli head, pesticides must be sprayed at the beginning of heading to prevent contamination of the head.

## **CHAPTER 2**

### **1986 BROCCOLI GROWERS SURVEY**

## INTRODUCTION

As a first step in developing a control program for insect pests of broccoli in Virginia, I decided to conduct a survey of growers to allow me to compile information on current practices and their costs. Such information would be very useful in comparing current procedures with future pest management strategies.

## MATERIAL AND METHODS

On March 3, 1987 the 1986 Broccoli Growers Survey was distributed to those growers present at the Spring Bunching Broccoli Meeting in Pittsylvania Co., VA. They were asked to complete the survey with only results from the 1986 Fall season and to check their records if they were unsure of an answer. A separate sheet was attached for them to leave their name and address if they were interested in cooperating in pest management research. This sheet would be detached before the survey was read. I informed them that it would only take about 30 minutes to complete and that upon completion they

should put the questionnaire into the the stamped return envelope to reach me by March 21.

A list of broccoli growers was obtained from the manager of the Southside Virginia Produce Cooperative, David Slabach. Questionnaires were mailed to 48 growers on March 4-5 (See appendix A for sample survey). Also, copies were sent to the extension agents in Brunswick, Campbell, Franklin, Halifax, Henry, Mecklenburg, and Pittsylvania Counties, to inform them I was sending questionnaires to growers in their respective regions.

## RESULTS AND DISCUSSION

Returns were low, approximately 17%. This was probably due to the low attendance at the Pittsylvania Co. meeting and to the time of the year -- growers were probably too busy preparing for the Spring planting to take the time to fill out the survey. However, I felt this time was the best. Many growers had lost a large percentage of their broccoli crop to frost in November, and I wanted to allow sufficient time before they were questioned about this season.

The mean acres of broccoli grown per grower was 6.2 acres. Growers (87.5%) planted an average of 3.6 acres of Green Valiant. An average of 1.8 acres of Packman were grown by 62.5% of the growers and an average 2.5 acres of Emperor was grown by 62.5% of the growers. Other varieties grown were

Cruiser and Galaxy. The double row was used by 87.5% as compared to 12.5% who used a 4-row spacing to grow their broccoli. Less than five percent of tobacco land was converted to broccoli production in Fall 1986 by 62.5% of the respondents (Table 1).

Worms, defined as larvae of insects such as the cabbage looper, the imported cabbageworm and the diamondback moth and others, were found in the broccoli plant BEFORE heading by 75% of the respondents (Table 1). The same number of respondents (37.5%) found one worm/plant and 2 to 5 worms/plant. The remaining 25% of the growers found no worms. Although 25% of the growers did not report any worms, 87.5% still applied insecticides before heading. These insecticides were applied at 7-10 day intervals (50%), 10 to 14 day intervals (12.5%), more than 14 day intervals (12.5%), infrequently (12.5%) and no response (12.5%). A mean of 2.4 insecticide sprays were applied for worms before heading at a cost of \$20.51/acre.

Worms were found during heading by 12.5% of the growers, with 25% indicating one/plant (Table 1). Other responses for worms/plant were 0 (50%) and no answer (25%). Although only 12.5% saw worms, 75% of the growers applied insecticides at heading at 7 to 10 day intervals for an average of 2.4 insecticide sprays at a cost of \$19.40/acre.

Since preheading insecticides are unnecessary, (12 larvae/plant did not significantly reduce yield) growers could have saved approximately 2.4 sprays at \$20/acre for a mean of

Table 1. Summary response by members of the Southside Virginia Produce Cooperative to the 1986 Broccoli Growers Survey

| BEFORE HEADING                                    |           |                   |      |                 |      |                      |                      |              |                 |                                |
|---------------------------------------------------|-----------|-------------------|------|-----------------|------|----------------------|----------------------|--------------|-----------------|--------------------------------|
| Conversion of tobacco land to broccoli production | % growers | worms in broccoli |      | worms per plant |      | Insecticides applied | Insecticides applied |              |                 | <u>Insecticides - mean</u>     |
|                                                   |           |                   |      | #               | %    |                      | Frequency            | %            |                 | number dollars sprays per acre |
| 0 to 5%                                           | 62.5      | yes               | 75   | 0               | 25   | yes 87.5             | < 7 days             | ----         | $\bar{x} = 2.4$ | $\bar{x} = \$20.51$            |
| 6 to 10%                                          | 12.5      | no                | 25   | 1               | 37.5 | no 12.5              | 7-10 days            | 50.0         |                 |                                |
| 11 to 15%                                         | 12.5      |                   |      | 2 to 5          | 37.5 |                      | 10-14 days           | 12.5         |                 |                                |
| 16 to 20%                                         | --        |                   |      | 6 to 10         | --   |                      | >14 days             | 12.5         |                 |                                |
| >20%                                              | 12.5      |                   |      | >10             | --   |                      | infrequently         | 12.5         |                 |                                |
|                                                   |           |                   |      | don't know      | --   |                      | no response          | 12.5         |                 |                                |
| DURING HEADING                                    |           |                   |      |                 |      |                      |                      |              |                 |                                |
|                                                   |           | worms in broccoli |      | worms per plant |      | Insecticides applied | Insecticides applied |              |                 | <u>Insecticides - mean</u>     |
|                                                   |           |                   |      | #               | %    |                      | Frequency            | %            |                 | number dollars sprays per acre |
|                                                   |           | yes               | 12.5 | 0               | 50   | yes                  | 75                   | < 7 days     | --              | $\bar{x} = 2.4$                |
|                                                   |           | no                | 87.5 | 1               | 25   | no                   | 25                   | 7-10 days    | 75              | $\bar{x} = \$19.40$            |
|                                                   |           |                   |      | 2 to 5          | --   |                      |                      | 10-14 days   | --              |                                |
|                                                   |           |                   |      | 6 to 10         | --   |                      |                      | >14 days     | --              |                                |
|                                                   |           |                   |      | >10             | --   |                      |                      | infrequently | --              |                                |
|                                                   |           |                   |      | dont know       | --   |                      |                      | no response  | 25              |                                |
|                                                   |           |                   |      | no response     | 25   |                      |                      |              |                 |                                |

6.2 acres leaving a total average savings of \$124 of insecticides per grower. This savings does not include an estimate of the time, labor and expenses to prepare the spray rig or apply the insecticide in the field. Insecticides were used during heading by 75% of the growers even though only 1 or less worms/head were found. This is probably the only way to prevent head contamination since thresholds for heading broccoli have not been developed.

Although insecticides, fungicides, and herbicides and their application were the lowest expense when expenses were ranked from highest (1) to lowest (8) (Table 2), these insecticide applications during heading are very important. If worms are found in the head, then the growers shipment can be turned down, leaving him/her with all expenses and no returns on investment and/or family labor.

Table 2. Rankings from the highest expense (1) to the lowest expense (8)/Acre and % of total production costs

| Items for ranking                    | Mean # | Ranking results | % of total production costs |
|--------------------------------------|--------|-----------------|-----------------------------|
| harvest and marketing                | 1.6    | 1               | 40.0                        |
| other                                | 2.5    | 2               | ----                        |
| seeds and seeding                    | 2.6    | 3               | 22.3                        |
| fertilizer and lime                  | 2.9    | 4               | 18.5                        |
| machinery and repairs<br>and rentals | 4.4    | 5               | 5.7                         |
| insecticide and application          | 5.1    | 6               | 5.4                         |
| fungicide and application            | 5.2    | 7               | 3.9                         |
| herbicide and application            | 5.3    | 8               | 4.2                         |

## CHAPTER 3

### BROCCOLI YIELD RESPONSE TO SELECTED LEVELS OF CABBAGE LOOPER LARVAE

## INTRODUCTION

Commercial broccoli production in Southside Virginia began in 1982 with 20 acres, increasing to 800 acres by 1986. As a new crop in traditionally tobacco areas, insect pest management practices had to be determined for the lepidopteran complex: the imported cabbageworm (ICW), Pieris rapae (L.); the cabbage looper (CL), Trichoplusia ni (Hubner); and the diamondback moth (DBM), Plutella xylostella (L.) The cabbage looper was the major pest of broccoli in Southside Virginia (McAvoy et al. 1986). Prophylactic sprays were recommended at 7-10 day intervals for the above cabbageworm complex with Bacillus thuringiensis, a synthetic pyrethroid and a fungicide tank mixed (O'Dell 1984). Cole crops were recommended for insecticidal treatment when there was an average of 0.5 CL or ICW larva or 1 DBM larva/plant (VCES 1986). O'Dell and Ramsey (1986) still recommended spraying weekly when insects threatened.

Research on pest management of broccoli (Chalfant and Young 1984, Wyman and Oatman 1977, Kennedy and Oatman 1976, and Cranshaw and Default 1985), is scarce compared to research on cabbage pest management. Recommendations by the Virginia Cooperative Extension Service must have been based on the reports of various studies on action thresholds of cabbage

(Greene 1972, Shepard 1973, Chalfant 1979, Chalfant et al. 1979, Workman et al. 1980, Shelton et al. 1982, Simonet and Morisak 1982, and Kirby and Slosser 1984). Due to the nature of cabbage plant growth, where insects may cause direct damage, these low thresholds may be necessary. However, in broccoli, insect pests would only be indirect pests of broccoli early in the season because the marketable product, the head or inflorescence, is only produced in the last two to three weeks. During heading the insects are pests because of contaminating the head rather than consuming it.

Broccoli production is in a transition stage and any contribution to pest management practices could have a strong impact on future management practices. A sound, ecologically balanced program at this stage could prevent growers from learning to rely on prophylactic sprays. My hypothesis is that preheading insecticide sprays are usually not necessary in broccoli grown in Virginia because the larval populations are seldom high enough to reduce yield. Therefore, the objective of this study was to determine yield response in Spring and Fall grown broccoli subjected to selective levels of cabbage loopers at preheading leaf stages.

## MATERIALS AND METHODS

### Spring 1986

Research was conducted at the Virginia Polytechnic Institute and State University Horticulture Research Farm, Montgomery Co., Va. Six week old Packman broccoli seedlings were transplanted on April 25 at distances of 25.4 cm between plants and 76 cm between rows. There were 18 rows each 22.9 m in the 0.03 hectare plot. Diazinon was applied ( $6.3 \times 10^{-4}$  L of 4EC/ L water with 4-6 oz applied per plant) at planting to control cabbage maggots. Plants were also given an application of liquid fertilizer (0.82 g/L of Peters 20-20-20). Before planting, the soil was fertilized according to soil testing results and Treflan, according to the label, was incorporated. Cutworm damage was discovered on April 29 and carbaryl (Sevin) was applied at 1.25 lb/acre at 8 pm on May 1. Plants that were damaged by cutworms were replaced on May 4. No other pesticides were applied after May 1.

The first and last two rows served as border rows. Each row was divided into ten treatment plots of five plants with 3 plants between treatments. Besides the natural and zero cabbage looper control there were 4 levels of CL raised on plants and 4 levels of CL raised on diet (Table 3). Rows 3, 5,

Table 3. Establishment of CL larvae on Spring grown Packman broccoli 1986

| <u>Treatment*</u> | June 3 1986              |        |                      | June 10 1986             |        |                      | June 1 - June 10                       |        |                      |
|-------------------|--------------------------|--------|----------------------|--------------------------|--------|----------------------|----------------------------------------|--------|----------------------|
|                   | <u>CL Larvae</u><br>Mean | (SE)   | % Estab-<br>lishment | <u>CL Larvae</u><br>Mean | (SE)   | % Estab-<br>lishment | <u>CL Larvae</u><br>9 day Mean<br>Mean | (SE)   | % Estab-<br>lishment |
| natural           | 0.07                     | (0.07) | --                   | 0.04                     | (0.21) | --                   | 0.22                                   | (0.15) | --                   |
| 0                 | 0.03                     | (0.03) | --                   | 0.27                     | (0.12) | --                   | 0.15                                   | (0.12) | --                   |
| 1 plant           | 0.68                     | (0.17) | 68                   | 0.71                     | (0.22) | 71                   | 0.70                                   | (0.02) | 70                   |
| 5 plant           | 2.60                     | (0.22) | 52                   | 3.43                     | (0.60) | 69                   | 3.02                                   | (0.42) | 60                   |
| 10 plant          | 5.24                     | (0.46) | 52                   | 5.68                     | (0.73) | 57                   | 5.46                                   | (0.22) | 55                   |
| 15 plant          | 8.43                     | (0.74) | 56                   | 8.27                     | (0.87) | 55                   | 8.35                                   | (0.08) | 56                   |
| 1 diet            | 0.40                     | (0.12) | 40                   | 0.23                     | (0.12) | 40                   | 0.32                                   | (0.08) | 32                   |
| 5 diet            | 3.20                     | (0.28) | 64                   | 1.00                     | (0.30) | 20                   | 2.10                                   | (1.10) | 42                   |
| 10 diet           | 4.77                     | (0.89) | 48                   | 1.60                     | (0.35) | 16                   | 3.18                                   | (1.58) | 32                   |
| 15 diet           | 7.03                     | (1.42) | 47                   | 1.27                     | (0.64) | 8                    | 4.15                                   | (2.88) | 28                   |

\* Treatment, except for natural and 0, refers to number of CL larvae applied per plant and how larvae were reared.

7, 9, 11 and 13 were the six replicates of this randomized complete block design.

Beginning May 9, all insects, including ICW and CL eggs, small larvae (instar 1-3), large larvae (instar 4-5) and pupae were recorded and removed weekly and then twice a week except in the natural treatment. To compare the induced cabbage looper levels with those naturally occurring, insects were recorded as mentioned above, but were not removed in this natural treatment. A control of zero insects was maintained through the beginning of harvest by recording all insects as mentioned above and removing them. On June 1, late second instar CL larvae reared on Packman broccoli were placed on leaves (average 7.7 leaves per plant) of five plants per replicate to achieve the following levels: 1, 5, 10, and 15 CL larvae per plant. Second instar CL's were applied to the same plants on June 3 and 4 (average 9.6 leaves per plant) to maintain the previously mentioned levels. There was no further maintenance of CL levels after June 4. CL larvae reared on diet (Henneberry and Kishaba 1966) were also applied to five plants per replicate in the field on the same dates to maintain the same levels. After application of larvae, the small CL, large CL, and pupae were recorded, together with the number of leaves and head diameter (cm).

Broccoli heads were harvested between 7 and 10.5 cm and stems were trimmed to 15 to 20 cm. Insects found in the head were recorded, removed and heads were weighed (grams). DMRT

(SAS 1985) was used to determine differences between treatments.

#### Fall 1986

For the Fall season, Packman broccoli seedlings were transplanted on August 13 with the same spacing except two rows were eliminated. Fertilizer and pesticide applications both pre-plant and at planting were similar; no pesticides were applied after planting.

The six treatments of natural, and 0, 1, 5, 10, and 15 Cl larvae per plant were replicated six times as in the Spring. Insects, leaves and head size were monitored as before, but larval rearing methods and applications to the plant were modified. Larvae were reared on Packman broccoli only; no diet reared larvae were used because of the poor establishment in Spring (Table 3). Fresh foliage was not provided to the young larvae once they reached the second instar and the old foliage had been consumed. The "starved" larvae were put in cups with a small leaf and transported to the field in a cooler. Leaves were punctured with the blunt end of a camel hair brush and larvae were applied to the cut edge of the leaf. CL larvae were applied on Sept. 7 (6 leaf stage) and again on Sept. 10 (6 leaf stage) to maintain the initial level of larvae. Harvest began on Sept. 29 and continued through October 21. Harvest data were recorded as before; once

harvest began, insect data were not recorded on plants remaining in the field.

### Spring 1987

Packman broccoli seedlings were transplanted on May 1 with the same planting size, plant spacing and number of replicates as the Fall 1986 season. Preplant herbicide and fertilizer applications were applied as in earlier seasons, but no liquid fertilizer or other pesticides were applied at or after planting.

The natural treatment was dropped from the experiment because of low natural CL infestations during the last two growing seasons. The five remaining treatments were applied at the four to six leaf stage; treatment plots consisted of 10 plants per replicate. Second instar CL larvae were applied on May 19 and 20 (4.8 leaf stage) and again three days later (5.7 leaf stage) to maintain the proposed insect levels.

The plants during this season were affected by poor soil condition. After the soil was tilled and plants transplanted, the top layer of the soil formed a hardened crust. The plants became stressed possibly due to the formation of this crust. Defoliation was measured by visually determining the percent defoliation of each leaf and then averaging the defoliation per plant.

Several soil properties were examined to quantify the stress. Our experimental field was compared with another field just 10 m away. The latter was planted one week later

than our field but was harvested approximately two to three weeks earlier. Two soil samples were randomly taken from each of the six experimental rows to measure pH; 12 samples were also taken from corresponding positions in the other, unstressed field. I also tried to indicate the presence of a crust in our field as compared to the other by measuring water infiltration depth (cm). A funnel with a .4 cm base was pushed 0.8 cm into the soil and 100 ml of water was allowed to drain for five minutes (all samples emptied and had stopped water movement within this five minutes). The depth of infiltration was recorded.

The stressed plants delayed harvest. Harvest finally began on June 23 and was discontinued on July 13. Insect counts were discontinued on June 22, but at harvest all insects present on leaves and head were recorded. The same head measurements were made.

Duncan's Multiple Range Test (SAS 1985) was used to determine differences in head weight, harvest date and head contamination between the treatments.

## RESULTS

### Spring 1986

Three plots were discarded after the lack of plant growth was observed on one side of the field. I assumed this was due to a previous herbicide spill. CL larvae were difficult to establish in the 1986 spring (Table 3). Three days after the initial inoculation, less than 68% of all the larvae reared on broccoli remained and less than 64% of the larvae reared on diet remained. Seven days after the re - inoculation, less than 40% of those reared on diet and 71% of those reared on broccoli remained.

CL larvae (9-day mean) were plotted against head weight (g) (Figure 1). There appears to be a trend of decreasing head weight up to 2 larvae, an increase at 3 larvae followed by a decrease at higher levels. However, there were no significant differences between head weight and CL larvae treatment (Duncans Multiple Range Test, SAS 1985) (Table 4). Thus the impact of these levels of CL feeding was not sufficient to depress yields of broccoli. This was compounded by the high variation in yields.

