Final Report

Co-developing and extending integrated Spodoptera frugiperda (fall armyworm) management systems for the Australian vegetable industry

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Project:

Co-developing and extending integrated Spodoptera frugiperda (fall armyworm) management systems for the Australian vegetable industry (VG20003)

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Public summary

Fall armyworm (FAW) was first detected in January 2020 in far-north Queensland. It quickly spread to several locations in the production areas of Qld, WA, NT, NSW and Vic causing major impacts for the sweet corn crops. FAW infestations were also recorded on brassicas, capsicum, melons, cucumber, eggplant, heliconia and okra. The rapid rise in FAW numbers has become a major threat to the integrated pest management (IPM) practices currently used by the vegetable industry. Hort Innovation funded this project to co-develop and deliver strategies to manage FAW in Australia. A participatory action research (PAR) approach was used to bring together knowledge and new experience with managing FAW from across peak industry bodies, researchers, private service providers, Hort Innovation Program Coordinators and Regional Development Officers. A communications and extension strategy was developed to increase FAW knowledge and awareness of R&D across the Australian vegetable industry. The project team linked with research funded by the Queensland Government and other Hort Innovation projects to deliver the latest information to industry.

Vegetable industry stakeholders have made significant changes and improvements to FAW management practices as a result of this project. This includes—better understanding of FAW biology and seasonal pattern, minimising the use of older and ineffective chemistries, practice change to new generation chemistries, understanding of endemic natural enemies of FAW and the aspiration to use them within an IPM program, improved knowledge of the insecticide resistance levels in FAW and implementation of large-scale seed treatment trials in sweet corn.

In the first year (2021), the project team consulted the sweet corn industry in the Bowen, Burdekin and Lockyer Valley regions to document current FAW control measures and, based on these findings, designed two best management options (BMO) for sweet corn. These BMOs were field tested during the 2021 season in Bowen and the outcomes were discussed with industry for designing large scale demonstration sites. The constant pressure of FAW required intensive monitoring and timely application of control measures to avoid significant crop losses.

In 2022, further improvements of FAW BMOs were co-developed in consultation with industry agronomists and technical staff from chemical companies. Three sweet corn demonstration sites were established at the DAF Research Facility Bowen to demonstrate BMOs against industry standards. The sites demonstrated the best performing chemistries, seed treatments, releases of beneficial insects, impact of FAW on crop phenology, FAW and other pest pressures, spray application methods, and preferred industry varieties. The commercially available egg parasitoid for heliothis and ladybird beetles for aphids were released using a drone. A larval parasitoid (*Cotesia* sp.) was also released against FAW.

Two new horticulture focused communications channels were established as part of the project to keep industry up to date with the latest information on FAW research, development and extension. These were the FAW newsletter that was launched nationally on 6 June 2022 and the FAW engagement hub (eHub) that was launched on 19 August 2022. In addition, the project team has extended and communicated FAW research and management strategies across the Australian vegetable industry through project team meetings, webinars, demonstration sites and field days, presentations at industry meetings, a FAW management guide, conferences and workshops, and industry magazines. The project has updated the compendium of FAW RD&E projects and activities currently undertaken in Australia with government agencies, industry organisations, universities and private companies. Information on endemic parasitoids, predators and other biocontrol agents of FAW were delivered to industry using the above approaches.

A co-design workshop was held on 17-18 November 2022 in Brisbane to develop a shared goal for FAW management for the Australian vegetable industry and to identify the research, development and extension objectives required to achieve the goal. Fifteen participants representing sweet corn companies, AUSVEG and Hort Innovation, DAF Qld and NSW DPI attended the workshop. A co-design approach was used during the workshop to capture project best bets and constraints, and to develop four industry-oriented objectives for achieving 'Sustainable area wide management of FAW for Australian Vegetables'.

Keywords: Fall armyworm, integrated pest management; vegetables; sweet corn; co-design; Co-development, PAR.

Introduction

Fall armyworm (FAW) was first detected in January 2020 in far-north Qld. Subsequent detections were reported in Bowen- Burdekin, Kununurra, Darwin, Katherine, Broome, Carnarvon, Bundaberg, Southern Qld, Northern NSW, Gippsland (Vic) and Tasmania.

