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Value of a control decision rule for leek moth infestations in leek

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Abstract

Fourteen commercial leek fields with first and second generation Leek moth, *Acrolepiopsis assectella* Z., (LM) injury were sampled during 1986 in The Netherlands. For both generations, plant injury was more prevalent in the perimeter of the field than in interior portions. A sequential sampling program for use in making treatment decisions for LM was developed. An economic analysis of the value of sampling information derived from the sequential sampling program was performed. The parameters used for the analysis were crop yield and value, expected level of LM infestation, potential loss of value due to LM infestation, effectiveness of insecticide application, and cost of sampling. Due mainly to the high value of the crop and low cost of treatment, analysis indicates that there is little difference between a sampling-based management plan and prophylactic application of insecticides in terms of pest control costs. Additionally, such a sampling-based management plan is relatively insensitive to changes in the parameters used in the model. Thus, development of a threshold linked to a sampling procedure will not reduce pest control costs. Use of the sampling-based management plan will also not significantly increase pest control costs and will likely result in reduced insecticide use compared with a prophylactic treatment program.

Introduction

The leek moth, *Acrolepiopsis assectella* Z., (LM) (Lepidoptera; Yponomeutidae; Acrolepiinae) is the primary insect pest of the ca. 2700 ha of leeks grown annually in The Netherlands. Damage by the larvae occurs as mining and perforations in the leaves or as distortion in older leaves due to earlier feeding. Depending on the planting time, leeks can be harvested in the summer or fall of the year that they were planted, or be allowed to overwinter in an early growth stage and harvested the following spring. The largest market is for summer and fall harvested leeks and, on a national average, chemical control is generally applied twice during the growing season for control of LM.

At present growers do not have any formal decision rules to guide their pest control actions for LM. One potentially useful type of pest control decision rule consists of a procedure for estimating or classifying pest densities, and guidelines for initiating controls based on the results of the sampling. These decision rules must take into account the pest population level, the value of the crop, the potential loss caused by various LM densities, the effectiveness and cost of the control tactic, and the cost of assessing the population. Without sampling based control decision rules for LM, and with the fear of insect damage in such a high value crop as leeks (ca. 37,000 guilders per ha), growers are conservative in their attitudes and treat whenever they fear any potential loss.

Studies conducted during 1981 in France and Spain indicated that the LM pheromone could be useful for providing early warning to growers (Rahn, 1982). However, no relationship was established between pheromone trap catch and egg or larval occurrence, or subsequent plant damage in a field. More recent information indicates that pheromone trapping results were not always reliable in following LM flights (Gill, 1985). Thus, pheromone monitoring does not provide reliable estimates of adult populations, let alone larval populations in the plants. Actual within-field sampling for the insect should provide the most reliable indication of potential loss in an individual field, but sampling for the insect on the plant is difficult. The eggs of LM are normally laid in the whorl of the plant and the emerging larvae mine and feed on the newest leaves (Bouchet, 1973; Gill, 1985). Practical considerations make it impossible to sample for the small and concealed eggs. Additionally, since it is difficult to find the young larvae when they are in the whorl of the plant, it becomes necessary to sample for the more easily visible feeding signs. If sampling is based on early feeding signs and good control measures are applied when these signs first appear, marketability is not affected (J. T., unpublished data).

In this paper we develop and evaluate a control decision rule for LM infesting leeks in The Netherlands. This decision rule consists of an action threshold (Stern, 1973) consisting of a proportion of leek moth infested plants and a binomial sequential sampling plan for classifying the proportion damaged plants with respect to this threshold. The control decision rule was studied from two perspectives. First, effective use of the sequential sampling plan requires knowledge on the spatial patterns of LM infestations in the field. If a strong border effect occurs, samples should be allocated to take this factor into account. The spatial pattern of LM infestation was studied using data collected in 14 commercial leek fields. Second, for a sampling program to be useful, the benefits obtained by sampling should outweigh the cost of obtaining the information (Nyrop *et al.*, 1986). We determined whether this was the case with the proposed LM control decision rule.

