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Final report

project	**Integrated disease management (IDM) for anthracnose, *Phytophthora* blight, and whitefly-transmitted geminivirus in chili pepper in Indonesia**
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Acronyms and Abbreviations

AIAT: Assessment Institute for Agricultural Technology

BPTP: Balai Pengkajian Teknologi Pertanian (same as AIAT)(Assessment Institute for Agricultural Technology; Indonesia)

Dinas Pertanian: Agricultural Extension office

IVegRI: Indonesian Vegetable Research Institute

IPB-Institute Pertanian Bogor; Bogor Agricultural University

AVRDC: AVRDC – The World Vegetable Center

PepYLCV: Pepper Yellow Leaf Curl Virus

TYLCTHV: Tomato Yellow Leaf Curls Thailand Virus

WTG: Whitefly Transmitted Geminivirus

Masl: meters above sea level

DAI: Days after inoculation

TYLCVKaV: Tomato Yellow Leaf Curl Kanchanaburi Virus

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The author wishes to express his gratitude to all members of the project team for their contributions toward the advance of our understanding of the factors influencing diseases challenging chili production in Indonesia, and methods for reducing their impact. All participants assisted in the preparation of this final report.

2 Executive summary

This project's main objective was to evaluate the efficacy of several crop management practices that could potentially limit infection and damage by one or more of the most damaging diseases of chili pepper in Indonesia—anthracnose, Phytophthora blight, and whitefly-transmitted geminivruses (WTG)—and to test integrated disease management packages for their efficacy in reducing losses. In addition to increasing marketable yields, it is hoped that these IDM strategies might reduce the frequency and rate of pesticide application, thereby improving the health prospects of farmers, their families and communities, and ultimately, consumers.

Following socioeconomic appraisals of the status and impacts of disease on the chili farming communities, a baseline study was designed to characterize the chief factors influencing the adoption of interventions. Simultaneously, clarification of the nature of the pathogens was undertaken, using diagnostic assays, including molecular profiling, to characterize the species and/or pathotype encountered. *Phytophthora capsici* shows substantial genetic diversity in Indonesia, harbouring all three levels (pathotypes) of pathogenicity, both mating types, and diversity for resistance to the fungicide metalaxyl. The causal agent of anthracnose was concentrated on two *Colletotrichum* species, *C. capsici and C. acutatum*. Causes of WTG were identified as predominantly Pepper yellow leaf curl Indonesia virus (PepYLCIDV), which is also infective in tomatoes, and also Tomato yellow leaf curl Kanchanburi virus (TYLCKaV), similar to races of the virus found in Thailand.

Agronomic interventions evaluated included raised beds with mulching using either rice straw or grey/black plastic film, foliar and basal applications of biopesticides and compost teas, low-cost drip irrigation systems, and barrier borders surrounding the chili fields, made initially of nylon mesh netting, then later with maize and yard-long beans; borders of *Crotalaria juncea* were a significant success and generated great interest among farmers. In one experiment, the *Crotalaria* barrier delayed viral disease incidence by approximately three weeks, compared with unprotected control plots. Consequent yields were improved by more than 70%. Maize barriers also performed well, though the crop performance was improved by only about 35%. This was consistent and significant across the five localities sampled for the trial. Biofungicides were variable in their effectiveness in reducing fungal disease losses, showing significant benefit in some trials, and no difference from synthetic fungicides in others. A program of alternating natural control sources (*Bacillus subtilis*) with synthetic products proved superior to applications of exclusively synthetic fungicide.

Host plant resistance also addressed as a key strategy to control the diseases. Candidate lines selected at AVRDC for resistance to one or more of the principal diseases were evaluated in Indonesia for their agronomic acceptability as well as tolerance to disease threats, and a few have shown potential, particularly PP05387-7558 (IR/PBC932//2*IR///Susan's Joy).

Several of the trials of candidate interventions were structured to include farmer field days and participatory reviews of the treatments. This allowed the candidate technologies to be exposed to numerous farmers and their communities. In conjunction with the local extension office (Dinas Pertanian), one activity scheduled meetings every few weeks to discuss aspects of farming innovations, and to review the trials in progress. Some treatments were informally adopted by farmers. After seeing barrier trials utilizing netting, fields were observed surrounded by barriers made of used plastic mulch sheeting.

Further refinement of disease resistant varieties is certainly required to provide stable and easily implemented defence against these threats. Continued monitoring of the spread of WTG may clarify questions regarding its origin, and control opportunity through selective weed management strategies or community-based implementation of 'crop-free periods' to interrupt the propagation cycle of the virus.

3 Background

Chili is one of the most important vegetable crops produced in Indonesia, with 1.09 million metric tons of green peppers produced in 2008 on more than 200,000 hectares (FAOSTAT, 2011). Peppers are widely consumed in sambal, fresh seasoning, and as a cooking ingredient. Farmers mainly produce their crop for commercial marketing. However, yields are quite low, averaging 5.38 t/ha, in contrast to more than 25 t/ha yields in Australia (FAOSTAT, 2011). Diseases attacking pepper constitute one of the key challenges to increasing productivity. Pesticides are applied sometimes twice weekly, and as frequently as 40 times over the course of the crop, often without significant benefit. Major diseases include Phytophthora blight, anthracnose, and whitefly-transmitted geminivirus (WTG). Phytophthora is favoured by wet conditions, particularly standing water around the roots; anthracnose is also supported by warm, rainy conditions. In contrast, WTG is favoured by mild dry weather that allows the whitefly vector to multiply and circulate within and between fields. Development of satisfactory control measures is a high priority for AVRDC – The World Vegetable Center (AVRDC) and Indonesian R&D collaboration.

Commercial cultivars carrying resistance to the diseases have not yet been released. Some cultural practices lead to disease development. Recommended fungicides for anthracnose and Phytophthora control are often ineffective, with excessive pesticide sprays (up to 100, averaging 40) applied to the crop. Yield losses of 50% in local and open pollinated varieties have been reported. Furthermore, whitefly-transmitted virus losses are compounded by inadequate control of vector and alternate hosts.

The project capitalizes on and complements progress made under previous AVRDC collaboration on chili disease management in Indonesia (funded by GTZ). Likelihood of success was enhanced through due attention to the socioeconomic context impacting technology/variety development and adoption in farmer-cantered approaches, as well as through the use of advanced approaches to pathogen characterization and efficient screening methodologies.

Some farmer practices—furrow irrigation, lack of crop rotation or mulching, and inadequate weed control—contribute to increased disease incidence and severity. Recent AVRDC collaboration in Indonesia has identified alternative, non-chemical approaches that reduce risks and losses (e.g. drip irrigation systems reduce Phytophthora losses compared with furrow irrigation). Sources of genetic resistance to Indonesian strains of anthracnose already have been identified by the AVRDC-GTZ chili project and have been incorporated into locally preferred varieties (PLVs). Sources of resistance to Phytophthora blight also have been identified and have been evaluated against Indonesian pathotypes of Phytophthora. Some chili varieties from India with resistance to WTG have been reported, but confirmation of resistance and assessment of their utility for Indonesia are needed, as well as screening of additional germplasm.

Collaborating partners with AVRDC included the Indonesian Vegetable Research Institute (IVegRI), and the Assessment Institute for Agricultural Technology (AIAT; equivalent to the Indonesian acronym 'BPTP' (Balai Pengkajian Teknologi Pertanian)), Central Java, which have staff specializing in vegetable diseases and experience in farmer participatory research. Bogor Agricultural University (IPB) has been a leader in studying geminiviruses of pepper and other vegetable crops as they occur in Indonesia, especially in Java. The New South Wales Department of Primary Industry (NSW-DPI), and (initially) the Commonwealth Scientific and Industrial Research Organization (CSIRO) have ongoing active research on integrated disease management, and whitefly diagnostics and control, respectively.

Chili Production in Australia

Chili is a minor vegetable crop in Australia and there are no reliable production statistics available. Australian chili production was estimated at about 1,000 t fresh weight nearly two decades ago (Miles, 1994). Chilies are commonly grouped with their close botanical relatives, capsicums, paprika or peppers in Australian economic and technical literature. They are grown commercially in all mainland Australian states.

Australian chili production occurs mostly in frost-free, tropical and subtropical areas (Hibberd, 2010). Queensland is the main producer of fresh market chilies in Australia, supplying domestic markets in all other states. In 2005, Queensland produced around 42,156 t of capsicums, chilies and peppers worth about AUD$69.5M. This is about 89% of the Australian production and 87% of its value, and was grown on 1,973 hectares (ABS, 2008; Anon, 2010). The major proportion of this data refers to capsicum production. In other states, fresh chilies are produced on a smaller scale in market gardens in peri-urban areas of Sydney (NSW), Geelong (Victoria), Perth (Western Australia), and Virginia (South Australia). Very little of the Australian chili crop is processed and the various dried and powdered products are imported. A decade ago it was estimated that the value of imported chili spice products was AUD$30M (Klieber, 2000).

The majority (80%) of Australia's capsicum and chili crops are grown outdoors, with greenhouse operations making up the remaining 20%. Both field and greenhouse production utilize trickle irrigation and polythene mulch. Despite increased capital costs for greenhouse production, yields are higher because crops can be harvested for much longer (up to 6 months) and plant yields are higher. Crop damage and losses from environmental factors such as rain and frost are also reduced.

Diseases of Chilies in Australia

Anthracnose is a common disease in Australia on a wide range of crop species, particularly tropical and temperate fruit (Persley et al., 2010). *Colletotrichum acutatum and C. gloeosporioides* previously been recorded on *Capsicum* species although they are insignificant on chilies except where wet weather occurs during ripening. Extended drought conditions persisting during the survey period probably explains why this disease was not recorded.

The cause of Phytophthora blight of chilies*, P. capsici,* is uncommon in Australia; it has been recorded only twice, and never from *Capsicum* species. Carter (1986) recorded it on eggplant from Carnarvon in Western Australia, while Weinert et al. (1999) reported two isolates from Queensland, on custard apple (*Annona squamosa*) and the ornamental vine, *Mandevilla* sp. The Western Australian record may be suspect as it was based only upon morphological taxonomy and no voucher specimens or cultures were lodged in a herbarium. In contrast, the Queensland records are more definitive, being confirmed by DNA sequence analyses of the ITS region of the rDNA gene and restriction enzyme digest profile comparisons with reference isolates. This pathogen was not recorded in chili crop surveys. Given the apparent limited distribution of this pathogen and lack of further host records, it poses a significant biosecurity threat to chilies and other susceptible crops, including tomatoes and cucurbits.

Tomato yellow leaf curl virus has only recently been recorded in Australia (van Brunschot et al., 2010). It was first observed causing chlorosis, leaf curling and stunting symptoms on tomatoes in southeast Queensland in 2006 and has more recently been found on tomatoes in northern NSW (D. Persley, DEEDI Queensland, pers. comm.). To date, there have been no records on commercial chili crops, although *Capsicum* (*C. annuum* cv. Yolo) was symptomlessly infected in a virus transmission study (van Brunschot et al., 2010). The efficient vector, silverleaf whitefly *(Bemisia tabaci* Biotype B) was introduced into Australia in the early 1990s and has since spread across most mainland states (Gunning et al., 1995; De Barro & Hart, 2000). Therefore TYLCV poses a significant biosecurity risk to chili and other susceptible crops across Australia.

Crop surveys revealed that Tomato spotted wilt virus (TSWV) and Potato virus Y were the major pathogens affecting chilies in NSW. TSWV and Capsicum chlorosis virus also were potentially significant pathogens of capsicums and chilies in Queensland. Bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*) was detected, but was not significant as extended drought conditions persisted during the survey period and this disease is more prevalent in warm and wet conditions. Powdery mildew was common on older plants but did not appear to cause significant crop losses during surveys. Minor diseases were recorded, including: Rhizoctonia root rot; a *Pythium* and *Fusarium* root rot complex; and root knot nematodes (*Meloidogyne* spp.).

Conclusions & Recommendations

Each of the diseases studied in this project have significant potential implications for the Australian chili spice industry. As noted above, each of the causal pathogens has been recorded in Australia, albeit only recently in the case of Tomato yellow curl virus. The geographically limited reports of *Phytophthora capsici* suggests that there is potential for this pathogen to spread into chili production. Anthracnose is likely to be problematic if the processing chili industry expands as this disease develops through the ripening and postharvest periods.

4 Objectives

The overall aim is to improve farmers' incomes by enhancing the stability of production and reducing losses in chilies due to selected fungal and viral diseases, with particular focus on Phytophthora blight, anthracnose, and whitefly-transmitted geminiviruses. This will be accomplished through the cooperative identification, dissemination, and adoption of 'best bet' integrated disease management practices, including cultural practice, and genetic components. These goals will be addressed through the following contributing objectives:

•To assess and address the socioeconomic and horticultural practices affecting adoption of disease control options in Central Java.

•To characterize biological factors affecting disease incidence and severity of anthracnose, Phytophthora blight, and whitefly-transmitted viruses (WTG) on chili.

•To assess integrated crop management strategies for sustainable control of anthracnose, Phytophthora blight and whitefly-transmitted viruses.

•To continue development of locally acceptable varieties carrying effective resistance to anthracnose and Phytophthora blight, and search for lines resistant to WTG.

While on-station research by AVRDC assessed the utility of several cultural practices, a major emphasis was collaborative trials and demonstrations with cooperating farmers in up to three chili producing regions. On-farm evaluation of candidate disease management practices facilitates farmer-participatory evaluation, adaptation, familiarization, and training to foster uptake and dissemination. Adaption and positive impact of control options in a few farms will hopefully motivate neighbouring farmers to adopt the innovations as well. The involvement and cooperation of IVegRI, AIAT/BPTP and local Agricultural Extension Services identified opportunities for further promotion of innovations through farmer field schools, advertised demonstration plantings, and informative literature.

5 Methodology

5.1 To assess and address the socioeconomic and horticultural practices affecting adoption of disease control options in Central Java

5.1.1 Preliminary project development trips by 2-3 people from AVRDC, IVegRI, and an Australian partner to target locales in Java in June and October, 2005 identified potential survey sites in Western/Central Java (production regions in Brebes district), South/Central Java (Magelang District), and in Central/Eastern Java (Rembang district). Building on socioeconomic ex-ante survey findings from the GTZ chili project (Mustafa and Kuswanti, 2005) conducted in selected sites in Western, Central, and Eastern Java, Rapid Rural Appraisal was carried out in three districts of Central Java in early 2007. This was done to estimate disease severity, economic losses, and farmers' current disease management strategies. It was carried out by site visits by a group of scientists to six chili production communities from three districts of Central Java, and in each community surveyed. With the help of semi-structured questionnaires and a checklist, an in-depth interview was carried out with a group of farmers, local agriculture experts, and researchers, with particular emphasis on Phytophthora and WTG. Findings of the survey were useful for selection of treatment options and project interventions in each of the project communities. Research sites were chosen on the basis of importance of the target diseases, maximum potential direct impact on local producers, and similarities to other important production regions.

5.1.2 Likewise, in 2008, a farmer household survey was carried out at three project targeted districts (Kamukten and Klampok villages in Brebes district (Kersana and Bulakamba subdistricts), Amartawang village in Magelang district (Mungkid subdistrict), and Meteseh village in Rembang district (Kaliori subdistrict) in Central Java to establish a baseline of current production practices of chili. Under the supervision of AVRDC's agricultural economist, the baseline study was carried out jointly by the AVRDC project team in Indonesia and a survey team from BPTP/Ungaran (socioeconomist and five survey enumerators), and also with active involvement of a socioeconomic from IVegRI.

5.1.3 Field surveys were conducted in the same districts where on-farm and farmers' participatory trials were carried out. This was done to identify constraints in crop adoption (varieties) and modern technologies so that these technologies can be adapted to meet the farmers' needs and suggestions.

5.1.4 Follow-up impact assessments of selected technology packages that were adapted and disseminated by the project team in the project targeted communities, and through on-farm trials, were carried out to evaluate the economic viability and social acceptability of the newly introduced disease management technologies. The field survey at each of the three communities was jointly carried out by a team of researchers including a research associate/socioeconomic based in the AVRDC project office in Indonesia and a socioeconomic of IVegRI and collaborators from local government agencies (BPTP and DINAS Pertanian), in coordination with the agricultural economist in AVRDC HQ. The farmer cooperators and their neighbouring farmers were asked for their feedback and comments on the technologies introduced. Impact of the three different sets of technology packages as perceived by the technology users (farmers) was assessed and documented.

5.2 To characterize biological factors affecting disease incidence and severity of anthracnose, Phytophthora blight, and whitefly-transmitted viruses (WTG) on chili

5.2.1 Pathogen isolates were collected and characterized using methods developed at AVRDC (*Phytophthora* and *Colletotrichum*) and/or at IPB (whitefly and begomovirus). Tours of fields by IVegRI and IPB staff, often accompanied by AVRDC personnel, were conducted annually to monitor spread and characteristics of the target diseases.

5.2.1.1 Survey of incidence of whitefly vector and correlation with geminivirus infestation (by IPB) was conducted in tandem with Activity 1 (Survey of genetic diversity of WTG in Java and outlying production locations). Whiteflies collected from the field were brought to the lab to study their genetic diversity and transmission ability. Using specific primers, amplification of mtCOI gene from individual whitefly was done for each of the field samples. The PCR product was further analysed through DNA sequences. During the survey important weed species also were identified for their role as possible host of whitefly.

5.2.1.2 Survey of weeds as alternative hosts of WTGs and whiteflies (by IPB) evaluated the role of weeds, especially those growing near chili pepper, as alternative hosts for both geminivirus and its insect vector, whitefly *B. tabaci*. Some of these weeds show characteristic symptoms of geminivirus infection and whitefly populations were occasionally encountered in these weeds. Therefore, weed samples were collected during the survey. Direct observation of whitefly populations was done to determine major weed species preferred by the whitefly. Identification of the species was done using specific book references for weed identification and confirmation with a weed specialist from Bogor Agricultural University. Detection of geminivirus infection from weed samples was done using standard polymerase chain reaction (PCR) protocol followed by nucleic acid sequence determination. Host range study was conducted in the screenhouse through transmission using whitefly.

5.2.1.3 Characterization of whitefly species and/or biotypes on crop and weed plants in chili pepper production systems in Central Java (by AVRDC) was undertaken to identify the whitefly species and/or their biotypes transmitting begomoviruses on peppers in Java, Indonesia. Extensive sampling totalling 44 samples from various cultivated and weed plants in pepper production systems was made in Bogor, Brebes, Cianjur, Yogyakarta, Kediri, Magelang, Pati, Rembang and Semarang areas. The samples were preserved in 95% ethanol immediately after the collection, shipped to the Entomology Laboratory at AVRDC - The World Vegetable Center, Taiwan and kept at -20˚C until further use.

5.2.2 Pathogens were characterized for species identification and genetic variation with regard to aggressiveness, pathotypes, mating types, sensitivity to metalaxyl (*Phytophthora*), as well as rDNA molecular profiles. AVRDC pathologists travelled to Indonesia and Indonesian scientists to AVRDC and Australia for training in effective disease diagnosis. Reliable screening facilities were established and methodologies refined to allow characterization of collected pathogen isolates, selection of aggressive isolates for further research, and for screening of breeding populations.

5.2.3 WTG incidence was assessed, and predominant virus species is maintained at IVegRI and IPB for characterization for host plant resistance studies.

5.2.4 Whitefly vector was collected and characterized using molecular tools. Total DNA was extracted from a single whitefly using Easy DNA High-Speed Extraction kit (Saturn Biotech Limited, Australia) as per the manufacturer's instructions. In brief, the insect was first rinsed with distilled water and placed on the filter paper for drying. The whole whitefly body was ground in 40 µl of the first solution, then incubated at 95˚C for 20 minutes. Finally, 10 µl of the second solution was added. The DNA samples were kept under -20˚C until used for PCR analysis. The mitochondrial cytochrome oxidase I (mtCOI) gene was amplified using the primer pairs C1-J-2195 (5'-TTGATTTTTTG GTCATCCAGAAGT-3') and L2-N-3014 (5'-TCCAATGCACTAATCTGCCATATT A-3") (Frohlich et al., 1999). The PCR amplifications were performed in 25 µl reaction volumes containing 2.5mM dNTPs, 25mM MgCl2, 0.5 units of Taq DNA polymerase, 5 µl of each primer and 2 µl of template DNA with the PCR program: 94˚C for 10 min followed by 35 cycles of 1 min at 94˚C denaturation, 1 min at 53˚C annealing, 1 min at 72˚C extension and final extension of 72˚C for 10 min in a MJ Research PTC-200 Peltier thermal cycler. About 5 µl of PCR products were separated on 1.5% agarose gels, stained in ethidium bromide solution, and the visualized with a UV light. About 20 µl PCR productions were submitted to Genomics BioSci and Tech Company (Taipei, Taiwan) for sequencing, and forward and reverse sequences were obtained.

The COI sequences were aligned and edited using BioEdit version 7.0 (Hall, 1999). The aligned sequences were then used for phylogenetic analysis using MEGA version 4.1 (Tamura et al., 2007). A neighbor-joining (NJ) tree (Saitou and Nei, 1987) of whitefly COI variants was constructed using Kimura's 2 parameter model (Kimura, 1980) with bootstrapping of 1000 times as implemented in MEGA version 4.1. The published COI sequences of *Bemisia tabaci* biotypes B, Q, New World, Asia-I and Asia-II were used as reference sequences in the phylogenetic analysis.

5.3 To assess integrated crop management strategies for sustainable control of anthracnose, Phytophthora blight and whitefly-transmitted viruses

In each of the three production areas, cooperating farmers were chosen to implement comparative evaluations of 'best bet' agronomic interventions to validate their utility before wider testing and promotion among Indonesian farmers. Demonstrations and trials of several practices in combination conducted at farmers' sites can identify those approaches that are likely to be the most useful. Complementary and backup research on improved crop management for disease control was conducted in experimental fields of AVRDC and IVegRI. Modified crop practices included raised beds, mulching (with plastic or rice straw), protected seedling production, starter solutions or fertilizers, biopesticides, drip irrigation, and protective barriers.

5.3.1.1 ICM activities in Brebes, Central Java

Role of Biofungicide and Mulch in Integrated Crop Management (ICM) of Chilli Pepper to Control Some Major Diseases in Brebes District, Central Java

The first trial was conducted at the IVegRI base area, Kersana, Brebes, in Central Java. The four treatments tested were: biofungicide (*Bacillus subtilis)* + silvery plastic mulch (B), Biofungicide + no mulch (C) and Fungicide + no mulch (D). Unpaired comparison methods were used to test the effect of the treatments. Two fungicides, Score (diphenolconzol) 250 EC and Bion (asinbenzolar s methyl + mancozeb) M 1/48 WP were applied.

The second trial was carried out at Klampok, one of the major chili production areas in the Brebes district. A split plot design was used with the following treatments: Main Plot was straw mulch on the chili bed consisting of 2 levels: (a) No Straw Mulch and (b) Straw Mulch; Sub Plot was biofungicide and synthetic fungicide application to control anthracnose diseases on chili that consisted of 4 patterns of biofungicide and synthetic fungicide application (A) *: B. subtilis* + *B. subtilis* + *B. subtilis* + *B. subtilis*); (B) Bion M 1/48 WP (synthetic fungicide) + *B. subtilis* + *B. subtilis* + Daconil 75 WP (synthetic fungicide) + *B. subtilis* + *B. subtilis* + Bion M 1/48 WP + *B. subtilis* + *B. subtilis* + Daconil 75 WP; (C) The same pattern as B treatment with three additional applications by three times of microorganic nutrient and (D) farmers' cultural practice with only periodic synthetic fungicide application.

The third trial (Farmer Participatory Plots) was executed in four locations. The trial treatments were "Introduced Technology" (IT) or IVegRI Plots, consisting of Straw Mulch + Compost + Compost tea + biofungicide (*Trichoderma* sp.) compared to "Farmers Plot" (FP) with traditional production practices using mineral fertilizer and synthetic pesticide. Plot size of each location was about ± 900 m2. Crop pattern was relay planting with shallot.

5.3.1.2 ICM activities in Magelang, Central Java

Improved Technology for Whitefly-transmitted Geminivirus Elimination by Using *Crotalaria* as Chili Barrier in Magelang

Preliminary trials evaluated borders for control of disease by using nylon mesh, either 1 m or 1.5 m in height, compared with unprotected checks.

The farmer participatory trial executed in Magelang aimed to reduce whitefly-transmitted geminivirus) on chili. Although this is a participatory trial, the plot set-up was designed to be used as a split plot design involving three main treatments: 1 m mesh barrier, 1.5 mesh barrier, and no barrier. Split treatments were synthetic insecticide vs. no insecticide.

Improved participatory technology was evaluated in Magelang from September 2009 to February 2010, in a factorial design experiment: First factor of this trial was three barrier plant types (1) *Crotalaria juncea* (sunn hemp) barrier, (2) maize barrier, and (3) control (without barrier). Second factor of the trial was pesticide application that consisted of two types (1) synthetic chemical pesticide (Daconil and Curacron), and (2) biopesticides (biofungicide active ingredient *Trichoderma;* bioinsecticide, *Dioscorea)*. Combination of these treatments was replicated in five locations: Gondowangi, Muntilan, Salam, Sawangan and Secang.

5.3.1.3 ICM activities in Rembang, Central Java

ICM work in Rembang conducted by Sutoyo (BPTP, Central Java)

Trial 1: Use of drip irrigation and nylon netting for integrated disease management of chili pepper. This trial was conducted from August to December 2008 (dry season) in Meteseh, Kaliori Sub-district, Rembang District. The experimental design used a randomized complete block design (RCBD) with the following treatments:

1. Drip irrigation + nylon netting
2. Drip irrigation + No nylon netting
3. No Drip irrigation + No nylon netting

Nylon netting: ± 50 x 50 mesh, 1.5 m in height. Drip kit was a low-cost kit (MTD-500) imported from India, with water storage tank elevated ± 2 m above ground). Chili variety: Express-99.

Trial 2: Use of drip irrigation for integrated disease management of chili pepper. This trial was conducted from July to December 2009 (dry season) in Meteseh, Kaliori Sub-District, Rembang District. The experimental design used an RCBD factorial with the treatments:

1. With drip irrigation
2. Without drip irrigation (existing farmer irrigation technique)

Drip type: 2 units of MTD-500, using a water tower and storage tank ± 8 m above ground.

Chili variety: TM-88

5.3.1.4 ICM activities at AVRDC, Taiwan

Integrated Disease Management of Chili Peppers with Emphasis on Improved Crop Management Strategies

Experiment 1. Varietal evaluation for yield and disease resistance of chili pepper grown under furrow and drip irrigation systems

Methods are available on request (Salas, 2008). In brief, a split plot trial with four replications was established. Main plots were irrigation systems (furrow vs. drip irrigation). Subplots consisted of five Indonesian varieties (Laris F1, Tanjung II, Jatilaba, Tit Super, and KR-Bogor) as well as a line developed at AVRDC. Soil moisture under drip irrigation was maintained at -20 kPa. Furrow irrigation was applied as needed to raise soil moisture to field capacity. Crop growth and maturity, disease incidence, and multiple harvests were evaluated for yield and fruit parameters. Yields and water use efficiency were calculated.

Experiment 2. Effects of a physical barrier and an insect growth regulator (IGR) on yield and whitefly numbers on chili pepper (Salas, 2008)

A factorial experiment was established as a RCBD with 4 replications. Experimental plots were covered with tunnels 1.4 m high and 3.15 m wide made of 32 mesh nylon netting, or 50 mesh netting, or no net covering. Some plots were sprayed alternately with the insect growth regulator pyriproxyfen at the recommended rate of 1000 ml/ha, while others were left unsprayed. Two weeks prior to transplanting chili seedlings (variety PP9955-15), three-week old cabbage seedlings were transplanted around all plots to attract and host whiteflies. Other insects were controlled by periodic application of the insecticides Decis, Anvil, and Abamectin at recommended rates. Whitefly populations were supplemented twice, beginning one week after transplanting, by releasing 300 adult whiteflies per plot onto adjacent cabbage plants. The insect growth regulator was applied 45 days after transplanting. Twice prior to IGR application and every two weeks thereafter, whitefly incidence on the pepper plants themselves was counted on individual leaves taken from top, middle, and lower canopy from 5 randomly selected plants per plot.

Experiment 3: Evaluation of Deficit Irrigation, Water Use Efficiency, Host Plant Resistance and Grafting to Minimize Disease Infestations and Sustain Optimal Chilli Pepper Yields

The goal of this activity was to evaluate irrigation management treatments, rootstock grafting, and variety on yield and disease incidence in peppers. Two field trials were conducted, one based on a -30 kPa soil moisture regime and the other on a -60 kPa regime. A split block design was used in each trial. Treatments entailed altering moisture levels during different developmental periods: 1-30, 31-60, 61-90, and 91-120 days after transplanting.

The three chili pepper varieties tested in these trials were:

V1: PP0438-8543 IR*3/PBC932//Susan's Joy (supposedly PC3 susceptible, anthracnose resistant)
V2: PP0537-7531 Jin'sJoy//Arunalu/IR (supposedly PC3 resistant, anthracnose susceptible)
V3: PP0337-7069 ShiangYenNo3/HiHot3 (supposedly PC3 susceptible, anthracnose susceptible)

All varieties were evaluated either on their own rootstocks (non-grafted), or grafted onto PI201232 (demonstrated resistant to *Phytophthora capsici,* pathotype 3).

More detailed descriptions of the methods can be found in a draft of the planned journal article in Appendix 8.

5.3.2 Recommended management practices demonstrated to farmers.

Farmers were involved in project activities by structuring trials as farmer participatory investigations, and by organizing recurring Farmers Field Meetings (FFM) to review the progress of field trials, and to share suggestions and commentary from project personnel, local extension officers, as well as among the farmers themselves. Large trials, such as factorial evaluations of barrier and pesticide treatments, served as the featured attraction for Farmer Field Days (FFD), in which large numbers of farmers and other members of the farming community were invited to attend for a day of presentations, hands-on demonstrations (e.g. of compost tea preparation), and tours of the trial fields. Variety evaluations were conducted in farmers' fields in the heart of chili production localities in both Magelang and Rembang districts, and these attracted numerous visits by interested passersby.

5.3.3 Ex-ante economic evaluations and ex-post impact evaluations were conducted through farmers' perception surveys to identify potential barriers to adoption of candidate practices (see Methods: Objective 1).

5.4 To continue development of locally acceptable varieties carrying effective resistance to anthracnose and Phytophthora blight, and search for lines resistant to WTG

Using screening methods developed at AVRDC, and in prior projects in Indonesia, more than 100 pepper lines were evaluated for resistance to WTG under protected conditions. Lines tested include popular Indonesian cultivars, commercial hybrids, improved open pollinated lines from IVegRI, and numerous intermediate and advanced generation selections from the AVRDC breeding program (generally rooted in Indonesian varietal backgrounds). Similar arrays of accessions were screened for resistance to anthracnose or Phytophthora.

5.4.1.1 Screening germplasm and breeding lines for anthracnose resistance was conducted in Subang, West Java, elevation 100 m above sea level, from January to May, 2008. A randomized complete block design with 3 replications was used, and an experiment unit consisted of 10 plants per plot. Forty-three genotypes developed by AVRDC, IVegRI, private sector companies, and farmers' local varieties were planted at a spacing of 80 cm x 50 cm. Manure (20 t/ha) and NPK fertilizer (1500 kg/ha) were applied 4 times. Pesticides were used adequately to maintain the plants, but no fungicides were applied after flowering. Data collected were: (1) Lesion Diameter (mm): laboratory inoculation by *Colletotrichum capsici, C. gloeosporioides,* and *C. acutatum* 6 days after inoculation (dai). (2) Horticulture traits: Plant vigour scored by 1=very poor, 3= poor, 5=good, 7=very good at 7 weeks after planting; Plant height (cm); Plant habit scored by 3=prostate, 5=intermediate/compact, 7=erect; Flowering date (days after planting/dap) (3) Yield and yield components: Yield/plot (g); Fruit weight (g); Fruit length (cm); Fruit width (cm); Fruit pedicel length (cm); Fruit wall thickness (mm); Number of locules.

A further experiment was conducted in Lembang, West Java at an elevation of 1250 m above sea level, evaluating 24 lines, planted in the open field at a spacing of 50 cm x 50 cm. Each entry was planted in plots measuring 1.5 m x 1 m with 6 plants/plot. Management practices were similar to the trial in Subang. The observed variables included: (1) The number of fruits per plant, (2) The weight of fruit per plant, and (3) Lesion Diameter (mm): laboratory inoculation by *Colletotrichum capsici and C. acutatum* at 6 days after inoculation (dai).

5.4.1.2 Screening germplasm and breeding lines for WTG resistance

In each commercial field observed, four random sub plots consisting of 100 plants each were chosen and plants showing geminivirus symptoms, other diseases and common pests in each sub plot were counted. Calculation of virus and wilt incidence was estimated as the sum of infected plants divided by number of total plants per sub plot multiplied by 100%. Percentage of disease incidence at the observation site is the average from four sub plots. The formula (Hiddema, 1972) used is shown below:

$$I = \frac{\sum (ai\ /\ ni\ ) \times 100\ \%}{4}$$

Where : I = Intensity of disease, a = number of infected plants,
n = number of observed plants
i = 1, 2, 3, and 4 (four sub plot observation site)

Lines were characterized on the basis of disease intensity:

Immune	= No symptoms at all, all plants look healthy (0%)
Resistant	= Disease intensity between 0.1 – 10.0 %
Moderately resistant	= Disease intensity between 10.1 – 20.0 %
Moderately susceptible	= Disease intensity between 20.1 – 30.0 %
Susceptible	= Disease intensity between 30.1 – 50.0 %

Highly susceptible = Disease intensity more than 50.0 %

Diseased samples (a branch and leaves) that showed clear symptoms of viral infection were collected for further investigation in Lembang. Occasionally, samples of infected live plants (stem, small branch, eaves and root) were taken for collection of geminiviruses in Lembang. Samples of WTG were collected from fields that showed high (greater than 50% plants displaying virus symptoms) infection of WTG. Seedlings of pepper planted in big test tubes (3-5 seedlings each) were prepared for whitefly sampling. Whiteflies were collected using an aspirator and directly placed into test tubes. Background information was gathered from farmers in the area, cooperating participants, and accompanying agriculture service officials.

Further evaluations of breeding materials for resistance to WTG were conducted in 2008-9 at the IVegRI station in Lembang. Material used was 92 pepper lines from AVRDC plus 8 local varieties, adapted to Indonesia's environmental conditions and market preferences (Table 1). Planting medium was a sterilized mixture of fermented cow dung + soil (1:1). About 30-50 seeds (depending on availability) of each entry were sown in plastic trays (40 x 60 x 20 cm) filled with sterilized soil. After the germinated seedlings had 2-3 true leaves, they were inoculated with WTG using whitefly vector. Insect vector was collected from diseased plants showing yellow symptoms. Insects that stayed on the leaf were sucked by aspirator until the number reached about 50 flies. These insects were transferred onto a tray, and then covered with a muslin cloth for 2-3 days to prevent escape. Every morning and afternoon the cover cloth was shaken by hand to move the insects to other plants and help spread the virus within the tray. On the third day the cloth was removed and seedlings were sprayed with insecticide. Inoculated plants were maintained and observed for symptoms. Intensity of symptom expression was scored on a scale of 0 (healthy-no symptoms) to 5 (severe symptoms). Appearance of symptoms of virus infection were noted until 42 days after inoculation. Resistance level was estimated as a combination of incidence (percent of plants showing symptoms), and severity (average subjective score), using the estimates of disease intensity as noted above.

Individual healthy looking plants from "immune" and "resistant" categories were planted in micro-plots in the field (5-6 plants each line), and covered with muslin fabric (or flowers wrapped with oiled paper to ensure self-pollination). Any plant subsequently showing WTG infection was rogued. Selfed seed was harvested after fruit ripening.

Variable data collected was: germination of seed, incubation time of each line, incidence and intensity of symptoms, agronomical characters, and the number (grams) of harvested seed.

5.4.1.3 Screening for Phytophthora resistance

Candidate multi-resistant lines introduced to farmers for evaluation

Eleven candidate multi-resistant lines introduced to farmers were planted on September 17, 2010 in Brebes, Centre Java. A randomized complete block design with 3 replications was used, and an experiment unit consisted of 30 plants per plot. Trial entries were 11 candidate multi-resistant lines and 4 local varieties as control.

5.4.2 Mapping populations were created at AVRDC using 5-6 candidate parents and the predominant local variety type 'Keriting' for future inheritance studies. The arrays of populations included the resistant and susceptible parents, the F_1 hybrid, F_2 segregating population and backcrosses of each parent to the F_1. These arrays will be screened for WTG resistance in carefully controlled screenhouse or cage conditions in which host plants infected with the virus and effective populations of the whitefly vector are present. Resistance in each of the candidate parents has not yet been assured as to specificity and uniformity, so additional validation of the screening procedure will be needed before undertaking this important task.

5.4.3 and 5.4.6 Promising entries were selfed, and progenies subjected to further cycles of reselection; Cross local varieties with disease resistance sources, make early generation selection.

Seed production of 14 local variety and 11 lines from AVRDC was conducted at IVegRI research station in Lembang, elevation 1250 masl (meters above sea level). from January – July 2007, and again in October 2009 with 95 breeding lines from AVRDC. The materials were sown in plastic containers and germinated in a newly renovated, insect-proof screenhouse. At the 4th leaf stage of growth, the seedlings were transplanted into 30 cm polybags on heat-sterilized soil, five polybags per line, and maintained with appropriate fertilizer, pesticide application, and irrigation. Individual flower buds were wrapped in small paper bags prior to opening to ensure self-pollination.

