Evaluation of the Peanut Southern Corn Rootworm Advisory

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ABSTRACT

The southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, is an annual soil insect pest of peanut (*Arachis hypogaea* L.) in Virginia, North Carolina, Texas, and other peanut growing states. Larvae feed on developing pods causing direct yield loss and indirect damage by allowing entry of secondary pathogens. Because southern corn rootworm is a soil pest, scouting is difficult and producers make preventive treatments without knowledge of actual pest abundance. A predictive index for southern corn rootworm injury was evaluated using 392 field case studies conducted in Virginia and North Carolina from 1997 to 2001. Factors influencing the index score (soil texture, soil drainage class, planting date, cultivar resistance, and field history of rootworm damage), and point assignments for predicting low, moderate, and high-risk fields were analyzed. The goal of this project was to determine which combination of factors provided the highest percentage of correct risk predictions. The best index combination used all five factors to determine the total point score, with 70 or more points indicating a high-risk field, 55 to 65 points a moderate-risk field, and less than or equal to 50 points a low-risk field. Growers who use the index eliminate a preventive insecticide treatment in low-risk and some moderate-risk fields. The index correctly predicted the level of pod damage in 45% (177 of 392) of the field case studies. Insecticide was correctly recommended in 46 fields. Thirty-three percent (131 of 392) of the fields were correctly identified as not needing treatment. There were 209 cases where there was an overestimation of pod damage with predictions of either a high or moderate level when only a low level occurred. In these cases, an insecticide treatment would have been recommended and an average of 6.1 and 2.6% pod damage, respectively, would have been prevented. Conversely, there were very few fields that should have been treated but were not treated (6 of 392). Overall, use of the index would have protected fields from pod damage and potential loss 98.5% of the time.

Key Words: *Diabrotica undecimpunctata howardi*, *Arachis hypogaea*, IPM, advisory, risk index.

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The southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, is a primary pest of peanut, *Arachis hypogaea* L., in southeastern Virginia (Miller, 1943; Boush *et al.*, 1963), North Carolina (Campbell and Emery, 1967), parts of Texas, and other peanut growing states. Because larvae are subterranean there are no practical scouting techniques or threshold numbers; therefore, most rootworm control by growers is preventive (Linker and Herbert, 2001). Surveys of growers showed that 90% of Virginia peanut acreage was treated for pod-feeding insects in 1990 (Phipps *et al.*, 1992).

Direct injury is caused by rootworm larvae penetrating the pod to feed on the kernel. Indirect pod damage may occur as injured peanuts are more susceptible to fungal infection and pod breakdown (Porter and Smith, 1974). Pod scarring, which occurs when larvae are unsuccessful at penetrating the outer pod wall but still leave signs of feeding, is undesirable (Brandenburg and Herbert, 1991). Ang *et al.* (1994) discovered that there was an 8.1 kg/ha reduction in yield for every 1% increase in mature pod damage.

Ang *et al.* (1994) calculated that 15% pod damage is needed to offset rootworm control costs (assuming a $0.50/kg selling price and $63/ha control costs). Bousch *et al.* (1963) estimated that at least half of the peanut acreage in Virginia is subject to rootworm injury, and Herbert *et al.* (1997) showed that approximately half of 44 field case studies in Virginia and North Carolina had greater than 15% pod damage. While rootworm injury rarely exceeds 25% in southeast Virginia (Miller, 1943), there are extreme cases with 30% (Herbert *et al.*, 1998) to over 60% (Bousch *et al.*, 1963) damaged pods.

Coffelt and Herbert (1994) reported that insecticide treatments significantly reduced the amount of damage from rootworm and increased yield, value, and total sound mature kernels. These treatments are usually made at pegging (Phipps *et al.*, 1992) or the R2 growth stage (Boote, 1982). It is important to determine which fields are at risk to rootworm injury and require treatment and which fields are not at risk, thereby saving application costs and reducing unnecessary pesticide use.

An index for determining the risk level of peanut fields to rootworm damage was developed by Herbert *et al.* (1997). It is based on soil texture, soil drainage class, planting date, cultivar resistance, and field history of rootworm damage, where each level of the different factors is assigned a point value (Table 1). It bases risk of rootworm damage on the total number of points—the more points, the greater the risk of damage. A similar point-based risk index for tomato spotted wilt virus in peanut was developed by Brown *et al.* (1997) and is based on factors including cultivar resistance, planting date, and insecticide usage. The Herbert *et al.* (1997) rootworm

Table 1. Point values for the southern corn rootworm risk index for peanut pod damage (from Herbert *et al.*, 1997).

