8. Leonian, L. H. 1922. Stem and fruit blight of peppers caused by *Phytophthora capsici* sp. nov. *Phytopathology* 12:401-408.
9. United States Department of Agriculture. 1960. Index of plant diseases in the United States. Agr. Handbook 165, 531 pp.
10. Weber, G. F. 1932. Diseases of peppers in Florida. *Univ. of Fla., IFAS, Agr. Expt. Sta. Bul 244.*
11. ———. 1973. Bacterial and fungal diseases of plants in the tropics. Univ. of Fla. Press, Gainesville 673 pp.
12. Wehlburg, C., S. A. Alfieri, Jr., K. R. Langdon, and J. W. Kimbrough. 1975. Index of plant diseases in Florida. *Fla. Dept. of Agr. and Consumer Serv. Bul. 11.*

Proc. Fla. State Hort. Soc. 92:106-108. 1979.

DISPERSION ANALYSIS AND SAMPLING PLANS FOR INSECT PESTS IN FLORIDA CELERY[1]

C. A. Musgrave, H. W. Beck, S. L. Poe
Department of Entomology and Nematology,
IFAS, University of Florida,
Gainesville, FL 32611

W. H. Denton[2], J. O. Strandberg, J. M. White
IFAS, University of Florida,
Agricultural Research and Education Center,
Sanford, FL 32771

W. G. Genung, and V. L. Guzman
IFAS, University of Florida,
Agricultural Research and Education Center,
Belle Glade, FL 33430

Abstract. **Scouts in Florida celery need effective procedures to monitor key insect pests such as the vegetable leafminer,** Liriomyza sativae **Blanchard (Diptera: Agromyzidae) and several species of foliage-feeding noctuid caterpillars. In conjunction with an intensive crop monitoring program conducted at Belle Glade and Lake Jem, Florida from August 1977 through June 1978, we obtained data on these 2 categories of insects that permitted analyses of pest dispersion and calculation of optimum sample sizes. Under the prevailing conditions, random samples of 100 mature petioles and 24 sweep samples per 12 A (4.86 ha) block were adequate to plot trends in populations of leafminer larvae and adults, respectively. Two shake samples/A were adequate for detection of noctuid larvae.**

In conjunction with programs in integrated pest management, one major thrust in crop protection research has involved critical evaluation of actual or potential pest damage before deciding whether to treat a crop with pesticides or rely on alternative strategies for pest control. This approach makes 3 demands on researchers: 1) identification of key pests, damage characteristics, and spatial distribution; 2) evaluation of various sampling routines for particular key pests in regard to precision, efficiency, and practicality; and 3) interpretation of scouting data as it affects the decision making process in crop management. In this paper we deal strictly with some of the key insect pests of celery, a multimillion dollar vegetable crop in Florida. The emphasis is on evaluation of sampling methods for adult and immature vegetable leafminer, *Liriomyza sativae* Blanchard (Diptera: Agromyzidae), and several species of foliage-feeding noctuid caterpillers. Investigations of these methods were part of an intensive interdisciplinary research program conducted in 1977-78 on the pests and production problems of Florida celery.

Materials and Methods

Two consecutive crops of celery '2-14' were surveyed twice weekly from August 1977 through March 1978 at a commercial farm near Belle Glade, Florida. Three consecutive crops, primarily of celery '2-14', were studied similarly from August 1977 through June 1978 at a second farm near Lake Jem, Florida. A grand total of 14 fields comprising 186 A (ca. 75 ha) were systematically surveyed for adult and larval vegetable leafminer, *Liriomyza sativae*, and foliage-feeding noctuid caterpillars including *Trichoplusia ni* Hübner), *Pseudoplusia includens* (Walker) (both plusiine loopers), *Spodoptera exigua* (Hübner) and *S. latifascia* (Walker). Supplementary data on ambient weather conditions (including minimum and maximum temperatures, RH, wind speed, and direction), plant growth, and disease were recorded also. All plants were transplanted into muck soil according to standard horticultural practices. In the fall and winter crops at both farms, one 12 A (4.86 ha) block was maintained by the grower using his selection of pesticides, rates, and application intervals. Fungicides and *Bacillus thuringiensis* (0.5 lb/A = 0.56 kg/ha) were used as needed on two 12 A blocks in both fall and winter crops at Lake Jem; the same materials were used as needed on two 12 A blocks in the fall and one 28 A block in the winter crop at Belle Glade. In the spring crop at Lake Jem only, three 12 A blocks were maintained with fungicides and permethrin (0.1 lb/A = 0.11 kg/ha) for leafminers and caterpillars; demand was determined from scouting data collected twice weekly. For initial studies on sampling techniques and pest distribution, all fields (each was ca. 264 ft x 200 ft or 805.2 m x 61 m) were stratified into either 0.5 A (0.2 ha) plots in an 8 x 3 pattern over the length of the field or 0.08 A (0.03 ha) plots in a 20 x 6 pattern. At Lake Jem, fields were not stratified in either the winter or spring.

