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Tolerance levels and sequential sampling tables for supervised control in cabbage crops

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Sets of tolerance levels for caterpillars and cabbage aphids for use in supervised control in red cabbage, savoy cabbage, spring cabbage, cauliflower and broccoli are given. These sets have been developed in the Netherlands and have to be verified and possibly adapted for local conditions. To simplify sampling procedures and reduce sampling time sequential sampling tables are given for the various tolerance levels used in cabbage crops.

INTRODUCTION

Slowly but surely insect pest management systems are being developed for a variety of crops including vegetable crops. Both in the United States (HOY *et al.*, 1983) and in Europe (HOMMES, 1983; THEUNISSEN & DEN OUDEN, 1985) various approaches of supervised control have been published and partly implemented in commercial cabbage growing. Implementation is a bottleneck in all cases because of the conditions to be met. One of the conditions regards the required simplicity of the supervised control methods as they are offered to the growers. The rules must be clear, simple and concise. As a result these methods are crude, lacking the complicating refinement which is possible when computer-aided advisory systems are derived from the accumulated experience while developing the rules.

A supervised control method consists of two elements: a set of standard criteria of what can be tolerated in a given situation and a sampling recipe how to assess the pest situation in the field. For Brussels sprouts and white cabbage these data have been given already (THEUNISSEN & DEN OUDEN, 1985). Sets of tolerance levels for other cabbage crops and sequential sampling tables for various tolerance levels are given here.

MATERIALS AND METHODS

Tolerance levels for the crops red cabbage, savoy cabbage, spring cabbage, cauliflower and broccoli were developed during four seasons on experimental fields of the Institute. Since no data were available on the relation between yield reduction and pest population densities the tolerable caterpillar and cabbage aphid populations at given growth stages were determined empirically during trials with various plantings per season. Experimental schemes were tested subsequently against conventional control methods to check on the quantitative and qualitative yield components. The basic requirement was to harvest at least the same quantity and quality of produce of the plots under supervised control as compared to conventional control. For the sake of simplicity the tolerance levels are expressed as percentages of plants infested with caterpillars and cabbage aphids at various growth stages, expressed in weeks after transplanting.

Since the same variables are used for all cabbage crops sequential sampling can be based on the different tolerance levels as practical approximations of the control threshold in a given situation. The calculated sequential sampling tables have been based on the following assumptions and conditions:

1. a binomial distribution of infested plants.
2. a tolerance level as a variable control threshold expressed as percentage of infested plants.
3. a margin of ±20% of the tolerance level is accepted in the decision making process.
4. an acceptable probability of overestimation of the pest population of 30% ($\alpha = 0.30$).
5. an acceptable probability of underestimation of the pest population of 10% ($\beta = 0.10$).

The margin of 20% is arbitrarily chosen as a compromise between accuracy and sample size. A smaller margin leads to a larger sample size. A larger margin results in quick decisions which, however, may be less reliable. The acceptable probabilities of overestimation and underestimation were discussed with plant protection specialists of the Extension Service and the values of 0.3 and 0.1 respectively were agreed upon based on their assessment of the supervised control system functioning in farmers' fields. The sequential sampling tables were calculated according to the paper by ONSAGER (1976).

Contrary to the sets of tolerance levels for Brussels sprouts and white cabbage (THEUNISSEN & DEN OUDEN, 1985) the sets mentioned here have not been tested yet in the various cabbage growing regions of the country. Since regional verification during a number of seasons is important to adapt the sets to local conditions they have to be considered as experimental sets of tolerance levels.

RESULTS

In Table 1 sets of tolerance levels for various cabbage crops are given.

