A Risk Index for Determining Insecticide Treatment for Southern Corn Rootworm in Peanut

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ABSTRACT

The southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, is a primary pest of peanut, *Arachis hypogaea* L., in Virginia and North Carolina and an occasional pest in South Carolina, Georgia, Alabama, and Texas. Currently, no alternatives involving integrated pest management exist for this pest, and control is based solely on preventive application of soil insecticides. Recent reductions in federal price support for peanut grown in the U.S. have provided incentives for growers to look for ways to reduce production costs. A risk index was developed that integrates factors that influence rootworm abundance and peanut pod damage to estimate levels of risk in individual peanut fields, and thus allows for more prescriptive and economical rootworm management. This index was evaluated using 44 field case studies in Virginia and North Carolina commercial peanut fields over the period 1989 to 1996. In each field case, predicted risk was compared to actual percent pod damage. Results showed that in 29 of 44 cases, the index accurately predicted general levels of risk to pod damage, and insecticide treatment decisions based on the index would have been correct in 32 of 44 cases. This report contains the individual index components, the justification for each, the indexing process, example index scenarios, and results of the process used in field case study evaluation.

Key Words: *Diabrotica undecimpunctata howardi* Barber, insects, IPM.

The southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, is a primary pest of peanut, *Arachis hypogaea* L., in Virginia and North Carolina and an occasional pest in South Carolina, Georgia, Alabama, and Texas. Larvae injure peanut by feeding on developing pods causing direct yield loss, or cause indirect loss by allowing entry of secondary microorganisms (Grayson and Poos, 1947). Pod yield losses in Virginia range from 100 to 500 kg/ha and exceed 1000 kg/ha (30% of total yield) in extreme cases (Herbert, 1989). Currently, management is based solely on preventive application of soil insecticides (chlorpyrifos, phorate, fonofos, or ethoprop) against larval populations (Herbert, 1993) since no effective rescue treatment is available. Producer surveys conducted in 1990 and 1991 showed that 90% of the peanut fields (*ca*. 33,000 ha) in Virginia (Phipps *et al*., 1990) and 65% of fields (*ca*. 39,000 ha) in North Carolina (Toth *et al*., 1991) are treated annually.

The development of good alternative management strategies for southern corn rootworm has been difficult and field sampling techniques, pest advisories, and economic thresholds have not been developed. Each year, this pest has several overlapping generations, and adults feed on hundreds of different host plant species. Because larvae feed underground, they are difficult to detect and current soil sampling procedures are too labor intensive to be adopted by growers or crop scouts. In

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addition, by the time large numbers of larvae are detected, it is too late to apply remedial insecticide treatments. Therefore, growers make preventive insecticide treatments with little knowledge of actual pest abundance or likelihood of crop loss.

Efforts to monitor or control adults, either as an indicator of possible risk or to minimize larval damage to pods, have not proven successful. Brandenburg *et al.* (1992) conducted studies in Virginia and North Carolina to determine whether number of adult males occurring in peanut fields from mid-June through mid-July, as detected using traps baited with female sex pheromone (10-methyl-2-tridecanone), was a reliable indicator of the level of risk to pod damage. They concluded that percent pod damage was not consistently related to number of adult males trapped and that trap catch was inconsistent within fields and years. Herbert *et al.* (1996) tested additional adult attractants for both sexes (TIC,1,2,4-trimethoxybenzene, indole and trans-cinnamaldehyde, and cinnamaldehyde alone), but again concluded that beetles trapped accounted for only 10% of the variance in pod damage. Adult control was evaluated in Virginia and North Carolina peanut fields by Barbercheck *et al.* (1995) over a 3-yr period using the aforementioned adult attractants impregnated with carbaryl as a toxicant. Efficacy was poor and pod damage was unaffected compared with standard larval insecticide treatments.

Recent reductions in the federal price support for peanut grown in the U.S. have compelled growers to look for ways to reduce production costs. Because of the expense, some growers are opting to remove rootworm treatments altogether from their management programs. Past research indicates that this is probably justified in some cases. In one study, 107 peanut fields in Virginia and North Carolina were evaluated. A significant number of fields had limited damage to rootworm in areas untreated with insecticide (Brandenburg *et al.*, 1992). In another series of studies, it took about 10 to 15% damage to mature pods to offset the cost of a standard rootworm insecticide treatment (Ang *et al.*, 1994). Unfortunately, high levels of damage have been reported consistently from both states and eliminating treatment of all fields could be costly in cases of severe damage.