Sweep net samples taken twice weekly were used to estimate populations of adult vegetable leafminers. Each sample consisted of 10 sweeps with a 15 in (38.1 cm) diameter net over 20-25 ft (6.1 m — 7.6 m) of celery. Sweep samples were taken at intensities of 1.6, 2, 12, and 24 samples/A. Plot sampling was tested using 0.5 A and 0.08 A plots with 1 and 2 samples per plot. Random sampling over entire 12 A blocks with 20 samples per block was used during the winter and spring crops at Lake Jem.

Larval leafminers were counted in foliage samples taken twice weekly. In the fall 1977 and winter 1978 crop at Belle Glade, maggots were counted in samples of 10 mature trifoliolates collected from 10 different plants in each plot. The same procedure was followed with 20 mature trifoliolates per sample per plot in the fall 1977 crop at Lake Jem. In the winter and spring crops 10 samples of 20 trifoliolates were taken at random from each 12 A block. Foliage samples were collected at intensities of 0.8, 1.6, 2, 12, and 24 samples per acre. The same procedures were used to count maggots and estimate foliar damage at both sites.

The relative precision of sampling whole petioles and whole plants was determined from earlier data files collected

[1]Florida Agricultural Experiment Station Journal Series No. 2026.
[2]Current address: Stauffer Chemical Company; Southeastern Field Research Station, 1691 Cameron Ave.; Sanford, FL 32771.

in conjunction with a celery plant growth/leafminer infestation study (1). Petioles of 20 plants in each of two 0.5 A (0.2 ha) management plots were labeled as they appeared. Maggots on each petiole of every plant were counted once weekly from late September 1976 through early January 1977. These plants provided data for analyses of leafminer infestations on per petiole and per whole plant bases.

For scouting purposes, noctuid caterpillars were categorized as either loopers or armyworms distinguished by the 2 pairs of terminal prolegs on loopers and 4 pairs on armyworms. Each caterpillar also was categorized visually by size: small (<0.5 in or <1 cm long), medium (0.5 in to 0.75 in or 1 cm to 1.9 cm) or large (>0.75 in or >1.9 cm). Scouts at Lake Jem used 3 methods to look for caterpillars in the fall 1977 crop: 1) shake samples consisted of vigorously shaking the foliage on 3 ft (ca. 0.9 m, 6 or 7 plants) of row before categorizing and counting the dislodged caterpillars; 2) sweep samples—the same samples used above for adult leafminers; and 3) foliage samples—the same samples used above for leafminer maggots. Scouts at Belle Glade used only the shake method in fall 1977. Scouts at both sites used only the shake method in the succeeding crops. Shake samples were taken also at intensities of 1.6, 2, 12, and 24 samples per acre.

Similar analyses were used for all scouting procedures. For data from each scouting date, descriptive statistics for each parameter mentioned above were calculated on a plot, section (plots grouped along either the length or width of a block), and block (i.e., entire 12 A field) basis. For studies of spatial distribution of leafminers and caterpillars, one-way or nested analyses of variance and Duncan's Multiple Range Test were used to discriminate significant differences in data. Optimum sample size and statistical precision (= standard error of the mean or SEM expressed in percent) were both calculated for sweep samples, samples of various units of foliage, and shake samples. All data were considered in formulation of a minimum labor scouting plan suitable for detecting insect pests and evaluating significant trends in their populations.

Results and Discussion

Analyses of sweep net samples from within individual fields indicated that there were detectable differences between different regions of particular blocks. However, patterns in the Lake Jem data did not illustrate any apparent gradients in population density suggestive of dispersion into or across blocks. Neither was the infestation clumped into identifiable regions of the field that could be spot-treated with insecticides. These data on pest distribution suggest that simple random sampling at a rate of 2 sweep samples per acre (=24 samples per 12 A block) was necessary to achieve satisfactory precision (SEM = 20%). Regression analyses of sample variances (s^2) and means ($\bar{x}$) produced the equations $s^2 = 2\bar{x}$ for $\bar{x} \leq 20$ and $s^2 = 0.004\bar{x}$ for $\bar{x} > 20$. Optimum sample sizes were calculated for several population densities and levels of precision based on this variance/mean relationship (Table 1).

