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Use of action thresholds on cotton crops in northern Togo

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Abstract. Studies were conducted on smallholder plots in northern Togo from 1988 to 1991 to determine the possibility of applying treatments according to action thresholds. Thresholds were defined for the following pests: *H. armigera, D. watersi, Earias* sp., *S. derogata* and *A. gossypii*. The threshold programme was compared to the routine insecticide application programme involving five applications fortnightly beginning 50 d.a.s. An u.l.v. formulation of a mixture of deltamethrine and dimethoate at 3 litres/ha was applied, in both programmes. The results obtained showed that seed cotton yields were significantly different in 1991 (164 kg/ha less in the threshold treatment programme). Calculation shows that a reduction in treatments from five to three is not economical for the producer under the cropping conditions of the experiment. However, it could be worthwhile for the cotton-growing development company, if solutions are found to the numerous practical problems brought to light by the experiments conducted over the past 4 years.

1. Introduction

In Togo (West Africa), cotton is cultivated over an area of around 80 000 ha and seed cotton production reaches 80 000 tonnes. Inputs (fertilizers, insecticides) are supplied to smallholders on credit by the Société Togolaise de Développement du Coton (SOTOCO). This company advises smallholders, through its supervisors, and distributes inputs in accordance with the cultivated areas declared by them. The cost of inputs is recovered when seed cotton is purchased by SOTOCO.

The ecological problems associated with using the chemical insecticides currently applied to cotton crops involve the risk of the appearance of resistance, the resurgence of new pests, side-effects on useful fauna and environmental pollution. Another worrying aspect is the cost of chemical protection. Insecticidal applications therefore need to be effective and justified.

Bearing in mind these aspects, an experiment was undertaken in Togo on cotton from 1988 to 1991 involving application thresholds on smallholdings.

The initial work carried out in this field by the Institute of Research on Cotton and Exotic Textiles, concentrated on methodology issues (Vaissayre, 1973, 1974). At the same time a treatment programme based on pest forecasting system was introduced in the Ivory Coast, then abandoned (Angelini, 1971).

More recent trials conducted in the Ivory Coast have been reported on by Ochou and Vaissayre (1989). The first approach in Togo on smallholdings was undertaken by Harnisch and Avouchinon (1986).

In our work we adopted the thresholds accepted by previous workers for noctuids following the work by Matthews and Tunstall (1968) in Zimbabwe.

The experiment was conducted in the savannah region of northern Togo, which is characterized by a single rainy season and mean annual rainfall of 880 mm. The pest complex primarily consists of the noctuids *Helicoverpa* (= *Heliothis*) *armigera* (Hübner), *Diparopsis watersi* (Rothschild), *Earias biplaga* Walker, whose larvae are clearly visible in the field, with no need to open the cotton bolls, the crambid *Syllepte derogata* (F.) and the aphid *Aphis gossypii* Glover.

Different villages were chosen, so as to work with smallholders with different technical abilities. Each year an observer from the station was assigned to the chosen village for the entire cotton growing period. Data on farmer acceptance of the strategy were also gathered during the experiments.

2. Materials and methods

In 1988 the experiment was conducted in farmers' fields near Dapaong. In 1989 and 1990 the experiment was conducted in Poissongui, a village located 30 km from Dapaong, and monitored in socioeconomic surveys conducted by the Station's Agroeconomics Section since 1985 (Faure *et al.*, 1989). It was thus possible to obtain cultural data difficult to obtain at other locations (Dapaong). In 1991, the village of Gando, 107 km from Dapaong, was chosen. In the savannah region the farming recommendations are as follows:

1. sowing from 1 to 30 June, with 15 kg/ha of seeds treated with an insecticide-fungicide mixture;
2. theoretical sowing density of around 100 000 plants/ha, with 0·75 m between rows and 0·25 m between planting holes, thinning to two plants per hole;
3. split fertilization: application of an NPKSB (15–25–15–5–1·8) basal dressing on sowing (150 kg/ha) and urea (50 kg/ha) on the 40th day after sowing (d.a.s.).

The chemical protection programme recommended includes five applications of a dual pyrethroid–organophosphorus mixture 14 days apart, starting 50 d.a.s.

