FINAL REPORT

PROJECT NO:	4091		
TITLE:	Biology, behavior and management of cutworms		
YEAR INITIATED:	1998-99	**CURRENT YEAR:**	2000-01
TERMINATING YEAR:	2000-01		
PERSONNEL:	Jay F. Brunner and Mike Doerr, WSU-TFREC, Wenatchee Peter Landolt, USDA-ARS, Wapato Richard Zack, WSU, Pullman Mark Hitchcox, GRA, WSU, Pullman		
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JUSTIFICATION:

When chlorinated hydrocarbons were lost (DTT and then chlordane) as chemical controls in fruit orchards, many predicted that populations of cutworms and armyworms (Noctuidae) would soon increase and cause serious crop injury. This did not occur and for the past 20 years cutworms have been a relatively minor problem in most fruit orchards. With introduction of "soft" controls in apple orchards, especially mating disruption, critics again forecast increased problems with many pests as broadspectrum insecticide use declined. This has not occurred yet although it still could. What has happened, however, has been an increase in populations of cutworms and armyworms, especially in the central basin of Washington and northeastern Oregon. Armyworms often follow a cyclical pattern of population increase and rapid decline, and these pests have been only sporadic problems in selected orchards. Cutworms, however, have been more of an annual problem in orchards and in the last two years one species, *Lacanobia subjuncta* (aka - lacanobia fruitworm), has caused considerable damage to fruit. One grower in northeastern Oregon has reported a loss of approximately $30,000 in one year to this pest.

There has been no active research on Noctuidae in Northwest fruit cropping systems for nearly 15 years. With the passage of FQPA-96 and the potential loss of older insecticides (for instance, EPA restrictions on the summer use of Lorsban or export restrictions on Thiodan treated orchards), it was time to revisit this pest complex and address how it will be managed in future years. The presence of lacanobia fruitworm suggests that there may have been some important shifts in the species complex of Noctuidae in Washington. If indeed this has occurred, it is critical to understand why and how this might influence pest management programs. This proposal outlined a study aimed at characterizing the noctuid complex in Washington, determining the phenology of key species and developing monitoring and management tactics to prevent crop loss.

OBJECTIVES:

1. Survey noctuids found in orchards throughout Washington identifying the most common species present and host plants they utilize.
2. Develop a predictive model for *L. subjucta* that will predict the presence of specific life stages during the growing season.
3. Develop chemical control tactics that will successfully suppress *L. subjucta* and other climbing cutworm species that threaten fruit crops.
4. Develop monitoring methods specifically for *L. subjuncta* based on larval and adult behavior.

SIGNIFICANT FINDINGS and ACCOMPLISHMENTS:

- The biology of *Lacanobia subjuncta* (lacanobia fruitworm) has been examined at several locations and accurately characterized for Washington conditions. This provides a solid basis for developing sound pest management strategies for dealing with this new pest.
- Mark Hitchcox was awarded his MS in Entomology for research on lacanobia fruitworm biology and phenology. Mark is now an employee of the Washington State Department of Agriculture working out of the Yakima office.
- A degree-day model has been developed that accurately predicts the development of lacanobia fruitworm. The lower threshold is 7°C (44°F) and an upper threshold is 31°C (88°F). Degree-day requirements based on constant temperature data for eggs, larvae and pupae were 137.1, 874.0 and 535.8 degree-days, respectively. Eggs, larvae and pupae required field temperatures of 130.7, 946.9 and 492.3 degree-days, respectively. The pre-oviposition period was estimated at 280 degree-days. This model will be very useful in timing control tactics and sampling activities.
- Following a fairly long pre-oviposition period, lacanobia fruitworm females lay eggs over a long period. At constant temperature, 22.5°C, lacanobia fruitworm lay eggs for 22 days. Fifty percent of eggs were deposited in 8 days. Field sampling of egg masses indicated the average mass contained approximately 150 eggs. Based on laboratory observations, a reasonable estimate for average female fecundity is 1000 eggs.
- Lacanobia fruitworm feeds on several broadleaf weeds (see report by Landolt) but is only a pest on apple.
- We hypothesize that lacanobia fruitworm became a pest because it developed resistance to selected organophosphate and carbamate insecticides. Lorsban, Lannate and Thiodan provided superior control of summer larvae. Success and Confirm were effective against young larvae. Surround is effective timed at the early hatch period but requires multiple applications. Ecozin and Avaunt* have utility as potential controls, but more research is needed on these products. Bt products and pyrethrums do not provide acceptable levels of control.
- The distinguishing features of various noctuid larvae found in orchards was described along with feeding behaviors. These will be published as a guide for growers and crop consultants.
- Various monitoring methods were used to measure densities of different lacanobia fruitworm life stages or feeding activities of larvae. The best predictor of fruit injury was obtained with visual observation of larval feeding activity on foliage. Percent shoot feeding of 30-35% correlated with a 1% fruit injury rating after the first lacanobia fruitworm generation. Peak pheromone trap captures of less than 150 per week did not appear to justify control applications against the first generation.
- There is promise that a food-bait trap developed by Dr. Peter Landolt will provide a method of monitoring lacanobia fruitworm adults, providing a better prediction of this pest's density in orchards and possibly forming the basis for a lure and kill technology.