Year-long establishment of FAW in the production areas in Qld, WA, NT, NSW and seasonal establishment in Vic has caused major impacts on the sweet corn and vegetable producers in those areas. In Australia, sweet corn and maize are reported as highly preferred host crops of FAW. Within the short period from the detection of FAW, significant crop damage (up to 90%) was observed in sweet corn crops in Qld, NT and WA, and NSW. Subsequent infestations have been recorded on some other horticulture crops such as brassicas, capsicum, melons, cucumber, eggplant, heliconia and okra. FAW has also become a significant pest for the production of fodder for the grains and livestock industry, mainly maize and sorghum.

In Qld, commercial sweet corn production is concentrated in the Bowen, Burdekin and Lockyer Valley regions and recently expanded to Bundaberg. In 2019, the Bowen and Burdekin sweet corn production area was estimated at 2200 ha with a value of $90 million (Subramaniam and Mullins 2020). In the dry tropics, commercial vegetable production is significant (13,000 ha with $620 million) with an extended season from February to November. The industry is concerned that FAW will move onto other crops.

Recent crop survey results (Hort Innovation project MT19015) also showed that FAW infestation in capsicum crops is widespread across several commercial farms in the Gumlu and Bowen region where fruit damage between 10 and 30% was recorded in the field and packhouse. In WA and NT, FAW damage was restricted to grass crops, maize, sweet corn, sorghum and Rhodes grass. Maize and sweet corn were badly damaged with reports of significant losses in Carnarvon crops.

The rapid rise in FAW numbers has become a major threat to the IPM practices currently used by the vegetable industry. The increased use of insecticides to control FAW in various crops is highly disruptive to natural enemies and biological control programs. There is also a concern that pesticide failure will occur due to current and emerging genetic resistance. FAW populations from the production regions of NT, NSW, Qld and WA were confirmed to already have gene alleles associated with organophosphate and carbamate resistance (Nguyen *et al.* 2021) and exhibited reduced sensitivities to pyrethroid insecticides (Bird *et al*. 2022). Therefore, the use of insecticides cannot be considered as a stand-alone technique to manage FAW infestations and their continued use may impose additional selection for resistance to currently effective insecticides. The development of IPM strategies will require multiple approaches for sustainable management of FAW in Australia.

The Hort Innovation funded project VG20003 strengthened linkages and shared resources with other FAW R&D projects to optimise efficiencies and research outcomes for the horticulture industry. This included linkages and collaboration with Queensland Government funded FAW research and industry communication in grains, cotton, horticultural crops, and pastures. The VG20003 project directly contributed to the Strategic Investment Plan (SIP) of the vegetable industry Outcomes 3 ‘increasing farm productivity and decreased production costs through reduced impact of pests’ by co-developing and delivering FAW management strategies and information resources.

Methodology

1. Participatory action research approach

The project used the participatory action research (PAR) approach to co-develop knowledge and practices for FAW management. This is a collaborative approach where stakeholders, including, agronomists researchers, chemical company technical experts, extension officers and crop consultants work together in the planning (formation of PAR group, engagement with the PAR group and stakeholders, co-development of demonstration sites), implementation (establishment of demonstration sites and conduct a field day), observation (observation of demonstration sites and field day), and reflection (facilitated meetings and feedback from growers and other stakeholders) stages to develop knowledge and information for FAW management.

Project team engaged the stakeholders with one-to-one and group discussions, and access to pest management information, farm spray records, and current crop management practices to, design best-bet FAW management strategies for field testing and validation. This captured and prioritized the experiential knowledge that existed to tackle this complex FAW problem. The supporting prompts were used to encourage participation and engagement of PAR group members during the project period. Additionally, knowledge, attitude, skills, aspirations, and practice changes (KASAP) on FAW management were documented in the PAR process (Table 1).

In the process the team consulted with a broad spectrum of local agronomists, chemical and seed companies, spray operators, to gather information and develop best management options (BMOs) for FAW management (see detail in Demonstration section).