In each of the study villages the experimental plots were sown and cultivated by the smallholders. The total area can therefore vary considerably. They were chosen by the

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observer and researchers after emergence, based on their homogeneity. Plots where upkeep was poor were eliminated, sometimes in mid-cultivation. The total number of plots chosen for the analyses therefore varied depending on the year: 12 in 1988, 10 in 1989, 13 in 1990, 20 in 1991. They were divided into plots of equal area, called sections A and B. The separation was marked out with 2-m high red poles. There was no border between the two sections. The area of these sections varied depending on the year, from 1330 m^2 to 6000 m^2.

Section A (control) received the recommended protection programme, i.e. five insecticide treatments fortnightly 50 d.a.s. onwards. In Gando in 1991 a sixth treatment was applied as the treatments had been started early, and the rainy season lasted longer than usual at the end of the cycle. Section B was treated as soon as an application threshold was reached.

All the farming work, from sowing to harvesting, was done by the smallholders. Insecticide treatments were carried out in accordance with recommendations made by the observer, who carried out observations and different measurements (section area, volume of formulations applied).

For economical reasons, observations began on 49 d.a.s. in B sections only, i.e. 1 day before the theoretical date of the first treatment in A sections. The last observations were made a week after the final treatment in the A sections. They were made using a pegboard, which is a rectangular 3-mm thick wooden board (20 × 30 cm) with several rows of holes 4 mm in diameter. The top row represents the plants observed (25 holes) and the lower rows are reserved for pests (aphids, *S. derogata*, caterpillars). Pegs are inserted and moved around on each observation.

In 1990 at Poissongui, farmers were asked to carry out observations themselves, to see whether the method was practicable, given the need to visit the plot each week. The thresholds adopted in Togo were those defined previously in the Ivory Coast and Zimbabwe (Sognigbe, 1990). Each week, 25 plants per section were chosen at random along a diagonal and observed. In 1988, only *H. armigera* and *D. watersi* eggs were observed, along with *Earias* sp. larvae. The thresholds were: fours *Earias* sp. larvae, one *H. armigera* egg and 3 *D. watersi* eggs.

From 1989 onwards the cumulative totals of *H. armigera*, *D. watersi*, and *Earias* sp. eggs and larvae were taken into consideration. Treatments were applied when four eggs or six eggs + larvae were observed. The other thresholds used each year were:

1. Six plants with rolled leaves containing living *S. derogata* larvae. From 1989 onwards, observations of this insect were halted at the end of October.
2. Thirty-one leaves infested by *A. gossypii* (four terminal leaves were observed per plant).

The area of sections A and B was calculated using the 'IRCT areas' software after inputting side length obtained using a surveyor's chain and the angle between the section sides and north, measured using a compass. Measurement of these areas was subsequently used to calculate the formulation volumes actually applied and the yields from each section.

The u.l.v. formulation applied during treatments contained a mixture of deltamethrin (3.3 g/l) and dimethoate (100 g/l). It was applied at the rate of 3 litres/ha using a Berthoud C8 sprayer with spinning disc fitted with a red nozzle and powered by eight 1·5 V batteries.

In order to simplify the observer's task and avoid complication for farmers, pests were not targeted in section B plots. Hence, if the aphid threshold was reached, the dual mixture was applied and not just the ingredient active against aphids (dimethoate).

Apart from 1988 the volumes actually applied in each treatment were measured by the observer using a graduated test tube, from the difference between the total volume poured into the tank and the volume remaining after treatment. Densities were calculated after counting the plants present in ten 20-linear-metre sections of cotton plants and measurement of the 20 interrows.

In 1988 yields were calculated after seed cotton harvesting from two 10 m squares marked out inside each section. From 1989 onwards the harvest involved the entire area of the sections A and B and the yields considered were from whole sections. Yields were weighed using a 50 kg spring balance.

An analysis of variance was carried out with the 'plant density' and 'seed cotton yield' variables, considering the plots as a whole as a Fisher block design, each plot being a replicate.

3. Results

3.1. Crop data

The cotton crop followed on from food plants such as sorghum, millet (*Pennisetum* sp.), groundnut or cowpea. The land was tilled with an ox-drawn plough. The observations carried out at Poissongui in 1989 and 1990 revealed the true fertilization conditions in the plots.