(A more detailed report can be obtained by requesting it from Jay Brunner [jfb@wsu.edu] or Mike Doerr [mdoerr@wsu.edu], WSU-TFREC, 1100 North Western Avenue, Wenatchee WA 98801.)

PROGRESS:

Biology, phenology and survey - The initial phase of any good scientific study is to "know the enemy." In this study cutworm larvae were collected from orchards throughout the state. As part of an effort to learn more about the life cycle and other aspects of cutworm biology, we examined its seasonal phenology and host plants utilized. We especially hoped to gain a preliminary insight into the population dynamics of the lacanobia fruitworm on a local scale by looking at a variety of plants as potential hosts and by sampling fruit trees throughout the season. Larvae were associated with the plants on which they were feeding at the time of collection. Because many cutworm species only feed at night, collections were conducted when necessary to make correct plant host associations. Larvae were reared on host plants or artificial diets as deemed appropriate. National experts identified adults to species.

Sampling for adult moths was accomplished with general purpose bucket-style traps (Unitrap, Pherotech, Inc.) baited with the sex pheromone of female lacanobia fruitworm. Traps were operated from late April through early October and serviced 1 to 3 times per week. Lures were replaced monthly. Traps were placed in 27 locations from Milton-Freewater, Oregon, through Yakima, Washington and Othello to Bridgeport, Washington.

Sampling for larvae was accomplished by tapping tree limbs with a sturdy rubber hose, dislodging lacanobia fruitworm larvae onto a standard beating tray used to sample pear psylla. Larvae collected on beating trays were brought into the laboratory for positive identification. All larvae in question were reared to the adult stage for identification. During peak periods of larval activity similar sampling was conducted on other trees and on weeds within apple orchards. Sampling on alternate hosts was conducted comprehensively twice, first in late June into early July, and again in September.

Season-long sampling for male lacanobia fruitworm moths indicated two major periods of flight. The **first flight** occurred roughly from **late April through June, with peak moth capture in early June**. The **second flight** began in **late July and lasted through September**. Lacanobia fruitworm moths were captured at each of the 27 locations monitored. Densities varied dramatically among locations from peak catches of 10 to over 850 per week.

Season-long sampling for **lacanobia fruitworm larvae** indicated two periods of larval activity. The **first generation of larvae occurred from early June through July**. The **second generation of larvae began in mid-August and was present through October**. Season-long larval sampling was conducted in apple orchards only. Although lacanobia fruitworm moths were captured at each location, larvae were not always detected.

Lacanobia fruitworm larvae were collected on a number of tree and weed species. Larvae were found **primarily on apple**, and only small numbers were found on pear, cherry, apricot and prune. In orchard ground cover larvae were most often collected from mallow, curly dock and dandelion.

Small numbers of parasites were obtained from field-collected lacanobia fruitworm larvae. Although not yet identified to species, these included several hymenopterous parasites and at least 3 species of Tachinidae.

Predictive degree-day model: The lacanobia fruitworm has proven to be the most damaging of the noctuid pests surveyed in this project. Insecticides are the primary means to control the lacanobia fruitworm. While Lorsban (organophosphate) and Thiodan (organochlorine) control all larval stages, selective or "softer" chemicals [e.g. Success (Naturalyte® fermentation product)] are most effective against young larvae. Optimizing the application timing of "softer" insecticides is critical to maintaining control of the lacanobia fruitworm while promoting integrated pest management during the summer.

