EVALUATION OF VARIOUS PEST-MANAGEMENT CHARACTERISTICS

G. Scott Smith, Michael E. Wetzstein, and G. Keith Douce

Abstract

Considering pest management in terms of a set of technology characteristics allows an investigation of various pest-management characteristics and how they relate to a total pest-management package. Employing restricted and unrestricted least squares in this investigation indicates the unique impact individual pest-management characteristics exert on net returns. A Stein-rule estimator is also employed in assessing this impact.

Key words: pest management, evaluation, technology adoption.

Both beneficial and detrimental impacts of pesticide use continue to be important issues affecting agriculture and society as a whole. Pesticide drift, pest resistance, and environmental degradation, along with the constant search for technologies that reduce costs and increase output, have heightened interest in the concept of pest management. Pest-management programs provide information on the optimal input mix and, as addressed by Headley, are considered technical changes.

Agricultural economists have responded to the interest in pest management by developing complex decision rules based on Headley's concept of economic thresholds. These complex rules are designed to replace simpler decision rules, commonly referred to as action thresholds (Moffitt et al.), which were developed by biological scientists. Action thresholds may be defined as the minimum pest density to make application of a fixed recommended-dosage rate profitable. This recommended-dosage rate is commonly based on published extension service recommendations. In practice, complex rules have generally not replaced such simpler decision rules (Moffitt et al.). This is not surprising given Akerlof and Yellen's conclusion that even relatively large deviations from rationality cause only small losses in net revenue. Empirical evidence supporting this conclusion is presented by Hall and Moffitt. They found that relative to an optimal solution, which is computationally burdensome to the producer, little net revenue is lost by using simpler decision rules.

These deviations from "optimal" decisions correspond to partial adoption of pest-management technologies. Technologies, including pest management, are generally composed of several characteristics and are introduced as a package (Feder et al.). Producers may adopt a complete package of technologies or subsets of a package. Generally, previous research has not considered the divisible properties of pest management, and, thus, pest-management programs have only been evaluated in terms of total management against "traditional" pest-control methods (Carlson; Hall; Hall and Duncan; Masud et al.; Reichelderfer and Bender; Rook and Carlson; and Teague and Shulstad).

Evaluating pest management in terms of a technology package approach provides the theoretical flexibility to consider partial pest-managment adoption. Wetzstein et al. implicitly attempted to employ this approach by first developing a list of criteria for "good" pest management which comprises a package of pest-management technologies for cotton producers. The pest-management characteristics based on this list were then transformed into pest-management indices by factor analysis. Partial adoption of a total pest-management package defined by the pest-management indices was then evaluated. A major limitation of this work was the inability to directly consider the degree of partial adoption for various characteristics of a technology package and, thus, to investigate the possible influence on adoption of each of the characteristics. Furthermore, their study was limited

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to a single production season and one crop. Providing such information on the ordering and clustering of characteristics within a package is not to suggest abandoning the package approach in carrying recommendations to producers (Mann). In general, a pest-management package may still be recommended; however, suggestions on how this package may be modified based on a producer's production process could be provided.

The objective of this paper is to illustrate how a technology package approach, providing the flexibility to consider partial adoption, may be employed in evaluation of pest management. Specifically, this paper extends the work by Wetzstein et al. to explicitly consider the degree of partial adoption for various characteristics of a technology package. In contrast to their study, three crops—soybeans, cotton, and peanuts—incorporating pest-management technologies over a four-year period are considered. Crop returns are modeled as a function of traditional inputs, pest density, and pest-management participation in a seemingly unrelated regression framework. Possible multicollinearity among pest-management characteristics motivates consideration of a Stein-rule formulation along with traditional estimates (Judge et al.).

