Effects of Cabbage Looper,[1] Imported Cabbageworm,[2] and Diamondback Moth[3] on Fresh Market and Processing Cabbage[4]

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ABSTRACT

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Action thresholds for lepidopterans on fresh market cabbage in New York are proposed. These are based on foliage consumption rates of the cabbage looper, *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), imported cabbageworm, *Pieris rapae* (L.) (Lepidoptera: Pieridae), and diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), incorporated with actual larval counts of these pests. Once head formation is initiated, cabbage can tolerate ca. 0.5 cabbage looper equivalents per plant before head damage occurs. Larval populations can be permitted to build before head formation, without a loss in weight or marketability, provided they are treated with an effective insecticide at head initiation and treated thereafter at a low threshold. Head weight, rather than cosmetic appearance, is more valid criterion for processing cabbage but was not accurately predicted by larval counts.

Over one-quarter of New York's 5,020 ha of cabbage is processed for sauerkraut, and the majority of this, as well as over 80% of the fresh market cabbage in the state, is grown in upstate New York (Anonymous 1979).

Several thresholds for lepidopterans on fresh market cabbage have been suggested. Greene (1972) proposed an action threshold of 0.1 cabbage looper larva per plant to obtain 100% marketable cabbage, whereas Chalfant et al. (1979) proposed a visual damage threshold of one to two new holes per plant and Workman et al. (1980) proposed one to two windows (initial feeding sites) per plant to obtain an acceptable level of fresh market cabbage. All these studies were conducted in southern states where pressure from lepidopterans tends to be more severe than in the North. Their thresholds for fresh market standards, where cosmetic injury is of prime importance, may be unrealistic for our area. Additionally, there are no reported threshold studies investigating processing cabbage in which weight of usable cabbage is a more valid criterion.

Growers who base treatment decisions on total larval counts may be misled because the main lepidopterous pests on cabbage, namely, the diamondback moth, *Plutella xylostella* (L.), imported cabbageworm, *Pieris rapae* (L.), and cabbage looper, *Trichoplusia ni* (Hübner), consume vastly different amounts of foliage. Thus, a total insect population may be high but not a threat to the crop because it is composed mostly of a species which consumes little foliage. Additionally, separate thresholds for each species do not take into consideration the occurrence of multiple subthreshold populations which, when combined together, are injurious. Likewise, action thresholds based on visual damage ratings may be inappropriate in some cases because some of the crop may already be lost. Larval counts provide a grower with lead time and help eliminate the loss in marketability.

[1]Lepidoptera: Noctuidae.
[2]Lepidoptera: Pieridae.
[3]Lepidoptera: Yponomeutidae.
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We propose the use of larval counts, combined with the species' foliage consumption rate, of the major lepidopterous pests of cabbage for treatment considerations for fresh market and processing cabbage in upstate New York.

Materials and Methods

Experiments were conducted in 1979 and 1980 on the Robbins Vegetable Research Farm near Geneva, N.Y., where caggabe, cv. 'Roundup,' was transplanted 12 to 13 July 1979 and 7 to 9 July 1980. In 1979 and 1980, plots were composed of four 15-m rows and four 7.5-m rows, respectively. Rows were spaced 0.9 m apart, with plant spacing of 41 cm. Plots were bordered by two rows of corn with 4.6-m alleyways between replicates. Twenty-five action threshold levels were replicated four times in a randomized complete block design. The treatment levels ($\bar{x}$ larvae per plant, regardless of insect species) before head formation (30 August 1979 and 3 September 1980) were: 0 to 0.4; 0.5 to 0.9; 1.0 to 1.9; 2.0 to 3.0; and untreated control. Once head formation was initiated, as evidenced by a ca. 7-cm-diameter firm leaf ball, the same five treatment levels were used in combination with each preheading level (an all-paired combination with 25 possible thresholds), except heading treatment levels were based on $\bar{x}$ cabbage looper equivalents (CLE) per plant rather than $\bar{x}$ larvae per plant. CLE standardizes insect damage by weighting each insect species by foliage consumption, i.e., 1 CLE = 20 diamondback moth larvae (B) = 1.5 imported cabbageworm (ICW) = 1 cabbage looper (CL) (Harcourt 1954). The rationale for this methodology was twofold: (1) younger plants are more susceptible to damage from feeding on their few frame leaves as well as their apical meristem, and the two pests present at this time (DB and ICW) both do similar feeding damage and are therefore a threat to delaying growth or aborting the developing cabbage head; and (2) once head formation has begun, the damage caused by any of these pests should be based on consumption of photosynthetic material, and each species consumes vastly different amounts of foliage.

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Plots were evaluated for larval population on a weekly basis, from 1 week after transplanting until harvest, by counting all larvae on 10 to 20 randomly selected plants per plot. When thresholds (based on the average of all four replications) were exceeded, permethrin (Ambush 2EC) was applied at 0.056 to 0.112 kg (AI)/ha by a tractor-mounted two-row sprayer (three nozzles per row) delivering 279 liters per ha at a pressure of 3.46 kg/cm^2.