Materials and methods

All field work was conducted on spring or early summer transplanted leeks during the summer of 1986 in The Netherlands. The data set consisted of samples taken in 14 commercial fields ranging in size from ca. 1–3 ha. Samples were taken in each field once during the season. Fields were divided into a grid with samples taken at uniform spacings. The number of sites per field varied from 115–189. At each site in the field five plants were inspected for signs of leek moth larvae injury and rated as either damaged or not. Additionally, damage was classified as either caused by first or second generation LM. All 14 fields were examined during the second generation of LM, since this is considered to be the more damaging generation in The Netherlands.

Within-field pattern of LM damage

The within field pattern of LM damage was analyzed by comparing the proportion of infested plants at the field border to the proportion in the interior of the field via ANOVA. The interior of each field contained from 54–127 sites and excluded the ca. 2 m of the field perimeter. The border of each field was considered to be the last row or plant in a row and 42 to 64 equally spaced sites in the border of each field were defined.

Construction of sampling program

Sampling for LM injury consists of classifying a plant as either damaged or not. Therefore, a binomial distribution can be used to describe the counts of LM injured plants. A sampling procedure was developed for classifying the proportion of plants (p) infested with LM as either above or below an action threshold (p_T) using Wald's sequential probability ratio test (SPRT) (Wald, 1947; Fowler and Lynch, 1987). With the SPRT the null hypothesis, H_0, is $p = p_0$ where $p_0 < p_T$; the alternate hypothesis, H_1, is $p = p_1$ where $p_1 > p_T$. The test constructed with these hyportheses is then used to test the hypothesis that $p \leq p_T$. If the null hypothesis is accepted, p is classified as less than p_T and the converse if the null hypothesis is rejected. Samples are drawn from a population and compared to a set of stop limits. The stop limits are used to determine whether sufficient sample information has been collected to classify the population parameters with a specified degree of precision.

The performance of a sequential sampling plan is judged by its operating characteristic (OC) and its average sample sizes (ASN). Both criteria have a specific value for each true value of the population parameter being classified. The OC is defined as the probability of accepting the null hypothesis given any true population parameter (P[accept $H_0 | p = p_t$]). The ASN provides the expected number of samples requires to terminate sampling given any true population parameter. A sampling plan is constructed by specifying p_0, p_1, α which is equal to 1-P(accept $H_0 | p = p_0$), and β which is equal to P(accept $H_0 | p = p_1$). Wald's procedure was used because it has the property that among all sequential procedures with the same α and β, it minimizes the ASN values for p_0 and p_1 (Hoel *et al.*, 1971). Values for the OC and ASN were approximated using equations provided by Fowler and Lynch (1987).

Determining the value of sampling information

The value of the sampling-based LM management plan was analyzed using the methods outlined by Nyrop *et al.* (1986). These methods are recapitulated here and details to the present analysis are added.

Let L[a, p] be a function describing the losses incurred when pest control action a is used to manage a LM infestation of p. Also, let d[z] be a decision rule that uses sample data to choose a particular pest control action. With most sequential classification sampling plants there are two potential outcomes of d[z] and associated actions; z_0 which is to classify the pest population as less than the treatment threshold with attendant no-treatment action a_0, and z_1 which is to classify the pest population as above the treatment threshold with attendant treatment action a_1. Let f(p) be a probability density function used to represent knowledge about LM infestations prior to sampling. This function is called a prior distribution. It may be based on long run historical averages of infestations or it may reflect naivety by being a uniform distribution. Finally, let P($z | p$) be a sampling likelihood which is the probability of z given p where z is the outcome of a sampling bout and p is the pest density. For sequential classification sampling, z is either acceptance (z_0) or rejection (z_1) of the null classification hypothesis. When a sequential classification sampling plan is used, the sampling likelihood for z_0 is given by the OC and the sampling likelihood for z_1 is given by 1-OC.

The expected loss for the least cost action to take when no sampling is performed is first determined by minimizing

$$\int_0^{p_{\max}} \mathrm{f}(p)\, \mathrm{L}(a, p)\, \mathrm{d}p \qquad \{1\}$$

with respect to a. This action is denoted as a^*. Note that in this equation $p_{\max}$ is the maximum LM infestation that is likely to occur and the integral of f(p) equals 1.0.