PEST-MANAGEMENT CHARACTERISTICS

For evaluation, Ruesink suggests that in cooperation with entomologists and other crop scientists, economists should develop a list of criteria for "good" pest management. In this spirit, Georgia extension entomologists established three pest-management characteristics for insect field scouting, the major pest-management program in Georgia. These characteristics dealt primarily with producer response to scouting reports on cotton, peanuts, and soybeans. Douce et al. provide a detailed description of these characteristics for cotton based on timing of chemical applications and incidence of insect action thresholds. Action thresholds associated with principal pests for the three crops are published by the Georgia Extension Service (Lambert and Herzog; Womack; and Suber and Todd). To retain an objective analysis, strict adherence to these thresholds was maintained.

The first characteristic, Characteristic 1, measures the proportion of "proper" pesticide applications to the total number of pesticide applications. A pesticide application is considered "proper" if the selection of materials was consistent with the pest(s) reported according to extension service control recommendations and the materials were applied within an appropriate time interval. The appropriate time interval for cotton is within 48 hours after an action threshold occurred; whereas, the interval for peanuts and soybeans is four days after a threshold occurred. Characteristic 2 measures the number of action thresholds treated to the total number of action thresholds, and Characteristic 3 measures the number of chemical sprays made after an action threshold is reached minus sprays before a threshold relative to total number of sprays. Spraying after a threshold is reached allows producers to maximize the effects of beneficial insects for pest control. Spraying before a threshold increases the probability of destroying beneficial insects.

These three pest-management characteristics are associated with "good" pest-management practices. Beneficial insects, action thresholds, timing of pesticide applications, pesticide materials, and application rates are considered by the three characteristics. Thus, the three pest-management characteristics are expected to be positively related to producers' net returns.

PEST-MANAGEMENT CHARACTERISTICS MODEL

Incorporating the above three pest-management characteristics into a theoretical model yields interesting insights for pest management. In a partial equilibrium framework, assume that the total pest-management package, X, influences net returns through the three pest-management characteristics. This relation between the total package, X, and the three pest-management characteristics may be denoted by $g_i(X)$, where $i = 1, 2, 3$ represent the pest-management characteristics. An individual producer's net return, π, resulting from the application of pest management may then be defined as

$$\pi = pf[Z, S, g_1(X), g_2(X), g_3(X)] - rX - wZ,$$

where p denotes the competitive output price; f(.) denotes the producer's production function; Z denotes a (1 by z) vector of production inputs other than pest-management characteristics; S denotes a (1 by s) vector of environmental conditions, including pest density; and r and w denote the price of pest management and the price vector associated with Z, respectively. The first-order Kuhn-Tucker conditions for maximizing π in terms of X are

$$\partial\pi/\partial X = VMP_1 + VMP_2 + VMP_3 - r \leq 0, \text{ and } X(\partial\pi/\partial X) = 0,$$

where $VMP_i = p(\partial f/\partial g_i)(\partial g_i/\partial X)$ is the value of marginal product associated with pest-management characteristic i. If the sum of the VMP's are less than the cost of pest management, r, a producer will not participate in pest management. Furthermore, even if VMP is zero or negative for some pest-management characteristics a producer may still partially participate in pest management if the sum of the positive VMP's equals or exceeds the cost of pest management, r.

In evaluation of pest management, interest is directed toward the relation between pest-management characteristics and net returns. Specifically of interest in this paper is the effect of evaluating pest-management characteristics as one package versus a set of characteristics. In general, multicollinearity may exist within the three pest-management characteristics making the establishment of direct relations between a pest-management characteristic and net returns difficult. Thus, a technique similar to that of Hill and Cartwright which adjusts for multicollinearity is employed to test the possibility of evaluating the pest-management characteristics as one package verus a set of characteristics. Specificially, restricted least squares in the form of principal component analysis may be employed to construct an index based on the pest-management characteristics. The model is then tested to determine if the restrictions correspond to the production processes. As an alternative to testing the truth or falsity of the restrictions, rules that mitigate multicollinearity problems of least squares estimates may be employed. This motivates the Stein-like estimator which shrinks the unrestricted estimates toward the restricted estimates when the restrictions, as reflected by the sample, are more correctly specified (Judge and Bock; Judge et al.).