Table 2 shows sequential sampling schemes calculated for a number of tolerance levels, including those used in Brussels sprouts and white cabbage (THEUNISSEN & DEN OUDEN, 1985). No treatment is necessary when in the left column the indicated number of infested plants or less is found on a total number of plants (central column) sampled. When the accumulated number of infested plants relative to the total sample size is equal or larger than the number in the right column treatment is considered to be necessary. A number of 10 plants is arbitrarily considered to be the minimum sample size to avoid gross sampling errors. The plants should be taken well spaced in the field along spraying lanes. If there is reason to suspect the presence of hot spots then these are to be sampled first or the field is to be sampled according to the suspected strata. These strata could be area's in the field where different population densities are suspected such as sheltered and open parts of the field. In such a way stratified sampling can be applied using sequential sampling methods. A maximum sample size has been set to break off sampling when no decision can be reached. For such cases a recommendation is added to the scheme.

Table 1. Sets of tolerance levels for some cabbage crops

Crop	Growth stage (weeks after transplanting)	Percentage of plants infested with caterpillars	cabbage aphids
Red cabbage	2	25	20
	4	35	20
	6	25	20
	8	20	5
	10	5	5
	12	30	20
	14	30	20
	16	10	5
	18	5	5
	.	.	.
Savoy cabbage	2	40	20
	4	40	20
	6	40	20
	7	10	5
	8	10	5
	10	10	5
	12	5	5
	.	.	.
Spring cabbage	2	20	20
	3	20	10
	4	10	10
	5	5	5
	6	5	5
	7	10	10
	8	10	10
	.	.	.
Cauliflower	2	40	20
	4	40	20
	6	40	10
	7	10	5
	8	5	5
	9	30	20
	10	20	10
	11	10	5
	12	5	5
	.	.	.
Broccoli	2	40	40
	3	40	40
	4	15	20
	5	15	10
	6	10	10
	7	10	10
	8	10	10
	9	20	20
	10	40	50
	.	.	.

DISCUSSION

Supervised control is the rational use of insecticides based on the use of tolerance levels and field sampling to assess the pest situation in individual fields. Integrated Pest Management usually consists of supervised control but is meant to be a more comprehensive system of pest control including resistent varieties or cultural methods such as planting time. In the meantime supervised control can be considered to be the first step towards integrated pest management. The tools for the grower are a set of criteria, tolerance levels, and a simple recipe to find out the pest situation in his fields.

The control threshold is the pest population density at which control has to be carried out to prevent it from growing to a density which inflicts economic damage to the crop. The actual numerical value of this threshold is determined by a number of factors such as the pest population-damage relationship, the price of the produce, the costs of control, the efficiency of control. Moreover it includes a good deal of speculation on the future development of a given pest population.

Table 2. Sequential sampling tables for various tolerance levels in supervised control in cabbage crops

Tolerance level	Number of plants infested [no control]	sampled	infested [control]	Remarks
50%	< 2	10	> 7	max. 20 plants, no decision:
	3	12	8	no control
	4	14	9	
	5	16	10	
	6	18	11	
	7	20	12	
40%	< 1	10	> 6	max. 30 plants, no decision:
	2	14	8	no control
	4	18	10	
	6	22	12	
	8	26	14	
	10	30	16	
35%	= 0	10	> 6	max. 30 plants, no decision:
	< 1	14	7	no control
	3	18	8	
	4	22	10	
	5	26	11	
	7	30	13	
30%		10	> 5	max. 45 plants, no decision:
	< 1	15	7	no control
	2	20	8	
	4	25	10	
	5	30	11	
	7	35	13	
	8	40	14	
	10	45	16	
25%		10	> 5	max. 50 plants, no decision:
	= 0	15	6	no control
	< 1	20	7	
	2	25	9	
	3	30	10	
	5	35	11	
	6	40	12	
	7	45	14	
	8	50	15	
20%		10	> 5	max. 60 plants, no decision:
	= 0	20	7	no control
	< 2	30	9	
	4	40	11	
	6	50	13	
	8	60	15	
15%		10	> 4	max. 70 plants, no decision:
		20	6	control
	= 0	30	7	
	< 2	40	9	
	4	50	10	
	5	60	12	
	7	70	13	
10%		10	> 4	max. 70 plants, no decision:
		20	5	control
		30	6	
		40	7	
	= 0	50	8	
	< 1	60	9	
	2	70	10	
5%		10	> 4	*)
		20	4	
		40	5	
		60	6	
		80	7	
	= 0	100	8	
	< 1	120	9	
4%		20	> 4	*)
		40	5	
		60	5	
		80	6	
		100	7	
	= 0	120	8	

*) In practice the tolerance levels of 4% and 5% mean that the crop must be virtually free of insect pests. As is apparent from the tables it requires large sample sizes to establish really whether or not this level is reached. No grower can be expected to continue sampling to satisfy the laws of probability once he is convinced that the pest population in his crop is sufficiently low or too high.

