Efficacy and Value of Prophylactic vs. Integrated Pest Management Approaches for Management of Cereal Leaf Beetle (Coleoptera: Chrysomelidae) in Wheat and Ramifications for Adoption by Growers

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ABSTRACT Cereal leaf beetle, *Oulema melanopus* L., can be effectively managed in southeastern U.S. wheat, *Triticum aestivum* L., with scouting and a single insecticide treatment, applied at the recommended economic threshold. However, many growers eschew this approach for a prophylactic treatment, often tank mixed with a nitrogen application before wheat growth stage 30. The efficacy of a prophylactic and an integrated pest management (IPM) approach was compared for 2 yr using small plot studies in North Carolina and regional surveys across North Carolina and Virginia. Economic analyses were performed, comparing the total cost of management of each approach using the regional survey data. From a cost perspective, the prophylactic approach was riskier, because when cereal leaf beetle densities were high, economic loss was also high. However, fields under the prophylactic approach did not exceed threshold as often as fields using IPM. Total cost of prophylactic management was also $20.72 less per hectare, giving this approach an economic advantage over IPM. The majority of fields under the IPM approach did not exceed the economic threshold. Hence, from an economic perspective, both the prophylactic and IPM approaches have advantages and disadvantages. This helps explain the partial, rather than complete, adoption of IPM by southeastern U.S. wheat growers. Cereal leaf beetle was spatially aggregated across the region in 2010, but not in 2011. As a result, from an economic standpoint, prophylaxis or IPM may have a better fit in localized areas of the region than others. Finally, because IPM adoption is favored when it has a strong economic advantage over alternative management approaches, more emphasis should be placed on research to reduce costs within the IPM approach.

KEY WORDS regional survey, economic analysis, risk aversion, pyrethroid

With higher grain prices and the relative low cost of application, fungicide use has greatly increased across field crops in recent years (Paul et al. 2011); a similar phenomenon is likely occurring with insecticides. The integrated pest management (IPM) approach does not obviate the use of pesticides. Nonetheless, a long-range goal of IPM is the reduction of pesticide use through the combined synergistic effects of multiple pest management tactics (Ehler 2006). In contrast to IPM, many southeastern U.S. wheat growers use prophylactic insecticide applications, a practice with origins and support from the agrochemistry industry. The timing of these insecticide sprays corresponds to plant, rather than pest, phenology. Prophylactic insecticide sprays are theoretically (Stern et al. 1959), and often practically, inferior to IPM (Smith et al. 1989, Harris et al. 1998, Greene et al. 2009, Bueno et al. 2011). However, the reasoning for the lack of adoption of IPM practices by growers can be complex. Adoption generally involves a risk aversion calculus based on the perceived relative low cost of a pesticide compared with the high yield benefit of the crop (Trumble 1998, Marra and Calson 2002). Furthermore, pests have a range of ecological complexity that spans factors such as differences in generations, behaviors, insecticidal tolerances, and proclivity to resistance development, further complicating the portability of the economic threshold concept. The use of economic comparisons of IPM and grower standard programs has been advocated as a method with which to overcome the barriers to IPM adoption (Trumble 1998).

The invasive cereal leaf beetle, *Oulema melanopus* L. (Coleoptera: Chrysomelidae), was first detected in Michigan during the 1960s. It is native to Europe and Asia and is a major pest of wheat, *Triticum aestivum*. Recognizing the threat of this pest to the U.S. wheat crop, large-scale quarantine, and eradication efforts endeavored to eliminate the beetle. These encom-
passed broad-spectrum insecticide sprays (organophosphates) over nearly a million hectares of the Midwest and generated numerous lawsuits from the general public on a yearly basis (Haynes and Gage 1981). This approach was terminated, because the cereal leaf beetle continued to spread (Haynes and Gage 1981) by natural means and human movement (e.g., as overwintering adults underneath the bark of Christmas trees; Hess 1971). It is now distributed across the upper Midwest and across many parts of the eastern, southern, and northwestern United States. Currently, it is threatening large wheat growing regions in the central Midwest, which represent ~40% of the U.S. wheat acreage (National Agricultural Pest Information System [NAPIS] 2011, U.S. Dep. Agric.—NASS [USDA—NASS] 2011). It is well established in the Southeast (Buntin et al. 2004), where it is the one of most significant insect pests of wheat.