In 1989 fertilizer was applied mixed with urea, either at planting time, or the day before. In 1990 the fertilizer was applied at planting time, except in three plots, where it was mixed with urea and applied on the 23rd, 30th and 32nd d.a.s., depending on the case. In Gando in 1991 fertilizer was mixed with urea and applied on the 21st and 54th d.a.s.

3.2. Insecticide treatments

In the A sections (control), the average volume applied per hectare and per treatment was 1·9 litres in 1989, 3·0 litres in 1990, and 2·5 litres in 1991, with substantial differences (1·2 to 4·5 litres/ha).

Substantial under-dosing can be seen in 1989 and 1991. In 1990 the 'insecticide' subscription was not collected from farmers participating in the trial, and it was seen that the recommended rates (3 litres/ha) were respected, or even increased. This was not the case in 1991.

On average the B sections received 2·9, 2·8, 2·9 and 3·5 treatments respectively each year (Table 1). Most of the B sections received 3 treatments, apart from those cultivated in 1991, which received 4 treatments.

3.3. *Overstepped application thresholds*

Table 1 shows the number of times each defined threshold was reached. Figure 1 shows the pattern of thresholds each year. In this figure the thresholds reached in 1988 for *H. armigera, D. watersi* and *Earias* sp. were grouped together. Considerable variability can be seen between years. In 1989 low aphid infestation was seen, whereas the *S. derogata* threshold was reached 23 times. In 1990 the aphid threshold was reached 30 times, whereas the larval threshold was only exceeded three times.

It can be seen that aphid infestations occurred at the beginning or middle of the campaign. The *S. derogata* threshold was exceeded by the third treatment date in the recommended programme (A), apart from years with heavy infestation, as in 1989. In this case the threshold could be reached as early as the date of the first treatment.

As regards larvae attacking fruiting organs, the threshold was usually reached as of the third treatment in the recommended programme.

Table 1. Total number of times on which defined thresholds were reached, and number of treatments applied in B sections

Year	1988	1989	1990	1991
Thresholds				
Earias sp.	3	—	—	—
D. watersi (eggs)	4	—	—	—
H. armigera (eggs)	3	—	—	—
Exocarpic larvae	—	9	3	12
Aphids	15	1	30	27
S. derogata	10	23	12	40
Number of plots receiving				
two treatments	1	2	2	—
three treatments	11	8	10	11
four treatments	—	—	1	9
Average number of treatments carried out	2·9	2·8	2·9	3·5

3.4. *Cropping density and yields observed*

In 1990 there were 15 150 plants/ha on average (extremes: 9035–20 944) and 38 500 plants/ha in 1991