Temperature-dependent development data were developed for eggs, larvae and pupae of the lacanobia fruitworm at constant temperatures ranging from 10.0°C-37.5°C. Constant temperature development was also compared to development under the fluctuating temperatures of field rearing. Minimum development temperature thresholds for eggs (Fig. 1), larvae and pupae of 6.6, 5.9 and 4.9°C, respectively, were established by extrapolating the linear regression equation for development to the x-axis. Optimal temperatures of development as described by McDonald (1990) for eggs, larvae and pupae were 28.8, 30.0 and 27.5°C, respectively.

Degree-day requirements were estimated from constant and fluctuating (field) temperature tests. Using a base temperature of 7°C (44 °F) and upper threshold of 31°C (88°F), average degree-day requirements based on constant temperature data for eggs, larvae and pupae were 137.1, 874.0 and 535.8 degree-days, respectively. Eggs, larvae and pupae required an average of 130.7, 946.9 and 492.3 degree-days, respectively, in the fluctuating temperatures. Preoviposition period data were collected from only one constant temperature, 22.2°C, so the estimate for degree-day requirements was less robust. At 22.2°C, the preoviposition period was 240 degree-days. This was adjusted to a higher value, 280 degree-days for model development, based on our experience with rearing lacanobia fruitworm at other temperatures. It should be noted that the degree-day requirements for the sixth instar are much more than the other instars. The lacanobia fruitworm sixth instar larvae entered a prepupal phase. This period likely accounted for the extended period noted for sixth instar larvae.

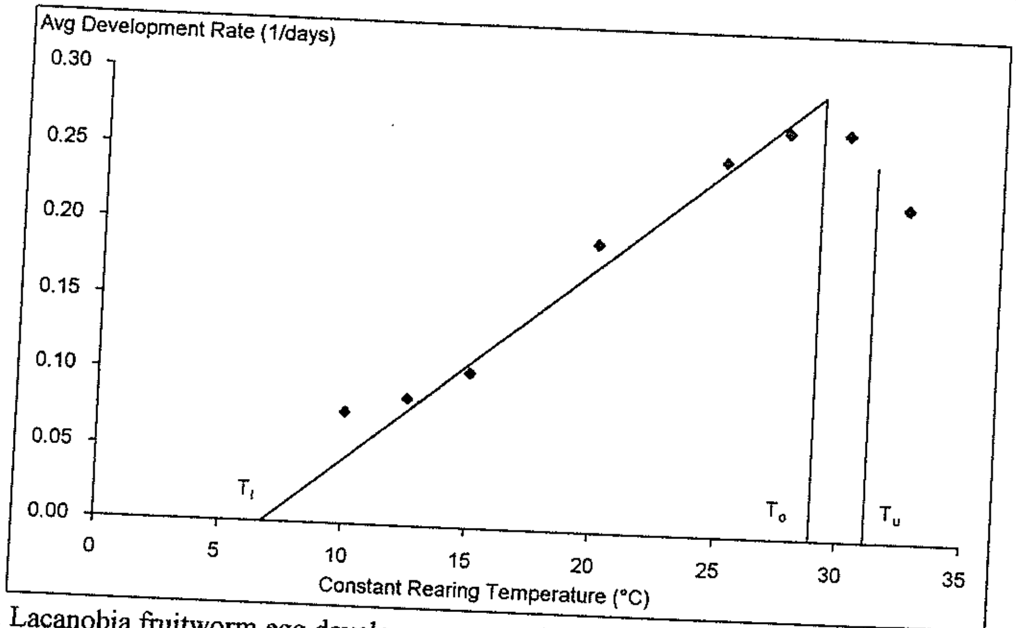

Figure 1. Lacanobia fruitworm egg development rates (1/days) under constant temperature regimes. Degree-day models were bound by the following parameters: T_l lower threshold of development, T_o optimal rearing temperature and T_u upper threshold for development.

Oviposition and hatch were monitored by searching for and flagging egg masses in the field. Data were presented as cumulative percentage of activity at degree-days from biofix. Oviposition began at 280 degree-days past biofix and lasted until 1000 degree-days. Hatch started at 400 degree-days past biofix and lasted until 1150 degree-days. These data are closely associated with model predictions developed from laboratory data.

