Theory and Practice of Integrated Pest Management in the 21st Century

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**Theory and practice of integrated pest management in the 21st century**

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**Introduction**

Webster defines a pest as any plant or animal that is detrimental to humans or human concerns (especially in agriculture or livestock production). Pest control has been a serious issue for humans since the dawn of civilization. Through the centuries, mechanical, biological, cultural and chemical controls of pests have evolved. The reasoned use of pesticides dates to at least 2500 BC, when sulfur was used as a control of mites and insects. As technology advanced, control measures were adjusted and new techniques and materials were discovered, and those changes greatly accelerated in the previous century.

**The evolution of pesticide use**

One marker of the dawn of the modern, artificially produced pesticide era is Paul Müller's 1939 discovery of DDT at the Geigy Chemical Company. During World War II, DDT found extensive and successful use in combating the insect vectors of yellow fever, malaria and typhus. About the same time, the chemical 2,4-D was developed as a defoliator to assist clearing vegetation for battle targeting in the war. At the end of the war, attention shifted to peacetime uses of these and other chemical "tools" to protect against pests, with crop production being the major focus. These new chemicals rapidly gained overwhelming popularity. However, dark clouds gathered on the horizon associated with the growing dependence on pesticides for economic pest control, notably the early development of resistant pest lines, and environmental concerns when products applied for good purposes wound up leaving the site and causing non-target damage, or lasted long enough to carry over and cause problems in subsequent crops. In 1947, the Federal Insecticide, Fungicide and Rodenticide act (FIFRA) became law, establishing a regulatory framework for registering pesticide products and regulating their safe use in the United States.

In the late 1950s, researchers explored scientific-based strategies toward wise use of pesticides, including using economic appropriateness as a key to decision making about product use and rates. The concepts of economic injury levels and economic thresholds were developed and employed as agriculturists learned to use pesticides more effectively. Economic injury levels (EILs) and economic thresholds (ETs) are derived by knowing what size pest population will cause sufficient damage to a crop that a practice or treatment will save at least the cost of treatment. These paired concepts are foundations of a management regime called Integrated Pest Management, or IPM. IPM encourages consideration of the use of different crop-appropriate and pest-appropriate tactics, including cultural—such as crop rotation or variety selection, mechanical—such as cultivation, biological—including both controlled releases and consideration of practices to avoid the loss of biocontrol agents and finally chemical—including pesticides. By understanding the dynamics of when a given pest is damaging and when it should
be controlled, these control tactics can be targeted most appropriately. Economic thresholds are important in that they anchor pest management decisions to an economic foundation—which is palatable to the grower who can see tangible benefits. But for some pest situations where research has not or cannot establish economic responses to base an ET, other reasonable action thresholds have been developed. These “nominal” thresholds are based upon a person’s understanding of the pest’s biology tied together with field experience, and are rarely based on rigorous research. Nominal thresholds tend to be static—that is, unchanging with changes in crop value, control costs, or plant development stage. As an example, the current threshold values used in Iowa for western bean cutworm management on corn are nominal thresholds. Although western bean cutworm has been reported in Iowa for decades, economically damaging populations were only observed, starting in the early 2000s. These nominal thresholds were applied based on experience of entomologists in Nebraska and other western states, while research is being conducted to better understand this cutworm’s response to Iowa conditions. IPM has taken a central role in modern commercial crop production that entails constant readjustment in crop management plans as observations, understanding of crop and pest development, technology and economics change.

In 1962, further attitude change toward pest management was highlighted with the publication of Silent Spring by Rachel Carson. The central theme of the book is a wake-up call to society in general about adverse effects on ecosystems from pesticide use. As the 1960s turned into the 70s, the United States established the Environmental Protection Agency (EPA) as an administrative unit to oversee and regulate most societal practices that carry environmental consequences. Very early on, administration of most of the regulatory function of FIFRA and related laws was transferred to the EPA. The core principles of IPM were encouraged as a way to approach wiser use of pesticides, because accommodation of environmental concerns and avoidance of adverse environmental effects are included and are part of decision making at the farm level.

**Changes in agriculture**

IPM is a system that incorporates change as conditions warrant. That ability to adopt is important because a major factor in agriculture is change. Farms are industries that function by coordinated use of four major natural resources, namely land, climate, labor and genetic material. Each of these four resources has been and will continue to be a focus of change that affects management decisions. Notable examples for each include the following:

**Land**

Perhaps the most constant of the four inputs, but increased understanding of land capabilities allowed for more appropriate uses with increased productivity. Erosion control practices including waterway and terrace establishment, or more subtle practices like improved crop residue management.

**Climate**

Understanding predictable patterns has historically changed farming practices. In the early 1900s, Iowa wheat farmers learned that damage from a particularly devastating pest called the Hessian fly could be minimized by planting after the fall “fly-free” date, so wheat was emerging after the fall oviposition. Fly-free dates varied from south to north based on climate. In recent
years, understanding how ambient temperatures affect development of several insect pests (including black cutworm, bean leaf beetle, and stalk borer) of corn and soybean allows for more effective scouting and treatment.