The project team drafted a paper entitled "The use of participatory approaches in the development and extension of fall armyworm management practices for the Australian vegetable industry" authored by Ramesh Puri, Siva Subramaniam, Heidi Parkes, Vasanthaverni Sivasubramaniam, John Stanley, Olive Hood and Tim Smith. The paper was presented at the APEN conference in Launceston, Tasmania on 16th November 2023. The paper received the best research paper for the Rural Extension and Innovation Systems Journal.

Table 1. Supporting prompts to engage participants and document KASAP changes on FAW management.

Step 1. Plan	• What are we trying to do, learn or achieve in FAW management? • What is the FAW situation and pressure? How does it differ from last year? • What are our current practices for managing FAW? • What do we not know? (Insecticide resistance, where are FAW breeding during off-season?) • What are the likely changes in knowledge, attitudes, skills, aspirations, and practice **(KASAP)** due to the activity?
Step 2. Act	• What methods were used? • What are our current practices for managing FAW (biological, chemical, monitoring)? How do we study insecticide resistance and FAW sample collection (larvae size, treatment history)? • How do we proceed with the demonstration site establishment (commercial farm or research station)?
Step 3. Observe	• What were the results? • What was the effect of seed treatment and other treatments?
Step 4. Reflect	• What does the data say (interpretation)? • What is its application to the growers and other stakeholders? • What did we learn? • What will we do differently? • What is the impact on growers and stakeholders **(KASAP)**? • What do you want to see in the next meeting?

2. FAW extension and communication

The project conducted extension and communication activities aligned with the project's extension and communication strategy document. The FAW project team meetings were conducted face-to-face and virtually (Teams meeting). An agenda was drafted before the meetings and circulated for improvement ahead of each meeting. The target audiences were growers, agronomists, chemical and seed companies, VegNET RDOs, funding agencies and DAF staff. The meetings were conducted to share experiences of the FAW situation nationally, provide FAW RD&E updates and conduct Q & A sessions. The project meetings were monitored and evaluated using a feedback survey form (Appendix 2). Additionally, the meeting notes were shared to the participants through the FAW newsletter and eHub.

The FAW newsletter articles were delivered based on grower and industry-identified need. The newsletter included the latest news updates on FAW management and progress, and outcomes of other R&D projects such as FAW activities and seasonal patterns, insecticide resistance results, endemic parasitoid and predators and newly funded projects. They were distributed using the Vision 6 platform (digital) and printed versions. The printed copies were distributed during industry visits, workshops, and field days. The digital distribution metrics for the newsletter (including percentage opened) are monitored using the platform's web analytics (Appendix 2).

The eHub on FAW RD&E for horticulture was launched to engage the growers, industry, VegNET RDOs, researchers, extensionist and relevant stakeholders with the latest FAW RD&E activities for horticulture. The engagement in eHub is monitored using the eHub web analytics (Appendix 2).

3. Development and demonstration of FAW management strategies and industry field day

Since the approval of project VG20003 (July 2021), several farm visits and informal meetings with agronomists were conducted to document the current management practices in sweet corn and other vegetable crops. In August 2021, a follow up face-to-face meeting was organised with local agronomists from Mulgowie farming company, VeeJay Kalfresh and consultant Lev Cookson to co-design FAW management strategies. Two best management options (BMO) were developed and circulated at the project team meeting and finalised for field testing. Two blocks of sweet corn (variety Astronaut) were planted on 7 Oct 2021, and monitored for FAW and other pests at 5 -7 days intervals. (Appendix 5)

In 2022, three sweet corn demonstration blocks were established at the Bowen Research Facility to test three different improved management options for FAW in sweet corn. The three FAW management options were co-designed by DAF researchers in consultation with sweet corn agronomists, chemical and seed companies, and spray operators (as described above in PAR methods section). FAW infestation and damage levels were monitored in all three demonstration blocks from seedling emergence to harvest. At weekly intervals, 96 plants per block (16 rows x 60 m) were searched in a stratified random fashion for FAW egg masses and larval presence per plant (6 plants/row, one plant randomly from each 10 m interval of row). Plant damage scores were also recorded according to Davis Scale (Davis and Williams 1992). FAW treatments were initiated based on the weekly monitoring results (Appendix 6). Insecticides sprays were applied using a tractor mounted air-assisted sprayer.