Cereal leaf beetle is a univoltine pest, with its population development closely correlated with temperature. Adults emerge from overwintering, when high temperatures are consistently warmer than 14°C, and move into wheat fields to mate and lay eggs (Helgesen and Haynes 1972, Guppy and Harcourt 1978). The larval stage of this insect injures wheat by removing photosynthates from the leaf. This can cause a cascade of negative indirect effects on the plant, such as water loss, early senescence, tiller reduction, and stem mortality (Haynes and Gage 1981), in addition to the loss of the cellular mechanisms responsible for filling grain. In general, cereal leaf beetle larvae infest and feed on wheat in North Carolina and Virginia from growth stage (GS) 45 (boot stage; Zadoks et al. 1974) to GS 83 (early dough stage) of crop development (Ihrig 2001).

Current effective management tactics for cereal leaf beetle (from both an economic and performance perspective) are limited to broad-spectrum insecticide applications (generally pyrethroids) at the field level. Although these insecticides (when applied at the correct time) are effective against cereal leaf beetle, they are also effective at eliminating natural enemies that may regulate cereal leaf beetle population densities (Theiling and Croft 1988). Furthermore, formerly secondary wheat pests, such as aphids, can increase abundance in the absence of their natural enemies. In the United States, ladybird beetles (Coleoptera: Coccinellidae) are cereal leaf beetle predators (Yun and Ruppel 1964), as are five parasitoid species, which were released in the 1960s (Philips et al. 2011). Although parasitism success rates of up to 90% were achieved from these classical biological control release efforts in some areas of the United States, the parasitoids did not establish well in North Carolina and Virginia (Philips et al. 2011). Additionally, parasitoids do not impact cereal leaf beetle population density in other areas of the United States, such as Indiana (Gutierrez et al. 1974). Finally, although some varieties of wheat demonstrate cereal leaf beetle resistance, these varieties yield less than commercially grown susceptible varieties; thus, they are not economically viable as a stand-alone long-term solution (Philips et al. 2011).

As a result IPM decisions to spray for cereal leaf beetle on wheat are generally based on several sampling visits over consecutive weeks in the spring. The economic threshold of 25 eggs and/or larvae per 100 tillers, with more larvae than eggs present, is recommended before insecticide treatment in both Virginia and North Carolina wheat. Because cereal leaf beetle is spatially-aggregated on a field-level (Reay—Jones 2010), visiting at least four sites per field is recommended (Herbert 2009, Reisig et al. 2011). All fields should be scouted, because predicting where outbreaks occur is not possible at this time.

A subset of southeastern U.S. wheat growers eschew the recommended IPM program and prophylactically treat for cereal leaf beetle, generally by tank mixing a pyrethroid with liquid nitrogen during their last spring nutrient application. Recommended times for the last green up application are when the wheat has reached GS 30 (Weisz and Heiniger 2011), which is when the stem begins to elongate. The date at which wheat reaches this growth stage depends on the planting date, variety, and weather; this can range from February to mid-March in North Carolina (Weisz and Heiniger 2011). In North Carolina and Virginia, larval cereal leaf beetle population densities generally peak around GS 45 (Philips et al. 2011). Therefore, insecticide applications at GS 30 may not be optimally timed. Furthermore, such applications likely eliminate beneficial predators and parasitoids, negating possible benefits from biological control.

