Pheromones for control of yellow stem borer in India: Does mating disruption meet the needs of the rice cultivator?

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Abstract

A hand-applied controlled release formulation, Selibate YSB®, of the sex pheromone of the yellow stem borer, *Scirpophaga incertulas*, was developed for use in control by mating disruption in India. The formulation provided excellent protection of the pheromone components, (*Z*)-9-hexadecenal and (*Z*)-11-hexadecenal, releasing the pheromone over a period of up to 100 days. Researcher-led, on-farm development trials were conducted to optimise the application rate, pheromone blend and timing of application. Four large scale, on-farm trials conducted in a range of agro-climatic zones subsequently confirmed the efficacy of the technique. In each case the results were similar, mating disruption with the natural blend of pheromone components at an application rate of 40 g AI per ha providing a level of control that was comparable to that obtained with conventional insecticides applied by farmers. Farmer participatory evaluation trials are on-going to assess the significance of the technology to rice cultivators. The trials are co-ordinated by non-governmental development organisations and monitored by socio-anthropologists and entomologists. Results so far suggest that the rice cultivators are keen to participate by providing land for trials, applying the lures and attending meetings arranged to learn more about their social, economic, cultural and institutional constraints to adopting the technology. Nevertheless, there is no evidence to suggest that they have modified their normal pest control practices when using mating disruption, a situation re-enforced by their natural aversion to risk and the fact that the technology can only be tested by involving significant areas of their rice crop.

Introduction

The demand for rice production in developing countries is expected to increase by 1.8% per annum. In India alone rice represents approximately one third of all food grain produced, ca. 74 million tons from 42 million ha in 1990 (Kanth, 1993). Since there is little land left to develop, demand can only be satisfied by increased productivity. In order to consolidate recent gains in productivity, many Asian countries have recognised the importance of encouraging sustainable production which puts a value on the environmental, social and economic costs of current rice cultivation practices. Excessive use of fertilisers and pesticides could be reduced by adopting need-based use of these inputs yielding an estimated saving of up to $2.5bn.

In many of the rice growing regions of Asia, and India in particular, the most economically important insect pest is the yellow stem borer, *Scirpophaga incertulas* Walker (Lepidoptera: Pyralidae) (Chelliah *et al.*, 1989; Geddes & Iles, 1991; Kalode & Krishnaiah, 1991). Oviposition on a rice crop initially occurs during the nursery stage and, if unchecked, can lead to significant damage during the vegetative growth stage. Damage is characterised by the central leaves of the culm drying up, a symptom known as dead heart (DH). Emerging adults oviposit on surviving rice plants as they enter their reproductive stage of development. The feeding activity of larvae from the second generation affects the development of the panicle and the filling of the caryopses. Plants that have started to bear panicles when attacked usually produce unfilled grains known as white heads (WH). The rice plant cannot compensate for this loss with the result that each WH represents a total loss of rice production from each tiller so affected.

In regions where *S. incertulas* is a perennial pest of economic importance, even with the use of cultural practices and tolerant varieties to suppress pest populations, intervention by chemical control, usually in the form of systemic insecticides, may be the only course presently available to rice cultivators. The systemic insecticides available to the smallholder in India, such as phorate and carbofuran, are relatively cheap and readily available but invariably toxic to a wide range of organisms apart from the target pests. The indiscriminate use of such insecticides can and does expose man and his domesticated animals to these compounds both during application and through subsequent ground water contamination. Insecticides can also cause a resurgence of secondary pests by killing predators and parasites that would normally control them. During the rainy season insecticides are generally ineffective since water levels cannot be controlled and they are leached out into the ground water.

Pheromones, on the other hand, are species-specific, have no adverse effects on the biota or the environment, are unaffected by rainfall and hence would be fully compatible with an integrated pest management (IPM) approach to control rice pests in both dry and wet season crops. By permeating the air with a synthetic blend of female pheromone components male moths are prevented from following odour trials of pheromone released by conspecific females. This results in a reduced level of mating, or mating disruption, that can subsequently lead to a significant reduction in the larval population of the next generation and hence a reduction in the damage sustained by a crop.