Seed production and characterization activities were conducted at the screenhouse located in the IVegRI research field from July to December 2009. The seed of 24 lines in which resistance to WTG, PB, and anthracnose were identified were sown on a germination bench in Petri dishes. After two weeks seedlings were transferred into cell plugs, and two weeks later, they were transferred to the screen house. Planting in the screen house used mulch with spacing of 50 cm x 50 cm. Each entry was planted in plots measuring 1.5 m x 1 m with 6 plants/plot. Manure (20 t/ha) and NPK fertilizer (1500 kg/ha) were applied four times.

Most recently, beginning in October 2010, a 3 x 3 diallel crossing block was established to generate new combinations for selection for improved resistance to Phytophthora blight. Sources of PB resistance (0836-6729-1, 0707-7540 B, 0737-7651-B) have been crossed with local Indonesian varieties (Tanjung-1, Tanjung-2, and Lembang-1) in a screen house at IVegRI. Hybrid seeds will be harvested when mature.

At AVRDC, intercrosses among resistant advanced lines were conducted annually during the fall-winter season in a dedicated greenhouse crossing block. Seed was germinated in cell trays with a peat/soil mix, and then transferred to large pots, generally 3-6 plants per entry. Emasculation and pollination were conducted as flowers matured, according to a cross-combination matrix table. At least two pollinations of each programmed cross were made to assure completion of all crosses.

5.4.4 and 5.4.6 Intermediate and advanced generation selections were evaluated under farmer-participatory conditions, for disease resistance, performance, and suitability (Indonesia).

Demonstration plantings of selected candidate lines were established in the Magelang and Rembang districts. Variety demonstration and evaluation trials were generally established as randomized complete block trials with two to three replications. Management practices to control disease and pests were not applied, in order to illustrate the innate potential of the lines.

6 Achievements against activities and outputs/milestones

Objective 1: To assess and address the socioeconomic and horticultural practices affecting adoption of disease control options in Central Java

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Rapid Rural Appraisal	•Agreement on best target location(s) x disease •Data on constraints to adoption of new technologies •Report on extent and impact of IDM practices introduced	Appraisal conducted March, 2007; Report submitted June, 2007	Results utilized in formulating household survey questionnaire for a detailed baseline survey. To some extent, determination of technologies that were adapted and introduced to farmers in the subsequent days were based on the issues jointly discussed and finalized with many local stakeholders during the survey, including the consultation done with local communities.
1.2	Profiling socioeconomic context of diseases in chili production, listing of currently employed disease/pest control strategies	Characterization of the chili growing farmers with regard to appropriate technological introduction	July, 2009	The baseline survey was done in 2008, and the final report published in 2009, with the details on socioeconomic context of insect pest and diseases on chili. The report was shared with all of the key partners in Indonesia and also with several other stakeholders in other countries in the Asia-Pacific region and other vegetable sector stakeholders globally. Information on survey of chili market was also shared in a seminar at AVRDC. All of these socioeconomic survey activities relate to assessment on constraints to chili production and adoption of technology in Indonesia.
1.3	Activity 1-3: Disease profile and farmers practice surveys through farmer perceptions of current/introduced control strategies	•Profile disease prevalence X eco-region X management practice •Data on current disease incidence and control practices, and adoption constraints for improved practices and technologies	2009	As part of the comprehensive baseline survey, information on the profile of major diseases and incidence, control practices, level of pesticide uses, and adoption constraints were analysed and documented in 2009. The insect and diseases severity by seasons have also been analysed and documented in the same report. Selected issues on diseases profiled, and farmers' adoption of diseases control practices have been detailed, analysed, and documented in the baseline survey as well as during the rapid community survey at the project sites. One journal paper manuscript has been submitted to Agricultural Systems (in review), and another manuscript is in-house review process (included in the appendix).

1.4	Evaluate the impact of introduced IDM strategies	•Quantification of adoption pattern and impact of the project on farmers' income, employment •Factors affecting adoption of chili pepper in high-input and low-input production systems in Indonesia analysed and documented	October 2010.	Cooperative and neighbour farmers have expressed interest to follow up and adopt technologies like drip irrigation in Rembang, compost teas in Brebes, and crop barriers in Magelang. The constraints and implications of adoption and impacts of these technologies were evaluated and the results (including perceived impacts of the technology sets) were shared at the project completion workshop in Indonesia in Sept. 2010. Later on, selected study findings were shared with a wider audience at a conference in December 2010.

Objective 2: To characterize biological factors affecting disease incidence and severity of anthracnose, Phytophthora blight, and whitefly-transmitted viruses (WTG) on chili

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Survey of genetic diversity of WTG, anthracnose, and Phytophthora, in Java and outlying production locations	•Pathotype of *Phytophthora capsici* determined and species of *Colletotrichum* associated with anthracnose determined based on molecular criteria; major species of WTG occurring in Java identified. •*P. capsici* isolates profiled against standard set of differential host lines; related to pathotype •Data on disease/ pathotype x eco-region and management practice	Activities completed in 2009 for virology and in 2010 for mycology. More collection trips conducted in 2010.	-Lab methods for isolating and characterizing *P. capsici* isolates improved at IVegRI. Isolates varying in colony type, mating type, and sensitivity to metalaxyl were found in fields in Lembang. Moreover, 3 pathotypes have been identified. -*C. acutatum* was confirmed as the predominant pathogen causing pepper anthracnose in Indonesia and Taiwan. Sequence variation of ITS region was found among *Colletotrichum* species infecting pepper. Restriction patterns by 3 enzymes could be used for species identification. -Reaction on 0538-8525 could differentiate two pathotypes of *C. acutatum.* -WTG isolates collected and characterized via restriction fragment profile; PepYLCIDV was the predominant WTG. However, another WTG new to the literature, TYLCKaV**,** was identified in Brebes. WTG disease occurs most in Magelang area, next in Rembang, least in Brebes. Whitefly vector adaptation limits disease to below 1200 m.

2.2	Survey on incidence of whitefly vector and correlation with eco-region/ management practices and begomovirus infestation	Report identifying major whitefly vector biotypes, association with disease incidence, and major agro-climatic adaptation factors	Reported in 2009	-*B. tabaci* and *Trialeurodes vaporariorum* were the two predominant whitefly species in the chili production systems of Java. *B. tabaci* is principal vector of WTG -*B. tabaci* occurred in locations with altitude of 1-1200 m asl; whereas *T. vaporariorum* was found only in altitude of 550-1200 m asl. Dominant species for location above 550 m asl was *T. vaporariorum* -Among the biotypes of *B. tabaci*, Asia I is the predominant biotype in Java. Neither biotype B nor biotype Q occurs in this region. -*B. tabaci* found in the chili pepper field beginning one week after transplanting, and increasing for 8 weeks or more; nymphs showed parasitism at that time, and populations subsequently declined. -Numerous weed and alternate crop species are preferred over pepper as hosts by whitefly for breeding and feeding.
2.3	In tandem with 2.2, survey and characterize presence and impact of geminiviruses in chili production regions	•Data and distribution information on begomovirus diversity. •Characterization of virus species/strains using molecular probes	WTG isolates collected from different locations in Central Java have been differentiated into several clusters, principally PYLCV	-Characterization of begomovirus isolates based on restriction enzyme patterns was conducted in both 2006 and 2007. - WTG incidence in Central Java and Yogyakarta continues higher compared to West Java, but in Cianjur and Sukabumi (West Java), incidence of WTG was higher than previous years. -Some local varieties seem to carry some resistance, and yield losses may be tolerated if infection is delayed -Significant occurrence of WTG in Brebes area were reported in fall 2010
2.4	Characterize whitefly behaviour relative to WTG transmission	•GV species/strains carried by different whitefly biotypes documented.	2010 No data on whitefly biotype differential behaviour	IPB survey found 27 weed species belonging to 16 families infected with begomovirus. Eight weed species commonly found in chili pepper fields also harbor WTG. Tests indicate some can be infected by virus strains attacking peppers.

PC = partner country, A = Australia

Objective 3: To assess integrated crop management strategies for sustainable control of anthracnose, Phytophthora blight and whitefly transmitted viruses

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Efficacy data for current practices compared to proposed alternatives in disease control	•Data and assessment of current practices •Data and evaluation of alternative practices •Data and evaluation of fungicide practices	2010	Trials implemented, testing- -mulch and biopesticides and compost teas 2007-9 -Biopesticide had little advantage over synthetics -barrier(net, maize, Crotalaria) 2007-10 -barriers 1.5 m or more in height helped reduce virus incidence -raised beds and drip irrigation 2009-10 --Drip irrigation reduced weeds, disease and increase yields, water use efficiency -- Plastic mulch reduced wilting, increased yields --Trials completed in Brebes and Magelang resulted in good technologies for farmer choices; results reported in Proceedings, Indonesian Horticultural Society Symposium in Bogor, in 2009; --Potential antagonistic microbes against *P. capsici* identified at AVRDC, and phosphoric acid treatment showed the best control effect on pepper Phytophthora blight and should be studied further.
3.2	Recommend-ations for two-three component management practices to reduce disease losses evaluated and adapted by selected farmers	•Demonstrations of effective disease management with candidate practices; farmer field days, reports, publications •Trained farmers and data collected on their assessment of practices	2009-2010	Trial/Demos in 2009-10: -Demo plots in Brebes for effective disease management with rice straw bedding and also with biopesticide and compost tea treatment practices showed reduced Phytophthora incidence and improved yields; Farmer Field Day in April 2009. -Farmer-based trials in four Magelang sub-districts demonstrated an 'Improved Package' (net, maize, yard-long bean, or *Crotalaria* barrier, with minimal chemical pesticide) compared with Farmer Plot (Farmers' traditional package: no barrier and application of full synthetic chemical pesticide). Results showed good performance and higher yields of Improved Package, except for bean barrier. which was equivalent to the no barrier plot. Farmer Field Day in February 2010. -Candidate resistant varieties displayed to farmers in Rembang, May 2010, and in Magelang, October 2010.

Objective 4: To continue development of locally acceptable varieties carrying effective resistance to anthracnose and phytophthora blight, and search for lines resistant to WTG.

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Screen germ-plasm for resistance to anthracnose and WTG	At least 100 genotypes evaluated (including *C. frutescens*); 2-5 resistance sources identified.	Report submitted in late 2009, for the accession testing on resistance on WTG IPB lines were tested in field in Yogyakarta	Out of 95 AVRDC lines tested, 5 were rated as immune to WTG (0735-5677-1 , 0735- 5617-1, 0735- 5623-1, 0735-5629-1 and 0735-5649-1) and 7 were resistant (0735-5687-1, 0735-5601-1 , 0735-5614-1, 0735- 5636-1 , 0735-5646-1, 0735-5670). Seed from selected plants of each line was multiplied. 40 lines reported as WTG resistant evaluated against TYLCThV at AVRDC; numerous lines showed no symptom development 'New Taro' was identified as a genotype that is adapted, resistant to anthracnose and high yielding in the lowland area. Accessions 0639-6515, 0636-6513, 0636-6508, 0635-5595, 0537-7559, 0237-7502 and 0635-5582 were identified as resistant potential lines for anthracnose. Some varieties seem to have low WTG disease level, i.e. IPB C-1, IPB C-2, and IPB C-46. Results of anthracnose screening in lab (IVegRI mycology) differed strongly from field observation (IVegRI breeding). - Sixteen out of 206 *Capsicum* accessions were identified to be resistant to CA1 pathotype of *C. acutatum.* -Two single plant selection of TC05415 were found to be resistant to all 3 pathotypes of *P. capsici.*
4.2	Establish mapping population for WTG inheritance study	Parent, F_1, F_2 and backcross seed produced.	2010	Crosses and backcrosses made between 'Keriting' parent and 5 potentially WTG-resistant parents (Perennial, NP-46-A, PSP-11, Tiwari, Lorai). Confirmation of resistant sources in Indonesia is needed before cross populations are evaluated.

4.3	Cross local varieties with PB resistance sources, make early generation selections	Screening facilities established, early generation selections characterized and advanced; progress reports, seed distributed to co-operators	Report from breeder submitted, 2010	Currently executed by Rinda Kirana, breeder from IVegRI -Facilities for screening for disease resistance established and functioning at IPB and IVegRI. At AVRDC, a molecular assay of a marker for Phytophthora resistance developed in CM334 failed to be detected in several alternative resistance sources. The potential for combining independent factors for resistance from several resistant parents should be explored.
4.4	Evaluate progenies in farmers fields for resistance, acceptability	Advanced lines selected with farmer involvement	Continuing in 2011, beyond project completion	In trials at Pedalangan (600 m), all genotypes tested were attacked by *Colletotrichum* spp., however, commercial varieties TM 999 and Lembang 1 showed less than 10% yield loss, while AVRDC line 0636-6516 lost more than 20%. Different result showed in Pandean; 0038-9155, 0635-5593, and 0636-6515 were totally free from disease attack, but the resistance was not stable.
4.5	Inter-cross best resistant selections, reselect in target areas	Resistance to PB and anthracnose combined into locally preferred variety types	2010	Advanced multi-resistant selections from other projects have been inter-crossed at AVRDC, to combine anthracnose and Phytophthora, as well as WTG resistance. -F_1s established in Spring 2010 combining resistances: --Phytophthora and Begomovirus: 7 --Anthracnose and Begomovirus: 18 --Anthracnose and Phytophthora: 8 Parent lines included progenies of 0636-6515 and -6516. -Six F_2 populations combining resistance to Phytophthora, anthracnose, as well as CMV, CVMV, PVY, ToMV, and/or BW -F_3 to F_7: Various populations screened for resistance to anthracnose and/or Phytophthora, but no begomovirus resistance -IVegRI breeder has multiplied source of seed for field screening on Phytophthora and anthracnose as well WTG testing. -Seeds multiplication for screening activity genotypic resistance against Phytophthora blight was executed.

4.6	Candidate multi-resistant lines introduced to farmers for evaluation and potential adoption	Advanced lines evaluated in participating farmer fields.	2010	Field demonstration of 25 candidate resistant lines in Rembang, early 2010, revealed 2-3 lines with potential for adoption. Similar trial, mid-2010, identified 0537-7558 as a strong candidate for release and promotion. -Former results identified lines 0636-6515 and 0636-6516 as potential parents for anthracnose resistance breeding, with yields similar to standard hybrid TM-999. Other lines that may be accepted included 0836-6741-1, 0836-6741-2, 0836-6729-1, 0737-7732-B, PP0537-7558, 0704-4728-1, PP0537-7558, 0707-7540-B, 0737-7651-B, 0707-7512-B, 0707-7514-B and 0737-7641-B -Seven candidate lines (plus 3 commercial checks) evaluated at two locations in Magelang area, and one location in Brebes area. Yields were not competitive and anthracnose resistance failed in Magelang trials. No disease developed in Tegal trial. Farmer opinion indicated no line was acceptable at present.

7 Key results and discussion

7.1 Crop and farmer characterization

Using the Rapid Rural Appraisal (RRA) technique in early 2007, the project assessed and documented the existing socioeconomic and horticultural practices followed on cultivation of chili pepper, with a focus on disease management practices, at six locations of three districts in Central Java, Indonesia. Using a multidisciplinary team, the appraisal focused on chili pepper farming practices followed in each of the six sites, with a focus on existing level of severity and disease management practices followed for anthracnose, Phytophthora and whitefly-transmitted geminiviruses. Physical, biological and socioeconomic factors in relation to managing these diseases were carried out, with an emphasis on assessing the cultural practices of farmers. The results and information from the RRA were highly valuable in designing the on-farm trials and project activities in each of the project sites. The detailed results and findings are summarised in a separate project report (See Appendix14).

The rapid rural appraisal was expanded into a baseline study (Mariyono and Bhattarai, 2009; see Appendix 1, Project Annual Report 2010) to fill information gaps and to analyse various issues regarding chili production at the village and farm household level in Indonesia. This study characterized the chili growing farmers with regard to appropriate technology introduction, profiled major insects and diseases of chili in the surveyed sites, and noted the pest management practices commonly adopted by the chili growers. The study documented resource allocation decisions of chili farmers in three selected communities of three districts—Magelang, Brebes, and Rembang—which represent distinct agro ecosystems of chili cultivation within Central Java province. The study characterized major production practices and socioeconomic features of chili farming, and has comparatively analysed how these cultivation practices and other key factors of production differ across locations, even within a small geographical region.

Farmers in Magelang and Brebes have been growing chili for more than 25 years; farmers in Rembang started cultivating chili about 10-12 years ago. Chili is grown largely by small- and medium-scale farmers, and most chili-growing farmers are younger and more educated than non-chili growing farmers. Most of the farmers surveyed cultivated an area of about 0.6 ha. Of the total farm land, on average about 0.2 ha/farming household was allocated for chili during the dry season, which is half of the land allocated for rice in the same season. Access to credit was not a problem for the majority of farmers, but only 16 % borrowed capital to grow chili. Because of the risk of crop failure from pests and diseases or loss of income due to excessive price fluctuation, most farmers were reluctant to use borrowed capital to cultivate chili. Although chili can be cultivated in Central Java during all seasons, many farmers grew less chili during the wet season due to the high risk of crop failure by flooding. Canals and tube wells accounted for 68 and 32 %, respectively, of irrigation sources for chili farming during the dry season.

Crop loss due to pests and diseases has increased in recent years, and some of these problems have become difficult to control. The study documented the extent of damage and farmers' concerns toward several major insect pests and diseases of chili. Among the eight major insect pests reported by farmers during the dry season, thrips, mites, and whitefly infestations were most severe. Likewise, among five diseases noted by farmers, the three most important—anthracnose (*Colletotrichum* spp.), geminiviruses, and Phytophthora—were more serious than the others. During the wet season, risk of anthracnose was very high; in the dry season, risk of yield loss by geminiviruses and Phytophthora (in shaded and poorly drained areas) was high. Within a province, the severity of insect pest and disease outbreaks varied by location and by season.

Most farmers controlled pests and diseases with chemical pesticides. There were more than 80 brand names of pesticides used by farmers in the three sites surveyed in 2007/08. On average farmers applied approximately 12 kg/ha of pesticide on chili in a three- to four-month period, and the frequency of spray averaged 23 times over each growing season. Overall, farmers in Brebes, who cultivate the local variety of chili, applied a greater quantity of pesticides and sprayed more than farmers in the other two survey sites where hybrid varieties or improved open pollinated lines are grown.

For the average chili farmer, middlemen and neighbouring farmers were the two most important sources of market information. Radio and television were mentioned by one-third of farmers as a source of information for market prices, but not with a high rank value. Farmers sold chili in several ways. Usually, collectors visited the villages to purchase chili to supply larger markets. Farmers preferred to sell chili on the same day of harvest, and they contacted at least one other trader to verify the prevailing price before selling their produce. Several farmers used mobile phones to obtain market price updates.

Chili is predominantly a cash crop; marketed surplus (proportion of market sale out of the total produce harvested) of chili was very high (nearly 100%) compared to rice (about 65%). This suggests a special role for chili in local economies and rural livelihoods in Indonesia. Profit motivates the decision to grow chili, the level of inputs applied, the risk/reward balance, and the crop intensification pattern followed.

Only around 15% of farmers in the survey sites attended agricultural training, usually through farmer field schools organized by the local Agricultural Office (Dinas Pertanian) and the Indonesian Vegetable Research Institution (IVegRI). Compared to Magelang and Brebes, chili farmers in Rembang previously attended fewer training and extension meetings, which is also the reason for their lower level of crop intensification practices and lower crop productivity.

In general, chili farmers at all three sites faced similar issues related to production, pests, diseases, irrigation, and marketing. However, each chili production area had also some specific problems, constraints, and risks. Location-specific differences must be taken into account when developing technology recommendation packages and new variety types to ensure wider adoption and impact.

7.2 Pathogen, vector, and alternate host characterization

-Whitefly-transmitted Geminivirus (WTG)

Field surveys of incidence of WTG were conducted in 2006-7 (14 sites Central Java and DI Yogyakarta) and again in 2009 (63 sites in West Java, Central Java, and DI Yogyakarta). Data collected were WTG incidence, evidence of whitefly and other viral and fungal diseases; companion plants interplanted with pepper in the field were also recorded (Table 1, Appendix 1). WTG incidence continued to be highest in the Magelang-Yogyakarta area, as reported by Hartono (2003) and Sulandari et al. (2001), where peppers may be planted continuously through the year. Brebes continued to show the least infestation of WTG, although an outbreak in the area was reported in late 2010 (Mariyono, pers. comm.). Other unidentified viruses caused mosaic symptoms. *Krupuk*, or curly stunt symptoms, may be characteristic of pepper begomoviruses or other viral disease.

Survey of WTG incidence, 2009 (AVRDC and IPB)

Begomoviruses cause severe disease epidemics of pepper plants in Java. In 2009, pepper plants were surveyed for virus diseases in the Brebes, Magelang, Yogyakarta, Rembang, and Kediri areas (Table 2, Appendix 1). Symptoms on diseased pepper plants included leaf yellowing, blistering, mosaic and mottle, and plant stunting. Disease incidence ranged from 50 to 100%. Pepper samples with symptoms were collected and detected for presence of begomoviruses by PCR using universal begomovirus primers. Begomoviruses were detected in 11 out of 12 pepper samples collected from the Brebes area, and in all 14 samples from Rembang, 15 from Magelang, 14 from Yogyakarta, 4 from Pati, and 10 from Kediri.

Based on the sequences of the 1.5 kb PCR amplicons, two pepper-infecting begomoviruses; Pepper yellow leaf curl Indonesia virus (PepYLCIDV) and Tomato yellow leaf curl Kanchanburi virus (TYLCKaV) were identified in the pepper samples (Table 2, Appendix 1). All the samples were also tested by ELISA for presence of *Cucumber mosaic virus* (CMV),*Chilli veinal mottle virus* (ChiVMV), *Pepper veinal mottle virus* (PVMV), *Potato virus Y* (PVY), *Pepper mild mottle virus* (PMMV),*Tomato mosaic virus* (ToMV) and serogroup 4 tospovirus (using antiserum for *Watermelon silver mottle virus*; WSMoV). Of the 69 pepper samples collected, 13 tested positive for CMV and 7 for ChiVMV, but none for other viruses. Samples of *Ageratum*, eggplant, tomato, and weeds showing virus-like symptoms were also tested for begomovirus infection. PepYLCIDV was detected in 4 of 6 diseased tomato plants and TYLCKaV in all 3 eggplants. The *Ageratum* and weed plants were infected by one or more other begomoviruses (Table 2, Appendix 1). The results indicate that pepper can be infected by two begomoviruses in the target areas. However, the PepYLCIDV is the predominant begomovirus and can also infect tomato plants. This confirmed a previous report of PepYLCIDV infecting pepper, tomato and *Ageratum*. The other pepper-infecting begomovirus TYLCKaV was also detected on diseased eggplants. Since the TYLCKaV was first reported to infect tomato and eggplant in Thailand in 2003 (Green et al., 2003), it was subsequently found to infect pepper in later surveys by AVRDC. Based on the high nucleotide sequence identity (98%) with TYLCKaV Thailand isolates, the detection of TYLCKaV in Java, Indonesia may be the result of the introduction of the virus from Thailand. The epidemic of pepper yellow leaf curl disease spreading through the Indonesian islands has been proposed to be the result of the introduction of the begomovirus and a virus-vectoring efficient *Bemisia tabaci* biotype from Thailand (De Barro et al., 2008). The presence of the TYLCKaV in Brebes, Central Java provides another evidence for the proposed route for the disease introduction. The presence of TYLCKaV should be seriously considered when developing pepper crop management strategies/practices and when developing virus resistant pepper lines for Indonesia.

Survey on incidence of whitefly vector and correlation with geminivirus infestation (by IPB)

Observation on the presence of whitefly in the field was done during the virus survey in 2006 and 2007 whereas in 2008 intensive collection of whitefly was conducted. A puparium and adult (imago) were collected from chili pepper and other plants nearby the chili pepper fields. The puparium was used for morphological-based identification of whitefly; the imago was used for molecular analysis based on mtCOI sequences (Activity 3).

B. tabaci was collected from location with altitude of 1-1200 m asl; *T. vaporariorum* was found only at altitudes of 550-1200 m asl. Dominant species for locations above 550 m asl was *T. vaporariorum*, although sometimes both species were found on one host plant (Table 3, Appendix 1). Both species are known to be polyphagous and cosmopolitan; therefore they can be found at all locations with different host plants. In addition, different species of whitefly from various plant species were collected (Table 4) to show the diversity of whitefly species.

Table 4. Whitefly Collection from Different Crops in Bogor, West Java (2007)

No.	Species	Host Plant
1	*Aleurodicus dispersus*	Cassava, papaya, chill pepper, banana, hibiscus, ficus
2	*Aleurodicus dugesii*	Chili pepper, hibiscus, papaya, citrus, yang bean
3	*Aleuroclava psidii*	Syzygium, nephellium
4	*Aleurocanthus citripedus*	Citrus
5	*Aleurothrixus antidesmae*	Canangium
6	*Rusostigma* sp.	Syzygium, morinda
7	*Vasdavidius* sp.	Morinda
8	*Aleuropleurocelus*	Morinda

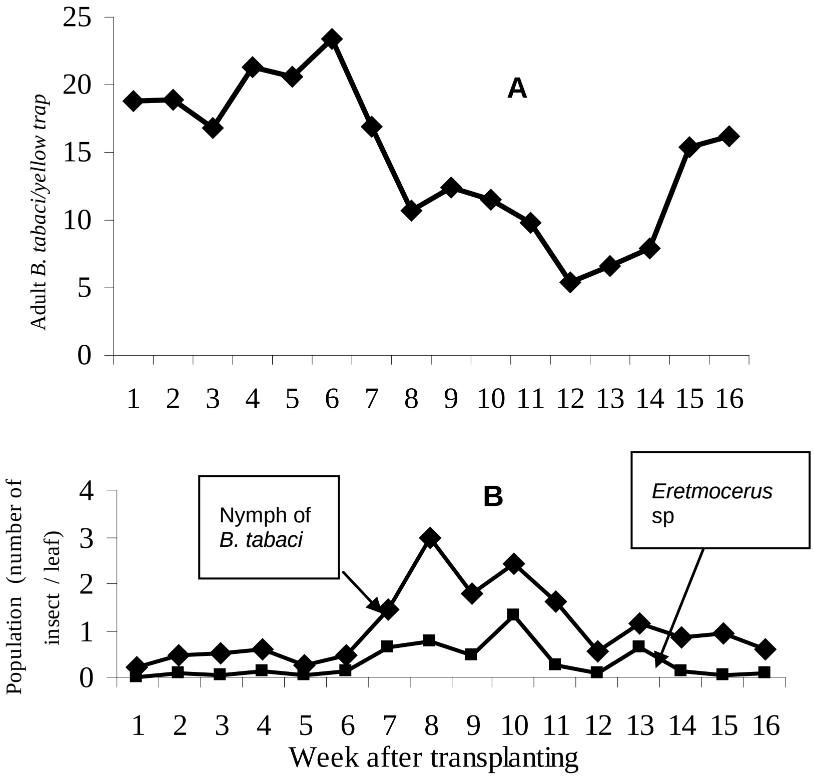

Figure 1. Population density of B. tabaci in chili pepper field at Pakem, Yogyakarta during dry season June – October 2009: A. Adult; B. Nymph and parasitoid (*Eretmocerus sp.).*

In mid-2009 a field experiment was set up at Pakem, Yogyakarta to observe a *B. tabaci* population during the growing season (1 to 16 weeks after transplanting [WAT]). *B. tabaci* was found in the chili pepper field after the first WAT, with a population density of 18.8 adults per yellow trap and 0.11 nymphs per leaf. The highest population density of adult *B. tabaci* was reached at 6 WAT, with 23.4 adults per yellow trap; the nymph population increased very steeply at 8 WAT when population density reached 2.96 nymphs per leaf. However, nymph population decreased over the subsequent two weeks, to 0.58 nymphs per leaf. Some nymphs was parasitized by *Eretmocerus* sp. (Hymenoptera: Aphelinidae), and it seems that population of *Eretmocerus* sp. is correlated with the population of nymphs (Fig. 1A and B). The role of parasitoids and predators in controlling population *of B. tabaci* should be further explored.

Survey of weeds as alternative hosts of WTGs and whiteflies

In 2009 a survey and a study were conducted on the role of weeds as alternative hosts of WTGs and *B. tabaci*. The main objectives of this activity were: (1) to identify weed species commonly found in chili pepper fields; (2) to determine the association of the weeds with WTGs *and B. tabaci*; (3) to detect WTGs infecting weeds; (4) to evaluate the potency of weeds as alternative host of WTGs through host range study.

Observation of weed species for its association with *B. tabaci* was conducted in two chili pepper fields located in the Harjobinangun village, Pakem district, Sleman regency, Yogyakarta, during the dry season from June to October 2009. Twenty-one weed and six crop plant species growing near chili pepper were associated with *B. tabaci* (Table 5). The majority of those plants can be colonized by *B. tabaci;* therefore they may contribute in the development of *B. tabaci* population in chili pepper fields.

Table 5. Exploration of crop and weed species around chili pepper plants that associated with *B. tabaci* at Harjobinangun village, Pakem regency, Sleman district, province of Yogyakarta during dry season from June to October 2009.

No.	Family	Species		No. Nymphs		Status of *B. tabaci* *(b)*
Weeds						
1	Amaranthaceae	*Amaranthus spinosus*		12	(50) (c)	Minor
2		*A. viridis*		41	(100)	Major
3	Asteraceae	*Ageratum conyzoides*		223	(250)	Major
4		*Crassocephalum crepidiodes*		14	(30)	Minor
5		*Eclipta prostrata*		57	(100)	Major
6		*Erigeron sumatrensis*		24	(60)	Minor
7		*Synedrella nodiflora*		88	(200)	Major
8	Brassicaceae	*Rorippa indica*		92	(100)	Major
9	Capparidaceae	*Cleome rutidosperma*		72	(150)	Major
10		*C. viscosa*		95	(150)	Major
11	Euphorbiaceae	*Croton hirtus*		23	(100)	Major
12		*Euphorbia hirta*		49	(150)	Major
13		*E. hypericifolia*		13	(50)	Minor
14		*E. prunifolia*		240	(150)	Major
15		*Phyllanthus debilis*		40	(150)	Major
16		*P. niruri*		91	(150)	Major
17	Lamiaceae	*Hyptis brevipes*		32	(100)	Major
18		*Leucas lavandulaefolia*		16	(50)	Minor
19	Oxalidaceae	*Oxalis barrelieri*		20	(50)	Minor
20	Rubiaceae	*Richardia brasiliensis*		12	(40)	Minor
21	Solanaceae	*Physalis angulata*		254	(250)	Major
Crop plants						
22	Araceae	*Colocasia esculenta*	Rendah	21	(30)	Minor
23	Convolvulaceae	*Ipomoea batatas*	Sedang	74	(100)	Major
24	Euphorbiaceae	*Manihot esculenta*	Rendah	485	(35)	Minor
25	Papilionaceae	*Arachis hypogea*	Tinggi	102	(200)	Major
26		*Phaseolus vulgaris*	Sedang	14	(50)	Minor
27	Solanaceae	*Solanum melongena*	Tinggi	190	(50)	Major

[a] Number of nymphs per 100 m^2 leaf area; [b] status *of B. tabaci* was considered major when number of nymphs > 20 per 100 m^2 leaf area; [c] number of leaf samples.

Weed species found near chili pepper plants may play an important role as alternative hosts for *B. tabaci*, or as reservoir for insect natural enemies, especially parasitoids and predators; they are most important as a virus reservoir.

Based on the survey, 27 weed species were found that belong to 16 families (Table 6, Appendix 1). There were 8 weed species commonly found in chili pepper fields: *Synedrella nodiflora, Euphorbia hirta, Oxalis corniculata, Portulaca oleraceae, Althernantera philoxeroides, Amaranthus lividus, Drymaria cordata* and *Hedyotis* sp*.* Some weed species were present at specific locations, such as *Galinsoga parviflora, Emilia sonchifolia, Porophillum ruderale, Ipomea triloba, Ludwigia peruviana,* and *Solanum nigrum* in West Java, *Cetripeda minima* in Central Java, and *Spigelia anthelmia* in Yogyakarta.

Specific symptoms involving yellowing of leaf and vein clearing ("netting" symptom) on 9 weed species, i.e. *A. conyzoides, C. minima, E. prostrate, P. ruderale, S. iabadicensis, G. peruviana, Croton hirtus, Ipomea triloba, Ludwigia peruviana* were observed (Fig. 2, Appendix 1). The first 5 weed species belong to the family *Compositae*, therefore further investigation on their role as an alternative host for WTG should be explored.

Weeds showing symptoms were further examined in the laboratory to detect the geminivirus infection using standard PCR technique for geminivirus. DNA fragment of 760 bp was successfully amplified from 9 weed species: *A. conyzoides* Bogor (AgrBgr), *A. conyzoides* Sukabumi (AgrSkm), *A. conyzoides* Magelang (AgrMgl), *A. conyzoides* Yogyakarta (AgrJgy), *A. conyzoides* Garut (AgrGrt), *C. minima* Magelang (CtpMgl), *C. hirtus* Yogyakarta (CrtJgy*), P. ruderale* Bogor (PrlBgr), and *S. iabadicensis* (SplMgl). Four other weed species (*G. parviflora* Garut, *E. prostrate* Brebes*, I. triloba* Garut, *and L. peruviana* Cianjur) did not yield any PCR product (Fig. 3). Some difficulties in the laboratory were encountered, especially in DNA extraction procedure, due to the nature of weed tissues. DNA fragment from PCR amplification will be used for sequencing to identify the geminivirus associated with these weed species.

In the host range study 10 weed species (*A. conyzoides, G. parviflora, P. ruderale, S. iabadicensis, S. nodiflora, L. peruviana, A. lividus, P. oleraceae, C. rutidosperma and P. debilis*) were inoculated artificially with pepper yellow leaf curl begomovirus (PepYLCIDV) isolates using *B. tabaci* in the screen house. Four weed species (*A. conyzoides, P. ruderale, S. iabadicensis, L. peruviana*) showed yellowing or netting symptom 7 – 20 days after inoculation while two weed species (*S. nodiflora* and *G. parviflora*) showed leaf curling and malformation 13 – 17 days after inoculation. Four other weed species *(A. lividus, P. oleraceae, C. rutidosperma* and *P. debilis*) failed to show symptoms 30 days after inoculation (Table 7).

Table 7. Incubation period, disease incidence, and symptom type observed during host range study in screen house.

Weed species	Symptom type	Incubation period (DAI)	Disease incidence (%)	PCR detection
Ageratum conyzoides	Netting	8-13	100	+
Galinsoga parviflora	Leaf curling & malformation	14-17	15	-
Porophillum ruderale	Netting	18-20	55	+
Spilanthes iabadicensis	Netting	11-15	100	+
Synedrella nodiflora	Leaf curling & malformation	13-15	10	+
Ludwigia peruviana	Netting	7-10	100	-
Amaranthus lividus	No symptom	NA	0	-
Portulaca oleraceae	No symptom	NA	0	-
Phyllanthus debilis	No symptom	NA	0	-
Cleome rutidosperma	No symptom	NA	0	-

DAI = days after inoculation; NA = not applied

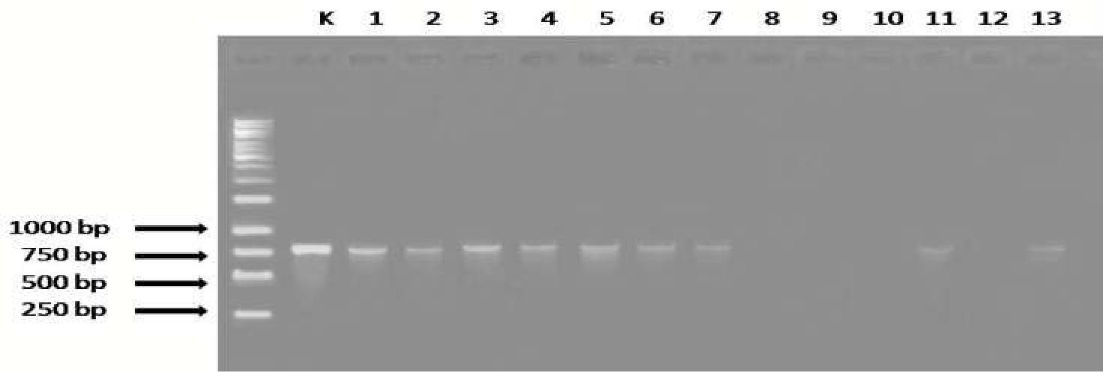

Figure 3. PCR amplification of WTGs isolated from weeds using universal primers (CP – V1 and CP – C1) : Chili pepper (K*); A. conyzoides Bogor (1); A. conyzoides Su kabumi (2); A. conyzoides Magelang (3); A. conyzoides Yogyakarata (4); A. conyzoides Garut (5); Spilanthes iabadiencis Magelang (6); Centripeda minima Magelang (7); Eclipta prostrate Brebes (8); Galinsoga parviflora Garut (9); Ipomea triloba Garut (10); Croton hirtus Yogyakarta (11); Ludwigia peruviana Cianjur (12); Porophillum ruderale Bogor (13).*

Characterization of whitefly species and/or biotypes on crop and weed plants in chili pepper production systems in Central Java (by AVRDC)

A total of 44 whitefly samples were collected from different host plants and locations in Indonesia (Table 8). The collected whitefly species were identified as *Bemisia tabaci, Trialeurodes vaporariorum* and *Aleurodicus dispersus* based on the morphological characters. Because *B. tabaci* has several biotypes, the biotype was confirmed using the partial mitochondrial COI gene sequences. The COI specific primer pairs, C1-J-2195 and L2-N-3014, amplified PCR products of approximately 800 bp size. The sequence alignment and editing resulted in a consensus sequence of 700 bp across all whitefly samples. Since we could not obtain the sequences for *T. vaporariorum* samples, we completely ignored those samples in the phylogenetic analysis and our major target was *B. tabaci*, which has several biotypes. Finally, a total of 32 COI sequences together with nine reference sequences of different whitefly species and/or biotypes reported in GenBank were assembled for the phylogenetic analysis. The neighbour-joining tree (Fig. 4) showed that two clear groups of the biotypes belonging to *B. tabaci* and a separate grouping of *A. dispersus* were observed. More than 90% of the *B. tabaci* samples did not show any variation and they clearly grouped with the biotype Asia I. This was already documented in a few other studies in Indonesia and our study confirmed those results. However, one sample (WFS 36) from a weed (*Trianthema* sp.) grouped with Asia II group, which belongs to an unidentified biotype.

