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Economic Thresholds for Today's Commodity Values

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This article will discuss economic thresholds, their development, and the effect of high commodity value on their determination.

Definitions

First, let's start with some definitions. Different disciplines often use terms a little differently, and definitions can vary somewhat among entomologists or even context. So, we will review a few definitions as they relate to arthropod pest management in field crops.

Injury: The physical harm to a commodity caused by the activity of a pest (e.g., eating leaves, tunneling through stalks, eating grain, etc.).

Damage: The value (in dollars or utility) lost to the commodity as a result of pest injury (e.g., yield loss, quality reduction, etc.). **Not all injury results in damage.**

Damage curve: The relationship between injury and yield.

Economic injury level: The smallest number of pests (or injury) that will cause yield losses equal to the pest management costs.

Economic threshold: The density of a pest (or level of injury) at which control measures should be initiated to prevent an increasing pest population from reaching the EIL.

Economic Threshold Development

Today it is understood that pest management, not pest eradication, is the most desirable strategy for dealing with pests to maintain environmental quality and to improve net profits. Usually, some levels of pests are tolerable and do not cause significant economic damage. Indeed, a low level of pests is usually desirable to maintain populations of natural enemies. Consequently, assessing pest status is critical. This is done by sampling to estimate how many insects are present or how much injury is occurring, and then weighting the impact of the pests against the current costs of managing them.

Two tools used in this decision process are the economic injury level (EIL) and the economic threshold (ET). These are procedures for assessing the impact of pests on yield and/or quality and the economic costs and benefits of management.

The Damage Curve

The damage curve is the relationship between different levels of injury and the yield response of a given commodity (e.g. soybeans, corn). In figure 1 we see a hypothetical damage curve. There are 7 components to this damage curve; tolerance, overcompensation, the damage boundary, compensation, linearity, desensitization, and inherent impunity.

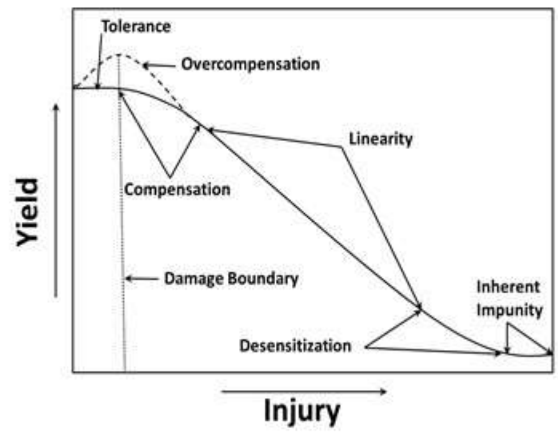

Figure 1. The damage curve and its components.

Tolerance is when plants can sustain some injury without any effect on yield. **Overcompensation** is observed in some plants, where a small amount of injury actually increases yield slightly (e.g. light defoliation of soybean). The **damage boundary** is the point at which yield loss caused by injury is detectable. **Compensation** is where there is increasing yield loss per unit of injury, and **linearity** is where there is maximum yield loss per unit of injury. **Desensitization** is where there is decreasing yield loss per unit of injury, and **inherent impunity** is where there is no more damage per unit of injury.

The damage curve in figure 1 is hypothetical. All plants may not display the complete set of damage curve components, and a number of factors can affect the relationship between injury and yield loss (i.e. the damage curve). These factors include the type of injury, the timing of injury, the intensity of injury, the location of injury (e.g. plant part, plant strata), and various environmental factors.

The type of injury is important because it determines how the plant is impaired by the injury (e.g. reduced photosynthesis), and can be classified as indirect, direct, or quantal injury. **Indirect injury** is the result of pest activity (e.g. feeding, tunneling, etc.) that harms a non-yield portion of a plant, such as defoliation of soybean. **Direct injury** is the result of pest activity that harms a yield portion of a plant, such as feeding on soybean seeds. **Quantal injury** is where the quantity injury is independent of the yield, such as with the transmission of soybean mosaic by soybean aphid.