DATA AND PROCEDURE

Evaluation of pest-management programs at a firm level requires detailed pest density and pesticide application data on at least weekly intervals. Data collection of this type is resource intensive and, thus, is not conducive to a large random sampling procedure necessary for industry-wide policy implications. However, the strength of a detailed weekly data-collection procedure is the ability to examine micro-level firm implications of pest-management programs. Although the data set used here is not a random sample, it was stratified to reflect principal production regions within Georgia. Specifically, data were collected from the various production regions for soybeans, cotton, and peanuts to avoid single site limitations in other studies (e.g., Hall and Moffitt). Multiple sites provide for a more robust model that reflects differences in production and costs associated with various soil types and climate across the state.

A total of 99 producers—39 cotton, 19 soybean, and 41 peanut producers—who participated in the extension-sponsored pest-management scouting program were involved in the study from 1981 through 1984. Detailed daily records were collected from participants by the Farm Economics Information Center (FEIC), Department of Agricultural Economics, University of Georgia. Personnel in local extension offices participated in the collection of the data and worked closely with both producers and FEIC personnel to include the timing as well as the technical aspects of production activities. Pesticide use for each producer's field was recorded as to the type of chemical applied, the amount of active ingredient used, the method by which the chemical was applied, and the date of application. In conjunction with extension and FEIC personnel, field scouts monitored pest densities for individual producer fields on a regular basis throughout the growing season. Individual producer values for each of the three pest-management characteristics were obtained through detailed analysis of individual field-level pest-density reports and pesticide-use records.

For each field, initial field histories listing early-season production inputs and prices paid for inputs, as well as machinery operations performed up to planting, were collected. During a production season, all chemical and irrigation applications were recorded on a daily basis. Detailed machinery and equipment use records were also maintained to account for cultural practices throughout the season. In calculating ownership costs for machinery and equipment, actual farm costs were used in an effort to more closely approximate production costs. Variable costs of machinery and equipment were calculated based on the Oklahoma State Budget Generator (Kletke) with parameters appropriate for Georgia. Items such as purchase price, present value, depreciation method, and average rate of interest paid on borrowed funds were obtained on a mail-in basis and by telephone to calculate actual costs of machinery, irrigation, and other production inputs. Personal contacts were made at the end of the production season to complete and verify the data, including harvest and marketing information.

Costs and returns were computed, based on the Oklahoma State Budget Generator (Kletke), on a per-acre basis or each producer. Producers' fields were aggregated by crop, and prices received each year for cotton, peanuts, and soybeans were computed as the simple average of the prices received by all participating producers.

An iterative seemingly unrelated regression (SUR) model was applied to estimate net returns for the three crops. The SUR model was motivated by possible collinearity among the disturbance terms in the regression equations. It was assumed that crop production processes are described by fertilizer, lime, and seed expenditures; irrigation, machinery, and labor expenditures; pesticide expenditure; pest density; and pest-management characteristics. Total number of action thresholds experienced by a producer for each crop during a growing season was employed as a surrogate for pest density. Means and variances for net returns, costs, action thresholds, and pest-management characteristics associated with the three crops are provided in Table 1. County and year dummy variables were also employed as a surrogate for regional and seasonal differences. All three crops were represented in two counties, Candler and Terrell, located in the southeastern and southwestern region of the state, respectively. Peanut and cotton data were collected in three southwestern counties—Calhoun, Dooly, and Turner—and one southeastern county—Emanuel. Soybean and cotton data were collected in Echols, a county bordering Florida, and cotton data were collected in Morgan, a piedmont county.