BMO 1 site: insecticide (cyantraniliprole) treated seeds were used to protect seedling from FAW damage and followed with conventional insecticide as foliar sprays.

BMO 2 and 3: seeds were not treated with inscectides but received conventional and biopesticide (NPV) sprays based on the monitoring results.

A field day was planned to showcase the three FAW management options close to the harvest. Sweet corn growers, agronomists and industry service providers were invited. The FAW field day was conducted on the demonstration sites on 19th October 2022. For the field day, forty cobs per boarder were collected, stripped of their husk and displayed on benches next to the crop. This clearly exhibited the proportion of cobs with FAW damage at the tip and along the side of each cob. Furthermore, a 10 m deep clearing was forged into the crop to display cobs while still attached to the plants. This allowed participants to access the crop and view the FAW damage pattern, infestation levels and marketable quality of cobs. At the field day, another two blocks of sweet

corn were used to demonstrate drone spray applications with three different spray volumes. Other activities included displays of endemic parasitoids, predators and pathogens that attack FAW in Australia. The field day was recorded for release as a virtual field day video that will be available on the Queensland Agriculture YouTube channel and the FAW eHub.

4. Measuring changes in Knowledge, Attitude, Skills, Aspiration and Practice (KASAP)

Data on baseline industry KASAP in FAW management strategies and then changes in KASAP by the sweet corn and vegetable industry was collected for the Bowen/ Burdekin region. Informal interviews and discussions with six agronomists, spray operators, resellers and crop consultants were conducted during the early part of the project (June 2021) and at the end of the project (October/November 2022). The following question guide was used in the one-on-one interviews:

How concerned are you about FAW?
Have you noticed FAW presence or damage on your farm or in the crops your monitor?
How confident are you in recognising FAW stages (adults, eggs, larvae and pupae) and FAW damage?
How do you monitor your crops for FAW?
Are you aware of the options available for FAW management in your crops?
How are you controlling FAW? What insecticides or other options are you using?
What are the main issues you think need to be addressed for successful FAW management?
How is your understanding, knowledge and skills in the following areas.

- FAW resistance to the insecticides currently used in your crop.
- Level of FAW control with insecticides that are permitted to use against FAW in your crops.
- FAW lifecycle and seasonal activities under local climatic conditions
- Endemic natural enemies (parasitic wasps, predators and pathogen) attacking FAW.
- Spray application techniques – any changes to have you made to spray gears to improve FAW control.

Detailed field notes were prepared by the interviewer directly post-interview (the discussions were not audio-recorded) and collated and analysed for themes.

5. Co-design workshop on FAW project extension

A co-designed workshop was held at Ecosciences Precinct, Brisbane to determine priority FAW RD&E objectives and activities for investment. The workshop used a co-design approach to identify the primary RD&E goal "sustainable FAW area-wide management for Australian vegetables". During the workshop, a variety of participatory methods were used to gather and refine the information. The target audiences were agronomists, researchers and extension staff representing DAF, sweet corn industry, DPI NSW, AUSVEG and Hort Innovation. The workshop was facilitated by John James (Enablers of Change) and coordinated by Olive Hood (Hort Innovation) and Tim Smith (Department of Agriculture and Fisheries). A timeline of the FAW incursion and responses was sought from participants and recorded. The following RD&E objectives were discussed by the participants: Efficient program management; Nationally coordinated regional area-wide management; Efficient integration of multiple management tools; and Effective monitoring and evaluation of progress.

Results and discussion

1. Engagement of PAR group

A total of 402 (PAR group members and other stakeholders) vegetable industry agronomists, researchers, and representatives from chemical and seed companies, nationally were engaged in facilitating the knowledge and co-development of the interim FAW management strategy. The participants were engaged through PAR group facilitated meetings, field visits by industry participants representing different Australian States and through the newsletters. The facilitated meetings were useful in identifying the research and information needs on three broad topics: biological control, insecticide resistance and sustainable integrated FAW management and monitoring.