Most yield loss research has been conducted on insect populations that correspond to the linear portion of the damage curve. This is for various reasons, two of which are that most economic damage occurs in the linear portion of the curve and research with low densities of insects is extremely difficult, and the high cost of research necessitates focusing research efforts on the region where the most relevant and useful information can be obtained.

Not All Thresholds are Created Equal

When EILs and ETs have not been established for a pest, nominal thresholds (a type of estimate) are used to aid in making management decisions. Nominal thresholds are used when the relationship between insect injury and economic loss has not been characterized. These thresholds are usually not based on research studies designed to examine specific yield-loss relationships, but rather on field examination, expert opinion, and experience. While better than no thresholds, nominal thresholds often are very conservative and do not reflect fluctuating economic conditions. Currently, many extension recommendations are based on nominal thresholds. They can often be identified as being a fixed number or simple range (e.g. 4 insects per sweep, 2-4 larvae per foot, etc.).

Simple economic thresholds are research based, calculated from EILs, and are often expressed as tables, such as bean leaf beetle on seedling soybean ET tables, or interactive worksheets.

Comprehensive economic thresholds are research based, often being complex models that may include a plant growth model, an insect seasonal development model, interactions with weed and disease biology and management, and so on. There are few truly comprehensive economic thresholds, although there are quite a few that are somewhere in between a simple and comprehensive level. Interestingly, an economic threshold derived from a relatively comprehensive research base is that for soybean aphids on soybean, which is expressed as a single value, 250 aphids/plant with aphid populations increasing.

EIL and ET Calculation

The EIL can be thought of as the break-even point between economic loss from the pest and the costs of managing the pest. Because economic conditions (e.g. commodity market value, management costs) fluctuate, the EIL will fluctuate. This can be illustrated by considering how a typical EIL is calculated. The EIL equals the pest management costs (C) divided by the commodity market value (V) times the yield loss per pest (DI) times the proportion of the pest population controlled (K), or

EIL = C/(V x DI x K.)

If management costs (C) increase, then it takes more pests to justify control action, so the EIL increases. Similarly, if market values (V) decrease, then more pests can be tolerated and again the EIL increases. Or, if you can expect to get better than standard coverage when you spray, and therefore can expect to kill a higher percentage of the pest (K), then the EIL increases.

Anything that changes any of the EIL variables will change the EIL. The EIL can also be thought of as a "tolerance index". That is, it indicates how many pests we can tolerate, given a specific set of costs, benefits, and plant response to injury. If the crop is of high value and/or susceptible to a particular pest injury, the EILs will tend to be low, indicating we can tolerate few pests before we incur economic damage. If the crop is of lower value and/or tolerant of a particular pest injury, the EILs will tend to be high because we can tolerate a higher number of pests before incurring economic damage.

Ideally, management action should be taken before a pest population reaches the EIL to avoid economic damage that could otherwise be prevented. To achieve this we use the economic threshold or ET, which is based on the EIL. The ET indicates when to take control action and is the pest density at which management action should be taken to prevent an increasing pest population from reaching the EIL. It assumes that once the ET is reached, there is a high probability that the EIL will subsequently be reached if no management action is taken. Because the ET is directly related to the EIL, changing economic conditions also will result in fluctuating ETs. Figure 2 presents the typical relationship between the EIL and ET.

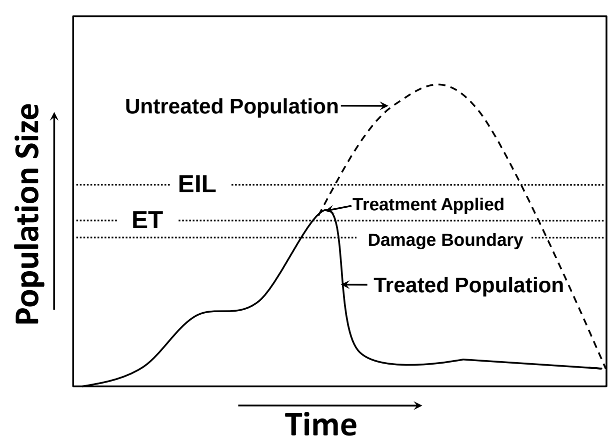

Figure 2. The relationship between the EIL and ET.