RESULTS

Examination of eigenvalues for the three pest-management participation characteristics provided evidence of multicollinearity. All three crops had one relatively large eigenvalue and two relatively small values. Thus, the last two principal components were set to zero for restricted SUR estimation. Table 2 presents the pest-management characteristics and factor loadings for the three indices. The factor loadings indicate the influence each characteristic exerts on the three indices. This provides a method for determining the role a

TABLE 1. MEAN VALUES OF NET RETURNS, COSTS, ACTION THRESHOLDS, AND PEST-MANAGEMENT CHARACTERISTICS FOR SOYBEAN, COTTON, AND PEANUT PRODUCTION IN GEORGIA, 1981-1984[a]

	Mean		
Variable	Soybeans	Cotton	Peanuts
Net Revenue (dollars per acre)	42.63 (5702)	1.89 (25752)	295.16 (30081)
Input Expenditures			
Fertilizer, Lime, and Seed (dollars per acre)	45.94 (400)	48.47 (575)	111.81 (784)
Irrigation, Machinery, and Labor (dollars per acre)	50.73 (466)	91.62 (2767)	171.99 (5930)
Pesticide (dollars per acre)	25.56 (190)	64.04 (1452)	87.16 (423)
Action Thresholds (number of thresholds)	0.63 (.697)	7.47 (19.62)	1.18 (0.80)
Pest Management[b]			
Characteristic 1	0.28 (0.12)	0.38 (0.08)	0.15 (0.24)
Characteristic 2	0.53 (0.21)	0.73 (0.04)	0.42 (.18)
Characteristic 3	−0.13 (0.38)	0.19 (0.22)	0.02 (0.46)

[a]Variances of variables appear in parentheses.

[b]Characteristic 1 denotes number of sprays made after threshold minus number of improper sprays relative to total number of sprays.

Characteristic 2 denotes number of times thresholds were reached minus number of times thresholds were reached and no proper spray was made relative to number of times thresholds were reached.

Characteristic 3 denotes number of properly timed sprays made after threshold minus number of sprays made before threshold relative to total number of sprays.

particular pest-management characteristic plays in the indices. From Table 2 the most important determinant of Characteristics 1 and 3 is Index 1 for all three crops. The only common index for Characteristic 2 is Index 2 for all the crops.

TABLE 2. PEST-MANAGEMENT CHARACTERISTICS AND FACTOR LOADINGS FOR THE PEST-MANAGEMENT INDICES

	Indices		
Characteristics[a]	1	2	3
Soybeans			
1	0.86	0.30	−0.41
2	−0.02	0.97	0.25
3	0.87	−0.28	0.41
Cotton			
1	0.88	−0.28	0.39
2	0.57	0.82	0.01
3	0.88	−0.25	−0.40
Peanuts			
1	0.79	−0.48	0.38
2	0.56	0.81	0.18
3	0.89	−0.09	−0.46

[a]Characteristic 1 denotes number of sprays made after threshold minus number of improper sprays relative to total number of sprays.

Characteristic 2 denotes number of times thresholds were reached minus number of times thresholds were reached and no proper spray was made relative to number of times thresholds were reached.

Characteristic 3 denotes number of properly timed sprays made after threshold minus number of sprays made before threshold relative to total number of sprays.

Logarithmic regression results for the restricted and unrestricted SUR estimators are presented in Tables 3 and 4, respectively. The weighted R^2 for the system corresponds to the appropriate F-test on all non-intercept parameters (McElroy). Although several of the coefficients associated with the unrestricted and restricted models for the traditional inputs have theoretically inconsistent signs, only fertilizer, lime and seed and pesticide expenditures for peanuts have coefficients which are both negative and significant at the five percent level. The negative coefficients suggest input usage above the economic efficiency level. Coefficients associated with action thresholds in both the restricted and unrestricted models are negative for all three crops. However, only the coefficients associated with thresholds for cotton are significant. This indicates the expected inverse relation between pest density and net returns.