If fields at risk could be identified, then a more prescriptive approach could be developed for making insecticide treatments. Southern corn rootworm populations occur sporadically from field to field and survival of larvae is highly dependent on soil moisture and factors that affect it. Peanut grown in soils with greater loam content and poor drainage typically sustain the greatest levels of pod damage compared with those grown in sandier-textured, well-drained soils (Ang *et al.*, 1994). Planting date and rate of peanut maturity also can play a significant role in determining risk to rootworm (Herbert, unpub. data). Faster maturing cultivars, or peanuts planted earlier, often develop mature pods that are not as susceptible to rootworm attack before the period of intense pest pressure in late July to early August (Herbert, unpub. data). An index was developed that integrates these factors to estimate level of risk to rootworm severity. This index should help growers identify fields that would benefit from rootworm treatments and those that would not, thus allowing for more economical management of this pest. Reported in this text are the individual index components, the justification for each, the indexing process, example scenarios, and index 'runs' of 44 actual field cases.

Materials and Methods

The factors presented here affect southern corn rootworm survival and consequent levels of peanut pod damage and are presented in the order that they appear in the index. Included is a justification of why each factor was selected and the assigned index values. Values were assigned subjectively based on known relationships of factors and pod damage and much trial and error. The complete index is presented in Table 1. Users can apply the system to any field prior to the period best suited for making insecticide treatment decisions. Values of individual factor responses are added to determine the total index score. If the total score is 50 or below, the field is considered to be at a low level of risk. A total score from 55 to 65 indicates a moderate level of risk, and a score greater than 65 indicates high risk.

Cultivar Resistance. Early work with field screening peanut for southern corn rootworm resistance indicated that spanish- and valencia-type peanuts exhibited a type of antixenosis expressed in the firmer pod quality compared with virginia-type peanut (Fronk, 1950). Similarly, Bousch and Alexander (1965) screened 2500 peanut lines and thought that the seasonal development of spanish and valencia types, in relation to the seasonal history of rootworm, resulted in a form of pseudoresistance, or reduced synchronization, with those types maturing more quickly than virginia types and developing firmer pods before rootworm larvae caused significant damage. Although virginia

Table 1. Southern corn rootworm risk index for peanut pod damage.

Peanut cultivar resistance	Value	Field history of rootworm damage	Value
Other	20	High	15
VA 93B	10	Moderate	10
NC 6	5	Low	5
		No	0
Soil texture			
Loam	15	**Planting date**	
Fine-sandy loam	10	After 15 May	15
Loamy sand	5	25 April-15 May	10
		Prior to April 25	5
Drainage class			
Poorly drained	20		
Somewhat poorly drained	15		
Moderately well drained	10		
Well drained	5		

Total score

Less than or equal to 50	LOW RISK
55-65	MODERATE RISK
Greater than 65	HIGH RISK

types do not compare favorably to spanish and valencia types in maturity rate and pest synchrony, newer virginia-type cultivars developed for earlier maturity do offer some advantage in this regard. For example, cv. VA 93B, the fastest maturing commercially available virginia-type peanut (Coffelt and Herbert, 1994), was observed with fewer pods punctured by rootworm compared to slower maturing lines in fields where several cultivars are grown (Herbert, unpub. data).

The presence of true resistance based on antibiotic qualities that inhibit larval survival was first reported in virginia-type peanut by Chalfant and Mitchell (1970). Two cultivars, GA 119-20 (Hammons, 1971) and VA 61R (Alexander and Allison, 1970), were consequently released but are no longer used commercially. The development and release of cv. NC 6 (Wynne *et al.*, 1977) provided the first rootworm resistance in a virginia-type cultivar which, at that time, also provided yield and quality comparable to other commercial cultivars. Although NC 6 is currently not planted by many producers because it does not compete well with newer cultivars in yield and disease resistance, a recently completed (1996) series of bioassay and field screening experiments showed that NC 6 still exhibits a higher level of antibiotic resistance and sustains less pod damage compared with six more recently released virginia-type cultivars (Petka *et al.*, 1997).