The expected loss for control costs dictated by sampling is calculated as

$$\int_0^{p_{\max}} \mathrm{f}(p) \sum_{i=0}^{1} \mathrm{L}(\mathrm{d}(z_i), p)\, \mathrm{P}(z_i | p)\, \mathrm{d}p\,. \qquad \{2\}$$

This can also be written as

$$\int_0^{p_{\max}} f(p)\,[L(a_0, p)\,OC(p) + L(a_1, p)(1\text{-}OC(p))]\,dp\,. \qquad \{3\}$$

The expected value of the sample information (EVSI) is the difference between the expected loss using a^* and the expected loss using the actions dictated by the outcome from sampling when the expectation in both cases is calculated using the sample likelihood functions. For example, if action a_1 is the least cost action to take if no sampling is performed, the expected loss for determining the EVSI using this a^* is calculated as

$$\int_0^{p_{\max}} f(p)\,[L(a_1, p)\,OC(p) + L(a_1, p)(1\text{-}OC(p))]\,dp \qquad \{4\}$$

$$= \int_0^{p_{\max}} f(p)\,L(a_1, p)\,dp\,. \qquad \{5\}$$

The expected value of the sample information is then the difference between equation {5} and quation {3}. If this value is negative, using sample information provided by the sampling protocol as a basis for determining management decisions may be an inferior strategy. However, even if the value of the sample information is negative, use of the decision rule may be beneficial based on other considerations such as reducing pesticide use. The negative value of the sample information then provides a measure of the average risk that must be born in order to reduce pesticide use. If the expected value of sample information is positive, it must be compared to the expected cost of sampling to ascertain the net worth of the sample information.

The expected cost of sampling information can be calculated using the ASN values as

$$\int_0^{1} f(p)\,ASN(p)\,C\,dp + FC \qquad \{6\}$$

where C is the per unit cost of collecting a sample and FC are the fixed costs for sampling a field. If the net worth of the sample information is positive, then from the standpoint of minimizing expected pest control costs, sampling is a worthwhile endeavor. If the net worth is negative, the value of sampling may have to be buttressed by external considerations such as the desire to minimize pesticide use in order to justify expenditures associated with sampling.

To conduct the analysis outlined above on the LM sampling-based management plan, the following parameters and models were used. In all cases, the first value or set of values given were used as a standard and subsequent values or ranges were used in a sensitivity analysis. The standard was calculated to provide a reference point for the sensitivity analysis. Numerical solutions were obtained by approximating $f(p)$ with a discrete distribution with 40 classes. As a result, all of the integrals described above are replaced by sums. All calculations were done using a spreadsheet on a micro computer.

A range of proportion damaged plants of 0 to 0.04875 was used to calculate the value of the sample information. A maximum of 0.04875 was used based on the data collected to determine the within field distribution of LM and because the OC is ca. 0.0 for p values greater than 0.04. As a result of the OC being ca. 0.0 there is little distinction in costs between a sampling based decision rule and a prophylactic treatment which is usually the least costly strategy with no sampling. A uniform distribution was used to represent possible LM infestations given no insecticide treatments. Different prior distributions were used in the sensitivity analysis.

The yield of leeks (*YIELD*) per hectare was initially set to 180,000 leeks. A range of values between 140,000 to 220,000 was used in a sensitivity analysis. The price per leek (*PRICE*) was initially set to 0.21 guilders. A range of 0.11 to 0.31 guilders per leek was included in the sensitivity analysis.

Leek moth damage or monetary loss (*DAMAGE*) was modelled as a reduction in the price per plant at harvest. For the standard, a LM injured leek suffered a 70% value reduction.

In the sensitivity analysis, percent reductions of 50 to 90% were used.

The cost of insecticides (*COST*) was set to 70 guilders per ha. This cost includes both material and application costs. No sensitivity analysis was performed on this parameter.

The effectiveness of an insecticide application (*EFFECT*) was modelled as a proportional reduction in *DAMAGE*. Thus, the effect of applying an insecticide was to diminish the reduction in price for a LM infested leek. The standard value for *EFFECT* was 0.7 and a range of 0.5 to 0.9 was included in the sensitivity analysis.