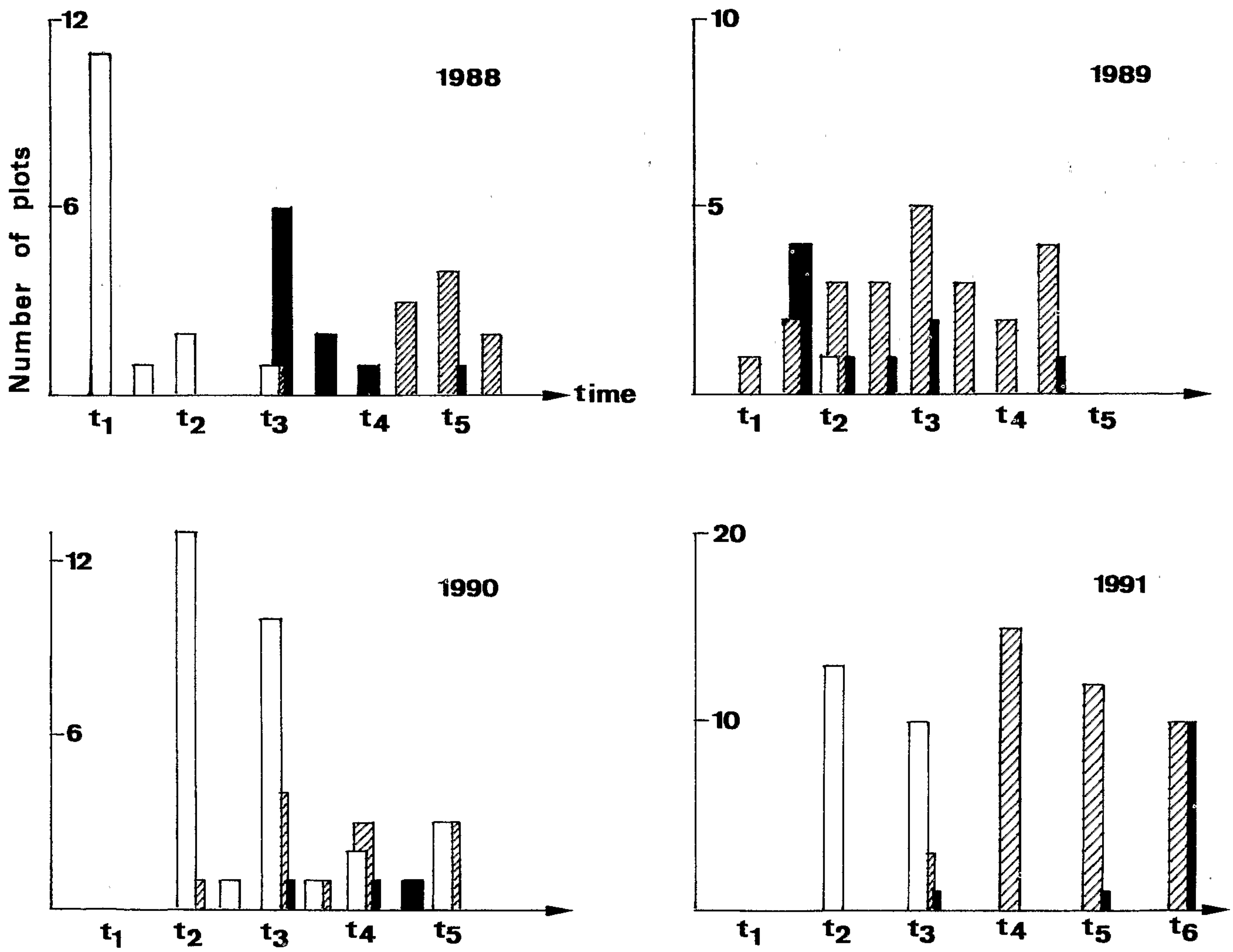

Figure 1. Number of plots (B sections) exceeding the thresholds for aphids (white columns), S. derogata *(shaded columns) and exocarpic eggs + caterpillars (black columns) (t_1, ... t_6: dates of treatments in the A sections).*

Table 2. Plot seed cotton yields (in kg/ha), means and results of the analysis of variance

Plots	Years, locations and sections							
	1988 (Dapaong)		1989 (Poissongui)		1990 (Poissongui)		1991 (Gando)	
	A	B	A	B	A	B	A	B
1	954	927	580	711	835	1011	1215	1008
2	767	582	541	790	905	1048	848	576
3	1207	1109	1007	1145	757	807	1277	899
4	962	959	1029	640	824	710	1250	1131
5	529	537	1073	1024	872	1031	500	302
6	869	719	904	1171	1314	1353	756	989
7	639	589	584	555	1095	728	802	427
8	949	972	1015	1020	1705	1359	907	490
9	1012	844	1694	1593	1353	864	836	1139
10	744	984	1505	1132	825	820	807	1085
11	767	922			1074	1392	867	629
12	1253	1362			1505	749	906	784
13					834	816	419	416
14							599	364
15							1316	774
16							1902	1049
17							1087	935
18							338	598
19							768	750
20							497	277
Means	888	875	992	978	1070	977	895	731
F_t	0·10 n.s.		0·04 n.s.		1·18 n.s.		6·36*	
CV	10·5%		16·3%		21·4		25·3%	
Gain (+) or losses (−) stemming from programme B (in CFA/ha)								
H1	+3740		+3880		−4260		−10400	
H2	+6260		+6520		−1740		−7400	

* Probability ($P = 0{\cdot}05$).

(extremes: 21 935–53 430). These values are far from the recommended theoretical value of 100 000 plants/ha.