Table 8. Geographic origin and host plant of *Bemisia tabaci* populations investigated in this study, and biotype for mitochondrial cytochrome oxidase sequences

Sample no.	Biotype	City	Crop
WFS3	Asia I	Magelang & Yogyakarta	Eggplant-1
WFS4	Asia I	Magelang & Yogyakarta	Cucumber
WFS5	Asia I	Magelang & Yogyakarta	Eggplant-2
WFS6	Asia I	Magelang & Yogyakarta	Eggplant-3
WFS8	Asia I	Magelang & Yogyakarta	Titonia
WFS11	Asia I	Magelang & Yogyakarta	Tomato
WFS13	Asia I	Brebes	Bawuan Klampok
WFS14	Asia I	Brebes	Soybean
WFS15	Asia I	Brebes	Eggplant
WFS16	Asia I	Brebes	Peanut
WFS17	Asia I	Brebes	Ceplukan
WFS18	Asia I	Brebes	Kangkong
WFS19	Asia I	unknown	Cucumber
WFS20	Asia I	unknown	Pepper
WFS21	Asia I	Cibeureur Darmage Bogor	Eggplant
WFS22	Asia I	Kuniran Batangan PATI	Peanut
WFS26	Asia I	Sendang Agong Kaliori Rembang	Eggplant
WFS27	Asia I	Sekarsari Sumber Rembang	Eggplant
WFS28	Asia I	Sekarsari Sumber Rembang	Luffa
WFS29	Asia I	Sekarsari Sumber Rembang	Peanut
WFS30	Asia I	Nglarangan Candi Bandungan Semarang	Eggplant
WFS31	Asia I	Meteseh Kaliori Rembang	Cucumber
WFS32	Asia I	Meteseh Kaliori Rembang	Peanut
WFS33	Asia I	Meteseh Kaliori Rembang	Yard-long bean
WFS34	Asia I	Meteseh Kaliori Rembang	Kangkong
WFS35	Asia I	Meteseh Kaliori Rembang	Yard-long bean
WFS36	Asia II	Meteseh Kaliori Rembang	Weed
WFS37	Asia I	Meteseh Kaliori Rembang	Jarong
WFS40	Asia I	Cipendawa Pacet Cianjur	Eggplant
WFS42	Asia I	Cipendawa Pacet Cianjur	Potato
WFS43	Asia I	Bantasari Rancaburngur Bogor	Eggplant
WFS44	Asia I	Bantasari Rancaburngur Bogor	Eggplant

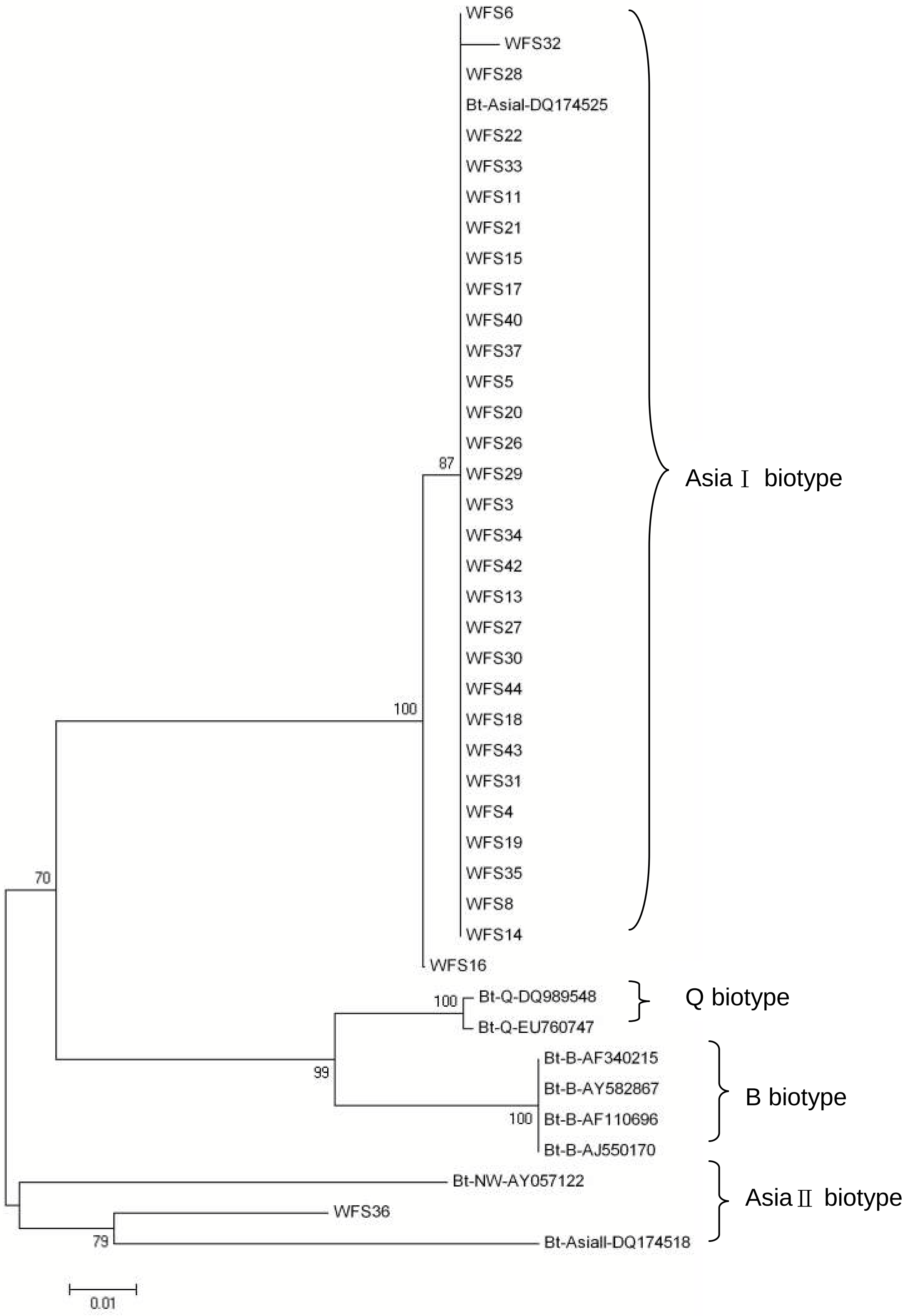

Figure 4. Neighbour-joining phylogenetic tree reconstructed using the whitefly mitochondrial cytochrome oxidase (mtCOI) sequence as a molecular marker. The horizontal branch length is drawn to scale, and the bar indicates 0.01 nt replacement per site

Anthracnose incidence and characterization

Initial surveys to collect samples of the anthracnose and Phytophthora pathogens infecting peppers were conducted in 2007, particularly in West and Central Java, but other accessions were gathered in Central Kalimantan and West Sumatra. Samples were wrapped in newspaper and returned to the IVegRI lab for analysis. Seventy accessions were confirmed to be *Colletotrichum*. Each isolate was examined by microscope and it was tentatively identified by species. *Colletotrichum acutatum* (52 isolates) was the most dominant; *C. capsici* (10 isolates*); C. gloeosporioides (*6 isolates); and *C. boniense* (2 isolates) were also characterized, but subsequently discounted as erroneous. Colony growth rate was characterized and spore dimensions were measured. Single spore isolates were gathered from these, and tested on fruits of a highly susceptible variety, 'Tit Super,' using a microinjection method developed at AVRDC, which punctures the cuticle and deposits 1 µl of spore suspension, or about 50 spores. Inoculated fruits were incubated for four days at 30ºC and high humidity (95-98% RH). Lesion diameter was measured with a circular gauge. Most aggressive isolates were found among *C. capsici and C. acutatum*.

Forty-three pepper genotypes were tested for resistance to isolates representing the four species: *C. acutatum*: Purworejo-1; *C. capsici*: Rancaekek*; C. gloeosporioides*: Ciamis-1; and *C. boniense*: Brebes-1. Pepper entries included lines contributed by AVRDC, research lines of IVegRI, and local improved varieties and land races. While no line displayed high levels of resistance to all species of *Colletotrichum*, several showed promise, including: P-2, 0038-9155, 0636-6501, 0636-6508, and 0636-6514. Incidentally, the last three promising lines derive from crosses made in conjunction with the GTZ-funded program to breed peppers for resistance to four diseases, including anthracnose; they contained in their parentage 50% of the locally selected and popular variety 'Jatilaba,' or, alternatively, KR-B ('Keriting' type from Bogor).

Identity of *Colletotrichum* species in current use (AVRDC)

Colletotrichum is a taxonomically confused genus in urgent need of revision (Cannon et al., 2000). Recent attempts have been made to clean up the *Colletotrichum* systematics based on phylogeny and polyphasic characteristics with comparisons made with type specimens. (Cai et al., 2009). The definitions of some *Colletotrichum* species have been revised, and a few new *Colletotrichum* species were also established. The name of *Colletotrichum* species associated with pepper anthracnose followed the updates that were proposed by Hyde et.al (2009). Four causal agents, *Colletotrichum acutatum, C. bonienense, C. gloeosporioides* and *C. capsici* (synonym of *C. truncatum*) were identified based on morphological and molecular characteristics. Isolates of *C. acutatum* need to be studied further, as some of them might belong to *C. simmondsii* based on latest reference (Shivas and Tan, 2009). The sequence of rDNA internal transcribed spacer (ITS) region (ITS1-5.8S-ITS2) of representative isolates from Taiwan and Indonesia was analysed and deposited in NCBI GenBank (DQ410028-36; DQ410048-55; HQ259123-32). The identity was confirmed by ITS phylogeny as well as nucleotide identity to reference sequence of related holotypes or epitype obtained from GenBank as follows: GU183331(*C. simmondsii*), AY376532 (*G. cingulata*), AB051400 (*C. bonienense*), and EF683602 (*C. capsici*).

Development of effective molecular criteria to differentiate *Colletotrichum* species associated with chili anthracnose

Based on the analysis of ITS sequence, restriction fragment length polymorphisms of rDNA internal transcribed spacer (ITS-RFLP) were developed to differentiate *Colletotrichum* species associated with pepper anthracnose. The isolates can be effectively identified based on the distinct RFLP patterns of the amplified product of universal primers ITS4/ITS5 and digestion respectively by AluI, RsaI, and BamHI (Fig. 5). This method offered reliable identification, and has been used to reliably distinguish pathogens associated with pepper anthracnose in Taiwan and Indonesia.

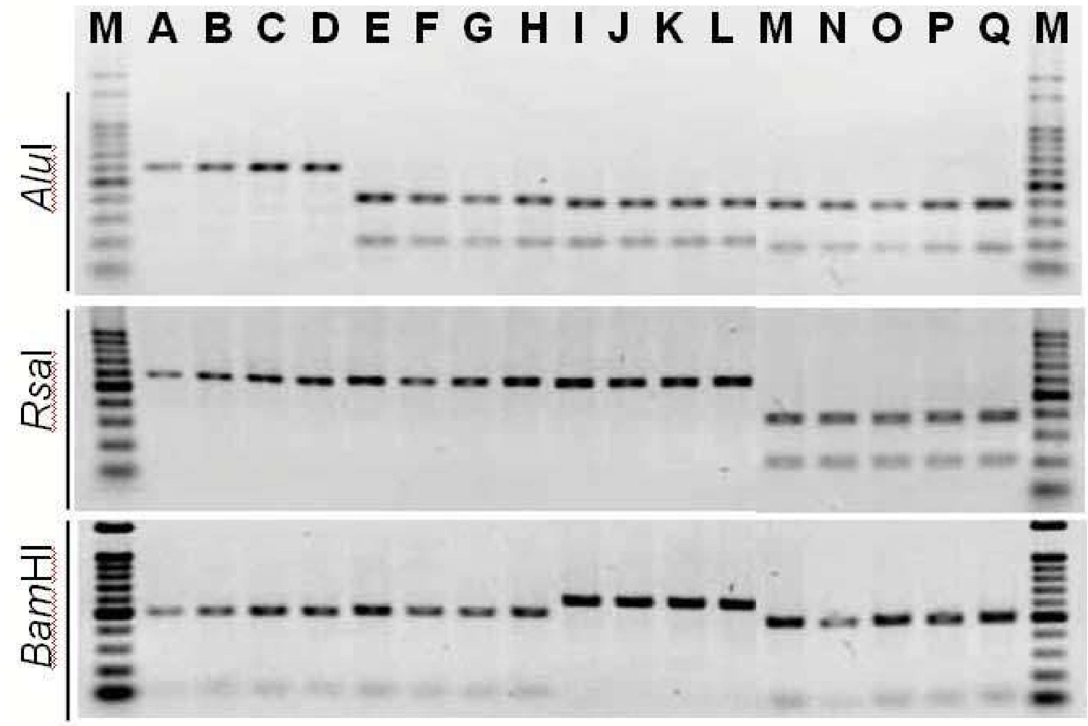

Figure 5. ITS-RFLP patterns resulted from restriction enzymes AluI, RsaI, and BamHI digestion could be used to differentiate four *Colletotrichum* species associated with pepper anthracnose. The non-digested and digested fragments were named as A and B, respectively. Lanes A-D showed patterns AAB was classified as *C. simmondsii*, lanes E-H showed patterns BAB was classified as *C. boninense*, lanes I-L showed patterns BAA was classified as *C. capsici*, and lanes M-Q showed patterns BAB was classified as *C. gloeosporioides.*

Identification of pathogen responsible for pepper anthracnose in Taiwan

A total of 330 *Colletotrichum* isolates collected form chili and sweet pepper in Taiwan during 2007-2009 were characterized. The identification was based on morphology, cultural characteristics and ITS-RFLP. A total of 211 *C. acutatum*, 12 *C. boninense*, 42 C. c*apsic*i, and 65 *C. gloeosporioides* isolates were identified. No close correlation between species and the geographic origin was found. *C. acutatum* was the predominant pathogen responsible for anthracnose on chili and sweet pepper in Taiwan. This pathogen is widely distributed over all production areas, while other *Colletotrichum* species are sparse or infrequently encountered.

Identification of pathogen responsible for chili anthracnose in Indonesia

A total of 86 *Colletotrichum* isolates collected form chili in Indonesia in 2009 (mostly in Java) were imported to AVRDC headquarters for species identification. Only *Colletotrichum acutatum* and *C. capsici* were identified based on phenotypic characteristics and ITS-RFLP (Table 9). The geographic origin of the collected isolates covered 18 regencies of Indonesia, located mostly in West and Central Java (Table 10). Result again confirmed *C. acutatum* as the predominant pathogen responsible for chili anthracnose in Java. However, this finding is in conflict with previous identification based on morphological criteria conducted by Dr. Euis (Technical Report 2008). Except for *C. acutatum and C. capsici*, no other *Colletotrichum* species associated with chili anthracnose in Indonesia was found in this survey.

This molecular method for distinguishing among *Colletotrichum* species was introduced to Indonesian scientists in this project. A test was applied by Dr. Asti Hidayat to the 86 isolates of *Colletotrichum* collected in 2007-8, and the initial observation was that some isolates appear to be mixtures of two species of *Colletotrichum*, rather than pure derivatives from a single spore. No isolates were confirmed as *C. gloeosporioides*, and many were recharacterized as either *C. acutatum,* or mixtures of *C. acutatum* with *C. capsici.*

Table 9. Phenotypic and molecular characteristics *of Colletotrichum* species associated with chili anthracnose in Java, Indonesia

Characteristics	***Colletotrichum acutatum***	***Colletotrichum capsici***
Colony appearance [a]	white to gray mycelium with reverse color of salmon red	white to gray mycelium with reverse colour of gray
Conidial morphology [a]	fusiform or cylindrical with acute end	falcate with acute apex
Conidial size (μm) [ab]	15.1(20.5-12.0)X4.0(5.1-3.1)	25.2 (29.8-22.4)X3.9(5.2-2.8)
Growth rate [a]	7.1 mm/day	10.0 mm/day
Presence of setae [a]	none	abundant
Protease activity [c]	strong	none
ITS/RFLP pattern [d]	ABA	BAA

[a] Phenotypic characteristics were examined by culturing tested isolates on PDA plate at 28°C.
[b] Length and breath (μm) of conidia were measured from 25 spores from PDA culture of each isolate. Five representative isolates of each species were sampled.
[c] Protease activity was rated by culturing *Colletotrichum* isolates on casein hydrolysis medium plate at 28°C. The diameter of clear zone and fungal colony were measured 4 days after inoculation.
[d] The PCR product amplified by primer ITS4/ITS5 were respectively digested by AluI, RsaI, and BamHI, and analysed through 2% agarose gel electrophoresis. Non-digested (type A) and digested fragments (type B) were identified for each restriction enzyme digestion.

Table 10. *Colletotrichum* isolates identified *as C. acutatum* (Ca) or *C. capsici* (Cc) associated with chili anthracnose collected in Indonesia for this study

Geographic unit	Province	Regency	Ca.	Cc
Sumatera	West Sumatera	Padang	2	0
Borneo	Central Borneo	Palangkaraya	2	0
Java	West Java	Bandung	21	4
Java	West Java	Bogor	2	0
Java	West Java	Ciamis	1	0
Java	West Java	Garut	3	0
Java	West Java	Sukabumi	2	0
Java	West Java	Tasikmalaya	3	0
Java	Central Java	Brebes	6	1
Java	Central Java	Kebumen	1	0
Java	Central Java	Magelang	13	0
Java	Central Java	Purworejo	2	2
Java	Central Java	Rembang	10	1
Java	Central Java	Solo	2	0
Java	Yogyakarta	Yogyakarta	2	0
Java	East Java	Wates	1	0
Java	East Java	Baron	3	0
Java	East Java	Malang	2	0
Total			78	8

Pathotype study of *Colletotrichum acutatum* in Taiwan

Symptoms of anthracnose on AVRDC resistant chili lines derived from PBC932 was observed at AVRDC headquarters farm. A preliminary study was designed to examine the pathotype differentiation of *Colletotrichum acutatum (*Ca) isolates based on the interaction with selected pepper lines. Five pepper entries, including one susceptible line 9955-15 (*C. annuum*), one resistant germplasm PBC932 *(C. chinense*) and three PBC932-derived lines (0038-9155, 0538-8515 and 0538-8525) were used in this study. Thirteen *Ca* isolates including Coll-153, routinely used for resistance screening at AVRDC, two isolates derived from lesions on resistant lines at AVRDC fields and 9 randomly selected isolates were used to evaluate their interaction with the above plant entries. Each host-pathogen interaction was evaluated by measuring the lesion diameter of inoculated fruits. Cluster analysis using lesion diameter data based on Euclidean distance as the unit was performed using software Mystate 1.2 (Windows version). The result revealed two distinct pathotypes, respectively named as CA1 and CA2 in Taiwan (Fig. 6). The breeding line 0538-8525 was proposed as a differential host for pathotype determination because it showed more strongly contrasting reactions than other accessions, resistant to Coll-153, but highly susceptible to Coll-524 (Fig. 7, Appendix 1).

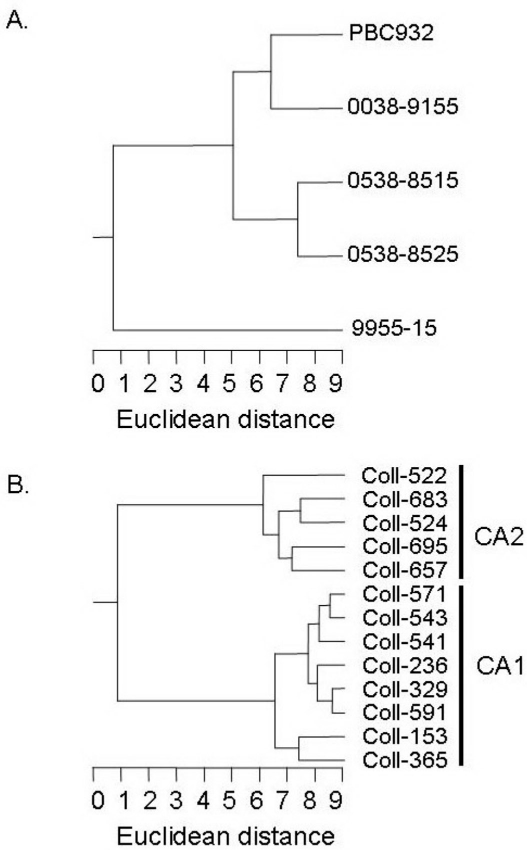

Figure 6. Cluster analysis elucidated the interaction of five pepper accessions with 13 *Colletotrichum acutatum* isolates. Measured lesion diameter (mm) of each host-pathogen interaction was analysed based on Euclidean distance using Mystate 1.2 (Windows version)

Characterization of *Phytophthora capsici* caused chili Phytophthora blight in Taiwan and Indonesia

Taiwan

A total of 169 *Phytophthora capsici* isolates were collected from pepper production areas in Taiwan during 2007-2010. Except for 58 isolates which were collected in 2010, the other

111 isolates were characterized for their mating type, *P. capsici* pathotypes and in-vitro sensitivity to metalaxyl (Table 11). The A2 mating type of *P. capsici* collected from pepper was identified for the first time in Taiwan. A2 mating type isolates seem to have gradually replaced the old A1 mating type. There were several different characteristics between A1 and A2 mating type isolates. The A2 mating type isolates produced longer sporangia of 60.4-73.4 x 40.9-51.8 (average 69.2 x 44.7) um in size, and most isolates (19/38) were more sensitive to metalaxyl than A1 mating type. Pathotype 3 (84/111) was the predominant pathotype in either A1 or A2 mating type populations, as found in other studies. So far, PI201234, a resistance source originally used in the pepper breeding program, was still resistant to all tested isolates. Nevertheless, co-existence of A1 and A2 mating types in the same field has been observed, and that may subsequently accelerate novel pathotype evolution through sexual recombination. It is necessary to continually monitor the dynamics of the local pathogen population.

Indonesia

Only 13 *P. capsici* isolates were successfully imported to AVRDC for species identification and characterization. All isolates, except Pc-id-1, were collected from Lembang, West Java, Indonesia. The mating type, in vitro sensitivity to metalaxyl, and colony morphology of each isolate was characterized (Table 12). Both A1 and A2 mating type were found. The coexistence of both mating type as well as diverse metalaxyl response among isolates from the same field (e.g. Langan sari) implies high genetic recombination potential of *P. capsici* in Indonesia. Based on communications with Dr. Euis, a total of 46 isolates were collected and characterized by IVegRI. Pathotype 2 seems to be predominant in Indonesia. Lack of enough *P. capsici* isolates collected from wider geographic areas did not permit us to draw conclusions regarding the variation of *P. capsici* associated with chili pepper in Java.

Table 11. Characterization of *Phytophthora capsici* collected from pepper in Taiwan

		Collected Year (No. of isolates)					
		2007 (14)		2008 (53)		2009 (44)	
Mating type [a]		**A1**	**A2**	**A1**	**A2**	**A1**	**A2**
(No. of isolates)		(14)	(0)	(38)	(15)	(21)	(23)
Pathotype [b]	1	3	0	8	0	1	0
	2	4	0	1	3	5	1
	3	7	0	29	12	15	21
In-vitro Sensitivity to Metalaxyl [c]	S	6	0	4	10	9	9
	IS	4	0	13	3	8	11
	R	4	0	21	2	4	3

[a] Mating type was determined by co-inoculating mycelial plugs of tested isolate and reference isolate (either A1 or A2 mating type) on rape seed agar plates. After 5 to 7 days of incubation at 24°C under darkness, the presence of oospores was examined along the merged zone of two isolates.

[b] Pathotype of each isolate was determined based on its reaction on 4 pepper cultivars/lines: 'Early Calwonder' (susceptible), PBC137 (resistant to pathotype 1), PBC 602 (resistant to pathotype 1 & 2), and PI201234 (resistant to pathotype 1, 2 & 3). Four-week-old seedlings were inoculated by drenching 5 mL of zoospore suspension ($1x10^5$ /mL) and incubated at greenhouse with temperatures ranging from 22-30°C. Disease incidence was determined at 21 days after inoculation. Mean of disease incidence < 30% was rated as resistant reaction for each host, whereas ≥70% was rated as susceptible reaction.

[c] The sensitivity to metalaxyl of each isolate was evaluated using potato dextrose agar plate amended with different concentration of metalaxyl. Radial growth was measured after four days of incubation at 28°C. Sensitivity/Insensitivity was determined by comparing the percentage of growth at both the 10 and 100 ppm levels to the control. Isolates that grew less than 40% of the control at both concentrations were rated as sensitive (S). The isolates that grew greater than 40% of the control only at the 10 ppm level were rated as intermediate sensitive (IS). The isolates that grew greater than 40% of the control at 100 ppm were rated as resistant (R).

Table 12. Geographic origin, host plant, mating type and the in vitro sensitivity of *Phytophthora capsici* isolates causing Phytophthora blight in Java, Indonesia

Isolate	Province	Regency	Area (location)	Host plant	MT[a]	MR[b]	CM[c]
Pc-id-1	Central Java	Magelang	Borobudur	*C. annuum*	A2	R	Fu
Pc-id-2	West Java	Bandung	Lembang (IVegRI)	*C. annuum*	A2	S	Fu
Pc-id-3	West Java	Bandung	Lembang (IVegRI)	*C. annuum*	A1	S	Fl
Pc-id-4	West Java	Bandung	Lembang (IVegRI)	*C. annuum*	A2	S	Fu
Pc-id-5	West Java	Bandung	Lembang (IVegRI)	*C. frutescens*	A2	S	Fu
Pc-id-6	West Java	Bandung	Lembang (IVegRI)	*C. frutescens*	A2	S	Fu
Pc-id-7	West Java	Bandung	Lembang (IVegRI)	*C. frutescens*	A2	S	Fu
Pc-id-8	West Java	Bandung	Lembang (IVegRI)	*C. annuum*	A2	R	Fu
Pc-id-9	West Java	Bandung	Lembang (Langan sari)	*C. frutescens*	A2	S	Fu
Pc-id-10	West Java	Bandung	Lembang (Langan sari)	*C. frutescens*	A2	IS	Fu
Pc-id-11	West Java	Bandung	Lembang (Langan sari)	*C. frutescens*	A2	S	Fu
pc-id-12	West Java	Bandung	Lembang (Langan sari)	*C. frutescens*	A1	R	Fu
pc-id-13	West Java	Bandung	Lembang (Langan sari)	*C. frutescens*	A1	R	Fu

[a] *Mating type (MT); See Table 3 footnote for assay method.*

[b] *Metalaxyl responses (MR); See Table 3 footnote for assay method.*

[c] *Colony morphology (CM) of each isolate was recorded on 7-day-old PDA cultures. Fuzzy (Fu) colony type with abundant aerial mycelium and Flat (Fl) type with stellate pattern were classified.*

Phytophthora capsici pathotype determination in Indonesia

Pathotype characterization in *Phytophthora capsici* is determined by comparing disease development in a defined array of differential hot peppers with distinct susceptibilities(Table 13). The result of the first observation at 2 weeks after inoculation found plant mortality ranging between 16 to 60% on the susceptible variety 'Early Calwonder.' By four weeks after inoculation, the number of dying plants had increased up to 100%. The highest mortality was caused by Brebes isolates and the least aggressive isolate came from Rembang. Although mortality on PBC137 was mild, between 3 to 10% upon early observation, it progressed to between 50 to 75 % mortality one month after inoculation. PBC602 displayed mortality between 20 to 50% after two weeks, but increased to between 47 to 93% in the full evaluation period, depending on the isolates used. Isolates from Lembang-2 and Brebes' have 47(MR) and 63% (MS) mortality, respectively. Four weeks after inoculation on the resistant PI201234, mortality ranged between 5 to 40%. It is very mild mortality and it can be concluded pathogen isolates fall within the normal range of aggressiveness. In general, those isolate consists of three pathotypes: Pathotype 1 (Lembang-2): Pathotype 2 (Brebes) and Pathotype 3 (Rembang, Lembang -1, Ciamis, and Tasikmalaya). These results reveal that substantial heterogeneity exists in Indonesia within *Phytophthora capsici*.

A further survey was conducted in March 2009, with some 14 samples collected, isolated and characterized. Six were Pathotype 2, and eight were the more severe Pathotype 3. A further follow-up survey was conducted in January 2010, and 47 samples were collected. Pathogenicity of 36 of these isolates was characterized using the differential host screening method. Eleven isolates were classified as Pathotype 1, 23 as Pathotype 2, and only two as Pathotype 3.

Table 13: Standard differential plants indicating pathotype of *P. capsici*

Standard Differential Variety	Pathotype 1	Pathotype 2	Pathotype 3
Early Calwonder	S	S	S
PBC-137	R	S	S
PBC-602	R	R	S
P-1201234	R	R	R

Evaluation of resistance in AVRDC lines

Seventeen pepper lines contributed by AVRDC were tested using a similar procedure, by drenching seedling cells with a suspension of *P. capsici* (Pathotype 3) and incubating 17 days before evaluation. Entries were from the USDA PI collection of *C. frutescens*, submitted as candidate lines for potential use as "cabe rawit" hot chilies. Entries 98 (PI439523), 99 (PI439524), and 100 (PI439525) performed best, with 80% of the plants free of disease symptoms; entry 90, with 50% symptom-free plants, and entry 97 with 20% symptom-free plants, also showed some potential. All other entries were 100% diseased, and rated as fully susceptible.

A further 75 chili pepper breeding selections were evaluated for resistance in March-April 2010, under glasshouse conditions at the IVegRI station in Lembang. Symptom development was measured six times over 39 days following inoculation. Two lines were 100% symptom-free at the end of the evaluation, and an additional 31 lines were categorized as 'resistant' (<20% of plants showed symptoms). Finally, to evaluate the value of laboratory screens for resistance, 23 lines determined to be resistant or moderately resistant by lab assay, plus three susceptible checks, were grown in the field during the 2010 rainy summer season, and evaluated bi-weekly for about 100 days. In the end, only six of these lines display field resistance sufficient to be rated as resistant (entries 5, 6, 10, 13, 15, and 26). All these had been selected as resistant in lab assays, and from 70 to 100% of the plants survived in the field. One line (entry 26), showed 100% resistance in all tests, and warrants further attention as a potential variety release and use as a parent in a resistance breeding program.

7.3 Evaluation and introduction of candidate integrated crop management practices

Results of Trials in Brebes

Role of Biofungicide and Mulch in Integrated Crop Management (ICM) of Chili Pepper to Control Some Major Diseases in Brebes District, Central Java

This factorial trial tested biofungicides (*Bacillus subtilis*) vs. synthetic fungicides, and plastic mulch vs. no mulch, measuring the effects on disease incidence and yield. The combination of biofungicide and silvery plastic mulch (SPM), provided lower virus incidence (4.5% and 5%) compared to without SPM (7% and 6.3%). Mulch delayed virus incidence significantly in the field, but biofungicide or chemical fungicide alone could not reduce it.

Phytophthora capsici and *Choanephora* spp. symptoms were present at low levels in all treatments. Effect of mulch and fungicide application did not demonstrate significantly difference between treatments to reduce *Choanephora* although mulch utilization achieved lower blight intensity than no mulch treatments.

The first ICM trial in Brebes resulted in significantly healthier fruit of mulch treatment plus biofungicide treatment (Table 14).

Table 14. Mean treatment comparisons in factorial ICM trial, Brebes 2007

Treatments	Healthy Fruit (g/bed)	Treatment significance	t.cal	t.(0.05,13)
A (Mulch+Biof)	4603.9	S	-3.89	1.77
B (Mulch+F-sin)	5496.2			
C (No-mulch+Biof)	2896.8	S	-2.31	1.77
D (No-mulch+F-sin)	3150.2			
A (Mulch+Biof)	4603.9	S	7.89	1.77
C (No-mulch+Biof)	2896.8			
B (Mulch+F-sin)	5496.2	S	22.37	1.77
D (No-mulch+F-sin)	3150.2			

Notes: S= significant between treatments

Conclusions from the first trial:

1. Plastic mulch and synthetic fungicide treatments increase production of healthy fruit on chili.

2. Plastic mulch could reduce chili infestations from with fruit fly and soft rot.

3. Biofungicide application did not reduce anthracnose diseases on chili fruit.

The second trial compared biofungicide (*Bacillus subtilis*) vs. synthetic fungicide, and some mixtures of biofungicide, synthetic fungicide, and micronutrient applications, as well as mulch vs. no-mulch treatments. See Sutarya et al. (2009) (Appendix 15, Project 2010 Annual Report). All treatments exhibited symptoms of low virus incidence on chili leaves in the field. There was an interaction effect between mulch and biofungicide treatment on virus incidence in the field at 88 and 98 DAT. After virus was already established on plants in the field, its presence increased more rapidly on no-mulch treatments than on mulch treatments in combination with biofungicide for biofungicide (A) and biofungicide plus micronutrient (C) treatments; these increases of virus incidence could reduce the chances of elucidating other significant differences. On both biofungicide treatments with mulch, the emergence of virus incidence could be delayed and reduced.

Table 15. Interaction of mulch and biofungicides on virus incidence of chili at 88 days after transplanting, Klampok, Brebes, December 2007-April 2008

Mulch	Biofungicide			
	A	**B**	**C**	**D**
No Mulch	39,00 a (A)	25,50 a (B)	24,00 a (B)	26,50 a (B)
Mulch	15,50 b (B)	24,50 a (A)	17,00 b (B)	25,50 a (A)

Treatments: (A*) B. subtilis* (as biofungicide) applied continuously every third day; (B) Bion M 1/48 WP (synthetic fungicide) in the rotation of + *B. subtilis* + *B. subtilis* + Daconil 75 WP (synthetic fungicide) + *B. subtilis* + *B. subtilis* + Bion M 1/48 WP + *B. subtilis* + *B. subtilis* + Daconil 75 WP; (C) same pattern as (B), with additional application of micro-organic nutrient suspension (compost tea) three times during chili plant growth; (D) Farmers' culture practice using synthetic fungicide, alternating applications so Bion M 1/48 WP and Daconil 75 WP, without biofungicide

Lower case annotations indicate significant differences among mulching treatments; upper case annotation indicate significant differences between biofungicide treatments

Biofungicide treatments also showed lower anthracnose infestation than synthetic fungicide treatments (Fig. 7). Anthracnose is a major production problem, and synthetic fungicides are no longer effective control measures. The effectiveness of the mixed treatments may be ascribed to alteration among various pesticides, synthetic and natural, which reduces the tendency for the fungus to develop resistance. *Bacillus subtilis* may also trigger the acquired systemic immunity defence system against anthracnose.

Figure 7. Percentage of anthracnose diseases incidence on biofungicide and mulch treatments

Although chili plants treated with biofungicide produced higher total fruit weight than plants treated with only synthetic fungicide on mulch as well as no mulch, mulch utilization had no significant effect on yield. This differed from prior studies, e.g. Vos et al. (1994). Chili plants treated by biofungicide (A, B, and C) showed the same capacity to produce chili fruit. Table 16 indicates that synthetic fungicide (Treatment D) showed lower marketable yields of chili fruit than biofungicide treatments.

Table 16. Effect of biofungicides on fruit harvested on chili, Klampok, Brebes, West Java, December 2007-April 2008.

Biofungicide treatments	Harvest of chili fruit/plot	
	Fruit number	Fruit weight (g)
A	1650,5 a	12383,6 a
B	1664,0 a	12568,8 a
C	1690,7 a	12852,1 a
D	1477,0 b	10771,2 b

Means followed by the same letters in the same column are not significantly different at 5% of Duncan's Multiple Range Test.

Conclusions from the second trial:

- Biofungicide treatments ‘A’ (*B. subtilis* + *B. subtilis* + *B. subtilis* + *B. subtilis*); ‘B’ (Bion + *B. subtilis* + *B. subtilis* + Daconil) and C (Bion + *B. subtilis* + *B. subtilis* + Daconil + micro organic nutrient application as much as three times) could reduce anthracnose disease on chili fruit.
- The biofungicides did not provide improved control of other fungal diseases - Cercospora leaf spot or Phytophthora infestation in the field.
- Biofungicide (A, B, and C) treatments could produce higher marketable fruit weight than synthetic fungicide (D) treatment.
- Straw mulch treatment could reduce virus incidence on chili in the field, but had no effect on anthracnose incidence.

Trial 3 results; 2009

On the third trial, the application of compost, straw mulch and compost tea constituted a new technology package for chili farmers in Brebes. While farmers are familiar with mulch and compost, compost tea application on chili plants is not widely known or utilized by chili farmers in Brebes. Participating farmers in four locations implemented the trials.

The dominant disease that can easily be seen by farmers in the rainy season in 2009 was wilting disease caused by bacteria. Symptoms of the disease are wilting leaves of chili plants, which remain green and in the daylight. Additionally, virus symptoms (leaf mosaic and malformations) were also note in the trial fields.

The addition of compost tea on pepper plants reduced wilting percentage when compared to plots not receiving compost tea in all four locations. Biofungicide reduced the incidence of wilting plants by 25.0%, 88.0%, 31.11% and 38.1% for the locations in Banda, Bengkok 1, Bengkok 2, and Randugede, respectively (from the observations at 82 days after planting). Incidence of virus in plot of straw mulch and compost treatments was relatively low when compared with plots that were not treated with mulch and compost (Table 17).