However, in order to utilise pheromones for control of insect pests by mating disruption it is necessary to develop a controlled release formulation and optimise its conditions for use. This work could be achieved on-station but as the technique works best in large contiguous areas of crop a decision was taken to conduct the trials on farmers' fields. While this provided an opportunity to involve rice cultivators in the development process their needs were largely ignored or taken for granted by researchers. As a consequence the technology developed evolved out of a series of highly ordered trials in which teams of people were employed to undertake the work to well-defined protocols. This left the question of farmer acceptance of the technology totally untested.

Since mating disruption requires large areas of crop to be treated and rice in India is cultivated primarily by farmers with access to land of typically between 0.1 and 1 ha it is inevitable that any farmer participatory evaluation trials would require rice cultivators to collaborate to ensure the technology has the best opportunity to work. In order to co-ordinate and motivate the rice cultivators the services of two non-governmental development organisations (NGOs) interested in environmentally acceptable pest control technologies, the Savada Valley Development Samithi (SVDS) and the Sri Vidya Trust (SVT), were engaged.

This paper will summarise the results of work undertaken to develop a controlled release formulation of the sex pheromone of *S. incertulas*, optimise the conditions for its use in control by mating disruption and assess its potential impact on small-holder rice cultivators in India through farmer participatory evaluation trials.

Methods

Location and application

On-farm development trials were conducted at four locations: Medchal 40 km north of Hyderabad, Warangal 150 km north east of Hyderabad, Nellore 200 km north of Chennai and Karjat 70 km east of Mumbai. On-farm evaluation or farmer participatory trials were conducted at two locations in coastal Andhra Pradesh: Anakapalle, Vishakhapatnam District, where the cultivators grow rice as a subsistence crop and sugarcane as the cash crop and Nadurubada, Kakinada District, where rice is grown in the wet season for home consumption and in the dry season as a cash crop. Typical farm holdings were between 0.1 and 1 ha. Farmers with plots in the pheromone-treated areas were asked to refrain from applying any insect pest control measures without first contacting project staff. Farmers with control plots were expected to continue their normal insect pest control routines (hereinafter termed “farmers’ practice”). Development trial plots were chosen that had similar planting dates and rice varieties. For logistical reasons pheromone applications were made sequentially and, on average, it took approximately 20 helpers one day to complete each 10 ha plot. Applications were made by attaching individual dispensers to one metre split bamboo or equivalent canes and placing these by hand in a 4 x 4 m grid over the trial plot (625 dispensers, typically 40 g AI per ha). At each on-farm evaluation trial site the number of pheromone dispensers and sticks given to each farmer depended on their area under cultivation within the trial plot and they were asked to apply the pheromone at their earliest convenience. Many rice cultivators opted to take additional dispensers for use in the nursery.

Mass trapping

Locally manufactured sleeve traps baited with standard lures were used as an alternative control technique to mating disruption for *S. incertulas* in on-farm evaluation trials. This involved the deployment of traps at a density of 20 per ha. Lures were changed every three weeks when the traps were checked for damage and catch.

Pheromone trap catch

Sleeve traps were used to monitor male *S. incertulas* populations in pheromone-treated and farmers’ practice plots. Traps were baited with 1 mg of a 1 : 3 blend of (*Z*)-9-hexadecenal (Z9-16:Ald) and (*Z*)-11-hexadecenal (Z11-16:Ald) in rubber septa (Cork *et al*., 1985). Dichlorvos strips were placed in the traps to kill trapped moths. Lures were replaced on average every 21 days and trap catch data collected at least once every two weeks. The level of communication disruption achieved in the pheromone-treated plots was calculated as 100 x (FP-PT)/FP, where FP and PT are the mean catch/trap/day in the farmers’ practice and pheromone-treated plots respectively.

Light trap catches

Light traps (modified Robinson pattern fitted with a 250W mercury-vapour bulb) were located adjacent to areas of paddy at least 500 m from the nearest pheromone-treated or farmers’ practice plots and any source of light.

Stem borer larval damage assessments

For large scale, on-farm development trials three sub-plots of 1 ha (100 m x 100 m) each were marked out in each pheromone-treated plot, at least 50 m from the nearest edge of the treatment area. Each assessment was made by examining all tillers in a total of 50 hills in each sub-plot. In the on-farm evaluation trials DH and WH assessments were made by examining all tillers in up to 25 hills per field and at least five fields per treatment area. Hills were selected at approximately 4 m intervals along randomly selected transects.