An analysis of variance carried out with cropping densities measured in 1990 and 1991 did not reveal any significant differences between the densities in A and B sections ($F_t = 0{\cdot}34$ and $F_t = 0{\cdot}42$ respectively).

Table 2 gives the yields obtained in each A and B sections in the 4 years of the experiment, along with the analysis of variance results.

Under the cropping conditions recorded from 1988 to 1990, and with average seed cotton yields varying between 875 and 1070 kg/ha, the analysis of variance for yields revealed no significant differences in production between programmes A and B, at Dapaong and Poissongui. However, in 1991 a difference of 164 kg/ha was revealed, in favour of the control plots.

3.5. *Acceptance of method by farmers*

In 1990 two farmers (out of 13) showed no interest in the trial. Of the 11 observations necessary, they only carried out one and four observations each.

Smallholder absences during observations were seen only at the end of the cropping cycle, during millet threshing, or during village group meetings. On the whole, farmers showed a definite interest in the method. The pegboards developed for this experiment were left with them to see whether they would continue to use the same protection method in 1991. However, additional constraints linked to the supervision system (introduction of a cotton 'subscription', availability of treatment equipment, batteries, etc.) were such that they preferred to apply the calendar programme.

In Gando in 1991, certain farmers refused to carry out treatments in the B sections when the threshold was reached between two control programme treatment dates. They preferred to treat the whole of the two sections on the same day. This led to changes in the behaviour of the observer, who intentionally chose plants in the least affected parts of the field, every other week, so as not to reach the threshold.

Although farmers are clearly interested in the method, practical application poses numerous organizational problems.

4. Discussion

The results obtained in our study concern cotton pest complex including the following main species: *H. armigera, D. watersi, Earias* sp., *S. derogata* and *A. gossypii*. It is also important to remember that, for economical reasons, no observations were carried out before the 49th d.a.s., hence no treatment before the theoretical date of the first treatment in the recommended schedule. If threshold application were to be practised in full, early treatments may be found necessary, particularly in the event of early aphid attacks (Marcoux, 1989). Finally, it needs to be pointed out that there was no 'targeting' of the pests found, and a formulation containing two active ingredients was applied as soon as any threshold was reached.

This approach most certainly played a role in pest evaluation, hence in determination of overstepped thresholds. It is possible that if only one active ingredient were applied (pyrethroid or organophosphorus), the complex observed would be modified.

The experiment conducted in Togo led to a comparison between two protection programmes, one of which ('threshold' programme) involved a smaller number of treatments, whose application over time varied since observations were carried out plot by plot. Application of the programme in Gando in 1991 was according to a proposal put forward by Marcoux (1989) in Zambia. Indeed, the programme implemented in the B plots corresponded to the recommended programme (control) from which treatments were removed if no threshold was reached.

Based on the experiments conducted in Togo from 1988 to 1991, it is possible to make several theoretical and practical comments.

4.1. Theoretical considerations of the thresholds adopted

In the case of exocarpic larvae the values adopted in our study were those defined by Matthews and Tunstall (1968) in Zimbabwe for *H. armigera* and *D. watersi* eggs. Like Balla (1982), we considered cumulative egg and larva numbers.

It is interesting to see that these values have been adopted in numerous studies, such as that by Ingram and Green (1972), to draw up a sequential sampling plan, or those by Burgess (1983) in Zimbabwe, Nyirendra (1988) in Malawi, or Javaid (1990a) in Zambia. However, the status of these pests may have evolved, given the changes in application techniques and with the launch of pyrethroids on the market (Cauquil, 1987; Matthews, 1990).

According to Headley (1972), the theoretical approach to defining a threshold requires a link to be made between damage and a pest population level, hence economic considerations need to be taken into account. These relations are difficult to detect for a given pest (Stern, 1973), or when considering a group of pests.

In 1973 Stern stated that economic thresholds had been established for only five species out of the 19 acknowledged to be cotton pests. It is worth noting that the number of economic thresholds mentioned more recently for the same crop in Central Africa only involved six species (Matthews, 1989). More extensive studies need to be conducted to check that the defined thresholds were well-founded.