It is clear that it is virtually impossible for the grower or adviser to calculate exactly the value of the control threshold at a moment when quick decisions have to be taken. To solve this problem the concept of tolerance levels has been developed. Tolerance levels are practical estimates of the control threshold in a given situation. Where the control threshold is the elusive and continuously changing economic equilibrium point of a number of variables the tolerance level is a fixed value under certain conditions. It may not give the maximal economic return but is to represent a safe and workable criterion for making pest control decisions.

The tolerance levels for a number of cabbage crops as they are given here still have to be adapted to local conditions. They have been developed to provide protection of the produce when necessary during the cropping season in relation to the biology of both the crop and the pest species. In all sets the tolerance drops suddenly at a certain moment. This is a moment in the development of the crop at which care must be taken to control pests in time to prevent problems later in the cropping season. For instance, in red cabbage the formation of the head starts at about 8 weeks after transplanting. This is the time cabbage aphids have to be controlled to prevent them to become enclosed in the growing head. At the same time the second flight of lepidopterous pests may have resulted in young caterpillars which have to be controlled to prevent them from boring into the head at a later stage. In general head, curd or bud formation is a critical stage.

When the marketable parts have been protected the tolerance can be increased for a while depending on the sensitivity of the crop and the seasonable development of the crop and the pest populations. These are the local factors to which the sets have to be adapted. The sets of tolerance levels should be used as guidelines not as laws. A growing season may be cold or very warm resulting in aberrations from the indicated development of the crop. When the biological rationale of the sets is clear they can be adapted easily to the current conditions at a given moment.

One of the problems in implementing supervised control is the time spent to field sampling. The effort of walking and making observations in the crop is often considered as too time-consuming and the demands for minimal sampling times are widespread. A systematic sampling method for use in cabbage crops which was developed earlier (Theunissen, 1984) takes about one hour/ha (100 plants). This method is less suitable for Brussels sprouts which grows tall but is useful for heading cabbage types ensuring a good coverage of the field. Both for Brussels sprouts and the other cabbage types sequential sampling schemes have been produced which reduce the average time spend sampling. The more an actual field situation deviates from the tolerance level the sooner a decision can be made. When the field situation and the tolerance level coincide the maximal number of samples will have to be taken. The sample size increases with decreasing tolerance level before a "no treatment necessary" decision can be taken even when no pest insects are present. The danger of sequential sampling is that decisions can be taken based upon only a small part of a field which is not necessarily representative for the entire field. Therefore, wide spacing of the sampling points and stratified sampling using sequential schemes can be recommended to overcome these risks. A wide spacing avoids taking samples in clusters of infested plants only. When a possible stratification in the distribution of pests in a field is suspected sequential sampling may be carried out within these strata.

ZUSAMMENFASSUNG

Toleranzgrenzen und Tabellen für eine sequentielle Stichprobenmethodik im Kohlanbau – Für den integrierten Pflanzenschutz im Acker- und Gemüsebau werden nach und nach Systeme für die einzelnen Kulturpflanzen entwickelt. Für die gezielte Schädlingsbekämpfung bei fünf Kohlarten werden in dieser Arbeit Serien von Toleranzgrenzen angegeben. Sie wurden in den Niederlanden entwickelt und müssen der lokalen Situation angepasst werden. Zur Vereinfachung des Vorgehens wurden Tabellen erstellt zur sequentiellen Probeentnahme bei verschieden hohen Toleranzgrenzen in den fünf Kohlarten.

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