Pesticides

ABSTRACT

The use of field scouting and insecticide use on Delta cotton farms was investigated. It was found that management and incremental value of scouting increased adoption of scouting. Scouting was not found to be a substitute for insecticide use on these farms. Scouting had a strong effect in increasing the value of the cotton produced.

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Analysis of Field Scouting and Insecticide Use

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I. Introduction.

There are several approaches to the use of pesticides to control crop pests. One possible approach is the use of routine pesticide sprays. An alternative system labeled "intergrated pest management" consists of a program combining biological and chemical controls with careful monitoring of the crop and pest conditions. Ideally, the chemical controls are applied only when they will prevent season-long crop damage which would be equal to or higher than the cost of the application.

The monitoring phase of pest management is known as field scouting or scouting. Scouting is a labor-intensive activity which can assist in timing of pesticide applications, identification of pest and beneficial species for chemical type decisions, and for collection of information on other crop stresses. Scouting is currently being practiced by farm operators, hired scouts and pest control specialists or consultants. In recent years, the federal-state extension service has supported pilot pest management programs.

There are current proposals to expand publicly funded research, extension and direct subsidies in the scouting area. Support for this position comes from several sources. Some entomologists feel that scouting can help delay insecticide treatments, and, thereby, encourage the activity of both the predator and the beneficial insects. An evaluation of nineteen pilot programs, most of which included scouting, showed most programs increased profits by increasing yields and or decreasing insecticide use (Von Rumker, 1974). However, several scouting programs increased insecticide use, making it difficult to determine what would have been done in the absence of the pilot programs in other cases. An analysis of the returns from the use of pest management consultants in California was made by comparing returns on farms using consultants and other farms which did not use consultants (Hall, 1977). Farms using consultants showed reduced use of pesticides per acre, with no significant changes in yields or profits. Rates of adoption of the use of consultants were found to be higher for risk adverse producers and for those growers with larger acreages (Wiley, 1974). Of course, if various forms of scouting can reduce insecticide use, and there are external effects from the pesticides, then public support for scouting might be justified.

Before major policy changes are made in the scouting area, it seems advisable to estimate the economic returns to scouting. To date the effect of operator or hired scouting on reducing crop loses and changing insecticide expenditures has not been seriously investigated.[1] This study reports on scouting activities in cotton production in the Southern part of the U.S. The next section provides a general choice model of pest control. Section III gives results on factors affecting use of scouting and how scouting affects insecticide use. The final section gives estimates of the productivity of scouting and implications for scouting investments.

II. The Value of Scouting.

Consider a situation in which the farm operator has three general choices in pest control for each decision period: (1) do nothing, (2) always apply a pesticide, or (3) scout and then based on the results of the scouting apply a

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[1]The Von Rumker et.al.(1974) study did not evaluate scouting per se. There are a few studies that compare scouting with other control strategies, (Salkin et.al., 1976), but effects on yields and insecticide use are usually assumed.

pesticide application or do nothing else. For each period the expected cost to the farmer of following choice (1) can be expressed as:

$$E_1(x) = \int_0^{\infty} f(x)h(x)dx = \int_{DTH}^{\infty} f(x)h(x)dx \qquad (1)$$

where: $E_1(x)$ is the expected loss measured in dollars from neither applying a pesticide without scouting nor scouting and then making a treatment decision, f(x) is the probability distribution of plant damage or insect infestations (figure 1a), and h(x) is the biological function that gives the yield loss associated with each pest infestation level or plant damage level (figure 1b). DTH is the damage threshold which is the point at which the insect infestation or plant damage begins to affect final yield. Choice 2 is:

$$E_2(x) = T \quad (2)$$

in which $E_2(x)$ is the expected co t measured in dollars from always applying a pesticide, and T is the dollar cost of a treatment with pesticide. Choice 3 is:

$$E_3(x) = \int_{DTH}^{ETH} f(x)h(x)dx + [\int_{ETH}^{\infty} f(x)dx] \cdot T + S \qquad (3)$$

where: $E_3(x)$ is the expected cost measured in dollars from scouting and then applying a pesticide if the scouting shows that the pest has reached economically damaging levels. ETH is the point at which the damage done to the plant in terms of yield loss equals the control cost and S is the cost of scouting and deciding about insect treatment in dollars.

The key feature of this approach to effective pest control is the yield loss function, h(x). The economic threshold, ETH is determined by when the yield loss function, h(x) equals T. This follows from the definition of the economic threshold given in equation (3) and the assumption that a pesticide treatment in a decision period will reduce the insect density to a negligible damage level.

