# Pest Smart interventions and their influence on farmer pest management practices in Tra Hat village, Bac Lieu Province, Vietnam

Results of a Survey

Working Paper No. 212

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Working Paper

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## Abstract

Climate change generally contributes to new and escalating crop pests and diseases, and their intractable management scenarios. Pest Smart, a package of climate-smart interventions, helps address these scenarios to build farmers' resilience to pests and diseases and provide them with knowledge in managing them. Among the interventions included are innovative participatory and climate-adaptive agricultural practices, ecological engineering (EE), and the use of non-chemical approaches underpinned by an advisory framework such as the plant clinic approach.

A pre-Pest Smart (baseline) and post-Pest Smart intervention study was carried out 15 months after the baseline study was conducted to assess the influence of the Pest Smart activities on farmers' practices, attitudes and beliefs on pest management in Tra Hat village, Bac Lieu Province, Vietnam. Farmers advocating Pest Smart activities showed favorable changes in their practices, attitudes and beliefs. Farmers reported an increase in dry yield of rice, reduced rice seeding rate (from 6.9 t/ha to 7.8 t/ha), reduced application of nitrogenous fertilizer (from 109.5 kg/ha to 93.3 kg/ha), and reduced number of insecticide sprays per season (from 3.4 times per season to 2.7 times per season). The perceived losses were also reduced significantly from 1,452 kg/ha to 718 kg/ha (reduction of 51% perceived loss of rice yield to pests).

More farmers also applied insecticides at a later rice growth stage (33 days after seeding) compared to as early as 19 DAS before the intervention. Farmers generally expressed a more positive attitude towards EE practices, but certain perceived barriers still remain, such as the difficulty of growing vegetables without pesticide use and the use of rice bunds for growing flowers. More time and sustained effort is needed to modify behaviors, retain positive changes, and remove the perceived barriers.

**Keywords:**
Pest Smart, pest and disease, ecological engineering

# About the authors

**Sivapragasam, A.**

Sivapragasam is currently the Regional Director of CABI-SEA, tasked to lead the Pest Smart project in three climate-smart villages (CSVs) in Tra Hat, Bac Lieu province under the CCAFS project initiative. For the past 2.5 years, he has been managing and actively implementing Pest Smart based interventions in three CSVs, in addition to implementing other regional projects for CABI such as Plantwise. Prior to CABI, Siva worked with various Malaysian organizations such as MARDI, and international organizations such as IRRI, FAO-UN, and CSIRO. He has a background in entomology and integrated pest management.

**Chien, H.V**

Chien is a consultant to the Pest Smart project on rice pest management, and is an expert on ecological engineering. Chien previously held the post of the Ex-Director of the Plant Protection Department, Southern Regional Plant Protection Center, MARD. Chien has worked extensively with IRRI and other international organizations. Aside from providing guidance and assistance to the extension staff in Tra Hat village, Bac Lieu, Chien also provides technical assistance on aspects of pest management to staff in Rohal Soung, a CSV in Cambodia.

**Khing, S.L.**

Khing is a scientist in CABI-SEA and has been actively implementing the Pest Smart project in three CSVs. Khing has a background on environmental science, and is a biotechnologist by training. Khing has more than six years of experience in biodiversity conservation, partnerships with corporate and government agencies in RSPO standards compliance and conservation of High Conservation Value (HCV) areas, community engagement for livelihood development, and environmental conservation programs amongst indigenous groups and school children. He also had about five years of experience in GIS mapping work.

**Duong, L.M.**

Duong is a local coordinator for Pest Smart activities in Tra Hat CSV. Duong holds the position of staff officer, Technical Office at the Department of Agriculture and Rural Development in Bac Lieu province.

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We would also like to extend our appreciation to Mr. Le Minh Duong, the Tra Hat CSV Coordinator and a technical officer from the Department of Agriculture and Rural Development of Bac Lieu province, who facilitated our access and coordinated with the village leader of Tra Hat for the implementation of activities. We would also like to thank SOFRI, for training extension workers into becoming plant doctors and for carrying out the plant clinics and the mango fruit fly bait trap experiment. Lastly, we would like to thank the farmers and village leaders of both Chau Thoi and Tra Hat who participated in the interviews and activities.

# Contents

# Acronyms

| | |
|---|---|
| CABI | Center for Agriculture and Biosciences International |
| CCAFS | CGIAR Research Program on Climate Change, Agriculture and Food Security |
| CSA | climate-smart agriculture |
| CSV | Climate-Smart Village |
| DARD | Department of Agriculture and Rural Development |
| DAS | days after sowing |
| EE | ecological engineering |
| FGD | focus group discussion |
| PC | plant clinic |
| PHR | plant health rally |
| PPD | Plant Protection Department |
| P&D | pests and diseases |
| PS | pest smart |
| SOFRI | Southern Horticultural Research Institute |
| WHO | World Health Organization |

# I. Background information

Many climate-smart agricultural (CSA) interventions are aimed at addressing largely abiotic, economic, and livelihood risks of farming communities. The biotic component of crop pests and diseases is dealt with to a lesser extent. In rice production systems alone, pests and diseases account for 37% yield loss (Oerke 2006). Climate change will alter and will possibly increase the frequency and duration of pest and disease outbreaks (Campbell et al. 2016), which will result to poor crop yield and the increased use of chemical control as a quick-fix solution. The excessive application of chemical pesticides creates an unsustainable scenario in agro-ecosystems such as the development of resistance to insecticides, and the contamination of fresh water sources and aquatic environment (Lu et al. 2015). Furthermore, the increased use of pesticides contributes to increased greenhouse gas emissions through industrial production inefficiencies (Dickie et al. 2014).

The summary reports are based on the various baseline surveys conducted in the three Climate-Smart Villages (CSVs) established by CCAFS-CGIAR such as Tra Hat (Vietnam), Rohal Soung (Cambodia), and Ekxang (Laos). These reports were presented at the 2015 CCAFS's Climate-Smart Villages (CSVs) Coordination Workshop held in Hanoi, and highlighted the significance of pests and diseases (P&D) and their management on crops grown by farmers in the three CSVs. The issue was compounded by the limited knowledge on the etiology of P&D and nutrient management regimes, widespread use of pesticides, and weak agricultural extension systems. It is well established that significant outbreaks of P&D, including those due to invasive ones, pose unpredictable risks that affect the resilience of farmers' livelihoods and food security.

Pest Smart (PS) interventions help by building resilience in the system through strengthening the adaptive capacity of farmers, and introducing climate-smart practices and low-cost technologies that farmers can effectively use. The activities will enable CSVs to protect and stabilize crop production, manage crop pests and diseases, restore ecosystem health, and educate and empower target communities to forge resilience to climate change. A key component of the project is addressing biotic issues, while modifying beliefs, and removing perceived barriers to sustain the uptake of the activities. Some of the climate-smart interventions that can be used are:

1. Use of a new extension paradigm and framework, (i.e. using trained 'Plant Doctors' to implement Plant Clinics);
2. Innovative communication resources (e.g. Plant Health Knowledge Bank, Pest Management Decision Guides, Fact Sheets); and
3. Ecological Engineering (EE) to enhance ecosystem biodiversity.