Only two virginia-type cultivars are recognized as providing significant levels of rootworm resistance: NC 6, which is based on proven antibiotic qualities, and VA 93B, which is based on earliness and lack of synchrony with larval rootworm populations. In the risk index, NC 6 is assigned a value of 5 and VA 93B a value of 10. NC 6 is considered to be of greater value in minimizing risk to rootworm damage, as antibiosis is effective and independent of the other factors that affect level of risk such as planting date or soil characteristics. VA 93B can minimize risk, but it is somewhat dependent on planting date, with earlier planting providing the least risk. All other cultivars are given a value of 20.

Soil Texture. Extensive literature on the biology of southern corn rootworm reveals that soil moisture is a key factor determining survival of eggs and larvae. Eggs require 100% relative humidity for the first 24 to 72 hr after oviposition (Krysan, 1976), and first and second instars survive best with relative humidity above 75% (Brust and House, 1990a,b). Soil moisture is related to many edaphic factors but is affected mostly by texture. Texture affects permeability, or perc, water-holding capacity, and to some extent drainage capacity. Soil textures in the majority of fields where peanuts are grown in the Virginia-North Carolina area are categorized into the three classes of loam, fine sandy loam, and loamy sand by the National Cooperative Soil Survey Standards, Soil Survey Manual (Soil Survey Staff, 1975). They are defined according to percentages of sand, silt, clay, and organic matter. Soil texture has been demonstrated (Herbert, unpub. data) to influence both survival of rootworm larvae and extent of peanut pod damage, with damage increasing as loam content in the soil increases. The index includes these three textures in order of highest to least risk beginning with loam with an assigned value of 15, fine sandy loam with 10, and loamy sand with 5.

Drainage Class. Soil drainage capacity also can affect soil moisture and, therefore, affect risk to rootworm. For example, even a coarse, sandy-textured soil will retain moisture, or wick moisture from lower levels, if drainage is poor because of a shallow water-impermeable soil layer. Soil drainage in the majority of Virginia-North Carolina peanut fields is categorized into four general classes (Soil Survey Staff, 1975). In order from least to best drained, they are poorly drained, somewhat poorly drained, moderately well drained, and well drained. A single study (Ang *et al.*, 1994) reports the relationship of soil drainage to peanut pod damage by southern corn rootworm. In 11 on-farm tests over a 2-yr period, it was determined that percentage of mature pods damaged by rootworm increased with an increase in field area that is poorly drained. Stepwise regression models showed that inherent drainage properties and the corresponding proportion of pod damage observed explained 45% of the variance in peanut yield.

The index includes the four drainage classes in order of highest to least risk beginning with poorly drained with an assigned value of 20, somewhat poorly drained with 15, moderately well drained with 10, and well drained with 5. Index users can obtain soil texture and drainage class information by consulting the USDA Soil Conservation Service Soil Survey Manual for their respective county. Fields can be located on the area photographs where each is assigned a number corresponding to a specific soil type name. A detailed description of texture and drainage class is presented for each soil type.

Field History of Rootworm Damage. Field history of rootworm damage is a good indicator of risk to damage in the current year. Although no experimental data currently exist, logically, any field with a history of damage likely has conditions that favor rootworm development (e.g., soil texture, drainage class, etc.). Thus, fields with a history of high levels of damage are at greatest risk and are assigned a value of 15. Fields with a history of low to moderate levels of damage in most years are assigned a value of 10. Those with a history of low levels of damage in some years are assigned a value of 5. Fields with no history of damage are assigned a value of 0. There is a problem with including this factor in the index. Currently, a majority of peanut producers in the Virginia-North Carolina peanut area have typically applied insecticides each year for many years to prevent rootworm damage. Because insecticides generally provide almost complete control, producers do not know whether fields are subject to damage or not. We feel it is still important to include this factor, however, because more growers are 'experimenting' with leaving some fields untreated, or are leaving untreated strips within fields to evaluate their insecticide treatments. This is being done partly in response to reduced profit margins but, in doing so, they will gain valuable knowledge of field histories that can be applied in the index.