Data were also analyzed to determine if looper infestations could influence date of harvest. The date for which at least 50% of all heads per replicate were harvested

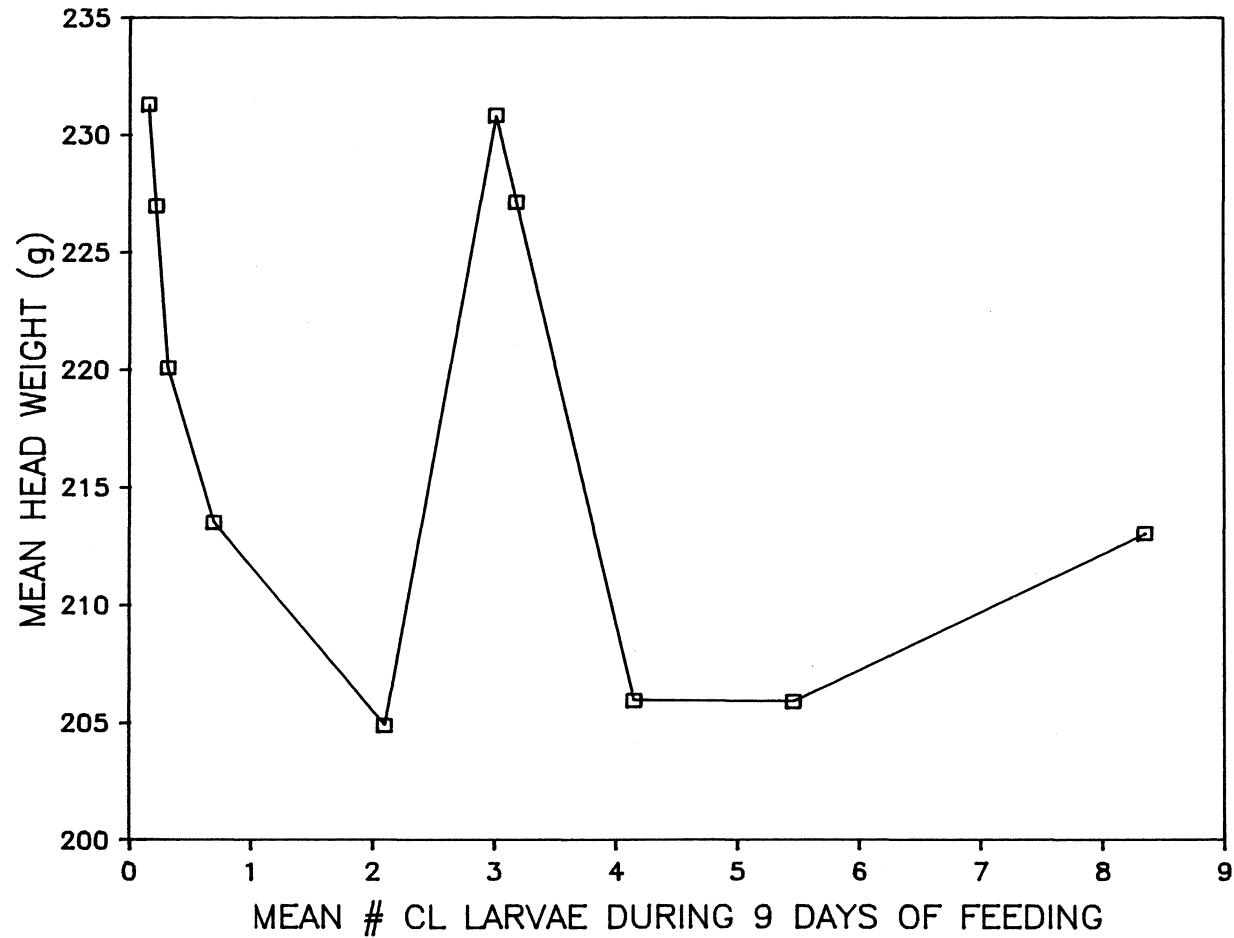


Figure 1. Packman broccoli yield response to mean number of CL larvae during 9 days of feeding (Spring 1986)

Table 4. Comparison of head weight and harvest date of 1986 Spring grown Packman broccoli by treatment

| Treatment* | N | Head weight (g) |          | Harvest date <sup>+</sup> |         |
|------------|---|-----------------|----------|---------------------------|---------|
|            |   | Mean            | (SE)     | Mean                      | (SE)    |
| natural    | 6 | 226.96          | (10.32)a | 167.6                     | (0.46)a |
| 0          | 6 | 231.28          | (12.94)a | 167.9                     | (0.70)a |
| 1 plant    | 5 | 213.48          | (14.81)a | 167.7                     | (0.33)a |
| 5 plant    | 6 | 230.81          | ( 7.51)a | 167.5                     | (0.50)a |
| 10 plant   | 5 | 205.89          | ( 8.17)a | 167.4                     | (0.05)a |
| 15 plant   | 6 | 213.02          | ( 9.06)a | 167.8                     | (0.82)a |
| 1 diet     | 6 | 220.06          | ( 5.85)a | 167.0                     | (0.51)a |
| 5 diet     | 5 | 204.86          | ( 8.34)a | 168.4                     | (0.73)a |
| 10 diet    | 6 | 227.11          | (14.65)a | 167.9                     | (0.65)a |
| 15 diet    | 6 | 205.93          | ( 6.53)a | 168.3                     | (0.50)a |

\*Treatment, except natural and 0, refers to the number of CL larvae applied per plant and how larvae were reared.

<sup>+</sup>Date determined by the mean Julian date per replicate per treatment.

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

was determined as the harvest date. No differences were found among the harvest dates of the various treatments (Table 4). This was not surprising as Packman broccoli has a very short harvest period and the minimum and maximum harvest dates between the treatments only differed by 1.4 days.

The mean CL larvae per head was not significantly different -- very few CL remained at this time. Although total ICW per head were slightly higher, ranging from 0 to 0.17, there were no significant differences (Table 5).

#### Fall 1986

The method of starving the loopers and puncturing the leaf for broccoli inoculation was successful and provided better establishment of loopers than in the Spring (Table 6). CL larvae did not significantly influence yield (Table 7). Wyman and Oatman (1977) also found that yield was not significantly reduced with a peak of nine larvae per broccoli plant. Although we had larval peaks of 13.6 per plant, there were still no differences in yield.

Yield does not appear to be significantly influenced by larval feeding at these levels, however, the same general trends appear in the Fall season (Figure 2) as it did in the Spring. Again, head weight appears to decline at one larva per plant followed by a stimulation and then a reduction in yield. The decline at one larva/plant is a curiosity, but there are a few plausible explanations. One explanation is

Table 5. Head contamination of Spring 1986 broccoli

| Treatment* | N | Total ICW |          | Total CL |          |
|------------|---|-----------|----------|----------|----------|
|            |   | Mean      | (SE)     | Mean     | (SE)     |
| natural    | 6 | 0.10      | (0.04) a | 0.00     | (0.00) a |
| 0          | 6 | 0.07      | (0.07) a | 0.00     | (0.00) a |
| 1 plant    | 5 | 0.05      | (0.05) a | 0.00     | (0.00) a |
| 5 plant    | 6 | 0.11      | (0.07) a | 0.03     | (0.03) a |
| 10 plant   | 5 | 0.12      | (0.08) a | 0.04     | (0.04) a |
| 15 plant   | 6 | 0.07      | (0.04) a | 0.03     | (0.03) a |
| 1 diet     | 6 | 0.00      | (0.00) a | 0.00     | (0.00) a |
| 5 diet     | 5 | 0.00      | (0.00) a | 0.00     | (0.00) a |
| 10 diet    | 6 | 0.13      | (0.08) a | 0.00     | (0.00) a |
| 15 diet    | 6 | 0.17      | (0.13) a | 0.00     | (0.00) a |

\*Treatment, except treatment 1 and 2, refers to number of CL larvae applied per plant and how larvae were reared.

Total refers to the sum of egg, small larva, large larva, and pupa of each insect.

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

Table 6. Establishment of CL larvae on Fall grown Packman broccoli 1986

| <u>Treatment*</u> | Sept. 10 1986    |        |                      | Sept. 13 1986    |        |                      | Sept. 7 - Sept. 22       |        |                      |
|-------------------|------------------|--------|----------------------|------------------|--------|----------------------|--------------------------|--------|----------------------|
|                   | <u>CL Larvae</u> |        | % Estab-<br>lishment | <u>CL Larvae</u> |        | % Estab-<br>lishment | <u>CL Larvae</u>         |        | % Estab-<br>lishment |
|                   | Mean             | (SE)   |                      | Mean             | (SE)   |                      | 15 day Mean<br>Mean (SE) |        |                      |
| Natural           | 0.00             | (0.00) | --                   | 0.03             | (0.03) | --                   | 0.03                     | (0.01) | --                   |
| 0                 | 0.00             | (0.00) | --                   | 0.00             | (0.00) | --                   | 0.00                     | (0.00) | --                   |
| 1                 | 0.97             | (0.13) | 97                   | 1.00             | (0.07) | 100                  | 0.82                     | (0.09) | 82                   |
| 5                 | 3.93             | (0.34) | 79                   | 4.43             | (0.28) | 89                   | 4.21                     | (0.23) | 84                   |
| 10                | 7.40             | (0.85) | 74                   | 9.07             | (0.30) | 91                   | 8.11                     | (0.40) | 81                   |
| 15                | 11.27            | (0.51) | 75                   | 13.63            | (0.36) | 91                   | 12.05                    | (0.58) | 80                   |

\* Treatment, except natural and 0, refers to number of CL larvae applied per plant.

Table 7. Comparison of head weight and harvest date of 1986 Fall grown Packman broccoli by treatment

| Treatment* | Head Weight (g) |           | Harvest date <sup>+</sup> |          |
|------------|-----------------|-----------|---------------------------|----------|
|            | Mean            | (SE)      | Mean                      | (SE)     |
| natural    | 196.2           | (10.64) a | 276.7                     | (0.59) a |
| 0          | 193.8           | ( 6.66) a | 277.5                     | (0.53) a |
| 1          | 182.0           | (12.31) a | 277.1                     | (1.01) a |
| 5          | 209.6           | (14.70) a | 277.1                     | (0.89) a |
| 10         | 199.3           | (15.07) a | 279.6                     | (1.08) a |
| 15         | 186.3           | (13.88) a | 278.9                     | (2.01) a |

\* Treatment, except for natural and 0, refers to number of larvae applied per plant.

<sup>+</sup> Date determined by the mean Julian date per replicate per treatment.

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

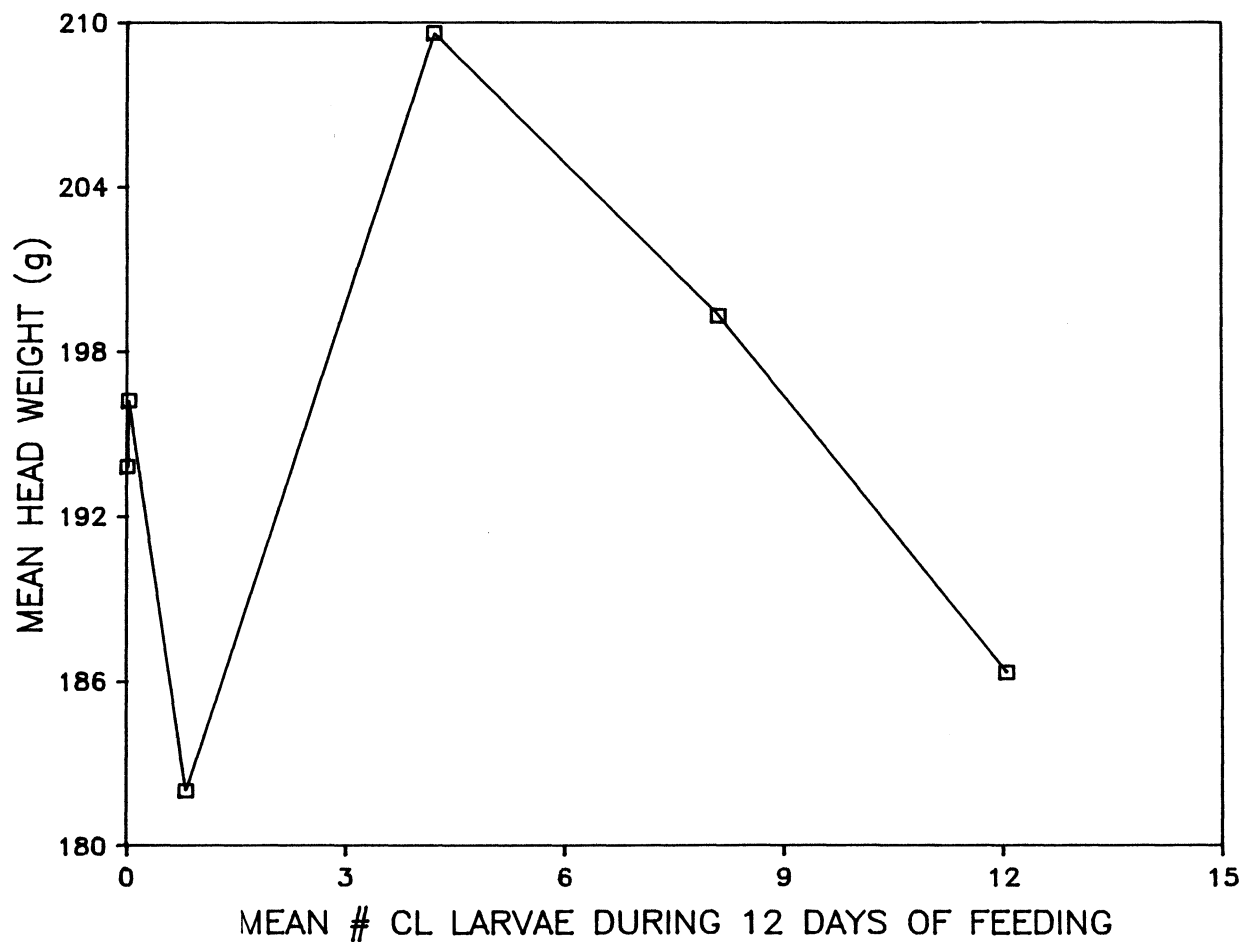


Figure 2. Packman broccoli yield response to mean number of CL larvae during 12 days of feeding (Fall 1986)

that feeding by one larva may reduce the photosynthate produced or the stored reserves of the plant without stimulating plant reaction. While more than one larva may reduce more of those stored reserves, this feeding may also stimulate the plant to replace these reserves. The difference in head weights between treatments however is small, as the maximum difference is only 27.6 grams.

These CL levels did not delay harvest (Table 7). Although the Fall harvest was longer than the Spring harvest period, only 3.7 days separated the treatments with the earliest and latest harvest date.

Head contamination is one of the most important concerns the grower has with broccoli harvest. The grower can be turned down at the market if the broccoli has insects in the head (Table 8). There were also very few ICW larvae in the head; however, there were significantly more ICW larvae in the natural treatment than three of the other treatments. This is also apparent in Spring 1987.

#### Spring 1987

CL inoculation was not as successful as the Fall inoculation, but a 10 day mean had an establishment of 74% or greater of the previously determined levels (Table 9). Head weight versus CL larvae trends were different from previous seasons, probably due to the stressed plants (Figure 3). Significant differences were found between the head weights of the treatments. Head weight decreased with increasing numbers

Table 8. Head contamination of Fall 1986 broccoli

| Treatment* | Total ICW |           | Total CL |          | Total DBM |          |
|------------|-----------|-----------|----------|----------|-----------|----------|
|            | Mean      | (SE)      | Mean     | (SE)     | Mean      | (SE)     |
| natural    | 0.20      | (0.07) a  | 0.00     | (0.00) a | 0.00      | (0.00) a |
| 0          | 0.03      | (0.03) b  | 0.00     | (0.00) a | 0.00      | (0.00) a |
| 1          | 0.03      | (0.03) b  | 0.00     | (0.00) a | 0.00      | (0.00) a |
| 5          | 0.00      | (0.00) b  | 0.00     | (0.00) a | 0.00      | (0.00) a |
| 10         | 0.11      | (0.11) ab | 0.03     | (0.03) a | 0.00      | (0.00) a |
| 15         | 0.03      | (0.03) b  | 0.00     | (0.00) a | 0.03      | (0.03) a |

\* Treatment, except natural and 0, refers to number of CL larvae applied per plant.

Total refers to the sum of egg, small larva, large larva, and pupa of the ICW and CL; and small larva, large larva and pupa of the DBM.

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985); N=6.

Table 9. Establishment of CL larvae on Spring grown Packman broccoli 1987

| Treatment* | May 22 1987  |          |  | May 26 1987  |          |  | May 29 1987 |          |  | May 19 - May 29 |          |  |
|------------|--------------|----------|--|--------------|----------|--|-------------|----------|--|-----------------|----------|--|
|            | CL Larvae    | % Estab- |  | CL Larvae    | % Estab- |  | CL Larvae   | % Estab- |  | CL Larvae       | % Estab- |  |
|            | Mean (SE)    | lishment |  | Mean (SE)    | lishment |  | Mean (SE)   | lishment |  | 10 day mean     | lishment |  |
|            |              |          |  |              |          |  |             |          |  | Mean (SE)       |          |  |
| 0          | 0.02 (0.02)  | --       |  | 0.05 (0.02)  | --       |  | 0.02 (0.02) | --       |  | 0.03 (0.01)     | --       |  |
| 1          | 1.19 (0.23)  | 119      |  | 1.52 (0.25)  | 152      |  | 1.09 (0.17) | 109      |  | 1.27 (0.13)     | 126      |  |
| 5          | 4.05 (0.25)  | 81       |  | 4.98 (0.27)  | 100      |  | 3.77 (0.26) | 75       |  | 4.27 (0.37)     | 85       |  |
| 10         | 7.37 (0.44)  | 74       |  | 8.52 (0.24)  | 85       |  | 6.19 (0.64) | 62       |  | 7.36 (0.67)     | 74       |  |
| 15         | 11.75 (0.57) | 78       |  | 12.88 (0.54) | 86       |  | 8.65 (0.80) | 58       |  | 11.09 (1.26)    | 74       |  |

\* Treatment, except treatment 0, refers to number of CL larvae applied.