This study evaluated the influence of some of the abovementioned climate-smart interventions for improving pest management and climate resilience of farmers in Tra Hat village, Vinh Loi district, Bac Lieu Province in Vietnam.

# II. Assessment study: Approach and methodology

## 2. Methods

### 2.1. Research sites

The study was carried out in the Vinh Loi district located within the Bac Lieu province of Vietnam. The treatment site is the Tra Hat hamlet, Chau Thoi commune, Vinh Loi district, and the control site is about 5 km away, in the Tram Mot hamlet, Long Thanh commune in Vinh Loi district.

The coordinates for Tra Hat is 9.35°-9.38° (Lat) and 105.65°-105.70° (Lon). The site is located in the Mekong Delta. The Chau Thoi commune has a population of 14 500 people covering an area of 4271 hectare of the Bac Lieu province. There are two main rice-cropping seasons in Tra Hat. The weather in Tra Hat has two distinct seasons—the rain season from May to November and the dry season from December to April. The freshwater source for agriculture is the rainfall, the Quan Lo Phung Hiep canal and groundwater. In recent years, sea level has risen, and the groundwater has been affected by saltwater intrusion.

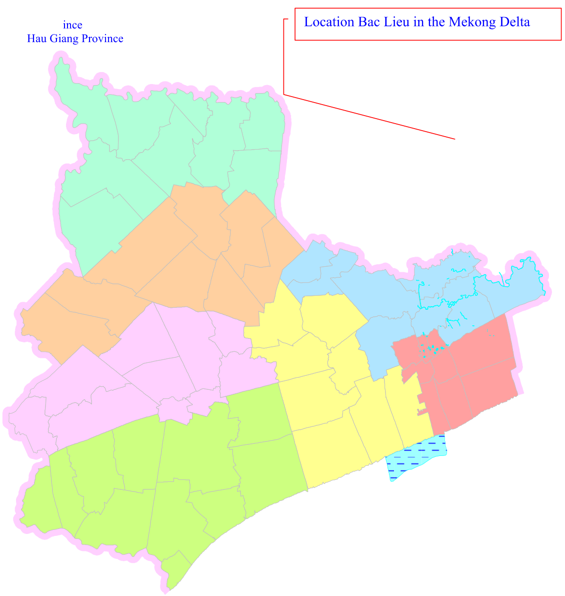


Figure 1. The location of Tra Hat hamlet in the Chau Thoi commune and the Tram Mot hamlet in the Long Thanh commune within the Vinh Loi district in Bac Lieu Province

### 2.2. Pest Smart project activities

Many of the activities or interventions described below resulted from the outputs of a focus group discussion (FGD) with farmers.

A. Ecological engineering

Ecological engineering (EE) is a recent concept of landscape manipulation to reduce pest problems in rice agro-ecosystems (Gurr et al. 2004). It involves growing nectar-producing flowering plants such as sesame, *Sesamum orientale* L., and cosmos flowers *Cosmos bipinnatus* on rice bunds to attract and provide refugia for parasitoids and beneficial insects, thereby providing opportunities for biological control of rice pests. If done successfully, EE reduces the need for pesticides and nitrogenous fertilizers to protect crops and guarantee yield (Lu et al. 2015).

Field trials of the ecological engineering and the "no-spray within the first 40 days" demo were conducted between September 2015 and October 2016. A total of six fields were set up for the trials, each 1ha in size. Three fields were allocated as demonstration plots (hereafter demo plots) and the three others were control plots (i.e. activities as usual by farmers). Farmers of the demo plots planted cosmos flowers on the bunds and were requested not to spray within the first 40 days after rice seeding.

B. Extension services using the Plant Clinic concept

The Plant Clinic is a concept based on CABI-led Plantwise framework model that mimics the human clinic. Patients or in our case, affected farmers, can bring diseased crops to get diagnosis and recommendation from a plant doctor on pests or disease control or management.
The technical personnel of Southern Horticultural Research Institute (SOFRI), based in Tiengiang Province were engaged as trainers as they were already part of the Plantwise program of CABI. Ten plant doctors from the Department of Agriculture and Rural Development underwent training before setting up plant clinic in Tra Hat. The topics covered in the training addressed crop (i.e. rice, fruit and vegetable) pests and diseases and their diagnosis, pesticides safe use, and plant clinic operation. Ten plant clinic sessions were held in Tra Hat. Farmers who visited the plant clinic were also given printed information on the particular pests / diseases and its management method.

C. Fruit fly trapping

A fruit fly trapping trial was also implemented by SOFRI in both Tra Hat and Tram Mot. Twenty methyl-eugenol traps were installed in 5 locations in Tra Hat (2 replicates of 5 traps) and Tram Mot (2 replicates of 5 traps). The traps were installed for a period of 3 months to capture fruit flies. Fruit flies that were captured were then collected, sorted, identified, and counted.

D. Education and awareness-raising

In addition to the activities outlined above, several training, education, and awareness-raising events were also organized. The list of events organized is listed below:

1. Plant health rallies (PHRs) on the use of pesticides in the rice ecosystem was conducted on 31 May 2016 and 17 August 2016 to about 40 farmers. There was also a PHR on fruit fly and its management by SOFRI in June 2016 provided to the Department of Agriculture and Rural Development (DARD) officers
2. Natural enemies and ethno-science for women on leaf-folders and parasitoid egg collection and hatching on 8 July 2016
3. Planning and implementing ecological engineering in fields in September 2015 and July 2016.

## 2.3. Survey questionnaire and data collection

The CABI team conducted three FGDs in Bac Lieu, Vietnam on 26 May 2015. The FGDs were carried out in the hamlets of Tra Hat (treatment) and Tram Mot (control). A total of 24 farmers participated in the FGDs. Farmers' knowledge, attitudes, concerns, pest management practices, and perceptions of climate change and its impact on crop production were evaluated. The information obtained from the FGDs was then used to design the survey questionnaire.

A draft survey questionnaire was developed in English. The questionnaire also contained belief statements –a set of statements where respondents are asked to indicate their degree of belief with each statement. Each degree of belief is given a numerical value from 1 to 5. These belief statements are not leading questions, as they are not phrased in a manner that suggests a particular reply. The descriptors, along with a 5-point Likert scale, were "Definitely not true," "In most cases not true," "Maybe true," "In most cases true," and "Always true." The draft questionnaire was then translated into Vietnamese and pre-tested on randomly selected respondent farmers in a village in Soc Trang province. The questionnaire was refined, and a final version was produced for the surveys.

The experimental design adopted for the intervention study was the "pre-test and post-test group." The pre-test survey, which formed the baseline, was conducted in July 2015. The surveys were conducted in both Tra Hat (treatment) and Tram Mot (control) villages. Final year students from Bac Lieu University were trained and supervised by CABI. A prompt chart with descriptor phrases was used to obtain farmers' scoring of the belief statements. The responses to the survey were immediately coded in the field with quality assurance checks conducted at the same time. Interviewers who had survey questionnaires with inaccurate or ambiguous responses were required to return to the respondents for clarifications.

A post-test survey was conducted in November 2016 to assess changes in farmers' beliefs and practices in Tra Hat resulting from the various interventions under the Pest Smart umbrella. The questionnaire used is similar to the questionnaire used in the pre-test survey. Owing to budget constraints, the post-test was only carried out among the farmers in Tra Hat village, and no information was collected from the control village. The CABI team interviewed the farmers and collected the responses. The enumerators underwent training before administering the questionnaire to farmers.