Note that in figure 2 the damage boundary, the point at which yield loss caused by injury is detectable, is below the ET. This is not always the case, as the damage boundary can below, at, or above the ET, depending on the specific crop/pest relationship. No damage is occurring at pest population levels below the damage boundary. Some damage is occurring at populations between the damage boundary and the EIL, but it is not economic damage – it is below the break-even point (i.e. the EIL). At population levels above the EIL, economic damage is occurring, and this is what a management plan that uses ETs is intended to prevent.

At first glance, EIL and ET development and calculation appear fairly straightforward, and one might expect there to be more true ETs and fewer nominal thresholds. However, while commodity market values and pest management costs are fairly easy estimate, a critical component in EIL, yield loss per pest, can be complicated and difficult to obtain. The major stumbling blocks are establishing the relationship between pest injury and yield loss and the variability in that relationship. A minimum of 2 to 3 years are required to complete the required research, and during this time differences in crop varieties, crop production practices, and particularly weather contribute to the variability in measured plant responses. Also, experimental methods can contribute to variability. Finding and manipulating the required numbers of insects is problematic and often requires rearing facilities, cages, etc.

Establishing an ET also is extremely complicated. Because the ET represents a prediction of when a pest population is going to reach the EIL, we ideally require a thorough understanding of the pest's population dynamics in the cropping system of interest. Again, this requires extensive research beyond that which established the EILs. A major reason we do not have EILs and ETs for every pest is the substantial research requirements of labor, time, and money required for establishing EILs and ETs. Consequently, ETs are often based on some percentage of the EIL, such as 80%.

The labor, time, money and experimental constraints also point to other limitations to EILs and ETs. The crop-yield relationships that result from a 2 to 3 year study may not be applicable across the entire range of grower management practices or environmental conditions. For example, EILs and ETs determined for 30-inch row soybeans may differ for drilled beans. In addition, plant response to injury can be affected by precipitation patterns and amounts. This illustrates the point that the EIL and ET are tools for decision making. They should not be the sole factor considered when making a pest management decision.

EILs and ETs must be used in the context of the current field conditions and economics. Remember, the use of thresholds assumes that the fields are properly scouted so that decisions can be made when pest problems first appear. Local weather conditions, crop production practices, soils, cultivar selection, field history, etc, will vary and should be considered. For example, thresholds may not be valid for circumstances where decisions must be made after significant injury (e.g. pest injury, herbicide injury) has already occurred. This may seem complicated. That's because it is. However, once you understand the factors going into EIL and ET development, you can use published ETs as a benchmark, and then adjust them to fit your own conditions. This is essentially what successful producers and crop consultants have been doing for years.

They also illustrate the importance of using the best thresholds and the best information to modify our use of thresholds. There are a few principles we can use in this process.

Using Economic Thresholds

Remember that ETs, and the EILs these are based on, are not single numbers (except in current soybean aphid recommendations, but that is a special case). They vary with crop value, management costs, and insecticide efficacy. The ETs will differ between different insecticides and between different rates of the same insecticide. The higher the crop value, the lower the ET. The higher the insecticide cost, the higher the ET. Often EILs and ETs are presented as single values. If this is all you have available, use the threshold with caution. If there is a table or formula or program for determining ETs, you may be able to determine the ET with the specific crop and insecticide costs for your situation. In this case, the ET is a better guideline, but it is still a guide.

Recent economic conditions have uncovered a problem for many published thresholds. They simply do not consider the high commodity values we have recently experienced. The initial tendency is to lower thresholds, either by some proportional reduction or, if available, using the new commodity values in the existing EIL formula. Although this may be appropriate in some situations, in some it is not, particularly when commodity values are relatively high.

A fundamental reason relates to the damage curve (Figure 1). We know that for many, if not most, relationships between injury and yield response there are certain low levels of injury, and hence pest density, where there is no yield loss (i.e. damage), and for some crops there is a slight yield increase – the tolerance or overcompensation zones of the damage curve. As noted earlier, we have very little research on crop injury or pest populations at these low levels, so we do not know precisely where the point of noticeable damage occurs. Simply lowering the threshold proportionally, as might be done with nominal thresholds or some simple economic thresholds, could set the threshold in the tolerance or overcompensation zone, where no yield loss occurs, or in the compensation zone where the yield loss may not be economic.