Further analyses of data from an earlier study on celery growth and sequential leafminer infestation (1) were used to compare the labor involved and relative precision of estimating populations of leafminer maggots from whole plants, whole mature petioles, and mature trifoliolates. Generally, variances for maggot counts from either whole plant or petiole counts were less consistent than variances for trifoliolate counts.

Equations relating sample variances and means were used to calculate the necessary number of samples of trifoliolates, petioles, or whole plants for a given precision

Table 1. Number of sweep net samples (10 sweeps per sample) needed per 12 A block of celery to achieve a given precision (SEM) in estimating numbers of adult vegetable leafminers at various pest densities (m) (based on $n = 20{,}000/SEM^2m$ for $m \leq 20$ and $40m/SEM^2$ for $m > 20$).

	m			
SEM (%)	1	10	100	1000
10	200	20	40	400
20	50	5	10	100
30	22.2	2.2	5	42

(Table 2). For trifoliolate samples only, the optimum number of samples and pest density were not related, whereas the number of petiole or whole plant samples needed for comparable levels of precision depended upon population density. Since the mean density of pests is not known beforehand, the number of samples used must be sufficient to detect even low densities of pests and to accurately gauge trends in pest populations that are likely to occur in the field. On the basis of these and previously collected data and the acceptability of SEM = 20%, a sampling plan for leafminer maggots can be based on 5 samples of 20 trifoliolates, 100 whole petioles, or 20 whole plants per 12 A block.

The power of the trifoliolate and petiole samples to discriminate differences among blocks (i.e., 12 A fields) was demonstrated throughout the study. In most cases there were significant differences in infestations among blocks on a farm. However, there was no consistency in which blocks had the highest densities and the ranking of blocks from highest to lowest density usually changed from one sampling date to the next. Within a block, differences between plots were found across the width of the field but there was usually no difference along the length of the field. Scouting bias or ephemeral concentrations of maggots in particular plots were likely sources of variation in these data.

Analyses of caterpillar sampling data suggested that a

Table 2. Number of foliage samples (n) per 12 A block needed to estimate the mean number of vegetable leafminer larvae per sample with a given precision (SEM = standard error of the mean) at different densities (m_1; m_2; m_3).

Samples of 20 trifoliolates; $n = 1840/(SEM)^2$; m_1 can assume any value.

SEM (%)	n
10	18.4
20	4.6
30	2

Samples of whole petioles; $n = [(3.9 \times 10^4)/m_2 + 2620)]/SEM^2$.

	No. of larvae per sample ($=m_2$)			
SEM (%)	1	10	100	1000
10	415	65	30	26
20	104	16	7	7
30	46	8	4	3

Samples of whole petioles; $n = (2.39 \times 10^4)m_3^{-0.49}/(SEM)^2$.

	No. of larvae per sample ($=m_3$)			
SEM (%)	1	10	100	1000
10	239	77	25	8
20	59	20	7	2
30	27	9	3	1

different sampling strategy and monitoring objectives were in order for these foliage-feeding pests. Available data suggested that good point density estimates could have been made only if sampling intensities exceeded 3/A. As this is too intense for survey purposes or commercial scouting, it was advisable to substitute a detection survey strategy that required much lower sampling intensity but which accurately determined when the density of noctuid larvae exceeded low levels. Since all of the shake, foliage, and sweep data for caterpillars fit a Poisson distribution, a single table was created, summarizing the number of any of these samples necessary per 12 A block to detect relative density levels of noctuid caterpillars with a given precision (Table 3). Recommendations shown in the table were based on the probability of detecting at least 1 larva for a given number of samples as predicted by a Poisson distribution.

Analyses of data for armyworms and loopers categorized by size indicated that fewer caterpillars were found as size decreased regardless of the sampling method. Nearly 5x more small than large larvae were captured. This suggested a different sampling efficiency for each size class or perhaps considerable mortality in later instars. Overall, total specimens collected per sample at the same population density declined from sweep, to shake, to foliage samples for armyworms and from shake, to sweep, to foliage for loopers. Some of the observed differences in efficiencies may pertain to differences in the amounts of foliage examined in each sample unit. Alternatively, scouts may avoid picking foliage with caterpillars on it, or the caterpillars may be lost before the foliage samples are examined.