Table 17. Virus incidence (%) on chili in IVegRI and farmers' technologies

No.	Locations	Virus incidence (%) at ….					
		54 dat		68 dat		82 dat	
		IVegRI	Farmers	IVegRI	Farmers	IVegRI	Farmers
1.	Banda	1.5	4.5	4.0	9.5	5.5	13.5
2.	Bengkok 1	3.5	5.0	5.0	12.5	9.0	17.5
3.	Bengkok 2	1.0	9.0	4.5	18	12.0	24.0
4.	Randugede	0.0	2.0	0.5	4.5	0.5	5.0

Straw mulch and compost tea produced relatively virus-free chili plants and fruit.

Yields of chili plants treated with compost tea are relatively taller compared to chili plant on untreated with compost tea. Compost tea provided as much as 38% reduction in anthracnose infection compared to farmers' treatments. Advantages in reduced disease were 17.04%, 37.53%, 38.75% and 25.78% for Banda, Bengkok 1, Bengkok 2, and Randugede, respectively (Table 18). On the other hand, infestation by *Helicoverpa armigera* was no better in the recommended treatments compared to farmers' practice.

Table 18. Percentage of healthy fruit and damage fruits on chili by IVegRI technology compared to farmers technologies in four locations, Kersana, Central Java

No.	Locations	Healthy Fruit (%)		Fruit infested with H. armigera (%)		Fruit infected with anthracnose (%)	
		IVegRI	Farmers	IVegRI	Farmers	IVegRI	Farmers
1.	Banda	56.9	49.6	28.4	32.7	14.7	17.8
2.	Bengkok 1	58.4	46.4	24.9	26.9	16.7	26.7
3.	Bengkok 2	55.6	51.1	31.7	28.2	12.7	20.7
4.	Randugede	48.7	47.9	33.0	27.4	18.3	24.7

Conclusion from the third trial:

- Applying compost tea to chili produced better vegetative growth than farmer practice in traits such as plant height, canopy, and shoot number.
- Compost tea could reduce wilt disease and anthracnose diseases in the field.
- In chili harvest, compost tea showed higher fruit yield than farmer practice in four locations.

Results of ICM trials in Magelang: Improved Technology for Whitefly Transmitted Geminivirus Elimination by Using Crotalaria as Chili Barrier in Magelang

Initial pilot studies implemented in the Magelang area in 2007-2008 utilized 32 mesh nylon netting, either 1 m or 1.5 m in height, to prevent infective whiteflies from entering into pepper plots. Results were significant because the netting barrier, especially at a height of 1.5 m, effectively slowed the development of WTG symptoms in the plots. This encouraged us to continue with the strategy, but to seek other barriers that might be less expensive and more appropriate to an integrated farming system. Further trials were implemented, utilizing maize and yard-long bean as barriers, with moderate success. Farmers showed interest in the strategy, and some used plastic mulch sheeting in their fields as a low-cost simulation.

In 2009, a trial was conducted in five locations in the Magelang district, where all locations were under WTG pressure, to evaluate the effectiveness of two barrier plantings (maize and sunn hemp [*Crotalaria juncea*]) and biopesticide vs. synthetic pesticide on chili pepper performance. Beginning with measurements 40 days after transplanting (DAT), virus incidence was significantly different among the barrier crop treatments (Table 19), and continued so through the course of the experiment. *Crotalaria* provided the greatest initial protection to the crop, and delayed the build-up of disease incidence by approximately three weeks. Maize barrier was intermediate in effectiveness in delaying incidence.

Table 19. The effect of barrier type to WTG incidence at 40-100 days after transplanting (DAT) on chili, Magelang (2010), Central Java, Indonesia.

No.	Barrier type	Incidence of WTG chili damage (%)			
		40 DAT	60 DAT	80 DAT	100 DAT
1.	Control	29.45 a	45.80 a	64.50 a	80.35 a
2.	Corn	20.65 b	35.10 b	53.70 b	71.65 ab
3.	*Crotalaria juncea*	13.05 c	30.55 b	46.80 b	63.35 b

While the barrier did not completely prevent the invasion of the viral vector or infection, the delay proved to provide a highly significant yield advantage by allowing substantial fruit set on the young plants. Both barrier types gave higher healthy fruit weight compared to no barrier (control) (Table 20). Marketable yields in the *Crotalaria* protected plots was significantly higher than when protected by maize, and greater still than unprotected plots. By using *Crotalaria* barrier, virus infestation was delayed up to 40-60 dat, allowing substantial fruit set on lower parts of the plants.

Table 20. The effect of barrier type and pesticide type versus marketed chili yield in five locations, Magelang (2010).

No.	Effect of barrier type and pesticide on chili yield in five locations					
	Barrier type		Pesticide type		Trial Locations	
	Barrier	Fruit weight (kg)	Pesticides	Fruit weight (kg)	Locations	Fruit weight (kg)
1.	Control	78.90 a	Bio pesticide	110.53 a	Gondowangi	83.52 a
2.	Corn	108.44 b	Synthetic	104.46 a	Muntilan	81.82 a
3.	Crotalaria	135.15 c	-	-	Salam	82.24 a
4.	-	-	-	-	Sawangan	125.03 b
5.	-	-	-	-	Secang	164.82 c

There was no significant difference in the effect of biopesticide compared to synthetic pesticide in this trial (data not shown). However, anthracnose infestation on chili fruits caused relatively little damage in the experimental trial plots compared with neighbouring farmer production. Since this benefit may be due to extra attention given to disease control in the experiment, it suggests that biopesticide treatments are at least as effective as vigorous applications of synthetic pesticide (Mancozeb), and may have other benefits, in terms of farmer and consumer safety, and cost savings.

ICM activities in Rembang, Central Java

Trial 1:

The 2008 trial, which compared the effects of drip irrigation and nylon net barriers, was largely successful, except for logistical modifications needed to distribute water to the drip tubing. Whitefly-transmitted geminivirus (WTG) intensity on chili pepper from Week 9 until Week 18 (after transplanting) steadily increased from approximately 10% to 90% (Fig. 8).

The drip irrigation plus nylon netting treatment consistently showed the lowest WTG intensity numerically. The drip irrigated treatment without nylon netting was consistently intermediate, whereas the treatment without drip irrigation or nylon netting was numerically highest on all sampled dates.

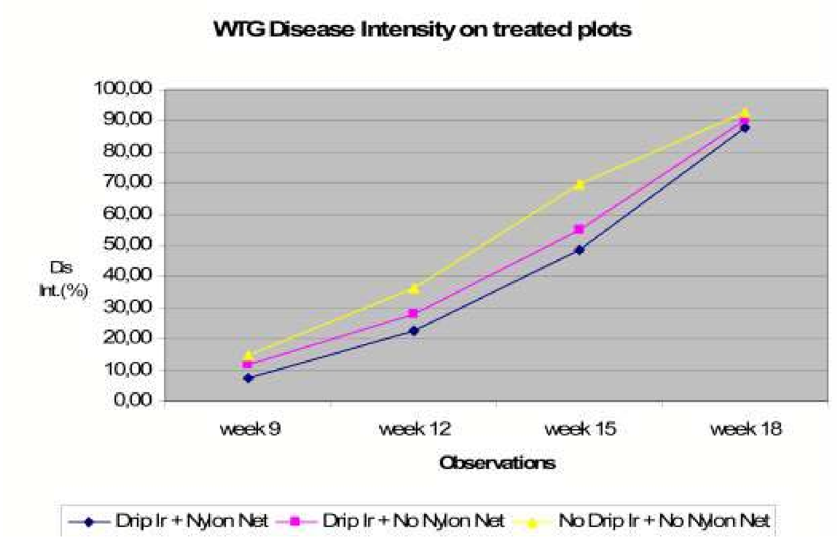

Figure 8. Whitefly-transmitted geminivirus disease intensity in Kaliori 2008 trial.

Plant height also tended to be tallest in the drip irrigation + nylon netting treatment, intermediate in the drip irrigation without nylon netting treatment, and lowest in the existing farmers' system (no drip and no nylon netting). Pepper yields among treatments were not significantly different; the drip irrigation + nylon netting treatment were highest and the existing farmers' system was lowest. The drip irrigation kits were very useful for chili pepper cultivation in Rembang, and technically have good prospects to be developed. They could decrease the infection of some diseases (WTG and 'Puckery' disease), reduce labour requirements, and save water and electricity for water pumps. However, a major constraint is the availability of lateral and emitter components in Indonesia.

Results of the 2009 trial showed that drip irrigation produced chili pepper plants that were about 14-20% taller than those under existing farmers' irrigation regimes. Similarly, pepper yields were slightly higher numerically with drip irrigation than without (Table 21). Levels of WTG incidence ranged from 69 to 82% on drip irrigated plots and 87 to 93% on those with existing irrigation regimes at 90 DAT. None of the differences were statistically significant. WTG incidence in Rembang is generally quite high, so netting barriers should be useful to farmers; however, farmers were not inclined to apply this technology since the price of chili was uncertain. This situation differed from muskmelons, which have a relatively higher and stable price; thus, melon farmers prefer to use nylon netting barriers. Drip irrigation kits were also a preferred technology for farmers, but limited availability made these not very practical according to some farmers.

Table 21. Effect of drip irrigation on disease incidence and yield of chili pepper, Rembang district, East Java, Indonesia, 2009.

Treatment	WTG1 (%)	Crinkle (%)	Sunburn (%)	Yield (kg/ha)
Drip irrigation	87.6	3.36	2.75	993
Sprinkler (traditional)	92.8	4.69	5.76	920
Difference	-5.2	-1.3	-3.01	+73

1WTG = Whitefly-transmitted geminivirus.

ICM activities at AVRDC, Taiwan

Integrated Disease Management of Chili Peppers with Emphasis on Improved Crop Management Strategies

Experiment 1. Varietal evaluation for yield and disease resistance of chili pepper grown under furrow and drip irrigation systems.

The different chili pepper varieties performed well in the drip irrigation system. The AVRDC-bred CCA321 out-yielded the popular Indonesian chili pepper varieties by as much as 43% despite its susceptibility to powdery mildew infection. 'Laris' displayed the most resistance to powdery mildew infection among the different varieties of chili peppers. Of the Indonesian varieties, 'KR-Bogor' was most susceptible to powdery mildew infection. The chili pepper varieties exhibited lower powdery mildew infection when grown under drip irrigation compared to furrow.

Experiment 2. Effects of a physical barrier and an insect growth regulator (IGR) on yield and whitefly numbers on chili pepper.

Tunnels made of #50 mesh nylon net were effective in preventing the entry of whitefly. However, chili pepper yield decreased when grown under the nylon net barrier. The insect growth regulator pyriproxyfen was also effective in controlling whiteflies. The use of #50 mesh nylon net tunnels was more cost-effective in controlling whitefly than the combination of #32 mesh nylon net barriers and the IGR. However, the “Open + IGR” treatment yielded better than those with the nylon net barrier, with or without the IGR.

Experiment 3. Evaluation of deficit irrigation, water use efficiency, host plant resistance and grafting to minimize disease infestations and sustain optimal chili pepper yields.

This study determined the influence of drip irrigation schemes on the incidence of soil-borne diseases in three varieties of grafted and non-grafted chili pepper.

The following are the major results:

1. The drip irrigation scheme which maintained soil moisture at -30 kPa resulted in lower (38*%) P. capsici* infection compared to the irrigation scheme of -60 kPa. This result is not consistent with general observations that disease incidence is reduced at low soil moisture. The lower incidence of *P. capsici* in the higher irrigation scheme (-30 kPa) may be attributed to healthier plants from improved root systems that prevented or reduced disease infection.

2. Grafted chili pepper plants were more tolerant to *P. capsici* and survived better than non-grafted plants. Grafted combinations resulted in 100% plant survival, whereas non-grafted plants succumbed to 38% mortality due to *P. capsici* infection.

3. The highest chili pepper yield of 28.9 t/ha was obtained from line PP0438-8543 grafted onto PI201232 rootstock.

4. More water stress (-60 kPa regime) led to increased early disease incidence (but no difference later), reduced plant height vegetative size and weight, and reduced fruit size and yield.

5. The timing of increased or reduced water stress showed no clear trends in either trial (both the -30 kPa and -60 kPa regimes).

6. Varieties with resistance to Phytophthora did not benefit from grafting. However when the susceptible variety PP0537-7531 was grafted onto the resistant rootstock PI 201232, mortality due to Phytophthora was dramatically reduced.

In-vitro screening of potential antagonists against Colletotrichum acutatum and Phytophthora capsici

A total of 70 candidate antagonists were collected. Among them, 58 were isolated from rhizosphere soils, three from commercial products, and 9 from other researchers in Taiwan.

The candidates were screened by paired culture method, with *C. acutatum* (Coll-153) on PDA plates. A total of 15 of *Bacillus* sp., *9 of Trichoderma* sp., *and 9 of Streptomyces* sp. isolates inhibited > 60% of the radical growth of *C. acutatum* were selected (Table 22).

Similarly, these same candidate antagonists were screened by paired culture method with *Phytophthora capsici* (Pc-134) on PDA plates. A total of 3 *Bacillus* sp., *8 of Trichoderma* sp., *and 6 of Streptomyces* sp. isolates inhibiting > 60% of the radical growth *of P. capsici* were selected (Table 22).

Table 22. Potential antagonists with growth inhibition effect against *Phytophthora capsici* and *Colletotrichum acutatum*

Antagonism species	Location collected	No. of isolates tested		No. of effective isolate	
				P. capsici	***C. acutatum***
Bacillus spp.	Tainan	1		0	1
	Kaohsiung	12		0	11
	Hualien	1		1	1
	Taitung	2		2	2
Trichoderma spp.	Tainan	5		5	5
	Nantou	1		1	1
	Changhua	1		0	1
	Chiayi	1		1	1
	Taitung	1		1	1
Streptomyces spp.	Kaohsiung	6		0	2
	Tainan	23		4	4
	Hualien	4		2	3

Efficacy of selected antagonists on the control of pepper anthracnose

Detached mature green fruits of the susceptible variety 'Susan's Joy' (AVPP9905) were used to evaluate the efficacy of selected antagonists for controlling anthracnose. Individual fruits were respectively treated with each tested antagonists. The treated fruits were inoculated by conidia spaying (5x104 spore/ml), and then incubated at 25^0 under darkness. Humidity was maintained at 100% RH for the first 24 hr, and then reduced to 95-98%. Symptom severity on each fruit was rated by measuring disease area (%) at 14 DAI. The results revealed a few antagonists, e.g. Tsay18 & Tv-R4-2, which could significantly reduce anthracnose severity; however, the degree of control was limited (Table 23).

Table 23. Efficacy of antagonists on the control of pepper anthracnose on detached fruits

Entry[a]	**Antagonist**	**Source**[b]	**Incidence (%)**[c]
Tsay-18	*Strep. saraceticus S-31*	NCHU	68.3d
Tv-R4-2	*Trichoderma* sp.	TARI	80.0 c
Bac-6	*Bacillus* sp.	AVRDC	95.4 b
Bac-10	*Bacillus* sp.	AVRDC	100.0 c
Str-14	*Streptomycetes* sp.	AVRDC	100.0 c
Str-24	*Streptomycetes* sp.	AVRDC	100.0 c

Water (Ck)			100.0 a

All entries were applied on detached fruits by spraying at the 7 day and 1 day prior to inoculation.

Tsay-18 (Tsay, Tung-Tsuan; National Chung-Hsing University); Tv-R4-2 (Taiwan Agriculture Research Institute); Bac-6 [isolated from Tainan (AVRDC)]; Bac-10 (Isolated from Kaohsiung); Str-14 [isolated from Tainan (AVRDC)]; Str-24 [isolated from Tainan (AVRDC)].

Disease incidence was evaluated at 14 days after inoculation. Means followed by same letter(s) are not significantly different at the 5% level by Duncan's multiple range test (DMRT).

Efficacy of biopesticides on the control of pepper Phytophthora

A susceptible pepper line PBC137 was used to evaluate the control efficacy of selected antagonists (2-week-old cultures contained spores and filtrate) and biopesticides (including systemic acquired resistance (SAR) inducers) on Phytophthora root rot. The antagonists were incorporated into potting mixture before sowing, and applied again by soil drenching (5 ml per plant) after 1, 2, and 3 week(s). The biopesticides were applied by drenching 5 ml per plant following product recommendations prior to and after inoculation. The treated plants (4-week-old) were inoculated with 5 ml zoospore suspension ($1X10^{-5}$) of Pc-134 (Pathotype 3). The disease severity and incidence was rated at 14 days after inoculation. The results revealed some antagonists could significantly reduce disease incidence about 10-20%, but could not completely suppress the disease (Table 24). In contrast, phosphorous acid (H_3PO_3) did reduce disease incidence to 16.7%, and was considered as the best treatment for disease control (Table 25).

Conclusion

Although several antagonists against *C. acutatum* and *P. capsici* were identified, only a few showed significant disease severity reduction in inoculation assays. For mass application of antagonists for disease control, formulation, effective delivery system as well as timing for application need to be studied further. Several biopesticides showed significant control effect. Phosphorus acid offered especially good protection effect on Phytophthora blight in greenhouse conditions. Its efficacy in the field should be studied further.

Table 24. Evaluation of selected antagonists on the control of pepper Phytophthora blight in greenhouse

Entry [a]	Antagonist	Treatment [b]	DSR [c]	Disease incidence (%) [d]
Tsay-18	*Strep. saraceticus S-31*	107~106 CFU e	3.0 d	79.2 c
Tv-R4-2	*Trichoderma* sp.	107~106 CFU	3.9 b	100.0 a
Bac-6	*Bacillus* sp.	107~106 CFU	3.7 c	91.7 b
Bac-10	*Bacillus* sp.	107~106 CFU	2.9 e	79.2 c
Tri-8	*Trichoderma* sp.	107~106 CFU	2.5 f	70.8 d
Str-14	*Streptomycetes* sp.	107~106 CFU	3.0 d	79.2 c
Str-24	*Streptomycetes* sp.	107~106 CFU	3.0 d	79.2 c
Water (Ck)			4.0 a	100.0 a

[a] Tsay-18 (Tsay, Tung-Tsuan; National Chung-Hsing University); Tv-R4-2 (Taiwan Agriculture Research Institute); Bac-6 [isolated from Tainan (AVRDC)]; Bac-10 (isolated from Kaohsiung)；Tri-8 (isolated from Kaohsiung); Str-14 [isolated from Tainan (AVRDC)]; Str-24 [isolated from Tainan (AVRDC)].

[b] All entries were mixed with peat moss before sowing, then applied by drenching (5 ml) at 1, 2, and 3 week(s) before inoculation.

[c] Disease severity rating (DSR) was evaluated at 14 days after inoculation. Means followed by same letter(s) are not significantly different at the 5% level by Duncan's multiple range test (DMRT).

[d] Means followed by same letter(s) are not significantly different at the 5% level by Duncan's multiple range test (DMRT). CFU: colony-forming unit

Table 25. Efficacy of non-fungicide chemical substances on the control of pepper Phytophthora blight in greenhouse

Entry	Treatment [a]	DSR [b]	Disease incidence (%) [c]
Chitosan	0.5%	3.6 c	94.4 b
Phosphorous acid	1000 ppm	0.6 f	16.7 e
Calcium-nitrate	1200 ppm	3.3 e	91.5 c
Potassium silicate	600 ppm	3.5 d	88.9 d
TEGO 51	100x	3.8 b	94.4 b
Water (control)		4.0 a	100.0 a

All entries were applied by drenching (5 ml) 1 day before and after inoculation.

Disease severity rating (DSR) was evaluated at 14 days after inoculation. Means followed by same letter(s) are not significantly different at the 5% level by Duncan's multiple range test (DMRT).

Means followed by same letter(s) are not significantly different at the 5% level by Duncan's multiple range test (DMRT).

7.4 Screening *Capsicum* germplasm for resistance sources to anthracnose and phytophthora blight

AVRDC-HQ Breeding Activities for Chili IDM project

At AVRDC, new crosses were made annually to combine superior sources of disease resistance with elite Indonesian OP varieties, mainly 'Jatilaba,' 'TitSuper' and 'KR-B' ('Keriting' from Bogor). Sources of resistance to anthracnose are progenies of interspecific crosses with PBC 932, a *Capsicum chinense* germplasm selection. Phytophthora resistant crosses have largely used the following lines: PI201234, PI188478, and PI201238. Resistance to WTG has provisionally been identified in the following parents, which have been used in crosses for breeding as well as in generating population for inheritance studies: Tiwari, NP46-A, Lorai, Perennial HDV, and PSP-11. In 2007-2008, four backcrosses of WTG resistant selections in Indonesian Keriting backgrounds were made to improve fruit type. In 2008-2009, thirty-five secondary recombinations were made, utilizing lines incorporating Indonesian backgrounds ('Jatilaba,' 'Tit-Super,' and 'KR-B') and displaying resistance to several diseases and viruses. Crosses made in 2009-2010 included parents with extremely high resistance to anthracnose found in *C. baccatum*: PBC80, PBC81, and PBC 1572 (PI594137) and *C. chinense*: PBC1755 (PI497985). In most cases, F_1s and segregating populations were advanced with selection for resistance to diseases that occur in Taiwan, namely anthracnose, Phytophthora, and various viruses, but not WTG. As uniformity is achieved, and resistance and yield potential are confirmed, intermediate and advanced generation selections have been forwarded to Indonesia for onsite evaluation and further selection. Seed shipments in 2009 from AVRDC to Indonesian cooperators included:

45 F_6 entries with potential resistance to WTG, and Indonesian varietal backgrounds ('Jatilaba,' 'Tit-Super,' or 'KR-B')

5 advanced generation lines selected at AVRDC in Indonesian backgrounds, with reported resistance to one or more disease: CMV, CVMV, bacterial wilt, anthracnose, or Phytophthora

12 advanced lines that had been identified as carrying anthracnose resistance in earlier generations at IVegRI

15 advanced generation lines carrying Phytophthora resistance

13 lines of *Capsicum frutescens* for evaluation in the Magelang area as new varieties of the "cabe rawit" type

Advanced lines with Indonesian background were included in AVRDC's International Chili Pepper Nurseries ICPN18 and ICPN19, and were utilized as parents in crosses made in 2008-2009:

ICPN18-2 KR-B//Kulim/HDA295

ICPN18-5 Jatilaba//Kulim/HDA248

ICPN18-6 TitSuper//Kulim/HDA248

ICPN19-5 Jatilaba/0209-4//Jatilaba/PBC495

ICPN19-6 SriSaket-1/2029-4//Srisaket-1/PBC495 [Thai Background, similar to Jatilaba]

ICPN19-10 Jatilaba/0209-4//Jatilaba/PBC122

These lines have been submitted to cooperators at IVegRI and IBP for characterization of resistance to WTG, and Indonesian strains of *Colletotrichum* and *Phytophthora*.

Anthracnose (IVegRI)

Accessions of *Capsicum annuum* (128), *C. baccatum* (6), *C. chinense* (30), *C. eximium* (1), *C. frutescens* (11) *and Capsicum* sp. (30) obtained from AVRDC's Genetic Resources and Seed Unit (GRSU) and AVRDC's Pepper Unit were screened at IVegRI (Table 26). Green mature fruits of each accession were evaluated using the microinjection method with 1 µl conidial suspension ($5x10^5$ zoospores/ml) of *Colletotrichum acutatum* Coll-153 (Pathotype CA1). The inoculated fruits were incubated at 25°C in darkness with 100% RH for the first 24 hours, and then reduced to 95–98% RH. Diameter of each lesion size developed on inoculated fruits was measured 5 days after inoculation. A total of 16 accessions with average lesion size less than 4 mm in diameter were rated as resistant: *C. annuum* accessions from AVRDC's germplasm collection: TC7507, TC6621, TC7505, TC7501 , TC5471, TC6498, TC7499, TC7503, TC7498*; and C. chinense* accessions provided by the pepper breeding program at AVRDC: PBC251, PBC272, PBC492a, PBC811, PBC879, PBC911, and PBC1752. From among promising breeding lines, 20 were resistant to *C. capsici*: 0038-9155, 0635-5595, 0636-6501, 0636-6503, 0636-6606, 0636-6507, 0636-6508, 0636-6509, 0636-6510, 0636-6512, 0636-6513, 0636-6514, 0636-6515, 0636-6516, P2, Local Majalengka, Local Pangalengan, Tanjung-2, Lembang-1 and Biola F1. Eight were resistant to *C. gloeosporioides*: 0537-7558, 0636-6606, 0636-6515, 0636-6516, Tanjung-2, Lembang-1, New Taro and Biola F1. Four lines were identified resistance to *C. acutatum*: 0707-7512 B, C04871, 0537-7558, and 0707-7514-B.

Table 26. Summary of screening results of 206 *Capsicum* germplasm accessions obtained from AVRDC for resistance to *Colletotrichum acutatum* Coll-153.

Pepper materials	No. Tested	No. of resistant accessions [a]
Germplasm from GRSU		
Capsicum annuum	128	7
Capsicum baccatum	6	1
Capsicum chinense	30	6
Capsicum eximium	1	0
Capsicum frutescens	11	0
Capsicum sp.	30	2

[a] Accessions with average lesion size less than 4 mm were rated as resistant.

Phytophthora blight

Accessions of *C. annuum* (58), *C. baccatum* (31), *C. chacoense* (23), *C. chinense* (311), *C. frutescens* (348), and *C. pubescens* (14) were screened in 2008. Six plants of 4-week-old seedlings each accession were inoculated with 5 ml zoospore suspension (Isolate Pc33E6=Pathotype 2; $1X10^5$ /ml) at stem base. No resistant accession was identified in this evaluation trial. However, seven symptom-free plants from accessions of *C. annuum* (3*), C. chinense* (2), and C*. frutescens* (2) were selected and self-pollinated. Progenies of selfed plants were evaluated for their resistance against three pathotypes (Pc1E8, Pc33E6 and Pc151) of *Phytophthora capsici* using the root-drench inoculation. The experiment was conducted following a randomized complete block design with 3 replications and 6 plants per accession per replication. The evaluation was repeated twice. In the end, two selections of TC05415 (*C. frutescens*) were found to be highly resistant against all three isolates, which could be used as an alternative source in breeding programs. Six breeding lines were resistant to PB (screen house conditions): 0707-7540 B, 0836-6729-1, 0737-7651-B, PP0537-7558, 0736-6741-1, and 0736-6744-1. Of these, resistance under field conditions was confirmed for 0836-6729-1, 0707-7540 B, 0836-6708-2, 0737-7651-B.

Geminivirus

Twenty lines of chili pepper received from AVRDC were planted in the screen house at IPB for evaluation of their response to begomovirus infection (20 plants for each line number). Data was collected for disease incidence and incubation period. Disease incidence varied greatly from 5% to 100% (Fig. 9) and symptoms were obvious mostly within 10 to 14 days after inoculation. At least four lines, i.e. 0735-5676-1, 0735-5680-1, 0737-7728-B, and ICPN 18-1 showing low disease level (<30%) probably can be used for genetic resources in developing varieties resistant to begomovirus.

3. Resistance Screening of Hot Pepper Germplasm against WTG at IVegRI.

In testing conducted at IVegRI, 89 pepper breeding lines were inoculated by virus-carrying whiteflies. The time needed for symptom development varied substantially among pepper lines, ranging from 14 to 35 days. Twenty-four lines began showing symptoms after 14 days, thirty-two lines needed 21 days, sixteen lines took 28 days, and three required 35 days. Symptoms of WTG also varied with entry, ranging from mild to severe infection. Based on disease incidence category, the lines were classified as immune, resistant, moderately resistant, moderately susceptible, susceptible, and highly susceptible. Only lines with category Immune (0% infection) or Resistant (> 0 - < 10% infection) were selected for selfing and seed production; 5-6 healthy plants of each line were grown in the field. Some failed to grow or produce seed. During growth and seed production, any plant showing symptoms of WTG was removed and destroyed. Character traits of the selected lines are presented in Table 27.

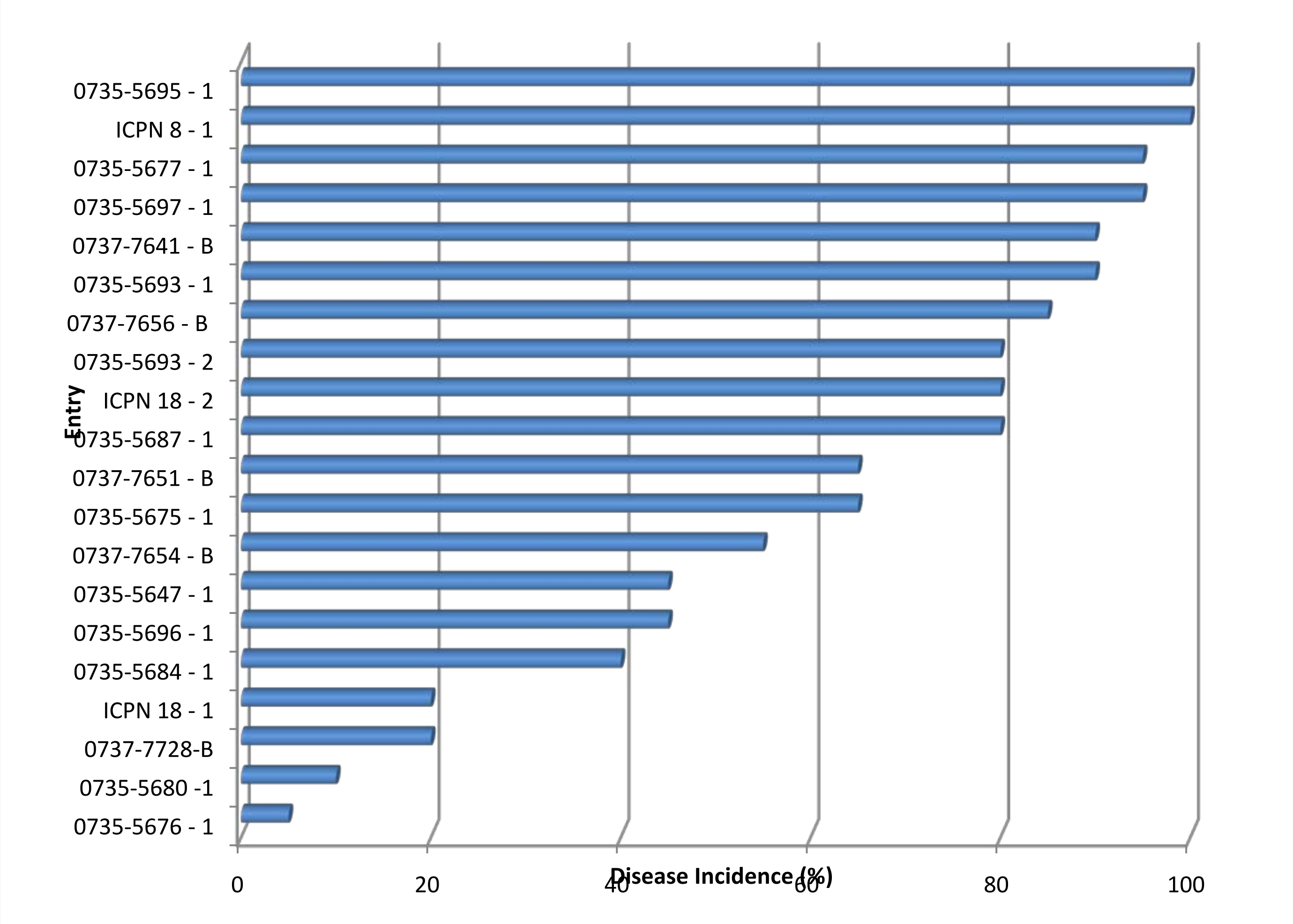

Figure 9. Disease intensity of 20 line numbers of chili pepper grown after artificial WTG inoculation using *B. tabaci* vector in screen house, IPB (October – November 2009).

Table 27: Fruit characters of lines rated as 'Immune' and 'Resistant' to WTG at IVegRI.

Number of Line	**Type of Fruit**				**Plant Height[e]**	**Harvest Seed (g)[f]**		**Recom-mended**
	Number[a]	**Size (cm)[b]**	**Color[c]**	**Shape[d]**		**OP**	**Isolated**	
Immune Line								
0735-5677-1	Many	8,5 x 0.8	RO	Rawit	Medium	5,37	7,56	@ / 7,56
0735-5696-1	Many	11,5 x 1,3	R	Besar-f	Short	0,96	0,26	-
0735-5604-1	Few	7,0 x 1,2	RY	Besar	Short	11,86	3,70	-
0735-5613-1	Many	6,2 x 1,1	R	Rawit-f	Medium	1,82	0,54	-
0735- 5617-1	Many	8,5 x 1,0	R	Besar	High	1,02	3,46	@ / 3,46
0735- 5623-1	Moderate	9,3 x 1,2	R	Besar	Medium	2,46	11,34	@ / 11,34
0735- 5626-1	Few	8,0 x 1,2	R	Besar	High	5,60	0,96	-
0735- 5629-1	Many	6,8 x 0,9	RV	Rawit	High	6,22	0	@ / 6,22
0735-5649-1	Many	9,5 x 1,3	RO	Besar	Medium	1,04	2,64	@ / 2,64
Resistant Line								
0735-5687-1	Many	11,0 x 1,1	R	Keriting	High	2,06	2,84	@ / 4,90
0735-5601-1	Many	7,0 x 1,2	RY	Rawit	Medium	9,64	0	@ / 9,64
0735-5601-2	Moderate	7,7 x 1,1	R	Besar	Short	9,70	7,2	-

0735-5608-1	Moderate	8,8 x 1,6	R	Rawit-f	Short	0,60	1,0	-
0735-5614-1	Moderate	7,0 x 0,8	RY	Rawit-f	Medium	1,70	1,34	@/ 3,04
0735- 5619-1	Moderate	11,5 x 1,2	R	Besar	Medium	2,74	0,66	-
0735- 5632-1	Moderate	8,4 x 1,15	RO	Besar	Medium	1,38	1,76	-
0735- 5636-1	Many	7,3 x 1,4	R	Besar	High	9,60	4,16	@ / 13,76
0735-5646-1	Many	10 x 1,2	RL	Besar	High	12,62	4,06	@ / 16,68
0735-5662-1	Many	7,1 x 1,12	R	Besar	Medium	7,74	4,16	-
0735-5670-1	Many	9,9 x 1,7	R	Besar	High	2,10	4,64	@ / 6,74
0735-7641-B	Many	14,4 x 1,0	R	Keriting	Short	1,98	1,18	@ / 3,16

[a] *Number of fruit: Many = inter-node shorter , almost every node has fruit, sometimes with fasciculate type; Moderate = inter-node was normal, fruit in every node; Few = Fruit set is rare*

[b] *Size of fruit: length x diameter of fruit (cm).*

[c] *Colour: R = R; ED, O = orange, Y = yellow, V = violet.. L = Light / shine*

[d] *Shape of fruit (Kusandriani, 1996): Rawit is small pepper , generally highly pungent, with erect flower and fruit; Besar is large and bigger pepper, medium hot, pendent fruit; Keriting is a long, thin pepper, pendent , mostly hot, with a rough fruit surface; f = fasciculate, more than one flower/fruit at each node*

[e] *Plant height = in cm*

[f] *Seed produced : OP= flowering and fruit production unprotected; Isolated plant = plant was covered with muslin cloth, or flower was covered with oil paper to avoid cross pollination*; 1. @ = selected line for further study (resistant field test in endemic area).

Among these candidate selections, eleven were introduced to farmers for evaluation and potential adoption in field trials in Brebes, and Secang, Central Java (0836-6741, 0836-6729, 0537-7558, 0737-7651 B, 0707-7512 B, 0636-6516, 0736-5680, 0735-5604, 0735-5613, 0735-5617, and 0735-5623. Seed was sown in September 2010. Initial subjective evaluation during the project completion workshop in late October highlighted the potential of one line, in particular-PP537-7558. While other entries showed occasional incidence of WTG, no plants of this line showed any symptoms at all. This was surprising, as it was included in the trials as possessing resistance to anthracnose, and there was no expectation that it should also carry resistance to WTG. Farmers visiting the plots admired the variety's large fruit size and high yield potential. IVegRI is making plans to register this variety, and promote it for general release. Subsequent eruptions of the volcano Mt. Merapi deposited a heavy blanket of toxic dust, which killed the trial before yield data could be compiled (Appendix 7).

Farmer participatory evaluation of candidate lines

A parallel field performance demonstration trial was established in Kaliori, Rembang District during the spring of 2010 (Table 28). The best lines among those evaluated included some noted to carry resistance to anthracnose, some with parentage that should confer some degree of geminivirus resistance, but none with notable Phytophthora resistance. Symptoms of geminivirus were infrequent and minor. Observation and evaluation by local farmers scored some lines well, though not equal to preferred local varieties.

Local varieties were crossed with PB resistance sources to make new materials for the continuing effort to improve the varietal background available to Indonesian chili farmers. The activity was established in a screen house at IVegRI. Planting date was September 21, 2010. Parental material has not been communicated.