The experimental objective described in this manuscript was to compare the prophylactic management approach to an IPM approach for cereal leaf beetle management. We hope that this will provide an explanation for the partial, rather than complete, adoption of IPM practices by southeastern U.S. wheat growers. Small plot experiments were designed to test the hypothesis that prophylactic pyrethroid applications in plots would effectively manage cereal leaf beetle, compared with plots using an IPM or untreated approach. Effective cereal leaf beetle management was defined as maintaining pest densities below the economic threshold. Furthermore, a 2-yr survey was conducted to compare the number of fields that reached cereal leaf beetle threshold levels using a prophylactic or an IPM-based approach. Both approaches were compared and contrasted in relation to pest management efficacy and economic cost and benefit. The ecological impact of each approach was not directly considered in these studies.

Materials and Methods

Small-Plot Trials. Wheat (variety, SS 8302) was planted on 29 October 2009 and 2 November 2010 at 134 kg seed/ha at the Tidewater Research Center, near Plymouth, NC. Field maintenance followed recommended North Carolina Cooperative Extension guidelines (Weisz 2011), except for insect pest management. Small plots, measuring 1.5 × 9.1 m were established by applying lambda-cyhalothrin (prophylactic treatment; Warrior II at 33.6 g ai/A, Syngenta
Crop Protection, Greensboro, NC) on 16 March 2010 and 14 March 2011. Plots of two treatment types and untreated controls were interspersed in a randomized complete block design. One treatment type was prophylaxis, where plots were treated with insecticide at GS 30 independent of cereal leaf beetle densities. The other treatment type was IPM, where plots were only treated if cereal leaf beetle densities reached threshold abundances (Herbert and Van Duyn 2009). Cereal leaf beetle eggs and larvae were sampled by pulling 10 random tillers from each plot and counting the number of eggs and larvae. Sampling took place once a week and was initiated in March and terminated at the end of April during both years. As an extrapolation of the published threshold based on 100 tillers per field, insecticide was applied to the IPM-treatment plots only if there was an average among the four plots of >2.5 eggs and/or larvae per plot (10 tillers) and there were more larvae than eggs. A single application of lambda-cyhalothrin (Warrior II at 33.6 g ai/A, Syngenta Crop Protection) was made on 16 April 2010 to the IPM treatment, but an application was not made to this treatment in 2011.

All plots planted in 2009 were harvested on 10 June 2010 using a Wintersteiger Delta plot combine (Wintersteiger Inc., Salt Lake City, UT) equipped with a HarvestMaster grain gauge (Juniper Systems, Inc., Logan, UT). All plots planted in 2010 were harvested on 10 June 2011 using a Cleaner K2 (AGCO, Duluth, GA) combine fitted with a HarvestMaster grain gauge (Juniper Systems, Inc.). Bushels were calculated by adjusting for recorded moisture and adjusting back to 14% standard moisture.

Cumulative insect-days were calculated for cereal leaf beetle larvae (Ruppel 1983). Cumulative larval-days, grain moisture, and bushels per acre were analyzed in separate analyses as the dependent variable using a general linear mixed models approach (PROC MIXED; SAS Institute 2008a). Treatment was specified as a fixed factor, while block was specified as a random factor. Mean separations were analyzed for statistical significant using Tukey’s honestly significant difference (HSD). Values were considered significantly different for all analyses using α < 0.05 as a threshold.

Regional Survey. Cooperative extension agents in North Carolina and Virginia were contacted in both 2010 and 2011 to select wheat fields under two management types in their respective counties. Fields were selected from counties spread across the wheat growing regions of North Carolina and Virginia. One type, designated IPM management was defined as fields that would either not be treated for insects for the duration of the growing season (untreated), or fields for which the grower used scouting and the published thresholds for cereal leaf beetle (Herbert 2009, Reisig et al. 2011) before making an insecticide treatment. The second type, designated prophylactic management, was defined as fields for which an insecticide application had been made near GS 30 and for which no scouting or economic threshold were used. Although active ingredient of the insecticide growers used varied, all growers treated with the pyrethroid class of chemicals. An attempt was made to select an equal number of fields of each type spread throughout each county, so that field location between field types (prophylactic and IPM) would be random. However, this was not always feasible, as there are some areas in which all growers use the prophylactic approach. In 2010, 72 IPM and 34 prophylactic fields were selected for sampling, while in 2011, 55 IPM and 35 prophylactic fields were selected for sampling (Fig. 1).