The relative abundance of larval stages was measured by collections from each of the sample orchards during the first generation. Larvae were more difficult to collect, as they matured and distributed themselves throughout the tree canopy and into the ground cover. First instar larvae were initially collected at 400 degree-days after biofix and continued to be collected in samples through 1400 degree-days. These data were consistent with the long oviposition and hatch periods. The first occurrence of sixth instar larvae was at 1000 degree-days. Larvae were collected through 2200 degree-days past biofix during the first generation. First generation degree-day estimates and field validations are summarized in Fig. 2.

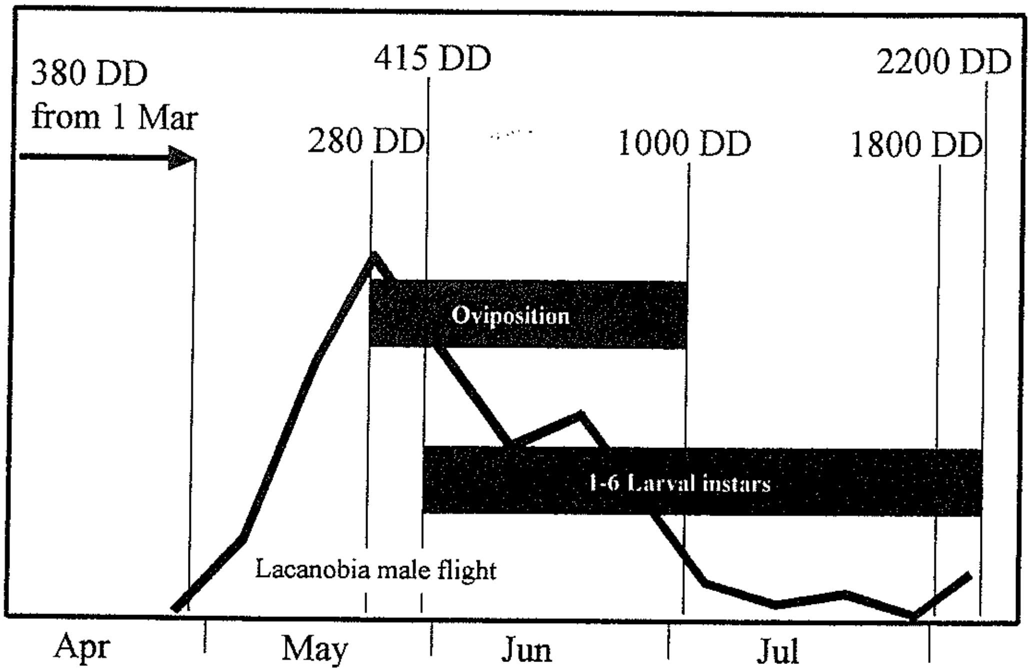

Figure 2. Degree day estimates for important phenological developments during the first generation of lacanobia fruitworm.

A stated purpose for developing a predictive model was to aid in the timing of insecticide applications. For example, an ideal timing for the application of a "soft" pesticide such as Success would be when the majority of eggs had hatched and while most larvae were still of a susceptible stage. Compiling the first generation information presented above, 80% egg hatch occurred at approximately 700 degree-days from biofix. At 700 degree-days the majority of larvae were in instars 1 through 3. The presence of more mature larvae was not noted until about 1000 degree-days. Therefore, the ideal timing for a Success application would be between 700 and 850 degree-days after biofix. The 150 degree-day window should provide sufficient opportunity to apply the insecticide during good weather conditions.

Chemical controls: Chemical control tactics to suppress the lacanobia fruitworm below damaging levels were evaluated through a series of laboratory bioassays and large plot field trials. Our ability to test experimental insecticides was limited because measurable lacanobia fruitworm populations generally occurred in fully mature apple orchards. Lorsban (chlorpyrifos) and Thiodan (endosulfan) controlled all larval stages. However, summer use of Lorsban is now banned, and use of Thiodan is restricted because of export concerns. Success (spinosad) and Confirm (tebufenozide) had good activity against young larvae. Confirm will likely be replaced by Intrepid (methoxyfenozide) which appears to have greater activity, at least in laboratory tests. Surround provided good suppression of lacanobia fruitworm with the best timing during the early egg hatch period. Ecozin appeared to be effective although multiple applications appear necessary. Ecozin did not result in immediate kill, but delayed mortality was noted and more testing is required before recommendations can be made. Avaunt, an experimental insecticide, demonstrated good activity against lacanobia fruitworm and may soon be registered for use on apple. Pyrethrum had some effect suppressing lacanobia fruitworm populations, but its short residual activity probably limits utility in all but organic orchards. Lannate (methomyl) was very effective but because it disrupts integrated mite control its use should be restricted to emergency situations only. Field observations of *Bacillus thuringiensis* products suggested that their use had little effect on lacanobia fruitworm.

