Comparison of Action Thresholds for Lepidopterous Larvae on Fresh-Market Cabbage[1]

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ABSTRACT

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Five different action thresholds for control of lepidopterous larvae on fresh-market cabbage were compared in Wisconsin and New York, and in Ontario, Canada, in 1981. An average of the three locations revealed that a threshold of one or more new feeding sites per head (Florida threshold) required far less time to assess and received the fewest insecticide applications (1.3), but also allowed the most injury. All other thresholds received three to four applications and provided acceptable and similar levels of marketability. Thresholds based on (1) egg and larval counts of imported cabbageworm (ICW), *Pieris rapae* (L.), and cabbage looper (CL), *Trichoplusia ni* (Hubner), and (2) feeding injury by larvae of ICW, CL, and diamondback moth (DB), *Plutella xylostella* (L.), required nearly 2.4-fold the evaluation time of the Florida threshold. A threshold based on 50% of sampled plants infested with any larvae of the three species required 1.6-fold the assessment time of the Florida threshold. A fortnightly insecticide application, without regard to insect pressure, provided results similar to all other thresholds, except that of Florida.

Cabbage is an important vegetable crop in the Great Lakes region of North America. Recently, several action thresholds for this area have been suggested for control of the major lepidoptera: diamondback moth (DB), *Plutella xylostella* (L.); imported cabbageworm (ICW), *Pieris rapae* (L.); and cabbage looper (CL), *Trichoplusia ni* (Hübner). In Ohio, Morisak and Şimonet (1981) reported a threshold based on sampling for infested plants rather than for number of larvae per plant. In their study, a combination of *Bacillus thuringiensis* Berliner and methomyl provided higher marketability at a threshold of 20% infested plants than at a threshold of 0.2 large larvae per plant and required significantly less sampling time. These thresholds were invoked only during the heading stage, but neither gave satisfactory results during late-season plantings which were severely infested with CL. In Ontario, Canada, Sears et al. (1981) utilized a threshold based on combinations of eggs and small and large larvae of ICW and CL and demonstrated effective control by using suspensions of *P. rapae* GV, *Autographa californica* NPV, and *B. thuringiensis*. This type of threshold, based on x egg and larval counts per plant, enabled insecticide applications to begin soon after peak oviposition periods and, hence, before significant larval feeding had occurred.

In New York, Shelton et al. (1982) utilized permethrin in a factorial experiment and determined that insecticides applied at a threshold of 0.5 cabbage looper equivalents (CLE) per plant during the heading period produced at least 95% uninjured cabbage, regardless of preheading populations. CLE standardized insect feeding by weighting each insect species based on foliage consumption (1 CLE = 20 DB = 1.5 ICW = 1 CL [Harcourt 1954]). In Florida and Georgia, Workman et al. (1980) reported that, during the heading stage, one feeding window (initial feeding site) per plant (based on head plus four wrapper leaves) was an effective action threshold for permethrin.

The previously mentioned thresholds were developed independently, and each emphasized different benefits (e.g., rapid evaluation, accurate estimate of age structure of population, relative foliage consumption, or assessment of injury to the cabbage head). Furthermore, the insecticides used in these thresholds were usually different and hence influenced each recommended action threshold (Simonet and Morisak 1982). This study compared these types of thresholds in side-by-side comparisons at three locations, utilizing the same insecticide.

Materials and Methods

Experiments were conducted during 1981 in three locations: University of Wisconsin Arlington Experimental Farm; Robbins Vegetable Research Farm near Geneva, N.Y.; and, University of Guelph Horticultural Research Station, Cambridge, Ontario, Canada. In each location, cabbage (cv 'Roundup') was transplanted (18, 19, and 24 June, respectively) into 48-row blocks replicated four times. Each block was 12 m in length and separated by 5 m of fallow ground. Blocks were evaluated weekly for larval populations before head formation and treated with permethrin at 0.05 kg of AI/ha if more than two larvae of any lepidopterous species per plant were found in a 100-plant sample taken over the entire field. Once head formation was initiated, as evidenced by a 7-cm leaf ball, each block was divided into six treatment plots of eight rows each. Treatments were arranged in an RCB design and consisted of four action thresholds, an untreated control, and a fortnightly application, regardless of insect pressure. The action thresholds were designated: (1) Florida; (2) Ohio; (3) Ontario; and (4) New York (Table 1). The Ohio and Ontario thresholds were higher than those previously reported, because permethrin was being used and similar marketability of all thresholds was desired.