From these fields, sampling was conducted once a week for a 4-wk period before the peak cereal leaf beetle infestation. In 2010 and 2011 sampling commenced in mid-April. Some population dynamics are known for cereal leaf beetle (Reay-Jones 2010) and sampling ended 4 wk after initiation because the peak larval abundance had passed. Some fields in Virginia were sampled for an additional week because the populations developed more slowly in these more northern latitudes. Date of sampling for each field was corresponded to the same day of the week in most cases, but, when it did not, was within 6–8 d of the previous sample date. Cereal leaf beetle egg and larva abundances were determined in each field following recommended sampling guidelines (Herbert and Van Duyn 2009). These procedures included visiting four sites in a single field and counting eggs and larvae on 25 tillers in each location.

Data were analyzed using a generalized linear mixed models approach using the logit (canonical) link (PROC GLIMMIX; SAS Institute 2008a). The dependent variable took the binomial form of a field reaching the economic threshold, or staying below the economic threshold, as defined by Herbert and Van Duyn (2009). The independent fixed variable was management strategy of the field (IPM or prophylactic). Each year was analyzed in separate models. Various models were compared with the null model, which only included treatment as an independent variable; examples of other models were those fit with spatial effects in the fixed and random statement and spline and radial smoothing models. Models were compared for goodness-of-fit using log likelihood, chi-squared statistics, and Akaike’s Information Criterion (Akaike 1973). In 2010, the best model was spatial, fitted with an anisotropic power covariance structure, while in 2011, the null model (treatment as the only independent variable) was the most appropriate.

Economic Analysis. Data from the regional survey for both years were used to determine the total cost per hectare of the prophylactic management approach using the following equation:

\[
\left(\frac{\text{Percent yield loss}}{100}\right) \times \left(\frac{\text{Bushels}}{\text{Hectare}}\right) \times \left(\frac{\text{Cost of grain loss}}{\text{Bushel}}\right) + \left(\frac{\text{Application cost}}{\text{Hectare}}\right)
\]

Because the highest larval densities were generally found during the third week, these data were used to estimate the population density of cereal leaf beetle in
each field. Many of these larvae had reached late-
instar by this time and it was assumed that all larvae
were fourth instars. Percent yield loss (from cereal
leaf beetle) was based on the sum of the average
number of larvae per tiller from each field on the third
week plus the estimated number of fourth-instar lar-
vae per tiller that would survive from un-hatched eggs,
also on the third weed. To estimate the fourth-instar
larvae that survived from eggs, the previously pub-
lished data and regression equation ($y = 0.36x - 0.01; 
\hat{r}^2 = 0.79$) shown in Fig. 1 of Ihrig et al. (2001)
were used. Percent yield loss was then estimated based on
the previously published relationship between fourth
instar larvae per stem and wheat yield loss shown in Fig.
3 of Ihrig et al. (2001). To do this, a polynomial equation
with a zero y-intercept was fit to the data in Fig. 3 using
the “Fit model” platform in JMP (SAS Institute 2008b).
The resulting equation was as follows:

Percent yield loss = 31.41x - 10.74x^2

where x was the estimated total number of fourth-
instar larvae per stem. This produced a line that was
very close to the linear regression that Ihrig et al.
(2001) published, but was more realistic, because no
yield loss was estimated when cereal leaf beetle larvae
were absent. Bushels were assumed to be 148 per ha,
the cost of grain loss was assigned a value of $6.00 per
bushel, and the application cost (cost of insecticide
alone) was set at $7.41 per ha. Insecticide costs were
estimated by informally polling agrichemical industry
representatives for the average retail price of an insec-
ticide in the pyrethroid class. Application costs associ-
ated with the nitrogen application, such as fuel, sprayer
use, and maintenance, and so forth, were not included in
the analysis because they were fixed independent of the
pest management approach used. In other words, all
growers applied top-dress nitrogen independent of whether or not their approach to pest management was prophylactic or followed IPM practices.