Factor	Level of factor	Value
Peanut cultivar resistance	Other	20
	VA 98R[a]	10
	NC 6	5
Soil texture	Loam	15
	Fine-sandy loam	10
	Loamy sand	5
Drainage class	Poorly drained	20
	Somewhat poorly drained	15
	Moderately well drained	10
	Well drained	5
Field history of rootworm damage	High	15
	Moderate	10
	Low	5
	No	0
Planting date	After 15 May	15
	25 April-15 May	10
	Prior to 25 April	5

[a]The cultivar VA 98R replaced VA 93B in the index in 2000. Both were assigned values of 10 points.

index recommends treating high-risk fields preventively and not treating low-risk fields. The index states that rootworm damage may not reach economically damaging levels in moderate-risk fields, and recommends that treatment decisions consider weather conditions, land-lease requirements, and the percentage of the field area that is poorly drained.

This paper re-evaluates the index and scoring system of Herbert *et al.* (1997) using an additional 392 field case studies. By expanding the number of studies, more growers could say that tests were conducted in their own "backyard," which increases grower awareness and confidence in the index. Growers may use the index to identify peanut fields that do and do not need preventive insecticide treatments and perhaps reduce overall insecticide use by eliminating those with marginal potential for profitable treatment.

Materials and Methods

The index was tested on 392 grower fields in North Carolina and Virginia from 1997 to 2001. Participating counties in North Carolina included Bertie, Bladen, Chowan, Edgecombe, Gates, Halifax, Martin, Northampton, Perquimans, and Pitt. Locations in Virginia included Dinwiddie, Greensville, Isle of Wight, Prince George, Southampton, Suffolk, Surry, and Sussex counties. Cooperative Extension agents and researchers encouraged growers to participate. Information on soil texture, drainage class, planting date, cultivar resistance, and field history of rootworm damage was collected. If field history of damage was unknown due to continuous preventive rootworm treatments, the field was assumed to have a moderate risk of damage. Weather information was not used in the index. Four insecticide-treated and untreated plots were established in different areas of each grower's field. The treated areas allowed for yield comparisons (where yields were taken), therefore making it possible to determine the loss due to not treating for southern corn rootworm. Minimum plot size was four (91 cm; 36 in) rows by the length of the field. About 2 wk prior to harvest (late Aug. to mid-Sept.), 100 mature pods were sampled from each of the eight strips, and mean percentage of rootworm-scarified (pod wall damage only) and penetrated pods (pod wall penetrated and kernel damage obvious) was determined for the two treatments. Mean percent total damage (scarified and penetrated) was determined for each field.

The actual level of pod damage (mean percent total damage) was compared to the index prediction based on research on the economics of controlling rootworm (Ang *et al.*, 1994), where actual pod damage from 0 to 14% was considered low risk; 15 to 34% was considered moderate risk; and greater than or equal to 35% indicated high risk. The justification for selection of the factors used in the index is given in detail by Herbert *et al.* (1997). Point values in Herbert *et al.* (1997) were used for the levels of each factor (Table 1). These values were assigned subjectively based on known relationships of factors and pod damage. Values were added to determine the total score. Multiple linear regression analysis (PROC REG) using backward model selection and Mallows' C_p statistic were used to determine the most important factors affecting pod damage for 1997 to 2000 data (SAS Institute, 1992). In backward stepwise regression, all nonsignificant terms and variables are eliminated beginning with the highest order interactions. The sums of squares of the deleted terms and variables are added to the error term, guaranteeing the independence of successive statistical tests. A strength of Mallows' C_p statistic is that it gives the best prediction of factors important to the advisory. In 2001, field history of damage was not included in the data collection process, so 2001 data were excluded from the regression analysis. The index was evaluated using different combinations of factors and different scores for "high," "moderate," and "low" levels of risk. The goal was to find a combination with the highest percentage of correct predictions. For this exercise, damage history was assumed to be moderate in all fields in 2001. Treatment decisions for low, moderate, and high-risk fields were the same as those used by Herbert *et al.* (1997) as described above. If a prediction for a case study matched its actual damage ranking, the case fit and was given a "Y" (yes, the index fit). If a prediction overestimated the actual pod damage, the case was given a "N+" (no, the index did not fit, and it overestimated the level of damage). When the prediction underestimated the actual pod damage, the case was given a "N-" (no, the index did not fit, and it underestimated the level of damage). For example, if the index predicted low risk when the actual pod damage was 16%, the case was assigned a "N-". If the index predicted high risk when the actual pod damage was 31%, the case was given a "N+". A case with 9% actual pod damage and a low predicted risk earned a "Y".