## 2.4. Data analyses

The data were coded using Excel and checked for errors or outliers before analyses. The Mann-Whitney U test was used to test for null hypothesis that there were no differences in the variables between pre- and post-test. The Chi-square test was used to test relationships between variables, and the F-statistic two sample test was used to determine if the respondents between the pre-test and post-test were homogenous.

# III. Key findings

**3. Results**

3.1. Profile of respondents

Sample sizes of the respondents from Tra Hat were different between the pre-test and post-test surveys. A total number of 150 farmers participated in the pre-test survey, but only 90 farmers attended the post-test survey since the other farmers were busy performing farm tasks and household chores (Table 1).

Table 1. Number of respondents at pre-test (July 2015) and post-test (November 2016) surveys

| | Pre-test | Post-test |
|---|---|---|
| Number of survey respondents | 150 | 90 |

The profiles of the farmer respondents from both the pre-test and post-test are shown in Table 2. There was no significant difference between the two groups, except for the area of rice cultivation. Thus, both groups were mostly homogenous. The mean ages of the two groups of farmers were 49 and 53 years. Both groups had an average of six years of schooling and more than 27 years of farming experience. The average rice farm size for pre-test group was 1.8 ha, while the average rice farm size for post-test group was 1.6 ha.

Table 2. Profile of farmer respondents in pre-test and post-test groups in Tra Hat

| | Pre-test N = 150 | Post-test N = 90 | F | p |
|---|---|---|---|---|
| Age (years) | 49.4 | 52.7 | 1.17 | 0.43 |
| Years of schooling (years) | 6.2 | 5.7 | 1.04 | 0.84 |
| Rice farming experience (years) | 27.5 | 32.4 | 1.15 | 0.49 |
| Rice area cultivated (ha) | 1.8 | 1.6 | 1.53 | 0.03* |

*F = variation among the sample means/variation within samples calculated by analysis of variance. The F-statistic is the square of the t-statistic from a two-sample t-test*

*p = probability of significance*

3.2. Changes in pest management practices and crop yields

There was no significant difference in the percentage of farmers who had participated in the Rice IPM trainings between the pre-test and post-test groups. However, there was an increase of 16.7% of farmers who had attended training in Rice IPM (Table 3).

Table 3. Percentage farmers who participated in IPM trainings in Tra Hat

| IPM training | % farmers participated Pre-test N = 148 | Post-test N = 90 | $X^2$ | p |
|---|---|---|---|---|
| Rice IPM | | | | |
| • Attend | 31.1 | 47.8 | $3.21^{ns}$ | 0.07 |
| • Did not attend | 68.9 | 52.2 | | |

*ns = not significant; *Significant difference at p = 0.05; **Significant difference at p = 0.01*

*The Chi-square test was used to test the null hypothesis that there was no difference between pre-test and post-test groups using nominal data.*

Changes in the farmers' pest management practices and crop yields over 15 months from the start of activity implementation are shown in Table 4. Farmers reported a significant increase of dry yield of 0.9 t/ha from 6.9 t/ha to 7.8 t/ha. The fresh yield from the pre-test, however, was not significantly different than that of the post-test. The rice-seeding rate used in sowing reduced significantly from 109.5 kg/ha to 93.3 kg/ha. Farmers in the post-test group had also reduced the application of nitrogen fertilizer from 109.5 kg/ha to 93.3 kg/ha, and the number of insecticide sprays from 3.4 times per season to 2.7 times per season. The survey also revealed that post-test farmers sprayed pesticides much later in the season (from early tillering stage (19.3 DAS) in pre-test group to late tillering stage (33.2 DAS) in the post-test group). The perceived losses of rice harvest to pests also declined significantly from 1452 kg/ha to 718 kg/ha.

Table 4. Changes in pest management practices and crop yields in Tra Hat

| | **Pre-test N = 150** | **Post-test N = 90** | **z** | **p** |
|---|---|---|---|---|
| Changes in yield (t/ha) | | | | |
| • Dry yield | 6.9 | 7.8 | -4.08 | < 0.01** |
| • Fresh yield | 7.3 | 7.6 | -1.22 | 0.22 |
| Seed rate used in rice sowing (kg/ha) | 146.7 | 29.1 | -10.08 | < 0.01** |
| Amount of nitrogen fertilizer (kg/ha) | 109.5 | 93.3 | -2.21 | 0.03* |
| Number of insecticide sprays | 3.4 | 2.7 | -3.67 | < 0.01** |
| Day of first insecticide application | 19.3 | 33.2 | -8.81 | < 0.01** |
| Perceived losses to pest kg/ha | 1452.25 | 717.51 | -3.26 | < 0.01** |

** Significant difference at p = 0.05; ** Significant difference at p = 0.01. The Mann-Whitney test was used to test the null hypothesis that there was no difference between pre-test and post-test groups. As the sample sizes were large (at least N=90), the z-values were used to determine significance.*

Based on the type of pesticides used, insecticides was rated as the highest for both pre-test and post-test groups. However, for the pre-test group, the next most significant pesticide type used was fungicide. Anti-microbials made up a small proportion of pesticide used (Table 5). These pesticides were used to control pests such as brown planthoppers, stem borers, leaf-folders, gall midges, cut worms and golden apple snails; diseases like blast bacterial leaf blight, yellow leaf spot, sheath blight, ragged stunt virus; and rodents (Table 6).

For the post-test group, the next most significant pesticide type used was molluscicide, followed by fungicide and plant growth regulators (Table 5). The target pests and diseases were brown plant hoppers, stem borers, rodents, blast, leaf folders, and sheath blight (Table 6).

Table 5. Types of pesticides used at various rice crop stages in Tra Hat

| | Pre-test | | | | | | Post-test | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days after seeding (DAS) | | | | | | | | | | | |
| | 0-15 | 16-20 | 21-40 | 41-60 | 61-70 | >70 | Seed treatment | 0-20 | 21-40 | 41-60 | 61-70 | > 70 |
| | % farmers | | | | | | | | | | | |
| Insecticide | 55.0 | 56.8 | 63.3 | 42.5 | 16.4 | 2.4 | 33.3 | 50.0 | 75.6 | 6.67 | 27.8 | 3.3 |
| Fungicide | 0.0 | 13.7 | 16.5 | 32.2 | 50.0 | 23.8 | 0.0 | 0.0 | 0.0 | 0.0 | 3.3 | 0.0 |
| Herbicide | 0.0 | 13.7 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Molluscicide | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| Acaricide | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Anti-microbial | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.3 | 0.0 |
| Plant growth regulator | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| Don’t remember | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 | 1.1 | 0.0 | 0.0 | 0.0 |