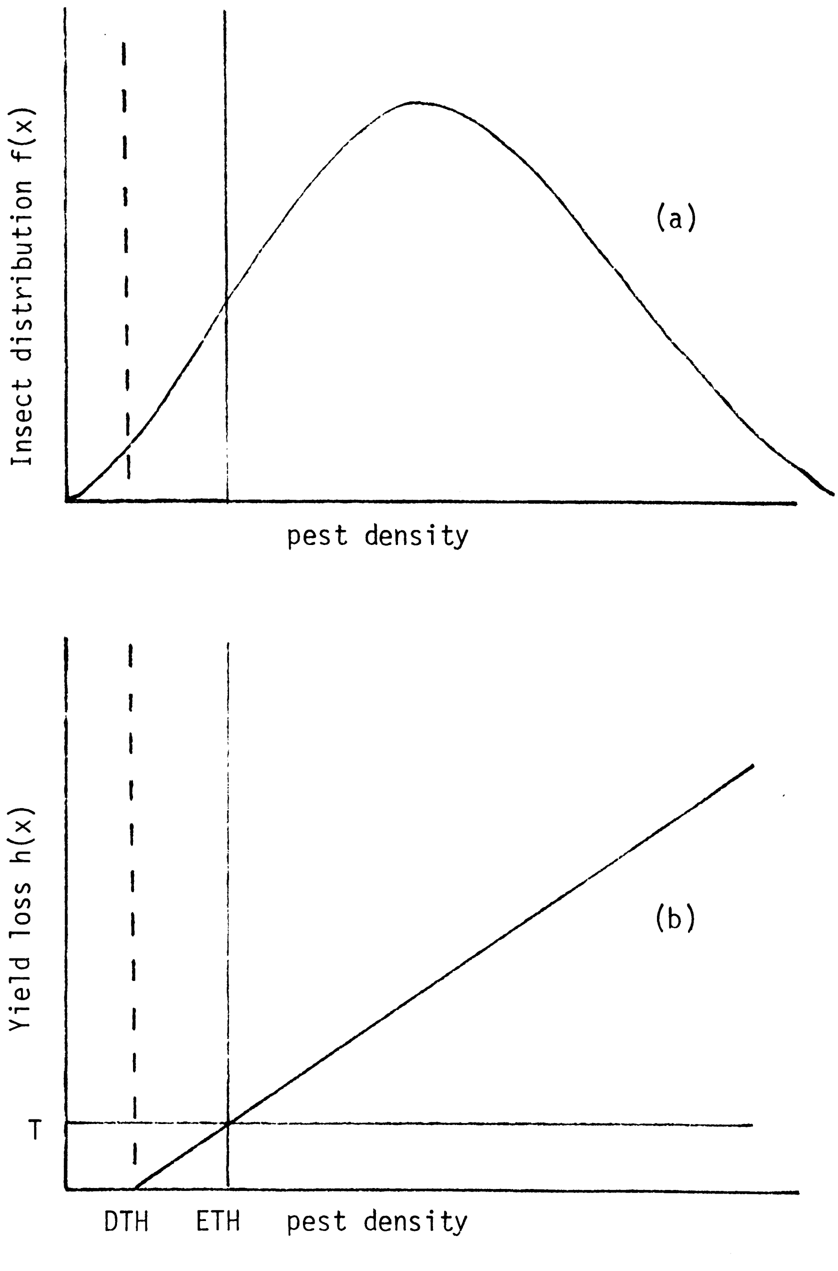

Figure 1. Relationships between pest distributions, yield loss and insecticide cost.

If the yield loss function (h(x)) is assumed to have a linear form such as, h(x) = ax, one can simplify the three pest control alternatives into the following discrete forms:

$E_1(x) = a\, \Sigma_{x=DTH}^{\infty} f(x)/N,$ (4)

$E_2(x) = T,$ (5)

$E_3(x) = (a\, \Sigma_{x=DTH}^{ETH} f(x) + n_3 T)/N + S,$ (6)

where: N is the total number of pest density observations, n_3 is the number of observations at levels ETH to ∞ . With these equations the expected cost of each of the three choices can be evaluated for each decision period.

A profit maximizing farm operator would have a value of scouting above the best of the two other alternatives computed as:

$S = \min\,(E_2(x) - E_3(x),\ E_1(x) - E_3(x)).$ (7)

A farm operator is hypothesized to compute this incremented value of scouting and make the choice which maximizes expected returns. However, relative prices of inputs, varying opportunity costs and the timeliness of the decision make this resource allocation difficult.

The management skills of the decision maker will probably affect his ability to utilize scouting information. Management skills as measured by education level were shown by Huffman (1974) to influence farmers' ability to make allocation decisions in fertilizer use. Farmers with more education and with more farming experience will probably be able to better analyze scouting information and better make pest control decisions on it. Thus, one would expect operators with higher management skills to utilize scouting more. A management index is computed and included in the above scouting use model (Grube, 1978).