Sweep-net samples of insect fauna

Sweep-net samples were taken in on-farm evaluation trials to assess the levels of natural enemies and pests. Typically ten sweeps were taken for each of five replicates per field.

Yield assessments

At least three 5 m x 5 m areas from each of the on-farm development trial plots were harvested and threshed by hand to obtain wet weight grain yield estimates from pheromone-treated and farmers' practice plots. Dry weight estimates were calculated by reducing the grain weight by 10% and converting to kg per ha.

Statistical analysis

Pheromone trap catch data, stem borer damage data and grain yield data were tested for standardised skewness and kurtosis using a standard software package (Statgraphics®, Version 5) and were not found to depart significantly from a normal distribution (range -2.0 to +2.0). The data were then compared statistically by analysis of variance (ANOVA).

Results

The efficacies of three pheromone blends were compared with farmers' practice plots treated with insecticides in a 10 ha, non-replicated, on-farm development trial. No significant differences in percentage communication (Table 1), larval damage estimates or yield could be attributed to changes in the pheromone blend, although in each case the level of WH recorded was significantly lower in the pheromone-treated plots than in the adjacent farmers' practice plots (Cork *et al*., 1996). As the addition of either (*Z*)-11-octadecenal or (*Z*)-13-octadecenal had no significant effect on mating disruption the other trials were conducted with the blends of Z9-16:Ald and Z11-16:Ald.

Assuming the larval generation causing WH damage is the most economically important a large-scale replicated (3 x 10 ha) on-farm development trial was undertaken to optimise the date of application with a long-duration, 130-day, rice variety. This trial confirmed that there was no significance difference in communication disruption, larval damage estimates (Figure 1) or yield whether the formulation is applied 9-12 or 39-44 days after transplanting (DAT) (Cork *et al*., 1996), providing a granular insecticide is applied in the nursery.

Table 1. Effect of pheromone blend in Selibate YSB® on communication disruption.

DAT	Average catch/trap/week Farmers' practice plots			Percent communication disruption			Average weekly light trap catch	
	Blend 1	Blend 2	Blend 3	Blend 1	Blend 2	Blend 3	Male	Female
40	1.6	0.6	0.8	100.0	100.0	100.0	na[1]	na
47	3.6	2.0	0.8	100.0	90.0	100.0	na	na
54	0.2	0	5.4	100.0	-	100.0	1.0	3.0
61	3.8	0.2	2.6	100.0	100.0	100.0	5.5	9.0
68	7.0	2.4	5.0	100.0	100.0	96.0	6.0	9.8
74	4.6	4.0	6.0	95.7	100.0	80.0	6.0	9.0
81	9.0	2.2	4.2	55.6	81.8	0	7.3	11.5
88	5.6	1.8	9.0	60.7	0	0	22.0	65.0
94	12.4	6.4	8.0	53.2	71.9	42.5	17.6	86.6
103	1.8	0	9.4	0	-	27.7	19.4	69.0
110	na	na	na	na	na	na	35.5	178.0

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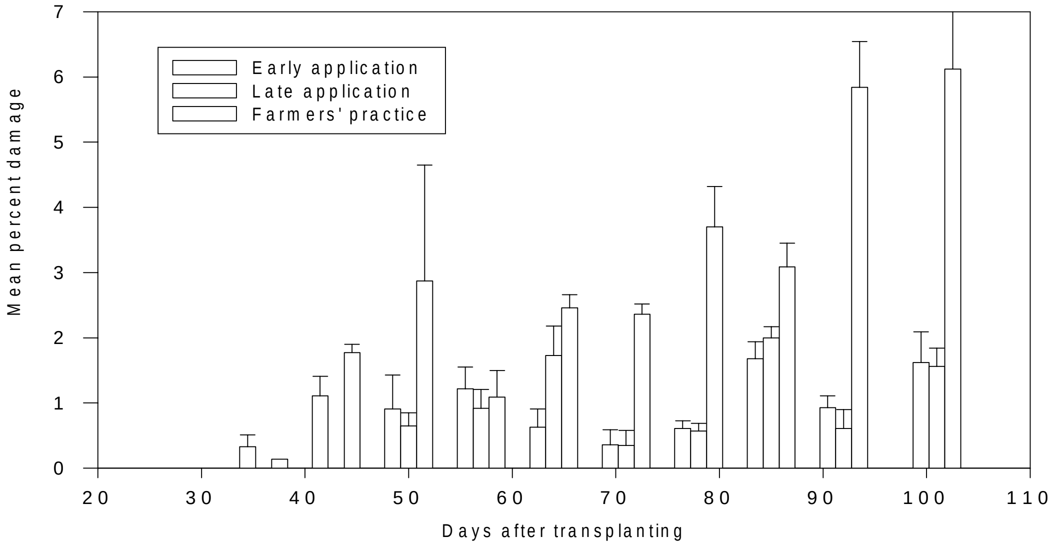
[1] na not available