The highest-rated needs of the industry were:

- To know whether adjuvants are adding to the efficacy of insecticides or not for FAW management
- To know the best time to spray (crop stage, time of the day, insect stage)
- To know the method to control FAW in the whorl
- To know where are FAW coming from in the production system
- To know how and where FAW survives during the off-season to initiate infestation in the immediate season
- To fast-track commercialisation of beneficial insects (predators and parasitoids) and biologicals (fungi, viruses), if they are effective in managing FAW
- Toxicity of insecticides on beneficial insects and biologicals
- To communicate FAW RD&E information to the industry

2. FAW extension and communication

Project and Industry meetings: The project team conducted five online meetings and one face-to-face project meeting during the project period (July 2021 to January 2023). The latest FAW research results were delivered to the industry via industry meetings, webinars, conference, field-walks and articles in industry magazines. A total of 60 participants representing sweet corn companies, vegetable industry, research organizations, peak industry bodies, private companies participated in the meetings (Appendix 1).

Key topics presented and discussed at the various project and industry meetings over the 18-month period:

- FAW pheromone trapping results – 2020/ 2021 and 2021/22
- Project communication and extension strategies.
- Co-design, test and validate interim IPM strategy for FAW in sweet corn
- Endemic parasitoids attacking FAW – interim field survey results of Qld, WA and NT of 2021
- Insecticide evaluation field trials updates 2021
- FAW situation – end of season industry update
- FAW - broadacre cropping demonstration trials 2022.
- FAW insecticide and biopesticide trials results 2022
- Insecticide resistance testing results 2021 and sample collection plan for 2022 season
- Management success and challenges with sweetcorn season 2021 /2022 – production regions of Bowen/ Burdekin; Lockyer Valley; Bundaberg.
- Extension and communications information on baseline study
- MT 19015 project: end of project FAW parasitoid survey results 2022
- Pesticide spray application workshop – Bowen
- Private research – update on new products

During project meetings and consultations, several issues impacting FAW control, knowledge gaps, information sharing and research priorities were identified. These included:

Industry issues:

- Prolonged rainy period and wet ground delayed ground application of insecticides for FAW control.

- Mainly three insecticides are effective for FAW management in sweet corn and resistance to any one of these insecticide groups will lead to overreliance and failure of the other products.
- Insecticide resistance monitoring results showed a high level of genetic resistance to carbamate and organophosphate group insecticides in FAW populations in Queensland.

Research needs and priorities:

- Industry has requested approval of aerial application in the FAW product labels
- Aerial or drone spraying is being considered as an alternative option during the wet season
- Sweet corn growers are willing to use natural enemies if commercially available.
- Fast track registration or approval for FAW attract and kill lure technology.
- Possible collaboration of potential VegNET Rapid AIM project with DAF/ Hort Innovation projects.
- Need to find effective female lure to improve FAW monitoring and management.

Knowledge gap:

- The amplitude of FAW pheromone trap catches of male moths and larval infestations in sweet corn is not obviously correlated. Male trap catches not to be used as standalone tool for making decision on control measures.
- There was increasing FAW moth activities early in production season 2022, based on pheromone trap catches.

Information sharing:

- Possible collaboration and sharing of FAW related information between broadacre and horticulture crops.
- Delivered key results of the parasitoid survey project **(MT19015)** including a list of endemic parasitoid attacking FAW stages
- Heliothis is also affecting the silk and tip of the corn at maturity stage

The project team also updated the group on the ongoing project activities in the region, including the FAW newsletter for horticulture and launch of the eHub for "Fall armyworm research, development and extension for horticulture".

Newsletter and eHub: The FAW eHub was published and updated regularly, and FAW newsletters were produced quarterly and distributed nationally using the Vision6 platform. These platforms were used to share the knowledge and research questions identified during the project meetings and engagement with industry and growers in the region.