According to Gutierrez *et al.* (1981), it is better to consider the field's production potential, pest destruction capabilities linked to when attacks take place, and the plant's compensation ability, which is particularly difficult to estimate (Delattre, 1982). These different aspects were not taken into account by our study.

For threshold definition, other studies could try to take into account the factors affecting pests, such as climate, socioeconomic aspects (cost of inputs, subscriptions, etc.) and natural enemies. For the last factor, Hasse *et al.* (1987) took into account the existence of predators in the Philippines (ants, spiders, coccinellids) to define thresholds. Ibrahim Abi and Karim (1990) showed that threshold treatments favoured predator and parasitoid activity.

It is possible to define several application periods for one threshold or several threshold levels, depending on the cropping period. Thus, Stern (1973) defined two periods for *Lygus* sp. In the case of Togo it did not appear worthwhile considering *S. derogata* damage at the end of the cotton cycle.

4.2. Consideration of practical aspects for threshold application on smallholdings

Treatment quality depends considerably on human factors. The walking speed observed often leads to underapplication on plots. Our results reveal a variation between years which can be substantial, even in the control programme, which involved six treatments in Gando in 1991 as opposed to the usual five. This variation is also seen in the number of thresholds exceeded each year.

The empirical approach adopted in Togo, which is immediately applicable in the field, was satisfactory 3 years out of 4. In fact, from 1988 to 1990 no significant difference in production was revealed between the B plots, which received three treatments, and the A plots (five treatments). This result is comparable with that reported by Javaid (1990a). However, in 1991 the average seed cotton production losses recorded were 164 kg/ha. These losses were not economically compensated for by the reduction of 2·5 treatments/ha.

A simple economic calculation was made with the average yields obtained each year with the two programmes. The price of seed cotton was fixed at 100 francs de la communauté financière africaine (CFA) per kg (current price) and two hypotheses were chosen for the price per litre of insecticide: hypothesis 1: 800 CFA, hypothesis 2: 1200 CFA. The gains (+) or losses (−) in CFA per hectare are given at the foot of Table 2. Taking the gains, which vary from 3740 to 6520 CFA/ha, the threshold programme is only of minor interest for farmers. In 1990 and 1991 this programme revealed losses of up to 10 400 CFA/ha. It therefore appears important to extend this type of study to a larger area, to enable better quantification of the risks involved. However, this could give rise to numerous practical problems.

The organization of treatments in the control programme is currently the responsibility of the development company supervisor, who determines up to eight treatment groups in his zone. Within these groups the sowing dates in the plots may be very different, which means that the same treatments are carried out on cotton plants of varying ages. In particular, the first treatment may be carried out too early or too late.

On a regional level the system based on a pest monitoring network with specialized observers and pest forecasting has been abandoned in the Ivory Coast (A. Angelini and M. Vaissayre, personal communication) On a smallholder plot level the farmer faces varying constraints: time for weekly observations, time for treament, training in recognizing the main pests and damage, insecticide application techniques and the choice of products applied (biological or chemical) if pest 'targeting' is required.

This practice also implies a certain amount of flexibility on the part of supervisors, who should rapidly supply application equipment, batteries and products, on request. This solution has been proposed in certain countries, then abandoned, such as in Zambia (Marcoux, 1989; Javaid, 1990b).

An intermediate solution could be to train officials from village groups, which are developing in all countries. These officials would carry out observations on a predetermined number of plots (30) belonging to farmers wishing to adopt the proposed programme. They would determine treatment dates if thresholds are overstepped in over 50% of the plots visited. The risks of such an approach would need to be studied, as the results in Gando in 1991 revealed that the calendar schedule of spray treatments was effective only in certain years. A certain standardization of cropping practices (especially sowing dates) and grouping plots in cropping blocks could also benefit the practical implementation of a protection programme based on thresholds. Current heterogeneity means that it is impossible to say that 'a given warning is valid over a large zone' (Delattre, 1982).

To conclude, the implementation of protection programmes based on application thresholds on smallholdings still requires further, relatively theoretical studies on threshold determination, training of officials from village groups and of supervisors, and a certain amount of 'flexibility' on the part of the latter, so as to favour farmer acceptance of the method.

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