Whether a decision was correct or incorrect was determined by comparison with actual percent pod damage for each case. The index was assumed to be correct when predicted low, moderate, or high risk was matched by respective low, moderate, or high actual pod damage. The index was also assumed to be correct when it predicted a moderate risk and actual damage was high, or when the index predicted a high risk and actual damage was moderate. These two scenarios were considered correct since the field would have been treated, thus protecting the crop from moderate or high levels of damage. Incorrect decisions occurred when the index predicted low risk and actual damage was moderate or high, or when moderate or high predicted risk was accompanied by low actual damage. Cases with low predicted damage but moderate or high actual damage would have resulted in yield loss. Cases with moderate or high predicted damage but low actual damage would have resulted in unnecessary insecticide use. Therefore, every observation fell into one of nine categories; five were "correct decision" and four were "incorrect decision." The chi-square test for goodness-of-fit was used to determine if the probability of making index-based treatment predictions was the same as that attributed to chance alone, corresponding to 5:4 (Ott, 1993).

Results and Discussion

The five combined factors of the index were significantly related to percent pod damage ($r^2 = 0.17$, $P < 0.01$). The backward selection procedure indicated that the most important factors influencing the index were field history of damage ($P < 0.01$), cultivar ($P = 0.03$), and soil texture ($P = 0.07$). Planting date and soil drainage were not significant factors ($P = 0.67$ and 0.63, respectively). Including only significant terms, the model was:

$$\text{Percent pod damage} = 10.77 - 0.40\,x_1 - 0.45\,x_2 + 1.06\,x_3 \quad \text{[Eq. 1]}$$

where x_1 = cultivar, x_2 = soil texture, and x_3 = damage history. This was the same as the best model using Mallows' C_P statistic ($C_P = 2.4034$):

$$\text{Percent pod damage} = 10.77 - 0.41\,x_1 - 0.45\,x_2 + 1.07\,x_3 \quad \text{[Eq. 2]}$$

The range of scores for the 392 field case studies is given in Figure 1; most (76%) were from 50 to 60. The most frequently occurring index score in the distribution was 50 (109 cases), and the median score was 55. Evaluation of the index using different factors and different scores for "high," "moderate," and "low" levels of risk showed that the best index included all five factors, where scores of 70 or more points indicated a high-risk field; 55, 60, or 65 points equaled a moderate-risk field; and scores less than or equal to 50 indicated a low-risk field (Table 2, combination 1). This is identical to the scoring system of Herbert *et al.* (1997). The total number of low, moderate, and high-risk predictions using combination 1 were 137, 224, and 31, respectively. Using combination 1, 41.6% of the cases resulted in "Y" ratings, indicating that the index was accurate at predicting the general level of risk to pod damage. The index overestimated pod damage 55.1% of the time ("N+"

Table 2. Percentages of correct predictions (Y), overestimates (N+), and underestimates (N-) of actual southern corn rootworm damage to peanut pods using different factors and risk index scoring systems. There were 392 field case studies from 1997-2001. Damage history was assumed to be moderate (= 10 points) in 2001.

No.	Combination	Prediction accuracy Y	N+	N-	Total score evaluation Low risk	Moderate risk	High risk
		%	%	%			
1	Complete index	41.6	55.1	3.3	≤ 50	55-65	≥ 70
2	Complete index	41.6	55.4	3.1	≤ 50	55-60	≥ 65
3	Complete index	41.6	54.3	4.1	≤ 50	55-70	≥ 75
4	Complete index	16.3	81.6	2.0	≤ 45	50-60	≥ 65
5	Complete index	16.3	81.4	2.3	≤ 45	50-65	≥ 70
6	Complete index	58.9	34.7	6.4	≤ 55	60-65	≥ 70
7	Cultivar, texture, drainage, planting date	24.5	72.5	3.1	≤ 35	40-50	≥ 55
8	Cultivar, texture, drainage, planting date	46.4	48.0	5.6	≤ 45	50	≥ 55
9	Cultivar, texture, history	14.3	83.7	2.0	≤ 25	30-40	≥ 45
10	Cultivar, texture, history	22.4	74.5	3.1	≤ 30	35-40	≥ 45
11	Cultivar, texture, history	58.7	34.7	6.6	≤ 35	40	≥ 45