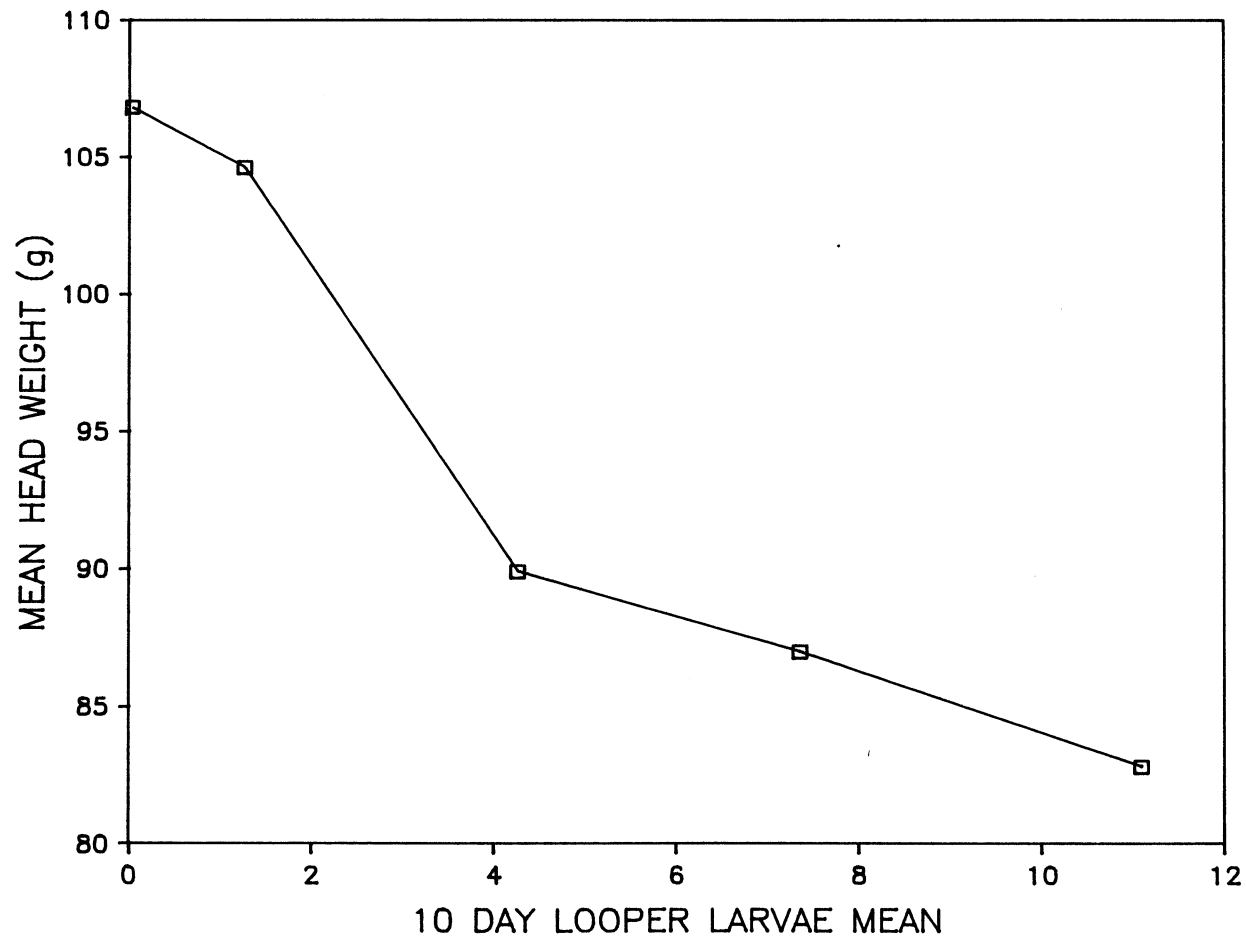


Figure 3. Packman broccoli yield response to mean number of CL larvae during 10 days of feeding (Spring 1987)

of loopers (Table 10). Percent defoliation reached 41.2 and 57.8% respectively in the two highest CL level treatments. These two treatments had significantly lower head weights than the treatments with 0.6 and 3.4 percent defoliation (Table 11). Although head weight was influenced by CL larval feeding, harvest date was not (Table 10).

The plants were visually observed for stress on June 15 and recorded as stressed or unstressed. One stressed and one unstressed plant was randomly chosen from each treatment per row except for row five which had insufficient number of stressed plants. Stressed plants had a significantly lower head weight (47.3 g) than unstressed plants (89.6g) (t test  $P=0.06$  (SAS 1985)).

The pH of our plot was 5.48 and that of the other plot was 5.06. While neither plot met the recommendation of a pH between 6 and 7, this did not explain why our field was stressed because the other plot had a lower pH. The difference appeared to be in soil texture. In the percolation test, our plot penetrated significantly less (1.06 cm) than the other plot (1.82 cm) in the time allotted (t test  $P=0.02$  (SAS 1985)).

The stressed condition of plants in 1987 was confirmed by the difference in head weights. Mean head weight of the control plot in Spring 1986 was 231 g; in Fall 1986, the control was 193 grams as compared to 106 g in Spring 1987. In addition, the 1987 heads were abnormally shaped and were not

Table 10. Comparison of head weight and harvest date of 1987 Spring grown Packman broccoli by treatment

| Treatment* | Head Weight (g) |           | Harvest date <sup>+</sup> |          |
|------------|-----------------|-----------|---------------------------|----------|
|            | Mean            | (SE)      | Mean                      | (SE)     |
| 0          | 106.79          | (9.51) a  | 183.6                     | (1.01) a |
| 1          | 104.59          | (2.78) a  | 184.2                     | (0.65) a |
| 5          | 89.88           | (4.60) ab | 184.2                     | (0.46) a |
| 10         | 86.97           | (5.04) b  | 185.7                     | (1.39) a |
| 15         | 82.80           | (8.23) b  | 185.5                     | (0.76) a |

\* Treatment, except treatment 0, refers to number of CL applied per plant.

<sup>+</sup> Date determined by the mean Julian date per replicate per treatment.

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

Table 11. Percent broccoli defoliation by date and treatment

| Treat-<br>ment <sup>*</sup> | % Defolition |              |              |              |              |                |
|-----------------------------|--------------|--------------|--------------|--------------|--------------|----------------|
|                             | May 29       | June 1       | June 5       | June 8       | June 11      | May 29-June 11 |
|                             | Mean (SE)    | Mean (SE)    | Mean (SE)    | Mean (SE)    | Mean (SE)    | Mean (SE)      |
| 0                           | 0.36 (0.14)  | 0.59 (0.24)  | 3.84 (3.34)  | 0.26 (0.16)  | 0.20 (0.15)  | 1.05 (0.70)    |
| 1                           | 1.78 (0.27)  | 3.45 (0.63)  | 2.66 (0.40)  | 1.44 (0.31)  | 1.32 (0.26)  | 2.13 (0.40)    |
| 5                           | 14.51 (2.84) | 19.23 (4.27) | 17.58 (2.40) | 12.36 (1.56) | 11.96 (1.88) | 15.13 (1.43)   |
| 10                          | 31.83 (5.85) | 41.23 (6.28) | 32.74 (6.06) | 23.18 (3.94) | 25.76 (3.39) | 30.95 (3.14)   |
| 15                          | 48.62 (5.16) | 57.81 (6.05) | 47.44 (5.01) | 38.15 (2.97) | 33.23 (2.65) | 45.05 (4.29)   |

\* Treatment, except treatment 0, refers to number CL applied per plant.

marketable. Another reason for market rejection was head contamination by insects (Table 12). More ICW were found in the control plot than the two highest looper treatments. Plants least damaged earlier in the season were preferred for oviposition by ICW (Radcliffe and Chapman 1966b)

Larvae in the head at harvest emphasize the importance of spraying pesticides during the heading period to prevent head contamination. However, as long as the plants are not stressed and larvae remain below 12/plant, preheading insecticide sprays are not important in preventing yield reduction. The importance of controlling larvae on broccoli is primarily to prevent them from contaminating the head. Recommendations by O'Dell and Ramsey (1987) for 1987 Spring bunching broccoli were to begin spray programs when broccoli starts heading or when at least 30% leaf damage exists before heading. Simultaneous studies are being conducted at Virginia Polytechnic Institute and State University to determine the efficacy of insecticides on lepidopterous pests of broccoli and the timing of these heading sprays.

Table 12. Head contamination of Spring 1987 broccoli

| Treatment* | Total ICW |          | Total CL |         | Total DBM |         |
|------------|-----------|----------|----------|---------|-----------|---------|
|            | Mean      | (SE)     | Mean     | (SE)    | Mean      | (SE)    |
| 0          | 1.79      | (0.31)a  | 0.00     | (0.00)a | 0.13      | (0.05)a |
| 1          | 1.48      | (0.23)ab | 0.00     | (0.00)a | 0.18      | (0.05)a |
| 5          | 1.24      | (0.16)ab | 0.04     | (0.02)a | 0.18      | (0.08)a |
| 10         | 1.15      | (0.24)b  | 0.02     | (0.02)a | 0.06      | (0.03)a |
| 15         | 1.19      | (0.12)b  | 0.03     | (0.03)a | 0.16      | (0.06)a |

\* Treatment, except treatment 0, refers to number of CL applied per plant.

Total refers to the sum of egg, small larva, large larva, and pupa of the ICW and CL; and small larva, large larva and pupa of the DBM.

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)); N=6.

## **CHAPTER 4**

### **BROCCOLI YIELD RESPONSE TO ARTIFICIAL DEFOLIATION DURING PREHEADING**

## INTRODUCTION

Artificial defoliation is often criticized as an inaccurate mimic of insect defoliation because it usually occurs faster than insect defoliation possibly causing a different response from the plant. In broccoli, one generation of cabbage looper larvae may defoliate the plant for 1-2 weeks, but in a crop that is ready for harvest in approximately 45 days post transplanting, one day of artificial defoliation when compared to one week of insect defoliation may not elicit a markedly different yield response by the plant. Because artificial defoliation could cause a more severe response than natural defoliation, action thresholds based on the artificial defoliation thresholds could result in insecticides being applied earlier than needed. Artificial defoliation of 100 and 50% of Premium Crop and Southern Comet, respectively, was needed to reduce broccoli yield in Minnesota (Cranshaw and Default 1985). It was the objective of this study to determine the yield response in Packman broccoli to 0, 25, 50, 75, and 100% artificial defoliation during preheading stages of the Spring and Fall seasons.

## MATERIALS AND METHODS

### Fall 1986

Packman broccoli seedlings were transplanted with 25.4 cm between plants and 76 cm between rows at the Virginia Polytechnic Institute and State University Horticulture Research Farm in Montgomery Co., Va on August 13. Field size was approximately 0.03 ha. Fertilizer, according to soil test results, and Treflan, according to the label, were incorporated before planting. At planting, plants were watered with Diazinon ( $6 \times 10^{-4}$  L of 4 EC/L water applied 4-6 oz/plant) and Peters (20-20-20) fertilizer. No other pesticides were applied.

Treatments were 0, 25, 50, 75, and 100% artificial defoliation. Plants were defoliated by using the midrib as a dividing line and assuming that 50% of the leaf lay to the right and left of the midrib (Figure 4). Plants were defoliated on September 9 at the 6 leaf stage. Treatments were randomly assigned to each row for a total of six rows. Each treatment consisted of five continuous plants.

Eggs, small larvae (instar 1-3), large larvae (instar 4-5) and pupae of the CL and ICW, as well as small larvae (instar 1-2), large larvae (instar 3-4) and pupae of the DBM



Figure 4. Artificial defoliation (A=0%, B=25%, C=50%, D=75% and E=100%) of broccoli leaves in the field

were recorded weekly and removed. The number of leaves and head size were also recorded weekly.

Heads were harvested between 7 and 10.5 cm in diameter and the stems trimmed to 15 to 20 cm. Insect contaminants of the head were recorded, and removed before the head was weighed (g).

### Spring 1987

The broccoli seedlings were transplanted on May 1 at the same spacing. Preplant fertilizer and Treflan were incorporated, no other pesticides were applied. The same treatments were defoliated on May 23 (6 leaf stage).

At harvest, insects on leaves and head were recorded and removed. Head size (cm diameter) and weight (g) were also recorded. DMRT (SAS 1985) was used to determine differences.

## RESULTS AND DISCUSSION

In the Fall season, there was a decrease in head weight with an increase in defoliation (Table 13). However, in the Spring, the relationship between head weight and percent defoliation was more complicated, as 25% defoliation actually caused a stimulation in yield, although the yield was not significantly different from the 0 or 50% defoliation (Table 13). The plants in the Spring planting were not uniformly stressed and thus did not show the distinct differences as

Table 13. Mean head weight and harvest date of five artificial defoliation treatments of Fall (1986) and Spring (1987) broccoli

| Season and<br>% defoliation | Head weight <sup>+</sup> |            | Harvest date <sup>*</sup> |          |
|-----------------------------|--------------------------|------------|---------------------------|----------|
|                             | Mean                     | (SE)       | Mean                      | (SE)     |
| <u>Fall 1986</u>            |                          |            |                           |          |
| 0                           | 187.43                   | (9.78) a   | 277.5                     | (1.13) b |
| 25                          | 181.43                   | (7.08) a   | 278.1                     | (0.84) b |
| 50                          | 160.88                   | (2.69) b   | 279.2                     | (1.09) b |
| 75                          | 144.08                   | (8.25) b   | 279.3                     | (0.97) b |
| 100                         | 81.27                    | (5.01) c   | 288.0                     | (2.46) a |
| <u>Spring 1987</u>          |                          |            |                           |          |
| 0                           | 114.81                   | (8.01) ab  | 188.1                     | (1.08) a |
| 25                          | 120.17                   | (10.67) a  | 184.5                     | (1.80) a |
| 50                          | 107.98                   | (8.23) abc | 185.6                     | (1.33) a |
| 75                          | 95.08                    | (9.23) bc  | 186.9                     | (1.54) a |
| 100                         | 86.44                    | (8.36) c   | 187.2                     | (1.71) a |

<sup>+</sup> grams.

<sup>\*</sup> Julian days.

Means within column and season followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

seen in the Fall planting. Still the trend of decreasing weight with increasing defoliation was evident.

Poston et al. (1976) showed that artificial defoliation along the midrib did not affect photosynthesis of the soybean plant when compared with other forms of defoliation such as the hole punch and cork-borer. Also defoliation caused by the hole punch, cork-borer and along-the-midrib adequately demonstrated soybean defoliation by the green cloverworm, Plathypena scabra (F.) and the painted lady, Cynthia cardui (L.). Thus, artificial defoliation along the midrib may not be as disruptive to plant growth as it appears. Even though the loss of foliage in artificial defoliation was abrupt, occurring in one day, as compared to a 9 to 15 day period caused by lepidopterous larval feeding, results from this defoliation method can be used as a crude indicator for preventing yield loss in broccoli.

## **CHAPTER 5**

### **VARIETAL PREFERENCES OF LEPIDOPTEROUS PESTS ON BROCCOLI**

## INTRODUCTION

In Southside Virginia, tobacco growers are supplementing their tobacco crop with broccoli and other crops due to predicted declines in the tobacco market. New management practices must be determined for each new crop. One management strategy that should be explored is the use of resistant varieties. The three major pests of broccoli in Virginia are the imported cabbageworm (ICW), Pieris rapae; the cabbage looper (CL), Trichoplusia ni (Hubner); and the diamondback moth (DBM), Plutella xylostella (L.) Resistance of the CL (Creighton 1984) and the DBM (Sun et al. 1978 and Liu et al. 1981) to insecticides is already known. The use of resistant varieties is especially important when the pests are resistant to insecticides.

Many studies have been performed on screening crucifers for resistance to pests (Harrison and Brubaker 1943, Radcliffe and Chapman 1965a, 1965b, 1966a, 1966b, Pimentel 1961, Chalfant and Brett 1967, and Brett and Sullivan 1974), but none to our knowledge has placed emphasis on broccoli varietal preferences of lepidopterous pests. It is the objective of this study to evaluate selected broccoli varieties for resistance to the three lepidoptera, ICW, CL, and DBM, in Southwestern Virginia.

## MATERIALS AND METHODS

### Spring 1986

Six week old broccoli seedlings were transplanted on April 26, 1986 at the Virginia Polytechnic Institute and State University Horticulture Research Farm in Montgomery Co., Virginia. Diazinon applied ( $6 \times 10^{-4}$  L of 4EC/L water at 4-6 oz/plant) in the water at transplanting was used to control the cabbage maggot. Peters fertilizer (0.82 g/L of 20-20-20) in the water was also applied to the transplants. Treflan, according to the label, and granular fertilizers, according to soil test results, were incorporated prior to planting. Plants were 25.4 cm apart and 76 cm between rows. Each variety had 60 plants (6 replications of 10) planted in a randomized complete block design. The six varieties selected for testing were Emperor, Green Defender, Green Valiant, Packman, Paragon and Southern Comet. (See Table 14 for varietal characteristics.) These varieties were chosen from broccoli varieties tested in Virginia and had achieved a score of at least three on an overall rating scale of one to five, five being the best rating (O'Dell 1985). Four of the six varieties were grown commercially in 1986. Green Defender was being tested as a possible replacement for the late maturing variety, Green Valiant, because it had a more slender stalk. Paragon was chosen because of its intermediate harvest date.

Table 14. Description of broccoli varieties \*

| Variety        | Maturity <sup>1</sup> | Uniform maturity <sup>2</sup> | Bud size <sup>3</sup> | Bud tightness <sup>4</sup> | Domed or flat | Head high or low in plant <sup>5</sup> | Color <sup>6</sup> | Overall rating <sup>2</sup> |
|----------------|-----------------------|-------------------------------|-----------------------|----------------------------|---------------|----------------------------------------|--------------------|-----------------------------|
| Emperor        | E                     | 2                             | M                     | T                          | D             | M                                      | DG                 | 3.0                         |
| Green Defender | L                     | 3                             | M                     | M                          | D             | H                                      | G                  | 4.0                         |
| Green Valiant  | L                     | 2                             | S                     | T                          | D             | M                                      | G                  | 3.5                         |
| Packman        | VE                    | 5                             | M                     | T                          | D             | H                                      | BG                 | 4.5                         |
| Paragon        | M                     | 3                             | L                     | T                          | D             | H                                      | DG                 | 3.5                         |
| Southern Comet | E                     | 4                             | M                     | M                          | D             | H                                      | BG                 | 4.0                         |

\* Modified from C. R. O'Dell 1985.

<sup>1</sup>VE = very early; E =early; M = midseason; L = late.

<sup>2</sup>1 =poor; 5 =best.

<sup>3</sup>S =small; M =medium; L =large.

<sup>4</sup>M =medium; T =tight.

<sup>5</sup>M =medium; H =high.

<sup>6</sup>G =green; BG =bluegreen; DG =dark green.

Five plants from each variety per row were randomly selected on each sampling date. Sampling began weekly and as the season progressed, was increased to twice a week. Each selected plant was searched for insects, including the ICW, CL, DBM and others. ICW and CL egg, small larvae (instar 1-3), large larvae (instar 4-5) and pupae were counted. Small larvae (instar 1-2), large larvae (instar 3-4) and pupae of the DBM were also recorded.

Heads were harvested between 7.5 and 10 cm diameter by pulling the plant from the ground, trimming the stem to between 15 and 20 cm and removing all leaves. Insects in the head were recorded and removed before the head was weighed.

#### Fall 1986

On August 14, the same varieties were transplanted, however, the size of each block was altered due to space constraints. Each replicate still contained ten plants, but five were placed in the first row and five in the adjacent second row. No further changes were made in the Fall, except that sampling was performed twice a week initially, weather permitting. The experiment was terminated on November 15 because the plants were killed by frost on November 13.

#### Spring 1987

The same six varieties were transplanted on May 2 with the same spacing as the Spring 1986 planting. Samples were taken twice a week. Sampling was discontinued on July 17 and

the plants were harvested on July 21 because later maturing varieties' growth was retarded.

The immature stages of each insect were analyzed, on the days when peak insect counts occurred, with  $\log(x+1)$  transformation because they fit a negative binomial distribution (Harcourt 1961, 1963). Duncan's Multiple Range Test (SAS 1985) was used to determine differences between insect abundance, and head contamination between varieties.