Once head formation was initiated, plots were evaluated on a weekly basis, using a nondestructive 10-plant sample from the middle four rows. Plot samples were

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Table 1.—Cabbage thresholds utilized in comparison tests in Wisconsin, New York, and Ontario, Canada, 1981

Action threshold name	Action threshold criteria[a]
Florida	≥1 New feeding site (3 > mm)/ plant (head plus four wrapper leaves)
Ohio	≥50% Of plants infested with ICW, CL, or DB larvae
Ontario	One of the following for ICW and CL only: (1) ≥3 Eggs/plant (2) ≥1.5 Small[b] larvae/plant (3) ≥0.5 Large[c] larvae/plant (4) Eggs + small[b] larvae ≥ 3/plant (5) Eggs + large[c] larvae ≥ 2.25/plant (6) Eggs + small larvae[b] + large larvae[c] ≥ 1/plant (7) Small[b] larvae + large[c] larvae ≥ 1/plant
New York	≥0.5 CLE[d]/plant
Fortnightly	Treated fortnightly without sampling

[a]Based on average of four replicates.
[b]≤2nd instar.
[c]≥3rd instar.
[d]See text.

taken based on the criteria established for each threshold: (1) new feeding sites (>3 mm) on the head plus four adjacent (wrapper) leaves (Florida); (2) number of plants infested with larvae of any of the three species (Ohio); (3) eggs and larvae of CL and ICW on the entire plant (Ontario); (4) CL, ICW, and DB larvae on the entire plant (New York). In the untreated control, CL and ICW eggs and CL, ICW, and DB larvae on the entire plant were enumerated. No counts were taken in the fortnightly sprayed plots. In the Florida threshold plots, the same 10 plants were sampled weekly, whereas 10 plants were randomly selected each week in the other plots. The time spent sampling each plot was recorded. When thresholds (based on the average of all four replicates) were exceeded, permethrin was applied at 0.05 to 0.1 kg of AI/ha by using a tractor-mounted, two-row sprayer with three nozzles per row to the middle six rows of each plot. The higher rate was applied only when CL became the dominant species.

Plants were evaluated for insect damage at harvest (23 September, Wisconsin; 24 September, New York; 22 September, Ontario). A sample of 20 to 25 whole plants per plot was checked for damage and rated on a 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 giving the plant a rating of 4 or above (Chalfant et al. [1979], modified from Greene et al. [1969]). Marketability was also evaluated, based on injury on the head plus four wrapper leaves alone. In this rating system, four categories were used: (1) marketable no. 1—no lepidopterous injury; (2) marketable no. 2—damage did not exceed (a) one 1.5-cm-diameter hole or series of holes equalling that area on the head, (b) four wrapper leaves had a total of not more than four 1.5-cm-diameter holes, or (c) presence of any insect frass or parts on head or four wrapper leaves; (3) not marketable no. 3—moderate damage; and (4) not marketable no. 4—severe damage. Mean separation tests were performed on arcsine transformed data of percent marketable and on raw damage ratings. Within each location, evaluation times were analyzed by using the mean evaluation time per week per treatment, with the seven sampling dates as replicates. In the summary of all locations, mean separation tests on damage ratings, percent marketable, and evaluation times were performed by partitioning out effects of location.

Results

No insecticides were applied specifically against lepidoptera before initial head formation. When treatment regimes during the heading stage were averaged over all locations, the Florida threshold required the fewest sprays ($x = 1.3$), whereas the Ontario threshold required the most ($x = 4.3$) (Table 2). The time required to assess populations and render treatment decisions in the Ontario and New York thresholds was similar, but ca. 2.4- and 1.6-fold that required for the Florida and Ohio thresholds, respectively (Table 2). In control plots in Wisconsin, New York, and Ontario, the peak larval populations of ICW and CL per plant were: 21.4, 2.6; 3.1, 8.8; and 3.4, 1.1, respectively (Table 2). Peak DB larval populations were <2 per plant at all locations.

Averaging all locations, damage ratings for the entire plant (1 to 6 scale) were highest for the Florida threshold ($x = 1.73$) but nearly identical for all other thresholds (Table 3). The number of uninjured heads (marketable no. 1) over all locations was lowest in the Florida threshold (69.7%), ranged from 92 to 94% in the other thresholds, and was 16.3% in the untreated control. Slightly injured heads (marketable no. 2) brought the total marketable to 90.3% for Florida, 98 to 100% for other thresholds, and 29.1% for the control. Although the highest insect populations were recorded in Wisconsin, this was not reflected in plant injury, because excessive rain during September prevented the population from moving onto the head.

Discussion

Each threshold tested exhibited certain advantages and

Table 2.—Weekly larval populations per plant of DB, imported ICW, and CL in untreated plots in Wisconsin, New York, and Ontario, 1981

Sampling period	Wisconsin			New York			Ontario		
	DB	ICW	CL	DB	ICW	CL	DB	ICW	CL
29 July–7 Aug.	0.4	3.8	0.3	1.8	0.7	0.7	0	0.6	0.1
6–13 Aug.	1.1	21.4	1.8	1.1	1.3	1.1	0.5	0.8	0.5
16–21 Aug.	0.2	18.8	2.2	0	3.1	0.4	0	1.7	1.1
20–27 Aug.	0.8	12.3	2.6	0	0.1	0.7	0	1.7	1.1
2–3 Sept.	0.4	0.4	2.2	0.1	0.4	1.9	0.1	3.4	0.4
10–11 Sept.	0.3	0.4	1.6	0	0.3	4.0	0	0.6	0.1
18–22 Sept.	0.1	0	0.4	0	0.2	8.8	0	0.1	0.1