With the variables listed above, the loss function when no insecticide is used $[\mathrm{L}(a_0, p)]$ is given as

$$PRICE^* \, DAMAGE^* \, p^* \, YIELD \, .$$

The loss function when an insecticide is used $[\mathrm{L}(a_1, p)]$ is given as

$$(1\text{-}EFFECT) \, [\mathrm{L}(a_0, p)] + COST \, .$$

The field size (*SIZE*) was initially set to 1.5 ha and a range of values of 0.5 to 2.5 ha was used in the sensitivity analysis. The field size influences the per hectare cost of sampling because the same ASN values apply to the entire range of field sizes. As a result, per ha sampling costs were modelled as

$$\int_0^1 \mathrm{f}(p) \, \mathrm{ASN}(p) \, C \, \mathrm{d}p / SIZE \, . \qquad \{7\}$$

The cost per sample (C) was set to 0.07 guilders per leek. This represents 1 person sampling 500 plants per hour at a cost of 35 guilders per hour. No fixed costs were included.

The final set of parameters required for the analysis, p_0, p_1, α, and β, are used to construct the OC and ASN of the sampling plan. The parameters α and β were both initially set to 0.1. The expected value of sample information was also calculated for both parameters equal to 0.05 and 0.20. To determine p_0 and p_1 the economic threshold for LM (p_T) was calculated for *PRICE* = {0.11, 0.16, 0.21, 0.26, 0.31} and *YIELD* = {140,000, 160,000, 180,000, 200,000, 220,000} using the relationship

$$p_T = [COST/(PRICE^* \, DAMAGE)/YIELD] \, (1\text{-}EFFECT).$$

Based on the range of p_T values, 0.01 was selected and p_0 was set equal to 0.005 and p_1 was set equal to 0.015. In the sensitivity analysis, the action threshold was decreased by setting p_1 to 0.01 and was raised by setting p_0 to 0.01 and p_1 to 0.02.

Using the methodology and parameters outlined above, the expected net worth of the sample information used in LM management was analyzed in four steps. First, a reference value was determined for the standard set of parameters. Second, a sensitivity analysis was conducted on these parameters. Third, the effect of changes in the distribution of potential LM infestation rates (the prior distribution) was investigated. Finally, the effect of changes in sampling plan parameters was determined.

Results and discussion

With-in field distribution

In the sampled fields, the highest average number of injured plants per cluster was in the border area of field 6 and this amounted to 0.403 injured plants per 5 plant cluster (Table 1). No fields were free of first generation LM injury, although 43% of the fields were free from second generation injury. In 11 of the 14 fields (79%), first generation injury was more abundant in the border area, however, only in 3 of these 11 fields were the differences statistically significant ($\alpha = 0.05$). Of the 8 fields which had second generation LM injury, in all but one of the cases injury was more abundant in the border areas. Only in 1 of these 7 fields though was the difference statistically significant. These data indicate LM has an irregular border effect in its distribution. Nonetheless, if one wishes to detect LM injury

Table 1. Proportion of leek plants injured by LM in border and interior portions of commercial fields in The Netherlands, 1986

Field	1st generation			2nd generation			No. cluster	
	border	interior	p[a]	border	interior	p[a]	border	interior
1	0.0188	0.0058	0.11	0.0124	0.0038	0.19	64	104
2	0.0136	0.0092	0.62	0.0090	0.0046	0.53	44	87
3	0.0096	0.0052	0.57	0.0058	0	0.32	42	77
4	0.0116	0.0202	0.43	0	0	–	52	79
5	0.0370	0.0260	0.47	0.0148	0	0.32	54	92
6	0.0806	0.0110	0.0	0.0128	0.0032	0.3	62	127
7	0.0042	0.0028	0.78	0	0	–	48	72
8	0.0130	0.0048	0.31	0	0.0024	0.32	46	84
9	0.0204	0.0022	0.06	0.0034	0	0.32	59	92
10	0.0286	0.0102	0.13	0	0	–	42	78
11	0.0090	0.0100	0.94	0	0	–	43	80
12	0.0282	0.0050	0.04	0	0	–	64	81
13	0.0304	0.0044	0.04	0.0218	0.0022	0.05	46	90
14	0.0032	0.0148	0.33	0	0	–	61	54

[a] Probability that infestation along border = infestation in interior of field assuming a normal distribution of means.

in a field, sampling the border areas should be emphasized.