Quality for Fresh Market

Plants were evaluated for insect damage at harvest (8 to 12 November 1979, and 28 to 31 October 1980). Damage was based on two scales: whole-plant scale of 1 to 6 with ratings 1 to 3 being increasing frame leaf damage and ratings 4 to 6 being increasing head (including four wrapper leaves) damage, with any damage to the head or wrapper leaves automatically giving the plant a rating of 4 or above (Chalfant et al. 1979); and head damage rating scale of 1 (no damage) to 3 (severe damage). Data were analyzed by two methods: regression analyses which related actual larval counts (preheading) and CLE (heading) to damage ratings; and mean separation tests which compared action thresholds to percent marketable heads. Regression analyses were performed by using the $\bar{x}$ number of larvae per plant and $\bar{x}$ number of CLE per plant of the four replications for a particular week and then averaging these weekly counts. Averages of the four replications for head weights and damage ratings were used as the dependent variable. Mean separation tests were performed on arcsine transformed data of percent marketable cabbage.

Yield

At harvest, 10 heads (plus wrapper leaves) per plot were taken and weighed (fresh market weight). After taking this initial weight, the heads were trimmed of all green leaves and core material, and slash cuts were made to remove any remaining insect damage, as recommended for processed cabbage (Anonymous 1944). These trimmed heads were reweighed (processing weight). During 1980, evaluations were also made on the number of plants with aborted or multiple heads to determine any relationships to early larval counts.

Results

During 1979, mean larval populations before head formation varied from 0.3 (0 to 0.4 threshold) to 1.8 larvae per plant (untreated). It was impossible to maintain the lowest CLE threshold during the head formation period, with the lowest count being 0.6 CLE per plant (0 to 0.4 threshold). Untreated levels reached 3.8 CLE per plant. During 1980, insect pressures before head formation varied from 0.5 (0 to 0.4 threshold) to 1.6 larvae per plant (untreated). Again, it was impossible to maintain the lowest CLE threshold during the head formation period (0.6 CLE per plant for 0 to 0.4 threshold). Population pressure after head formation was more severe during 1980, with untreated populations reaching 6.9 CLE per plant. In 1979, species composition (%) for DB, ICW, and CL was 17.8, 71.7, and 10.5 before head formation, and 4.6, 21.4, and 74.0, respectively, thereafter. In 1980, species composition was 21.6, 74.9, and 3.5 before head formation, and 0.6, 7.4, and 92, respectively, thereafter.

Quality for Fresh Market

Mean damage ratings per treatment varied considerably when using an overall plant damage rating of 1 to 6 and ranged from no damage (1.0) to severe damage (5.4, 1979, and 5.5, 1980). Overall plant damage ratings were significantly correlated with early and late larval counts (r^2 = 0.91 and 0.88 in 1979 and 1980, respectively, with 23 df).

Head damage ratings (1 to 3) likewise varied from no damage (1.0) to severe (2.4 and 2.5 in 1979 and 1980, respectively). Because of the separation into preheading and heading thresholds, some treatments had extensive frame leaf damage but no head injury. Therefore, the scale of 1 to 3 (head damage rating only) was more appropriate for estimating the quality of cabbage for fresh market standards. In this rating system, damage was significantly (P = 0.05) correlated (r^2 = 0.75 and 0.89 in 1979 and 1980, respectively, with 23 df) to $\bar{x}$ CLE per plant. The regression equations were not significantly (P = 0.05) different between the 2 years and were combined to give a better estimator of P (Snedecor and Cochran 1967): damage rating = y = 0.851 + $0.212x_1$; r^2 = 0.87, where x_1 = $\bar{x}$ CLE/plant during head formation.

To obtain a damage rating of 1 (no damage), x_1 could not exceed 0.7 CLE. At the lowest threshold (0 to 0.4) during head formation, the earlier preheading threshold levels did not affect percent marketable heads. This suggests that larval populations can be allowed to build before head formation without any loss in marketability, provided they are treated with an effective insecticide at head formation and treated thereafter at a low threshold. At higher thresholds (0.5 to 1.9) during heading, there was a tendency for higher percent marketability where preheading threshold levels were low. Lower larval pressure in 1979 accounted for higher marketability than 1980, despite use of the same action threshold levels. However, a comparison between regression analyses of actual CLE per plant for both years and mean separation of thresholds (Table 1) corroborate each other and suggest a generalized threshold of ca. 0.5 CLE per plant during head formation to obtain ca. 95% uninjured cabbage.