Table 3.—Mean damage ratings,[a] marketability, insecticide applications, and evaluation times for treatments comparing action thresholds for fresh-market cabbage in Wisconsin, New York, and Ontario, 1981

Location	Treatment	Damage rating	% marketable			% nonmarketable		No. of sprays	Evaluation time[b]
			Total	1	2	3	4		
Wisconsin	Florida	1.14a	100b	91.0b	9.0b	0a	0a	1	2:36a
	Ohio	1.06a	100b	98.0b	2.0a	0a	0a	3	3:28a
	Ontario	1.07a	100b	96.0bc	4.0ab	0a	0a	6	9:36b
	New York	1.04a	100b	98.0c	2.0a	0a	0a	4	8:29b
	Fortnightly	1.06a	100b	95.0bc	5.0ab	0a	0a	4	—
	Control	2.26b	72.0a	47.0a	25.0c	24.0b	4.0b	—	8:52b
New York	Florida	2.09b	95.0b	71.2b	23.8b	5.0b	0a	2	4:26a
	Ohio	1.30a	100b	92.5c	7.5a	0a	0a	4	8:32b
	Ontario	1.15a	100b	97.5c	2.5a	0a	0a	5	12:17c
	New York	1.17a	100b	96.2c	3.8a	0a	0a	5	12:14c
	Fortnightly	1.21a	100b	93.7c	6.3a	0a	0a	4	—
	Control	5.21c	6.2a	0a	6.2b	72.5c	21.2b	—	13:29c
Ontario	Florida	1.96b	76.0b	47.0b	29.0b	23.0b	1.0a	1	6:07a
	Ohio	1.19a	96.0c	88.0c	8.0a	4.0a	0a	2	7:53ab
	Ontario	1.11a	100c	89.0c	11.0a	0a	0a	2	10:25b
	New York	1.16a	98.0c	87.0c	11.0a	2.0a	0a	2	10:23b
	Fortnightly	1.13a	99.0c	88.0c	11.0a	1.0a	0a	4	—
	Control	3.83c	9.0a	2.0a	7.0a	72.0c	19.0b	—	11:31b
Mean	Florida	1.73b	90.3b	69.7b	20.6b	9.4b	0.3a	1.3a	4:23a
	Ohio	1.18a	98.7b	92.8c	5.8a	1.4a	0a	3.0b	6:39b
	Ontario	1.11a	100b	94.2c	5.8a	0a	0a	4.3b	10:46c
	New York	1.12a	99.3b	93.7c	5.6a	0.7a	0a	3.7b	10:22c
	Fortnightly	1.13a	99.7b	92.2c	7.4a	0.3a	0a	4.0b	—
	Control	3.77b	29.1a	16.3a	12.7ab	56.2c	14.8b	—	11:17c

[a] Mean separation vertical. Means followed by the same letter, within each section, are not significantly different, by Waller and Duncan (P = 0.05).

[b] Mean for season based on 10-plant sample (min:sec).

faults. The Florida threshold took far less time to assess and required the fewest sprays, but its use resulted in the most injury. While using this threshold, it was difficult to differentiate new feeding sites from old ones, especially when scouting was only performed once a week. Lowering this threshold would improve marketability without increasing sampling time. However, there is a risk in disregarding larvae on the frame leaves, because they could move to and severely injure the head between sampling dates.

The Ontario threshold gave the most accurate assessment of ICW and CL populations and their age structures, although it did not account for DB which, in some years, is a serious pest. The rationale for including eggs in the treatment decision was to prevent damage by larvae resulting from intense ovipositional periods. In these tests, some sprays were applied specifically because of egg counts, although these are not necessarily good indicators of subsequent damaging ICW populations (Harcourt 1966). However, with the use of slower-acting microbial insecticides, egg thresholds may be advantageous.

The New York threshold was based on amounts of foliage consumed by larvae. However, it did not take into account the size of larvae, which determines the amount of foliage consumed and which could influence control tactics. Better precision would be important when CL are present, because they are more difficult to control in later instars.

The Ohio threshold produced high marketability and a moderate amount of sampling time over the whole season. However, after a spray application it took nearly as long as other methods to assess the population, because few, if any, larvae remained on the plant. This threshold equated DB and CL in a treatment decision, although the CL is a more serious threat. It should be noted that decisions from this type of threshold assessment may differ from an assessment of the mean per plant because of insect distributions changing substantially during the season.

Although the fortnightly schedule, invoked without plant sampling, gave control similar to the Ohio, Ontario, and New York thresholds, this control tactic could not be relied on to provide effective and economical control under all circumstances.

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