Planting Date. Although unreported in current literature, planting date has been observed to affect levels of rootworm damage to peanut (Herbert, unpub. data). Planting early has resulted in less pod damage than expected in a number of fields. Compared with normal or late planted peanuts, early plantings have pods that are tougher and less penetrable by rootworm larvae when populations of rootworm larvae are typically peaking in late July through mid-August (Ang *et al.*, 1994). From laboratory bioassays, Petka *et al.* (1997) reported that even third instar rootworms did not survive well on mature peanut pods compared with immature pods, and larval feeding resulted in only superficial pod scarring and little penetration.

In the index, there are three planting date groupings that include actual planting dates used by most producers in the Virginia-North Carolina peanut area. Planting before 25 April is considered early and is assigned the value of 5, representing the least risk to rootworm. Planting between 25 April through 15 May is considered a normal planting time and is assigned a value of 10, with somewhat more risk. Late planting, after 15 May, is assigned a value of 15 representing the highest risk.

Rainfall. Although rainfall definitely affects soil moisture, and therefore rootworm survival and pod damage, it is not currently considered in the risk index. If fields are identified as needing an insecticide treatment, research has shown that the best time to make applications is sometime from the third week in June through mid-July. Application at that time provides excellent larval control without significant vine damage which could increase susceptibility to peanut disease by allowing for light soil incorporation, thus improving insecticide activity. Although rainfall just prior to and during the period of peak larval activity (late July to early August) is an important factor, it cannot be predicted at the time insecticides should be applied. An in-season adjustment factor to accommodate general rainfall trends during a season (e.g., generally wet vs. generally dry) is under consideration. This could update the risk index for producers considering late season insecticide treatments. However, this is not fully developed or available at this time.

Development Scenarios. Numerous field scenarios were developed to allow adjustment of the index. These scenarios were constructed to contain sets of conditions (e.g., cultivars, planting dates, soil characteristics) which represent a range of situations known to occur throughout the Virginia-North Carolina peanut area. Scenarios were designed intentionally to evaluate the index at the very low, middle, and very high, risk extremes. Scenarios and their risk scores allowed for adjustment of the index to reasonably fit known observed levels of peanut pod damage.

Representative scenarios are presented (Table 2) with three cultivars that provide the three levels of available rootworm resistance: NC 6 (most resistant), VA 93B (some resistance), and NC 7 (susceptible). In each scenario, factors affecting rootworm survival and pod damage go from least (left) to greatest risk (right). From left to right, loam content increases, soil drainage decreases, planting date becomes later, and field history of rootworm damage goes from none to heavy. Test scenarios showed that the index provided reasonable outcomes, compared with our knowledge of rootworm damage in peanut fields observed over many years of research and working with growers. Results showed that NC 6 planted early into a very low risk, well drained loamy sand soil with no history of rootworm damage had the lowest total index score of 20 (Table 2). In a higher risk situation—i.e., planted later into a moderately well drained fine sandy loam soil with a history of rootworm damage—the total index score reached 40, which is still in the low-risk range but borders on moderate risk. Even in what would be considered a high risk scenario for other cultivars—i.e., planted late into a somewhat poorly drained, loamy soil with a history of rootworm damage—the total index score for NC 6 (55) still fell into the moderate risk category. These findings match what has been observed in growers' fields where NC 6 is planted commercially. NC 6 is not widely used but is planted by some producers that have high risk soils and a history of rootworm damage. NC 6 sustains some damage in very high risk soils, but less than susceptible cultivars, and can often be treated with reduced amounts of insecticide compared with susceptible cultivars (Wynne *et al.*, 1977).

Table 2. Southern corn rootworm risk index development scenarios.