To be adopted, scouting must increase profitability. One possible way would be to decrease insecticide expenditures or use while maintaining constant yields. Alternatively, for areas in which pest problems are infrequent, scouting might increase expected profits through increased insecticide use, but reduced pest damage and even higher crop revenues. These might be thought of as the substitute and complement features of scouting and insecticide use, respectively. This notion will be tested by analyzing the impact of scouting on insecticide use in the next section.

III. Scouting and Insecticide Use.

The scouting choice model given above was tested on a group of Delta area cotton farmers. These farmers have had available classes and bulletins (Barnes, et.al., 1972) on scouting for primary insect pests of cotton for about twenty years. This area was chosen because of the availability of insect infestation records by week and by county for the 1966 to 1972 period. Other data were gathered from a one page survey of cotton growers using the random sample of growers from the 1972 USDA Cost of Cotton Survey (USDA, 1974).

The expected value of damage above the recommended treatment threshold (see equation 4) was computed for each county and for each week by regressing observable fractions of fields infested at any level, and those fields above the economic threshold on the observed value of damage. This was found to be a convenient way to use readily available infestation indicators to obtain the more specific expected value of damage needed in the model (Grube, 1978). This and the management index for each operator were utilized in the following scouting use equation:

$$P_{wi} = a + b\, S_{wi} + c\, M_i + u_{wi}, \quad (8)$$

where:

P_{wi} = is a 0 or 1 variable which measures whether the ith farmer scouted in the wth week,

S_{wi} = is the expected value of scouting computed in equation (7) for the ith farmer at the county level in the wth week,

M_i = the management ability index of the ith farmer and

a, b, c are estimated constants from a logit regression routine (Nerlove and Press, 1976).

Table 1 shows the weekly scouting results. It can be seen that higher management skills strongly increase the probability of scouting being practiced in all but the first last weeks. The value of scouting (S_{wi}) is also significant in the six weeks near the center of the crop protection season. The scouting value variable had the expected positive sign in all but one week. Less accurate data because of incomplete scouting records probably accounts for the less definitive results at the beginning and end of the season. Other versions of the model (assuming less infestation history, or a simpler version of value of scouting) gave very similar results. Producers are considering returns and costs in choosing whether to use scouting.

The impact of scouting on insecticide use was evaluated in a simple linear equation of the following form:

$$A_i = b_1 + b_2 SH_i + b_3 EA_i + b_4 (EA \cdot SH)_i + b_5 M_i + U_i, \quad (9)$$

where A_i is the number of insecticide applications applied by farmer i. SH_i is the number of hours of scouting per acre on the ith farm. EA_i is the expected number of applications based on the number of times the pest infestation exceeded the recommended treatment threshold for farmer i at the county level, and M_i is the management index discussed above. A cross product term (EA·SH) is included to test if scouting is more helpful in making treatment decisions at low pest population levels.

The model in equation (9) was estimated by ordinary least squares. The equation estimated for 71 farmers was (t values in parentheses):

Table 1. Probability of Scouting by Weeks.[a]

Week	Number Scouting[b]	Constant	Value of Scouting S_{wi} [c]	Management, M_i [c]
1	19	5.003 (0.85)	12.177 (1.02)	0.016 (0.08)
2	36	-3.144** (2.19)	-2.884 (1.18)	0.353** (2.07)
3	42	-2.094** (2.49)	0.630** (1.71)	0.428*** (2.40)
4	48	-1.958** (2.38)	0.408** (1.94)	0.436*** (2.36)
5	54	-1.842** (2.18)	0.378** (2.10)	0.419** (2.16)
6	54	-2.029** (2.41)	0.203** (2.25)	0.418** (2.18)
7	54	-2.484*** (2.78)	0.176** (2.25)	0.485*** (2.54)
8	48	-2.847*** (3.11)	0.249*** (2.53)	0.457*** (2.47)
9	42	-1.634** (2.13)	0.061 (1.09)	0.347** (2.04)
10	33	-1.557** (2.01)	0.044 (0.81)	0.292** (1.72)
11	19	-1.058 (1.22)	0.043 (0.57)	0.082 (0.44)

[a]The dependent variable is the standard normal deviate or the probability of using scouting.

[b]The total sa;ple size was 84 for all weeks.

[c]The .01, .05 and .10 levels of significance are designated by ***, ** and * respectively. The significance of the constant term was tested with a two-tailed test while the other two terms were tested with a one-tailed test since they were a priori expected to be positive. The numbers in parentheses are asymtoptic "t" values. R^2 is undefined.

$$A_i = \underset{(1.67)}{3.65} - \underset{(.96)}{5.24SH} + \underset{(4.55)}{2.30EA} + \underset{(1.50)}{3.69(EA \cdot SH)} + \underset{(1.07)}{.59M}, \quad R^2 = .54$$

Only the expected applications variable (EA) computed from the pest populations is statistically significant at the ten percent or lower level.[2] The overall impact of scouting hours (SH) on insecticide applications is negligible (not different from zero). Both substitution and complementarity situations between scouting and insecticides must exist on this set of farms. The set of farms was further divided into two sets: one in which scouting was expected to increase (complement case) and a second set in which scouting was expected to decrease (substitute case) insecticide use based on pest population data. The model fit to the complementing case data had a statistically significant positive sigh on the scouting hours variable, indicating scouting was inducing more treatments where they were needed. However, the substitute case data set showed no effect of scouting hours on insecticide use much as the result given in the previous paragraph.

