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ASEAN ACTION PLAN ON FALL ARMYWORM

REGIONAL RESISTANCE MANAGEMENT PROGRAMME FOR FALL ARMYWORM

CONCEPT PAPER

ASEAN FAW ACTION PLAN
Supporting IPM Across Southeast Asia

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Introduction

This document sets out the Regional Resistance Management Programme for Fall Armyworm (FAW) across Southeast Asia under the ASEAN Action Plan on FAW.

Preventing or mitigating the onset of resistance in FAW populations to different management options is a critical action of the Action Plan. It ensures that farmers have ongoing access to a range of effective options in the IPM toolbox to sustainably manage FAW. This Programme sets out the framework for action and was developed in consultation with stakeholders across 2021, including through a regional workshop and public written feedback process on a draft concept note.

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Summary

The Fall Armyworm [Spodoptera frugiperda (J.E. Smith); FAW] has emerged as a serious threat to the food and feed security of millions of smallholder farmers in the ASEAN region over the last three years. The damage is especially significant across maize crops in the region, although the pest has caused minor economic damage to sorghum, millets, and a few other crops.

The ASEAN Action Plan on FAW sets out a regionally agreed multi-stakeholder model for supporting Southeast Asian countries to monitor and manage the pest by using integrated pest management (IPM) approaches. Preventing or mitigating the onset of resistance in FAW populations to different management options is a key action of the ASEAN FAW Action Plan. It ensures that farmers have ongoing access to a range of effective options in the IPM toolbox to sustainably manage FAW. For clarity, IPM tools include those related to surveillance and monitoring, physical and cultural actions, conservation and augmentative biological control, deployment of resistant varieties, biopesticides, semiochemicals, botanicals, etc. and, only when needed, application of environmentally safer synthetic pesticides.

Three specific areas for development are proposed as part of the FAW Resistance Management Programme:

1. Regional FAW surveillance and resistance monitoring
A successful resistance management programme depends on a well-designed detection and monitoring system. The combination of field-based approaches on an areawide scale with laboratory-based tools will ensure a better understanding of the FAW incidences and resistance profiles across the region and help underpin present and future FAW response strategies.

2. Country-specific and regional FAW resistance management guidelines inclusive of all possible IPM practices
Consistent and robust resistant management approaches applied across the region are vital to preventing/mitigating resistance development in FAW populations. This requires the development and dissemination of clear, science-based information and training on monitoring, and the responsible use of FAW management controls as part of a robust IPM approach.

3. Integrating host plant resistance with other compatible IPM tactics for sustainable FAW control in the ASEAN region
Host plant resistance is a major component for the sustainable management of FAW. Transgenic (*Bt*) maize with resistance to FAW is already being commercialized in a few countries in Asia (Philippines and Vietnam), while significant progress has been made by CIMMYT in developing elite maize germplasm with native genetic resistance to FAW. There is a substantial opportunity for developing and deploying elite climate-resilient maize hybrids with host plant resistance to FAW and integrating these with other compatible IPM tactics in the ASEAN to proactively manage pest and disease threats while improving productivity and resilience of maize varieties cultivated by farming communities.

Background

FAW was first reported in Southeast Asia in late 2018. It has since rapidly spread, and its presence is now confirmed across the region.

The pest has caused major damage to maize and is a potential threat to other crops. Now that FAW is established in the region, management will need to be focused on sustainable control. The impact of FAW damage on crop yield and to the livelihoods of smallholder farmers in Southeast Asia is a serious issue for food, feed, and income security in the region. This is further exacerbated by the severe impact of Covid-19 related implications on agricultural supply chains.

ASEAN farmers are in urgent need of effective, safe, affordable, and regionally relevant FAW management solutions. Appropriate, cost-effective, practical IPM methods need to be either developed or validated, and further piloted, promoted, and scaled up.

IPM entails the tactical integration and deliberate prioritization of crop protection practices to keep pest populations below economically damaging levels, in which the use of preventative tactics (e.g., monitoring of pest and natural enemy population levels, field damage, crop sanitation, intercropping) and early and eco-friendly interventions (e.g., pest-resistant varieties, biological control) are prioritized.

It is imperative to effectively address risks related to resistance in FAW populations to control measures, especially to conventional chemical pesticides and *Bt* transgenes. A regional approach is necessary as no country alone can effectively manage the evolution of pest resistance to currently used chemistries in the ASEAN countries, given the transboundary nature of the pest and its ability to move rapidly over significant distances. A good strategy applied in one country could be rendered ineffective if pest resistance emerges in neighbouring countries.