	Risk index					
	NC 6					
	Low		Low		Moderate	
Cultivar	NC 6	5	NC 6	5	NC 6	5
Soil texture[a]	LS	5	FSL	10	L	15
Soil drainage[b]	WD	5	MWD	10	SPD	15
Damage history	None	0	Low	5	High	15
Planting date	Apr 20	5	May 5	10	April 20	5
Score (Total)		20		40		55
	VA 93B					
	Low		Moderate		High	
Cultivar	VA 93B	10	VA 93B	10	VA 93B	10
Soil texture	LS	5	FSL	10	L	15
Soil drainage	WD	5	MWD	10	SPD	15
Damage history	None	0	Mod	10	High	15
Planting date	Apr 20	5	May 20	15	May 20	15
Score (Total)		25		55		70
	NC 7					
	Low		Moderate		High	
Cultivar	NC 7	20	NC 7	20	NC 7	20
Soil texture	LS	5	FSL	10	L	15
Soil drainage	WD	5	MWD	10	SPD	15
Damage history	None	0	Mod	10	High	15
Planting date	Apr 20	5	May 20	15	May 5	10
Score (Total)		35		65		75

[a]Soil texture: LS = loamy sand; FSL = fine sandy loam; L = loam.
[b]Soil drainage: WD = well drained; MWD = moderately well drained; SPD = somewhat poorly drained.

VA 93B offers some resistance based on lack of synchrony with the pest, as it matures quickly compared with other cultivars and can have tougher pods when larvae begin feeding. When planted early into a low risk well drained loamy soil soil with no rootworm history, the resulting total index score of 25 indicated low risk (Table. 2). Planted later into a higher risk moderately well drained fine sandy loam soil with rootworm history, VA 93B had an index score of 55, which fell into the moderate risk category. When advanced to a higher risk scenario with late planting into somewhat poorly drained loam soil with rootworm history, VA 93B advanced to the high risk level (70). These findings also coincide with observations in some fields. VA 93B is planted by some Virginia and North Carolina peanut growers because of the earliness it provides. If planted early, VA 93B can sustain pod damage; but on close inspection, damage is mostly superficial with little actual puncturing of the pod wall and little consequence in terms of yield. If planted late or if planted into very high risk soils, VA 93B becomes moderately or even highly susceptible (but no more than other cultivars).

Scenarios with NC 7 (Table 2), the susceptible cultivar, represent the majority of commercially used peanut cultivars. In the least risk scenario (i.e., planted early into the lowest risk soil with no rootworm history), the total index score for NC 7 (35) fell into the low risk category. Advancement to a scenario with a moderate level of risk resulted in a moderate risk index score (65). Advancement to a high risk scenario (i.e., planted late into somewhat poorly drained loam soil with rootworm history) resulted in a high index score (75). Most susceptible cultivars respond in this manner. If planted in low risk situations, damage occurs on a small percentage of pods. Pod damage increases as factors become more conducive for rootworm development, and in extreme cases many pods can sustain damage.

Index Evaluation. The risk index was evaluated by applying it to a series of actual past field cases (case studies). Case studies were developed from data collected from 44 individual commercial peanut fields in Virginia and North Carolina over the period from 1989 to 1996. In order to qualify as a case study, information on cultivar, planting date, and soil characters had to be known; and there had to be pod damage data from peanuts not treated with insecticide for rootworm control. Some case studies were taken from previous replicated (four replicates), randomized complete block design field trials, with pod damage data taken from untreated controls. In other cases, replicated insecticide-treated and untreated strips (four replicates randomly assigned) were established in producers' fields, and pod damage data were taken from the untreated replicates. Pod damage was assessed about 2 wk before harvest (late August to mid-September) by determining the percentage of pods either scarified (pod wall damage only) or penetrated (pod wall penetrated and kernel damage obvious) among all pods removed from five randomly selected plants per replicate. Pods were classified as immature or mature based on color change to the outer pod wall and pod wall toughness. If pods appeared scarred, they were opened to determine if penetration and kernel damage had occurred. Total percent pod damage (percentage of all pods, immature plus mature, scarified or penetrated) was used to evaluate the risk index. Pod damage by insects other than rootworm was noted but not included in pod damage totals.