The traditional procedure, such as principal component analysis, is to consider only the indices associated with relatively large eigenvalues. This corresponds to the restricted SUR estimates in Table 3. All of the coefficients associated with pest management are positive and significant at the ten percent level. Thus, considering pest management as a total package results in a direct positive impact on net returns. Index 1 loads highly on the first and third pest-management characteristics for all three crops which indicates that "proper" pesticide applications and consideration of beneficial predators significantly enhance net returns.

Considering the characteristics of pest management separately, as in the unrestricted model from Table 4, the coefficients for Index 1 and Index 2 for soybeans and Index 3 for cotton are positive and significant. Disturbing results are the significant negative coefficients associated with Index 2 for cotton and peanuts. In order to further understand these results, it is necessary to trace through the factor loading matrix in Table 2 to identify which pest-management characteristics are associated with Index 2. Notice that Index 2 is the most important determinant of Characteristic 2 for all three crops. Furthermore, the coefficient associated with Index 1 for cotton is significantly negative, and the coefficient associated with Index 1 for peanuts is no longer significant. Index 2 is also a major determinant of pest-management Characteristic 1 for cotton and peanuts. Thus, the drop in significance of Index 1 for peanuts, the negative coefficient for Index 1 for cotton, and the negative relation between Index 2 and net returns for cotton and peanuts all indicate a negative relation between pest-management Characteristic 2 and net returns for cotton and peanut production.

Characteristic 2 is associated with the appropriate use of action thresholds, implying possible inappropriate threshold recommendations for cotton and peanuts. Producers are generally following pest-management recommendations in terms of proper applications. However, the number of treatments indicated by action thresholds may be incorrect. This is consistent with the general philosophy in extension of providing conservative action threshold recommendations in order to serve a wide range of clientele with differing management abilities. As a result, treatment is suggested at relatively low levels of pest infestation. This may result in pesticide applications in excess of the profit-maximizing number (Adams). Insect pressure affecting yields is generally significantly higher and exists for a longer period of time for cotton than for peanuts, resulting in a smaller number of action thresholds for peanuts compared to cotton as shown in Table 1. Thus, conservative

TABLE 3. RESTRICTED SUR RESULTS FOR SOYBEAN, COTTON, AND PEANUT NET RETURN ESTIMATIONS, GEORGIA, 1981-1984[a]

Independent Variable	Crop		
	Soybeans	Cotton	Peanuts
Intercept	17.01**	13.75**	34.47***
	(8.80)	(5.93)	(12.16)
Input Expenditures			
Fertilizer, Lime, and Seed	0.01	1.02*	−3.74**
	(1.95)	(0.72)	(2.07)
Irrigation, Machinery, and Labor	2.59**	−0.77	0.77*
	(1.35)	(0.99)	(0.47)
Pesticide	−1.46	0.94	−3.25*
	(2.54)	(0.92)	(2.09)
Action Thresholds	−1.06	−2.28***	−0.50
	(2.01)	(0.71)	(1.37)
Pest Management			
Index 1	0.06*	0.04*	0.10**
	(0.04)	(0.02)	(0.05)
Index 2	–	–	–
Index 3	–	–	–
Dummy Variables			
1982	1.55	−0.15	−2.58**
	(3.08)	(2.02)	(1.36)
1983	−8.00*	−0.67	−1.25
	(5.80)	(1.48)	(1.60)
1984	0.46	−2.47*	−0.24
	(3.65)	(1.73)	(1.21)
Calhoun	–	−1.82	0.73
		(1.96)	(1.58)
Candler	1.27	−0.55	−0.09
	(7.26)	(1.92)	(1.21)
Dooly	–	−3.47**	0.44
		(2.14)	(1.51)
Early	–	–	1.92
			(2.66)
Echols	1.42	0.01	–
	(4.67)	(2.13)	
Emanuel	–	−0.06	−1.54
		(2.24)	(1.49)
Morgan	–	−0.24	–
		(2.13)	
Terrel	–	−0.90	−1.04
		(1.91)	(1.50)
		$R^2 = 0.58$	

[a]Standard errors of estimates appear in parentheses with the following significance levels: *0.10 significance level; **0.05 significance level; ***0.01 significance level. Turner County and 1981 are the base county and year employed.

action thresholds for peanuts indicate proportionately more thresholds to be treated with pesticides. This further explains the negative significant coefficient associated with peanut pesticide expenditures for the restricted and unrestricted models.