Table 6. Most important rice pests of farmers reported during the pre-test and post-test surveys

| Rice Pest | Pre-Treatment | | Post-Treatment | |
|---|---|---|---|---|
| | No. | % | No. | % |
| Bacterial leaf blight | 3 | 2 | 0 | 0 |
| Blast | 29 | 19.3 | 5 | 5.6 |
| Brown plant hopper | 65 | 43.3 | 72 | 80 |
| Cutworm | 1 | 0.7 | | |
| Gall midge | 2 | 1.3 | | |
| Golden apple snail | 1 | 0.7 | | |
| Leaf folder | 14 | 9.3 | 1 | 1.1 |
| Ragged stunt virus | 1 | 0.7 | 0 | 0 |
| Red stripe, yellow leaf, yellow spot disease | 2 | 1.3 | 0 | 0 |
| Rodent | 1 | 0.7 | 6 | 6.7 |
| Sheath blight | 1 | 0.7 | 1 | 1.1 |
| Stem borer | 20 | 13.3 | 7 | 7.8 |
| Don’t know | 1 | 0.7 | 0 | 0 |
| None | 9 | 6 | 1 | 1.1 |

| Chemical class/common name | Crop stage (Days after seeding) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | WHO Class | Seed treatment n=114 | 0-20 n=119 | 21-40 n=132 | 41-60 n=123 | 61-70 n=101 | > 70 n=10 | Seed treatment n=30 | 0-20 n=42 | 21-40 n=65 | 41-60 n=57 | 61-70 n=24 | > 70 n=3 |
| | % farmers | | | | | | | | | | | | |
| **Amphipathic glycosides + isoflavone** | | | | | | | | | | | | |
| Saponin + rotenone | II | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Anthranilic diamide** | | | | | | | | | | | | |
| Rynaxypyr (Chlorantraniliprole) | U | 0.0 | 12.6 | 15.9 | 11.4 | 1.0 | 0.0 | 0.0 | 2.4 | 1.5 | 0.0 | 4.2 | 0.0 |
| Chlorantraniliprole +thiamethoxam | U + III | 0.0 | 0.0 | 0.0 | 15.4 | 2.0 | 0.0 | 0.0 | 2.4 | 9.2 | 3.5 | 0.0 | 0.0 |
| **Avermectin** | | | | | | | | | | | | |
| Abamectin | III | 0.0 | 0.8 | 2.3 | 4.1 | 1.0 | 0.0 | 0.0 | 4.8 | 3.1 | 0.0 | 0.0 | 0.0 |
| **Benzoylureas** | | | | | | | | | | | | |
| Chlorfluazuron | III | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Organophosphate** | | | | | | | | | | | | |
| Diazinon | II | 0.0 | 5.0 | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 16.7 | 18.5 | 3.5 | 0.0 | 0.0 |
| Dimethoate | III | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Chlorpyrifos | III | 0.0 | 10.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Profenofos | II | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| Chemical class/common name | Crop stage (Days after seeding) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **WHO Class** | **Seed treatment n=114** | **0-20 n=119** | **21-40 n=132** | **41-60 n=123** | **61-70 n=101** | **> 70 n=10** | **Seed treatment n=30** | **0-20 n=42** | **21-40 n=65** | **41-60 n=57** | **61-70 n=24** | **> 70 n=3** |
| | % farmers | | | | | | | | | | | | |
| Quinalphos | II | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 1.5 | 0.0 | 0.0 | 0.0 |
| **Carbamates** | | | | | | | | | | | | |
| BPMC (fenobucarb) | II | 0.0 | 2.5 | 0.8 | 0.8 | 1.0 | 0.0 | 0.0 | 2.4 | 3.1 | 3.5 | 8.3 | 0.0 |
| Carbofuran | Ib | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Pyrethroids** | | | | | | | | | | | | |
| Cypermethrin | II | 1.8 | 8.4 | 1.5 | 0.8 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cypermethrin + chlorpyrifos ethyl | II + II | 0.0 | 10.1 | 6.1 | 3.3 | 1.0 | 0.0 | 0.0 | 7.1 | 7.7 | 12.3 | 0.0 | 33.3 |
| Deltamethrin | II | 0.0 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lambda cyhalothrin | II | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Etofenprox | U | 2.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| **Chemical class/common name** | **Crop stage (Days after seeding)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **WHO Class** | **Seed treatment n=114** | **0-20 n=119** | **21-40 n=132** | **41-60 n=123** | **61-70 n=101** | **> 70 n=10** | **Seed treatment n=30** | **0-20 n=42** | **21-40 n=65** | **41-60 n=57** | **61-70 n=24** | **> 70 n=3** |
| | % farmers | | | | | | | | | | | | |
| **Pyrethroids** | | | | | | | | | | | | | |
| Sumithrin | U | 0.0 | 0.0 | 0.8 | 4.1 | 6.9 | 10.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Permethrin | II | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.8 | 1.5 | 1.8 | 0.0 | 0.0 |
| **Pyrazole** | | | | | | | | | | | | | |
| Fipronil | II | 1.8 | 10.1 | 12.1 | 2.4 | 2.0 | 0.0 | 0.0 | 16.7 | 23.1 | 5.3 | 8.3 | 0.0 |
| **Nereistoxin** | | | | | | | | | | | | | |
| Cartap | II | 0.0 | 0.6 | 1.5 | 0.8 | 1.0 | 0.0 | 0.0 | 2.4 | 4.6 | 1.8 | 0.0 | 0.0 |
| Nereistoxin | N/A | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Neonicotinoid** | | | | | | | | | | | | | |
| Imidacloprid | II | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Thiamethoxam | III | 88.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| Chemical class/common name | Crop stage (Days after seeding) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **WHO Class** | **Seed treatment n=114** | **0-20 n=119** | **21-40 n=132** | **41-60 n=123** | **61-70 n=101** | **> 70 n=10** | **Seed treatment n=30** | **0-20 n=42** | **21-40 n=65** | **41-60 n=57** | **61-70 n=24** | **> 70 n=3** |
| | % farmers | | | | | | | | | | | | |
| Dinotefuran | N/A | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Thiamethoxam + difenoconazole + fludioxonil | III + II + U | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 |
| **Thiadiazin** | | | | | | | | | | | | | |
| Buprofezin | III | 0.0 | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.1 | 14.0 | 8.3 | 0.0 |
| **Triazine** | | | | | | | | | | | | | |
| Pymetrozine | III | 0.0 | 10.1 | 15.2 | 24.4 | 16.8 | 0.0 | 0.0 | 9,5 | 12.3 | 45.6 | 62.5 | 66.7 |
| **Phthalic diamides** | | | | | | | | | | | | | |
| Flubendiamide | N/A | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.8 | 9.2 | 8.8 | 8.3 | 0.0 |
| **Oxadiazine** | | | | | | | | | | | | | |
| Indoxacarb | II | 0.0 | 2.4 | 3.0 | 1.6 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Farmers used the most number of insecticides during the rice seedling, booting, and tillering stages but as shown in Table 6, there were indications of small changes in the number, types, and classes of insecticides used to control rice pests.

The pre-test farmers used 5 types of insecticides—neonicotinoids, pyrazoles, and pyrethroids of WHO Classes II and III as seed treatment. The post-test farmer group, on the other hand, reduced the number of insecticides applied to one type and maintained the use of thiomethoxam (neonicotinoid) (WHO Class III) as seed treatment.