Furthermore, an ASEAN resistance management program must anticipate and minimize the risks of insecticide resistance development in the entire regional ecosystem. Conventional chemical insecticide applications directed against one single pest in a given crop can trigger the development of resistance in non-target pests and/or lead to a resurgence of secondary (polyphagous) pests. Coordinated regional approaches on host plant resistance (HPR) represent another major opportunity for sustainable management of FAW in the future.

Any resistance management strategy needs well-coordinated multi-stakeholder actions underpinned by transparent science-based approaches. A strong regulatory environment is critical to support the implementation of appropriate and timely actions at the farm-, national- and regional levels.

The Resistance Management Programme will also identify opportunities for women empowerment, gender integration and social inclusion across all its activities.

Monitoring resistance emergence in FAW populations and management strategies

Monitoring

Evidence of the evolution of resistance of FAW already exists. Recent studies using genetic markers and genome sequencing have revealed that FAW populations in Africa (e.g., Malawi, Uganda, Kenya) as well as Asia (e.g., China, Indonesia), and Australia, appear to have evolved resistance to organophosphates and pyrethroid insecticides (Li et al. 2020 [1], Boaventura et al. 2020 [2]; Guan et al. 2020 [3]; GRDC 2020 [4]).

Since it arrived in China in 2018, local farmers have largely resorted to the use of conventional synthetic pesticides for FAW management and pesticide application rates have tripled (Yang et al., 2021) [5]. Current pest management schemes with an almost exclusive reliance on conventional synthetic products have the potential to further aggravate insecticide resistance issues.

It is, therefore, critical to understand the current resistance profiles in FAW populations, as well as to monitor the possible emergence of resistance. It is also vital to implement a robust IPM approach that places significant emphasis on monitoring, surveillance, scouting and judicious management. Predicting when a pest will be present and then assessing the level and severity of an infestation allows timely mitigation of the problem using the fewest and safest interventions to effectively and economically guard against yield loss while preserving needed ecosystem services and minimizing harm to the environment (Prasanna et al. 2018 – Fall Armyworm in Africa: A Guide for Integrated Pest Management). Early, well-informed action plays a key role in insect resistance management.

Chemical Insecticides

Currently, registered chemical insecticides in the ASEAN region make up a shortlist of about 7 chemicals representing just 5 different modes of actions (MoA) (IRAC). Studies undertaken globally show that the repeated exposure of multiple pest generations to the same insecticide MoA leads to insect resistance; FAW is no exception. With limited choices, ASEAN farmers can end up spraying single-MOA synthetic insecticides and thereby raise the likelihood of insecticide resistance development among both target and non-target pests. Furthermore, the poor management of synthetic pesticides (e.g., wrong doses, sequence, timing, application modes) can compromise the success of both regional and national FAW management programmes.

Globally, FAW populations have evolved resistance to Carbamates (Group 1A); Organophosphates (Group 1B); Pyrethroids (Group 3A); Bacillus thuringiensis Cry1F protein (Group 11A); Benzoylureas (Group 15). Though diamides (Group 28) and spinetoram (Group 5) overall still work well, resistance to these compounds has also been detected in some countries (e.g., in Puerto Rico). Prophylactic usage modes such as insecticidal seed coatings or soil drenches further raise the likelihood of resistance development. The use of low-cost generics can also be an issue as they can trigger overuse and are often not accompanied by proper usage guidelines. Likewise, the trade of unregistered (generic) or banned insecticides can also undermine the success of resistance management programs.

Lowering farmers' overreliance upon chemical pesticides requires regional and area-wide approaches to be adopted. The active rotation of low-risk synthetic and biological insecticides with different MoAs, along with the integration of other tactics such as host plant resistance, biopesticides, semiochemicals, conservation and augmentative biological control, and cultural practices is important (Sparks et al., 2020).

Bt-Maize Technologies

Currently, *Bt*-maize is being commercialized in the Philippines and Viet Nam and the cultivated *Bt* technologies include *Bt*-11, MON 810, MON 810 x TC 1507, MON 89034, *Bt*-11 x TC 1507 x GA21, and *Bt*-11 x MIR162 x MON89034 x GA21. Other ASEAN countries may consider the use of *Bt*-maize technologies in the future. Dual-gene *Bt*-maize products have been found to be efficacious against FAW in the countries cultivating *Bt*-maize.

The sustainability of these products relies heavily on robust resistance management and risk mitigation strategies, which are critical for preserving the benefits (and value) of *Bt* crop technologies to support FAW control. It should be noted that the insect resistance management (IRM) strategies for *Bt*-maize are part of the product registration package in these countries.