One conclusion which one can draw from this analysis of scouting is that more scouting may not lead to less insecticide use per acre. This result was also found in some yet unpublished work on soybeans. More hours of soybean scouting, even adjusting for pest populations, did not lower per acre insecticide application rates.

Let us turn to the output increasing effects of field scouting to determine if scouting is raising per acre yields.

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[2]The coefficient on expected number of applications was always 2.0-2.8 for several forms of the model. This means that this number of applications were made on the average each time a report of a treatable pest population was present. There are two possible reasons for this. Firstly, a farmer will probably apply insecticides to all his fields if some need treatment. Secondly, if a field is near the treatment criteria, the farmer may guess that it will be over the criteria before the next scouting time.

IV. Production Function with Scouting.

Since scouting was not found to decrease insecticide use, it was hypothesized that scouting must have been adopted because it had the potential of increasing yields and profits. A Cobb-Douglas production function was used to test this hypothesis. If scouting increases profits, then the coefficient which will be estimated for scouting time should be positive.

Three sets of results are presented in Table 2. The first is the "usual" production function. This contains the variables that are usually included in farm level production functions. The second set includes a measurement of scouting time for each farm. The third set also includes a measure of insect damage and the management quality index discussed above. It can be seen that scouting has a positive effect on the value of cotton which is produced. The overall fit of the model is improved when scouting hours are included. The interactions between scouting, expected insect damage and insecticides are interesting. The inclusion of insect damage would be expected to increase the coefficient on the insecticide variable since insecticide use and expected insect damage should be correlated. In this case the opposite appears to occur.

Marginal value products were computed for each of the variables in Table 2 (Grube, 1978). An additional hour of scouting was estimated to increase cotton revenues by approximately $30. This may be above the opportunity cost of time for managers and it is clearly above commonly quoted hired scouting wages (Von Rumker, 1974). This suggests more scouting in the future. Other marginal value products were similar to other cotton studies (Carlson, 1977). Here, there was an indication of over use of insecticides as suggested in the last section on insecticide use.

Table 2. Coefficients of Cotton Production Functions.

Independent Variables	Dependent variables: Value of cotton produced (Q)[a, b, c] (1)	(2)	(3)
Intercept	2.896*** (5.50)	3.165*** (5.97)	2.871*** (2.73)
Land, x_1 (acres)	0.379*** (2.56)	0.389*** (2.69)	0.420*** (2.73)
Labor, x_2 (dollars)	0.121 (1.14)	0.123 (1.19)	0.114 (1.06)
Equipment, x_3 (dollars)	0.386*** (4.00)	0.371*** (3.93)	0.356*** (3.63)
Materials, x_4 (dollars)	0.125 (1.10)	0.102 (0.91)	0.082 (0.71)
Insecticide, x_5 (dollars)	0.013** (2.15)	0.008 (1.34)	0.010* (1.32)
Scouting, x_6 (hours)		0.018** (2.04)	0.019** (2.06)
Insect damage expected, x_7			-0.066* (1.28)
Management, x_8			0.134 (0.59)
R^2	0.953	0.956	0.958
N	71	71	71

[a]Means of variables were, Q = $50,757, x_1 = 235 acres, x_2 = $5912, x_3 = $13,845, x_4 = $5,913, x_5 = $1876.6, x_6 = 32.5 hrs., x_7 = .934, x_8 = .07.

[b]The .01, .05 and .10 levels of significance are indicated by ***, ** and * respectively. Since the signs of the coefficients can be predicted a priori, one-tailed tests are used.

[c]The numbers in parentheses are t values.

VI. Policy Implications.

This study suggests that scouting has returns above costs even if it does not act as a direct alternative to the use of chemical pesticides. Scouting was found to increase yields and to complement insecticide use in some low pest pressure cases. The use of scouting was found to be encouraged by high expected incremental values relative to other pest control programs and by higher management skills. The latter finding may be especially important in determining who will benefit from scouting subsidies. Similarly, training better general managers may be an important way to increase the use of scouting.

Operator and hired employee scouting is probably a viable alternative to the pest control consultant, especially where free rider and yield impacts are important relative to pesticide reduction. Many crops have small amounts of pesticides applied over large averages. These seem to be important areas where more work is needed on scouting productivity.

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