[2] All pheromone blends contained a 1 : 10 mixture of Z9-16:Ald : Z11-16:Ald. In addition blend 2 contained 10% Z11-18:Ald and blend 3 contained 10% of Z13-18:Ald.

Figure 1. Effect of timing of application of Selibate YSB® on efficacy of mating disruption.



The application rate of pheromone was optimised in a series of small scale replicated (3 x 1 ha) plots in on-farm development trials using the 1 : 3 blend of Z9-16:Ald and Z11-16:Ald. The results showed that application rates of 10 or 20 g AI ha were ineffective at controlling *S. incertulas* while 40 and 80 g AI per ha gave high levels of control (Table 2). 40 g AI is currently recommended for control of *S. incertulas* by mating disruption, although with increased area of application there is probably scope for a further reduction in dose.

Table 2. Effect of application rate of Selibate YSB® on larval damage estimates

Treatment	Larval damage assessments				
	25 DAT (DH)	35 DAT (DH)	45 DAT (DH)	69 DAT (WH)	82 DAT (WH)
80g AI per ha	0.2	0	0.16	5.53	3.27
40g AI per ha	0.18	0	0.11	6.49	4.64
20g AI per ha	0.59	0.43	1.24	8.65	8.17
10g AI per ha	0.74	0.28	0.31	9.77	8.16
Local farmers practice	0.98	0.76	1.12	21.77	14.88
Distant farmers practice	1.36	1.93	1.14	21.67	14.27

[1] Three 1 ha plots per treatment applied 14 days after transplant.

On-farm develop trials were conducted at four locations in India to determine whether the optimised mating disruption protocol developed for controlling *S. incertulas* was applicable to a range of agro-climatic zones. The results confirmed that in each case control of *S. incertulas* was as effective as that obtained with conventional insecticides (Cork *et al*., 1998) and where insecticides were not applied damage was significantly reduced (Table 3) and yields increased by between 50 - 75% (Table 4) (Sawant *et al*., 1995).

Table 3. Large scale trials: Larval damage in pheromone-treated and farmers' practice plots

Trial Location	Days after transplanting	Mean percent damage ± Standard Error		Analysis of variance[3]	
		Pheromone[1]	Farmers' practice[2]	F ratio	Signif. level
Medchal, 1994	37	2.06±0.83	3.80±0.43	3.40	0.08
	86	5.28±0.74	13.04±1.39	24.22	0.0002
Warangal, 1994	30	2.76±0.57	6.96±1.97	4.17	0.06
	79	11.89±3.67	18.48±5.32	1.04	0.3
Nellore, 1995	62	2.12±0.5	8.14±1.27	19.42	0.0004
	96	3.77±0.42	10.08±1.67	13.45	0.0021
Karjat, 1995	40	4.4±0.36	11.73±0.47	152.2	0.0
	69	11.03±0.98	15.87±0.7	16.1	0.001

[1] Mean percent damage of three 1 ha replicates within each of three 10 ha pheromone-treated plots per location.

[2] Mean percent damage of three 1 ha replicates adjacent to each of the three pheromone-treated plots per location.

[3] df = 17

Table 4. Large scale trials: Yield in pheromone-treated and farmers' practice plots

Trial Location	Rice yield, dry weight (kg/ha) ± SE[1]		Analysis of variance		
	Pheromone-	Farmers' practice	df	F ratio	Signif. level
Medchal, 1994	4108±164	3835±201	17	1.12	0.29
Warangal, 1994	4036±212	3715±114	17	1.26	0.28
Nellore, 1995	6400±231	6733±233	14	0.94	0.36
Karjat, 1995	4600±416	2800±400	5	9.72	0.03

[1] Mean ± standard error of three crop cuts of 25 m sq/replicate and three replicates per treatment.