Current IRM strategies for *Bt*-maize rely on a) high dose/refugia strategy, and b) pyramiding transgenes with different modes of action. The high dose/refugia strategy provides an opportunity for a higher number of susceptible adult insects to mate with any homozygotic resistant moth which emerges in the *Bt*-transgenic cultivar. This leads to a heterozygotic progeny susceptible to the high doses of the *Bt* toxin. The second strategy uses plants that express two or more *Bt* proteins, "stacking' resistance genes with different MoAs against the same target pest. Theoretically, only the individuals who are homozygous for resistance to all proteins survive on *Bt* plants under this strategy, provided that the resistance traits are recessive [6]. Farmers' education and training on *Bt*-maize and IRM, the highest level of refuge compliance (e.g., seed-blend deployment [7]) and multi-stakeholder strategies for IRM are vital.

In the same way, the pyramided traits reduce the speed of resistance to *Bt*-crops, the blending, or the 'stacking' of different MoA for pest control to protect *Bt*-crops, will likely delay the development of resistance to *Bt*-crops and extend the lifespan of transgenic technologies in the region. As *Bt*-maize varieties can substantially reduce (or even eliminate) insecticide use, they can contribute to IPM systems with a strong biological control component (Romeis et al., 2006[8]; 2019[9]). Field studies have shown that the abundance, activity, and pest control action of biological control agents are similar in *Bt* and non-*Bt* crops. Consequently, by conserving or actively releasing biological control agents in *Bt*-maize fields, one can counteract the emergence of pest resistance and further support an IPM approach.

Native genetic resistance to FAW, coupled with climate resilience

Significant progress has been made by CIMMYT in breeding elite maize lines and hybrids with native genetic resistance to FAW in Africa, based on the strong foundation of insect-resistant germplasm developed and validated at the breeding hubs in Mexico and Kenya (Prasanna et al., 2018 [10], 2021 [11]). Intensive work undertaken during the last three years resulted in the identification and announcement of three promising FAW-tolerant elite maize hybrids by CIMMYT in December 2020 to partners in sub-Saharan Africa [12]. These elite FAW-tolerant maize hybrids are undergoing national performance trials (NPTs) in several countries in Africa and have the potential to be introduced to countries in the ASEAN.

CIMMYT's strong partnerships and work on climate-resilient maize in Asia over the last decade has led to the development and release of over 30 climate-resilient (e.g., tolerance to drought, heat and waterlogging, and resistance to major diseases) in Asia [13]. This offers a powerful opportunity to integrate native genetic resistance to FAW with climate-adaptive and other farmer-preferred traits in elite maize genetic backgrounds adapted to the ASEAN region. As native genetic resistance to FAW is polygenic (unlike the oligogenic nature of transgenic resistance) and does not exert high selection pressure on the insect, it is much more durable. In addition, owing to a different MoA, native genetic resistant maize germplasm can serve as an effective platform for introgressing *Bt* transgene(s) as a part of a resistance management strategy.

Biocontrol

The use of biocontrol in IRM schemes can help slow the speed of development of FAW resistance to both insecticidal MoAs and genetic traits of *Bt*-crops. Biocontrol is also a key component of a robust IPM approach. Consequently, the ASEAN Action Plan includes a specific Biocontrol Programme which focuses on the use and scale-up of classical, augmentative, and conservation biocontrol approaches, as well as bioprotection technologies that are used to manage agricultural pests utilizing specific biological effects (e.g., semiochemicals). It is intended that the Resistance Management Programme effectively leverages the complementary Biocontrol Programme within its activities, as appropriate, and incorporates relevant learnings and knowledge.

Other Initiatives in the Region

The purpose of this section is to highlight related efforts in the region to which the ASEAN Plan would draw on, with the aim that these partners would contribute their findings to the overall development of the regional ASEAN Management Plan. Avoiding duplication of efforts and leveraging off different programmes, where appropriate, is important.

Australia (CSIRO/ACIAR/GRDC) has recently started a project in Indonesia, Vietnam, Laos, Myanmar, Cambodia, Philippines, Malaysia, and Australia, which will conduct a genetic characterisation of FAW populations and assess for insecticide sensitivities through bioassays of live caterpillars exposed to different insecticide modes of action. The project will also look for genetic markers that could suggest insecticide resistance through the whole-genome sequencing approach.

The University of Gadjah Mada, Indonesia is working on baseline susceptibility as well and has established a laboratory population that has collected FAW from the “first” arrival in 2019 as a reference population.