Table 28. Ten entries receiving the best overall scores among 25 lines evaluated in early 2010 in Kaliori, Rembang, Central Java, Indonesia

Entry	ID	Comment	overall	shape	performance	Acceptability

26	TM999	Comm. Ck	15.000	5.000	5.000	5.000
27	Taro	Comm. Ck	14.429	4.857	4.714	4.857
21	0737-7651-1	like Tampar	13.714	4.286	4.571	4.857
19	0537-7558	anthracnose res	12.429	3.714	4.714	4.000
11	0537-7558	anthracnose res	12.000	3.714	4.429	3.857
22	0707-7512-B	Keriting	10.714	3.429	3.000	4.286
13	0735-5677-1		11.286	3.286	4.000	4.000
10	0737-7732-B	compact	10.000	3.429	2.857	3.714
9	0836-6729-1	loaded	10.000	3.857	2.714	3.429
24	0737-7641-B	like Tampar	10.000	3.571	2.714	3.714
23	0707-7514-B		10.143	3.286	2.857	4.000
6	0836-6715-1	upright	9.714	4.000	2.571	3.143

Synthesis of Geminivirus resistance evaluations in Indonesia 2009-2010

The three evaluations noted above were independently conducted and compared: the virus reaction assays conducted by Asti Hidayat at IPB (Bogor, West Java), the virus infection observations conducted by Dr. Duriat et al. at IVegRI (Lembang, West Java), and variety demonstration plantings conducted by BPTP (Rembang District, Central Java). Although similar sets of seed lines were provided to each cooperator by AVRDC in May 2009, relatively few of the same lines were evaluated by two of the three studies. The IVegRI virology group evaluated many lines for resistance to geminivirus without regard to the fact that some were included as carriers of resistance to Phytophthora or anthracnose. Many of these lines, however, were surprisingly rated as resistant (3) or immune (2) to geminivirus, and warrant further examination. Among the 45 lines nominated for their possible resistance to geminivirus, 9 were rated as immune (no plants displaying symptoms, and 13 were rated as resistant (less than 10% of plants showing symptoms). Ten lines were tested by both IVegRI and IPB: two lines rated as immune by IVegRI were reported by IPB to show virus symptoms on 45 and 95% of the plants, while two lines showing less than 10% symptoms were rated by IVegRI as either moderately resistant, or susceptible. Clearly, screening methodologies need to be refined in order to achieve greater repeatability and robustness across locations.

IMPACT ASSESSMENT

Perceived impact assessment (or documentation of outcome) of the technology packages adapted by the project in the three targeted communities were carried out in late 2010. A rapid survey and assessment was carried out in the selected three communities, where the farmers' level dissemination of the technologies was carried out earlier (see Appendix 20). The survey documented farmers' feedback and perceptions, and the effects of the three technology packages adapted and disseminated from the on-farm research trials. A total of 18 farmers were surveyed individually, consisting of 14 farmer co-operators in Magelang who were practicing crop barrier technologies, four farmer co-operators in Brebes using biopesticides, and a separate group of four farmers (and neighbouring farmers) practicing low-cost drip irrigation in Rembang. The surveys utilized semi-structured questionnaires. The details on technology packages have been noted in earlier sections of this report. The results and findings of the rapid assessment are summarized below.

Overall, farmers gave very high scores when ranking the preferences of the three technology packages. Almost 85% of farmers surveyed indicated they were highly interested in using the technology; the remaining farmers were doubtful, but did not reject the technologies. In fact, 80 % of the surveyed farmers (farmer cooperators) also used the technologies on a small scale, as part of on-farm evaluation and adaptation. Only around 10% of farmers stated that the new technologies may conflict with local cultivation practices and norms. The farmers surveyed also mentioned that the new technology sets were easily observable and acceptable to average farmers in the locality. This means that new technologies were visible to others farmers (potential users) in the communities. All of these suggest that the level of compatibility of technology innovation and potential adoption is relatively high.

The characteristics representing relative advantage are reductions in the use of synthetic pesticides, inorganic fertilizers, and labour, and increases in productivity and profit.

Technological package 1 (crop barrier), which was introduced in Magelang, was able to reduce the use of synthetic pesticides by almost 20%; whereas the reduction in use of synthetic pesticides by technological packages 2 (crop barrier + biofungicide/compost teas) and 3 (Barrier + Drip irrigation) was only around 10%. Technological package 2, which was introduced in Brebes, was able to reduce the use of inorganic fertilizers by 20%. Technological packages of 1 and 3, which were introduced in Magelang and Rembang respectively, had no effect on the use of inorganic fertilizers.

Farmers reported that introduction of the technological packages of crop barriers and biopesticides slightly increased labour use. Farmers also reported that the low-cost drip irrigation package reduced labour use in Rembang by 25% compared with traditional irrigation methods. Likewise, technological packages of crop barriers and biopesticides have led to enhanced productivity by around 15% and 20% in Magelang and Brebes, respectively. In the case of crop barriers, the increase in production resulted from delayed virus infection, larger size and greater number of fruits, and longer harvesting period. The increase in production as a result of the biopesticide package was due to lower levels of weeds, larger size, and greater number of fruits.

8 Impacts

8.1 Scientific impacts – now and in 5 years

Molecular characterization of whiteflies and begomoviruses by IPB has identified previously undocumented categories of both associated with the disease in Central Java. Numerous weed species have been implicated in the disease context, as not only potential hosts for begomoviruses in general, but as potential carriers of the virus strains infecting pepper. Whitefly may prefer other crops over pepper, but can still visit and transfer the virus. After two months of crop growth, whitefly populations may come under pressure from parasitoids, which may limit disease transmission. These are among the findings of MSc thesis projects conducted by students of Dr. Hidayat (Hendrival, 2009).

In Taiwan, begomovirus was found in pepper plants for the first time in 2009. Follow-up trials confirmed this observation and identified numerous lines that appear to be resistant to the *Tomato yellow leaf curl Thailand virus* (TYLCTHV). This has been reported in scientific journals (Shih et al., 2010).

In 2009-2010, three paper manuscripts were prepared out of the project work, and shared with global audiences at international conferences, including the XVI International Symposium on Horticultural Economics and Management, June 28-July 02, 2009 in Chiang Mai, Thailand (Bhattarai and Mariyono, 2009), and the Symposium on Vegetable R & D in Sumatra and Java, held at the Indonesian Hort. Society Annual Scientific Seminar and Congress 2009, in Bogor (Appendices 10, 11, 12, and 13). Two additional manuscripts have been written and refined for high impact journals, and they are now undergoing internal review at AVRDC-HQ (Appendices 17 and 18). Other papers out of the project work have been prepared and submitted to two international conferences, including the First International Symposium on Sustainable Vegetable Production in South-East Asia (supported by ISHS) in March, 2011 to be held in Salatiga, Central Java, Indonesia (Appendix 16). Additional manuscripts are being prepared, and will be submitted for publication to peer-reviewed journals shortly.

Over the course of four years, the project-supported participants/project scientists/partners also presented a number of high quality papers and research findings at national and international seminars. The project economist (Bhattarai) also presented a paper on socioeconomics of chili cultivation and related issues at the International Horticultural Congress 2010 in Lisbon (ISHS congress, August 2010). The project findings were shared with horticultural sector academics and practitioners globally. The rapid assessment of risk- and profit-related trade-off issues for vegetables, as a new tools and techniques adapted out of this project work, was appreciated by several academicians and scholars internationally. These risk assessment tools adapted and developed by the chili IDM project have been shared with partners in another ACIAR-funded project in Aceh province of Indonesia. An ACIAR-funded project team in Cambodia (HORT/2006/107 "Strengthening the Cambodian and Australian vegetable industries through adoption of improved production and postharvest practices") is also adapting the same tools and techniques for their use.

The First International Symposium on Anthracnose in Pepper was organized by AVRDC and the National Horticulture Research Institute (NHRI) of South Korea, and convened in September 17-19, 2007(Oh and Kim, 2007). More than 30 presentations and posters were presented, including three from AVRDC staff. Their presentations focused on important developments derived from this and prior collaborative projects with Indonesian researchers. The symposium outlined the basis and starting materials for much of the resistance breeding that was utilized and advanced in this project.

The project team members in Indonesia took active part in the Indonesia Horticulture Congress organized in Bogor in November 2009. The project team organized a separate symposium to review AVRDC project activities in Indonesia, and the project team was able to present five papers on different topics related to this project. Staff members of BPTP in Aceh received exposure to data entry, data processing, and application of statistical software during data entry and preliminary analysis, especially on statistical software for social science (SPSS). This helped the capacity building process of social science research within BPTP/Ungaran, which provided a good opportunity to share the project activities and project findings with national horticultural sector scientists and key stakeholders and planners in Indonesia.

8.2 Capacity impacts – now and in 5 years

Farmers from local and more remote communities have participated in simple farmer field meetings, and they have relayed their observations to their neighbours. In one case, a farmer observed our barrier trial in the Magelang area, and volunteered to undertake a similar trial in his distant community. This has been a focus of many farmer visits, which have seen the notable delay and reduced incidence of virus disease in the plot protected by netting, and especially by *Crotalaria*. Farmers learned the technique for making biopesticide and simple composting equipment. Beneficial microorganisms were also demonstrated. This has been well-received by government extension representatives, as it harmonizes with current "back to nature" campaigns to promote biological alternatives to chemical pesticides. Cooperation with Dinas Pertanian-Magelang District Officer has also increased. The leader of a new governmental extension system, the Board of Extension Executor (Badan Pelaksana Penyuluh), attended the Field Day event in Brebes in April 2009, and expressed his appreciation. District Extension offices (Dinas Pertanian) have been critically important in contacting farmers to participate in our farmer Field Meetings, and to cooperate in establishing trials.

The capacity of local partners from IVegRI and BPTP was improved through participating with scientists from AVRDC in developing and implementing integrated data collection for the baseline survey (including both quantitative and qualitative base survey tools). Staff members of BPTP received exposure to data entry, data processing, and application of statistical software during data entry and preliminary analysis, especially to statistical software for social science (SPSS). This helped the capacity building process of social science research within BPTP/Ungaran. In 2009, AVRDC pathologist Dr. T.C. Wang trained about five researchers from IVegRI in identification, diagnosis, and management of Phytophthora and anthracnose diseases on chili. In 2010, AVRDC mycologist Zong-ming Sheu, also visited IVegRI to enhance Phytophthora sample collection, isolation, identification, and characterization.

Asma Sembiring, one of the socioeconomists of IVegRI, visited AVRDC headquarters in Taiwan, and received exposure to vegetable marketing systems in selected markets in southern Taiwan. This training was funded by IARD/Indonesia and also partly supported by this project. Asma also partly supported these project activities in IVegRI.

During the project activities, several national and local partners from Indonesia were involved in implementing the project activities. For example, researchers from IVegRI and BPTP/Ungaran, and DINAS-Pertanian/Magelang were largely involved in implementing the project activities in their respective jurisdictions. At least four graduate students from Bogor Agricultural University, under the supervision of the project virologist from Indonesia (Dr. Asti Hidayat), were also involved in completion of components of academic work, and they completed their Ph.D. research work out of the project support.

For the crop barrier technologies, the project team closely worked with the DINAS, and as result there is already a higher scope of out-scaling and up-scaling as well as on-scaling of the technologies to several other villages in Magelang district, largely funded from the Indonesian government. Likewise, other districts in Central Java where the disease pressure of geminivirus is very high, are also likely to adopt this technology with technical support from BPTP/Central Java and IVegRI.

IMPACT of ICM Components

Broader dissemination of the improved technology was done through Farmer Field Days (FFDs) and Farmer Field Meetings (FFMs), and in closely working with the participating farmers, chili growing communities, and local extension officials of Dinas Pertanian and BPTP.

In Brebes, where soil respiration and anthracnose are the main problems, utilization of straw mulch and compost tea gave farmers tools to improve their cropping environment. Producing compost tea and biopesticides themselves also stimulated them to apply these materials on their fields. They demonstrated that soil conditions improved and disease pressure diminished when straw mulch and compost tea were used. However, it was difficult for farmers to accept biopesticide utilization and production because of technical difficulties in producing the formulas at home. Farmers need biopesticides to be readily available from commercial sources. The potential effectiveness of the biofungicide was sometimes not well-demonstrated, and farmers were not convinced that it could reduce anthracnose.

FFD in Brebes produced greater numbers of interested farmers to attend and to participate directly in the field. More than 75 farmers attended the FFD organized in Brebes in 2008/2009, where they were exposed to different aspects of the technology package (rice mulch and biopesticides) used in controlling soil-borne diseases on chili.

FFM and FFD were well-attended by key farmers in Magelang; the response was good. Two Farmer Field Days were organized, but numerous additional meetings and discussions were attended by farmers from distant villages, such as Kaliangrik and Secang. Free discussion from farmer to farmer with the guidance of AVRDC's Central Java team (Drs. Dibiyantoro and Mariyono) and Dinas Pertanian Magelang (Magelang Agricultural District leaders and extension officers, led by Mr. Yoga and Mr. Pratomo). Farmer Field Meeting programs were conducted in Keji, Sawangan, Kaliangrik, and Secang villages.

The adoption of even very simple new technologies was very well-received, as the technologies increased chili yield 8.2 -16 t/ha, which is 2-4 times greater than production normally achieved by common farmers. The average initial score was raised from 5.7 to 8.3. Farmers showed increased interest in Improved Technologies (IT) compared to Farmer Technologies (FT); they went on to adopt elements of IT to reduce WTG incidence in the field, and recognized the benefit gained by delaying spread of WTG, which ultimately reduced damage and resulted in higher yields. Trials also stimulated farmers to apply the neglected green manure crop *Crotalaria* in a new way, thus refamiliarising them with a traditional crop amendment.

In Rembang, demonstration of low-cost drip irrigation was well-received, as water shortage is a continuing challenge. Adaptation of the drip system gave farmers confidence in implementing a system. They expressed interest in using drip irrigation systems, but on higher value crops such as melons rather than chilies. Evaluation of new disease resistant lines was not very successful, because the lines fell short in matching the commercial fruit shape and size demanded by local consumers. Disease incidence was relatively slight (some virus) so the advantages of genetic disease resistance were not apparent. Farmers nevertheless were willing to participate in future variety evaluation trials.

8.3 Community impacts – now and in 5 years

The Chili IDM project in Indonesia has attempted to address crop production strategic needs in three geographically separated regions. Close communication among farmers, extension officers and AVRDC project personnel in Indonesia has been challenging. Frequent contact among project members, farmers, and associated extension offices occurred in the Brebes area, as it was only 45 minutes from the office. The two other targeted areas were very far away from the project office in Tegal (8 hours travel), and the collaborators' offices were also quite distant from the project office (Bogor and Lembang, West Java, 9 and 6 hours, respectively; Ungaran, Central Java, 4 hours). However the most active collaboration was with the progressive farmers and Dinas Pertanian (District Extension) personnel in Magelang.

After the socioeconomic survey report, researchers from national organizations and partner agencies recognized the severity of several insect pests on chili, and understood better the farmers' perception towards these insect pests, their importance, and the need for effective control measures. Likewise, from the participatory on-farm trials carried out at the community/village level, several of the constraints of chili cultivation are now better understood by project staff. The community-level impacts are illustrated by the following economic, social, and environmental categories.

Economic impacts

Farmers became more aware of the economic importance and levels of risk, cost, and income associated with chili cultivation in each of the project sites. Currently, an average chili farmer in Central Java applies about 12 kg/ha of pesticides per chili field, which varies from 5 kg/ha of chemicals in Rembang to 22 kg/ha in Brebes site. Out of the total production cost, about 25% is for pesticide use. Labour for chili farming (per ha and per crop season basis) is about 560 man days in Central Java, which is about 3.5 times higher than that of labour for paddy farming in the area (180 man days/ha). Hence, any improvement of technologies that can reduce use of pesticides (like IDM tools evaluated by the project) would have high economic impacts on the livelihoods of chili farmers and community.

The most obvious impact has been the voluntary adoption of barrier strategies to reduce whitefly incidence in pepper fields and delay disease onset. This can potentially reduce the geminivirus disease pressure and spread, as well as the costs related to pesticide application, including the high environmental and social cost associated with pesticide use. The use of nylon netting or maize borders to prevent the WTG vector was of interest to farmers, but was not adopted by many of the farmer co-operators because of the high costs of implementation. Much more favourable response has been encountered with the use of *Crotalaria* to form the border, not only because of improved yield and quality in the chili crop, but also because of its easy management, dense stand, tall growth, and value as a post-crop green manure. Grower interest may have been strengthened by the strong market price for chilies in 2009 and 2010, which coincided with the demonstration planting of the *Crotalaria* border, doubly rewarding improved productivity. During the rapid impact assessment and consultation with farmers in Magelang, those who had adopted the crop barrier reported that their overall profit from the chili plot was enhanced by around 15-20% after adoption of the crop barrier technology. This is largely due to delay in onset of disease infestation, resulting in improved yields, and saving on pesticide input costs.

Many chili fields display a bright mottle of yellow plants infected by begomovirus. However, farmers feel that the plants are still productive, and decline to remove these potential infective havens within their fields. The economic wisdom of that practice should be evaluated.

Drip irrigation during the dry season, when many fields are left fallow, offered clear economic potential for the target areas. The project introduced this technology with low-cost drip kits imported at substantial cost from India. These kits needed modification to adapt to local conditions, but were subsequently successful and appreciated. In the field trial in Rembang, the kits saved irrigation-related labour costs by around 30%. Unfortunately, there was no local distributor of the equipment and supplies, so adoption was delayed.

Social impacts

The baseline survey highlighted some of the social dimensions involved in chili pepper production, particularly the comparative riskiness of the endeavour, and the large regional differences in the adoption of modern hybrid varieties. Chili farmers tend to be slightly younger and better educated than their rice-growing neighbours, and consequently seem to be more receptive to suggestions that can improve their productivity. In Rembang and Brebes, peppers occupy a contingent, although important, place in the seasonal rice rotations, due to periodic scarcity or oversupply of water. Thus in Rembang, where much land lies fallow during the dry season due to lack of water, drip irrigation opens opportunities for a supplemental vegetable crop that was unaffordable under conventional practice. Similarly, barrier plantings to inhibit whitefly movement and virus infection were poorly received because of the high costs of net barrier materials, or the excessive diversion of crop land for a maize barrier; the reintroduction of *Crotalaria* (which some farmers used in years past as a green manure fallow crop) has stimulated interest in the crop protective strategy. Although most AVRDC candidate lines have problems with poor adaptation to the climate, disease environment, or market demands, project personnel were able to develop good relations with farmers, and farmers were willing to participate in evaluations in hopes of identifying a "breakthrough" variety. Farmers did not reported any negative factors associated with the technology packages introduced/adapted by the project in each of the three sites, except for the high cost of drip irrigation equipment, and difficulties in obtaining biopesticides commercially or in formulating them by themselves. If these market constraints were alleviated, more farmers are likely to try these innovations.

Environmental impacts

The baseline study reported factors that encourage/discourage farmers to use pesticides when cultivating chili in Central Java, Indonesia. On average, farmers apply 12 kg/ha of pesticide on chili in a crop season of four months. Factors associated with application of higher doses of pesticides are increases in prices for chili, number of observed insect pests, share of non-hybrid varieties, and use of pesticide “cocktails.” Factors lowering pesticide use are increases in prices of pesticides, level of farmers’ education, farmers’ experience in growing chili, number of observed diseases, and area planted to chili. Pesticide use can be reduced by training and exposing farmers to improved pest and disease management practices and providing alternative control strategies. Policies related to price of pesticides would not be effective, as farmers’ reliance on pesticides was high. These findings will be useful for reducing pesticide use in chili farming in Indonesia and in tropical vegetable farming, in general.

This project included biopesticide and compost tea formulations in candidate practices; both showed some value in reducing disease incidence and certainly improved crop vigour and yield. Exposing these technologies to farmers and agricultural official staff can contribute to environmental awareness among farmers, and their adoption will help maintain environmental stability, increase biodiversity to improve the insect pest/predator balance, and reduce environmental pollution. The field trial in Brebes found that conventional practice of applying a known fungicide to control anthracnose had diminished effectiveness, while inclusion of alternating applications of low-toxicity biological fungicides developed at IVegRI could restore good control. Substitution of more environmentally benign pesticides can be a valuable innovation for benefit of the environment, the consumer, and the farmer.

Using rice straw for mulching vegetable beds enhances field sanitation and adds organic matter back to the soil matrix. Compost tea and composter equipment save and recycle agricultural and household waste. Barrier crops such as *Crotalaria*, which had become disused in recent years as cultivation became more intensive and based on external inputs, have a useful second life as a green manure additive to build up soil health. Leaves of *Crotalaria* and field waste such as weeds could be processed as compost by using simple equipment that farmer may already have. The use of *Crotalaria* also delays whitefly incidence, resulting in reduction in environmentally detrimental pesticides by approximately 20%. Composting and fertilization with compost teas has been shown to reduce plant diseases, as well as increase plant health and yield, while reducing use of inorganic fertilizers by 20%. Use of biofungicides for integrated crop management could potentially reduce use of synthetic chemical fungicide by two-thirds, leading to a safer environment for the farmer, the community, and the consumer.

8.4 Communication and dissemination activities

Meetings and training sessions with farmers are summarized in Table 29. As much as possible, farmers were involved in participatory trials and in demonstrations of the candidate technologies. Exposure to the methods motivated some farmers to apply them in their own fields.

The largest number of interested farmers attended the Farmers' Field Day (FFD) in Brebes and saw candidate methods demonstrated directly in the field. Use of straw mulch and compost tea gave a distinct benefit to the farmer. Unfortunately, demonstrations of biofungicide *B.subtilis* did not satisfactorily reduce anthracnose significantly, and home production remains difficult to adopt.

From 2008-2010, Farmers Field Meetings (FFM), and group discussions following day-long hands-on training were frequently conducted in several villages in Magelang, where the participatory research trials (on-farm trials) were conducted. IDM project staff in Indonesia took active part in organizing the meetings in close cooperation and with the support of DINAS/Magelang office.

The combination of FFD and FFM was successfully implemented with key farmers in Magelang. The average initial score of familiarity with IDM strategies of farmers increased from 5.7 to 8.3. Farmers were interested in *Crotalaria* barriers, in contrast to convention practice, and the farmers were able to directly observe the delayed Incidence of WTG, reduced damage, and higher yields in the improved technology treatments. They expressed a willingness to reintroduce *Crotalaria,* a traditional but neglected companion crop. Other technologies, including simple composting equipment and use of rabbit urine, were shared among the farmers. FFD presentations were organized twice and attracted farmers from distant communities, who may further the spread of the technology and promote its broader adoption.

Because of the remote location and difficulty in organizing training events, little extension activity was carried out in the Rembang area. In May 2009 and 2010, meetings among participating farmers and representatives from AVRDC and the project personnel were held to discuss trials and their interpretation. Farmers were eager to ask questions and provide comments on the progress of the drip irrigation and variety evaluation trials.

Table 29. Summary listing of training activities organized by the project.

Month and Year	Activities done/ Locations	Remarks/No of farmers attended/participants
A. FFM (Farmer Field Meetings- training, formatted as farmer meeting and discussion)		
January – February 2007	- FFM and farmer discussion in Kersana, Brebes when ICM in Kersana was organized	9 farmers in Kersana
April 2007	-Final farmer meeting for 2007 in Kersana, Brebes	Extension from Dinas Brebes, IVegRI Lembang and representative in Brebes, IDM team, and 13 farmers
December 2007- March 2008	-ICM in Klampok, organized FFM in Klampok, Brebes	5 key farmers in Klampok
April 2008	-Final meeting in Klampok, Brebes	Brebes extension, IVegRI Lembang, Brebes, IDM and 5 farmers
November 2008-April 2009	-ICM in Kersana (3 locations) and Randugede (1location), Brebes	BPP Tanjung leader+extension and crop protection staff, also involved, IVegRI Lembang and Brebes, IDM, BPTP and 40 farmers
July-December 2008	1st ICM for dissemination in Magelang (5 sub-districts)	Local village authority, IDM, IVegRI and Dinas extension for crop protection and also from horticultural section.
3rd week July 2008	FFM 1: Field discussion : general problem and chili losses in the field	
21 September 2008	FFM 2: Pre-test for farmer participants by IDM in Dinas Pertanian office.	Average participants 25-33 farmers every time meeting
14 -16 October 2008	FFM 3: Integrated Control of Insect Pest on Chili	25 farmers
16 October 2008	FFM 4: Farmers group dynamics and major diseases discussion	25-33 farmers
August 2009-January 2010	2nd ICM in Magelang 5 sub-district locations	125 farmers spread out in 5 sub-districts and also Kaliangrik
September – December 2010	ICM special issue on *Crotalaria* barrier in Secang	Field activity during workshop

Month and Year	Activities done/ Locations	Remarks/No of farmers attended/participants
B. FFD (Farmer Field Day)		
22 April 2009	FFD in Kersana, Brebes Technology dissemination subject: Straw usage, plus compost application also compost as biofungicide. Reduced biopesticide in general. Increase yield.	BPP Tanjung leader+extension and crop protection staff also involved, IVegRI Lembang and Brebes, IDM, BPTP and 70 farmers; in total, about 100 participants.
29 September 2010	FFD in Secang and Sawangan, Magelang.	ACIAR evaluators, IDM team from AVRDC HQ, IDM team Indonesians, IPB, UGM, Dinas leader and staffs, farmers, local authorities, totally about 73 people.

Month and Year	Activities Done/Locations	Remarks/No. of farmers Attended/Participants
C. Workshops/Seminars		
27 August 2008	IVegRI Progress and achievement of IDM project, for future work.	IDM participants gave their progress report in Lembang
May 2009	In IVegRI, progress report by IDM participants	IDM participants and IVegRI leader
June 2009	A day seminar organized at BPTP NAD, Banda Aceh to share the chili IDM project findings (chili production practices) with the BPTP project team in Aceh.	Presentation of Drs. Madhu Bhattarai and Joko Mariyono. The seminar was attended by agricultural officials of Aceh, lecturers and students of Syiah Kuala University-Aceh.
July 2009	A paper was presented at ISHS – organized international workshop on Economics and Management and training in Chiang Mai, Thailand	About 150 participants attended the conference
October 2009 (PERHORTI, IPB)	IDM-AVRDC took part actively in International Horticultural Workshop in Bogor	IDM (Anna and Joko), IVegRI (Rakhmat Sutarya), BPTP (Sutoyo) and IPB and most of PERHORTI members in Indonesia.
3-4 May 2010	Project review and planning meeting at Hotel Panorama, Lembang	IDM participants and IVegRI leader and Dr. Paul Gniffke
28 -30 September 2010	IDM Completion Workshop in Hotel Puri Asri, Magelang Evaluation of IDM project execution and future work.	ACIAR evaluators, IDM team from AVRDC HQ, IDM team Indonesians, IPB, UGM, Dinas leader and Head of Horticultural section, Head of food crops, IVegRI leader, BPTP representative and Ministry of Agriculture representative from Jakarta (Dr. Eri Sofiari)
2nd July 2010	Participation at seminar in development economics, LPEM Univ., Indonesia, and collaboration with ANU, Canberra	Joko Mariyono participated and shared work with about 26 participants.
28-29 July 2010	10th Indonesian Regional Science Association meeting in Surabaya	A paper presented by Joko Mariyono, to about 400 participants
1-2 December 2010	International Conference on Food safety and Food security, Yogyakarta	Presentation made by Joko Mariyono to about 200 conference participants
March 2011 (forthcoming)	1st ISHS Symposium on Sustainable Vegetable Production in Southeast Asia, Salatiga-Indonesia. Two papers will be presented in the symposium	About 500 participants are expected to attend.

Month and Year	Activities done/ Locations	Remarks/No of farmers attended/participants
D. Press brief and news published locally		
October 2006	Local newspaper	Picture already sent
September 2010	Articles in Magelang, Yogyakarta, and Central Java newspapers published	Newspaper already given to HD and Picture already sent

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AVRDC's popular illustrated book "Pepper Diseases: a Field Guide" has been translated into Bahasa Indonesia by Dr. Dibiyantoro and Dr. Asti Hidayat. This book includes photos and descriptive text, and is a significant aid to farmers, extension agents, and researchers in field identification of pepper crop diseases, including those targeted in this project. It has been distributed through IDB, IVegRI, and BPTP. Initial response from a small group of farmers in the Rembang area has been very positive.

Conferences:

The project team members in Indonesia took active part in the Indonesia Horticulture Congress organized in Bogor, November 2009. The project team organized a separate symposium (”Symposium on Vegetable R & D in Sumatra and Java") on AVRDC project activities in Indonesia, and the project team was able to present five papers on different topics out of the chili IDM project activities in Indonesia. This gave a good opportunity share the project activities and project findings with national horticultural sector scientists and key stakeholders and planners in Indonesia.

Dr. Hidayat attended:

- Indonesian Plant Pathology Society meeting: Makassar, August 4 – 7, 2009
- Australian Plant Pathology Society annual meeting: Newcastle, New South Wales, Australia, September 29 – October 1, 2009
- World Congress on Virus and Infection: Busan, Korea, August 1-3, 2010

9 Conclusions and Recommendations

9.1 Conclusions

Pepper (*Capsicum spp*.) is a highly profitable cash crop popular with farmers and their markets, but its production also poses significant risks. Peppers continue to grow under substantial pressure from pests and diseases. Whitefly-transmitted gemininviruses have become the most prominent viral disease in Indonesia, and incidence continues to expand. Anthracnose likewise is a serious threat to crop productivity during rainy weather. Phytophthora was found in only isolated pockets, but the diversity of the pathogen indicates that it has the potential to recombine to produce more virulent and more widespread isolates, and so cannot be ignored. Significant economic losses in crop productivity result in the chili farmer resorting to expensive and hazardous programs of pesticide application, often to little avail.

Nevertheless, options have been identified to address these challenges. As appropriate, relatively simple agronomic adjustments, such as raised beds and plastic mulches, can reduce losses related to excessive soil moisture and competing weed growth. Drip irrigation also mitigates damage due to irregular flood irrigation, and makes much more efficient use of water resources. Biofungicides *(Bacillus subtilis*) has been shown to be a potent complement to conventional synthetic fungicides, which may have lost their effectiveness due to overuse. Production of seedlings under insect-proof netting can prevent early infection by WTG or other insect-vectored diseases, while barrier crops surrounding the chili planting can delay the onset of disease incidence enough to allow plants to achieve potential productivity, and to continue production well beyond normal. Sunn hemp (*Crotalaria juncea)* is particularly promising, as it complements the pepper crop with a valuable green manure, and may even improve the nitrogen status of the soil.

The long-term solution—host plant resistance—is also within reach of a conscientious and long-term breeding program. Sources of resistance to all three pathogens have been identified by AVRDC researchers, and new resistant accessions have been found through the activities of this project. Initial breeding lines selected in Taiwan were less successful than hoped due to differences in the disease pathotype encountered, inadequate adaptation to the target growing environment, and inability to meet consumer demands regarding fruit size, shape, colour, flavour, or pungency. A small handful of promising lines have been identified (notably PP0537-7558) that will be submitted for further validation and potential release to farming communities.

9.2 Recommendations

- *Crotalaria* barrier borders provide significant protection against whiteflies, and consequently, defence against infection by WTG. Further evaluations and demonstrations are merited.
- Drip irrigation systems have proved highly favourable in maximizing water use efficiency, reducing labour costs, controlling weeds, and reducing soil-borne diseases. Farming areas particularly prone to water shortages, or with a long dry season, should be encouraged to consider the merits of drip systems.
- Biofungicides, when used in rotation with synthetic fungicides, may contribute materially to control of anthracnose by broadening the sources of control, further tests and validation of its benefits are warranted.
- Surveillance of important pests and diseases (especially WTG) on pepper should be executed regularly and continue to predict and prevent outbreaks in other areas.

- Pyriproxyfen is highly recommended for controlling whiteflies, not only in chili pepper but also in other vegetables susceptible to geminivirus.
- Nylon net barrier with #50 mesh should be used to exclude whiteflies during seedling production, especially when the geminivirus poses a threat to vegetable production. Companion crop borders, notably *Crotalaria*, may provide significant protection by delaying initial infection, reducing the overall insect pressure, and altering the microclimate under which the pepper crop is grown; its use should be further evaluated as an alternative to pesticide application programs.
- Based on participatory trial results from Kaliori in 2010, and associated evaluations at IPB and IVegRI, the following AVRDC lines are recommended for further evaluation, and possible commercialization:

Kaliori

Entry	**Line**	**Parentage**	**Comments**
11/19	0537-7558	Jin'sJoy//Kulai*3/PBC932,	"I" re Duriat; res.Anthr
22	0707-7512-B	KR-B/VC246//KR-B/0209-4 ,	
21	0737-7651-1	KR-B/VC246//KR-B/0209-4,	65% virused in Asti's trials,"S". re Duriat
24	0737-7641-B	KR-B/VC246//KR-B/0209-4	90% virused in Asti's trials, "R" re Duriat
13	0735-5677-1	KR-B (res BW)/NP-46-A	95% virused in Asti's trials, "I" re Duriat
N/I [a]	0735-5676-1	CCA7475-4-1-1-1 KR-B (res BW)/NP-46-A	5% virused in Asti's trials
N/I [a]	0735-5680-1	CCA7424-1-3-1-1 Lorai/KR-B (res BW)	10% virused in Asti's trials
Resel'd[b]	0937-7635-1	CCA7475-4-1-1-1-1-4-1-1 KR-B (res BW)/NP-46-A	F910PYT
Resel'd [b]	0937-7637-1	CCA7475-4-1-1-1-2-2-1-1 KR-B (res BW)/NP-46-A	F910PYT
Resel'd [b]	0937-7614-1	CCA7389-1-1-1-1-1-1-1 Kulim/HDA248//Perennial HDV	F9 1009-increase
Resel'd [b]	0937-7615-1	CCA7389-1-1-1-1-1-2-1 Kulim/HDA248//Perennial HDV	F9 1009-increase
Resel'd [b]	0937-7616-1	CCA7389-1-1-1-2-1-1-1 Kulim/HDA248//Perennial HDV	F91009-increase
Resel'd [b]	0937-7616-2	CCA7389-1-1-1-2-1-1-2 Kulim/HDA248//Perennial HDV	F91009-increase
Resel'd [b]	0937-7623-1	CCA7390-2-1-2-1-1-2-1 Kulim/HDA248//PSP-11	F91009-increase
Resel'd [b]	0937-7624-1	CCA7390-2-2-1-1-1-1-1 Kulim/HDA248//PSP-11	F91009-increase
Resel'd [b]	0937-7626-1	CCA7394-4-2-1-1-1-1-1 Kulim/HDA248//Tiwari	F91009-increase
Resel'd [b]	0937-7629-1	CCA7398-4-1-4-1-1-1-1 Kulim/HDA248//Lorai	F91009-increase
Resel'd [b]	0937-7631-1	CCA7399-2-2-1-1-1-1-1 Kulim/HDA248//Puri Red	F91009-increase
Resel'd [b]	0937-7636-1	CCA7475-4-1-1-1-2-1-1 KR-B(res BW)/NP-46-A	F91009-increase
Resel'd [b]	0937-7638-1	CCA7475-4-1-1-1-2-3-1 KR-B(res BW)/NP-46-A	F91009-increase
Resel'd [b]	0937-7641-1	CCA7475-4-1-2-1-2-1-1 KR-B(res BW)/NP-46-A	F91009-increase
Resel'd [b]	0937-7641-2	CCA7475-4-1-2-1-2-1-2 KR-B(res BW)/NP-46-A	F91009-increase
Resel'd [b]	0937-7642-1	CCA7475-4-1-2-1-2-2-1 KR-B(res BW)/NP-46-A	F91009-increase

[a] not included in field evaluation, but promising in resistance screening and fruit type

[b] Reselected progenies of candidate lines, should be more uniform for resistance and performance; some also show partial resistance to CVMV, Bacterial Wilt and anthracnose.

This table includes AVRDC reselections of the lines reported as immune or resistant by IVegRI or IPB. The original lines, and reselections thereof, should also be evaluated: Twelve lines that were immune (0735-5677-1, 0735- 5617-1, 0735- 5623-1, 0735-5629-1 and 0735-5649-1) and resistant (0735-5687-1, 0735-5601-1, 0735-5614-1, 0735- 5636-1, 0735-5646-1, 0735-5670-1) against WTG resulted from this activity should be continued with the field test in endemic areas using prepared seeds.

- Certainly, the line PP0537-7558 should be increased and subjected to extensive multilocation testing to confirm both its resistance to two or more diseases, and also its yield potential and consumer acceptability. It should then be officially and promoted to appropriate farming communities.

- Further screening for resistance to diseases, particularly WTG, should be pursued, both under lab conditions in laboratory work at IVegRI and IPB, and under unprotected field conditions at multiple locations. Ongoing pathology research should clarify conditions contributing to infection and disease development, and economic thresholds for disease incidence and timing.

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11 Appendixes

See Table of contents (pp iii-v) for listing of documents included in separate volume of Appendices.

AVRDC – The World Vegetable Center's Global Technology Dissemination: Approaches, Roles and Activities

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Keywords: technology dissemination, dissemination approach, germplasm exchange, disaster response, training

Abstract

Technology dissemination is an important part of AVRDC - The World Vegetable Center's research and development (R&D) activities. AVRDC's Global Technology Dissemination (GTD) group was formed in 2008 to catalyze the dissemination of vegetable R&D technologies to farmers and other end-users. Various technology dissemination methods are described, including germplasm exchange, Farmer Field Schools, field days, demonstrations, extension publications, and seed kits for disaster response. GTD is mainly concerned about technologies that can be applied by resource-poor farmers and which create on-farm impacts that fulfill AVRDC's mission to alleviate poverty and malnutrition in the developing world through the increased production and consumption of safe vegetables.

INTRODUCTION

Technology dissemination is an important part of AVRDC - The World Vegetable Center's research and development (R&D) activities. AVRDC's Global Technology Dissemination (GTD) group was formed in July 2008 to catalyze the dissemination of vegetable R&D technologies to farmers and other end-users. GTD coordinates technology transfer activities at AVRDC with the aim of disseminating and upscaling AVRDC's vegetable production and consumption technologies in locations where the largest impacts can be generated. AVRDC is attempting to build its capacity to respond to disasters around the world in ways that fit with regional needs and center on vegetable-related solutions. Technology dissemination also occurs through training scientists at AVRDC Headquarters and Regional Centers. GTD also coordinates many R&D activities with the Regional Centers and Offices to enhance implementation of AVRDC's Mission.