In the fall of 1999 a laboratory colony of lacanobia fruitworm was established at the Tree Fruit Research and Extension Center. From this colony we began a series of dose-response bioassays on neonate larvae. These assays should help to determine which insecticides show promise as controls in the future. From bioassay evaluations conducted to date, products that show promise as controls for lacanobia fruitworm are Confirm, Intrepid, Lorsban, Malathion, Thiodan, Asana, Larvin*, Lannate, Avaunt*, Success and Proclaim* (those products followed by * are not yet registered for use on tree fruit). Preliminary studies with our laboratory colony indicate that they become much more susceptible to organophosphate and carbamate insecticides after only 3 generations, suggesting that resistance may not be strongly fixed in field populations.

Behavior: An understanding of the life cycle and behavior of noctuid pests aided in the diagnosis of foliage or fruit injury. The spotted cutworm overwinters in the larval stage and is present in apple orchards during the spring. Spotted cutworm larvae cause damage at a time when the lacanobia fruitworm is still in the overwintering pupal stage. Bertha armyworm is most often associated with injury to pear, a host on which lacanobia fruitworm is rare. Bertha armyworm requires a primary host other than tree fruits to complete life cycle. Thus, bertha armyworm was most often associated with orchards having poor broadleaf weed control. There were many orchards where the lacanobia fruitworm and the bertha armyworm coexisted. Arctiid larvae were sufficiently different in appearance from the lacanobia fruitworm that distinguishing the two was not difficult. Although arctiids laid eggs on apple at the same time as the lacanobia fruitworm, their larvae probably do not feed very long on apple. Feeding behavior of redhumped and yellownecked caterpillars (family Notodontidae) was sufficiently different from the lacanobia fruitworm that distinguishing between them was relatively easy. In our studies care was always taken to record fruit and foliage injury that was consistent with lacanobia fruitworm behavior. A photo key of the distinguishing characteristics of key noctuids is being developed to aid in species identification.

Monitoring methods: Three sampling methods have proven effective in monitoring lacanobia fruitworm populations. A general purpose bucket-style trap baited with a sex pheromone was highly attractive to males, a limb tap/beating tray technique was useful as a direct sampling method for larvae, and visual examination of foliage for signs of feeding activity provided a good indicator of larval presence. In addition, a food-bait type lure developed by Dr. Peter Landolt was useful for monitoring all noctuid adults.

Sex pheromone traps were used to monitor lacanobia fruitworm males in 27 locations over three years. The pheromone was highly attractive and high captures of moths occurred (600 moths/week) in orchards containing few larvae. In order to limit the effect of outside populations biasing trap data, pheromone traps should be placed in the center of large orchard blocks (10 acres or larger). Traps should be in place by full bloom to establish biofix in order to use the degree-day model to time spray applications.

Direct sampling of larvae using a limb tap/beating tray technique required a large number of samples to accurately measure populations. At least 50 beating tray samples spread through a large block were necessary to obtain an accurate measure lacanobia fruitworm density. Larvae were more likely to be dislodged where foliage was most dense. Therefore, sampling should be concentrated in the lower interior of the trees. Greater numbers of small (instars 1-4) larvae were dislodged with beat tray sampling. This method should be used when 80% hatch is predicted or just prior to a pesticide application.

The most reliable measure of lacanobia fruitworm density was a visual inspection of foliage feeding. It was best to conduct this sample after egg hatch was complete and before larvae became mature. In general, this occurred near the end of June. While this sample timing may be too late to make a decision to apply selective insecticides, it can be used to determine the need for insecticides that will protect the crop from losses due to feeding of large larvae. Visual inspection also requires that a large number of trees be examined because lacanobia fruitworm larvae are not uniformly distributed throughout the orchard. Twenty shoots from 50 trees should be examined in a large block, noting the percentage of shoots that show feeding damage.