Structured interviews based on a prepared questionnaire were conducted with randomly selected small-holder rice cultivators at two locations in Andhra Pradesh where on-farm development pheromone trials were conducted, Medchal and Warangal. The surveys showed that although 92% of farmers applied insecticides for stem borer control and 60% of those questioned in Warangal applied more than two treatments they only accounted for 4.2% of the cost of production. The major costs were related to labour inputs for land preparation, weeding and harvesting.

In the first on-farm farmer evaluation trial conducted in Dippapalem a 10 ha plot was selected by the farmers. The plot was cultivated by 62 rice farmers, many of whom were tenants. The area of land cultivated by individuals in the trial plot ranged from 0.08 to 0.56 ha, although many farmers had land in other areas where they cultivated rice, sugarcane or dryland crops. The crop was late planted due to poor rains but despite that stem borer incidence was low. Farmers reported they were unable to distinguish between levels of stem borer damage in trial and non-trial areas. However, damage estimates generated by field sampling showed a significant difference between pheromone-treated and untreated fields, 0.5 and 2.8% respectively (ANOVA, df = 1,8; F = 0.02). The farmers felt the trial had not provided an adequate test of mating disruption and wanted to try again in a more typical season. During the village selection process villagers had suggested that *S. incertulas* was a significant problem, and indeed one of the few pest problems they recognised. However, during the informal trial evaluation interviews conducted with groups of farmers some suggested that they undertook the trial more because the SVDS was promoting the technology than because *S. incertulas* was important to them.

In a second trial village, Erravaram, the SVDS had less influence. The farmers were provided with the option of trying mating disruption or mass trapping for control of *S. incertulas*. They opted to provide a 5 ha plot for each technique and decided they would not involve rice cultivators from other villages. This decision profoundly affected the mass trapping trial since many of the fields in the area selected were cultivated, through not necessarily owned, by farmers from other villages. This meant that the treatment plot was fragmented. Sweep-net sampling in trial and non-trial areas taken in the vegetative stage of development confirmed the presence of significant numbers of insect predators, such as *Paederus*, *Casnoidea*, *Micraspis*, Odonata and arachnids such as *Tetragnatha*. The only injurious pests observed were leaffolders, *Cnaphalocrocis medinalis,* but their impact on the crop was negligible. Larval damage estimates suggested there was no difference between trial and non-trial plots with DH counts of 6.9 and 4.9% in mating disruption and mass trapping plots respectively and 7.7% and 5.8% DH in the respective adjacent non-trial plots. However, despite early assurances from the SVDS staff that the farmers were not applying pesticides in the trial plots rice cultivators were observed applying foliar sprays. The impact of these insecticides on *S. incertulas* it uncertain but clearly complicates the interpretation of trial results. When questioned the farmers indicated the spraying was in response to the high insect populations they had observed, although they did not distinguish between beneficial and damaging insects.

A third trial was initiated in Nadurubada, where rice is cultivated as a cash crop. The farmers are relatively wealthy having landholdings of several ha. The NGO involved, the SVT, had little influence with the villagers and the trials were arranged primarily through contacts with the village leader or Sarpanch. The rice cultivators were found to have a better understanding of rice pest related problems than the subsistence farmers in Erravaram and Dippapalem. They planted a high-yielding hybrid rice variety, applied high levels of fertiliser and typically applied six rounds of mixed pesticide sprays across the season. The pesticides were applied prophylactically except the last application which was specifically timed to control planthoppers. The farmers selected 5 ha plots for both mating disruption and mass trapping trials and applied the traps and pheromone dispensers from the nursery period. Sweep-net samples taken at the flowering stage in the crop and found an almost total absence of arthropods in both trial and non-trial areas, apart from a low density of *Tetragnatha*. Stem borer damage estimates in the heading stage suggested that there was no difference between trial and non-trial areas, with DH counts of 2.1 and 2.3% in mating disruption and mass trapping plots respectively and 3.7 and 1.0% DH in adjacent non-trial plots respectively. However, given the high levels of insecticide inputs this result was to be expected. Farmers acknowledged their actions had compromised the trials but were not prepared to risk their crop, which they estimated at approximately 7 tonnes per ha. However, they had observed white-backed planthopper, *Sogatella furcifera*, in some fields and knew that their pest control practices would be insufficient to control it effectively. Sweep-net samples of those fields showed no natural enemies at all. Since the problem was largely of their own making through suppression of natural enemies this may form the basis for a compromise in future trials. They suggested that the wet season crop would be a better test of the technology since they did not apply pesticides to that crop because it was for home consumption and had traditionally less stem borer damage.