The border effect potentially complicates use of the sequential sampling procedure for making treatment decisions because the procedure classifies the population from a complete field with respect to an action threshold. The border effect can be accounted for in one of four possible ways. First, all sampling could be done from border sites. This is the most conservative approach. Second, the border effect could be ignored and samples taken from throughout the field. Third, the border and interior portions of a field could be sampled separately. Finally, the border areas could be prophylactically treated and the interior portions of the field sampled. Further discussion of these options will be delayed until an analysis of the value of the sample information.

Construction of sampling plan

Curves consisting of OC and ASN values for the standard sequential sampling plan ($p_0 = 0.005$, $p_1 = 0.015$, $\alpha = 0.1$, and $\beta = 0.1$) are shown in Fig. 1. These curves show that erroneous classifications and high average sample sizes are confined to a relatively small subset of the possible infestation rates (p). However, these figures

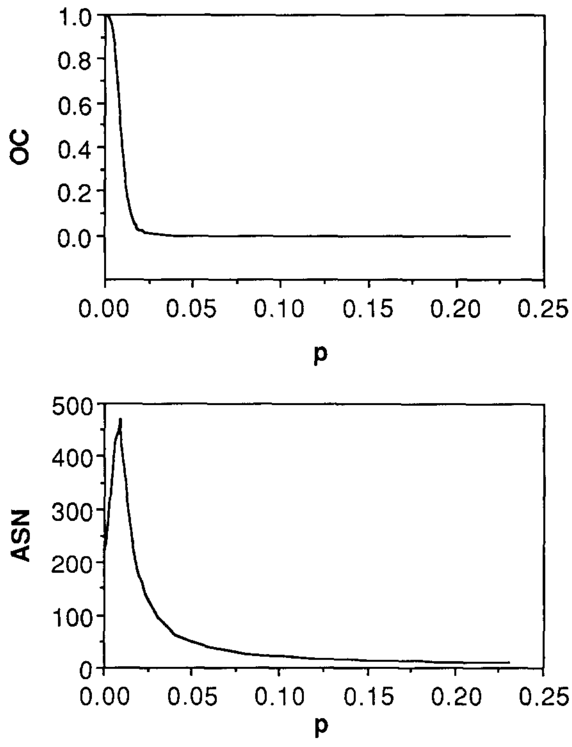

Fig. 1. Operating characteristic (OC) and average sample sizes (ASN) for a sequential sampling plan used to classify the proportion of leeks (P) damaged by leek moth.

by themselves do not reveal anything about the economic viability of a management plan based on this sampling plan.

Value of sampling information

For the standard set of model parameters, the least costly management strategy to use if no sample information is collected is to apply an insecticide prophylactically. This result might be arrived at without any analysis owing to the very low threshold, relatively low cost of insecticide applications, and high value of the crop. However, it should be pointed out these conditions do not necessarily lead to a negative value for the sample information in all cases. This will be discussed further later in the paper. Prophylactic pesticide application is not the best strategy to use for all combinations of the parameters used in the model.

The expected loss for the sampling-based management strategy is 252.9 guilders per ha when the standard set of parameters (*YIELD* = 180,000, *DAMAGE* = 0.70, *EFFECT* = 0.70, *PRICE* = 0.21, *SIZE* = 1.5) are used. If no sampling is done and an insecticide is applied prophylactically, the expected loss is 247.8 guilders per ha. Therefore, the expected value of the sample information is − 5.1 guilders per ha, a small negative amount. The expected cost of sampling is 8.8 guilders per ha.

The remainder of this section will deal with the influence of changes in the parameters of the model on the net worth of the sample information. The first variable to be addressed is field size because this variable simply scales the expected cost of sampling. For a one hectare field, the expected cost of sampling is 13.3 guilders. Dividing this amount by the field size yields the new expected cost of sampling.