Yield

Neither whole head weights (fresh market) nor trimmed head weights (processed) were significantly (P = 0.05) correlated with preheading or heading larval counts (r^2 = −0.05 and −0.07, respectively, in 1979, and 0.23 and 0.24, respectively, in 1980, with 23 df). Fresh market head weight over all treatments averaged 3.4 kg in 1979 and 3.6 kg in 1980. Trimming off damaged and green leaves and core material resulted in usable cabbage for processing of 77 and 76% of the original head

Table 1.—Cabbage injury resulting from different preheading and heading action thresholds, Geneva, N.Y., 1979–1980

Threshold		% Uninjured cabbage[c,d]	
Preheading[a]	Heading[b]	1979	1980
0.0–0.4	0.0–0.4	100a	100a
0.5–0.9	0.0–0.4	100a	97.5a
1.0–1.9	0.0–0.4	100a	97.5a
2.0–3.0	0.0–0.4	100a	95ab
Untreated	0.0–0.4	100a	97.5a
0.0–0.4	0.5–0.9	95b	90b
0.5–0.9	0.5–0.9	95b	82.5cd
1.0–1.9	0.5–0.9	92.5bc	82.5cd
2.0–3.0	0.5–0.9	90bcd	85d
Untreated	0.5–0.9	90cd	80cd
0.0–0.4	1.0–1.9	85cd	87.5bc
0.5–0.9	1.0–1.9	80cd	65e
1.0–1.9	1.0–1.9	77.5ef	77.5de
2.0–3.0	1.0–1.9	75ef	62.5e
Untreated	1.0–1.9	77.5ef	65e
0.0–0.4	2.0–3.0	75ef	60ef
0.5–0.9	2.0–3.0	72.5f	42.5fg
1.0–1.9	2.0–3.0	77.5ef	65e
2.0–3.0	2.0–3.0	55g	22.5h
Untreated	2.0–3.0	55g	42.5g
0.0–0.4	Untreated	45gh	0.0j
0.5–0.9	Untreated	45gh	0.0j
1.0–1.9	Untreated	30i	12.50hi
2.0–3.0	Untreated	47.5gh	10.00i
Untreated	Untreated	37.5hi	5.00ij

[a] $\bar{x}$ Number of larvae per plant.
[b] $\bar{x}$ Number of CLE per plant.
[c] No insect feeding on head plus four wrapper leaves.
[d] Column means with similar letteres are not significantly different at 5% level, by Duncan's multiple range test.

weights for 1979 and 1980, respectively. No difference in number of aborted or multiple heads were detected between treatments.

Discussion

These data on quality of fresh market cabbage indicate higher acceptable thresholds than those suggested previously by researchers in Florida and Georgia (Greene 1972, Chalfant et al. 1979, Workman et al. 1980). In upstate New York, because of our cooler temperatures and lower insect pressures, an action threshold of 0.5 CLE per plant should result in ca. 95% of the crop without any head injury. In practice and depending upon supply, some slightly damaged heads will be accepted for fresh market, so the percent marketable would even be higher than 95%. With less control due to a poorer insecticide or application method, a lower threshold would be required (Simonet and Morisak 1982). Eckenrode et al. (1981) compared the effectiveness of commercially used insecticides, and these data could be used to adjust thresholds depending upon their effectiveness compared with permethrin. In all cases, however, such thresholds must be used in conjunction with a weekly scouting plan so that pest populations do not get out of hand before control strategies are required.

Two factors should be noted. First, these recommended thresholds ignore age of larvae. The younger larvae, most importantly CL, are more susceptible to insecticides, and control strategies should be directed at them. This will also help eliminate head injury since young larvae tend to be on frame leaves and move toward the head during later instars. Second, head formation is a long process. Even though head formation is initiated, leaves which cover the developing head will unfold and become frame leaves until the head has nearly reached its final size. Injury to these early head leaves, which will later unfold, will not affect marketability. Therefore, an effective strategy is to suppress the larval population so that it is minimal at the time when no more head leaves unfold and the head is nearly mature.

Combining larval counts into CLEs during the heading period should avoid the potential for excessive insecticide usage. Since DB, for example, consume very little foliage compared to CL, treatment decisions should take this into account, and DB would rarely enter into treatment decisions based on CLEs during the heading period. However, ICW, which consumes more foliage and is present in significant numbers, can influence a treatment decision. Scouts could easily incorporate this system of weighting counts by carrying a hand-held calculator.

Although larval counts during heading are good indicators of subsequent fresh market grades, neither preheading nor heading larval counts in 1979 and 1980 were good predictors of yield based on weight alone. Other climatic and edaphic factors seem more important. Since weight, rather than appearance, is of primary concern in processed cabbage, treatment decisions should be evaluated carefully. With intense lepidopterous populations, some reduction in head weight can be expected but, under our normal insect pressures and good growing conditions, lepidopterous populations are not good predictors of yield. Furthermore, because cabbage heads must be trimmed of all green leaves to prevent discoloration of the sauerkraut (one of the major factors in reduction of grade [Promisel 1977]), and because most all lepidopteran feeding injury occurs on the green leaves which must be trimmed anyway (Shelton and Andaloro 1982), appearance of insect damage to these parts is not cost effective for implementing control measures.

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