Thresholds: In an effort to establish treatment thresholds the relationship between pheromone trap catch, shoot injury, beating tray samples and fruit injury was examined. Data were taken from orchards that had limited insecticide inputs such as from untreated portions of chemical trials. Our ultimate goal was to predict fruit injury from various measures of lacanobia fruitworm populations or activities. However, it turns out that there is not a good correlation between any measure of lacanobia fruitworm density or activity and fruit injury. This is most likely because lacanobia fruitworm only incidentally feeds on fruit, and horticultural effects like crop load, clustering of fruit, shoot growth, weed management and fruit maturity can all affect the amount of fruit damage that occurs.

The relationship between foliage feeding and fruit injury is presented in Fig. 3. A 30-35% level of shoot feeding was correlated with 1% fruit injury. It appears that apple orchards can tolerate a high lacanobia fruitworm density before significant fruit injury occurs. However, this threshold is based on foliage feeding at 100% egg hatch and was thus too late to apply insecticides that must be targeted at young larvae. Therefore, treatment thresholds based on trap catch or beating trays were needed to predict either fruit injury or shoot infestations.

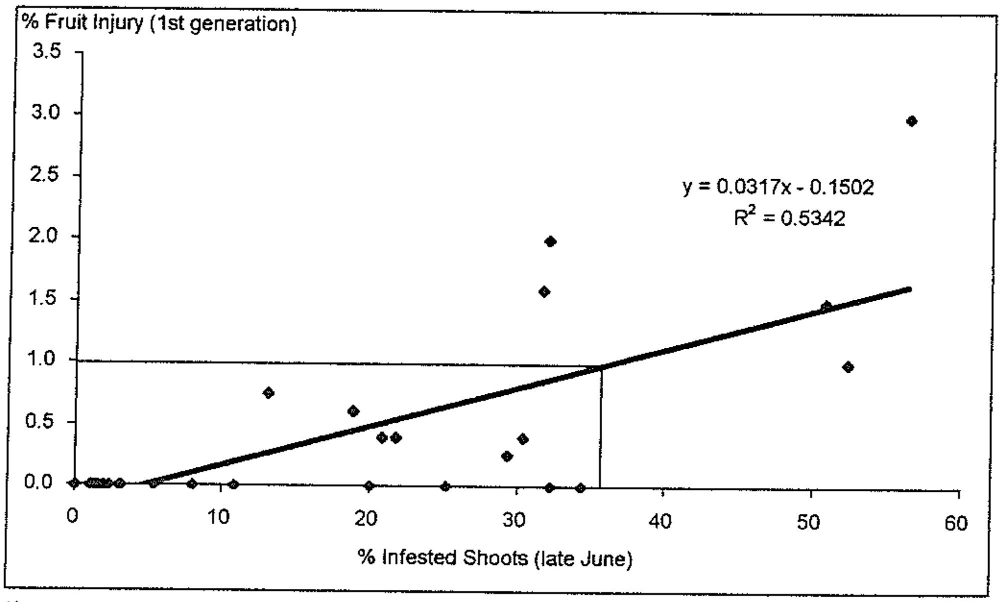

Figure 3. Correlation of lacanobia fruitworm larva infested shoots in late June and fruit injury noted at the end of the first generation (early August).

Peak trap catch provides an indicator of population level in an area and can serve as a presence/absence indicator. Orchards with peak trap catch less than 150 moths/week did not have shoot injury in the critical 30-35% range. The problem was that some orchards had very high peak trap catches but had low levels of foliage feeding. Therefore, a peak trap catch that exceeds 150/week should trigger a search for egg masses in late May or early June and/or use of beating tray samples and foliage inspection in mid-June to further assess lacanobia fruitworm densities. If egg masses or larvae are not detected in the orchard, then controls are most likely not required. A sample of neighboring blocks or areas containing weeds such as mallow, curly dock, dandelion, pigweed or lambs quarter may reveal the external source of moths. What constitutes a treatable population is the most important decision for managing lacanobia fruitworm. It is apparent that, after three years of intensive sampling, no single measure of lacanobia fruitworm density provided an accurate and reliable treatment threshold.