To evaluate the accuracy of the index, outcomes of specific case study indices [i.e., predicted risk levels (low, moderate, high)] were compared to the average total percent pod damage for that case. Total pod damage between 0 and 14% was considered to indicate low risk, between 15 and 34% indicated moderate risk, and 35% and greater indicated high risk. These damage rankings were established based on work by Ang *et al.* (1994) who concluded that at least 10 to 15% pod damage was needed to offset the cost of standard insecticide treatment. If predictions on specific case studies fit the damage rankings, the case was given a 'Y' (yes). For example, a case study prediction of low risk with a total pod damage of 8.0% would be given a 'Y'. Predictions that did not fit damage rankings were given either an 'N+' (no, and the index overestimated the risk—e.g., a prediction of high risk when total pod damage was 28.0%) or an 'N-' (no, and the index underestimated the risk—e.g., a prediction of low risk when total pod damage was 18.0%).

To further evaluate the index, chi square analyses (Steele and Torrie, 1980) were used to determine if insecticide treatment based on its use would have produced more correct than incorrect decisions, as determined by comparison to actual percentage pod damage in each field case. For example, if percentage pod damage was 15% or greater and a treatment was indicated, the index was considered correct. Likewise, if pod damage was less than 15% and no treatment was indicated, the index also was considered correct. Analyses examined for departures from hypothesis of an equal number of correct versus incorrect decisions and ratios of incorrect to incorrect decisions corresponding to 75:25, 85:15, and 90:10.

Results and Discussion

Evaluation of the index using field case studies showed that 29 of 44 cases resulted in 'Y' ratings which indicated that in the majority of cases the index was accurate at predicting general level of risk to pod damage (Table 3). Thirteen cases received 'N+' ratings indicating that the index tended to overestimate pod damage risk. In most of those cases, the index predicted moderate damage and only slight damage actually occurred. This warrants further investigation, but could indicate that rootworm infestations throughout the peanut area are more sporadic than previously thought and, even though conditions may be favorable, infestations do not always manifest. Only two cases received an 'N-' rating or underestimated risk to pod damage. In both of those cases, index scores were moderate (60 and 65) but very close to the high rating (a score of greater than 65) and pod damage was considered high (44.5 and 68.5%).

Chi square anaylses indicated that more correct than incorrect insecticide treatments decisions would have been made using the index ($c^2 = 12$, 1 df, $P \leq 0.01$), so using the index was better than random chance. A total of 32 of the 44 treatment decisions would have been correct: in nine cases, the index predicted L (no treatment indicated) and pod damage was below 15%; in 18 cases, the index predicted M (treatment indicated) and pod damage was between 15 and 34%; in two cases, the index predicted H (treatment indicated) and pod damage exceeded 35%. In addition, in two cases, M was predicted (treatment indicated) and pod damage exceeded 35% so, even though the index underestimated the level of pod damage, the treatment would have correctly minimized damage. Also, in one case, H was predicted (indicating treatment) but only 28.8% pod damage resulted, again correctly minimizing the pod damage even though the index overestimated the damage. With these results in mind, according to the chi square analyses, treatment/no treatment decisions would have been correct 74% of the time ($\chi^2 = 0$, 1 df, $P > 0.03$) and not significantly different from being correct 85% of the time ($\chi^2 = 3.45$, 1 df, $P > 0.05$). The index did not produce correct decisions 90% of the time, however, we concluded that 74% accuracy was produced from using it.

For management of this sporadic pest, given all of the variables that influence pod damage, estimates of the three levels of risk seem to be reasonably accurate.

Table 3. Field case studies comparing the southern corn rootworm risk index total score and prediction to actual pod (total percentage) damage in Virginia and North Carolina.