The insecticides applied by pre-test farmers at the seedling stage were anthranilic diamides, avermection, carbamates, pyrethroids, pyrazole, nereistoxin, triazine, and oxadiazine of WHO Classes II, III, and U. The post-test farmers reduced the number of insecticides used from 15 types to 14 types, and these were from the insecticide groups of amphipathic glycosides + isoflavone, anthranilic diamide, avermectin, benzoylureas, organophosphate, carbamates pyrethroids, pyrazole, nereistoxin, triazine, and phthalic diamides of WHO Classes II, III, and U.

During the tillering stage, pre-test farmers reported the use of less insecticides compared to the post-test group. In the pre-test group, 13 insecticides were used and these ranged from anthranilic diamide, avermectin, carbamates, pyrethroids, pyrazole, nereistoxin, thiadiazin, triazine, and oxadiazine of WHO Classes II, III, and U. In this stage, the post-test group used insecticides from the groups of anthranilic diamide, avermectin, organophosphate, carbamates, pyrethroids, pyrazole, nereistoxin, neonicotinoid, thiadiazin, triazine, and phthalic diamides of WHO Classes II, III, and U.

The pre-test group used 13 types of insecticides during the booting stage, compared to the post-test group which used 10 types of pesticides. The insecticides used by the pre-test group ranged from anthranilic diamides, avermectin, carbamates, pyrethroids, pyrazole, nereistoxin, triazine, and oxadiazine of WHO Classes Ib, II, III, and U. In contrast, the post-test group did not report the use of carbofuran, and the pesticides they used during the booting stage were from the groups of anthranilic diamide, organophosphate, carbamate, pyrethroids, pyrazole, nereistoxin, thiadizin, and phthalic diamide of WHO Classes II, III, and U.

During the flowering stage, pre-test farmers used 11 types of insecticides from the groups of anthranilic diamide, avermectin, carbamates, pyrethroids, pyrazole, nereistoxin, triazine, and oxadiazine of WHO Classes II, III, and U. On the other hand, post-test farmers reported use of less insecticides—6 types from the groups of anthranilic diamide, carbamate, pyrazole, thiadiazin, triazine, and phthalic diamide of WHO Classes II, III, and U.

In the ripening stage, pre-test farmers used only one insecticide—pyrethroid of WHO Class U. In contrast, the post-test farmers used 2 types of insecticides—a pyrethroid and a triazine of WHO Classes II and III.

In terms of the classes of insecticides used, the list below outlines the minor changes reported by post-test farmers:

1. Did not use carbofuran (WHO Class Ib)
2. Used less WHO Class II insecticides (only by 1 count)
3. Used more WHO Class III insecticides (only by 1 count)
4. Used less insecticides of WHO Class U (by 5 counts)

### 3.3. Changes in fertilizer applications in rice farms

Changes in the mean number of fertilizer applications at different rice growth stage and the total amount of fertilizer (kg/ha) are outlined in Table 7. No significant difference in the mean number of fertilizer applications during the seeding and booting stages were found between pre-test and post-test groups. However, there was a significant reduction of fertilizer applications at the tillering stage and a significant increase in the flowering stage. The total N, P, and K applied at all rice crop stages were also significantly reduced in the post-test group.

Table 7. Changes in fertilizer applications in rice farms of Tra Hat

| | **Pre-test N = 150** | **Post-test N = 90** | **z** | **p** |
|---|---|---|---|---|
| Mean number of fertilizer applications | | | | |
| • Crop stage/fertilizer type (DAS) | | | | |
| o 0-15 | 1.11 | 1.02 | -0.12 | 0.9 |
| o 16-40 | 1.64 | 1 | -5.44 | < 0.01** |
| o 41-60 | 1.19 | 1.01 | -1.59 | 0.11 |
| o 61-70 | 0.45 | 1.08 | -5.49 | < 0.01** |
| Amount of fertilizer (kg/ha) applied | | | | |
| • Total N | 110.3 | 93.3 | -2.2 | 0.03* |
| • Total P | 81.6 | 38.9 | -9.62 | < 0.01** |
| • Total K | 23.8 | 17 | -4.52 | < 0.01** |

** Significant difference at p = 0.05; ** Significant difference at p = 0.01. The Mann-Whitney test was used to test the null hypothesis that there was no difference between pre-test and post-test groups. As the sample sizes were large (at least N=90), the z-values were used to determine significance.*

3.4. Beliefs towards pest management and ecological engineering

The changes in the farmers' beliefs and barriers towards ecological engineering and pest management are shown in Table 8.

There were large differences in the percentage of farmers in the pre-test and post-test group who indicated agreement with belief statements for ecological engineering practices. Post-test farmers expressed more positive attitudes in most belief statements, suggesting that the Pest Smart activities created positive changes to farmers' attitudes towards ecological engineering. The key statements to which farmers had the most positive response change was "Planting nectar-rich flowers on the bunds can make the landscape beautiful." This is followed by "Nectar-rich flowers will attract natural enemies which will help protect the rice crop," and "Straw that has been decomposed will supply nutrients for the soil and rice plant".

Perceived barriers may reduce the adoption of the activity even though respondents may have indicated positive response to behavioral and subjective norms (Heong et al. 2014). Perceived barriers relating to bund use for planting flowers (i.e. "Increasing beneficial flowers on bunds is additional burden to farmers") have decreased in the post-test group. Yet, there was an increase in the percentage of farmers from the post-test group who scored highly on the use of pesticide for vegetable crops (i.e. "It is difficult to grow vegetables without pesticide use"). There was also a small increase in the percentage of farmers who did not agree to plant flowers on the bunds because "Our bunds are used for walking, so we cannot grow flowers on them".

In the evaluation for change in beliefs regarding pest management, there was a small increase in the percentage of farmers who had scored favorably for increased awareness of beneficial insects (i.e. "All insects in rice fields are harmful and will reduce yields"). There was an even greater increase in the percentage of farmers who did not believe that frequent insecticide applications will kill useful organisms and soil microorganisms and reduce soil fertility. More farmers in post-test group believed that "During the first 40 days after sowing, pesticides should be used to prevent pests and diseases" and "Insecticide spraying for insect control always increases yield".

Table 8. Percentage of farmers (%) who believe that the statement is always true

| No | Statement | Pre-test | Post-test | $X^2$ |
|---|---|---|---|---|
| **A) Beliefs/Attitudes in Ecological Engineering** | | | | |
| 1 | All useful organisms in the rice field—bees and parasitoids must be protected from spraying | 31.3 | 37.8 | 33.0** |
| 2 | Bees and parasitoids will help me reduce the number of insecticide sprays | 33.3 | 35.6 | 25.2** |
| 3 | Straw burning can kill a lot of useful organisms in the rice field | 51.3 | 53.3 | 35.7** |
| 4 | Farmers should use straw as organic fertilizer or cattle feed instead of burning it | 48.7 | 45.6 | 39.7** |
| 5 | In the autumn rice season, farmers should bury straw to speed up decomposition | 56.0 | 56.7 | 32.4** |
| 6 | Straw that has been decomposed will supply nutrients for the soil and rice plant | 64.0 | 80.0 | 14.8** |
| 7 | Using more nitrogen application will make rice grow better | 56.0 | 64.4 | 36.6** |
| 8 | Planting nectar-rich flowers on the bunds will reduce insecticide use | 34.0 | 77.8 | 65.9** |
| 9 | Nectar-rich flowers on the bunds will attract natural enemies which will help protect the rice crop | 34.0 | 50.0 | 30.4** |
| 10 | Planting nectar-rich flowers on the bunds can make the landscape beautiful | 70.0 | 80.0 | 13.9** |
| 11 | The plants around the rice fields provide homes to natural enemies that protect rice | 47.3 | 46.7 | 19.8** |
| 12 | When there are lots of flowers on bunds, there is no need for leaf folder control | 16.7 | 26.7 | 66.5** |
| **B) Perceived Barriers in Ecological Engineering** | | | | |
| 14 | Increasing beneficial flowers on bunds is additional burden to farmers | 40.7 | 34.4 | 10.5* |
| 15 | Our bunds are narrow so there is no place for beneficial flowers | 62.7 | 57.8 | 10.8* |
| 16 | Our bunds are used for walking so we cannot grow flowers on them | 58.0 | 61.1 | 10.0* |