## RESULTS

### Spring 1986 *Pieris rapae*

The first generation of eggs had the highest count on June 20 (Julian date 171) (Figure 5). On June 27 (Julian date 178) and on July 1 (182), the small larval count and the large larval count were respectively the highest for the season. The pupal count was the highest on July 4 (185). The next generation of eggs occurred on July 11 (192). Harvest had begun on June 18 (169) and by July 11 the replicate numbers were no longer the same and while the abundance of ICW on these varieties can be tested statistically, the results may have no meaning biologically. Plants were no longer evenly spaced or distributed which could affect oviposition site selection by the ICW.

The immature stages of ICW were analyzed on the days where peak counts occurred using a log ( $X + 1$ ) transformation and Duncans Multiple Range Test (SAS 1985) to test for differences between the varieties. There were no significant differences of eggs per variety but Green Defender had the highest count and Packman the lowest (Table 15). Varietal preference of ICW on broccoli is basically determined by ovipositional preference, so the egg counts/plant are very important. Larval counts are also important because of the

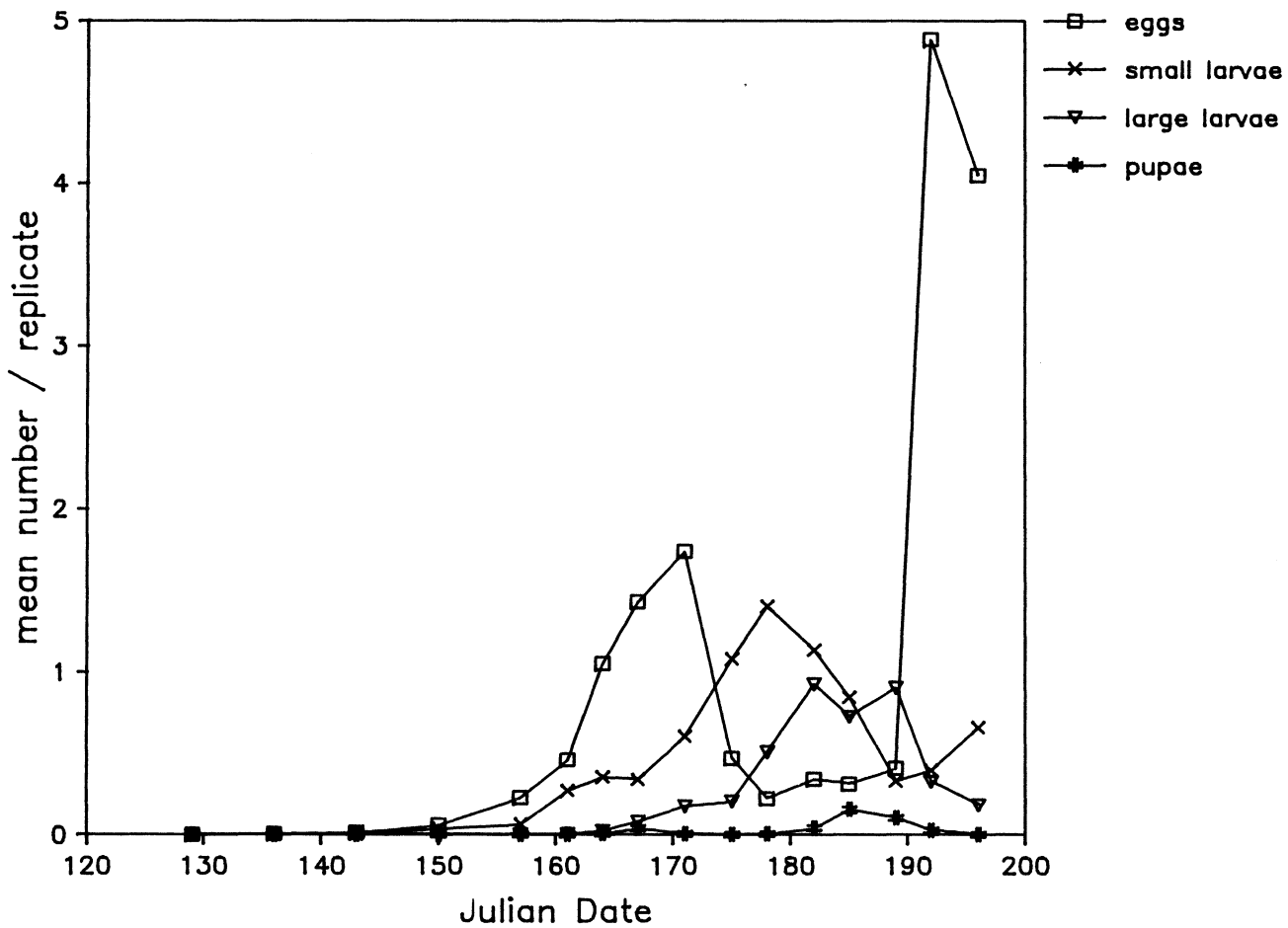


Figure 5. Seasonal abundance of ICW (Spring 1986)

Table 15. Abundance of ICW on broccoli varieties (Spring 1986)

| Variety | Immature ICW means by Julian Date |       |           |        |           |       |       |       |     |       |
|---------|-----------------------------------|-------|-----------|--------|-----------|-------|-------|-------|-----|-------|
|         | 171                               |       | 178       |        | 182       |       | 185   |       | 192 |       |
|         | Eggs                              |       | S. larvae |        | L. larvae |       | Pupae |       | Egg |       |
|         | N                                 | Mean  | N         | Mean   | N         | Mean  | N     | Mean  | N   | Mean  |
| G Def   | 6                                 | 2.37a | 6         | 2.70a  | 6         | 1.56a | 6     | 0.09a | 6   | 3.67a |
| S Comet | 6                                 | 1.22a | 2         | 0.66c  | 2         | 0.19a | 2     | 0.19a | 1   | 2.16a |
| G Val   | 6                                 | 1.91a | 5         | 1.50b  | 5         | 0.94a | 5     | 0.15a | 3   | 5.65a |
| Packman | 6                                 | 1.34a | 2         | 1.00bc | 1         | 1.00a | 1     | 0.41a | -   | ----  |
| Paragon | 6                                 | 1.58a | 5         | 0.54c  | 3         | 0.37a | 2     | 0.19a | 1   | 6.00a |
| Emperor | 6                                 | 2.22a | 4         | 1.76ab | 3         | 1.08a | 2     | 0.19a | 2   | 8.96a |

Means followed by the same letter are not significantly different (P=0.05 DMRT (SAS 1985)).

G Def = Green Defender; S Comet = Southern Comet; G Valiant = Green Valiant.

Numbers are back-transformed from  $\log(x + 1)$ .

sampling time, as some eggs could hatch before being counted. If some plants showed antibiosis, then larval counts could also be important. Small larval counts were highest on Green Defender and low on Southern Comet and Paragon. This was also true for large larvae (but not significantly). Pupal counts were low possibly due to the wandering of the late fifth instars looking for a pupation site. No significant differences were found among the number of eggs on Julian date 192. Emperor had the highest count but no interpretation can be made because of the unequal plant number and distribution per variety at that time.

#### Fall 1986 *Pieris rapae*

From Figure 6, 3 generations of ICW can be seen. The first generation on Fall broccoli (high egg counts on 238, small larval counts on 255, large larval counts on 263 and pupae on 276) was probably a result of the remaining second Spring generation since the numbers were so low. The second generation of the Fall season had the highest egg count on September 26 (Julian date 269); the highest small larval count was on October 14 (287) and the highest large larval count was on October 14 (287). Pupal counts were low throughout the season.

The last generation of ICW had a high count of eggs on October 25 (298) and a high count of small larvae on November 6 (310). The large larvae had a high count on November 10

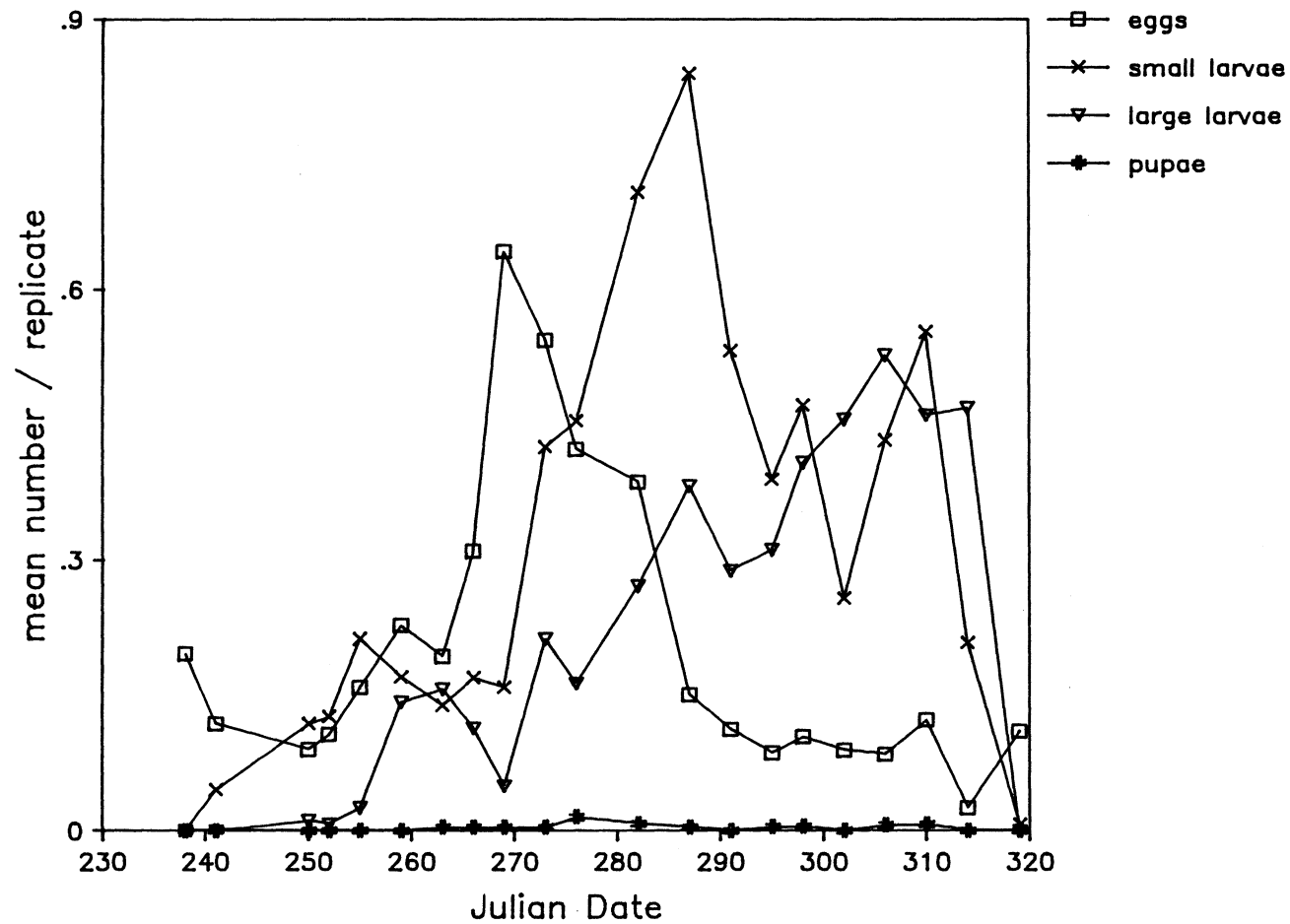


Figure 6. Seasonal abundance of ICW (Fall 1986)

(314). In the Fall especially, large larvae search for a site to pupate and overwinter other than the broccoli field. Also the killing frost which destroyed the integrity of the broccoli plants probably strongly affected the large larval survival.

Log(x + 1) transformation and DMRT were conducted on ICW immature stages that had high counts on the above mentioned dates (Table 16). Green Defender appeared to be the preferred variety. It had a higher count of eggs, small and large larvae in the first generation and a higher small and large larval count in the second generation than several of the other varieties (where significant differences were found). It is harder to determine which varieties are not preferred since the levels of the different immature stages of ICW did not show a constant pattern with variety. Several varieties had lower counts of ICW stages, although not consistently. Emperor and Southern Comet were in the lowest DMRT grouping for four out of five dates that had significant differences. Other varieties such as Packman, Paragon and Green Valiant were intermediate -- they sometimes had the lowest counts, but not as often as Southern Comet and Emperor.

#### Spring 1987 *Pieris rapae*

Spring 1987 results indicate a first generation not seen in the 1986 Spring season (Figure 7). These ICW eggs probably came from the overwintering pupae emerging, feeding and

Table 16. Abundance of ICW on broccoli varieties (Fall 1986)

| Variety | Immature ICW abundance by Julian Date |        |           |       |           |        |       |       |      |       |
|---------|---------------------------------------|--------|-----------|-------|-----------|--------|-------|-------|------|-------|
|         | 238                                   |        | 255       |       | 263       |        | 276   |       | 269  |       |
|         | Eggs                                  |        | S. Larvae |       | L. larvae |        | Pupae |       | Eggs |       |
|         | N                                     | Mean   | N         | Mean  | N         | Mean   | N     | Mean  | N    | Mean  |
| S Comet | 6                                     | 0.07b  | 6         | 0.12b | 6         | 0.05b  | 6     | 0.00a | 6    | 0.43a |
| Paragon | 6                                     | 0.28ab | 6         | 0.20b | 6         | 0.15ab | 6     | 0.00a | 6    | 0.54a |
| Packman | 6                                     | 0.12b  | 6         | 0.07b | 6         | 0.12ab | 6     | 0.00a | 6    | 0.85a |
| Emperor | 6                                     | 0.25ab | 6         | 0.18b | 6         | 0.09b  | 6     | 0.02a | 6    | 0.71a |
| G Val   | 6                                     | 0.10b  | 6         | 0.22b | 6         | 0.18ab | 6     | 0.02a | 6    | 0.63a |
| G Def   | 6                                     | 0.39a  | 6         | 0.53a | 6         | 0.39a  | 6     | 0.05a | 6    | 0.69a |

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

G Def = Green Defender; G Val = Green Valiant; S Comet = Southern Comet.

Numbers are back-transformed from  $\log(x + 1)$ .

Table 16 continued. Abundance of ICW on broccoli varieties (Fall 1986)

| Immature ICW abundance by Julian Date |        |           |        |       |       |      |       |           |       |           |       |
|---------------------------------------|--------|-----------|--------|-------|-------|------|-------|-----------|-------|-----------|-------|
| 287                                   |        | 287       |        | 310   |       | 298  |       | 310       |       | 314       |       |
| S. Larvae                             |        | L. larvae |        | Pupae |       | Eggs |       | S. Larvae |       | L. larvae |       |
| N                                     | Mean   | N         | Mean   | N     | Mean  | N    | Mean  | N         | Mean  | N         | Mean  |
| 6                                     | 0.51b  | 6         | 0.15b  | 4     | 0.00a | 4    | 0.14a | 4         | 0.39a | 4         | 0.55a |
| 6                                     | 0.85ab | 6         | 0.42bc | 5     | 0.00a | 5    | 0.00a | 5         | 0.38a | 4         | 0.20a |
| 6                                     | 0.85ab | 6         | 0.12c  | 4     | 0.00a | 4    | 0.12a | 4         | 0.19a | 4         | 0.09a |
| 6                                     | 0.44b  | 6         | 0.26bc | 1     | 0.00a | 3    | 0.23a | 1         | 1.00a | 1         | 0.00a |
| 6                                     | 0.81ab | 6         | 0.56ab | 5     | 0.03a | 6    | 0.10a | 5         | 0.38a | 5         | 0.35a |
| 6                                     | 1.87a  | 6         | 0.94a  | 5     | 0.00a | 6    | 0.11a | 5         | 1.52a | 5         | 0.46a |

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

Numbers are back-transformed from  $\log(x + 1)$ .

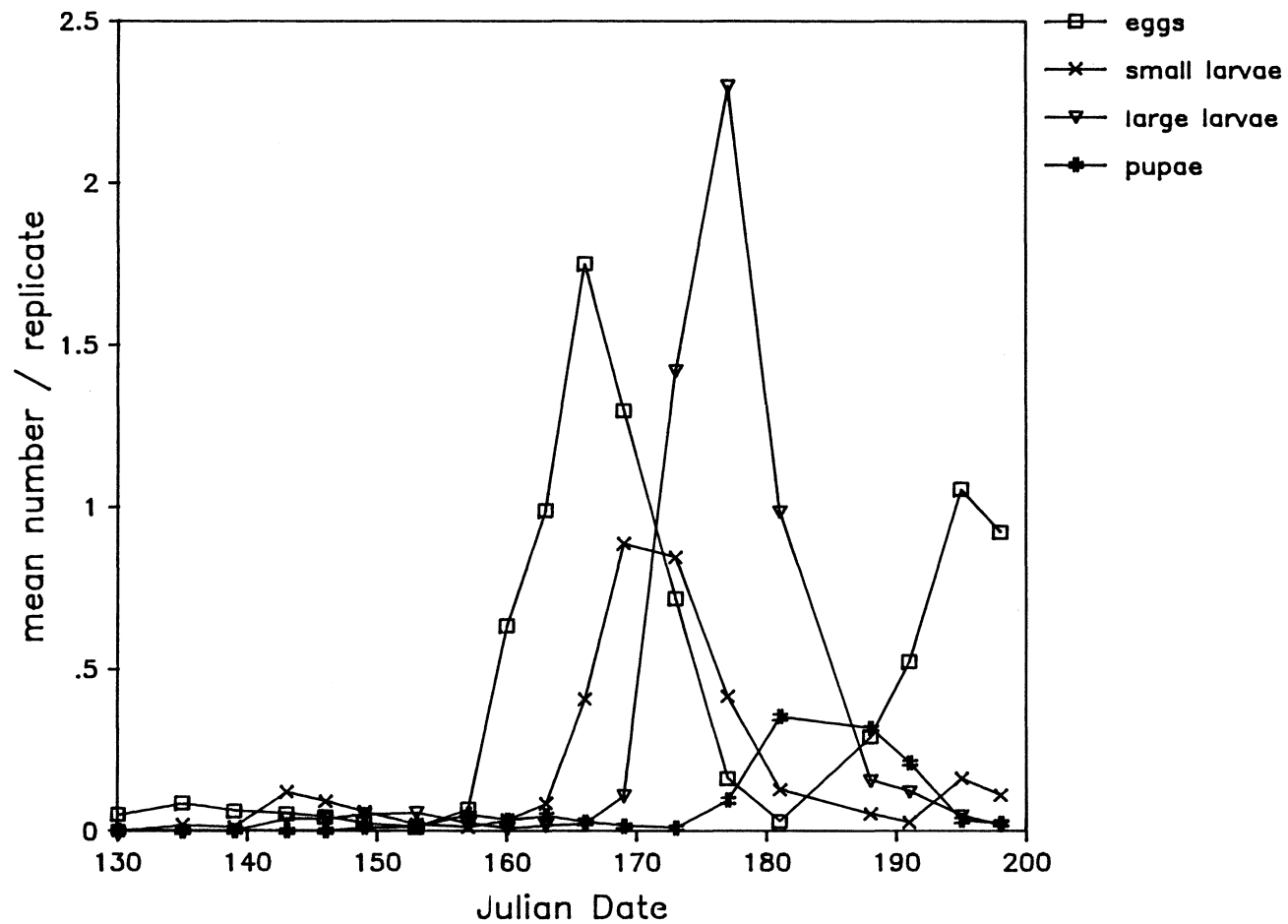


Figure 7. Seasonal abundance of ICW (Spring 1987)

ovipositing on wild mustards. Once the cultivated mustard, broccoli, was planted the butterflies also oviposited on it. It appears that on May 15 (Julian date 135) eggs were laid on broccoli by those few remaining ICW adults still alive. The small and large larval and pupal peak counts were on Julian days 143, 153, and 157 respectively. The next generation of eggs on broccoli occurred on June 15 (166). A lower small larval count was found on June 18 (169). The highest count of large larvae occurred on June 26 (177) and of pupae on June 30 (181). The second broccoli generation of ICW had the highest egg count on July 14 (195). Plants in this 1987 Spring planting were stressed and growth was retarded. Harvest which had begun by June 18 in 1986, did not begin until July 4 in 1987.