The total cost per hectare of the IPM approach was estimated similarly, except that percent yield loss (from cereal leaf beetle) was estimated in two different ways. Using the equation for percent yield loss for forth-instar larvae per stem presented previously, percent yield loss was assumed to be 7.18% if a field reached the economic threshold at any point during the sampling period (weeks 1 through 4). The reasoning for this is that when a field over threshold was treated with an insecticide, all cereal leaf beetle larvae and the resulting yield reductions were eliminated. Until the field received an application of insecticide, some yield loss was incurred because of larval feeding. Finally, because this application required an application in addition to that of top-dressed nitrogen, additional application costs were incurred and were included in the estimation of loss. Total cost per hectare for these fields included scouting costs ($7.41), insecticide costs ($7.41 for insecticide and $14.83 for application), loss because of larvae feeding before the insecticide application ($63.77), and yield loss per hectare because of driving over wheat after jointing. Scouting for cereal leaf beetle involves several trips to the field that are generally made independent of other activities associated with consulting (i.e., tissue sampling, weed management, etc.). Therefore, scouting costs were determined by informally polling independent crop consultants for the portion of wheat scouting dedicated to cereal leaf beetle management. The yield loss because of driving over wheat over jointing (assumed to be 100%) was estimated on a per hectare basis for a sprayer with a 27.4 m wide boom and two 38.1 cm tire tracks using the following equation:

\[
\text{Cost of grain loss per hectare} = \text{Bushels per hectare} \times \left( \frac{2 \times \text{Tire width}}{\text{Boom length}} \right) \times \left( \frac{\text{Cost of grain loss}}{\text{Bushel}} \right)
\]

This measurement of loss was not incorporated into the calculations for the prophylactic approach, because there are no yield loss associated with driving over wheat before GS 31 (Lee et al. 2009). The same figures for bushels and cost of grain loss per hectare were used as those for the prophylactic approach calculations. If the field was under threshold by the third week of sampling, a second method of estimation was used to calculate the total cost per hectare of the IPM approach. This approach was the same as that for the prophylactic fields, except that application costs were assumed to be zero because no insecticide was applied.

For field types under both the prophylactic and IPM approach, total cost per hectare was estimated for individual fields. Percentiles, including the mean and median value, extreme values, quartiles, and coefficients of variation were then calculated (PROC UNIVARIATE; SAS Institute 2008a). Total costs of the approaches were compared using a nonparametric Wilcoxon paired sample test (PROC NPAR1WAY; SAS Institute 2008a).

**Results**

**Small Plot Trials.** At the time of the 2010 application (GS 30) in the prophylactic treatment, adults were abundant with very few eggs present (Fig. 2). In contrast, adults, eggs and larvae were found at extremely low abundances in 2011 through the duration of the experiment. Cumulative larval-days were highest in untreated plots, followed by the prophylactic treatment, followed by the IPM treatment in 2010 (Fig. 2; \( F = 70.37; \ df = 2, 6; P < 0.0001 \)). Bushels per hectare were not significantly different among treatments in 2010 (Table 1; \( F = 3.67; \ df = 2, 6; P = 0.09 \)), but grain moisture was significantly higher in the IPM treatment than the prophylactic or check treatment (Table 1; \( F = 18.93; \ df = 2, 6; P = 0.0026 \)). In 2011, cereal leaf beetle densities were very low. Cumulative larval-days averaged 6.1, 3.5, and 4.4 on 22 April in the untreated,
Table 1. Yield (kg/ha, adjusted for moisture) and percent grain moisture ± SEM for small plot trials