** Significant difference at p = 0.05; ** Significant difference at p = 0.01. The Chi-square test was used to test the null hypothesis that there was no difference between pre-test and post-test groups using nominal data*

| | | | | |
|---|---|---|---|---|
| 17 | The beneficial flowers on bunds will die because we burn our rice straw | 63.3 | 48.9 | 22.3** |
| 18 | It is difficult to grow vegetables without pesticide use | 6.7 | 42.2 | 124.6** |
| **C) Beliefs/Attitudes in Pest and Disease Management** | | | | |
| 19 | Frequent insecticide sprays will kill useful organisms and microorganisms in the soil | 31.3 | 4.4 | 27.2** |
| 20 | Frequent insecticide sprays can destroy the soil and reduce plant growth | 51.3 | 8.9 | 58.7** |
| 21 | All insects in rice fields are harmful and will reduce yields | 32.7 | 14.4 | 22.4** |
| 22 | Insecticide spraying for insect control always increases yield | 19.3 | 23.3 | 25.1** |
| 23 | To control hoppers we must spray frequently according to schedule | 51.3 | 0.0 | 97.0** |
| 24 | Insect resistant varieties do not need any insecticides | 28.0 | 20.0 | 50.6** |
| 25 | If we spray for leaf folders we can get brown plant hopper (BPH) outbreak | 14.0 | 24.4 | 25.0** |
| 26 | When the rice crop is young, insecticides must be used | 23.3 | 7.8 | 20.2** |
| 27 | Insecticides are the only way to manage insect pests | 24.7 | 10.0 | 57.4** |
| 28 | There is no need to use herbicides on bunds | 42.7 | 15.6 | 33.0** |
| 29 | During the first 40 days after sowing, pesticides should be used to prevent pests and diseases | 17.3 | 41.1 | 74.3** |
| 30 | The newer insecticides are always the better | 15.3 | 13.3 | 62.8** |
| 31 | Leaf folders are serious pests and insecticides must be used when we see them | 17.3 | 41.1 | 74.3** |
| 32 | A few leaves damaged by leaf folders do not cause loss | 42.0 | 46.7 | 22.23** |
| 33 | The pesticides sales agent always provide the best advice | 44.7 | 2.2 | 75.4** |
| 34 | Fruit trees need to be sprayed to have good yield | 30.7 | 14.4 | 20.72** |
| 35 | Vegetable crops must be sprayed with insecticides to have good yield | 42.0 | 17.8 | 41.72** |
| 36 | Without insecticide application, it is impossible to grow vegetables | 37.3 | 34.4 | 12.73* |
| 37 | Pesticide application is the only way to control pests and diseases in vegetables | 37.3 | 14.4 | 32.78** |
| 38 | Pesticides should not be applied just before harvesting vegetables | 38.0 | 54.4 | 32.6** |
| 39 | When temperature is high, pests will increase | 68.0 | 16.7 | 91.52** |
| 40 | When temperature is high, spiders and natural enemies cannot survive | 53.7 | 7.8 | 78.1** |

** Significant difference at p = 0.05; ** Significant difference at p = 0.01. The Chi-square test was used to test the null hypothesis that there was no difference between pre-test and post-test groups using nominal data*

3.5. Perceived changes to local climatic conditions and its effects on crop yield, pests and diseases, and beneficial insects

The changes in the perceived changes to local climatic conditions and its effects on crop yield, pests and diseases, and beneficial insects are detailed in Table 9. The pre-test assessed the observation of climatic changes by farmers from the period of 2013 to 2015, while the post-test measured the observation of the climatic changes in 2016. Most post-test farmers expressed that that local climatic conditions have changed within the time frame of 4 years. The significant climatic changes reported by farmers were:

1. Later onset of rains
2. More frequent and heavy storms; and
3. Faster rising tides.

Although there were non-significant changes in the changes of temperature, majority of farmers believed that higher temperatures would increase the population of insect pests and worsen the diseases on rice, vegetables, and fruit crops.

There was a significant increase in the percentage of farmers who believe that erratic rainfall patterns:

1. adversely affected the yields of all crops—rice, vegetables, and fruits;
2. reduced rice pests and diseases and the populations of natural enemies/beneficial organisms; and
3. increased fruit and vegetable pests and diseases and the populations of natural enemies/beneficial organisms.

In terms of wind strength, some of the farmers reported that winds were now stronger. However, there was also a significant proportion of respondents who felt that the wind strength remained unchanged.

Table 9. Perceived changes to local climatic conditions and its effects on crop yield, pests and diseases, and beneficial insects (% farmers) (from 2013 – 2016)

| No | Statement | Pre-test | Post-test | $X^2$ |
|---|---|---|---|---|
| 1 | Change in onset of rains | | | 10.2** |
| | - earlier start of rains | 35.3 | 21.1 | 4.8* |
| | - later start of rains | 54.0 | 74.4 | 9.1** |
| | - no change | 10.7 | 4.4 | $2.1^{ns}$ |
| 2 | Change in the amount of rain in the previous years | | | 22.6** |
| | - too much rain | 48.0 | 73.3 | 13.8** |
| | - less rain (drought) | 32.0 | 25.6 | $0.8^{ns}$ |
| | - no change | 20.0 | 1.1 | $16.2^{ns}$ |
| 3 | Change in frequency of rains | | | 13.9** |
| | - frequent rains | 43.3 | 67.8 | 12.5** |
| | - less frequent rains | 48.0 | 25.6 | 10.9** |
| | - no change | 8.7 | 6.7 | $0.1^{ns}$ |