### Table 1. Examples of degree days for insect management on Iowa corn

<table>
<thead>
<tr>
<th>Pest</th>
<th>Base (°F)</th>
<th>Use of Degree Days (DD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedcorn maggot</td>
<td>39</td>
<td>Adults emerge at about 200, 600 and 1000 DD</td>
</tr>
<tr>
<td>Black cutworm</td>
<td>51*</td>
<td>300 DD from egglaying to cutting</td>
</tr>
<tr>
<td>Stalk borer</td>
<td>41</td>
<td>When 1,300-1,400 DD have occurred in an area, scout by pulling whorls to determine if larvae are present.</td>
</tr>
<tr>
<td>Western bean cutworm</td>
<td>50</td>
<td>50% adult emergence and egglaying at 1422 DD after May 1</td>
</tr>
</tbody>
</table>

*previously was 50°F but current research has established 51°F as more accurate.

### Labor

The shift from horse-driven implements to internal combustion engines permanently changed agriculture, allowing larger, faster equipment that could cover more acres in less time with fewer operators needed per acre. With fewer operators needed per acre, the number of farm units has dropped through time.

### Genetic materials

The introduction of hybrid corn to agriculture revolutionized agronomy in the Cornbelt. And this revolution has continued as plant breeders have discovered traits that have improved yield potential and afforded insect and disease tolerance and resistance. In the last two decades, access to technologies that allow insertion of new genetic material from other species into the genome have dramatically altered the crops we grow. Chief among these are Bt-resistance for insect management and herbicide resistance for weed management. These new technologies can provide great economic benefits but also present great challenges. As with any new advance, there are consequent peripheral considerations. Genetically engineered crops are viewed skeptically by some as a threat to natural ecosystems, and containment of the genetic from “escaping” the field is raised as a concern. But greater concerns lie in the widespread use of one of these transgenic tools. One is that widespread use may lead to the target pest potentially developing tolerance or resistance to that tool so it loses effectiveness. In addition, the blanket use of a transgenic crop (or some non-transgenic practices, for that matter) can lull the producer into a false sense of security. From the assumption that a transgenic crop is controlling a pest has sometimes led growers to reduce monitoring of weed or insect issues, reducing their ability to catch emerging problems early.

### IPM in the 2000s

For more than 40 years, average Iowa farm sizes have steadily increased concurrently with a decrease in the number of farms operations, while total acreage farmed in Iowa is essentially unchanged (Figures 1 and 2).
Figure 1. Average Iowa farm size 1975--2007.

Figure 2. Number of farm operators 1975--2007.
The trend of fewer operators on larger farms has implications to crop management systems. But perhaps an equally important change from the increase in average farm size is the shift toward both extremes in farm size. So the average farm size is still that, but many operations now fall farther and farther to the extreme in farm size.

Table 2. Iowa farm size trends from 1974 to 2002.

<table>
<thead>
<tr>
<th>Farm size group:</th>
<th>1974</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 50 acres</td>
<td>14,652 (11.6%)</td>
<td>21,089 (23.3%)</td>
</tr>
<tr>
<td>50—499 acres</td>
<td>97,098 (77.0%)</td>
<td>48,969 (54%)</td>
</tr>
<tr>
<td>500 acres or greater</td>
<td>14,374 (11.4%)</td>
<td>20,597 (23.1%)</td>
</tr>
<tr>
<td>2000 acres or greater</td>
<td>150 (0.1%)</td>
<td>1,321 (1.4%)</td>
</tr>
<tr>
<td>Total number of farms</td>
<td>126,124</td>
<td>90,655</td>
</tr>
</tbody>
</table>

Many of the smallest farms are either diversified, producing specialty organic or niche crops, or are dedicated to production of high unit-value crops like wine grapes or other fruits or vegetables. The larger farm units are nearly all dedicated to corn and soybean production. In addition, the percentage of farm operators who engage in part-time off-farm employment increased from 26% in 1950 to 55.7% in 2002. This stratification of farm size and increase in off-farm employment has done several things. One is that for corn and soybean production there are increasingly fewer producers making decisions about more and more acres, perhaps with increasingly reduced time. As farms have consolidated, often agricultural service providers have consolidated in turn. The reduction in numbers of agricultural service providers means that the information flow from applied research to the growers who use the information must be channeled appropriately.

Conclusions
Although it may seem on the surface that some pest problems have been simplified or solved by technological advancements, the need for integrated pest management in Iowa crop production will remain. As both input costs and commodity value fluctuate and as established pests adjust to technologies and new pest problems arise, challenges will remain. Economic thresholds that drive pest management decisions may change, but IPM will remain as a key to economic and environmental sustainability. The biggest challenges will be maintaining communication between applied researchers, private and public sector agronomists and farmers. Assessment of pest populations and crop conditions must be designed that are easy for growers to understand and implement, while the results gained are still valid.
References