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>Bu/ha</th>
<th>% grain moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>IPM</td>
<td>86.5 ± 3.1a*</td>
<td>9.12 ± 0.05a</td>
</tr>
<tr>
<td></td>
<td>Prophylactic</td>
<td>80.7 ± 0.5a</td>
<td>8.96 ± 0.03ab</td>
</tr>
<tr>
<td></td>
<td>Untreated</td>
<td>75.4 ± 2.9a</td>
<td>8.78 ± 0.05b</td>
</tr>
<tr>
<td>2011</td>
<td>IPM</td>
<td>83.9 ± 6.4a</td>
<td>14.83 ± 0.03a</td>
</tr>
<tr>
<td></td>
<td>Prophylactic</td>
<td>73.1 ± 1.7a</td>
<td>14.81 ± 0.02a</td>
</tr>
<tr>
<td></td>
<td>Untreated</td>
<td>75.2 ± 5.6a</td>
<td>14.30 ± 0.00a</td>
</tr>
</tbody>
</table>

Small plot treatments included a check, insecticide at GS 30, and insecticide applied only if cereal leaf beetle abundance exceeded threshold.
*Means that are within a column, during the same year, and followed by the same letter are not significantly different (P < 0.05; Tukey’s honestly significant difference test used for mean separation).

There are many different reasons why growers do not adopt IPM practices, including constraints during the critical scouting time, risk-aversion, the perception of killing nontarget pests (pests including, and other than, cereal leaf beetle), various savings (economic and time) achieved by reducing trips across a field, ease of implementation, pressure from agrochemical industry representatives, and so forth. However, based on the results of this study, the lack of complete adoption of IPM practices by growers could partly be a consequence of the calculated average economic benefit of using the prophylactic approach. Farms are businesses and owners must make decisions based on profit and loss. As a result, showing a benefit to IPM practices in terms of positive economics can be an effective approach to increasing IPM acceptance (Trumble 1998). Conversely, because IPM of cereal leaf beetle in Southeastern wheat is widely perceived as less cost effective than prophylaxis, this raises the question of why any growers use IPM for pest management in Southeastern wheat. The question may be partly answered by the studies presented here, through a bifurcated categorization of risk-averse growers. Fields under the prophylactic approach do not exceed threshold as often as fields using the IPM approach. Hence, some growers will chose the prophylactic approach to minimize the risk of exceeding threshold. In contrast, when cereal leaf beetle densities are extremely high, total cost of management for fields under the prophylactic approach can be extremely high (up to $146.27 per hectare). Thus, growers using the IPM approach can avoid these high losses by applying an insecticide during a critical time of cereal leaf beetle population development, eliminating most larvae and relying on residual insecticide to eliminate those hatching from eggs.

The partial adoption of IPM practices in Southeastern wheat, in contrast to prophylaxis, may also be because of the uncertain spatial distribution of this pest. For example, the approach used to determine if a field exceeded threshold in the regional survey (following published scouting recommendations) were to divide a field into four sections and to sample 25 tillers from each of these sites. Field size in North Carolina and Virginia can vary considerably, from less than a hectare, to areas of continuous wheat across many square kilometers. Thus, determining the economic threshold is highly dependent upon the spatial distribution pattern and high degree of spatial aggregation of cereal leaf beetle (Reay-Jones 2010). It is also possible that cereal leaf beetle is aggregated on a regional level, with areas more prone to cereal leaf beetle infestation than others. In 2010, but not in 2011, a spatial effects model was more representative than the null model without spatial effects. Further research is needed to determine the extent to which cereal leaf beetle is regionally aggregated and the underlying ecological factors for this aggregation. This phenomenon could influence the ratio of growers that adopt IPM practices.

The goal of IPM is to balance the tension between sound ecological and economical management.

and prophylactic, and IPM plots, respectively. Hence, cumulative larval-days were not significantly different among treatments ($F = 0.64; \text{df} = 2, 6; P = 0.56$). Similarly, there were no significant differences among treatments when the factors of bushels per hectare ($F = 2.22; \text{df} = 2, 14; P = 0.15$) or grain moisture ($F = 0.27; \text{df} = 2, 14; P = 0.77$) were analyzed (Table 1).