Where EIL formulas exist, one might ask "why not simply use the new commodity values in the existing EIL formula and use those EILs to determine the new ETs?" While this would likely be an appropriate step when commodity values were only slightly higher than those originally used in the EIL calculations, for some crops the recent commodity values have been so much higher that doing this would be inappropriate. This again relates to the damage curve. As noted earlier, most research has been conducted on insect populations that correspond to the linear portion of the damage curve. The yield loss per unit of injury is constant along this portion of the curve, and a corresponding EIL formula, such as EIL = C/(V x DI x K.), assumes this linearity. At curvilinear portions of the curve (e.g. the tolerance or compensation zone of Figure 1), the EIL formula no longer applies. One could again be setting the EIL at pest densities corresponding to the tolerance or overcompensation zones of the damage curve.

Another reason that simply lowering the thresholds may be inappropriate relates to the specificity of the particular pest/crop system under consideration. For example, the current economic threshold for the soybean aphid on late vegetative through R5 stage soybeans is 250 aphids per plant (field average) with 80% of the plants infested and populations increasing. Depending on economic conditions, this gives you about five to seven days to schedule treatment before populations reach economic injury levels. The density of 250 aphids per plant is not only well below EILs, which are typically well over twice the ET, but also below the damage boundary. No yield loss occurs at 250 aphids per plant. Researchers have observed that once aphid densities reach 250 aphids per plant, the probability is high that the populations will subsequently reach economically damaging levels, however, the ultimate density level cannot be predicted. At population densities below 250 aphids per plant, and particularly below 100 aphids per plant, there is no damage and population densities often remain low. So even when EILs are lower because of high commodity values, the economic threshold of 250 aphids per plant remains an appropriate trigger to take action. What does happen is that instead of a treatment window of up to seven days, the treatment window is reduced to 4-5 days.

So What To Do?

As indicated above, there is no one-size-fits-all solution to altering ETs. Fortunately, extension entomologists are aware of this dilemma and are doing several things about it.

Extension entomologists in each state, including Nebraska, are reviewing thresholds and addressing higher commodity values when making management recommendations. In Nebraska, our pest management articles in the *CropWatch* newsletter (http://cropwatch.unl.edu) will be written considering the most current and projected commodity values.

New research is being conducted to better describe the entire damage curve for various pest/crop systems. For example, Nebraska entomologists are examining western bean cutworm ecology and injury to corn.

If you only have extension recommendations published prior to 2007 available, you will have to use your experience when considering if to lower the thresholds. Remember, nominal thresholds are already very conservative, so do not lower them very much, if at all. If there is a range, such as 2-4 insects per plant, use the lower value. Be careful at proportionally lowering thresholds from ET tables. If the commodity values are higher, but relatively close to those in the published ET table, lowering the ETs is probably appropriate. If the commodity values are much higher (e.g. 2X or more), however, proportionally lowering ETs may be inappropriate.

You can always contact your local extension office or go to http://cropwatch.unl.edu/ for the most current information.

A Final Word

Even the best threshold is only a guide for your decision. Good thresholds will help you avoid unnecessary insecticide use. Good thresholds also provide a great starting point for considering the specifics of your pest and crop situation. The best use of thresholds is to weigh their likely accuracy (is the threshold a single number, is it specific to your situation), and then consider how you might need to modify the decision indicated by the threshold to fit your circumstances. Generally, vigorous crops can tolerate more injury and stressed crops are less able to tolerate injury.

Entomologists are working on developing better sampling plans and better thresholds for improving pest management decisions. Thresholds are valuable aids for producers, but knowing how to use them is at least as important as the thresholds themselves. The more we understand about the pest situation and the growth of the crop, the better our pest management decisions are likely to be. We may not always have thresholds as good as we might like, and we may not always have as much information about a given pest situation as we might like. But the better our thresholds and the better our understanding of the crop, the closer we will get to making the best decisions.

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