Year	Location	Cultivar	Soil texture	Soil drainage	Damage history	Plant date (mo-day)	Total score	Predicted risk level	% Pod damage	Observed risk level	Index fit
					Virginia						
1996	Sussex	VA-C 92R (20)[a]	LS-Tarboro (5)	MWD (10)	Low (5)	5-6 (10)	50	L	13.3	L	Y
1996	Suffolk	VA-C 92R (20)	LS-Eunola (5)	MWD (10)	Mod (10)	5-3 (10)	55	M	28.5	M	Y
1996	Suffolk	VA-C 92R (20)	LS-Eunola (5)	MWD (10)	Mod (10)	5-23 (15)	60	M	18.7	M	Y
1996	Southampton	VA-C 92R (20)	FSL-Slagle (10)	MWD (10)	Low (5)	5-5 (10)	55	M	19.0	M	Y
1996	Sussex	NC 7 (20)	FSL-Eulonia (10)	MWD (10)	Low (5)	5-10 (10)	55	M	19.4	M	Y
1996	Surry	NC-V11 (20)	FSL-Slagle (10)	MWD (10)	High (15)	5-16 (15)	70	H	28.8	M	N+
1996	Greensville	VA-C 92R (20)	FSL-Mataponi (10)	MWD (10)	High (15)	4-21 (5)	60	M	24.1	M	Y
1996	Isle of Wight	VA-C 92R (20)	FSL-Slagle (10)	MWD (10)	No (0)	5-4 (10)	50	L	8.9	L	Y
1996	Isle of Wight	NC 7 (20)	FSL-Slagle (10)	MWD (10)	No (0)	4-28 (10)	50	L	4.6	L	Y
1995	Suffolk	VA- C 92R (20)	LS-Eunola (5)	MWD (10)	Mod (10)	5-8 (10)	55	M	23.4	M	Y
1995	Greensville	VA-C 92R (20)	FSL-Mataponi (10)	MWD (10)	High (15)	4-23 (5)	60	M	44.5	H	N-
1995	Surry	VA-C 92R (20)	FSL-Slagle (10)	MWD (10)	Mod (10)	5-16 (15)	65	M	28.9	M	Y
1995	Southampton	NC 6 (5)	FSL-Slagle (10)	MWD (10)	Low (5)	5-16 (15)	45	L	11.4	L	Y
1995	Surry	VA-C 92R (20)	FSL-Slagle (10)	MWD (10)	Low (5)	5-3 (10)	55	M	7.4	L	N+
1995	Suffolk	NC 6 (5)	L-Wahee (15)	SWPD (15)	High (15)	5-5 (10)	60	M	15.0	M	Y
1994	Suffolk	NC 7 (20)	LS-Eunola (5)	MWD (10)	Low (5)	5-8 (10)	50	L	8.0	L	Y
1994	Suffolk	NC 7 (20)	LS-Eunola (5)	MWD (10)	Mod (10)	5-8 (10)	55	M	25.3	M	Y
1994	Surry	NC 7 (20)	FSL-Slagle (10)	MWD (10)	Mod (10)	4-28 (10)	60	M	8.1	L	N+
1994	Suffolk	NC 7 (20)	L-Wahee (15)	SWPD (15)	High (15)	5-17 (15)	80	H	51.3	H	Y
1994	Suffolk	Other (20)	LS-Kenansville (5)	WD (5)	No (0)	5-6 (10)	40	L	3.0	L	Y
1994	Suffolk	NC 7 (20)	FSL-Emporia (10)	WD (5)	Mod (10)	5-6 (10)	55	M	22.8	M	Y
1994	Surry	Other (20)	L-Caroline (15)	WD (5)	Low (5)	5-5 (10)	55	M	15.7	M	Y
1994	Suffolk	NC 7 (20)	LS-Eunola (5)	MWD (10)	Mod (10)	5-8 (10)	55	M	22.0	M	Y
1994	Suffolk	NC 7 (20)	FSL-Goldsboro (10)	MWD (10)	Mod (10)	5-8 (10)	60	M	34.2	M	Y
1994	Surry	Other (20)	L-Tetotum (15)	MWD (10)	Mod (10)	4-28 (10)	65	M	4.3	L	N+
1994	Suffolk	NC 7 (20)	LS-Eunola (5)	SWPD (15)	Mod (10)	5-6 (10)	60	M	4.5	L	N+
1994	Suffolk	NC 7 (20)	FSL-Lynchburg (10)	SWPD (15)	Low(5)	5-4 (10)	60	M	15.5	M	Y
1994	Suffolk	NC 7 (20)	L-Wahee (15)	SWPD (15)	High (15)	5-2 (10)	75	H	35.0	H	Y
1994	Suffolk	NC 7 (20)	LS-Eunola (5)	PD (20)	Low (5)	5-8 (10)	60	M	19.5	M	Y
1994	Suffolk	NC 7 (20)	FSL-Rains (10)	PD (20)	Mod (10)	4-28 (10)	70	H	0.5	L	N+
1994	Suffolk	NC 7 (20)	L-Wahee (15)	PD (20)	Mod (10)	5-1 (10)	75	H	3.9	L	N+
1993	Suffolk	NC 7 (20)	LS-Eunola (5)	MWD (10)	Mod (10)	5-8 (10)	55	M	22.0	M	Y
1993	Suffolk	NC 7 (20)	LS-Eunola (5)	MWD (10)	Low (5)	5-8 (10)	50	L	1.5	L	Y
					North Carolina						
1996	Woodville	NC 7 (20)	LS-Goldsboro (5)	MWD (10)	Low (5)	5-10 (10)	50	L	8.0	L	Y
1996	Woodville	NC 9 (20)	LS-Goldsboro (5)	MWD (10)	Low (5)	5-13 (10)	50	L	6.5	L	Y
1996	Merry Hill	NC 7 (20)	LS-Craven (5)	MWD (10)	Mod (10)	5-10 (10)	55	M	5.0	L	N+
1996	Merry Hill	NC-V 11 (20)	LS-Goldsboro (5)	MWD (10)	High (15)	5-10 (10)	60	M	6.8	L	N+
1995	Merry Hill	NC 7 (20)	LS-Goldsboro (5)	MWD (10)	High (15)	5-17 (15)	65	M	15.3	M	Y
1994	Merry Hill	NC-V 11 (20)	LS-Craven (5)	MWD (10)	High (15)	5-10 (10)	60	M	8.0	L	N+
1993	Merry Hill	NC 7 (20)	LS-Craven (5)	MWD (10)	Mod (10)	5-15 (10)	55	M	5.8	L	N+
1991	Merry Hill	NC 10C (20)	LS-Goldsboro (5)	MWD (10)	Mod (10)	5-16 (15)	60	M	6.0	L	N+
1989	Chowan	Florigiant (20)	LS-Vahalla (5)	WD (5)	Mod (10)	5-19 (15)	55	M	5.0	L	N+
1989	Pitt	Florigiant (20)	LS-Exum (5)	MWD (10)	High (15)	5-27 (15)	65	M	68.5	H	N-
1989	Halifax	NC 10C (20)	LS-Goldsboro (5)	MWD (10)	High (15)	5-30 (15)	65	M	33.3	M	Y