On five of the dates mentioned above, Green Defender had the highest ICW immature stage counts and only six dates had significant differences. This includes 3 dates when egg counts were the highest (Table 17). There does not appear to be an ovipositional switch from damaged to undamaged plants. Renwicke and Radke (1981) found T. ni laid less eggs on plants already damaged and that ICW had a similar response (Renwicke and Radke 1985), but not as strong. They suggested field populations would never be high enough to elicit such an ovipositional deterrence by ICW.

Spring 1986 Plutella xylostella

Table 17. Abundance of ICW on broccoli varieties (Spring 1987)

| Immature ICW abundance by Julian Date |      |        |           |        |           |       |       |       |      |       |
|---------------------------------------|------|--------|-----------|--------|-----------|-------|-------|-------|------|-------|
| Variety                               | 135  |        | 143       |        | 153       |       | 157   |       | 166  |       |
|                                       | Eggs |        | S. larvae |        | L. larvae |       | Pupae |       | Eggs |       |
|                                       | N    | Mean   | N         | Mean   | N         | Mean  | N     | Mean  | N    | Mean  |
| Emperor                               | 6    | 0.11ab | 6         | 0.07b  | 6         | 0.02a | 6     | 0.10a | 6    | 1.70b |
| G Def                                 | 6    | 0.20a  | 6         | 0.31a  | 6         | 0.12a | 6     | 0.02a | 6    | 3.69a |
| G Val                                 | 6    | 0.05b  | 6         | 0.12ab | 6         | 0.05a | 6     | 0.02a | 6    | 1.22b |
| Packman                               | 6    | 0.05b  | 6         | 0.07b  | 6         | 0.07a | 6     | 0.05a | 6    | 1.84b |
| Paragon                               | 6    | 0.07b  | 6         | 0.05b  | 6         | 0.05a | 6     | 0.07a | 6    | 1.54b |
| S Comet                               | 6    | 0.05b  | 6         | 0.12ab | 6         | 0.04a | 6     | 0.05a | 6    | 1.14b |

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

G Def=Green Defender; G Val= Green Valiant; S Comet= Southern comet.

Numbers are back-transformed from  $\log(x + 1)$ .

Table 17 continued . Abundance of ICW on broccoli varieties (Spring 1987)

| Immature ICW abundance by Julian Date |        |           |       |       |        |      |        |
|---------------------------------------|--------|-----------|-------|-------|--------|------|--------|
| 169                                   |        | 177       |       | 181   |        | 195  |        |
| S. larvae                             |        | L. larvae |       | Pupae |        | Eggs |        |
| N                                     | Mean   | N         | Mean  | N     | Mean   | N    | Mean   |
| 6                                     | 0.60bc | 6         | 2.79a | 6     | 0.50ab | 5    | 0.37b  |
| 6                                     | 1.85a  | 6         | 1.83a | 6     | 0.15b  | 6    | 2.61a  |
| 6                                     | 0.34c  | 6         | 2.02a | 6     | 0.64a  | 6    | 1.06ab |
| 6                                     | 1.15ab | 6         | 2.12a | 6     | 0.37ab | 1    | 0.00b  |
| 6                                     | 0.87bc | 6         | 2.24a | 6     | 0.19b  | 6    | 0.86ab |
| 6                                     | 0.83bc | 6         | 2.96a | 6     | 0.33ab | 5    | 1.03ab |

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

Numbers are back-transformed from  $\log(x + 1)$ .

Numbers of DBM were low (Figure 8). The highest count of any instar was 0.5/plant on July 8 (Julian date 189) of the large larvae. Small larval counts peaked on June 10 (161). Three days later the highest count for the first generation of large larvae was recorded. Pupal count did not reach a peak until July 1 (167). The second generation's highest small larval count occurred on July 4 (185) and the large larval count on July 8 (189).

The above peaks were analyzed in the same manner as ICW. Emperor had a significantly higher small larval count on June 10 (161) than Southern Comet or Paragon (Table 18).

#### Fall 1986 Plutella xylostella

There appears to be five generations (or at least five dates where small larval counts are high) of DBM in the Fall (Figure 9). High small larval counts were found on the following dates: September 16 (259), September 30 (273), October 14 (287), October 25 (298) and November 6 (310). Similarly, high large larval counts were recorded on : September 20 (263), October 9 (282), October 22 (295), and November 2 (306). The four dates that indicated pupal count peaks were September 23 (266), October 14 (287), October 25 (298), and November 2 (306).

These counts were analyzed like the ICW data (Table 19). Significant differences were found on small larval dates of September 16, October 25 and November 6. Emperor had

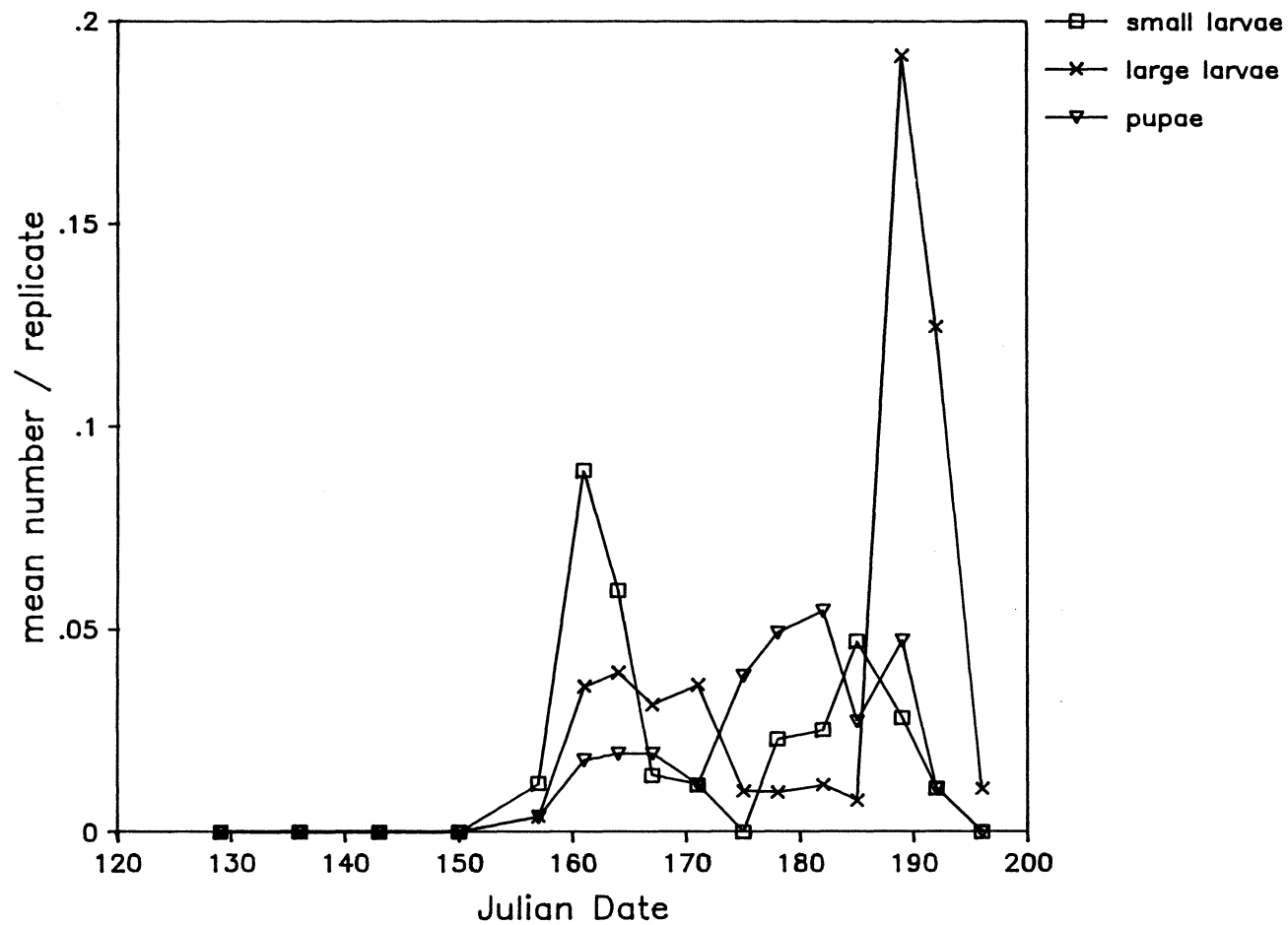


Figure 8. Seasonal abundance of DBM (Spring 1986)

Table 18. Abundance of DBM on broccoli varieties (Spring 1986)

| Immature DBM abundance by Julian Date |           |         |           |       |       |       |           |       |           |       |       |       |
|---------------------------------------|-----------|---------|-----------|-------|-------|-------|-----------|-------|-----------|-------|-------|-------|
| Variety                               | 161       |         | 164       |       | 167   |       | 185       |       | 189       |       | 189   |       |
|                                       | S. larvae |         | L. larvae |       | Pupae |       | S. larvae |       | L. larvae |       | Pupae |       |
|                                       | N         | Mean    | N         | Mean  | N     | Mean  | N         | Mean  | N         | Mean  | N     | Mean  |
| G Def                                 | 6         | 0.14ab  | 6         | 0.05a | 6     | 0.05a | 6         | 0.02a | 6         | 0.12a | 6     | 0.00a |
| S Comet                               | 6         | 0.02bc  | 6         | 0.07a | 6     | 0.00a | 2         | 0.00a | 2         | 0.19a | 2     | 0.19a |
| G Val                                 | 6         | 0.12ab  | 6         | 0.05a | 6     | 0.02a | 5         | 0.15a | 4         | 0.49a | 4     | 0.09a |
| Packman                               | 6         | 0.10abc | 6         | 0.05a | 6     | 0.00a | 1         | 0.00a | -         | ---   | -     | ---   |
| Paragon                               | 6         | 0.00c   | 6         | 0.00a | 6     | 0.05a | 2         | 0.00a | 1         | 0.00a | 1     | 0.00a |
| Emperor                               | 6         | 0.16a   | 6         | 0.02a | 6     | 0.00a | 2         | 0.00a | 2         | 0.00a | 2     | 0.00a |

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

G Def = Green Defender; G Val = Green Valiant; S Comet = Southern Comet.

Numbers are back-transformed from  $\log(x + 1)$ .

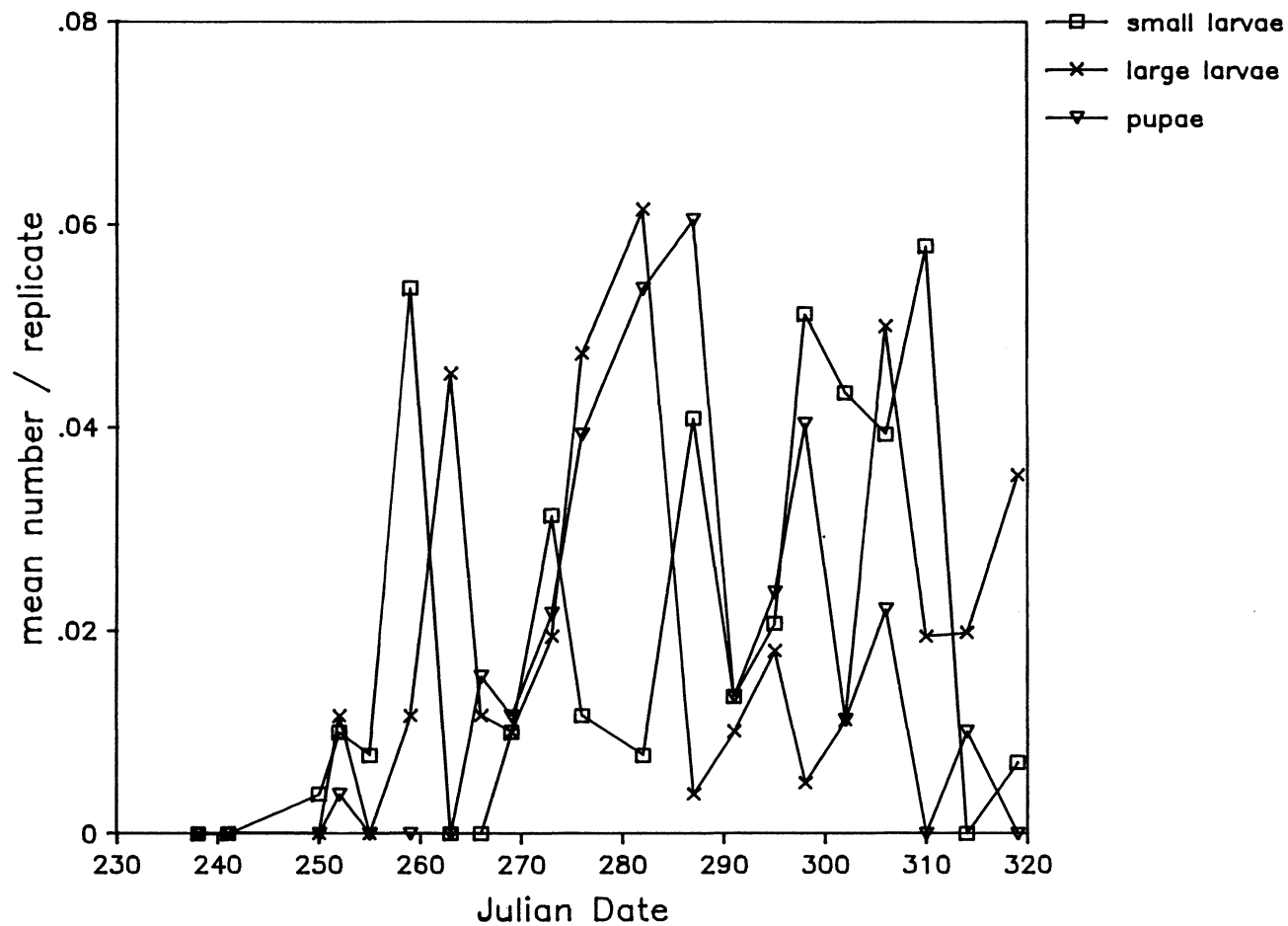


Figure 9. Seasonal abundance of DBM (Fall 1986)

Table 19. Abundance of DBM on broccoli varieties (Fall 1986)

| Immature DBM abundance by Julian Date |           |        |           |       |       |       |           |       |           |       |       |       |
|---------------------------------------|-----------|--------|-----------|-------|-------|-------|-----------|-------|-----------|-------|-------|-------|
| Variety                               | 259       |        | 263       |       | 266   |       | 273       |       | 282       |       | 287   |       |
|                                       | S. larvae |        | L. larvae |       | Pupae |       | S. larvae |       | L. larvae |       | Pupae |       |
|                                       | N         | Mean   | N         | Mean  | N     | Mean  | N         | Mean  | N         | Mean  | N     | Mean  |
| S Comet                               | 6         | 0.12ab | 6         | 0.07a | 6     | 0.00a | 6         | 0.02a | 6         | 0.06a | 6     | 0.15a |
| Paragon                               | 6         | 0.05ab | 6         | 0.00a | 6     | 0.05a | 6         | 0.02a | 6         | 0.09a | 6     | 0.07a |
| Packman                               | 6         | 0.00b  | 6         | 0.02a | 6     | 0.00a | 6         | 0.00a | 6         | 0.12a | 6     | 0.00a |
| Emperor                               | 6         | 0.12a  | 6         | 0.02a | 6     | 0.00a | 6         | 0.05a | 6         | 0.05a | 6     | 0.05a |
| G Val                                 | 6         | 0.02ab | 6         | 0.05a | 6     | 0.02a | 6         | 0.05a | 6         | 0.02a | 6     | 0.05a |
| G Def                                 | 6         | 0.02ab | 6         | 0.11a | 6     | 0.02a | 6         | 0.05a | 6         | 0.02a | 6     | 0.05a |

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

G Def = Green Defender; G Val = Green Valiant; S Comet = Southern Comet.

Numbers are transformed from  $\log(x + 1)$ .

Table 19 continued. Abundance of DBM on broccoli varieties (Fall 1986)

| Immature DBM abundance by Julian Date |       |           |       |       |       |           |       |           |       |       |       |
|---------------------------------------|-------|-----------|-------|-------|-------|-----------|-------|-----------|-------|-------|-------|
| 287                                   |       | 295       |       | 298   |       | 298       |       | 306       |       | 306   |       |
| S. larvae                             |       | L. Larvae |       | Pupae |       | S. Larvae |       | L. larvae |       | Pupae |       |
| N                                     | Mean  | N         | Mean  | N     | Mean  | N         | Mean  | N         | Mean  | N     | Mean  |
| 6                                     | 0.06a | 4         | 0.00a | 4     | 0.00a | 4         | 0.00b | 4         | 0.00a | 4     | 0.00a |
| 6                                     | 0.02a | 5         | 0.03a | 5     | 0.18a | 5         | 0.03b | 5         | 0.06a | 5     | 0.03a |
| 6                                     | 0.00a | 5         | 0.00a | 4     | 0.00a | 4         | 0.00b | 4         | 0.00a | 4     | 0.00a |
| 6                                     | 0.07a | 5         | 0.00a | 3     | 0.00a | 3         | 0.00b | 2         | 0.00a | 2     | 0.00a |
| 6                                     | 0.02a | 6         | 0.02a | 6     | 0.02a | 6         | 0.03b | 6         | 0.06a | 6     | 0.05a |
| 6                                     | 0.07a | 6         | 0.05a | 6     | 0.02a | 6         | 0.19a | 6         | 0.12a | 6     | 0.02a |

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

Numbers are transformed from  $\log(x + 1)$ .

significantly more small larvae than Packman on September 16. On October 25, Green Defender had significantly higher counts than all other varieties, but on November 6, Emperor had significantly higher counts than all other varieties. October 25 and November 6 are dates after harvest had begun and several plots had been harvested, thus changing the spacial distribution of the broccoli plants throughout the experimental field. Therefore, I cannot say that the varieties alone were influencing host selection.