ROLE OF GLOBAL TECHNOLOGY DISSEMINATION AT AVRDC

AVRDC's Global Technology Dissemination group has three main goals: (1) to integrate vegetable technologies from AVRDC and other sources and make them readily available to farmers, trainers, consumers, public/private institutions and other end users; (2) to respond to disaster situations in less-developed countries by providing appropriate short-term development activities in ways that are in line with AVRDC's strengths and abilities; (3) to enable training and capacity building activities at Headquarters (HQ) to be conducted in an effective and efficient manner. The human resources in GTD currently include two internationally recruited scientists and eight nationally recruited staff, who are located at AVRDC

Headquarters in Taiwan. One internationally recruited scientist located in Cameroon is an adjunct member of GTD.

GTD actively disseminates technologies that involve all five of AVRDC's R&D Themes: Germplasm, Breeding, Production, Marketing and Nutrition. The GTD group also plays an important role in AVRDC's development-oriented donor-funded projects. GTD leads a project in Indonesia and provides support to a wide range of projects in Asia, Africa and the Pacific. GTD's major activities and services include the following:

Technology Integration

The process of integrating vegetable technologies from AVRDC and other sources into coherent and holistic packages that can be adapted by resource-poor farmers was initiated by holding meetings and distributing a questionnaire to gather information on AVRDC's mature technologies. GTD's definition of a mature technology is one that is ready to disseminate to farmers and other end users. GTD is in the midst of creating a user-friendly database of mature vegetable technologies and this will be available on AVRDC's new website soon.

'D' Project Development

GTD works with AVRDC scientists and administrators to develop project proposals with pro-poor development/extension components oriented towards local stakeholders' needs. The recommended process for AVRDC's development projects is to first conduct a participatory appraisal to identify local constraints and subsequently hold a planning workshop to: (1) design applied research trials to adapt appropriate technologies to local agro-ecological and socio-economic situations; (2) define technology dissemination strategies; (3) redesign any other aspects of the project's work plan so that they fit with local stakeholders' needs (Figure 1). As the project is carried out, improved technologies are adapted and disseminated to stakeholders according to the work plan designed after the participatory appraisal, increasing the likelihood that these technologies will be adopted.

To increase the scope of AVRDC's development efforts, there are plans to expand activities in the following areas: vegetable germplasm conservation and accelerating utilization; dissemination of safe and effective vegetable production practices; plant health services; protected structures for vegetable production; vegetable seed kits for disaster response; vegetable agroforestry systems; and vegetable integrated pest management for South and Southeast Asia, Africa and the South Pacific.

Extension Publication Development

Extension publications need to be farmer-friendly, with color photos, drawings, and non-technical language. After GTD's mature technology database is completed, gaps in AVRDC's extension publication portfolio will be determined and the necessary factsheets, booklets, posters and brochures will be designed and published to increase technology dissemination efficiency.

GTD produces a news bulletin entitled *Feedback from the Field* to provide feedback to AVRDC's research groups about local vegetable production and consumption constraints to enable our research to be more pertinent to end users. It started as an internal AVRDC publication but is now being distributed externally also. It is issued quarterly (January, April, July and October) starting from January 2009. Submission of materials is open to anyone; if interested, please send your news of anything urgent from the field to tech_dissemination@worldveg.org. The most recent issue (Issue 3 - July 2009) can be downloaded from the AVRDC website (www.avrdc.org).

In addition, a searchable database of AVRDC's extension publications was developed and is available on AVRDC's website under the 'Extension Publication' category. It will be updated regularly.

Germplasm Exchange

AVRDC - The World Vegetable Center distributes germplasm accessions conserved in its genebank and breeding lines developed by its breeding units to National Agricultural Research and Extension Services (NARES), non-government organizations, private sector institutions and other interested parties around the globe. The Genetic Resources and Seed Unit (GRSU) serves as the exit point for all materials going out of AVRDC. GRSU processes requests for germplasm accessions, while GTD processes requests for breeding lines and combined requests for breeding lines and germplasm accessions.

Requesters must agree to the terms and conditions of AVRDC's Material Transfer Agreements (MTAs) before their requests are processed. Germplasm accessions and breeding lines are accompanied by MTA1 and MTA2, respectively. The MTAs state that distributed vegetable genetic resources can be used or conserved for the purposes of research, breeding and training for food and agriculture. Chemical, pharmaceutical and/or other non-food/feed industrial uses are not allowed. The recipients of germplasm accessions and breeding lines should not claim any form of intellectual property or other rights that limit the access to and use of the said materials or their genetic parts or components in the form received. This will ensure that the vegetable genetic resources held in-trust and developed by AVRDC are available to all interested parties. In MTA2, commercialization of AVRDC breeding lines and products derived from them will involve an agreement with AVRDC. In MTA1, recipients can release outstanding germplasm accessions to farmers for cultivation without entering into an agreement with AVRDC.

The conservation of the genebank materials which involve viability testing, regeneration, characterization, medium- and long-term storage, and documentation; the development of new breeding lines; and seed processing for plant quarantine certification and shipping entail extensive human and financial resources. Thus, AVRDC is obliged to charge for seed distribution to achieve partial cost recovery. Advanced research institutes, universities and the private sector are US$30 per germplasm accession and US$50 per breeding lines for seed processing and shipping. National programs and universities in developing countries are charged a lump sum fee of US$30 per shipment of up to 15 germplasm accessions and/or breeding lines, and US$6 and US$20 for each additional germplasm accession and breeding line, respectively.

From January 2009 to date, GTD has received 90 seed requests from 27 countries (Table 1). Around 77% of the seed requests (around 640 seed packets) have been completed. Taiwan, India and China are the top three recipients. In Taiwan most requests are for AVRDC's cytoplasmic male sterile and restorer pepper lines. Around 48% of the seed requests are from the private sector. Most recipients of AVRDC breeding lines are involved in variety testing and/or variety development.

AVRDC Demonstration Garden

A 0.63 ha demonstration garden is maintained year-round to display AVRDC's improved vegetable lines, selected nutritious indigenous vegetables and field ready technologies. It serves as a platform for information dissemination and exchange, scientific education and aesthetic appreciation for the staff and visitors. GTD is in charge of the maintenance and management of this garden. It is divided into different areas for AVRDC-developed promising lines (about 45 lines); African (about 70 lines), Asian (about 50 lines), Pacific (about 20 lines) and aquatic indigenous vegetables (about 10 lines); priority crops for disaster response (6 crops) and field ready technology demonstrations, including grafting, low-cost drip irrigation, starter solution technology, a net house and a net tunnel. A garden tour is given once a week on average based on requests. Visitors to this garden numbered 343 over the past year (Table 2). Our visitors are from all over the world.

Training for Capacity Building

GTD provides an important service by facilitating administrative issues and logistics for trainees coming to AVRDC Headquarters for capacity building activities across a wide range of disciplines. AVRDC offers many opportunities for scientists and students to participate in its research and development (R&D) programs. Through these opportunities AVRDC is contributing to building the capacity of well-trained and highly motivated scientists engaged in vegetable research, development/extension, and policy formulation worldwide. These training opportunities also provide AVRDC a means of strengthening its R&D capacity in critical areas. A total of 38 people from 13 countries were trained over the past year at AVRDC Headquarters (Table 3). For further information on training at AVRDC, please check our website.

Disaster Response

Natural and man-made disasters can have profound effects on the agricultural systems of rural people. One way to rebuild the food supply system in a short time after a disaster occurs is to ensure access to vegetable seeds to provide a quick and nutritious supply of vegetables. To ensure seed is available when and where it is needed, AVRDC – The World Vegetable Center's Headquarters and its Regional Centers plan to work together to prepare 50,000 vegetable seed kits each year. Each kit provides enough seeds for one household to grow vegetables on 100 m^2 of land to enhance vegetable consumption during the initial months after a disaster.

The objectives of this program are to respond to nutritional crises and immediately contribute to the rehabilitation of vegetable production in the most vulnerable farming communities in disaster-affected regions by providing vegetable seed kits for the disaster victims. The kits will include various kinds of nutrient-rich, fast-growing, and locally appropriate vegetable seeds, in addition to relevant technical information in local languages on vegetable production and food preparation and preservation methods.

The appropriate crops for the kits have been selected based on the following criteria: commonly cultivated in many tropical and subtropical less-developed countries, nutritious, hardy, fast-growing, low input requirements, and relatively free of pest and disease problems. The crops that have been selected for Southeast and East Asia are kangkong, amaranth, Malabar spinach, okra, jute mallow and mungbean. Different crops have been selected for Sub-Saharan Africa and South Asia which fit local preferences.

Easy-to-understand instructions for cultivation, field management, and food preparation will be available in various local languages and included in the kits. To be ready for disasters before they occur, the seed kits will be assembled and all possible quarantine processing will be conducted ahead of time with countries where disasters are more likely. The vegetable seed kits will be distributed mainly to farmers in disaster-affected areas in cooperation with relief agencies through the most effective and appropriate means.

TECHNOLOGY DISSEMINATION METHODS/APPROACHES

A range of effective technology dissemination methods are listed below, although this is not meant to be a comprehensive list:

- Training of Trainers (ToT)
- Farmer Field Schools (FFS)
- Field days
- Fact sheets, booklets, leaflets, posters and other extension publications
- Demonstration plots
- Radio or TV programs, videos
- Communication forums
- Dramas
- Campaigns to spread simple messages
- Lessons in the curriculum for children's school programs
- Mobile Integrated Pest Management/Integrated Crop Management teaching laboratories
- Cell phone messages/ broadcasts
- Plant health clinics

Technology dissemination activities take place in a specific historical, political, economic, agroclimatic and institutional context. The influence of these contextual factors may be crucial in determining the outcome of a particular extension activity. Appropriate dissemination methods are chosen based on the local situation (although the available budget often determines what is feasible). Often a participatory approach is needed when implementing development/ extension activities to maximize impact at the stakeholder level.

Application of the 'training of trainers' approach: Training of Trainers (ToT) and Vegetable Integrated Crop Management (ICM) Workshop, Aceh, Indonesia

In a project led by GTD, a participatory assessment and baseline survey determined that chili pepper is the most important vegetable crop in tsunami-affected areas of Aceh Besar, Pidie, Pidie Jaya, Bireuen, and Aceh Utara Districts. Furthermore, the baseline survey confirmed the high income potential that chili pepper has for Aceh farmers and their strong interest in planting it. According to baseline survey results, the major problems with chili pepper at the farmer level are pest and disease attacks, among them anthracnose and thrips. Nutrient deficiencies (N, P and micronutrients) were also common in many of the fields visited during the participatory assessment. A ToT and Vegetable ICM Workshop was then designed to respond to the needs of farmers in Aceh, targeting the aforementioned issues.

A total of 35 participants, including 20 FFS trainers/facilitators and 15 agricultural R&D staff, attended the ToT and ICM Workshop focused on chili pepper, which was held in Saree, Aceh Besar on 13-24 October 2008. Evaluation questionnaires were distributed on the closing day of the training and were filled in by all the participants. The participants ranked the usefulness of the subject matter as 9.06 (range 1-10, maximum is 10), and on average, they experienced 57% improvement in their knowledge and understanding of vegetable production as a result of the ToT and ICM Workshop. The FFS Facilitators organized and led FFS over the following year.

Application of the Farmer Field School approach: a case from Aceh, Indonesia

AVRDC and the Assessment Institute for Agricultural Technology (AIAT or BPTP) are training farmers, through Farmer Field Schools (FFS), on improved production practices of vegetable farming in the tsunami-affected areas of Aceh, Indonesia. This FFS program aims to include 1600 farmers by November 2009 and up to this point over 1450 farmers have already been trained on chili pepper ICM practices. Eighty FFS are being organized in five districts of Aceh. The market price of chili was high over the past year, making it a very popular crop with farmers; chili was chosen as the priority crop for the FFS based on results from a participatory assessment and baseline survey.

Through restoration of soil fertility on vegetable farmland and dissemination of vegetable production technologies, the project plans to improve community livelihoods in these tsunami-affected areas. At present, an evaluation of the FFS is being conducted using a framework of Participatory Impact Assessment (PIA). In the FFS, 15 different crop production technologies are emphasized. Among them, farmers have given a high preference for adoption of the following technologies:

- Composting/Bokashi preparation
- Pest and disease identification
- Application of botanical pesticides
- Proper methods of pesticide use
- Netting to protect seedlings from pests and diseases

The preliminary impacts of FFS training on improving farmers' knowledge and skill on cultivation of chili with low-input systems and IPM technologies were astonishing. During a recent survey, the FFS participants reported that, with the knowledge they gained from the training and by adopting the selected ICM techniques learnt from the FFS, their average chili productivity would increase by over 30-40% and the profit would rise by 50% within 1-2 years. The average yield of chili in the FFS ICM plots was 50% higher than in the local farmers' treatment plots. The higher profit from the improved method of chili farming is also largely due to cost-saving on pesticides and other chemical inputs due to adoption of low-cost ICM technologies.

Application of the field day approach: Field Day of Cytoplasmic Male Sterility in Sweet Pepper to Produce Hybrid Seed, Taiwan

Pepper breeders at AVRDC – The World Vegetable Center took on the challenge and worked for more than a decade to develop methods and materials for cytoplasmic male sterility (CMS) in both hot and sweet peppers. To date, the breeding program has made available more than 20 sterile lines and their maintainers. The success of this long effort was showcased in a field day held on 4 June 2009 at AVRDC Headquarters in Taiwan. More than 60 representatives from Taiwan's seed industry, universities, and government agricultural research stations attended the event.

Four presentations were given to introduce the CMS in pepper and its breeding work in AVRDC. Commercial production of hybrids is feasible only if a reliable and cost-effective pollination control system is available. During hybrid seed production, several methods can be used to prevent selfpollination of the female line, including removing the anthers or male flowers by hand or machine, applying male-specific gametocides, or employing cytoplasmic or genic male sterility systems.

The presentations were followed by a field demonstration tour of several CMS sweet pepper hybrid combinations using AVRDC developed parents and a comparison of hybrids using CMS sterile parents vs. hybrids generated with related maintainer lines. Cages for bee-mediated crosspollination and seed production were also displayed. Participants received seed samples of some lines and will report the results of their own trials. Comments from participants were generally positive and AVRDC's continued effort to advance CMS in sweet pepper was encouraged.

Application of the extension publication approach

Example 1: an extension brochure in Indonesian entitled "Natural Enemies Help Farmers Control Pests" (*Musuh Alami Membantu Petani Mengendalikan Hama*) is now in preparation and will be distributed to 4000 farmers and extension specialists in Aceh by the end of 2009. English and Indonesian versions of this brochure will also be available on the AVRDC website soon.

Example 2: an extension book in English of 60 promising indigenous vegetables was published by AVRDC in September 2009. This book provides detailed information on plant distribution, botanical features, environmental factors, production methods, edible parts and health values for 60 promising indigenous vegetables with pictures and captions. The photographs show features such as the typical appearance of the plant, growth form, leaves, flowers, fruits, and seeds. To encourage readers to fully appreciate the culinary and aesthetic value of indigenous vegetables and integrate them into their lives this book also highlights attractive flower arrangements and appetizing recipes. In addition, a photo gallery shows some social marketing activities conducted at AVRDC-The World Vegetable Center's Headquarters in Taiwan. For readers seeking more specific details on certain indigenous vegetables, an extensive list of references is provided.

Indigenous vegetables play a very important role for enhancing diversity of vegetable consumption and micronutrient intake. Some indigenous vegetables may be globally distributed, but most of them tend to occupy special niches. Many of them are underutilized due to lack of knowledge of their value, particularly in regions where they are not native. Indigenous vegetables usually are less susceptible to pest infestations, have lower input requirements for cultivation, and are easily planted in most tropical developing countries. This book provides intensive information about 60 promising indigenous vegetables for farmers and varietal trial collaborators in developing countries.

FUTURE PROSPECTS

Technology dissemination activities at AVRDC continue to expand, partly due to the formation of the Global Technology Dissemination group in 2008. GTD aims to continue focusing activities in tropical Asia and increase our involvement in Sub-Saharan Africa, Latin America and Central Asia in the future. GTD hopes to increase our role in: (1) guiding AVRDC's R&D projects on participatory appraisal methods; (2) developing projects based on participatory appraisal results to tailor implementation to better meet stakeholders' needs; (3) developing a research program focused on technology dissemination and farmer education methods (efficiency, cost-effectiveness); (4) providing a technology transfer link between AVRDC's Regional Centers and Headquarter's researchers, to enable information to flow efficiently to the field. GTD is mainly concerned about technologies that can be applied by resource-poor farmers and which create on-farm impacts that fulfill AVRDC's mission to alleviate poverty and malnutrition in the developing world through the increased production and consumption of safe vegetables.

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Tables

Table 1. Number of seed requests from the private sector, government research centers, and universities.

Country	No. of requests	Private sector	Research centers	Universities
Afghanistan	1	-	1	-
Cameroon	2	-	2	-
China	8	-	3	5
Congo	1	1	-	-
Fiji	1	-	1	-
France (Reunion Island)	1	-	1	-
Ghana	1	-	-	1
India	13	11	-	2
Indonesia	3	-	2	1
Italy	1	1	-	-
Japan	2	2	-	-
Kenya	2	2	-	-
Mali	2	-	2	-
Mauritius	1	-	1	-
Myanmar	1	-	-	1
Nigeria	1	-	1	-
Pakistan	2	1	1	-
Senegal	1	1	-	-
South Africa	2	1	1	-
Switzerland	1	-	1	-
Taiwan	25	16	8	1
Tanzania	2	-	2	-
Thailand	5	3	1	1
Tonga	1	-	1	-
Uganda	2	1	-	1
USA	6	3	-	3
Vietnam	2	-	2	-
Total	90	43	31	16

Table 2. Number of visitors to the AVRDC Demonstration Garden from July 2008 to June 2009.

Visiting time	No. of group	No. of visitors	No. of countries
Jul.-Sept. 2008	8	85	4
Oct.-Dec. 2008	4	55	11
Jan.-Mar. 2009	7	127	4
Apr.-Jun. 2009	6	76	7
Total	25	343	26

Table 3. Number of people trained at AVRDC Headquarters from July 2008 to June 2009.

Country	No. of trainees
Australia	1
Benin	1
Brazil	1
Canada	1
Germany	3
Honduras	1
India	4
Korea	3
Nicaragua	1
Philippines	7
Taiwan	12
Tanzania	1
USA	2
Total	38

Figures

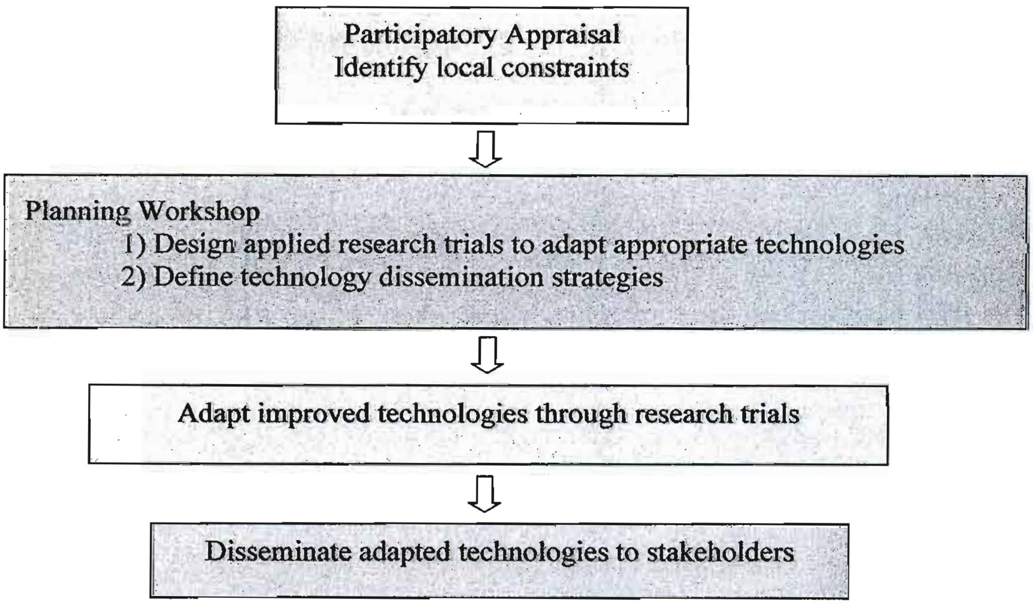

Figure 1. Global Technology Dissemination strategy and process for agricultural development projects.

Factors determinants of pesticides use and disease management practices adopted on chili farming in Central Java, Indonesia2

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Keywords: chili farming, pesticide use, subjective economic threshold, socio-economic factor, tobit analyses, Central java, Indonesia.

– 2009

Abstract

This paper analyzes factors that determine level of pesticide use in chili farming in Central Java. Chili is intensively cultivated in Central Java, and so farmers also apply very high doses of pesticide on chili field. However, there is a wide variation on level of pesticide use across farmers and across the locations within the province. Using a theory of subjective economic threshold (ET), we have analyzed here factors affecting pesticides use decision of average farmers. Data for this study were compiled from a project–led baseline survey conducted in Central Java in early 2008, which involves individual survey of 160 chili growing farm households from three districts: Magelang, Brebes and Rembang. The results show that factors leading to higher doses of application of pesticides are market price of chili, number of insect pests on the field as observed by farmers, non-hybrid variety of chili grown, and more frequency of spray (number of spray) in a season, cocktail method of pesticide spray, and production location. On the other hand, factors that contribute in less use of pesticides use are increased prices of pesticides, higher level of farmers' education and long years of farming experience, more number of diseases observed by farmers, and large acreage cultivated to chili. On an average, farmers are using about 12 kg of pesticide per hectare of chili, and it varies from 22 kg/ha in Brebes to 5.3 kg/ha in Rembang site. To reduce pesticides use (per hectare basis) in chili farming, farmers need more training and exposure to the improved crop management practices, growing resistant to common pests and diseases, reduce the frequency of spray and apply single method of targeted pesticide.

INTRODUCTION

Although chili is not staple food for Indonesian community, it is an important and essential component of the daily Indonesian diet. In addition, with largest crop acreage among fresh vegetables, chili is an important component of agricultural sector policy and government activities. For a diet of ordinary Indonesian, it has to be available everyday and in fresh form, thus, the demand for chili is relatively stable year-round but its supply is not so stable year round. Due to very volatile prices, chili price also frequently becomes a national debated public policy agenda in Indonesia. Because of key component in diet of an average

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people, news on increase or decrease in chili price and its market supply frequently gets national coverage; and becomes a critical issue in farming sector.

National level of chili production in Indonesia has declined recently, but it also fluctuates across the years. Sustaining a constant level of jump in production and productivity of chili, however, is being a difficult task now. Recently, the annual variation on farm values of aggregate chili produced were higher than production, due to high fluctuation in prices than production (Mustafa et al. 2006).

Chili is grown mainly in Java and Sumatra Islands. Out of the total production in the country, more than 20% of chili production was harvested from West Java followed by 17% and 10% from East and Central Java, respectively (BPS 2008). Central Java is the largest chili-producing provinces in terms of chili crop acreage in Indonesia, and it also supplies chili to several other urban centers. Chili production in Central Java is largely concentrated in few places. The top-five districts are Brebes, Magelang, Rembang, Temanggung and Wonosobo (Table 1). In 2007, average chilli yield was highest in Brebes and it was lowest in Rembang.

Table 1. Chili area and production in the top-10 districts of Central Java, 2007

	Area		**Production (t)**		
District	hectare	Share (%)	t	Share (%)	Yield (t/ha)
Brebes	4302	18	34290	30	7.97
Magelang	4062	17	27425	24	6.75
Rembang	3110	13	5728	5	1.84
Temanggung	2817	12	7505	7	2.66
Wonosobo	2432	10	10072	9	4.14
Central Java (Total)	24391	100%	114797	100%	4.71

Source: BPS, 2008

Various factors determine the variation in chilli yield across the sites. Variations on level of pressures from fungal and viral diseases (largely anthracnose and geminivirus) are some of the important factors. They not only reduce overall crop productivity as well marketable yield, but also substantially increase economic risks to the farmer due to high probably of crop damage or crop failure by these diseases. Even though chemical control measures are frequently ineffective or expensive, also potentially causes adverse impact on health both in lowland (Kishi et al. 1995) and highland (Pawukir and Mariyono 2002); chilli farmers use pesticides to control these diseases (and pests). Range of other alternate measures (or non-chemical control measures) has not been so widely used by all chilli growers, but to a limited extent.

Despite of a greater focus on awareness on the health and environmental hazards associated with overuses of pesticide on vegetables, the trend on pesticide use has not yet been reversed. In the vegetable productions, misuse or over use of pesticides is one of the key health and environmental concerns worldwide (Baral et al. 2006). A comparison of pesticide-use intensity in the context of India revealed highest use in chilli, which amount for 5.13 kg of a.i./ha, and the lowest was in while cauliflower, with 2.77 kg of a.i./ ha; despite more number of pesticide applications, the intensity of application (actual amount of chemicals applied) was low in the case of Cauliflower.

Large number of farmers were applying pesticides more than 6 kg of a.i. /ha (of chemical ingredients in different pesticides) for chilli, cauliflower, and Okra in the case of India (Jeyanthi and Kombairaju, 2005). To promote a wise use of pesticides in vegetables, which is the aim and objectives of many international protocol and agreements, we need to know location specific factors determining level and intensity of pesticides use in a location. In this context, the major objective of this paper is to analyze factors affecting pesticide use on chili production in the three communities in Central Java.

LITERATURE REVIEW

Using pesticide, vegetable growers want to guarantee for certain level of crop yield, and income, and minimize risk of crop failure (Farrel 1998). Many modern farming practices, such as new cultivation techniques, large single cropping, and the new high-yielding crop varieties, the backbone of the successful Green Revolution in Asia, are made possible mostly by the availability and use of pesticides. By reducing yield losses caused by pest attacks, pesticides give economic benefit to the farmers. For instance, completely elimination of pesticides use in an intensive farming can substantially reduce vegetable crop's yield (Knutson and Smith, 1999), and in many cases, it even lead to zero level of production. The loss could vary by location, nature of farming, history of pest infestation, and many other factors.

Economic motive (reducing yield loss and increasing income) is one of the key motive and rationality for using pesticides by farmers, and so the level and intensity of pesticides use for a crop. Hence, pesticide use decision is strongly related to price of pesticides and price of crop harvested (ex-ante price), and price of other agricultural inputs. For example, a study by Rahman (2003) in Bangladesh suggested that some farmers treated fertilizers as substitute to pesticides; and he found that an increase in fertilizer price increased pesticide use by rice farmers in Bangladesh. Likewise, an increase in pesticide price reduces its demand. Mariyono (2008a, b) reported that an increase in the prices of rice and soybean in Indonesia induced farmers to use more pesticides to get more farm income and profit. Likewise, Selvarajah and Thiruchelvam (2007) suggested that high price of pesticides minimized level of pesticides use in India, but level of availability of family members in spraying led to increase use of pesticides. But, their study did not find any significant relationship between strength of spray with mixtures of pesticides use, with farmers' education, or experience in production of the crop. Farmers' decision to pesticides use on crop is in fact also same as buying an insurance, i.e., as a preventive mechanism against crop failure due to pests and disease attack.

Level of pesticide use is also dependent on commodity types and agronomical practices followed. Econometric estimation by Heimlich et al. (2000) for US case shows a substantial reduction in herbicide use associated with increased adoption of genetically modified soybeans, corn and cotton. In another study in Bangladesh, farmers applied 12-18 times more pesticide on vegetables than on cereals. Adoption of modern technologies on vegetables, however, generally reduced the number of sprays and the quantity of pesticide. The number of pesticide sprays by non-adopter (farmers) of modern technology was double than that of technology adopter (Ali and Hau 2001). The reduction in pesticide use was mainly attributed to the vegetable production training of collaborative farmers on the judicious use of pesticide. Another study by Selvarajah and Thiruchelvam (2007) in India shows that the estimated average amounts of active ingredients of pesticide applied were 1.9 kg and 11.5 kg/ha/yr for paddy and chili field, respectively. That is almost 6 times higher in case of chili than that of the case in Rice.

Likewise, in Rahman (2003) study, size of farm affected level of pesticides use. Land ownership was significantly positively associated with pesticide use indicating that large farm households used more pesticides, consistent with expectation. The availability of cash, approximated by the agricultural credit variable, was significant and positively related with pesticides use, indicating that greater liquidity increases level of pesticides use.

Level of pesticide use is also affected by the knowledge achieved by farmers. Thus, factors affecting farmers' knowledge will have direct and indirect impacts on pesticides use. Past studies in Indonesia (Mariyono 2007, 2008c) show that pesticide use also dropped along with the increase in number of IPM training. More experienced farmers will have better prediction on estimating yield lost associated with pests and diseases; thus they are more tolerant to the presence of pests, and they can delay spraying and wait until the pest attach reaches economic threshold.

The types of econometric modeling in the literature so far are largely based on underlying input demand function derived from production function of a crop (commodity). The concept of input demand estimation is true if the input is productive, i.e., higher use of input also leads to higher level of output. However, the case of pesticide is a different from that of pesticides use. Unlike fertilizers, higher level of pesticides use does not necessary always leads to a higher yield, thus, they are considered as protective inputs. Pesticide will have significant effect on yield if pests and diseases exist, otherwise not. In this paper, we apply the same concept of economic threshold to and use a pesticide determinant model to evaluate effects of selected factors on chili farmers' decision to use pesticides in Central Java.

RESEARCH METHODOLOGY

Theoretical framework. In economic rationality, farmers' decision to spray pesticides can be considered protective inputs, not productive inputs (Lichtenberg and Zilberman 1986). Thus, pesticides will provide a significant contribution to production if serious P^* attack exists and if the pesticides work effectively to control the attack. If farmers do not observe the level of pest attack, they will not use pesticides more than necessary.

However, economic rationality also suggests that objectives of plant protection are not only for high yield, but also to minimize risk and to ensure economic efficiency on use of pesticide chemicals; thus a concept of "economic threshold" (or *ET*) is important in determining both farmers' decision to use pesticide and its level of uses (quantity of uses and its intensity). The *ET* in plant protection is linked to economic efficiency and economic feasibility of a rational decision maker (resource user or farmer). Several concepts of economic threshold have been introduced in IPM strategy, but economic assessment of factors determinants are still less understood topics. In this study, a mathematical model has been formulated using a concept of economic threshold, as has also been suggested by Mariyono (2007) earlier.

Economic Threshold: For any level of pest attack, there exists a maximum acceptable level of pest attack such that the expected value of yield loss associated with the pest is equal to the cost of pest control using pesticides. The maximum acceptable level of pest attack is called economic threshold (*ET*).

A graphical explanation of *ET* is in Figure 1. In the plane of pests (*P*) and monetary value of yield loss (in Y-axis), there are two curves: value of yield losses (Y_L) which is a monotonically increasing function of *P* (level of pest attack), and cost of pesticide, *C*, which is horizontal (constant). Both curves cross at P* called here as *ET*, i.e., the level of *P* that causes value of yield losses equal to the cost of pesticide. The cost of pesticides is constant as it is independent of pest infestation

Proposition: The level of pesticide use is dependent on *ET* value. When the *ET* is high, the level effective pesticide use will be low.

This means amount of pesticides is not affected by level of *P*. Base on the definition of *ET*, there exist a proposition related to the level of pesticide use as follow.

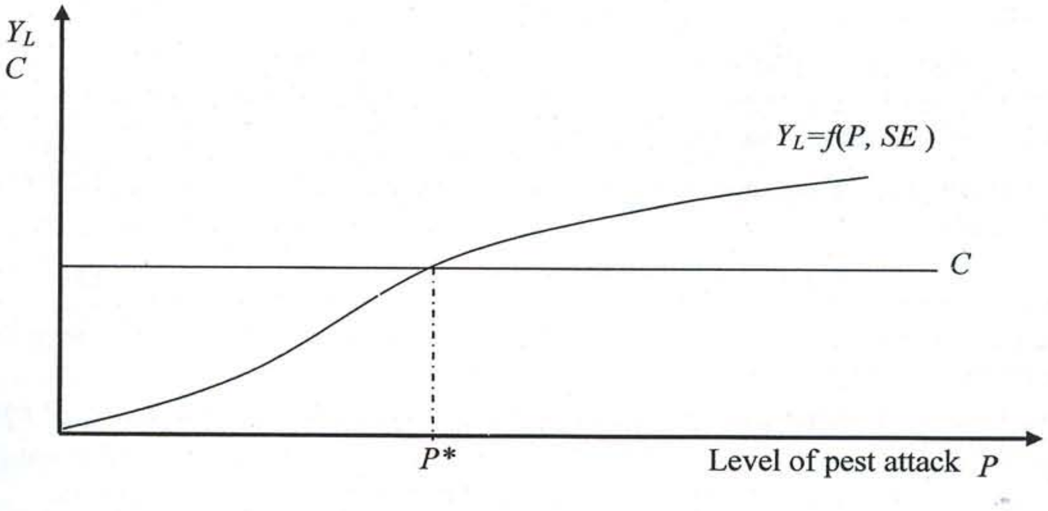

Figure 1. Yield loss function and Economic Threshold level

where:

P =	Level of pest attack	*P** =	Economic threshold level
SE=	Socioeconomic factors	Y_L =	Value of yield losses
C=	Cost of pesticides		

Proof: the maximum acceptable level of pest infestation represents the *ET* of pest. When the *ET* level is high, it is more likely that the observable level of pest infestation is lower than that of *ET*. Consequently, value of yield losses associated with such pest infestation is lower than the cost of controlling pest by pesticides spray, wherein, the use of pesticides has not been required. On the contrary, when the *ET* level is low it is more likely that the observable level of pest infestation exceeds the level of *ET*. Consequently, value of yield losses associated with such pest infestation would be higher than the cost of controlling pest through using pesticides; and the use of pesticides is required. Pesticides therefore will be more frequently used. We can formulate the relationship in mathematical terms as:

$$PS = f(P^*) \tag{1}$$

where, PS is level of pesticide use. In this case, $\partial PS / \partial P^* < 0$, meaning that increase in *ET* leads to decrease in pesticide use.

The maximum acceptable level of pest attack is not static, however. This depends on price of the product (which determines expected value of yield loss), and the price of pesticides. Any change in both prices will lead to a change in the maximum acceptable level of *P*. Furthermore, the maximum acceptable level of pest attack is subjective. The subjectivity comes from the farmers' ability on predicting the expected value of yield loss associated with a certain level of *P* they observe. Each farmer has different prediction because of variation in farmers' socioeconomic characteristics, in terms of both personal and household characteristics. Thus, another formulation of ET can be written as:

$$P^* = f(\overline{P}, PP, PC, SE, AT) \tag{2}$$

where

$\overline{P}$ = observed level of pests,
PP = pesticide price,
PC = price of commodity,
SE = socio-economic factors,
AT = agronomic and technical factors.

P^* is not observable, so we can substitute P^* from equation (2) into equation (1), then we have

$$PS = f(\overline{P}, PP, PC, SE, AT) \tag{3}$$

Equation (3) suggests that the level of pesticide use depends on observed level of pests, pesticide price, crops price, and farmers' socio-economic characteristics.

Mathematical model and estimation. From the definition and proposition of *ET*s and other functions (equations 1 to 3), a mathematical models of pesticides use is formulated as in equation (4), which can be estimated by a regression analysis.

$$PS = \beta_0 + \beta_1\overline{P} + \beta_2 PP + \beta_3 PC + \beta_4 SE + \beta_5 AT + \varepsilon \tag{4}$$

Where β_{is}^* are coefficients to be estimated, and ε represents all other variables that also influence variation of pesticide level, but are not included in equation 4.

Equation (4) can be estimated using ordinary least squared (OLS) form of regression. However, farmers have realized that there are adverse impacts of pesticides on human health and agro-ecosystem; farmers essentially want to use pesticide at less than optimum, and some may not apply any pesticide at all. Because of dichotomous type of dependent variable (0 and 1), and inclusion of intensity on level of pesticides used, estimating equation using OLS regression will lead to biased βs. To overcome this problem, *Tobit* regression model is used as suggested by Greene (2003).

Data and variables. Data are collected from a baseline survey, which was conducted in 2008. The survey covered Magelang, Brebes and Rembang districts, which are the main chili-producing region in Central Java. Out of 160 chili-growing households surveyed, 49 from Magelang, 60 from Brebes and 51 from Rembang.

Table 2. Definition and measurement of selected variables

Variables	Definition	Measure
Pesticide use[1]	Quantity of formulation of pesticides	g/ha
Diseases	Number of diseases found by farmers in chili	numeral
Pests	Number of pests found by farmers in chili	numeral
Chili price	Market price of chili received by farmers	Rp/kg
Pesticide price[2]	Average price of composite pesticides used by farmers	Rp/g
Education level	Time (year) spent in formal education	year
Chili growing experience	Time spent for chili farming	year
Area	Area planted to chili in a season	m^2
Frequency	Number of sprays per growing season	times
Non-hybrid[3]	Type of chili varieties grown by farmers	dummy
Cocktail[3]	Method of pesticide application by mixing all pesticides	dummy
Brebes[3]	One of the locations with a more pesticides use	dummy

Note: [1]) 1 ml liquid pesticides is assumed to 1g, and pesticides consist of both insecticides and fungicides; [2]) pesticide price = total cost of pesticide/total quantity of pesticides used; [3]) 1= non-hybrid chili, cocktail methods of pesticides application, and Brebes; 0=otherwise

Various types of socio-economic and agronomic practices of chili-farming were recorded in the field survey. But, only selected variables that are more relevant to farmers' decision to pesticide spray are included for statistical modeling. Definition and measurement of these variables are in Table 2.