The remaining four parameters included in the sensitivity analysis influence the expected value of the decision rule. Each of these variables was studied independently by holding all other variables constant. Unfortunately, the effect produced by changes in one variable can not be added to the effect produced by another variable to yield the total effect resulting from changes in both variables because the models for calculating the EVSI are not linear.

The influence of the price per leek (*PRICE*), plant density (*YIELD*), loss due to LM infestation (*DAMAGE*), and insecticide efficacy (*EFFECT*), on the expected value of sample information (EVSI) is shown in Table 2. Each of these variables influence the EVSI in a closely linear fashion. As the price per leek and loss due to LM infestation declines, the EVSI increases. This occurs because the value of sampling lies in not applying an insecticide when it is not required. As price declines and loss due to injury declines, the value of applying an insecticide decreases but the cost of application does not and as a result the net benefits of

Table 2. Influence of four model parameters on the expected value of sample information (EVSI) used to make leek moth (LM) control decisions

Constants:	Damage = 0.7 Yield = 180 k Effect = 0.7		Price[b] = 0.21 Yield = 180 k Effect = 0.7		Price = 0.21 Damage = 0.7 Effect = 0.7		Price = 0.21 Damage = 0.7 Yield = 180 k	
Variable parameter:	Price	EVSI	Damage	EVSI	Yield	EVSI	Effect	EVSI
	0.11	3.3	0.5	− 0.03	140 k	− 1.1	0.5	− 0.003
	0.16	− 0.9	0.6	− 2.5	160 k	− 3.1	0.6	− 2.5
	0.21	− 5.1	0.7	− 5.1	187 k	− 5.1	0.7	− 5.1
	0.26	− 9.3	0.8	− 7.6	200 k	− 7.0	0.8	− 7.6
	0.31	− 13.4	0.9	− 10.1	220 k	− 8.9	0.9	− 10.1

[a] Reduction in price due to leak moth injury.

[b] Guilders per leak.

[c] Plants per ha, k = 1000.

an insecticide treatment decrease. Therefore, the value of the sample information increases because it is calculated as the difference between the losses sustained when an insecticide is always applied and the losses incurred with a sampling-based management program. As the yield of leeks per ha and the insecticide efficacy declines, the EVSI also increases. In the case of yield this occurs because the benefits from insecticide treatments on a per hectare basis decline. The EVSI increases as insecticide efficacy declines because the benefits obtained with an insecticide treatment decrease. The change in the EVSI for each of these variables is, however, modest. Changes in any one of these variables alone does not increase the value of the sample information enough to offset the cost of sampling in most cases. When the values of these four parameters that produce the highest EVSI are used in combination, the EVSI = 11.1 guilders per ha. For field sizes greater than 1.1 ha, this will result in a positive, albeit small, net value for the sample information.

The prior distribution of LM infested plants was changed to reflect a greater likelihood for no infested plants. This was done by increasing the probability for the $p = 0.0$ class $[\mathrm{P}(p = 0.0)]$ in the prior distribution while equally decreasing the probabilities for all other classes. With a uniform distribution $\mathrm{P}(p = 0.0) = 0.00125$. The influence of increasing this probability on the EVSI and the cost of sampling is shown in figure 2. When the standard set of parameters were used the net value of the sample information remains negative until $\mathrm{P}(p = 0.0)$ exceeds ca. 0.25. Thus, in a situation where the likelihood of LM infestation is relatively low, the sampling information has net positive value. When the set of model parameters were used that produced the maximum EVSI value (*YIELD* = 140,000, *DAMAGE* = 0.5, *EFFECT* = 0.5, *P*RICE = 0.11, *SIZE* = 1.5) the net value of the sample information was always positive. In this case though the EVSI reached a peak when $\mathrm{P}(p = 0.0) \approx 0.26$ and declined as the probability increased further. The reason for this is that the optimal action in the absence of sampling (a^*) changed from applying an insecticide (a_1) to doing nothing (a_0) for the larger values of $\mathrm{P}(p = 0.0)$. As $\mathrm{P}(p = 0.0)$ increased, the difference between the expected net losses accrued with and without sampling decreased, resulting in a decline in the EVSI. The difference between the expected losses declined because action a_0 is weighed more heavily as $\mathrm{P}(p = 0.0)$ increases and action a_0 is the optimal action to take when no sampling is done.