#### Spring 1987 Plutella xylostella

Only one generation of DBM was evident in this season (Figure 10). Small larval and large larval counts were highest on the same date June 15 (166), indicating that an earlier small larval count peak may have been missed. On June 18 (169), the pupal count was the highest. DBM had higher counts this season than any of the previous seasons. No significant differences between varieties were found on any of the above mentioned dates (analysis same as that of ICW, Table 20). Although no varietal preferences were found this season, Emperor was preferred by DBM during the Spring 1986 and Fall 1986 seasons.

#### Spring 1986 Trichoplusia ni

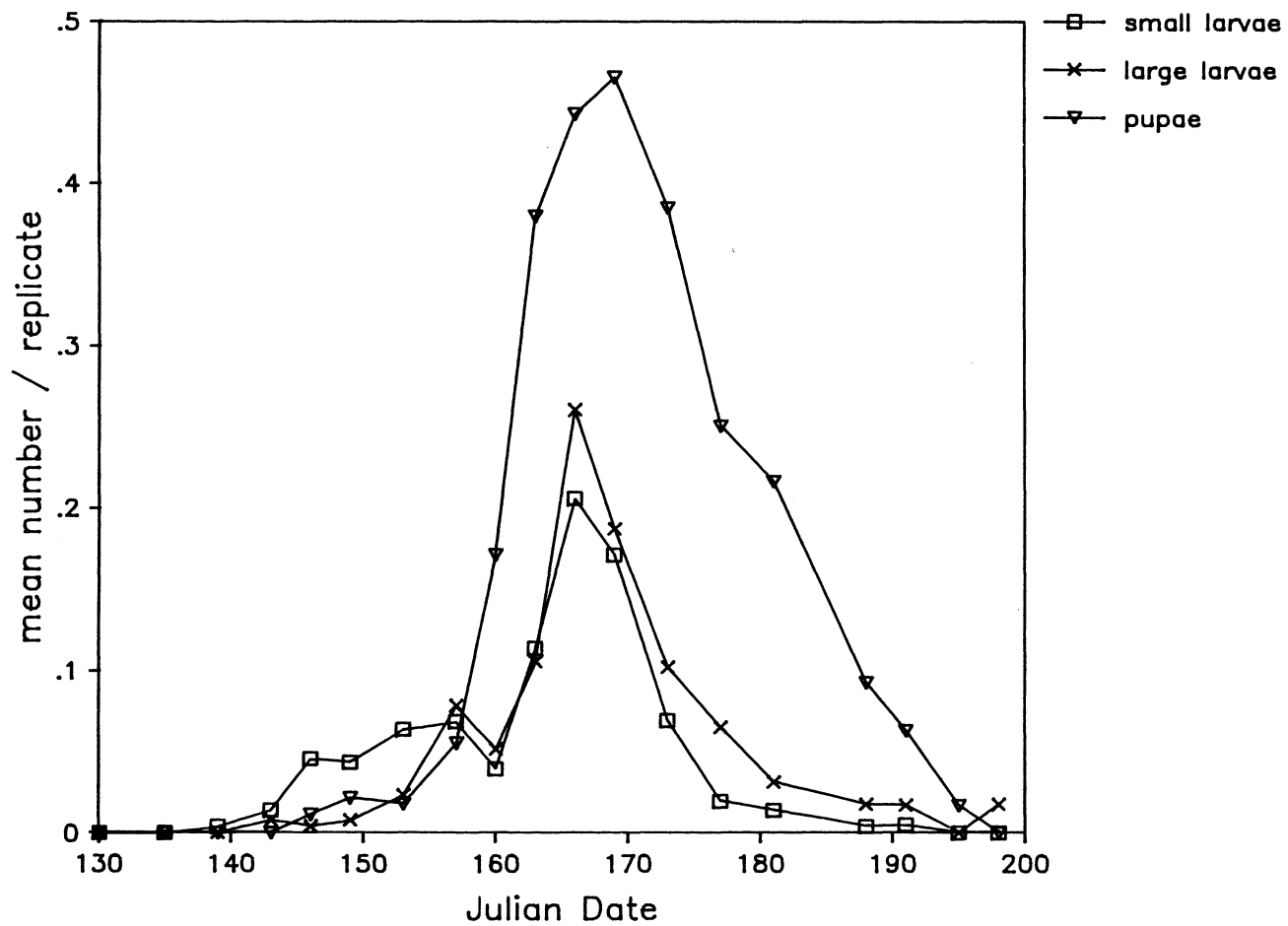


Figure 10. Seasonal abundance of DBM (Spring 1987)

Table 20. Abundance of DBM on broccoli varieties (Spring 1987)

| Immature DBM by Julian Date |           |       |           |       |       |       |
|-----------------------------|-----------|-------|-----------|-------|-------|-------|
| Variety                     | 166       |       | 166       |       | 169   |       |
|                             | S. larvae |       | L. larvae |       | Pupae |       |
|                             | N         | Mean  | N         | Mean  | N     | Mean  |
| Emperor                     | 6         | 0.15a | 6         | 0.19a | 6     | 0.53a |
| G Def                       | 6         | 0.20a | 6         | 0.36a | 6     | 0.40a |
| G Val                       | 6         | 0.24a | 6         | 0.16a | 6     | 0.26a |
| Packman                     | 6         | 0.21a | 6         | 0.39a | 6     | 0.51a |
| Paragon                     | 6         | 0.31a | 6         | 0.20a | 6     | 0.51a |
| S Comet                     | 6         | 0.14a | 6         | 0.28a | 6     | 0.62a |

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

G Def = Green Defender; G Val = Green Valiant; S Comet = Southern Comet.

Numbers are back-transformed from  $\log(x + 1)$ .

One and a half generations of CL were recorded in the Spring 1986 season (Figure 11). The highest egg count was recorded on May 30 (Julian date 150), while the small larval and large larval counts peaked on June 6 (157) and June 10 (161), respectively. The highest pupal count was observed six days after the large larval peak count. The second generation of eggs reached a high count on July 8 (189). The small larval count of the second generation was highest on July 10 (191).

Of all these peak dates, significant differences were found between the varieties on only one date. On June 10 (161), more large larvae were found on Green Defender than on Paragon (Table 21).

#### Fall 1986 Trichoplusia ni

One generation was apparent in the Fall 1986 season (Figure 12). On September 16 (Julian date 259), the highest number of eggs were counted. The small larval count did not reach a peak until September 30 (273) and large larval count did not peak until October 3 (276). A very small pupal count occurred on October 18 (291) to indicate the pupal count peak. No significant differences were found between varieties in either egg, small and large larvae or pupae on their respective peak days (Table 22).

#### Spring 1987 Trichoplusia ni

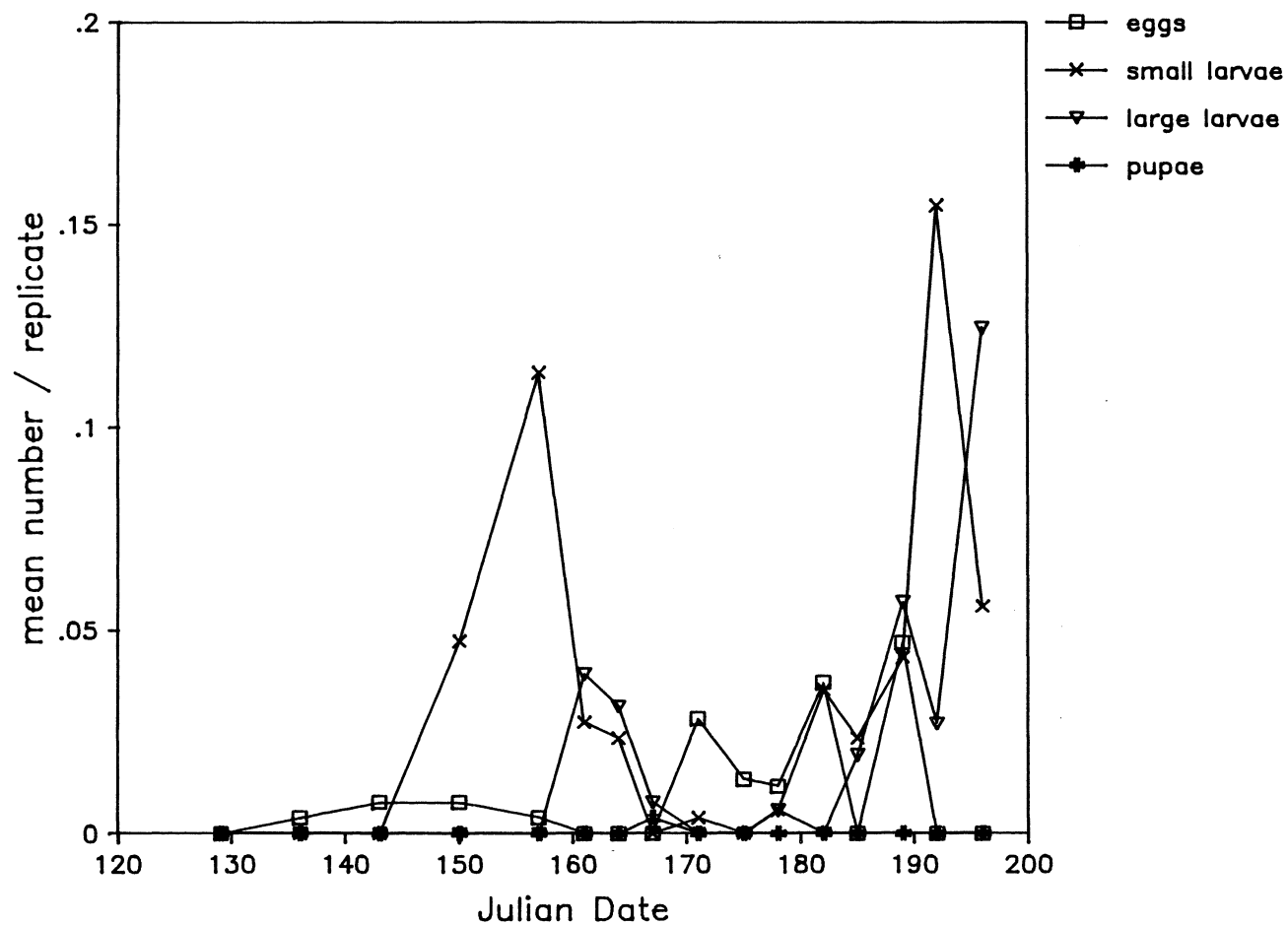


Figure 11. Seasonal abundance of CL (Spring 1986)

Table 21. Abundance of CL on broccoli varieties (Spring 1986)

| Immature CL by Julian Date |      |       |           |       |           |        |       |       |      |       |           |       |
|----------------------------|------|-------|-----------|-------|-----------|--------|-------|-------|------|-------|-----------|-------|
| Variety                    | 150  |       | 157       |       | 161       |        | 167   |       | 189  |       | 192       |       |
|                            | Eggs |       | S. larvae |       | L. larvae |        | Pupae |       | Eggs |       | S. larvae |       |
|                            | N    | Mean  | N         | Mean  | N         | Mean   | N     | Mean  | N    | Mean  | N         | Mean  |
| G Def                      | 6    | 0.05a | 6         | 0.14a | 6         | 0.10a  | 6     | 0.02a | 6    | 0.02a | 6         | 0.22a |
| S Comet                    | 6    | 0.00a | 6         | 0.16a | 6         | 0.07ab | 6     | 0.00a | 2    | 0.32a | 1         | 0.00a |
| G Val                      | 6    | 0.00a | 6         | 0.10a | 6         | 0.02ab | 6     | 0.00a | 4    | 0.00a | 3         | 0.26a |
| Packman                    | 6    | 0.00a | 6         | 0.13a | 6         | 0.02ab | 6     | 0.00a | —    | ----  | —         | ----  |
| Paragon                    | 6    | 0.00a | 6         | 0.12a | 6         | 0.00b  | 6     | 0.00a | 1    | 0.00a | 1         | 0.00a |
| Emperor                    | 6    | 0.00a | 6         | 0.04a | 6         | 0.02ab | 6     | 0.00a | 2    | 0.00a | 2         | 0.00a |

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

G Def = Green Defender; G Val = Green Valiant; S Comet = Southern Comet.

Numbers are back-transformed from  $\log(x + 1)$ .

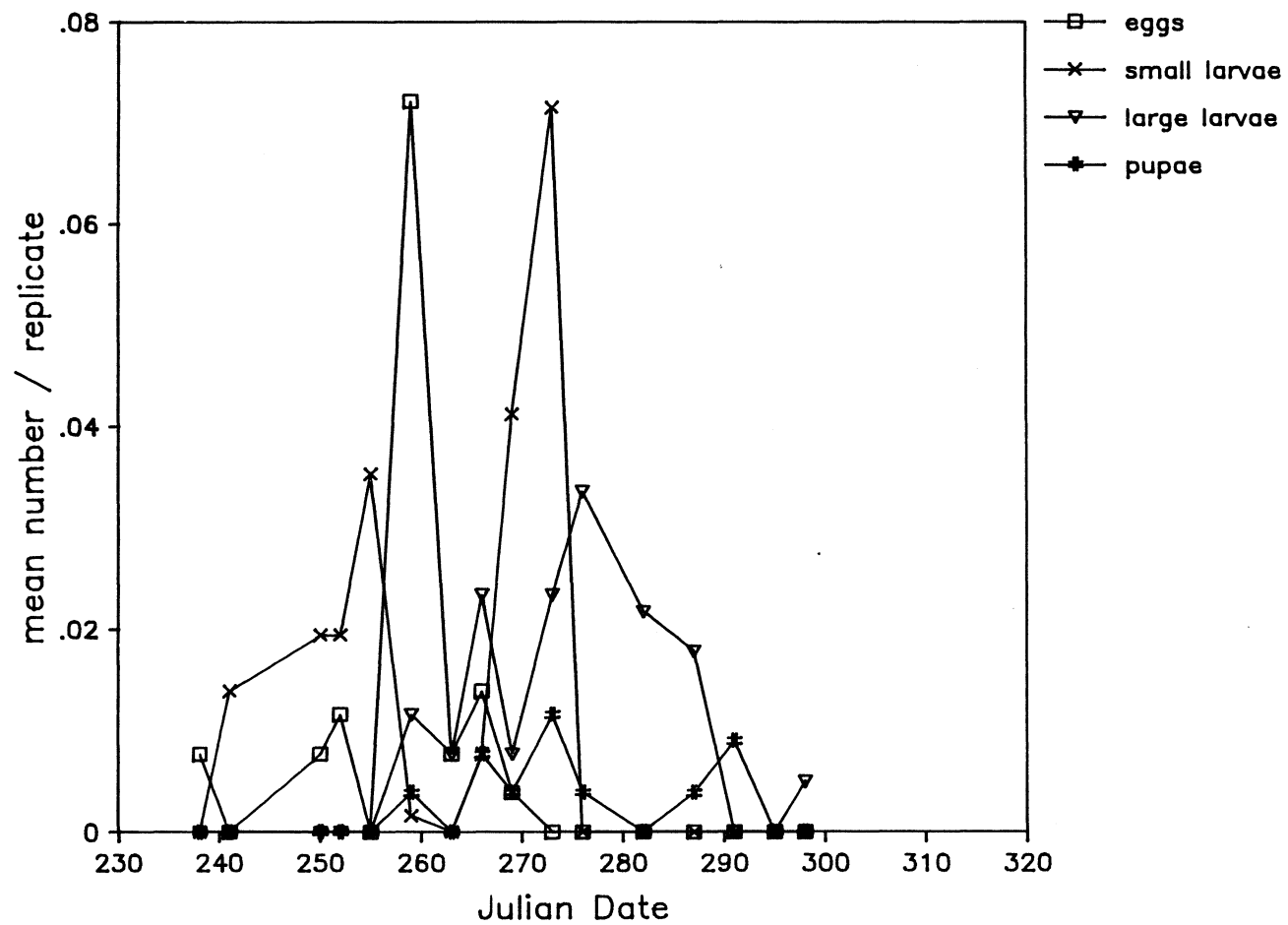


Figure 12. Seasonal abundance of CL (Fall 1986)

Table 22. Abundance of CL on broccoli varieties (Fall 1986)

| Variety | Immature CL abundance by Julian Date |       |           |       |           |       |       |       |
|---------|--------------------------------------|-------|-----------|-------|-----------|-------|-------|-------|
|         | 259                                  |       | 273       |       | 276       |       | 291   |       |
|         | Eggs                                 |       | S. Larvae |       | L. larvae |       | Pupae |       |
|         | N                                    | Mean  | N         | Mean  | N         | Mean  | N     | Mean  |
| S Comet | 6                                    | 0.04a | 6         | 0.11a | 6         | 0.06a | 6     | 0.00a |
| Paragon | 6                                    | 0.05a | 6         | 0.05a | 6         | 0.02a | 6     | 0.00a |
| Packman | 6                                    | 0.07a | 6         | 0.11a | 6         | 0.05a | 6     | 0.03a |
| Emperor | 6                                    | 0.11a | 6         | 0.13a | 6         | 0.00a | 6     | 0.00a |
| G Val   | 6                                    | 0.05a | 6         | 0.04a | 6         | 0.00a | 6     | 0.00a |
| G Def   | 6                                    | 0.12a | 6         | 0.00a | 6         | 0.07a | 6     | 0.02a |

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS (SAS 1985))).

G Def = Green Defender; G Val = Green Valaint; S Comet = Southern Comet.

Numbers are back-transformed from  $\log(x + 1)$ .

One generation of CL occurred in the Spring 1987 season (Figure 13). Egg counts reached a high on June 15 (166), small and large larval counts peaked on June 30 (181) and July 7 (188). Pupal counts were also the highest on July 7 (188). No significant differences of CL abundance between varieties was found on any of these dates (Table 23). Cabbage loopers were present in very low numbers thereby making it difficult to find any differences in counts among varieties.

To simplify the problem of determining which varieties were preferred by the three lepidopterous pests, all insect counts (eggs, small and large larvae, and pupae of ICW and CL; and small and large larvae, and pupae of DBM) were summed through each season (Table 24). It is apparent that Green Defender had the highest count of insects for all 3 seasons. Southern Comet and Packman were in the lowest DMRT grouping for total insects for all three seasons. Emperor and Paragon were in the lowest DMRT grouping 2 out of 3 seasons.