Table 3. Number of shake, sweep, or foliage samples needed per 12 A block of celery to detect noctuid loopers and armyworms at various levels of probability and relative population densities.

	Mean number of larvae per sample[y]										
P_d[z]	0.01	0.02	0.03	0.04	0.05	0.075	0.1	0.2	0.3	0.4	0.5
0.99	460	230	153	115	92	61	46	23	15	11	9
0.95	300	150	100	75	60	40	30	15	10	8	6
0.90	230	115	76	57	46	31	23	12	8	6	5
0.80	160	80	54	40	32	22	16	8	6	4	4
0.70	120	60	40	30	24	17	12	6	4	3	3
0.50	70	35	23	18	14	10	7	4	3	2	2

[z]P_d = Desired probability of detecting 1 or more worms in n samples.
[y]Mean larvae per sample depends on the sample method used.

Armyworms appeared to occupy the highest foliage on plants in the range of sweep nets; they did not seem to anchor themselves to foliage with silk as did some of the loopers. Shake samples at an intensity of 2/A are sufficient for detection of either category of noctuid larvae.

In this paper we have alluded to procedures for detecting particular insect pests and estimating their relative numbers. As described, the procedures are precise and offer a minimum of labor to collect and process. In addition to providing insight on spatial distributions of principal insect pests, they also have provided data useful for description of temporal trends in pest populations. Thus far our efforts in actually managing pest populations in celery have been preliminary but the results have been most encouraging. Development of sampling procedures for pests ultimately offers the key to judicious use of pest management tactics.

Literature Cited

1. Musgrave, C. A., D. R. Bennett, S. L. Poe, W. H. Denton, J. O. Strandberg, and J. M. White. 1977. Growth characteristics of celery '2-14' in central Florida. *Proc. Fla. State Hort. Soc.* 90:402-404.

Proc. Fla. State Hort. Soc. 92:108-110. 1979.

SAMPLE SIZE, AGE OF CELERY PETIOLE AND REARING CONDITIONS AFFECT EMERGENCE OF VEGETABLE LEAFMINERS AND PARASITES[1]

EARL H. TRYON, JR. AND SYDNEY L. POE
IFAS, Department of Entomology and Nematology,
University of Florida,
Gainesville, FL 32611

Additional index words. Liriomyza sativae Blanchard, vegetable leafminer, celery, parasites.

Abstract. **Ten to eleven week old celery grown in Belle Glade, Florida (spring 1978) was sampled to determine the effect of sample size, age of celery petiole and rearing conditions on** Liriomyza sativae **Blanchard and its parasites. Samples of leaflets were removed and placed into 1 pint ice cream cartons to determine the influence of the number of leaflets on the number of insects that emerge per leaflet. Leaflets were removed from celery petioles of varying ages and insects reared in pint sized containers in 2 different environments.**

The average number of insects reared per leaflet did not vary significantly for samples of 8 to 20 celery leaflets per pint sample (mean 5.5 to 6.0 insects/leaflet). Fewer than 8 celery leaflets per sample resulted in significantly fewer (P = 0.05) insects (mean 1.8 to 4.4 insects) reared per leaflet. In a laboratory environment of >88% RH and 24°C, adult insect emergence was lower than the emergence from samples held at 23°C and 57% RH in the samples with the larger numbers of celery leaflets. A significantly (P = 0.05) larger number of adult insects (nearly 50% of all adults) was reared from mature petioles (#6 to 9) than from the oldest (#7 to 5) and youngest (#10 to 15) petioles.

The celery leaflet sample size (biomass), rearing environments (humidity) and leaflet location (age) on the celery stalk influence the numbers of adult leafminers and parasites that emerged from each leaflet.

The vegetable leafminer, *Liriomyza sativae* Blanchard, is an important pest of Florida's 12,000 acre commercial celery industry. Leafminer has been economically important on celery since 1972 (8). Early research (1940's-1960's) dealt with extensive efforts to control the insect with insecticides. However, the tolerance of leafminers to many currently registered pesticides promoted integrated management programs (6, 13). Research has focused on hosts resistant to leafminer, on leafminer biology, natural enemies associated

[1]Florida Agricultural Experiment Station Journal Series No. 1974.