Regional Survey. In 2010, fewer fields under the prophylactic approach (9%) exceeded threshold than fields under the IPM approach (44% exceeded threshold; $F = 8.17; \text{df} = 1, 103; P = 0.0051$; Fig. 1A). In 2011, fields under the prophylactic approach (%) did not exceed threshold more than fields under the IPM approach (16% exceeded threshold; $F = 0.00; \text{df} = 1, 118; P = 0.97$; Fig. 1B).

Economic Analysis. Using the prophylactic approach, the mean total cost per hectare of managing cereal leaf beetle was lower ($18.72), than using the IPM approach ($39.44; Z = -4.06; P < 0.0001$). The total cost per hectare to manage cereal leaf beetle was more variable using the prophylactic approach (CV = 145.1), ranging from a low of $7.41 and a high of $146.27. The IPM approach was less variable (CV = 9.12), ranging from a low of $7.41 and a high of $54.35 (Fig. 3).

Discussion

From a risk-management perspective, cereal leaf beetle larvae were most effectively managed using an IPM approach versus a prophylactic insecticide spray approach. Using an IPM approach, cereal leaf beetle population development was arrested in the 2010 small-plot experiments and total costs of management per hectare (from the multiyear whole field surveys) were less variable above the upper quartile of the data distribution using an IPM approach. Furthermore, although no fields under a prophylactic spray regime exceeded the economic threshold in 2011, the number exceeding threshold was not significantly different than that for fields under IPM. In contrast, prophylactic spray fields did not reach the economic threshold as often as fields using IPM in 2010. The total cost of management per hectare for both years combined was $20.72 less using the prophylactic approach.

Discussion

From a risk-management perspective, cereal leaf beetle larvae were most effectively managed using an IPM approach versus a prophylactic insecticide spray approach. Using an IPM approach, cereal leaf beetle population development was arrested in the 2010 small-plot experiments and total costs of management per hectare (from the multiyear whole field surveys) were less variable above the upper quartile of the data distribution using an IPM approach. Furthermore, although no fields under a prophylactic spray regime exceeded the economic threshold in 2011, the number exceeding threshold was not significantly different than that for fields under IPM. In contrast, prophylactic spray fields did not reach the economic threshold as often as fields using IPM in 2010. The total cost of management per hectare for both years combined was $20.72 less using the prophylactic approach.
(Prokopy 2003); the studies presented here do little to enhance the ecological pole of this dialectic. Because cereal leaf beetle can be managed with a single insecticide application and because the majority of fields under the IPM approach do not exceed threshold, IPM is more ecologically friendly than prophylaxis, where all fields are treated with insecticide. For IPM to be adopted in this system, it will be necessary to move past the economic presentation suggested by Trumble (1998), while still emphasizing the importance of economics in IPM. Aerial applications of insecticide are possible in some parts of the Southeast. If the yield loss because of wheel traffic is eliminated from the equation, the cost of IPM practices is slightly less than those for prophylaxis. IPM practices can also be enhanced and the total cost reduced by improving scouting. A new preliminary degree-day model from North Carolina and Virginia can explain 94% of the variation seen in cereal leaf beetle larval developmental time and predict peak egg number within 4 of the observed peak (Philips et al. in press). Scouting costs are relatively high for this pest because they involve multiple trips to a field. If these can be reduced, scouting costs can be reduced. This model suggests that scouting can be reduced to one to two trips, thus significantly reducing this significant expense, thus potentially making the IPM approach more economically attractive. Finally, although biological control is not effective in cereal leaf beetle management, the elimination of beneficial arthropods via the use of early broad spectrum insecticide applications (i.e., pyrethroids) may increase population levels of other wheat pests.

In conclusion, from an economic perspective, both the prophylactic and IPM approaches have advantages and disadvantages. This partly explains the incomplete adoption of IPM by southeastern U.S. wheat growers. From an ecological perspective, the IPM approach is superior and scouting efficiencies and other components should be explored and incorporated into recommendations. Because the adoption of IPM in agricultural systems is favored by a strong economic advantage over alternative management approaches, more emphasis should be placed on research to reduce costs within the IPM approach in Southeastern wheat insect pest management.

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