*ns = not significant; * Significant difference at p = 0.05; ** Significant difference at p = 0.01. The Chi-square test was used to test the null hypothesis that there was no difference between pre-test and post-test groups using nominal data.*

| No | Statement | Pre-test | Post-test | $X^2$ |
|---|---|---|---|---|
| 4 | Attributes of drought | | | $6.4^{ns}$ |
| | - longer | 47.3 | 52.2 | $0.4^{ns}$ |
| | - more intense | 21.3 | 28.9 | $0.0^{ns}$ |
| | - more frequent | 6.0 | 6.7 | $1.4^{ns}$ |
| | - no change | 25.3 | 12.2 | 5.2* |
| 5 | Attributes of winds | | | 6.4* |
| | - stronger | 84.0 | 71.1 | 4.9* |
| | - weaker | 5.3 | 6.7 | $0.0^{ns}$ |
| | - no change | 10.7 | 22.2 | 5.0* |
| 6 | Sea level rise | | | 105.7** |
| | - rising, higher tides / increasing quickly | 24.7 | 87.8 | 87.2** |
| | - flooding of coastal areas / increasing but near sea only | 19.3 | 8.9 | 3.9* |
| | - storm surges | 0.0 | 3.3 | $2.7^{ns}$ |
| | - no change | 32.0 | 0.0 | 34.0** |
| | - don't know | 18.0 | 0.0 | 16.5** |
| 7 | Recent changes in the temperatures observed | | | $6.0^{ns}$ |
| | - warmer | 88.7 | 91.1 | $0.2^{ns}$ |
| | - cooler | 8.0 | 2.2 | $2.5^{ns}$ |
| | - no change | 2.7 | 6.7 | $1.4^{ns}$ |
| 8 | Effect of high temperature on yields of rice | | | $4.0^{ns}$ |
| | - Decreased yield | 68.7 | 80.0 | $3.1^{ns}$ |
| | - No change | 30.7 | 20.0 | $2.8^{ns}$ |
| 9 | Effect of high temperatures on yields of fruit crop | | | $0.6^{ns}$ |
| | - Decreased yield | 6.7 | 17.8 | $0.6^{ns}$ |
| | - No change | 4.0 | 4.4 | |
| 10 | Effect of high temperatures on yields of vegetables | | | |
| | - Decreased Yield | 8.7 | 17.8 | $0.0^{ns}$ |
| | - No change | 2.7 | 5.6 | |
| 11 | Effect of high temperatures on insect pests and diseases of rice | | | 180.8** |
| | - Increased populations | 4.0 | 87.8 | 169.0** |
| | - No effect | 18.0 | 11.1 | $1.6^{ns}$ |
| | - Reduced populations | 78.0 | 1.1 | 4.8* |
| 12 | Effect of high temperatures on insect pests and diseases of fruit crops | | | 38.9** |
| | - Increased populations | 0.0 | 18.9 | 21.7** |
| | - No effect | 2.0 | 4.4 | $0.0^{ns}$ |
| | - Reduced populations | 9.3 | 0.0 | 24.0** |
| 13 | Effect of high temperatures on insect pests and diseases on vegetables | | | 37.6** |
| | - Increased populations | 0.0 | 20.0 | 22.6** |

*ns = not significant; * Significant difference at p = 0.05; ** Significant difference at p = 0.01. The Chi-square test was used to test the null hypothesis that there was no difference between pre-test and post-test groups using nominal data.*

| No | Statement | Pre-test | Post-test | $X^2$ |
|---|---|---|---|---|
| | - No effect | 2.0 | 3.3 | < 0.01 |
| | - Reduced populations | 9.3 | 1.1 | 21.4** |
| 14 | Effect of high temperatures on natural enemies or beneficial organisms of rice crops | | | $6.5^{ns}$ |
| | - Reduced populations | 42.0 | 48.9 | $0.7^{ns}$ |
| | - No effect | 35.3 | 41.1 | $0.5^{ns}$ |
| | - Increased populations | 21.3 | 10.0 | 4.5* |
| 15 | Effect of high temperatures on natural enemies or beneficial organisms of fruit crops | | | 11.0* |
| | - Reduced populations | 5.3 | 15.6 | $0.1^{ns}$ |
| | - No effect | 4.0 | 8.9 | $< 0.01^{ns}$ |
| | - Increased populations | 2.0 | 3.3 | $0.0^{ns}$ |
| 16 | Effect of high temperatures on natural enemies or beneficial organisms of vegetables | | | 13.0** |
| | - Reduced populations | 3.3 | 14.4 | $1.4^{ns}$ |
| | - No effect | 6.7 | 11.1 | $0.7^{ns}$ |
| | - Increased populations | 2.0 | 3.3 | $0.0^{ns}$ |
| 17 | Effect of erratic rainfall on yields of rice | | | 113.3** |
| | - Increased yield | 17.3 | 5.6 | 6.0* |
| | - Decreased yield | 14.0 | 83.3 | 109.1** |
| | - No change | 68.0 | 11.1 | 71.8** |
| 18 | Effect of erratic rainfall on the yields of fruit crops | | | 25.9** |
| | - Increased yield | 2.0 | 1.1 | $1.0^{ns}$ |
| | - Decreased yield | 2.7 | 23.3 | 11.6** |
| | - No change | 6.7 | 4.4 | 7.0* |
| 19 | Effect of erratic rainfall on the yields of vegetables | | | 31.0** |
| | - Increased yield | 1.3 | 1.1 | $0.2^{ns}$ |
| | - Decreased yield | 2.7 | 25.6 | 15.9** |
| | - No change | 7.3 | 2.2 | 13.3** |
| 20 | Effect of erratic rainfall on insect pests and diseases of rice | | | 137.9** |
| | - Increased populations | 6.0 | 73.3 | 114.2** |
| | - No change | 20.7 | 22.2 | $0.0^{ns}$ |
| | - Reduced populations | 72.0 | 4.4 | 102.8** |
| 21 | Effect of erratic rainfall on insect pests and diseases of fruit crops | | | 47.7** |
| | - Increased populations | 0.0 | 23.3 | 23.7** |
| | - No change | 2.0 | 5.6 | $< 0.01^{ns}$ |
| | - Reduced populations | 9.3 | 0.0 | 28.1** |
| 22 | Effect of erratic rainfall on insect pests and diseases of vegetables | | | 46.9** |
| | - Increased populations | 0.7 | 26.7 | 29.2** |

*ns = not significant; * Significant difference at p = 0.05; ** Significant difference at p = 0.01. The Chi-square test was used to test the null hypothesis that there was no difference between pre-test and post-test groups using nominal data.*

| No | Statement | Pre-test | Post-test | $X^2$ |
|---|---|---|---|---|
| | - No change | 2.0 | 2.2 | $0.2^{ns}$ |
| | - Reduced populations | 9.3 | 0.0 | 26.2** |
| 23 | Effect of erratic rainfall on natural enemies or beneficial organisms of rice | | | 19.7** |
| | - Reduced populations | 34.7 | 53.3 | 6.7* |
| | - No change | 46.0 | 45.6 | $0.0^{ns}$ |
| | - Increased populations | 17.3 | 1.1 | 13.6** |
| 24 | Effect of erratic rainfall on natural enemies or beneficial organisms of fruit crops | | | 24.8** |
| | - Reduced populations | 4.0 | 0.0 | 8.2** |
| | - No change | 4.0 | 8.9 | $< 0.01^{ns}$ |
| | - Increased populations | 2.7 | 18.9 | 5.6* |
| 25 | Effect of erratic rainfall on natural enemies or beneficial organisms of vegetables | | | 24.8** |
| | - Reduced populations | 3.3 | 0.0 | 5.8* |
| | - No change | 6.0 | 8.9 | $1.1^{ns}$ |
| | - Increased populations | 2.0 | 18.9 | 8.4** |

*ns = not significant; * Significant difference at p = 0.05; ** Significant difference at p = 0.01. The Chi-square test was used to test the null hypothesis that there was no difference between pre-test and post-test groups using nominal data.*

# IV. Discussion

The Pest Smart interventions were designed to train farmers on fundamental ecological principles, provide immediate diagnosis of crop problems, and disseminate plant health and crop management advice to farmers using plant advisors and information through community-based plant clinics modeled after CABI's flagship Plantwise program. Environmentally-friendly EE innovations improve smallholder livelihoods and food security, and restore biodiversity functions in agro-ecosystems to build resilience to climate change. The pre-test (or baseline) and post-test survey were conducted 17 months apart (July 2015 and November 2016) while the activities started only on September 2015 (thus, only 15 months of activities).