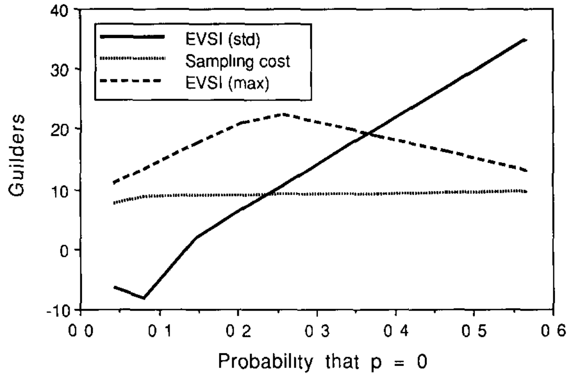

Fig. 2. Influence of the likelihood that no leeks are damaged by leek moth (Probability that p = 0.0) on the expected value of sample information (EVSI) for a leek moth sequential sampling plan. EVSI(std) is the expected value for the standard set of model parameters and EVSI(max) is the expected value for the model parameters that produced the largest EVSI with a uniform prior.

When the parameters α and β of the sampling plan were changed to 0.05 and the standard set of parameters were used, the EVSI = ~4.41 guilders par ha and the expected cost of the sample information = 12.84 guilders. Thus, improving the precision of the sampling plan caused an increase in both the value of the sampling information and in the sampling costs. The differences between these two values did not change appreciably relative to the original α and β values (0.1 for both). Decreasing the precision of the sampling plan and the average sample size by setting α and β to 0.20 resulted in an EVSI of − 13.66 guilders and expected sampling costs of 4.33 guilders per ha. Thus, while the sampling costs declined, the value of the sample information also declined.

The effect of decreasing the action threshold by setting p_0 to 0.005 and p_1 to 0.01 was to increase the EVSI to 0.14 guilders per ha and the sampling costs to 17.04 guilders. Once again, the net value of the sample information is negative. When the threshold was raised by setting p_0 to 0.01 and p_1 to 0.02 the EVSI sunk to -22.60 guilders per ha and cost of sampling $= 14.23$ guilders, clearly an undesirable situation.

Results from the analysis of the EVSI signal a possible enigma for pest management. A dictum of IPM is that sampling pest populations should be done prior to any treatment decision. From the grower standpoint, however, minimizing risk remains the main goal with profit as a close second. In the case of LM, there is usually little difference between a management plan that employs sampling and an action threshold and properly timed prophylactic application of insecticides in terms of pest control costs. As a result, there is little economic incentive for growers to adopt a sampling based LM management strategy. Our analysis indicates that this situation is relatively insensitive to changes in the parameters. Only the prior distribution significantly influences this conclusion. In cases where the likehood for no or very low LM infestation is high, such as during cool wet summers (J. T., unpublished data) the sampling and action threshold management plan probably has positive net worth. Under these conditions the question of the border effect for LM infestation must be addressed with respect to the sampling plan.

The most conservative approach is to restrict the sampling universe to the field borders. This is also the most likely approach to be adopted by growers. This sampling strategy was not explicitly considered in the economic analysis of the sample information. However, the effect of restricting sampling to the field border is to lower the action threshold for the complete field. Decreasing the action threshold did not dramatically alter the conclusion reached from the study of the EVSI when a uniform prior was used. Extending this result to the current situation implies that if the EVSI is positive when the complete field is the sample universe, the same will be true when sampling is focussed on the border areas.

If growers apply two applications of insecticides (the standard practice), then in most years their least costly management strategy will be to apply these in a well timed-manner without assessing actual infestations in their fields. Well-timed applications could be achieved by inspecting border areas for initial injury by larvae. Prophylactic pesticide use is a least cost LM management strategy provided all of the costs of using insecticides have been considered. If, however, there are significant adverse non target effects or there is an established goal of reducing pesticide use, then the sampling based management plan might be very valuable provided it leads to a reduction in the number of pesticide applications. This can be investigated by determining the expected outcome of sampling.