RESULTS AND DISCUSSION

Description of pesticide use, by mixture, is in Table 3. Farmers applied pesticides by both single and mixed method of uses. Quantity of pesticides applied by mixed method (cocktail) was four times higher than that by single method. Spatially, quantity of pesticide used in Brebes was the highest (22 kg/ha) among three regions.

Table 3. Quantity of pesticide use by application methods and by location

Particulars	Quantity of pesticides (gram/ha)							
	Magelang (N=49)		Brebes (N=60)		Rembang (N=51)		All sites (N=160)	
	N	Mean	N	Mean	N	Mean	N	Mean
Single	2	6,602.1	29	6056.2	51	5,263.0	101	5,769.2

	1							
Cocktail	28	7,648.8	31	3,6807.2^{M,S}	0	.	59	22,969.3^{S}
Overall	49	7,200.3	60	2,1944.2^{M,R}	51	5,263.0	160	12,111.7

Note: It is assumed that a liter of liquid pesticides is equal to a kg. Significant different of mean across sites is indicated by superscript M, B and R. Significant different of mean between single and cocktail is indicated by superscript S and C. Mean comparison is tested at 95 % of confidence interval.

The level of pesticides use by varieties of chili is in Table 4. Highest quantity of pesticides was applied for local variety and lowest was for hybrid variety. In fact, non-hybrid varieties were mostly grown in Brebes, where higher quantity of pesticides was also applied, and in cocktail form. Brebes is known as one of the very heavily pesticide-used sites in the Indonesia, also massive promotions and advertisement of pesticides are there done by pesticides companies and dealers.

Table 4. Quantity of pesticide use, by types of variety

Particulars	Quantity of pesticides (gram/ha)							
	Magelang (N=49)		Brebes (N=60)		Rembang (N=51)		All sites (N=160)	
	N	Mean	N	Mean	N	Mean	N	Mean
Hybrid	49	7,200.3	0		20	5,333.1	69	6,659
OP	0	.	38	9,999.3	0	.	38	9,999.3
Local	0	.	22	42,576.3^{R,L}	31	5,217.7	53	20,725.1^{HO}

Note: This is based on assumption that a liter of liquid pesticides is equal to a kg. Significant different of mean across sites is indicated by superscript M, B and R. Significant different of mean across varieties is indicated by superscript H, O and L. Mean comparison is tested at 95 % of confidence interval.

The results from regression analysis of equation (5) explaining factors impact on level of pesticides use are reported in Table 5. All coefficients from both of the models estimated are significant at 10 % of the significant level. When the models are estimated using OLS, both show that around 60% of variation in pesticide use can be explained. Model 2 is obtained by restricting the assumption that education and experience in chili farming have the same effect in terms of sign and magnitude. Based on Model 2, the result suggests that pesticide use increase when farmers observe more pests. This is reasonable because controlling pest can limit the yield loss by pest, as the plant could still recover when pests are killed. Conversely, farmers reduce pesticides when they observe more number of diseases in the field. Plant infected by diseases less likely to recover, so farmers also behave rationally here. Thus, farmers used pesticides when the level of diseases is low. Thus, curative decision is for pests and preventive is for diseases.

In models 1 and 2, the sign of pesticide price is negative, meaning that increase in price of pesticides leads to reduction in pesticide use. The sign of chili price, as per priori expectation, is positive, meaning that increase in price of chili leads to increase in pesticide use. Both results are logical and consistent with rational decision of farmers in terms of maximizing profit from crop production.

Age of household has positive effects on pesticide use, meaning that older farmers use more pesticides than younger farmers, *cetaris paribus*. This implies that older farmers have lower prediction for economic threshold of pests, so they use measure that is more preventive in disease management than that of younger farmers. In contrast, education and experience in chili farming have negative impact on pesticide use. An educated and more experience in chili farming uses less pesticide than those with lower level of education and experience. This indicates that education and experience in chili farming lead to better prediction on economic threshold level, and less dependent upon preventive to diseases. It could be the case that education and experience could also improve understanding in pests, diseases and pesticides; thus better optimizing the pesticides and inputs use.

Frequency of spray has positive impact on pesticide use level. This is normal that more frequent a farmer sprays on crop, higher amount of pesticides applied. When farmers operate a larger size of farming, they apply less quantity of pesticides in per hectare basis. This finding is different from that of Rahman (2003) study in Bangladesh, who reported that the greater size of farm in Bangladesh used higher level of pesticide use. In case of Indonesia, farmers with small farm size tend to use more pesticide per hectares basis. Also, small farm operates more intensively than large-size chili farm, and so more quantity of pesticides used on small-farm plot.

Table 5. Factors affecting pesticide use

	Model 1		**Model 2**	
Variables	Coefficient	t-value	Coefficient	t-value
Constant	-11624.8	-1.64[a]	-13535.3	-2.34[a]
Pest	9185.5	4.33[a]	9046.4	4.30[a]
Diseases	-12153.8	-4.94[a]	-11970.8	-4.93[a]
Price of pesticides	-5.14	-1.57[b]	-5.04	-1.54[b]
Price of chili	1.51	3.49[a]	1.50	3.45[a]
Age of household head	256.7	2.60[a]	279.9	3.27[a]
Education	-495.3	-1.42[n]		
Chili experience	-313.5	-2.54[a]		
Education + experience			-340	-3.09[a]
Frequency	255.5	2.91[a]	253.0	2.88[a]
Chili-sown area	-1.54	-2.22[a]	-1.54	-2.22[a]
Non-hybrid	6189.1	2.34[a]	6214.7	2.35[a]
Cocktail	11826.3	5.58[a]	11723.2	5.56[a]
Brebes	9868.7	2.91[a]	10404.8	3.25[a]
F_{test} for $\beta_{educ} = \beta_{ch\_exper}$	0.22[n]			
χ^2 for log-ratio	145.06[a]		144.84[a]	
Adj. R^2 (in OLS)	0.61		0.61	

Note: dependent variable is pesticide use per hectare; a: significant at 5% level; b: significant at 10%

The effects of Non-hybrid varieties and cocktail spray have positive effects on pesticide use. Non-hybrid varieties and cocktail spray are also strongly related to the chili locations because many farmers in Brebes grow non-hybrid varieties and apply cocktail spray. Farmers who grew non-hybrid chili used more pesticides than those who grew hybrid, which suggests that non-hybrid chili types need more protection from pests and diseases. Likewise, farmers applying cocktail spray use more pesticides that those who apply single spray. When farmers observe more number of insect pests and diseases, they are also likely to use mixture of various insecticides and fungicides to control range of pests and diseases at the same. This is unlikely for farmers who apply single spray, who likely to use appropriate pesticide to control targeted pests, or to control targeted diseases. Farmers in Brebes used more pesticides than those in other region. Pesticides application practice in Brebes is also deeply rooted in socio-culture and past history, as massive promotion of agrochemicals and pesticides have been done in Brebes by pesticides companies than in Magelang and Rembang. In addition, Brebes is closer to big chili (and vegetable) markets; all these factors lead to more intensive and high inputs based vegetable cultivation in Brebes than that of other two places.

CONCLUSION AND SUGGESTION

Yield losses on chili due to pests and diseases is significantly high in Indonesia, thus, pesticides use is very much a core part of the farming, and its uses have been in increasing trend over the recent past. Nevertheless, farmers also have different options and strategies to overcome the problem of pests and diseases on a crop; and application of pesticides is one option among many other alternatives. Several factors affect on level of pesticide use on chili at a place, this paper has evaluated relative impacts of some of the selected socio-economic factors and farmers' characteristics affecting farmers' pesticides use decision in Central Java. This is done using Economic Threshold (ET) concept of pest related damage an econometric model, in fact, the generic form of econometric model used for analysis here can be used in other crops (places) as well. Level of pests and diseases attack (incidence) is certainly one of the main factors as controlling the pest population is the very purpose for application of pesticides. We have demonstrated that chili farmers used more pesticides (insecticides) when they observed more insect pests in the field. But, they would use more pesticides (fungicides) when the disease infection is still at low or at moderate level. It is considered too late if farmers found high level of disease attacks. This could be the reasons for higher level of pesticides use in the survey sites. Older farmers were less tolerant toward level of pests and diseases attack, and that this leads to increase in use of pesticides, but those framers with higher education and experience in chili farming were using less pesticide. Likewise, those farmers using hybrid varieties of chili and following single type of pesticides spray were using less number of sprays. Hybrid varieties were more resistant or tolerant to pests and diseases; and farmers were applying pesticides more appropriately when applying single pesticide for a targeted pest, thus both are effective strategies to reduce pesticides use on chili. Likewise, farmers' level training and demonstration on proper uses and application of pesticides will go long way in improving farmers' capacity and skill in using the right kind and right dose of pesticides

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Factors affecting adoption of chili crop in Central Java

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Keywords: chili farming, chili adoption, technology adoption, economic analysis, logit model, Central Java.

Abstract

This paper analyzes socio-economic factors that affect farmers to adopt chili farming in Central Java. As chili cultivation is more profitable and more labor intensive than rice and other crop cultivations, while adopting chili farming, farmers increase household income and provide more employment; but there are also several constraints associated with cultivation of chili. This study assesses importance of these factors in chili growing decision of farmers. Data for this study were compiled from a baseline survey conducted during early 2008. The household survey was conducted by personally interviewing 220 farmers of three districts: Magelang, Brebes and Rembang. The result from econometric model shows younger farmers are more likely to adopt chili farming than others. However, more experienced farmers in vegetable farming are more likely to adopt chili farming. Better access to credit and ownership of mobile phone also lead to farmers more likely to adopt chili farming. Thus, chili should be introduced to young and vegetable-experienced farmers. To encourage farmers to grow chili, farm credit should also be more available and accessible. Strengthening communication network (mobile phone) to farmers) is also expected to encourage to grow more chili and other high value vegetables due to better access to market price information.

INTRODUCTION

Adoption of new technology and innovation has driven technological change in the agricultural sector, and its pace in Asia has increased tremendously after the Green Revolution in late 1960. Study of adoption of technology is important to understand factors associated with application of a technology (or a new crop, a high yielding variety, or new production technology). Since the history, changes in agricultural technology have always been an important component in the progress of human societies, and more so recently in development of modern agriculture with range of technologies (Huang et al. 2004). In fact, successful adoption of technology 'can be a powerful force in reducing poverty' (de Janvry and Sadoulet 2002: 1), as agriculture sector has a multiplier effect on a whole economy (Khan and Thorbecke 1988).

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In spite of general acknowledgment of the central role of technological change and technology adoption in influencing economic growth, productivity and competitiveness, there is a lack of understanding on actual path how economic forces influence technological change in agriculture. Technological change can be influenced by a variety of factors (Martin and Warr 1994), but its determinants and process of technology changes are less understood topic in the literature.

Levels and types of agricultural support given by government also have important effects on the development and adoption of new technology, and eventually impacts on technological change. In fact, technological change is more of local specific, largely affected by variation in economic, social and institutional settings; and so the process of institutionalization of new technology in one place is different from others.

Recently, many new agricultural technologies have been introduced in Indonesia. Intensive chili farming is one of such technology. As an important component in the cropping system in Asia, in terms of crop acreage, chili is ranked as first and third most important vegetable in Asia and in the world, respectively (Ali 2006). In Indonesia, chili provides the greatest share in terms of vegetable values (Vos and Duriat 1995). If farmers rapidly adopt the modern technology, chili farming is expected to contribute more in economy. Nevertheless, the introduction of new technology has met with only partial success. The conventional wisdom is that constraints to the rapid adoption of innovation involve factors such as lack of credit, limited access to technological and market information, inadequate holding of farm-size, insufficient human capitals, chaotic supply of complementary inputs, and inappropriate transportation infrastructure. Thus, in this paper, using statistical model, we evaluate why some farmers are willing to grow chili and others are not willing to grow it.

LITERATURE REVIEW

Technological progress in agriculture is driven by adoption of new technology and innovation. Without adoption of technology, the new technology and innovation are useless and agricultural sector becomes stagnant. Therefore, adoption of innovation of agricultural technology has attracted considerable attention among development economists for a long time, as livelihoods of majority of the population in developing countries depends upon agricultural and because new technology seems to provide opportunity to increase production and income substantially (Feder et al. 1985).

Since Griliches pioneering work on adoption of hybrid corn in the USA in 1957, majority of the adoption research has been done to answer one of question: what determines whether a particular producer adopts or rejects an innovation (Ghadim and Panell 1999). In those studies, factors affecting adoption of agricultural innovation are grouped into socio-economic elements, farm characteristics, and policy factors.

Past studies have shown that attempts to identify factors that may explain differences in adoption between poor (small) and larger farmers, and they indicate that education, farm size, and frequency of contacts with extension staff are significant factors for poor farmers, but not for richer farmers to adopt improved coffee management recommendations. A good synthesis and summary of such recent literature on technology adoption in agriculture can be found in Doss (2006).

In the vegetable production practices, there are very limited studies on adoption of new technology. In reality, production of vegetables and high value crops, including chili, is directly linked to crop intensification and crop diversification. In the absence of limited economic study explaining factors contributing to farmers' decision to grow to chili (Ali 2006), we consider farmers decision to grow chili as the same process as adoption of new production technology (new crop technology). Chili is a high value crop compared to paddy and other vegetables such as yard long bean and bitter gourd, which farmers considered less risky than chili. Chili cultivation is a highly lucrative agribusiness with high pay-off, but also with a substantial risk due to high incidence of pests and diseases as well as high volatility on its market prices.

METHODOLOGY

We have used technology adoption framework of CIMMYT (1993) for analyzing factors explaining farmers' chili production decision in the surveyed sites. These factors include mostly farmers' socioeconomic characteristics, education level, assets position, access to credit, and access to communication factor.

Data and variables. This study is based on data collected from a project baseline survey carried out in early 2008. This baseline survey collected both secondary and primary data. Primary data were collected at farm level, based on community/ village level and at the individual level. Three villages each from three districts (Magelang, Brebes, and Rembang) were selected for the detailed survey. Household level information was collected using individual interview, and qualitative data were collected from group discussion among farmers. Each of the communities/districts selected is an intensive chili production area, and with a distinct variation of production characteristic of chili farming in Central Java (Table 1)

Table 1. Field study sites and household survey sample size in Central Java, 2008.

	Number of farmers surveyed by district			
Household survey	**Magelang**	**Brebes**	**Remban g**	**Total**
Chili grower	49	60	51	160
Non- chili grower	21	20	21	62
Total farmers surveyed	70	80	72	222

More than 250 farmers were individually surveyed, but after cleaning data, a total samples of 222 farmer households spread in three districts were selected. Around of one third households were non-chili growing farmers, which consisted of farmers who never grow chili and farmers who no longer grow chili for the last 3-4 years but some of them were growing chili before 2003, but have abandoned it now. The distributions of sample size for households, villages, and districts are in Table 1.

The baseline survey was comprehensive comprising of over 500 variables related to chili farming characteristics (18-page questionnaires). But, only selected information and key variables relevant to the scope of this paper (factors related to chili adoption) are presented here. Details are in Mariyono and Bhattarai (2009). Definition and measurement of key variable influencing decision to grow chili are in Table 2.

Table 2. Definition and measurement of selected variables

Variables	Definition	Measure
Chili grower r	Farmer who were grow chili during the survey (or also considered here as technology adopter)	1=yes
Non-chili grower*	Farmers who were not growing chili during survey (or considered as non-adopter of the technology)	0=yes
Age of household head	Age of household head	Year
Education of household head	Time (year) spent for formal education	Year
Experience in vegetable farming	Time spent for vegetable farming	Year
Family member	Number of family members in a household	Number
Size of farm	Area of cultivated lands	$1000m^2$
Number of plots	Number of plots (land parcels)	Numeral
Wealth rank status	Social status in the village 1= poor, 2=medium, 3=rich	Category
Access to credit	Whether farmers accessing credit for farming	1=yes; 0= no
Participating training	Whether farmers were trained in the past.	1=yes; 0 = no
Mobile phone ownership	Whether farmers own and use cell phone in the farming business activities (for marketing)	1=yes; 0 = no

Note: *) either stop growing chili in the past few years (5 years), or never grow chili because of various reasons.

Econometric modeling. The effects of variables listed in Table 2 with chili growing decision are evaluated using equation (1). This is done following the procedures for formulation of technology adoption model by Johnston and Di'Nardo (1997).

$$\mathbf{X}_i\beta = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \varepsilon \qquad (1)$$

where X is a vector of socioeconomic factors, ε is error terms; βs are coefficients to be estimated, and subscript i represents individual sample observation.

This study employs logit model to predict the probability of adopting chilli production technology. The equation (1) was used in establishing a logit model for analysis. In mathematical terms, the logit model that describes the probability of adopting and not adopting of a particular technology given socioeconomic factors of farmer can be expressed in two ways as given in equations 2a and 2b.

$$P\{Y_i = 1\} = \frac{exp\{X_i\beta\}}{1 + exp\{X_i\beta\}} \tag{2a}$$

$$P\{Y_i = 0\} = \frac{1}{1 + \exp\{\mathbf{X}_i\beta\}} \tag{2b}$$

where Y_i is technology introduced for adoption, in this it is the chili production decision; whether chili grower (Y=1) or not chili grower (Y=0). The ratio of equation (2a) to equation (2b) and then taking natural logarithm of both left and right hand sides, we have derived equation 3 below.

$$\begin{aligned} \ln\frac{P\{Y_i = 1\}}{P\{Y_i = 0\}} &= \mathbf{X}_i\beta \\ &= \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \varepsilon \end{aligned} \tag{3}$$

The model shows that the probability of Y_i to be equal to one, which follows a cumulative logistic distribution, is dependent on some socioeconomic factors $\mathbf{X}$. When Y_i is equal to one, farmer adopts the technology in question. If β is positive, it means that one point increase in $X_{k=j}$ will result in more adoption of the technology, and vice versa (details in Verbeek, 2000).

Testing of hypothesis. To identify whether the socioeconomic factors selected in Table 2 actually affect probability of adopting components of technology, a hypothesis is built. The hypothesis is that the probability of adopting components of technology is affected by socioeconomic factors and other characteristics embedded in farmers. It is formulated as:

Ho: $\beta_0 = \beta_1 = \beta_2 = \beta_3 = \ldots = \beta_k = 0$, and H_1: one of them $\neq 0$

This hypothesis will be rejected if likelihood ratio (LR) is greater that χ^2 critical at 1%, 5% and 10%. For individual impact of each socioeconomic factor, the hypothesis is formulated as:

Ho: $\beta_k = 0$ and H_1: $\beta_k >$ or $<$ 0, for k=1, 2,...

The hypothesis will be rejected if z-ratio is greater than z critical at 1%, 5% and 10% levels. If those hypotheses are rejected, these mean that the corresponding factors have significant impact on the probability of adopting technology.

RESULTS AND DISCUSSION

Descriptive analysis of the variables

In Table 3, we have provided selected socio-economic characteristics of household as listed in Table 2 earlier. Overall, socioeconomic characteristics of farmers in the surveyed sites varied by location and by farmers' types. In general, chili-growing farmers were typically younger than their counterpart non-chili growing farmers were; but they had almost similar level of education level and number of family members in the household as that of non-chili grower. Chili growers were about six years of less experienced in farming in general than non-chili growers (24 years vs. 19 years of experience). Nevertheless, chili growers and non-chili growers had almost same level of vegetable growing experience, as well as years for growing chili. Average farmers had an average of ten years of experience in growing chili. Interestingly, non-chili growers farmers now had also got experienced in chili production of about 10 years, but had abandoned it now because of several factors such as not wanted to take market risk, less family members in house to work on chili farm, than farmers who no longer growing chili. There was no significant difference on education level of the household heads of the two farmers groups.

In general, farmers in Brebes, in spite of their relatively younger age, were more experienced in overall farming as well as in vegetable farming than those in other two districts. This suggests that farmers in Brebes started operating their farms much earlier age than those in other two locations. Other details on characteristics of these factors and their variation across the sites are in Mariyono and Bhattarai (2009).

Table 3. Households' characteristics, by age, experiences and size of family

		Number and percentage of farmers											
Characteristics		Magelang (N=70)			Brebes (N=80)			Rembang (N=72)			Average (222)		
		n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
Chili adopter (N=160)	Age (year)	49	41.80	9.91	60	43.47	12.05	51	44.75	9.70	160	43.36	10.70
	Education (year)	49	9.78 [BR, N]	3.04	60	7.03	2.07	51	7.02	2.50	160	7.87	2.82
	Farming experience (year)	49	15.37	7.79	60	23.60 [MR]	11.79	51	16.75	10.08	160	18.89	10.75
	Vegetable experience (year)	49	10.69 [R,N]	7.01	60	16.18 [MR]	12.26	51	6.04	4.81	160	11.27	9.79
	Chili experience (year)	49	9.61 [R]	6.60	60	19.60 [MR, N]	11.59	51	5.14	2.59	160	11.93	10.19
	Total family members	49	3.86	1.02	59	4.14	1.43	51	4.35	1.16	159	4.12	1.24
Non chili adopter (N=62)	Age (year)	21	54.95 [BR, A]	12.36	20	42.70	9.42	21	45.52	9.24	62	47.81 [A]	11.56
	Education (year)	21	7.10	2.96	20	7.20	2.98	21	6.90	2.07	62	7.06	2.66
	Farming experience (year)	21	33.43 [BR, A]	15.82	20	19.95	7.66	21	19.00	9.53	62	24.19 [A]	13.22
	Vegetable experience (year)	21	5.67	12.86	20	15.40 [MR]	7.69	21	6.95	3.63	62	9.24	9.78
	Chili experience (year)	21	13.57	18.22	20	7.55	10.00	21	5.33	3.09	62	8.84	12.48
	Total family members	21	3.57	1.50	19	4.42	.96	21	4.33	1.32	61	4.10	1.33
Total (N=222)	Age (year)	70	45.74	12.23	80	43.27	11.40	72	44.97	9.51	222	44.60	11.10
	Education (year)	70	8.97 [BR]	3.24	80	7.08	2.31	72	6.99	2.37	222	7.64	2.80
	Farming experience (year)	70	20.79	13.57	80	22.69 [R]	10.97	72	17.40	9.91	222	20.37	11.70
	Vegetable experience	70	9.19	9.35	80	15.99 [MR]	11.26	72	6.31	4.49	222	10.70	9.81

11.07	10.93
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RESULTS FROM ECONOMETRIC ANALYSIS

As reported in Table 3, these farmers' specific socio-economic characteristics are expected to explain why some farmers grow chili and others do not grow it, or abandoned it after growing some years. Using econometric models as reported in equation (3), we have evaluated the relationship in quantitative term, and their relative strength in explaining variation of farmers chili cultivation decision are reported in Table 4. In overall, the results from logit form of regression model is significant at 99% confident level, in spite of relatively low coefficient of determinants (noted by pseudo R^2), which accounts for 24%. This results is reasonable in the absence of several other factors (agro-ecological factors, structural, institutional and policy elements) in our model that also determine farmers' decision to grow chili in a place. But, compilation of all of this information at household level, as needed for econometric modeling (equation 3) is out of scope of this study.

Among the variables selected, age of household head (in years) has significant negative impact, meaning that when the farmers are getting older, they are less likely to grow chili. This is a reasonable case because older farmers will be less capable to operate intensive and drudgery of chili farming practices, and its regular supervision task. At many cases, farmers used to grow chili earlier, but have abandoned it now because of their age factor. Besides, their children and other younger members of the household are living in urban area or nearby city, attending colleagues, etc. Intensive chili farming needs more labor than growing other food crops; therefore, older farmers have departed from chili cultivation practices recently because of age factor.

In our model, formal education has significant negative impact on probability of average farmers to grow chili in a location. This implies that farmers with higher education are less likely to adopt chili crop. It could be because of the fact that a very high-educated farmer is likely to do some other comfortable business in the village than engaging in a labor-intensive chili production practice. This is contrary to our expectation, but it needs to be explored more in subsequent study. It is also likely to have a non-linear relationship between education and chili-growing decision, a middle level educated farmer will engage more in chili farming but not by a very low -educated as well as a very high-educated farmers.

Experience in vegetable farming has significant positive impact on the probability of farmers to grow chili. Thus, farmers with more experience in vegetable are more likely to grow chili. This is a plausible finding. Experience is a good teacher. With more experience in vegetable farming, which is relatively riskier than rice and other food crops, farmers can cope with problem and risk associated with chili farming. Chili is also one of the riskiest crops grown in the area, with high variation of chili yields among chili growers (Mustafa et al. 2006; Mariyono and Bhattarai 2009).

The impact of number of family member is insignificant but with negative sign. This indicates that farmers with large number of family members do not necessarily grow chili, even though chili farming is a labor-intensive task. All family members of a household do not engage in chili farming, but only trained or experienced members.

Table 4. Estimated logit regression model

Variables	Coefficient	Std. Err.	z
Constant	2.1634	1.4632	1.48*
Age of household head	-0.0464	0.0185	-2.52**
Education of household head	-0.1047	0.0802	-1.31*
Experience in vegetable farm	0.0487	0.0188	2.59**
Family member	-0.0661	0.1427	-0.46
Size of farm	1.98E-05	7.22E-05	0.27
Number of plots	-0.1098	0.1495	-0.73
Wealth rank status	0.3148	0.2660	1.18
Access to credit	2.2641	1.1138	2.03**
Participating training	0.5121	0.5734	0.89
Mobile phone ownership	3.6561	1.0365	3.53**
Number of observation	220		
LR χ^2_{10}	62.85**		
Pseudo R^2	0.242		

Note: *) significant at 90% confident interval; **) significant at 99% confident interval

Size of farm is insignificant but positive effect in explaining decision to grow chili. There is a tendency that farmers with large farm are more likely to grow chili farming because of need of higher operating capital. Farmers with larger farm are richer and can also manage for such high operation capital than those with small farms. But, insignificant impact indicates that opportunity for farmers to adopt chili farming is equal between small and large farm. This could be due to no major difficulty for farmers to access credit to meet high operating capital for chili if they want to grow it.

Number of plots, which represent land fragmentation, has insignificant negative impact on decision to grow chili. Farmers with more fragmented land tend to be less likely to grow chili. This is plausible because farmers need to monitor chili field regularly, and also pest control and other operation will be easier if it is grown in one plot than in the case of many plots. Moreover, because of other factors, in our model, the impact of land fragmentation is insignificant.

Wealth rank status is marginally significant with positive sign. This means that high-income farmers are more likely to grow chili than that of the low-income farmers. . This is consistent to the effect of size of land, where larger farmers indicate richer farmers. However, the net effect of wealth is marginal in our model as farmers in the surveyed sites have relatively easy access to credit if they want to grow chili.

The variable “access to credit’ has positive and significant effect on decision to grow chili. This means that farmers who can access credit are much more likely to grow chili than that of other farmers. Farmers can finance high requirement of operating capital for chili from credit. This is also the reason for relatively less importance (lower value of marginal effects in Table 4) of size of farm and wealth status of household on the likelihood of farmers to grow chili.

Training in agricultural practices, as of priori expectation, has positive impact on decision to grow chili, even though it is insignificant. Training leads to farmers more likely to adopt chili farming as farmers improve their knowledge and understanding of sophistication of vegetable farming, including chili. This is also consistent with the effect of farmers' experience in vegetable farming as noted earlier.

Last but not least, mobile phone ownership of farmers has positive and significant impact on probability of farmers to adopt chili farming. Farmers who have got personal mobile phone are more likely to adopt chili farming than other farmers are. This is logical because using mobile farmers can get more accurate market information (prevailing price at the markets) than others. In many cases, farmers with mobile phone gets chili price information by calling 2-3 traders nearby the village, before picking up the chili in the following morning. Thus, access to cell phone facility has dramatically changed the flow of market information system (MIS) in these chili production pockets in Indonesia recently. In much extent, this has also strengthened the farmers' bargaining position for price in the recent past.

CONCLUSIONS AND POLICY IMPLICATIONS

Chili cultivation provides more income and employment than other crops, and the whole rural community is benefited due to more employment created in the rural communities. However, chili growing has largely been done by small fraction of farmers in the survey sites. There are some major socio-economic as well as other higher order factors (access to services, capital, etc) affecting the decision of average farmers for their decision to grow chili in the survey locations. Using statistical modeling approach, we have analyzed evaluated the impacts of some of these factors with farmers decision to grow chili in a location. We found that farmers' age, level of their formal education (in years), is significant but with negative impact on farmers decision to grow chili in the surveyed locations. However, we also found that experience in cultivation of vegetables, level of access to credit and ownership of cellular phone have positive and significant impacts on farmers decision to grow chili in the surveyed locations. Thus, the study findings also suggest that chili farming technology if introduced to farmers' community where farmers are still young, with enough experience in vegetable farming, access to credit, then such technologies is likely to be adopted by many farmers in the community. Likewise, in a community where farmers have already been well familiar in use of cellular phone, farmers would be more likely to adopt chili cultivation practices than that of the other communities, *cetaris paribus*. In the context of limited literature that explain farmers behavior in adoption of certain particular vegetable crop, or technology adoption in vegetable sector, the findings from the study would likely to contribute in better planning and targeting vegetable sector research and development activities in Indonesia, and in tropical Asia, in general.

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Integrated Chili Management to Control Some Major Diseases in Brebes district, Central Java, Indonesia

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Keywords : Chili pepper, straw mulch, anthracnose, chili virus, bio-fungicide.

Abstract

Under the sponsorship of the ACIAR-Funded on Chili Integrated Diseases Management project in Central Java, Indonesia; a preliminary participatory trial was executed to evaluate the effect of mulch and bio fungicide to control anthracnose and other important disease in Brebes. Brebes, at the north coast of Java, is one of the most important chili pepper central production in Indonesia, with its major limiting factors for marketable yield are anthracnose, virus diseases and leaf spot. Farmers have to face a difficult problems, where District of Agricultural extension also found the most difficult questions from farmers dealing with these major diseases. Goal of Brebes trial is, to answer farmer problems on diseases for their commercial chili, since chili has a high market price. The trial introduced straw mulch application plus bio-fungicide, mainly to reduce anthracnose incidence. Mulching is a main plot, whereas bio-fungicide versus synthetic chemical fungicide as sub plot treatment. Mulch utilization exhibited delayed and reduced of virus infestation on chili in the field. Percentage of virus infestation showed lower on mulch treatment than no mulch treatment, almost 50% reduced. Mulch utilization did not affect significantly different on aphid population on chili. Bio-fungicide treatment showed non significantly different as well at 38 dap-88 dap; one these virus vector known is aphid.There was no significant different among treatments against leaf spot (Cercospora). Higher yield was achieved by mulch treated plot plus bio fungicide, and good harvest time allow chili price gave benefit to farmers. Chili plants treated by the bio-fungicide showed a similar capacity to produce chili fruit, and produced higher yield than synthetic fungicide treated plots. Mulch treatment could not reduced anthracnose diseases on chili, however, application of bio-fungicide could reduce significantly different for anthracnose disease of chili fruit compared to synthetic fungicide treatment.

INTRODUCTION

In Asia, Indonesia (176,261 ha) is the second largest chili production country after China (602,503 ha) (Ali, 2006), however our chili productivity is very much lower than China (3.14 t/ha compared to 19.13 t/ha). According to Mustafa *et al.* (2006), chili production in Central Java, produced chili only about 12%, East java is 19% and the highest is, West Java 23%.

Chili pepper is one of the most important cash crops providing nutritional and financial benefits to smallholder farm in Indonesia. It enhances food palatability and also rich in Vitamin C (Ali, 2006). Primarily, chili is cultivated in Java and Sumatra. The productivity of chili (3.14 t/ha) has various constraints. Losses to pest and disease infestations (35-90%) are reported to be one of the serious problem faced by farm operators (RRA, 2007).

The availability of commercial cultivars resistant to pests and diseases are still very limited, this may cause farmers mostly rely on pesticides to control pests and diseases.

About 55-61% of Indonesian chili is produced in the Java island, whereas average yield achieved only about 2.1- 4.1 t/ha, Brebes is chili central production lowland area. The Integrated Diseases Management (IDM) project, aimed to improve chili farmers to implement the introduced technology for yield loss reduction; associated with selected disease of chili pepper in Java, which is anthracnose in Brebes.

According to RRA survey of the IDM project, conducted in 2007, synthetic chemical pesticides appeared to be the major method to control pest and disease on chili.

In lowland area mainly, beside diseases, insect problems such *Thrips parvispinus* is a notorius problem on chili (Dibiyantoro, 1994).

Mechanical control measures such as rouging was not practiced by the chili farmers. The intensity of pesticide use depends on farmers finance condition. Frequency of pesticides application varied, between twice a week to every day spraying, may cause resistance of target pests. Generally, the average application interval was 3 days and using the mixture of two up to six pesticides in a cocktail is a common practice to control pest and diseases on chili (Vos *et. al*., 1994).

A preliminary on-farm field trial was conducted in Brebes, Central Java for a period of six months in 2008. The objective of this trial were :

1. To identify the effect of mulching in Brebes area for lowland chili production, which is not common for Brebes farmers.
2. To apply bio-pesticide as the effort of reducing chemical synthetic pesticide in controlling anthracnose disease, as well other important diseases.
3. To improve farmers participant skill and knowledge in more safety production

METHODS

Preliminary participatory trial was executed in Klampok, Brebes, Central Java, Indonesia. Chili is a relayed crop after shallots in Brebes area, when shallots were 35 days old in the field.

Split Plot Design was used in this trial with following treatment: Main Plot was straw mulch application on the chili bed that consist of 2 level ie (a) No Straw Mulch and (b) Straw Mulch; Sub Plots were bio-fungicide and synthetic fungicide application to control anthracnose diseases on chili that consist of 4 pattern levels of bio-fungicide and synthetic fungicide application ie (A) : *B. subtilis* (as bio fungicide) + *B. subtilis* + *B. subtilis* + *B. subtilis*); (B) Bion M 1/48 WP (synthetic fungicide) + *B. subtilis* + *B. subtilis* + Daconil 75 WP (synthetic fungicide) + *B. subtilis* + *B. subtilis* + Bion M 1/48 WP + *B. subtilis* + *B. subtilis* + Daconil 75 WP; (C) The pattern of fungicide application was the same as B treatment with additional treatment with three times of micro organic nutrient application during chili plant growth; (D) Farmers culture practice with chemical fungicides.

Plant development, major insect and diseases were recorded every ten days. Diseases incidence was determined by counting number of damages caused by diseases on the fruit from the total harvested fruits of each harvesting time. Fruit was considered damaged if single lesion was found. Diseased and healthy fruit were counted to determine the percentage of the yield that was marketable in each plot. Pest and disease infestation observation include virus incidence, percentage of *Cercospora* intensity, late blight, anthracnose disease and sucking insect pest population.

RESULTS AND DISCUSSION

Performance of vegetative development is provided by Table 1 and Table 2. Seemingly mulch and bio fungicide treatments were not significantly different to plant development.

Table 1. Effect of mulch on plant height development of chili, Klampok, Brebes, Central Java, 2008

Mulch treatments	Average of Plant Height at .... Days After Planting (dap)					
	38	48	58	68	78	88
No Mulch	32,02 a	35,67 a	39,78 a	42,07 a	43,85 a	44,78 a
Mulch	32,63 a	35,92 a	38,78 a	40,19 a	42,46 a	44,04 a

Note: Means followed by the same letters in the same column are not significantly different at 5% of Duncan Multiple Range Test.

Table 2. Effect of bio fungicides on plant height development of chili, Klampok, Brebes, Central Java, 2008

Bio fungicide treatments	Average of Plant Height at .... Days After Planting (dap)					
	38	48	58	68	78	88
A	34,70 a	44,35 a	48,54 a	51,03 a	51,66 a	52,61 a
B	35,14 a	45,85 a	49,58 a	51,16 a	52,36 a	55,06 a
C	35,81 a	46,50 a	49,29 a	51,89 a	52,77 a	53,96 a
D	34,63 a	44,45 a	49,54 a	51,53 a	52,43 a	53,09 a

Note: Means followed by the same letters in the same column are not significantly different at 5% of Duncan Multiple Range Test.

Virus infection on chili was almost found at anywhere, in chili trial area in the field of Klampok (Brebes). Their symptoms was light and heavy mosaic of the leaves, narrow leaves, curling and malformation. Their growth of chili plant was abnormal and stunting. The stunting plant commonly did not produce fruits. Virus incidence of the trial was assumed there was virus introduction from neighboring field, according to aphid monitoring, that was found in the field. Mulch utilization showed significantly effect of virus incidence on chili in the field (Table 3 and Table 4). There were an interaction effect between mulch and bio fungicide treatment on virus incidence in the field at 88 and 98 days after planting. Meaning, after virus was already exist on chili plant in the field, virus incidence would be accelerated by aphid vector on no mulch, in spite of virus incidence on mulch in combination with bio fungicide for A and C treatments, acceleration of virus incidence could be reduced significantly different. On both bio fungicide treatment (A and C) with mulch utilization, their emerge of virus incidence could be inhibited and reduced. Effect of these bio fungicide treatments assumed might triggered the immunities system of chili plant.