Discussion

India has been enormously successful in increasing its rice production to keep pace with consumption. However, scientists are well aware of the social and environmental cost of this achievement and many are concerned about its sustainability. In order to consolidate these gains and build the foundations for further increases in yield environmentally acceptable and sustainable inputs are required. To achieve these objectives scientists are actively developing alternative pest control technologies that meet these criteria. Many of the insect pests of rice in India have only achieved pest status through excessive and indiscriminate use of insecticides. Such insecticides suppress natural predator populations that would normally control these secondary pests. However, by using insect control technologies that are species-specific and environmentally benign the possibility of controlling primary pests such as the yellow stem borer, *S. incertulas*, exists without affecting the natural balance of predators. These criteria are satisfied by the use of insect pheromones for control.

On-farm development trials conducted by researchers using prescribed protocols and teams of labourers have now demonstrated that *S. incertulas* can be controlled effectively by mating disruption with synthetic sex pheromones. In separate trials the Directorate of Rice Research (K. Krishnaiah, personal communication) demonstrated that mass trapping with synthetic pheromone is also efficacious.

A prerequisite for successful application of mating disruption and mass trapping is the need to use large contiguous areas of rice. Since most of the rice grown in India is cultivated by small-scale subsistence farmers any validation process for the technology through on-farm participatory trials has to achieve community uptake of the technology. The most important institutional requirement of this approach is to identify an intermediate organisation that is interested in supporting the validation process. In this context we chose two NGO’s and they are in-turn supported by a Telegu speaking socio-anthropologist familiar with crop protection issues. His role is crucial since he is not only required to conduct research to understand the social, economic and institutional constraints under which the validation process is conducted but also provide assistance to the intermediate organisations to introduce and organise the validation trials.

In the framework of conventional farming systems research validation is a fundamental step before a science-led technology can be released and promoted. Ideally validation should take place in the context of currently used farmer practice with no financial or other inputs that might influence the outcome of the process. It should focus on technical feasibility, social and cultural acceptability and economic viability. In order for the validation process to achieve its objectives entomologists and socio-anthropologists need to accommodate the conditions imposed by the intermediate organisations and the farmers. This compromise is dynamic involving a process of continual negotiation. The results of initial trials conducted in Andhra Pradesh highlighted a number of flaws in the process which ultimately resulted in a failure to achieve a satisfactory evaluation of the technologies being tested. However, through effective monitoring both in the field and through social research the reasons for the failures are well understood. We now have to enter into a period of re-negotiation with the farmers and NGOs to highlight the nature of the problems encountered and seek ways to accommodate them.

Our experiences graphically illustrate the problems encountered when technologies are conceived by scientists and developed out of the social and cultural context in which they are intended to be used. However, given the budgetary constraints inflicted on researchers and the inevitable additional cost associated with developing technologies with active farmer participation, it is uncertain whether mating disruption and mass trapping technologies for control of *S. incertulas* would have been developed by any means other than the route chosen. If, as seems likely, the small-scale rice cultivators will not or cannot act to test the technologies under offer then other incentives will be needed to promote the technology.

IPM technologies are invariably more labour intensive and require higher levels of technical organisation than the use of conventional pesticides. In order to promote such technologies farmers need incentives to change their pest control strategies. Heong and Escalada (1997) have already pointed out that pesticides are often preferred because they are better promoted and more readily available to farmers than alternative strategies promoted by government agencies.

Assuming that pheromone-based control technologies can be successfully validated by farmer participatory trials, their ability to achieve impact will be crucially linked to government commitment to promote them through such incentives as taxation on polluting technologies, stricter pesticide residue limits on food stuffs and farmer education. Regarding the latter, NGO’s are uniquely placed to promote IPM technologies. However, in the experience of this project, they are currently ill-equipped to tackle the issues since, at least in India, they are primarily concerned with social development issues and not crop protection.

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