The OC provides the probability that the null hypothesis (no treatment) will be aceepted for any true infestation rate (p). An average value for the OC can be calculated as

$$\int_0^{p_{\max}} \mathrm{f}(p)\,\mathrm{OC}(p)\,\mathrm{d}p\,. \qquad \{8\}$$

This integral can be interpreted as the expected frequency of no spray decisions given a particular prior distribution for LM infestation [$\mathrm{f}(p)$].

For a uniform prior it is expected that no pesticide will be applied 22% of the time. If the likehood for no infestation increases, the savings in pesticide applications likewise increases. For example, using the prior distributions employed previously, when $\mathrm{P}(p = 0) = 0.072$ the savings is ca. 26%, when $\mathrm{P}(p = 0) = 0.133$ the savings is ca. 31%, and when $\mathrm{P}(p = 0) = 0.21$ the savings is ca. 36%. Thus, while the net value of the sample information may be slightly negative from a direct pest control cost perspective, use of the sampling procedure may significantly reduce pesticide use.

Based on this study one must not conclude that sampling and action thresholds are inappropriate for crops with relatively low treatment thresholds and that can be effectively treated with low cost insecticides. A study similar to the one reported herein of a pest control decision rule for European corn borer (ECB) *Ostrinia nubialis* [Hubner]) infesting sweet corn in New York showed that the net value of the sample information is positive over a wide range of parameters used in the analysis (J. N., unpublished data). The treatment threshold for ECB in New York is 2% of the plants ($p = 0.02$) infested with either eggs or small larvae.

The principal reason for the difference between the corn and leek systems is that sweet corn in New York is ca. 20 times less valuable per hectare than leek in The Netherlands (value of sweet corn is ca. 860 US dollars per hectare). The cost of treating sweet corn is estimated to be 22 US dollars per hectare which is 70% of the treatment cost used in the analysis for leak. A decrease in treatment cost would tend to decrease the value of the sample information. The modelled effectiveness of pesticide treatments on sweet corn was the same as that used in the leek moth analysis.

The differences in the results obtained for the sweet corn and leek analyses illustrates the need to assess the economic value of sampling information in each crop/pest situation. In cases like LM, the short term strategy for growers would indicate that sampling pest densities is not economically worthwhile. In the longer term, however, they must consider other externalities such as the bluidup of pesticides resistance and environmental and human exposure to toxicants.

Zusammenfassung

Bewertung einer Entscheidungsregel für Bekämpfung von Lauchmottenbefall in Porree

In den Niederlanden wurde 1986 der durch den Befall der ersten und zweiten Generation der Lauchmotte (*Acrolepiosis assectella* Z.) verursachte Schaden auf 14 kommerziell genutzten Porreefeldern ermittelt. Für beide Generationen wurde an den Feldrändern ein deutlich höherer Befall als in dem inneren Bereich eines Feldes festgestellt. Zur Bekämpfung der Lauchmotte wurde als Entscheidungsmodell ein sequentielles Probenahmeverfahren entwickelt. Der Informationsgehalt der sequentiellen Befallserhebung wurde einer ökonomischen Bewertung unterzogen. Hierbei wurden folgende Parameter zugrunde gelegt: Erntemenge und Ertrag, erwarteter Befallsgrad sowie hierdurch verursachter möglicher Ertragsverlust, Wirkungsgrad einer Insektizidbehandlung und Kosten der Stichprobennahme. Die Analyse der einzelnen Parameter ergab nur eine geringe Kostendifferenz zwischen einer gezielten Bekämpfung nach sequentieller Probenahme und prophylaktischen Insektizidspritzungen, bedingt durch den hohen Wert der Kultur und die niedrigen Kosten einer Bekämpfung. Darüber hinaus ist das Verfahren einer gezielten Lauchmottenbekämpfung gegeüber Veränderungen der obengenannten Parameter relativ unempfindlich. Deshalb wird die Entwicklung eines Schwellenwertes der mit Probenahmeverfahren verbunden ist die Bekämpfungskosten nicht reduzieren. Die Anwendung der Probenahmeplans würde Bekämpfungskosten auch nicht erhöhen und würde wahrscheinlich Insecktizidverbrauch reduzieren im Vergleich zu einen prophylaktischen Behandlungsprogramm.

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