The project team has created a network of eight institutions to share FAW RD&E nationally. These institutions comprised of Government (Agriculture Victoria, Queensland DAF Grains team), Research Centres (CSIRO), Extension (APEN, VegNET RDOs nationally), Industry peak bodies (AUSVEG), Grower associations (Bowen Gumlu Growers Association), and University (Macquarie University).

The project released four issues of the "Fall armyworm newsletter" in June, October and December 2022, and March 2023 which were distributed to 204 stakeholders.

Some of the key information shared via newsletters and eHub*:*

- Pheromone trap catches of fall armyworm in Bowen region
- Insecticide resistance monitoring of FAW
- Methodology on identification of FAW through in-field DNA testing
- Strategies to manage insecticide resistance in fall armyworm (grains and horticulture)
- Automated detection of early fall armyworm damage in sweet corn and maize
- Night vision of fall armyworm male moths at pheromone trap in Bowen
- Fall armyworm management and selection pressure on insecticides.

- Native Queensland fungus: A promising biopesticides for managing fall armyworm.
- Endemic parasitoid of fall armyworm in Australia
- Guidance for scouting fall armyworm on sweet corn and maize
- News articles on the outcome of the Project meetings, field walks, field days and farm visits

The eHub enabled stakeholders to keep up-to-date with the latest FAW RD&E activities for horticulture and engage with information resources and the project team.

From the date of its publication, 5124 page views have been recorded with 1656 unique visitors. Likewise, the video has been viewed 25 times and 245 downloads are made until 04/01/2023 (Appendix 2, Figure 2).

Additionally, the FAW eHub provided a platform to engage with stakeholders. During the project period, the team received nine submissions through the eHub including requests for information on management of FAW larvae and NPV performance, requests for FAW RD&E resources generally, and expressions of interest in getting involved in FAW research.

3. Demonstration sites for FAW management and industry field day

Demonstration blocks 2021: Based on the monitoring results inscectides sprays were applied using tractor mounted air-assisted boom sprayer with spray volume of 300 to 500 L. FAW pressure was very high from emergence to harvest. In both BMOs, biopesticide Nucleopolyhedrovirus (NPV) sprays were included during mid to late vegetative stages. The commercially available egg parasitoid, *Trichogramma pretiosum* was released three times (total of 120,000 wasps) during NPV sprays for both blocks. The sampling data revealed that egg parasitism caused by *T. pretiosum* was very low. There is a need for an efficient biocontrol agent to use within future IPM programs for FAW. The data collected from this BMO trial was reviewed and used for establishing demonstration sites for next season (Appendix 5).

- The key findings were: Early vegetative stages (emergence to V4) were highly attractive and vulnerable to FAW damage – application of fast acting and more efficacious insecticides at 7 days interval is critical.
- Slow acting softer products such as Fawligen could be used during mid to late vegetative stages and only working against neonate and smaller size (less than 4 mm) stages.
- Early tasseling, silking and cob development need to be protected to minimise damage in cobs.
- *T. pretiosum* releases in the blocks failed to give sufficient egg parasitism in FAW.

The industry knowledge and information gaps identified within the current management strategies include:

- Lack of understanding on how the egg parasitoid *T. pretiosum* that was released for Heliothis control is contributing to FAW management within the existing IPM.
- Need for more information on lure and kill technology that specifically targets FAW female moths so that it can be incorporated into future AWM programs (agronomists have indicated that the currently approved lure and kill product Magnet (permit 89398) is less effective in attracting and killing FAW moths).
- Uncertainty about the field efficacy of few insecticides (under APVMA permits) against FAW stages.