[a]Numbers in parentheses are values given to each variable within index. Abbreviations are: Soil texture - L = loam, FSL = fine sandy loam, LS = loamy sand; soil drainage - PD = poorly drained, SWPD = somewhat poorly drained, MWD = moderately well drained, WD = well drained; predicted and observed risk level - L = low risk, M = moderate risk, H = high risk; index fit - Y = prediction fits level of pod damage, N+ = prediction overestimated pod damage, N- = prediction underestimated pod damage.

Although the index tends to overestimate risk and could lead to unnecessary use of insecticide, it tends to minimize yield losses to rootworm. For index adopters, we recommend not treating fields that clearly fall into the 'low risk' rating level and treating those fields that clearly fall into the 'high risk' rating level. The decision regarding 'moderate risk' fields will not be as clear and may require consideration of additional factors such as farm solvency, land lease requirements, seasonal weather conditions, etc. The data show that many 'moderate risk' fields, especially those with lower index scores, do not sustain economic levels of rootworm damage. Thus, no treatment would be the correct response. However, some 'moderate risk' fields will sustain damage in some years and need application of insecticides.

Because fewer acres of peanuts are grown in the U.S. compared with cotton, soybeans, corn, or small grains, relatively fewer resources and/or research hours have been focused on peanut insect pest biology or management. As a result, developing integrated pest management (IPM) programs has been slow. With the recent decrease in peanut price supports and the trend for decreasing acreage, limited resources will be available to develop a model for predicting pod damage by southern corn rootworm. The proposed risk index introduces the first IPM-oriented approach in peanut by incorporating important factors that influence pod damage. It currently offers an improved management strategy compared with the all-or-none treatment practices now used by many peanut producers. Adoption of this risk index should result in more efficient use of insecticides and reduced costs in peanut production.

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