In terms of the theoretical model, the complete package of pest management appears to be profitable. However, not all parts of the total package are profitable. Proper timing of pesticide applications and consideration of beneficials significantly increase net returns; whereas, following recommended action thresholds for cotton and peanuts may negatively impact net returns.

The relatively small number of significant coefficients associated with the dummy variables in both the restricted and unrestricted model indicates little structural difference among the dummy variables and the base county and year employed in the regressions. Only three year dummy variables are significant in the unrestricted and restricted model, and only one and three county dummy variables are significant in the restricted and unrestricted models, respectively.

The results differ according to whether pest-management characteristics are considered individually or as a total package. Results also suggest a potential problem with action thresholds for cotton and peanuts. Of further interest is assessing the significance of this problem. The likelihood ratio statistic, λ, which may be employed for testing the validity of the restrictions is 3.01. This traditional test statistic yields a value relatively close to the critical value for $F_{(.01, 6, 51)} = 3.21$. Under the pretest scenario the hypothesis that the restrictions hold at this level of significance is not rejected. However, at the five percent level the critical value is 2.30 and the hypothesis would be rejected. At the calculated level of λ, there exists a 98.6 percent level of confidence that the restricted estimates are correct.

An alternative pretest estimator, Wallace's minimum average risk criterion, supports the traditional pretest criterion at the five percent significance level indicating rejection of the hypothesis. Unfortunately, this pretest estimator tends to be overly conservative (Wallace). Inconclusive results from these pretest estimators are of concern considering the difference in magnitudes between the unrestricted and restricted coefficients for pest management Index 1. Except possibly for exposition there is little purpose in obtaining alternative pretest estimators. Of relevance is whether there exist procedures for improving the precision of the regression results. As noted by Judge et al., a Stein-like procedure can improve precision by weighing both the restricted and unrestricted estimates. If the restrictions do not generally hold, then the Stein-like estimates will be close to the unrestricted estimates indicating the necessity to consider pest management in terms of its characteristics.

The Stein-like estimates, presented in Table 5, result in a significant reduction in the magnitude of the coefficients towards the restricted model. This is particularly true for the large negative coefficient associated with pest-management Index 2 for cotton, whose absolute value was reduced by more than 25 percent. Thus, rather than choosing between a pest-management package in total or investigating its various characteristics based on pretest estimators, the Stein-like estimator takes a linear combination of the unrestricted and restricted estimators. The Stein-like estimator adjusts the coefficients associated

TABLE 4. UNRESTRICTED SUR RESULTS FOR SOYBEAN, COTTON, AND PEANUT NET RETURN ESTIMATIONS, GEORGIA, 1981–1984[a]