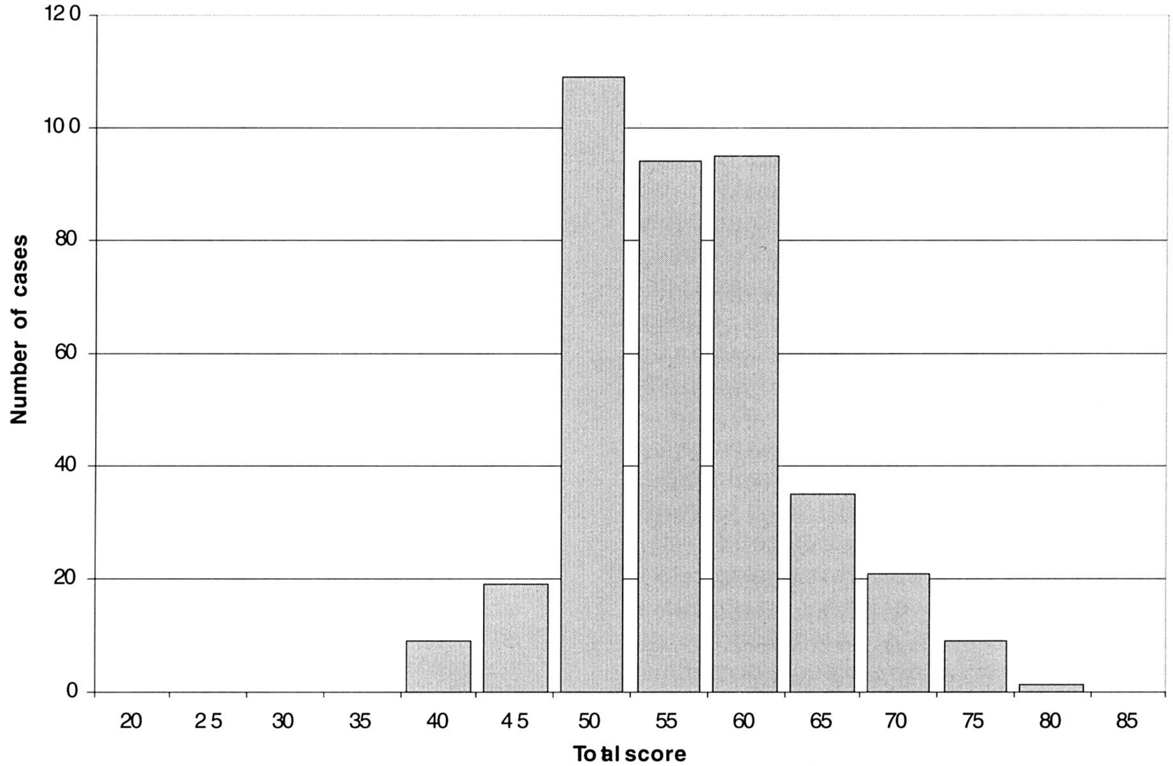

Fig. 1. Total score distribution among the 392 field case studies using the southern corn rootworm risk index for peanut (1997-2001 seasons). Points were assigned to different levels of five factors comprising the index using the methods of Herbert *et al.* (1997). Points were added to obtain the total score. Higher scores indicate a greater risk of rootworm damage.

ratings). Only 13 (3.3%) of the fields examined had damage above the rootworm risk index prediction (indicated by a "N-"). Of the 3.3% with underestimated damage levels, seven cases predicted a moderate-risk for the field when actual pod damage exceeded 35%. Assuming that the moderate-risk fields were treated, damage would have been minimized. Therefore, only six of 392 field studies had underestimates of damage that would have resulted in growers not treating fields, when treatment was necessary to prevent economic damage.