In the Philippines, the University of Philippines-Los Banos and East-West Seed Company are working together to develop an effective insecticide management program as a component of IPM for FAW in maize. The project aims to:

- generate baseline information on crop protection practices among corn growers
- generate baseline susceptibility data for conventional insecticides against FAW
- generate baseline susceptibility data for botanical insecticides against FAW
- determine field bio-efficacy of conventional and botanical insecticides against FAW
- craft an insecticide resistance management program for FAW

China is undertaking extensive research on various facets of fall armyworm control including resistance management and planning. CAAS has expressed interest in working with the ASEAN FAW Action Plan on resistance management.

The Japan International Research Center for Agricultural Sciences is planning a project for developing integrated pest management (IPM) of fall armyworm (FAW) in the Indochina region, including Thailand and Myanmar. The information-sharing of pesticide susceptibility is included in this project.

Project Action Plan

1. Regional FAW Surveillance & Resistance Monitoring

Tracking pest resistance in the field and thereby proactively detect and counter emerging problems, resistance monitoring is vital. To monitor resistance in FAW populations, we will collaborate with farmers and scientists in partner countries to implement monitoring approaches that are harmonized across all involved countries.

Key Activities:

- Organize regional and or country-level Workshops on FAW Insect Resistance Monitoring and Management involving relevant stakeholders
- Create common understanding and share good practices across the public and private sector for managing resistance
- Design and implement target country-specific and region-wide FAW surveillance and monitoring programmes, geared towards resistance monitoring.
- Monitor the genetic diversity of FAW populations in the ASEAN, including the possibility of changes in allele frequencies of loci known to be associated with resistance to Bt toxins and commonly used synthetic insecticides.

2. Country-Specific and Regional FAW Resistance Management

We will conduct workshops with local scientists, and partner with local farmers and organizations, government agencies, the private sector, and other stakeholders to support the development of IRM plans suitable for implementation in the target countries in the ASEAN (Annex 1). Economic and social concerns that influence the adoption of IRM plans, including the use of different MoA (e.g., conventional pesticides, Bt-crops, biocontrol etc) will be considered along with the biological data to maximize community participation and increase positive impacts.

The ASEAN FAW Action Plan Biocontrol Programme will assess regulatory and market barriers to the registration and commercialization of bioprotection tactics such as biopesticides, semiochemicals and invertebrate natural enemies. This work will be shared with the Resistance Management programme who will be responsible for reviewing the current legislation and prevailing practices across ASEAN member countries for registration of synthetic pesticides, as well as developing best proactive guidance for resistance management that draws on a range of FAW control measures in an integrated manner.

Key Activities:

- Undertake a systematic mapping exercise of critical gaps in national response capacity related to resistance management [14].
- Explore ways to bring attention to the negative impacts of illegal imports of synthetic pesticides, use of banned substances and the proliferation of unregistered products.
- Establish field trials to ascertain FAW economic thresholds under local agroecological contexts and define economically justified management schemes accordingly.
- Develop, and/or actively disseminate pesticide use and risk management guidelines that set out efficacious and economically justified low-risk pesticide use based upon guidelines as set out in Jepson et al. (2020) including reviewing current registration and use of convention chemical insecticides in the region.
- Assess the level of implementation of Bt resistance management in the Philippines and Viet Nam and their potential impact on the evolution of FAW resistance to Bt insecticidal genes.
- Develop regional best practice guidelines on resistance management, including advice on the use of a range of bioprotectants and cultural practices, and support their implementation and adaptation into national and local-level policy.
- Design educational and training resources both with and for different stakeholder groups in local languages to support IPM practices on-farm as part of a resistance management plan (or vice-versa), including for regulators responsible for developing national and local-level policy.

3. Integrating tactics such as monitoring, host plant resistance and biological control plus selective, IPM-compatible chemical insecticides (and usage modes) for sustainable FAW control in the ASEAN

Insufficient attention has been so far given to the integration of host plant resistance to FAW with other IPM tactics, and to quantify the benefits of host plant resistance in multi-tactic IPM programs. We will attempt to fill this critical gap through this project in Southeast Asia.

Key Activities:

- Establish necessary screenhouse infrastructure (for validation of source germplasm from CIMMYT with native genetic resistance to FAW).
- Testing, varietal release and widespread deployment of CIMMYT's "first-generation" white maize hybrids with FAW resistance, in the ASEAN countries where white maize varieties are grown and consumed by local populations.
- Strengthening the capacity of NARES institutions in the ASEAN in breeding and deploying improved maize varieties with resistance to FAW and other important climate-adaptive and agronomic traits relevant for the smallholders.
- Form an alliance between CIMMYT and Bt technology providers for transferring Bt-based resistance into appropriate genetic backgrounds (with native genetic resistance to FAW and other climate-resilient traits)
- Devise and implement effective and scalable IPM packages with a combination of host plant resistance and compatible IPM tactics, involving good agronomic practices, IPM-compatible chemical insecticides and usage modes, invertebrate biological control agents, semiochemicals and biopesticides.
- Promote extensive awareness among extension agents and farming communities through field days and communication resources about validated IPM packages and their benefits.