Since ICW never reached 7 larvae/plant on any sample date, these levels of ICW probably would not have caused a reduction in yield. Packman, Paragon and Southern Comet had less ICW in the head at harvest than Green Defender, Green Valiant and Emperor (Table 25) in Spring 1986. Small and large larval counts peaked on Julian days 178 and 182 respectively. Southern Comet was harvested on 173 (Packman 172 and Paragon 173) before the small larval counts were too

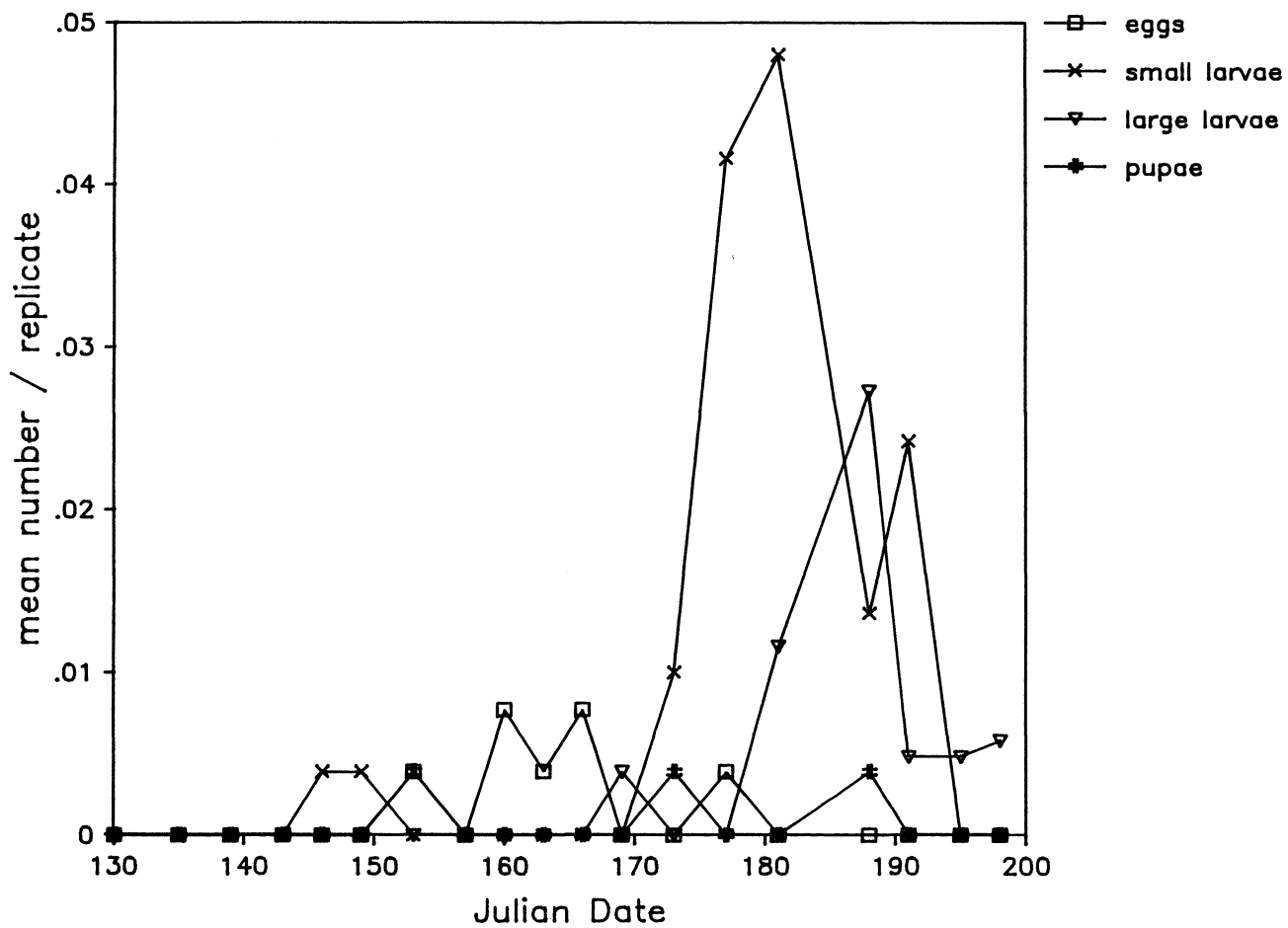


Figure 13. Seasonal abundance of CL (Spring 1987)

Table 23. Abundance of CL on broccoli varieties (Spring 1987)

| Immature CL abundance by Julian Date |      |       |           |       |           |       |       |       |
|--------------------------------------|------|-------|-----------|-------|-----------|-------|-------|-------|
| Variety                              | 166  |       | 181       |       | 188       |       | 188   |       |
|                                      | Eggs |       | S. larvae |       | L. larvae |       | Pupae |       |
|                                      | N    | Mean  | N         | Mean  | N         | Mean  | N     | Mean  |
| Emperor                              | 6    | 0.06a | 6         | 0.02a | 6         | 0.00a | 6     | 0.00a |
| G Def                                | 6    | 0.04a | 6         | 0.00a | 6         | 0.05a | 6     | 0.00a |
| G Val                                | 6    | 0.04a | 6         | 0.05a | 6         | 0.00a | 6     | 0.00a |
| Packman                              | 6    | 0.09a | 6         | 0.07a | 6         | 0.12a | 6     | 0.00a |
| Paragon                              | 6    | 0.08a | 6         | 0.05a | 6         | 0.00a | 6     | 0.02a |
| S Comet                              | 6    | 0.15a | 6         | 0.10a | 6         | 0.00a | 6     | 0.00a |

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

G Def = Green Defender; G Val = Green Valiant; S Comet = Southern Comet.

Numbers are back-transformed from  $\log(x + 1)$ .

Table 24. Total of all insects counted on each variety by season

| Variety        | Total insects |               |              |
|----------------|---------------|---------------|--------------|
|                | Spring 86     | Fall 86       | Spring 87    |
|                | Mean (SE)     | Mean (SE)     | Mean (SE)    |
| Emperor        | 18.50 (.35)b  | 14.85 (.11)c  | 25.92 (.14)b |
| Green Defender | 50.29 (.10)a  | 50.29 (.09)a  | 46.86 (.13)a |
| Green Valiant  | 26.54 (.18)bc | 21.39 (.07)b  | 27.18 (.13)b |
| Packman        | 11.88 (.12)c  | 15.22 (.10)c  | 27.84 (.07)b |
| Paragon        | 14.14 (.24)c  | 17.62 (.15)bc | 27.84 (.17)b |
| Southern Comet | 11.59 (.24)c  | 13.79 (.10)c  | 32.11 (.09)b |

Total insects = the sum of egg, small larva, large larva and pupa of ICW and CL and small larva, large larva and pupa of DBM through the season.

Means within columns followed by the same letter are not significantly different using DMRT (P=0.05,SAS 1985).

Numbers are back-transformed from  $\log(x + 1)$ .

Table 25. Harvest date and head contamination of six broccoli varieties (Spring 1986)

| Variety        | Harvest date* |          | Total ICW |         | Total CL |         | Total DBM |         |
|----------------|---------------|----------|-----------|---------|----------|---------|-----------|---------|
|                | Mean          | (SE)     | Mean      | (SE)    | Mean     | (SE)    | Mean      | (SE)    |
| Green Defender | 191.7         | (0.69)a  | 0.61      | (0.06)a | 0.03     | (0.02)a | 0.00      | (0.00)a |
| Southern Comet | 173.0         | (1.69)cd | 0.28      | (0.07)b | 0.00     | (0.00)b | 0.02      | (0.02)a |
| Green Valiant  | 180.3         | (1.40)b  | 0.95      | (0.08)a | 0.00     | (0.00)b | 0.01      | (0.01)a |
| Packman        | 171.6         | (1.26)d  | 0.25      | (0.12)b | 0.00     | (0.00)b | 0.01      | (0.01)a |
| Paragon        | 172.6         | (1.06)d  | 0.30      | (0.06)b | 0.00     | (0.00)b | 0.00      | (0.00)a |
| Emperor        | 176.6         | (1.51)bc | 0.73      | (0.07)a | 0.00     | (0.00)b | 0.00      | (0.00)a |

N=6.

\* Julian days.

Total refers to the egg, small larva, large larva and pupa of ICW and CL; and small larva, large larva and pupa of DBM.

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

Insect numbers are back-transformed from  $\log(X + 1)$ .

high. CL and diamondback moth counts were so low that discussion is not warranted.

In the Fall growing season, the longer season varieties, Green Defender and Green Valiant, had more ICW than the shorter season varieties, Southern Comet, Packman and Emperor (Table 26). Southern Comet, Packman and Emperor were harvested before the small larvae had a high count. Paragon had an intermediate number of ICW in the head - its harvest date was one day after the small larval count peaked. CL and DBM numbers were low and are not discussed.

In the Spring 1987 planting, the last large larval ICW count peak occurred on Julian date 177. In this case, the shorter season varieties, Packman and Southern Comet, were harvested closest to the large larval count peak (Table 27) and had the most head contamination. Paragon, Emperor, and Green Valiant had less ICW. Normally, the shorter season varieties would have been harvested earlier in the season, thus avoiding the larval peaks, but drought like conditions caused by the formation of a crust, stressed the plants delaying growth and harvest.

It is my recommendation that shorter season (least days to maturity) varieties should be planted in the Spring season, thus avoiding insects and the higher temperatures of the summer. Those varieties planted in the Fall should be timed to avoid insect infestations using the short season varieties. By using models driven by temperature, light, and humidity,

Table 26. Harvest date and head contamination of six broccoli varieties (Fall 1986)

| Variety        | Harvest date* |         | Total ICW |          | Total CL |         | Total DBM |         |
|----------------|---------------|---------|-----------|----------|----------|---------|-----------|---------|
|                | Mean          | (SE)    | Mean      | (SE)     | Mean     | (SE)    | Mean      | (SE)    |
| Southern Comet | 286.6         | (3.00)c | 0.60      | (0.08)c  | 0.00     | (0.00)a | 0.00      | (0.00)b |
| Paragon        | 288.4         | (2.83)c | 1.01      | (0.13)bc | 0.01     | (0.01)a | 0.00      | (0.00)b |
| Packman        | 282.6         | (1.75)c | 0.64      | (0.11)c  | 0.00     | (0.00)a | 0.01      | (0.01)b |
| Emperor        | 284.4         | (1.69)c | 0.47      | (0.09)c  | 0.03     | (0.03)a | 0.00      | (0.00)b |
| Green Valiant  | 297.7         | (1.98)b | 1.42      | (0.12)ab | 0.00     | (0.00)a | 0.05      | (0.02)a |
| Green Defender | 304.8         | (1.30)a | 2.19      | (0.16)a  | 0.00     | (0.00)a | 0.01      | (0.01)b |

N=6.

\* Julian days

Total refers to the egg, small larva, large larva and pupa of ICW and CL; and small larva, large larva and pupa of DBM.

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

Insect numbers are back-transformed from  $\log(X + 1)$ .

Table 27. Harvest date and head contamination of six broccoli varieties (Spring 1987)

| Variety        | Harvest date* |         | Total ICW |          | Total CL |          | Total DBM |         |
|----------------|---------------|---------|-----------|----------|----------|----------|-----------|---------|
|                | Mean          | (SE)    | Mean      | (SE)     | Mean     | (SE)     | Mean      | (SE)    |
| Emperor        | 193.4         | (1.26)b | 0.42      | (0.06)b  | 0.04     | (0.04)ab | 0.08      | (0.04)a |
| Green Defender | -----         |         | -----     |          | -----    |          | -----     |         |
| Green Valiant  | 200.3         | (1.18)a | 0.37      | (0.09)b  | 0.00     | (0.00)b  | 0.07      | (0.07)a |
| Packman        | 187.9         | (0.49)c | 0.60      | (0.10)ab | 0.07     | (0.03)a  | 0.05      | (0.02)a |
| Paragon        | 193.8         | (1.67)b | 0.32      | (0.07)b  | 0.00     | (0.00)b  | 0.09      | (0.02)a |
| Southern Comet | 190.1         | (0.73)c | 0.90      | (0.04)a  | 0.00     | (0.00)b  | 0.12      | (0.03)a |

Green Defender was not harvested due to slow growth.

N=6.

\* Julian days.

Total refers to the egg, small larva, large larva and pupae of ICW and CL; and small larva, large larva and pupa of DBM.

Means followed by the same letter are not significantly different (DMRT  $P=0.05$  (SAS 1985)).

Insect numbers are back-transformed from  $\log(X + 1)$ .

insect count peaks can be predicted from previous seasons. Since degree days to harvest is known for each variety, these shorter season varieties can be planted to avoid peak larval count. Shorter season varieties should also be recommended because they are exposed to the fluctuations in the environment and its unpredicted variability (drought and killing frosts) less than the late maturing varieties.

## CHAPTER 6

DEVELOPMENT, CONSUMPTION, AND OVIPOSITION BY  
PIERIS RAPAE (L.) (LEPIDOPTERA: PIERIDAE)  
ON BROCCOLI VARIETIES IN THE LABORATORY

## INTRODUCTION

While broccoli varieties have been tested for their horticultural qualities (O'Dell 1985 and Hill 1987), no one has specifically tested them for their susceptibility to insects. Field observations by the author indicated that Green Defender, a long season variety, was preferred by the imported cabbageworm (ICW), Pieris rapae (L.). The shorter season varieties, Packman, Southern Comet and Emperor (all commercially grown in Southside Virginia) had low to intermediate numbers of P. rapae. In order to determine if this lower number of P. rapae was due to mortality or interference in development, the rate of development, pupal weight and relative fecundity of P. rapae on these four broccoli varieties were compared in the laboratory. Also, the same six varieties that were grown in the field were used to determine if ovipositional preferences were (1) similar to field results and (2) influenced by the variety on which the insects were reared on.

## MATERIALS AND METHODS

### Development

Egg sheets were collected from an existing ICW colony at VPI and SU and held at 10° C until needed. Four pieces of egg sheet, each containing 20 - 30 eggs, were put on a leaf in a container containing one of the four broccoli varieties Emperor, Green Defender, Packman, and Southern Comet. Eggs were observed for hatch in a growth chamber (27° C, 16L:8D) between 2000 and 2200. Upon hatching, 20 first instar larvae were put on a leaf of each variety in a separate container. This was repeated three times. Observations were made daily between 2000 and 2200. Leaves were changed as necessary (approximately every three days). When larvae reached the third instar, containers were prepared to measure leaf consumption.

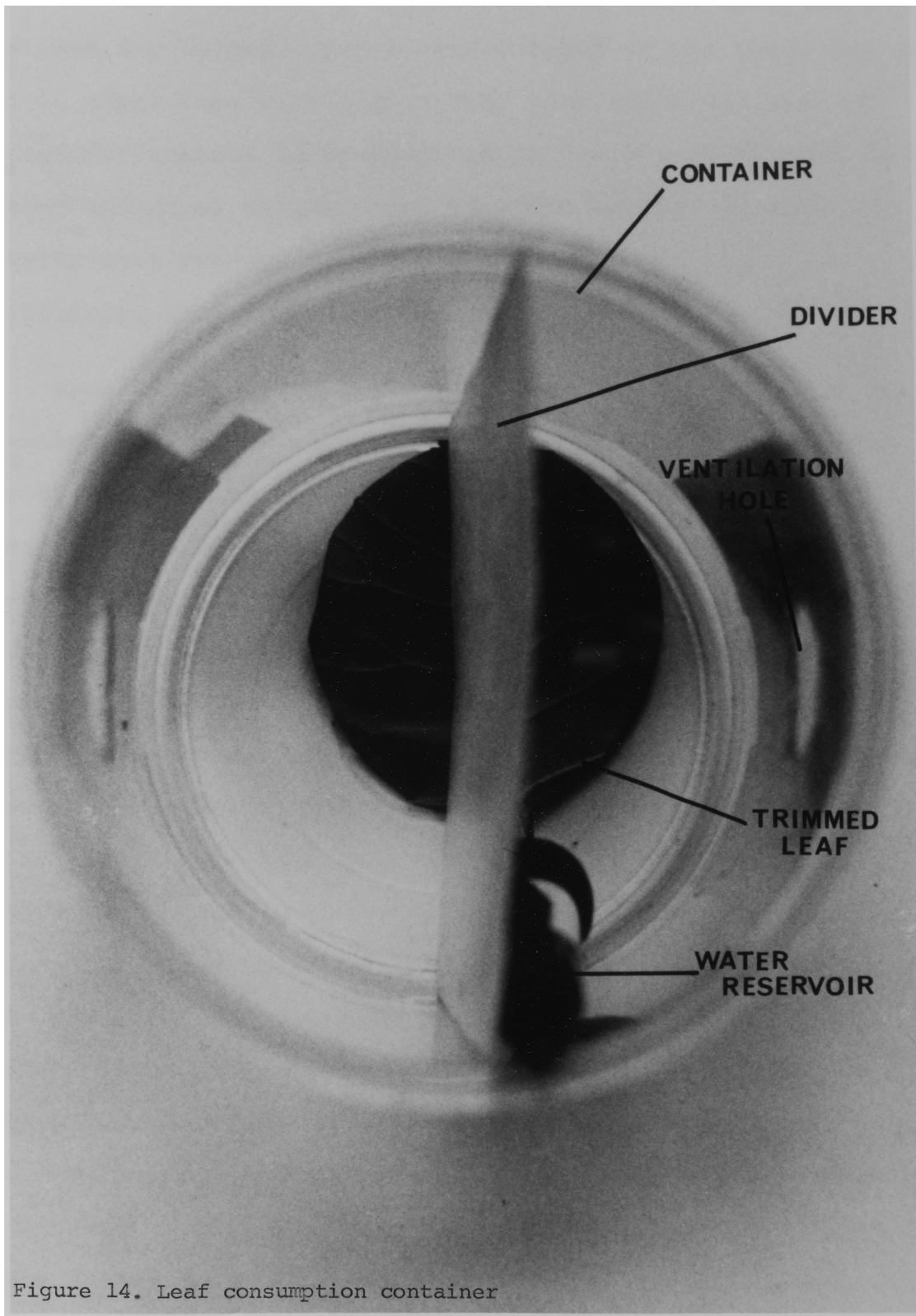
### Consumption

A plastic container (11 cm deep, and 12 cm and 9.6 cm diameter of top and bottom, respectively) with two ventilation holes (2.4 cm diameter) covered with organdy was used. Leaves were trimmed to an equal area on both the left and right side of the midrib by placing a template over the midrib and trimming any excess leaf. The trimmed leaf was placed on the bottom of the container and a divider was placed over the leaf

separating the right side from the left (Figure 14). Upon reaching the fourth instar, five larvae were placed on the underside of the right leaf. Larval growth was monitored as before. Duncan's multiple range test (SAS 1985) was used to determine differences in immature developmental time of the ICW reared on the test varieties.