Other total score evaluations had a wide range of percentages of "Y", "N+", and "N-" cases (Table 2). Some combinations were similar to combination 1, while others failed to adequately predict damage. Combination 2 differed from combination 1 by having fewer moderate and more high-risk predictions (189 and 66, respectively). This was caused by combination 2 having only two possible moderate scores (55 or 60), since scores totaling 65 points were included in the high-risk category. In combination 3, expanding the moderate risk category to 55 to 70 resulted in more "N-" cases (4.1%). In combinations 4 and 5, manipulating the scores so that moderate risk was 50 to 60 or 50 to 65 dropped the percentage of "N-" cases to 2.0 and 2.3, respectively. However, "Y" cases fell to 16.3% and "N+" cases were greater than 81%. The high number of "N+" cases was due to the total score falling into the "moderate risk" category 76 and 85% of the time for combinations 4 and 5, respectively. Combination 6 had the highest percentage of "Y" cases, but also had more "N-" cases than all but one other combination. Since "N-" cases may cause growers to not treat when treatment is needed, the economic loss associated with this underestimation of damage represents the worst scenario. The index was evaluated with field damage history omitted in combinations 7 and 8. Using combination 7, damage was overestimated 72.5% of the time. Combination 8 had a high percentage of "Y" cases, but only had one value comprising the moderate risk category and 5.6% "N-" cases. Combinations 9 to 11 considered only the three factors that the regression analysis considered most significant—cultivar resistance, soil texture, and damage history. These were not chosen to represent the index because they had either a low number of—"Y" cases (combinations 9 and 10) or too many "N-" cases (combination 11).

Choosing the "best" index is subjective. However, the factors and scoring system of combination 1 in Table 2 offer a high level of protection, a low chance of not protecting the field when it is needed, and a good range of scores for low, moderate, and high-risk categories. Using the index was different from random chance (χ^2 = 17.18, df = 1, $P < 0.01$). However, the number of actual correct predictions (177) was fewer than expected (218).

Even though rootworms prefer to feed on immature pods, only mature pods were sampled in our experiment. This was different from Herbert *et al.* (1997), who sampled both mature and immature pods. Immature pods are not marketable and it is mature pod damage that is economically important. Superficial scarring to pods does not currently result in discounts at the buying point as grades are based on kernel quality only. Sampling mature pods prior to harvest may discount earlier damage, decay, and compensation; however, damaged or decayed pods seldom make it into trailers since they are often blown out during the picking process, and heavy damage resulting in pod loss is reflected in yield reduction. Unlike lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller), southern corn rootworm is not cited as a species that is associated with development of aflatoxigenic fungi (Lynch and Mack, 1995).

To be effective, insecticide treatments must be applied in late June to mid-July, so weather information (i.e., rainfall) during late July to mid-August when rootworm populations peak is not useful. However, soil moisture is important in understanding rootworm response to treatments. Future research where irrigation is manipulated could be helpful in improving our understanding of soil moisture and rootworm injury. Knowing that irrigation increases risk, we have included that statement in the peanut rootworm advisory. Currently, less than 2% of North Carolina and Virginia peanut fields are irrigated.

In summary, there is no practical rootworm larvae sampling method that growers or crop consultants would adopt, and this has made it difficult to develop thresholds or other integrated pest management (IPM) techniques for rootworm in peanut. Growers need to predict whether their fields will require a preventive insecticide treatment several weeks prior to the appearance of the pest. The index, now called the Peanut Southern Corn Rootworm Advisory (http://ipm.ncsu.edu/scr) (Herbert, 2003) has been evaluated in 392 fields since release of the original index in 1997. It correctly predicted the level of pod damage in 45% (177 of 392) of the field case studies. Insecticide was correctly recommended in 46 fields and those treatments would have eliminated an average of 40% pod damage. Thirty-three percent (131 of 392) of the fields were correctly identified as not needing treatment. This index is conservative as it errs towards crop protection, even at the risk of recommending some unnecessary treatments. There were 209 cases where there was an overestimation of pod damage with predictions of either a high or moderate level when only a low level occurred. In these cases, an insecticide treatment would have been recommended and an average of 6.1 and 2.6% pod damage, respectively, would have been prevented. Given current crop value estimates this would have resulted in enough increased yield to offset application costs. Conversely, there were very few fields that should have been treated but were not (6 of 392). Overall, use of the index would have protected fields from pod damage and potential loss 98.5% of the time. Compared with cited soil insecticide use patterns by growers, use of the index would result in a 33% reduction in the total number of acres treated. Many growers, especially those with sandy-natured soil fields, could reduce inputs with no crop value loss. Widespread adoption of this index would result in more efficient use of insecticide while reducing overall all production costs.

Acknowledgments

The authors wish to thank the many North Carolina and Virginia peanut growers who allowed research and validation studies to be conducted on their farms. The Center for Agricultural Partnerships (Asheville, NC) is acknowledged for their assistance with this project. The Virginia Peanut Board, North Carolina Peanut Growers Assoc., Peanut CRSP USAID grant no. LAG-G-00-96-90013-00, and USEPA Pest Management Alternatives Program (USDA) in cooperation with Rural Advancement Foundation International, are acknowledged for their financial support throughout this study.

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