Independent Variable	Crop		
	Soybeans	Cotton	Peanuts
Intercept	30.46**	9.36*	51.98***
	(17.78)	(5.87)	(15.88)
Input Expenditures			
Fertilizer, Lime, and Seed	−1.77	1.91***	−6.83***
	(2.38)	(0.58)	(2.64)
Irrigation, Machinery, and Labor	2.13	−0.56	2.45*
	(4.89)	(0.90)	(1.67)
Pesticide	−0.45	1.39*	−5.46**
	(2.82)	(0.95)	(2.71)
Action Thresholds	−2.78	−3.94***	−0.63
	(2.13)	(0.80)	(1.60)
Pest Management			
Index 1	1.18*	−0.29*	0.08
	(0.83)	(0.21)	(0.11)
Index 2	15.38*	−11.23***	−0.49*
	(11.06)	(3.79)	(0.30)
Index 3	16.52	10.80***	0.50
	(13.45)	(3.10)	(2.19)
Dummy Variables			
1982	−3.74	0.45	−3.24**
	(4.38)	(1.83)	(1.52)
1983	−2.79	−0.82	−2.41
	(6.16)	(1.33)	(1.85)
1984	−12.19*	−4.01***	−1.60
	(8.67)	(1.43)	(1.58)
Calhoun	—	−4.43***	−0.90
		(1.68)	(2.07)
Candler	2.39	−2.66*	−1.82
	(8.31)	(1.69)	(1.96)
Dooly	—	−4.71***	−1.44
		(1.50)	(2.05)
Early	—	—	0.91
			(3.59)
Echols	0.33	−1.75	—
	(4.84)	(1.99)	
Emanuel	—	−2.15	−2.41
		(2.06)	(2.12)
Morgan	—	−0.69	—
		(1.83)	
Terrel	—	−3.33**	−1.94
		(1.73)	(1.82)
		$R^2 = 0.73$	

[a]Standard errors of estimates appear in parentheses with the following significance levels: *0.10 significance level; **0.05 significance level; ***0.01 significance level. Turner County and 1981 are the base county and year employed.

TABLE 5. STEIN-RULE RESULTS FOR SOYBEAN, COTTON, AND PEANUT NET RETURN ESTIMATIONS, GEORGIA, 1981-1984

Independent Variable	Crop		
	Soybeans	Cotton	Peanuts
Intercept	29.87	9.86	42.67
Input Expenditures			
Fertilizer, Lime, and Seed	−1.41	1.39	−5.33
Irrigation, Machinery, and Labor	2.58	−0.61	2.11
Pesticide	−0.58	1.21	−4.72
Action Thresholds	−2.46	−3.54	−0.40
Pest Management			
Index 1	1.02	−0.23	0.09
Index 2	13.38	−8.39	−0.36
Index 3	13.22	8.47	0.72
Dummy Variables			
1982	−2.85	0.36	−2.63
1983	−3.66	−0.91	−1.69
1984	−10.51	−2.93	−1.00
Calhoun	—	−3.30	−0.59
Candler	2.25	−1.78	−1.42
Dooly	—	−4.19	−1.11
Early	—	—	0.94
Echols	0.53	−1.11	—
Emanuel	—	−1.27	−2.20
Morgan	—	−0.51	—
Terrel	—	−2.70	−1.83
		$\lambda = 3.01$	

with the pest-management characteristics approach (the unrestricted model) by considering the total package approach (the restricted model). This results in moderating the coefficients associated with the unrestricted model. Thus, Stein-like estimates may yield superior estimates for purposes of pest-management program evaluation.

CONCLUSIONS

As suggested by Ruesink, a list of "good" pest-management criteria was developed as characteristics in a total pest-management package. Based on detailed daily records of pest pressure, pesticide applications, and all other production practices the impacts on net returns of various characteristics in a pest-management package were investigated. Restricted least squares and Stein-like estimators were employed to account for the likely collinearity among the three pest-management characteristics.

Although definitive conclusions cannot be drawn from the results of this study, there are implications for policy decisions. The results of this research indicate that in terms of a total package, pest management is effective in increasing producers' net returns. However, this generality does not hold for each pest-management characteristic. For cotton and peanut production, the results indicate inappropriate action threshold recommendations which is consistent with extension's philosophy of providing conservative recommendations. Thus, adjustments in threshold levels may be warranted. Further research is required for a definitive statement on this issue. Specifically, action threshold modeling in a dynamic stochastic framework is required. This research does suggest that failure to consider individual pest-management characteristics, by only considering a total pest-management package, may mask some important underlying relations between pest management and the production process. Failure to discover these relations may contribute to prolonged errors in policy.

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