Logistics

Project Duration

Five years (2022-2026) aligned with the ASEAN FAW Action Plan.

Partners

The public sector (IARCs, NARS; NPPOs; Government Agencies), and private sector will need to work closely to effectively implement the project. Farmers and civil society organizations are also critical stakeholders that need to play a key role in the delivery of the activities.

Potential partners include the ASEAN FAW Action Plan Secretariat, CIMMYT, USAID, USDA, IRAC/Agrichemical companies/Croplife Asia, IBMA and biological control companies, CPCrop, East-West Seed, ASEAN government regulators/Department of Agriculture, China, Australia including CSIRO, and the FAO.

Project Management

Based on this concept document a project plan will be developed. This will outline a budget for the activities and a roadmap for the implementation of activities. The project, under the ASEAN FAW Action Plan, will be coordinated and managed by ASEAN FAW Action Secretariat with CIMMYT as the lead technical partner. Various partnerships can be progressed according to the project and funding arrangements, however.

The project steering committee (SC), with focal points from various partner institutions, will be formulated. The committee shall meet on a bimonthly basis to assess the progress (i.e., 6 times throughout 12 months)

The project SC team shall comprise the ASEAN Action Plan secretariat (Secretariat); CIMMYT (technical lead), at least three Government Taskforce representatives including the Taskforce Chair (MARD Viet Nam), CAAS China, Australia Govt., JIRCAS, IRAC Asia, as well as significant donors of the programme. Other existing members of the project team are invited to remain a member of the Group. Additional members can join as motivated to contribute to the programme of work, by invitation of the Secretariat.

The Resistance Management Programme will also identify opportunities for women empowerment, gender integration and social inclusion across all its activities and report annually on progress.

Endnotes

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Annex 1. FAW resistance management approach in different ASEAN countries.

Country	Product Line	Rationale	Resistance monitoring approach	
			Laboratory based	Field based
Myanmar	Insecticides	Few registered products; off label use; limited knowledge on resistance management; possible lack of capacities for lab-based monitoring; no regulations for monitoring resistance; moderate to high levels of penetration of illegal products; resistance monitoring investments low from public and private sectors.	☒	☑
Cambodia	Insecticides		☒	☑
Laos PDR	Insecticides		☒	☑
Viet Nam	Insecticides and *Bt* technologies	Good number of registered products; off label use; moderate knowledge on resistance management; fair capacities for lab-based monitoring; no regulations for monitoring resistance (insecticides or Bt); moderate to high levels of penetration of illegal products.	☑ Recommended only if there is value and interest from stakeholders	☑ Recommended annually for insecticides and Bt technologies
Thailand	Insecticides	Good number of registered products; moderate knowledge on resistance management; good capacities for lab-based monitoring with Government; no regulations for monitoring resistance; moderate levels of penetration of illegal products; Private companies active.	☑ Insecticides – DoA has interest in both lab and field-based approaches. Needs more discussion.	
Indonesia	Insecticides and *Bt* technologies (possibly near future)	Good number of registered products; Good knowledge on resistance management; capacities and expertise for lab-based monitoring with academia; no regulations for monitoring resistance; moderate levels of penetration of illegal products; Private companies active.	☑ Annual field-based monitoring encouraged for both product lines. Laboratory assays can be recommended annually or biennially for insecticides, considering large acreage and two seasons of maize. Laboratory assays with *Bt* proteins is technology-specific (= tech provider's role)	
Philippines	Insecticides and *Bt* technologies	Good number of registered products; Good knowledge on resistance management; Good capacities and expertise with academia for lab-based monitoring; Strong regulations for monitoring Bt resistance; No regulations for monitoring insecticide resistance; low to moderate levels of penetration of illegal products; Private companies active.	☑ Every two years for Insecticides.	☑ Annually being done for Bt technologies. Recommended for insecticides
Malaysia	Insecticides	Few registered products (chemical and biological) with known efficacy; Lab and field -based data to ascertain efficacy versus crop stage, infestation levels, mode of application etc to formulate resistance management approach is lacking; moderate knowledge or expertise on resistance level determination and its consequential management (e.g., cross-resistance); baseline resistance monitoring strategy not available;		

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