Table 3. Effect of mulch and bio fungicides on virus incidence of chili at 88 days after planting, Klampok, Brebes, Central Java, 2008

Mulch	Bio fungicide			
	A	B	C	D
No Mulch (NM)	39,00 a (A)	25,50 a (B)	24,00 a (B)	26,50 a (B)
Mulch (M)	15,50 b (B)	24,50 a (A)	17,00 b (B)	25,50 a (A)

Table 4. Effect of mulch and bio fungicides on virus incidence of chili at 98 days after planting, Klampok, Brebes, Central Java, 2008

Mulch	Bio fungicide			
	A	B	C	D
NM	51 a (A)	35 a (B)	35,5 a (B)	36,5 a (B)
M	23,5 b (B)	33,5 a (A)	26 b (B)	34 a (A)

It is practically impossible to identify specific chili virus in the field based on symptoms, according to ELISA test, Duriat (1989) described that viruses infecting on chili in Indonesia were PVY, CMY, TEV, TRV, TRSV, PVX, PVM and AMV. Mulch application exhibited reduction of virus infestation on chili in the field. It seem in percentage of virus infestation showed lower (15.50%) on mulch treatment than no mulch treatment (39%).

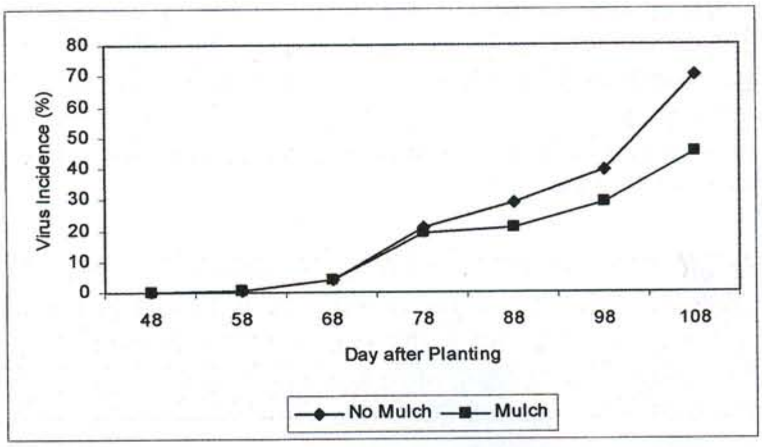

Figure 1. Percentage of virus incidence on chili trial of mulch treatments

Result of insect monitoring on chili in the field found that aphid and Thrips were pre dominantly insect pest on chili, in Brebes. Population of both insects were varied in fluctuation. Effect of mulch treatment on aphid is shown on Table 5. Aphid population on 38 and 48 days after planting was high, but after 48 days after planting, gone lower than at the early observation. Statistically test showed that mulch utilization did not affect significantly different on aphid population on chili.

Table 5. Effect of mulch on aphid population of chili, Klampok, Brebes, Central Java, 2008

Mulch treatments	Average of Aphid Population at .... Days After Planting					
	38	48	58	68	78	88
No Mulch	1,08 a	1,04 a	0,08 a	0,39 a	0,78 a	0,00 a
Mulch	1,19 a	0,81 a	0,00 a	0,38 a	0,18 a	0,00 a

Thrips population also showed variation in fluctuation on every observation. High population of Thrips occurred on 58 and 78 days after planting. According to statistic test showed that mulch effect non significantly different on Thrips population (Table 6). Practically in this trial, mulch treatment in certain case could not reduce Thrips population on chili.

Table 6. Effect of mulch on Thrips population of chili, Klampok, Brebes, Central Java, 2008

Mulch treatments	Average of Thrips Population at .... Days After Planting					
	38	48	58	68	78	88
No Mulch	0,99 a	0,79 a	2,67 a	1,87 a	2,51 a	1,57 a
Mulch	0,89 a	1,04 a	2,31 a	1,99 a	2,17 a	1,23 a

Other major disease emerged on chili was leaf spot (*Cercospora spp.)* with their intensity provided on Table 7. Leaf spot disease appeared before 38 days after planting in low percentage, the symptom was almost found on each plant. The result showed that effect of mulch and bio fungicide (Table 8.) were non significantly different on leaves spot (*Cercospora spp.*), meaning treatments could not reduce leave spot infestation of chili.

Table 7. Effect of mulch on *Cercospora* spots infestation on chili, Klampok, Brebes, Central Java, 2008

Mulch treatments	Average of Cercospora at .... Days After Planting					
	38	48	58	68	78	88
No Mulch	9,43 a	13,45 a	17,78 a	18,30 a	14,78 a	15,23 a
Mulch	8,25 a	12,87 a	14,08 a	18,05 a	16,50 a	13,40 a

Table 8. Effect of bio fungicides on *Cercospora* spots infestation on chili, Klampok, Brebes, Central Java, 2008

Bio-fungicide treatments	Average of Cercospora at .... Days After Planting					
	38	48	58	68	78	88
A	12,60 a	11,45 a	16,75 a	18,00 a	16,85 a	14,30 a
B	8,75 a	13,00 a	17,55 a	18,60 a	15,55 a	13,30 a
C	7,00 a	14,25 a	13,35 a	17,30 a	12,65 a	13,35 a
D	7,00 a	13,95 a	16,05 a	18,80 a	17,50 a	16,30 a

Other disease that appear on chili was late blight infestation, caused by *Phytophthora capcisi.* Disease intensity of late blight infestation could be seen at Table 9. Whereas bio-fungicide application (Table 10) could not prevent late blight infestation on chili in the field.

Table 9. Effect of bio fungicides on late blight (*Phytophthora*) infestation of chili, Klampok, Brebes, Central Java, 2008

Mulch treatments	Average of *Phytophthora* at .... Days After Planting					
	38	48	58	68	78	88
No Mulch	0,0 a	0,0 a	0,95 a	1,10 a	3,55 a	6,80 a
Mulch	0,0 a	0,0 a	0,75 a	1,65 a	4,55 a	7,85 a

Table 10. Effect of bio fungicides on late blight (*Phytophthora*) infestation of chili, Klampok, Brebes, Central Java, 2008

Biofungicide treatments	Average of at .... Days After Planting					
	38	48	58	68	78	88
A	0,00 a	0,00 a	1,30 a	1,60 a	4,30 a	8,15 a
B	0,00 a	0,00 a	0,60 a	0,80 a	3,70 a	7,40 a
C	0,00 a	0,00 a	0,30 a	0,80 a	2,60 a	4,65 a
D	0,00 a	0,00 a	1,10 a	2,30 a	5,60 a	9,10 a

Mulch utilization did not give the effect significantly different of total production of chili fruits (Fig.2). It was assumed that mulch utilization on chili was conducted in the rainy season. Vos *et al.* (1994) described that mulching was recommended as a component within an ICM program for chili. The overall positive effect of plastic mulch on crop health contributed to improve crop production, although effect of rice straw mulch had variable effect on crop health.

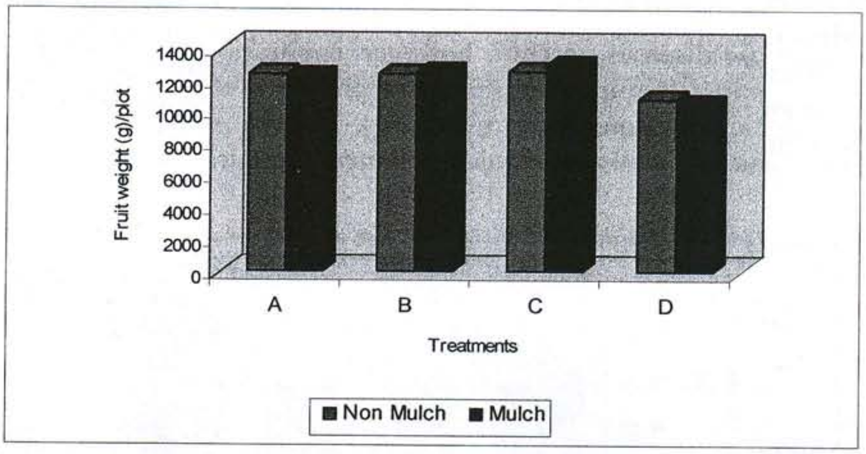

Figure 2. Total fruit weight of chili on bio fungicide and mulch treatments

Table 11. Effect of mulch on fruit harvested on chili, Klampok, Brebes, Central Java, 2008.

Treatments	Harvest of chili fruit/plot	
	Fruit number	Fruit weight (g)
No mulch	1623.60 a	12110.35 a
Mulch	1617.50 a	12177.50 a

Chili plants treated bio fungicide (A,. B and C treatments) showed the same capacity to produce chili fruit. The third of the bio fungicide treatments produced the higher production than synthetic fungicide (D treatment). So in this trial, fungicide synthetic had shown lower production of chili fruit than bio fungicide treatments.

Table 12. Effect of bio fungicides on fruit harvested on chili, Klampok, Brebes, Central Java, 2008.

Bio fungicide treatments	Harvest of chili fruit/plot	
	Fruit number	Fruit weight (g)
A	1650,5 a	12383,6 a
B	1664,0 a	12568,8 a
C	1690,7 a	12852,1 a
D	1477,0 b	10771,2 b

The case of anthracnose infestation on chili fruits, bio fungicide treatments showed lower anthracnose infestation than synthetic fungicide. The synthetic one may not reduce anthracnose infestation on chili fruit. In this case, bio fungicide spraying could be one of alternative to control anthracnose diseases on chili and could be used to prevent the anthracnose disease on chili. There was an assumption on the possibility of sensitivity modification of anthracnose fungus against synthetic fungicide that applied by the farmers on chili in the fields. The fungus of anthracnose in the field was insensitive more to fungicides sprayed by the farmer in the field.

Fruit rot caused by anthracnose was main problem disease in central production of chili. Anthracnose disease always almost found on chili every season, in the dry as well as in a wet season in Brebes. Mulch treatment could not reduce anthracnose diseases on chili, however, application of bio fungicide could reduce significantly different for anthracnose disease of chili fruit compared with synthetic fungicide treatment (D treatment), it was shown with the higher percentage of mulch as well as no mulch treatments (Figure 3).

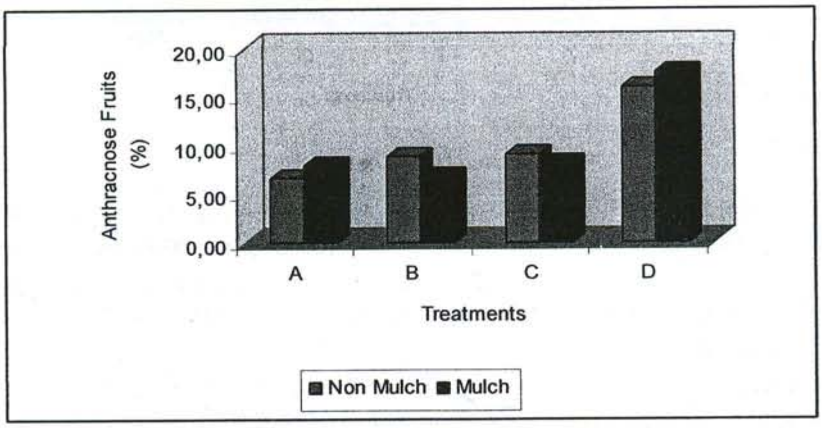

Figure 3. Percentage of anthracnose diseases incidence on bio fungicide and mulch treatments

Table 13. Effect of bio fungicides on marketable and anthracnose fruit on chili, Klampok, Brebes, Central Java, 2008.

Bio fungicide treatments	Harvest of chili fruit/plot	
	Marketable fruits (%)	Anthracnose fruits (%)
A	89,87 a	7,30 a
B	89,29 a	7,90 a
C	88,72 a	8,67 a
D	77,57 b	16,75 b

Amount of healthy fruits (marketable) were 89.87%, 89.29%, 88.72% and 77.57% respectively for A, B, C dan D treatments (Table 13). On chili plant applied bio fungicide treatment produce the higher healthy chili fruit than chili plant treated synthetic fungicide continuously. The third of biofungicide treatments produce no significant different for percentage of diseases fruits. Their reduction of fruit anthracnose diseases on chili plant treated with biofungicide was assumed that *Bacillus subtilis* (an active ingredient of biofungicide) could trigered immunity system of chili plant against anthracnose diseases on chili. This phenomenon was the same case on *Arabidopsis* to be resistant to *Pseudomonas syringae* (Ryals *et. al.*, 1996).

Chili fruits harvested also infected with fruit rot caused by *Bactrocera spp* (fruit fly). Fruit fly was also major constraint on chili. Chili fruit infected with fruit fly become rotten and it will be unmarketable.

Table 14. Effect of mulch treatment on fruit fly infestation of chili fruit, Klampok, Brebes, Central Java, 2008

Mulch treatments	Fruits infected with fruit fly (%)	Bio fungicides treatments	Fruits infected with fruit fly (%)
No mulch	3.33 a	A	2.42 a
		B	2.61 a
Mulch	2.73 a	C	2.29 a
		D	4.79 b

Mulch did not have effect to reduce fruit fly infestation on chili in the field.
The third of bio fungicide treatments (C) reduced fruit fly infestation on chili in the field. Reduction of fruit fly infestation caused by the third of bio fungicide application was significantly different compared with synthetic fungicide treatment continuously.

CONCLUSIONS

- Bio fungicide treatments A (*B. subtilis* + *B. subtilis* + *B. subtilis* + *B. subtilis)*; B (Bion + *B. subtilis* + *B. subtilis* + Daconil) and C (Bion + *B. subtilis* + *B. subtilis* + Daconil + micro organic nutrient application as much as 3 times) could reduce anthracnose disease and fruit fly infestation on chili fruit.
- Bio fungicide (A, B and C) treatments could produce higher marketable fruit weight than synthetic fungicide (D) treatment.
- Straw mulch treatment could reduce virus incidence on chili in the field.

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Socioeconomic Analysis and Participatory Risk Assessment of Chilli Cultivation in Central Java, Indonesia

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Key words: *chilli pepper production, constraints analysis of vegetable farming, Participatory Risk and Return Trade-Off analysis; farmers' perception analysis, Central Java, Indonesia*

Abstract

This study provides an overview of socioeconomic factors affecting farmers' decisions to grow chilli and allocate acreage to the crop. Chilli is very popular and widely cultivated throughout Indonesia, even though most of the chilli growers surveyed reported chilli cultivation is a very risky enterprise compared with growing other vegetables and paddy. Nevertheless, the relatively high price chilli fetches at the market provides a positive incentive to millions of small-scale farmers to grow chilli. Using a Participatory Risk and Return Trade-off analysis, we assessed farmers' perceived risk associated with cultivation of chilli and other vegetables. The results suggest farmers consider chilli cultivation to be about four times more profitable but also four times more risky than paddy cultivation. An index value was assigned on relative risk, return, and working capital requirements for each of the crops selected, and these indexes vary across 11 crops. This analytical technique also can be included in participatory appraisals and stakeholder analyses of rural development projects.

INTRODUCTION

Chilli pepper (*Capsicum* spp.) is grown throughout Indonesia. In 2007, chilli was cultivated on more than 190,000 ha in Indonesia, with production of more than 1 million t, accounting for about five percent of the world's total market share (BPS 2008; FAOSTAT 2009). In 2007, chilli was cultivated on more than 18,225 ha in Central Java province, which has the country's largest share of chilli acreage. This study is based on a survey carried out at the community and individual farm household level during March–August 2008 in three communities in the Central Java districts of Magelang, Brebes, and Rembang. In 2007, these three districts accounted for about 50 percent of the total chilli crop acreage in Central Java. Assessing the chilli farming constraints in these three districts of Central Java has value for Indonesia and other parts of Asia where chilli is cultivated intensively.

Compared to other countries in Asia, Indonesia's chilli productivity level (about 5 t/ha) is still very low (Mustafa et al. 2006). Major problems and constraints include poor crop management techniques, widespread use of low quality seed, high production costs, inadequate marketing infrastructure, and farmers' lack of knowledge of improved production practices or of integrated technology packages (Vos 1994; Basuki et al. 2009).

Analyzing factors affecting farmers' crop-choice decisions, assessing their constraints and opportunities, and their perceptions of risk and return toward different crops provide information for effective agricultural policy planning and decision making. The fact that vegetable sector produces more income and employment than cereal and staple crops sectors has been well documented (Weinberger and Lumpkin 2007; Ali 2008; Johnson et al. 2009). Likewise, in a five-country case study in tropical Asia, Everaats and de Putter (2009) emphasized the importance of public policy, credit, infrastructure, and innovative extension methods for the effective diffusion of vegetable sector technologies, especially those related to seed.

Compared to cereals, vegetable cultivation requires a high level of working capital, and it is also a risky enterprise due to its intensive farming practices, the highly perishable nature of produce, and volatility of market prices. However, risk and return related trade-off issues of vegetable farming are addressed inadequately in the literature. Past studies on farmers' risk largely focused on cereals, livestock, and other commercial farm practices (Michele et al. 2003; Hardaker et al. 2004). For a pragmatic policy analysis, we need to know factors affecting farmers' crop-choice decisions and risk and return related trade-off issues. Ali (2006) has shown that chilli is a profitable crop, but the capital requirement for chilli is also four times more than that of paddy, with more incidences of pests and diseases, and with more fluctuation of market prices than cereals. All of these facts clearly suggest that risk-related factors are also critical in farmers' decisions on chilli acreage and level of intensification. While discussing broader socioeconomic and technical constraints on chilli cultivation, we also briefly summarize the level of perceived risk and return associated with chilli farming in Central Java.

The major purpose of this paper is to assess farmers' concerns and socioeconomic factors related to chilli production in the selected communities in Indonesia. The specific objectives are: a) to assess socioeconomic factors of chilli production; b) to evaluate farm-level constraints of chilli cultivation; and c) to analyse risk and return trade-offs in chilli cultivation.

The scope of this paper is limited to documentation of selected information and findings on socioeconomic concerns and farmers' subjective perceptions on risk and return related trade-off issues for chilli and other vegetables cultivated in the three communities surveyed. Only an overview is provided here. Details on methodologies used and findings of the household survey will be presented in two forthcoming AVRDC reports.

METHODOLOGY

We adopted integrated qualitative and quantitative survey tools to assess range of issues on chilli farming, and farmers' constraints and opportunities for chilli production in Central Java.

Participatory Rural Appraisal (PRA) tools and techniques (Martin and Sherington 1997; Chambers and Mayoux 2003) were used to collect farmers' concerns and to identify factors affecting chilli cultivation. These tools were a key informant survey, focus group discussions, and participatory risk assessment. Using focus group discussions with 8 to 10 chilli growers in each community, we collected information on chilli production practices and growers' major concerns and constraints. In addition, with a structured questionnaire, we interviewed 222 households (160 chilli growers and 62 non-chilli growers) individually across the three districts. Related to the results presented in this paper, three separate tools of socioeconomic analysis were used. Information on community level factors (Table 1) and individual chilli growers' constraints (Table 2) was obtained from focus group discussions and household surveys. Farmers' perceived risk associated with chilli cultivation is assessed using participatory risk assessment. Details are in Bhattarai and Mariyono (forthcoming).

Risk in farming is the possibility of adversity or loss from uncertain events, and it refers to "uncertainty that negatively affects an individual's welfare"; it may be due to production, marketing, financial, or institutional factors (Harwood et al. 1999). In economics, risk is defined and differentiated from events that are purely uncertain. When the probability of loss associated with an event is known (or can be guessed), then such occurrence in economics is referred to as risk—but when the probability of an event is not known, then it is deemed as an uncertainty, or uncertain event (Hardaker et al. 2004). In this study, our aim is not to define risk beforehand but rather to assess farmers' subjective perceptions of overall risk (a combination of production, market, financial, institutional risks, etc.) associated with cultivation of chilli and other vegetables and paddy. Using a participatory framework of assessment, the risk estimated in this study the perceived and relative risk at the farmers' group level, not the individual farmer's absolute risk factor. In reality, each farmer may have a different degree of risk aversion, the assessment of which would require a large-scale risk-focused study. Hence, risk for a crop mentioned in this paper should be considered as "perceived risk" of a group of farmers for cultivation of the particular crop.

Using a methodology of participatory risk assessment, and a framework of risk and return trade-off of financial economics, we have developed a tool for evaluating risk and return trade-off on crop choice decisions of farmers. In disaster assessment, the participatory risk assessment approach is used to acquire information rapidly so that decisions can be made as quickly as possible. Smith et al. (2000) used participatory tools for risk mapping by assigning a risk index of 1 to 7 to uncertain events in pastoral livelihoods in Africa.

By adapting this risk assessment methodology, combining it with ranking tools of participatory assessment, and setting it in a framework of risk and return trade-off analysis from financial economics, we developed a tool specifically suited to assess farmers' subjective perceptions towards risk associated with the cultivation of a range of crops in a location. Average perceptions of a group of 8–10 farmers on overall risk, expected profit, and need of working capital for cultivation of a range of crops was obtained in a matrix, which we call Participatory Risk and Return Trade-off (PRATO) analysis. Using a relative scale (1 to 10; 1 = minimum value, 10 = maximum value), farmers' groups assigned a specific number (index) value for risk, return, and working capital for 11 crops (Table 3, Figure 2). We carried out PRATO analysis in each of the three communities surveyed, but due to space constraints, we present results here only from the Magelang site.

RESULTS AND FINDINGS

Chilli cultivation in Central Java

In Indonesia, the price of chilli is more volatile than that of paddy or other crops. Seasonal prices fluctuate significantly in response to market supply. It was noticed that even within the same day the price of chilli could change from morning to afternoon, driven by external news such as reports of flooding in major chilli production areas, changes in world market prices, etc. The monthly average farm-gate prices of three crops (chilli, paddy, and shallot) in 2007, as reported by a farmers' group in Brebes, are reported in Figure 1. Coefficient of Variation (a measure of volatility of price, and also a measure of risk) of chilli prices was 43 percent, almost four times higher than that of paddy. Because prices fluctuate widely for chilli, farmers in Indonesia consider chilli to be a very risky crop, even though farmers there can cultivate chilli year-round. During the field survey, several farmers reported that the fluctuating price for chilli is a key source of risk and a major concern.

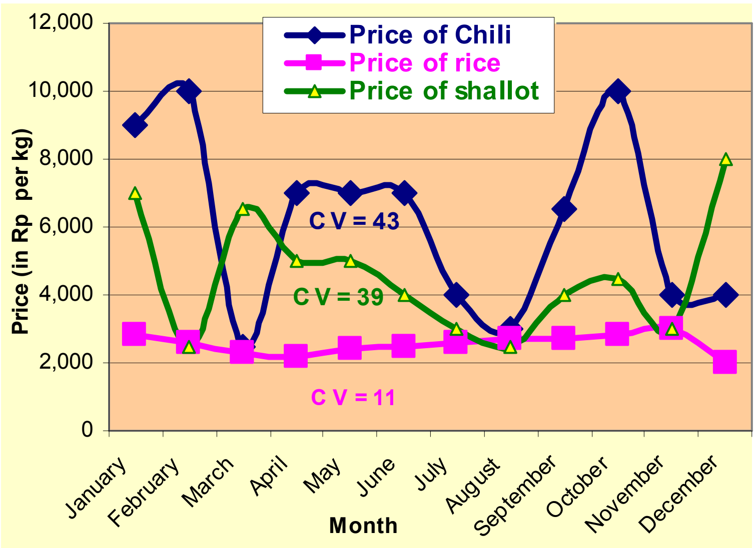

Figure 1. Monthly farm-gate prices of chilli, rice, and shallot in Brebes, Central Java, Indonesia, 2007

Factors affecting chilli production

Specific factors affecting farmers' crop production decisions may vary by crop type, production location, and season. Based on group discussions in each of the three communities, we have summarized factors that affect farmers' decisions to grow chilli in the region (Table 1). Some factors are common across the locations, but there are some important differences as well.

Table 1. Technological and institutional factors affecting adoption of chilli in Central Java, 2008

No	Magelang	Brebes	Rembang
A. Factors that encourage adoption of chilli			
1	Availability of water	Easy to sell	Availability of water
2	Availability of pesticides	Availability of pesticides	Availability of pesticides
3	Availability of new high yielding varieties of chilli	Availability of new high yielding varieties of chill	Availability of new high yielding varieties of chill
4		Support from extension office	Support from agricultural office
5	Proximity to vegetable market	Proximity to vegetable market	
B. Factors that discourage adoption of chilli			
1	Pests and diseases attack	Pests and diseases attack	Pests and diseases attack
2	High price fluctuation	High price fluctuation	High price fluctuation
3		Lack of water for irrigation	Cost of pumping water
4	More profitability from competing crops (tobacco and paddy)	More profitability from competing crops (shallot and paddy)	More profitability from competing crops (melon and paddy)

Note: Farmers listed these factors during the focus group discussions in each of the three communities surveyed.

Chilli farmers' constraints and concerns

During our individual household survey, more than 97 percent of chilli growers reported viral diseases (geminiviruses) as their top concern in chilli farming, as indicated by its lowest rank number (Table 2). Fungal disease and bacterial disease also were reported as major problems by 96 percent and 92 percent of the households, respectively. The high fluctuation of price was reported as the highest ranking factor (1.03) by 66 percent of households. The information from the participatory rural assessment (in Table 1) was consistent with that of the household survey.

Table 2. Major chilli production constraints expressed by farmers' problem ranking index

Major concerns and constraints of production	Average rank value for each of the major concerns											
	Magelang (N=49)			Brebes (N=60)			Rembang (N=51)			Overall Sample (N=160)		
	n	Mean rank	S D	n	Mean rank	S D	n	Mean rank	S D	n	Mean rank	S D
1. Virus diseases	44	1.61^{BR}	.54	60	1.03	.18	51	1.12	.43	155	1.23	.46
2. Fungal diseases	44	1.43^{B}	.50	60	1.17	.56	49	2.59^{MB}	.54	153	1.70	.82
3. Bacterial diseases	36	2.94^{BR}	.33	60	1.10	.40	51	2.31^{B}	.62	147	1.97	.90
4. Lack of information on pest management	10	2.10	.32	4	3.00^{M}	.00	45	2.93^{M}	.50	59	2.80	.55
5. High price fluctuation	40	1.03	.16	15	1.07	.26	50	1.02	.14	105	1.03	.17
6. Exploitation by traders	13	1.92	.64	6	1.67	.52	46	2.15	.42	65	2.06	.50
7. Other diseases	4	3.75^{B}	.50	17	1.06	.24	1	2.00	.	22	1.59	1.10

N = total sample of household survey in each communities/districts; n = Number of responded for each factors.
Mean Rank = Weightage Average Rank. In index: 1 = most important concern. SD = Standard Deviation value.
Significant different of mean across sites is indicated by superscript M, B and R; wherein, ^{M} = Magelang, ^{B} = Brebes, and ^{R} = Rembang. Mean comparison is tested at 95 % of confidence interval.

During the survey, we also noticed that to minimize yield loss farmers try to adopt a variety of chilli that is resistant to a particular pest and disease. In Magelang, farmers usually grow hybrids. In Brebes, farmers usually grow open-pollinated or local varieties. In Rembang, 50 percent of chilli varieties cultivated are hybrids, and also large number of open pollinated varieties. Chilli farming practice in Rembang is also less intensive than that of the other two sites.

Risks and return related trade-off from chilli cultivation

The negative factors of chilli farming listed in Table 1, and the constraints summarized in Table 2, are closely related to risk associated with chilli cultivation. The increasing incidence of diseases and pests, high fluctuation of market prices, and inadequate access to water in the dry season are some of the major factors farmers worry about most when deciding how much acreage to allocate for chilli. During our survey, almost all farmers noted that growing chilli is a risky (*risiko* in Bahasa Indonesia) compared to cultivation of other vegetables and paddy. But many of them also said that they would like to grow chilli, at least on a small plot area (around 0.1 ha) largely because of high profits from chilli, if they were lucky to get good market prices and good yield. This suggests that different farmers perceive different levels of risk across the vegetables (and paddy), and that the perceived risk level varies across the farmers. We also observed that a typical farmer allocates only a modest amount of land to chilli cultivation (0.1 to 0.2 ha per household). Over two-thirds of chilli cultivation is an intensive farming practice with high levels of inputs (Ali 2006). Therefore, in this study, we have tried to assess farmers' perceived risk as an index value and in relative terms.

Using PRATO analysis, we estimated an overall farmers' group (or proxy to a community) perceived risk associated with cultivation of chilli and a range of other vegetables and paddy crops. The results from the study in Magelang are in Table 3.

Table 3. Expected returns and risk on vegetable cultivation, Magelang, Indonesia, 2008.

S. N.	Crops	Profit obtained	Risk level	Working capital need	Remarks (underlined factors (reasons) for risk)
1	Chilli	6	9-10	9	Price and diseases (Anthracnose)
2	Rice	3	2-4	2-3	(Tungro virus; rat, plant hoppers)
3	Tobacco	8	9-10	8	Bad weather causing low quality
4	Watermelon	6	9-10	7-8	Price and diseases, cannot grow
5	Tomato	4	9-10	3-4	Price and fruit borer, wilt
6	Cucumber	5	1-2	3-4	Lower price and pest (caterpillars)
7	Bitter gourd	7	5	1-2	Pests (fruit fly)
8	Chinese Cabbage	2-3	2-3	1	
9	Peanut	2-3	2-3	1	
10	Cabbage	3-4	5-6	4-5	Price and pest: caterpillar
11	Yard-long bean	7	2-4	1-2	Price and pests: aphids, fruit borer

Index: 1 = lowest value; 10 = highest value

For some crops, the farmers' group could not come to a consensus for an exact number, but preferred to use a range.

The results in Table 3 show farmers perceive that the relative profitability of chilli cultivation is on average four times higher than that of paddy cultivation, but the overall perceived risk (i.e., subjective risk and also relative risk) associated with chilli cultivation is also four times higher than that of paddy cultivation (Figure 2). The high level of farmers' perceived risk factor for chilli cultivation is due to probability of loss associated with Anthracnose attack (which can lead to 100 percent crop failure), as well as high fluctuation of chilli prices at local markets. The results from PRATO analysis are consistent with the survey results reported in Tables 1 and 2. A working capital requirement for chilli cultivation, in relative terms, was 4 to 5 times higher than that of paddy cultivation, consistent with previous findings (Ali 2006). We also noticed that those farmers who already have enough disposable capital on hand (or who have better access to low-cost credit locally) prefer to grow chilli on larger areas (0.2 ha or more), and others would decide crop acreage as per the availability of disposal capital.

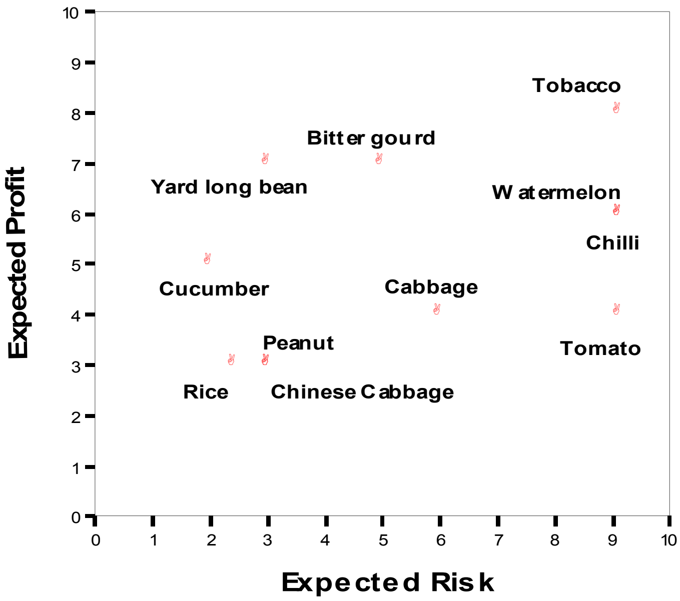

Figure 2. Trade-off on risk and return, selected vegetables in Magelang, Indonesia, 2008 (Plotted from the data in Table 3).

Most farmers do not borrow capital from credit institutions to grow chilli; in fact, formal credit institutions (banks and cooperatives) do not easily provide loans for chilli cultivation. Chilli collectors provide a modest level of credit, and they later purchase chilli from the farmers who had borrowed capital earlier (sometimes at a slightly lower crop price). All of these arrangements are due to variations in return from chilli farming in the region, and from the perceived risk level of an average farmer. Among 11 commonly cultivated vegetables and cereals selected for PRATO analysis in Magelang (Table 3), farmers noted yard-long bean required a relatively moderate level of operating capital but had the potential for almost the same return as chilli. The low expected risk and high expected profit from yard-long bean could also account for the recent rapid expansion of yard-long bean acreage in Central Java. The results on risk-return trade-off of vegetables in Figure 2 are conceptually same as the risk-return trade-off of financial stocks. One of the reasons a typical farmer diversifies acreage among different crops is to reduce perceived risk, or to minimize the probability of loss from a particular crop. The results suggest there is an advantage to growing several different crops instead of a single crop, due to the wide variation on return (and risk) across the range of crops.

CONCLUSIONS AND IMPLICATIONS

Many factors affect the crop choice decisions of an average farmer. Better access to marketing, easy-to-apply crop protection and management technology, and ready access and support from local agricultural extension agencies are factors that positively affect chilli acreage in all three communities surveyed. The high incidence of pest and diseases and the high fluctuation of market prices are the two most important factors that contribute to high risk in chilli farming. The factors causing a high fluctuation of return from chilli discourage farmers from expanding chilli acreage. Adverse effects of these factors on chilli farmers' welfare loss (profit loss) can be minimized by the adoption of appropriate technology packages, including new resistant varieties, improved crop management practices, more effective pest and disease control methods, and setting up a better market information system so that farmers get up-to-date information on prices.

Using PRATO analysis, we can better understand the relative risk factors associated with cultivation of chilli and several other high value vegetables, and we can compare these factors with paddy. As shown by our analysis, chilli growers in Magelang (and in Central Java) consider that their relative profit as well as the relative risk (perceived risk) associated with chilli cultivation is about four times higher than that of paddy.

The information on constraints and opportunities of chilli cultivation at the farmers' level, and their perceived relative risk factors across the crops, is useful for understanding of socioeconomic, institutional, and crop management factors affecting farmers' crop choice decisions in Central Java. The study findings can be useful for designing targeted vegetable sector policies in Indonesia and other tropical countries.

The major shortcoming of PRATO analysis is that the results (index number) on perceived risk, return, and working capital vary by the structure of the farmers' group involved in the focus group discussions. This is a general concern for all field survey and participatory assessment approaches. To address this issue, we included different categories of farmers (rich, middle income, poor, younger, older) in the group. Results also may vary by production systems.

The PRATO analysis, as developed and illustrated here, can be applied to other cases involving stakeholders with alternate choices. PRATO analysis can be adapted in participatory rural appraisals when designing any vegetable or agricultural sector development intervention.

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Disease Notes

First Report of *Tomato yellow leaf curl Thailand virus* Associated with Pepper Leaf Curl Disease in Taiwan

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Whitefly-transmitted begomoviruses (family *Geminiviridae*, genus *Begomovirus*) cause severe epidemic and high yield losses on pepper (*Capsicum annuum*) crops in many areas of the world. In Taiwan, pepper plants showing leaf curling, blistering, distortion, mild vein yellowing, and stunting were observed in fields in Tainan County in 2007, but with disease incidence less than 10%. However, disease incidence of more than 70% was observed in some fields in Pingtung, Kaohsiung, Chiayi, and Yunlin counties in 2009. Two symptomatic samples in 2007 and three for each county in 2009 were collected for begomovirus detection. Viral DNA was extracted and tested for the presence of begomoviral DNA-A, DNA-B, and associated satellite DNA by PCR using primer pairs PAL1v1978/PAR1c715 (4), DNABLC1/DNABLV2 (2), and Beta01/Beta02 (1), respectively. The expected 1.5-kb PCR product for DNA-A and 2.6-kb for DNA-B were obtained from all samples. However, DNA-beta was not detectable in any of the samples. One positive sample from each, Pingtung (LG6-2), Kaoshiung (LJ3-5), Tainan (P2-4), Chiayi (SG4-3), and Yunlin (HW2-2), were selected for further molecular characterization of DNA-A and DNA-B. On the basis of the sequences of the 1.5-kb DNA-A and 2.6-kb DNA-B PCR product, specific PCR primers were designed to obtain the complete DNA-A and DNA-B sequences for pepper-infecting begomovirus isolate LG6-2 (GenBank Accession Nos. GU208515 and GU208519), LJ3-5 (GenBank Nos. GU208516 and GU208520), P2-4 (GenBank Nos. EU249457 and EU249458), SG4-3 (GenBank Nos. GU208517 and GU208521), and HW2-2 (GenBank Nos. GU208518 and GU208522). The five isolates each contained the begomoviral conserved nonanucleotide sequence-TAATATTAC in DNA-As and DNA-Bs, six open reading frames (ORFs AV1, AV2, AC1, AC2, AC3, and AC4) in DNA-As, and two open reading frames (ORFs BV1 and BC1) in DNA-Bs. Sequence comparison by MegAlign software (DNASTAR, Inc. Madison, WI) showed that the five pepper-infecting begomovirus isolates had 99% nucleotide sequence identity in DNA-As and DNA-Bs and so they are considered isolates of the same species. BLASTn analysis with begomovirus sequences available in the GenBank database at the National Center for Biotechnology Information (Bethesda, MD) indicated that the DNA-As and DNA-Bs of the five isolates had the highest nucleotide sequence identity of 99% each with the respective DNA-A and DNA-B of *Tomato yellow leaf curl Thailand virus* (TYLCTHV; GenBank Nos. EF577266 and EF577267), a recently emerging bipartite begomovirus infecting tomato in Taiwan (3). On the basis of the DNA-A sequence comparison and the International Committee on Taxonomy of Viruses demarcation of species at 89% sequence identity, these virus isolates belong to the species TYLCTHV. The isolate P2-4 was found transmissible to *C. annuum* 'Early Calwonder' by whitefly (*Bemisia tabaci* biotype B) and induced the same leaf curling, blistering, and mild vein yellowing symptoms as those observed in pepper fields. To our knowledge, this is the first report of a begomovirus infecting pepper in Taiwan. The presence of TYLCTHV in the major pepper-production areas should be taken into consideration for pepper disease management and in developing begomovirus resistant pepper cultivars for Taiwan.

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