There was significant evidence of favorable changes in the agricultural practices and beliefs of farmers in Tra Hat over the 15-month period. Over the same duration, the Pest Smart project activities have built linkages between farmers, community leaders, civil society organizations, and local government officials. These also strengthened the capacity and knowledge of the various stakeholders involved in the project. The crop pest and disease management activities mostly focused on rice, as this is the key crop in many farming communities in Vietnam and in countries across Southeast Asia. However, localized efforts to address fruit and vegetable crops pest and disease problems were introduced, as these crops provide supplementary income for farmers.

The post-test farmers reported an increase in dry yield of rice (Table 4), with the reduction of rice seeding rate, application of nitrogenous fertilizer and number of insecticide sprays. The perceptions about pest damage and losses have also reduced significantly from 1452.25 kg/ha to 717.51 kg/ha (reduction of 51% perceived loss of rice yield to pests). In both pre-test and post-test groups, the key rice insect pests reported were brown planthoppers, stem borers and leaf folders. This concurs with Heong et al. (1998), who noted that rice farmers in Asia generally overestimate losses due to highly visible pest damage, such as leaf folders and stem borers.

The number of farmers who sprayed insecticides during the early crop stages had significantly declined. It was a common practice for farmers to spray in the early crop stages to control leaf folders and other defoliators (Heong et al 1998). The pre-test farmers reported spraying as early as 19 days after seeding. After the EE training and campaign for no spraying during the first 40 days, post-test farmers reported that the earliest spray was 33 days after seeding (Table 4). This indicates that the campaign and training has achieved some success in modifying farmers' spray behavior. The change in spray behavior is also reflected in the reduction of the mean number of sprays from 3.4 times per season to 2.7 times per season.

The main type of pesticides used was mainly insecticide (Table 5), for insect pests were the key rice pests reported by farmers (Table 6). Most of the pesticides used were WHO Classes II (moderately hazardous) and III (slightly hazardous). Although one pre-test farmer reported the use of carbofuran, WHO Class Ib (highly hazardous), no evidence of use was found in the post-test. There was a need to ascertain at a later stage if this change was a change in respondent behavior, or if the respondent did not participate in the post-test survey. The top insecticides used by post-test farmers were diazinon (organophosphate), permethrin (pyrethroids), fipronil (pyrazole), buprofezin (thiadiazin), and fluebendiamide (phthalic diamide). Similar to Parveen and Nakagoshi (2001) and Chakraborty and Newton (2011), farmers believe that pesticide is the most effective means of pest control, and they will apply it when there are both perceived and actual threats. In the post-test survey, the percentage of farmers who believed in this assumption was significantly reduced.

The main rice production system in Tra Hat is the flooded paddy system which is either irrigated or rainfed. Owing to this nature of rice production system, there are two-fold effects of fertilizer overuse, particularly nitrogenous fertilizers. The first would be the emission of nitrous oxide from rice fields during the drainage and drying cycles, before permanent flooding (Freney 1997, Dickie et al 2014). The second is the direct contribution to planthopper nutrition by increasing availability of soluble proteins in rice plants, thereby resulting in high population growth rate (Lu and Heong 2009). From the results shown in Table 7, the Pest Smart interventions have significantly reduced the mean number of fertilizer applications at most stages of rice production (i.e. seedling to booting stage), and also the amount of fertilizers (i.e. Total N, P, and K) by 16% to 52%. The mean number of fertilizer application at the flowering and grain ripening stage doubled at the post-test stage. The increased use of fertilizer corroborated with the increase of farmers' belief that "Using more nitrogen application will make rice grow better". Perhaps, the assumption that increased soil nutrition through fertilization would promote better flowering, panicle initiation, and grain yields may be attributed to this response in practice and belief. It should be noted that different rice varieties may have different responses to fertilizer uptake, and high fertilizer rates may cause lodging or plant hopper outbreak.

The post-test farmers have expressed more positive attitude towards EE practices, and less rated that their bunds were too narrow for planting flowers (Table 8). However, other perceived barriers did not gain favorable change such as the difficulty to grow vegetables without pesticide use, and bunds are used for walking, hence, flowers cannot be grown on the bunds (Table 8). The removal of perceived barriers will take more time, and attitudes can be modified if there were more demo plots available and if farmers were given a longer project duration to observe the impacts of EE on P&Ds (more than 2 rice cropping seasons). It has to be noted that at this point that the EE demo plots were only conducted in rice fields; therefore, attitudes towards pesticide use for vegetable crops did not change.

Although there were slight improvements in practices, many farmers still believed in early crop spraying and in the use of pesticides as a means to ensure good yield (Table 8). Therefore, it is crucial to continue the activities over a longer duration and reinforce the values introduced by the activities to ensure that attitudes are changed and sustained.

The research team was not able to calculate belief indices from the post-test survey. Cronbach's alpha was used to assess reliability of the belief statements. The closer the Cronbach's alpha value to 1, the higher the internal consistency (Heong et al. 2014). High internal inconsistencies were found in the responses obtained from farmers, as the Cronbach's alpha value was less than 0.4. The desirable Cronbach's alpha value would be at least 0.7, which was obtainable from the pre-test farmer group. Therefore, in this report, the research team was only able to perform comparison of the belief statements using Chi-square test to derive changes (if any, and if the changes are of significance).

Similar to the analyses performed on the belief scoring, only the comparison of climatic changes perceptions using Chi-square test to evaluate changes across the 17 months duration (from the baseline survey) was performed. Many farmers in Tra Hat have noted that local climatic conditions have changed in recent years, and its effects were later onset of rains, more frequent and heavy storms during rainy season, and the faster rising of tides at the coasts (Table 9). However, the knowledge and perceptions on the effects of climatic changes on crop P&Ds and natural enemies or beneficial insects were limited.

It has to be noted that during data collection from control village of Tram Mot at the pre-test survey stage as a means to account for confounding factors underlying the responses obtained from Tra Hat, there was no funding to conduct the post-test survey at the control village. It should also be noted that the enumerators were plant health training personnel from the Sub-PPD, Bac Lieu Province. At this point, the research team was unable to attribute the changes in practice and attitudes (both favorable and non-favorable) reported solely to Pest Smart interventions. Yet, the findings indicated that the project has managed to effect favorable changes albeit in a short time (15 months).

It is recommended that some of the key interventions (i.e. EE and Plant Clinics) be continued over a longer duration. There is also a need to develop information materials to enhance farmers' knowledge, and provide an avenue for them to make informed decisions about key crop P&Ds; impacts of climate change on agroecosystems and P&Ds; pesticide use; and create ecologically balanced agro-ecosystems.

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