Leaves, which were collected from the middle third of the field grown plant, were changed as consumed. Leaves were obtained from field grown plants because I felt the cuticle, as well as other plant characteristics, of greenhouse grown plants was different from field grown plants. Also, Dickson and Eckenrode (1975) found that varietal preference tests performed on greenhouse grown plants yielded different results from the same tests performed on field grown plants. Test leaves were selected from the middle third of the plant because younger leaves (top third) were not large enough and the older leaves (lower third) were senescing.

At leaf change, plant consumption was determined. Upon removal, the left and right side (if any remained) were cut from the midrib, placed in an aluminum dish and heated at 120°C in a drying oven for 48 hours. Preliminary work had indicated a minimal change in dry weight after 48 hrs. Also, no significant difference from zero was found using a paired t-test on the difference of left and right sides of the leaf (before any feeding) when leaves were dried for 48 hrs at 120°C ( $\alpha = 0.05$ ,  $N=100$ ) (Zar 1984). Dry weight (g)



consumed was computed by subtracting the right dry weight from the left dry weight. Pupae were weighed on the third day and put in paper cups with lids. DMRT (SAS 1985) was used to detect differences in consumption of the fourth through fifth instar and pupal weight based upon the variety on which the insects were reared.

#### Oviposition Preferences

Upon eclosion, adults were sexed and maintained in the greenhouse in cages with the same variety the insects were reared on. Adults were fed a 10% sugar solution in yellow sponges contained in an aluminum dish. Three to five days post eclosion, females were removed and placed in oviposition cages. Each oviposition cage contained ten females and one broccoli plant of each of the varieties - Emperor, Green Defender, Green Valiant, Packman, Paragon, and Southern Comet. Plants were rotated clockwise to a new position in the cage daily. Eggs per plant were counted every other day. However, ants were discovered in the cages after day 3 of the experiment after they had carried some of the larvae away. (The day 5 count would have included the sum of eggs and larvae since the larvae hatch around day 3). All ants were killed and removed from the cages. Aluminum pie pans beneath the cage supports were checked for adequate water more often to prevent reentry by the ants. New plants were put into the cages on day 8 and 11. The number of eggs/plant counted three

days after exposure to the adults was used to indicate if larval host influenced oviposition.

## RESULTS

The days from hatch through pupae were analyzed using DMRT (Table 28). Days to reach pupae, that is the days until the fifth instar molted, were not affected by the variety on which the larvae were reared. However, larvae reared on Packman developed significantly faster to the third instar than those reared on Emperor, and development to the fifth instar was faster on Packman than on the three other varieties. Since Packman is an early maturing variety, it is possible that more nutrients are present in the leaf at a given time than in the other varieties, allowing the larvae to develop faster. I thought P. rapae development might have been slower on Green Defender since the plant grew slower in the field than the other varieties - but this was not the case. P. rapae feeding on Green Defender developed about the same rate as on Emperor and Southern Comet. Green Defender may have more of a constant supply of nutrients, with less turnover of nutrients because growth would be slower and lower leaves would be senescing slower.

Survival rate was not computed because death of the later instars was due mostly to handling. Several larvae were caught under the broccoli leaf and when the lid was closed, the pressure of the barrier on the leaf was so great, it

Table 28. Development (days) for P. rapae according to broccoli variety reared on

| Cumulative days to reach instar |          |      |          |       |          |      |          |      |          |       |       |       |
|---------------------------------|----------|------|----------|-------|----------|------|----------|------|----------|-------|-------|-------|
| Variety                         | Instar 2 |      | Instar 3 |       | Instar 4 |      | Instar 5 |      | Prepupae |       | Pupae |       |
|                                 | N        | Mean | N        | Mean  | N        | Mean | N        | Mean | N        | Mean  | N     | Mean  |
| Emperor                         | 3        | 3.9a | 3        | 5.8a  | 3        | 7.5a | 12       | 9.4a | 12       | 12.0a | 12    | 13.0a |
| S Comet                         | 3        | 3.9a | 3        | 5.7ab | 3        | 7.5a | 11       | 9.6a | 11       | 12.0a | 11    | 13.0a |
| G Def                           | 3        | 3.8a | 3        | 5.6ab | 3        | 7.5a | 12       | 9.4a | 12       | 11.9a | 12    | 12.9a |
| Packman                         | 3        | 3.8a | 3        | 5.3b  | 3        | 7.0a | 11       | 8.8b | 12       | 11.6a | 12    | 12.5a |

S Comet = Southern Comet, G Def = Green Defender.

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

actually killed the larvae. Also, when one dead larva was discovered in one container with Southern Comet broccoli, the entire contents of the container was discarded to prevent spread of suspected disease.

No statistical difference in grams (dry weight) consumed was detected among any of the varieties (Table 29), irrespective of the length of time for P. rapae to develop. Although not significant, more Southern Comet was consumed than the other varieties. Pupae of larvae reared on Southern Comet weighed significantly more than those reared on Packman (Table 29).

When eggs/female were totalled per day 3 of plant introduction, a greater percentage of eggs appeared to be laid per P. rapae female reared on Southern Comet than those laid by females reared on Green Defender (Table 29). Although Green Defender seemed to be the variety preferred for oviposition by P. rapae in the field, Green Defender did not appear to be the preferred variety in the greenhouse when oviposition was compared between varieties. Only P. rapae females reared on Emperor seemed to have any varietal preferences (Table 30); all females reared on the other varieties did not appear to oviposit preferentially on any variety. For females reared on Emperor, a greater percentage of eggs was appeared to be laid on Emperor and Paragon than on Green Defender and Packman. The lack of preference for Green

Table 29. Leaf matter consumption of four broccoli varieties by fourth through fifth instar P. rapae larvae; pupal weight and % eggs/female/day 3 of plant introduction

| Variety<br>reared on | Broccoli leaf consumed |                       |         | Pupal weight |       |           | % eggs/female* |        |
|----------------------|------------------------|-----------------------|---------|--------------|-------|-----------|----------------|--------|
|                      | N                      | Mean<br>dryweight (g) | (SE)    | N            | Mean  | (SE)      | N              | Mean   |
| Southern Comet       | 11                     | 0.15                  | (0.03)a | 11           | 0.156 | (0.003)a  | 3              | 36.13  |
| Green Defender       | 12                     | 0.14                  | (0.01)a | 12           | 0.150 | (0.003)ab | 3              | 14.60  |
| Packman              | 12                     | 0.12                  | (0.01)a | 12           | 0.146 | (0.004)b  | 3              | 21.40  |
| Emperor              | 12                     | 0.12                  | (0.01)a | 12           | 0.153 | (0.003)ab | 3              | 27.87b |

Means followed by the same letter are not significantly different (DMRT P=0.05 (SAS 1985)).

\* Data presented in original form - not analyzed.

Table 30. Three day mean % eggs per P. rapae female laid on each variety

| Broccoli variety   |           |            |         |         |
|--------------------|-----------|------------|---------|---------|
| Eggs Oviposited on | Reared on |            |         |         |
|                    | Emperor   | G Defender | Packman | S Comet |
| Emperor            | 27.5      | 27.6       | 25.8    | 18.6    |
| G Defender         | 10.8      | 10.8       | 12.2    | 19.6    |
| G Valiant          | 15.9      | 22.1       | 22.9    | 17.0    |
| Packman            | 9.0       | 9.7        | 11.6    | 12.6    |
| Paragon            | 21.5      | 9.5        | 24.5    | 16.6    |
| S Comet            | 15.2      | 20.3       | 14.0    | 15.8    |

Data presented in original form - not analyzed; N=3.

G Defender = Green Defender; G Valiant = Green Valiant; S Comet = Southern Comet.

Each column represents a separate cage.

Defender is opposite to what the field data suggest.

Plausible explanations are:

1) greenhouse studies, even with field grown plants, do not reflect varietal ovipositional preference in the field, or

2) plants taken from the field might not have been injured to the same degree. For example, plants such as Green Defender might have been injured more than Emperor, causing a deterrent effect of Green Defender on P. rapae.

I do not feel that variety used for rearing the insects influenced ovipositional choice. Even though those females reared on Emperor seemed to prefer Emperor, the % eggs laid on Paragon did not seem different from those laid on Emperor. Also those females reared on Emperor were the only females to seem to show a preference. If varietal influence was important, this should also be true of the females reared on all the varieties. Hovanitz and Chang (1962, 1963a) showed an induced larval preference. Tests of P. rapae reared on different species of plants showed some ovipositional preference for plants previously reared upon (Hovanitz and Chang 1963b). However, this was not seen with our study of P. rapae with broccoli varieties. Perhaps differences in the varieties did not differ (chemically or physically) as much as the plants used by Hovanitz and Chang (1963b).

## SUMMARY

Results of the 1986 Broccoli Growers Survey indicated an average of 6.2 acres per farm grown with Green Valiant (87.5% of respondents), Packman and Emperor (62.5% of respondents). Less than 5% of this land was previously in tobacco production. Although only 25% of the growers found 2 to 5 worms per plant before heading (75% found less), 2.4 insecticide applications were applied averaging \$20.51/acre. During heading, 2.4 insecticide applications cost \$19.40/acre.

Means of 8.4 (Spring) and 12.1 (Fall) cabbage looper larvae/plant did not significantly reduce yield (head weight) in 1986. Under stressed conditions, means of 7.4 and 11.1 cabbage looper larvae/plant (Spring 1987) significantly reduced head weight. Harvest date was not delayed or shortened by any of the cabbage looper levels mentioned above. Since growers reported the highest level of 2 to 5 larvae/plant and levels of 7.4 cabbage loopers under stressed conditions were necessary to reduce yield, growers could have saved 2.4 insecticide sprays at \$20.51/acre before heading.

Artificially defoliated Packman broccoli caused a reduction in yield at 50% or higher defoliation in the Fall 1986 growing season. Harvest date was significantly delayed

at 100% defoliation. In Spring 1987, under stressed conditions, a stimulation in yield was recorded at 25% defoliation (between 25 and 50% insect defoliation reduced yield in the Spring 1987 yield reduction plot) and 75% defoliation significantly reduced yield. No delay in harvest date was experienced in the stressed Spring 1987 planting.

The imported cabbageworm was the most abundant pest on broccoli grown in Montgomery Co., Virginia. Total insect (egg, small and large larvae, and pupae of the imported cabbageworm and the cabbage looper; and small and large larvae, and pupae of the diamondback moth) counts summed through each of three seasons indicated Green Defender was a preferred variety. Green Defender was originally considered for commercial broccoli production to replace Green Valiant because of its smaller stem width. However, Green Defender did not pack well with other varieties due to its green coloration and was not used. Packman and Southern Comet, both commercially grown varieties, had the lowest total insect counts summed through each season. Those varieties harvested before insect (mainly imported cabbageworm) larval counts were high had less head contamination. This generally applied to the shorter season varieties. Future management strategies could use models based on temperature, humidity and photoperiod to predict population peaks of insects and harvest dates of the varieties so head contamination could be reduced by timing the varieties to be harvested before (or after)

insect populations peaked. Short season varieties are now recommended (O'Dell and Ramsey 1987), especially in the Spring.

Laboratory studies of Pieris rapae development, consumption and oviposition on broccoli varieties was performed to identify reasons why Southern Comet, Packman, and Emperor had usually lower insect counts than Green Defender. Larvae developed faster on Packman based on days to reach the fifth instar. Broccoli consumption (grams dry weight) did not differ significantly among any of the varieties, although larvae reared on Southern Comet appeared to feed more than larvae reared on the other varieties. P. rapae reared on Southern Comet weighed more than those reared on Packman. Also P. rapae females reared on Southern Comet appeared to lay more eggs/female per day than those reared on Green Defender. Larval host variety did not consistently influence ovipositional choice. Unfortunately, due to handling, the percent survival could not be calculated. Southern Comet, although not preferred by P. rapae for oviposition, appears to be the best host among the four broccoli varieties tested for P. rapae. Packman and Emperor (although Emperor is preferred by the diamondback moth) are excellent choices for commercial broccoli production because they are not preferred by P. rapae for oviposition.

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## APPENDIX



## VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

*Blacksburg, Virginia 24061 USA*

DEPARTMENT OF ENTOMOLOGY

Dear Broccoli Grower:

As a first step in developing a control program for insect pests of broccoli in Virginia, I am compiling information on current practices. This information will be very useful in comparing current procedures with future pest management strategies. It is necessary that you fill out the questionnaire accurately for maximum benefit. Please check your records if you are unsure about an answer.

I have attached a separate sheet for you to leave your name and address if you are interested in cooperating in pest management research. This sheet will be detached before the survey is read, so your answers will remain confidential. This questionnaire will probably take about 30 minutes to complete. It is vital that we have returns from the majority of growers, so please fill out the questionnaire, put it in the return envelope, and drop it in the mail by March 21, 1987.

I would like to thank you and encourage you to call if you have any questions. I can be reached at 1-703-961-7963 or you can leave a message at 1-703-961-6341 and I'll return your call.

Thank you for your cooperation,

Karen M. Vail  
Dept. Entomology  
Virginia Polytechnic Institute  
and State University

## 1986 BROCCOLI GROWERS SURVEY

This survey focuses on the broccoli you grew in the Fall 1986 season. For each item, please circle the number of the appropriate answer or fill-in the blank.

## CROP INFORMATION

1. Please list the broccoli varieties and the number of acres you grew during the 1986 Fall Season. variety(acres)
1. \_\_\_\_\_ ( )      3. \_\_\_\_\_ ( )  
2. \_\_\_\_\_ ( )      4. \_\_\_\_\_ ( )
2. What type of spacing was used to grow the broccoli?  
1. single-row      3. triple-row      5. other, \_\_\_\_\_  
2. double-row      4. 4-row
3. Please list crops grown in your broccoli field just prior to the Fall 1986 planting. If no crops were grown, write none.  
1. \_\_\_\_\_      3. \_\_\_\_\_  
2. \_\_\_\_\_      4. \_\_\_\_\_
4. Please list all crops and the number of acres that you grew, other than broccoli, during 1986.  
1. \_\_\_\_\_ ( )      3. \_\_\_\_\_ ( )      5. \_\_\_\_\_ ( )  
2. \_\_\_\_\_ ( )      4. \_\_\_\_\_ ( )      6. \_\_\_\_\_ ( )
5. Was any of your Fall 1986 broccoli planted on land that you had previously used for tobacco?  
1. yes      2. no
- 5a. If yes, how many acres of land previously used to grow tobacco were used for broccoli production in Fall 1986?  
\_\_\_\_\_
6. What percentage of tobacco land have you converted to broccoli production in Fall 1986?  
1. 0 to 5 %      3. 11 to 15 %      5. more than 20 %  
2. 6 to 10 %      4. 16 to 20 %

## PEST PROBLEMS BEFORE HEADING

7. Were worms feeding on the broccoli plant BEFORE heading in Fall 1986? ("worms" refers to the larvae of insects such as the cabbage looper, imported cabbage worm, diamondback moth and others)  
1. yes      2. no      3. don't know
8. How many worms were feeding on each plant BEFORE heading?  
1. 0      3. 2 to 5      5. more than 10  
2. 1      4. 6 to 10      6. don't know

9. Were insecticides applied for worms BEFORE heading in Fall 1986?  
1.yes 2. no
- 9a. If yes, how often were insecticides applied BEFORE heading?  
1. lessthan every 7 days 4. more than 14 day intervals  
2. 7 to 10 day intervals 5. infrequently  
3. 10 to 14 day intervals
10. How many total insecticide sprays were applied for worms BEFORE heading in Fall 1986? \_\_\_\_\_
11. How much did you spend per acre on insecticide applications BEFORE heading in Fall 1986? \$ \_\_\_\_\_

## PEST PROBLEMS DURING HEADING

12. Were worms feeding on the broccoli plant DURING heading in Fall 1986?
  1. yes
  2. no
13. How many worms were feeding on each plant DURING heading?
  1. 0
  2. 1
  3. 2 to 5
  4. 6 to 10
  5. more than 10
  6. don't know
14. Were insecticides applied for worms DURING heading in Fall 1986?
  1. yes
  2. no
  - 14a. If yes, how often were insecticides applied DURING heading?
    1. less than every 7 days
    2. 7 to 10 day intervals
    3. 14 day intervals
    4. more than 14 day intervals
    5. infrequently
15. How many total insecticide sprays were applied for worms DURING heading in Fall 1986? \_\_\_\_\_
16. How much did you spend per acre on insecticide applications DURING heading in Fall 1986? \$ \_\_\_\_\_

## SUMMARY OF EXPENSES

17. Please rank the following expenses from the highest expense (1) to the lowest expense (8) /acre and indicate the dollars spent/acre in 1986:

|                                         | Ranking | \$ spent |
|-----------------------------------------|---------|----------|
| 1. seeds and seeding                    | _____   | _____    |
| 2. fertilizer and lime                  | _____   | _____    |
| 3. herbicide and application            | _____   | _____    |
| 4. insecticide and application          | _____   | _____    |
| 5. fungicide and application            | _____   | _____    |
| 6. Machinery and repairs<br>and rentals | _____   | _____    |
| 7. Marketing costs                      | _____   | _____    |
| 8. Other                                | _____   | _____    |

## HARVEST INFORMATION

18. What was your average harvest of broccoli for Fall 1986?
- |                             |                             |
|-----------------------------|-----------------------------|
| 1. less than 300 boxes/acre | 3. 351 to 400 boxes/acre    |
| 2. 300 to 350 boxes/acre    | 4. more than 400 boxes/acre |
19. If you had a box rejected for sale, was it because:
- |                             |                          |
|-----------------------------|--------------------------|
| 1. worms were in the head   | 4. head rot              |
| 2. aphids were in the head  | 5. other, specify: _____ |
| 3. the heads were too small |                          |

## PEST CONTROL CONSIDERATIONS

20. How important do you think worm control is in broccoli production?
- |                   |                         |
|-------------------|-------------------------|
| 1. very important | 3. not very important   |
| 2. important      | 4. not important at all |
21. Would you be interested in a scouting program where people would check your fields for pests and make control recommendations?
- |        |       |               |
|--------|-------|---------------|
| 1. yes | 2. no | 3. don't know |
|--------|-------|---------------|
22. Would you fund the operating costs for such a scouting program?
- |        |       |
|--------|-------|
| 1. yes | 2. no |
|--------|-------|
23. How much would you pay for such a scouting program on a seasonal basis? \_\_\_\_\_
24. Please list the town and county where your broccoli was grown.
- |              |              |
|--------------|--------------|
| town _____   | town _____   |
| county _____ | county _____ |

25. If a broccoli pest management project was developed to test pest resistant varieties, to determine when and if pesticides should be applied, etc., would you be interested in cooperating?
1. yes                      2. no
26. If yes, leave name, address and phone number where you can be contacted: (Remember this page will be detached before the survey is read so that your answers will remain confidential)

NAME \_\_\_\_\_  
ADDRESS \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
PHONE \_\_\_\_\_

Your cooperation is greatly appreciated.

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the scanned document**