Demonstration blocks 2022: In designing FAW best management options (BMOs), the team considered the best performing chemistries and their impact on beneficial insects, crop phenology stages, FAW and other pest pressures, spray application methods and varieties with industry standards. Two BMOs were based on the approved products and currently available resources for industry. The third BMO had a promising unregistered product, (recently registered as Vayego® to use against FAW in sweet corn) and an improved hybrid sweet corn variety. FAW pressure was low to moderate during the vegetative stage and increased to moderate to high levels during tasseling and silking (19 to 54% infestation). The weekly monitoring results were used as a decision-making tool for applying insecticide sprays. The demo blocks were sprayed using an air-assisted boom with spray volume of 300 to 500 L/ ha. Approved biopesticides such as Fawligen and Spodovir were used during mid to late

vegetative stages that were mainly worked against neonate and smaller size (less than 4 mm) stages. Demo site 1 demonstrated the effect of seed treatment on preventing FAW damage and seedling mortality up to three weeks. The results gave the industry confidence to participate in the large-scale trials conducted on their farms by the chemical company (see Appendix 6).

Beneficial insects: The release of ladybird beetles (*Harmonia octomaculata*), just before tassel initiation, gave good control of aphids. The ladybird population established in the sweet corn blocks within two weeks. The participants were able to see the presence of the egg, larval and adult stages where softer insecticide options were used. The larval parasitoid, (*Cotesia* sp.) was released into a field-cage for demonstration purposes. The effectiveness of *Cotesia* was not assessed during the trial. There was no evidence of egg parasitism following the release of the egg parasitoid, *Trichogramma pretiosum.* The participants gained a better understanding of the types of endemic predators and parasitoids associated with FAW, aphids and green vegetable bugs. The displays of endemic predators, parasitoids and pathogens that attack fall armyworm created interest among participants. They interacted with the entomologists and gained knowledge on the potential of natural enemies.

The FAW field day was attended by 22 agronomists, researchers, and representatives from sweet corn and chemical and seed companies. Participants represented around 60% of the production area of sweet corn and 40% of vegetable crops in Qld. These demonstration sites provided an opportunity for industry participants to clearly view the performance of FAW treatment options. They had very productive discussions on various management and production issues with project staff, technical experts of private companies, and agronomists.

Over 60% of the field day participants responded that it was a valuable forum for engaging, sharing, learning, and accessing BMOs (Figure 1).

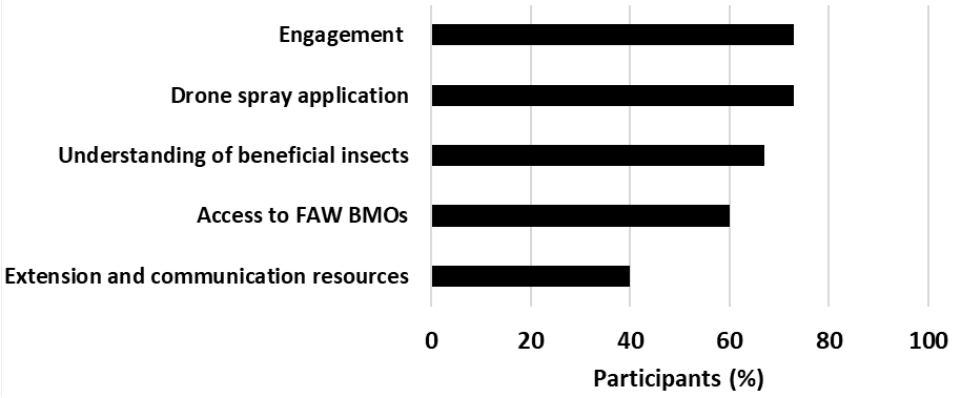

Figure 1. Participants respond to their valuable useful aspects of the field day (top five in order)

Spray demonstration: Drone spray applications of a non-toxic dye at three different volumes (30, 40 and 50 L /ha) was demonstrated at the field day. Participants viewed the differences in spray droplet distribution and penetration throughout the crop canopy and discussed with the drone pilot to gain a better understanding of drone spray application details.

Industry benefits: The information collected from the three demonstration sites was summarised and distributed to participants at the field day (Appendix 6). A media story was published in the local newspaper (Whitsunday Times) and broadcasted by ABC Rural. A virtual field day video will be available to industry on the Queensland Agriculture YouTube channel and the fall armyworm eHub. Around 82 % of the participants responded that the field day was a valuable resource for engaging, sharing, learning, and accessing fall armyworm management options. Similarly, the respondents intend to change their practice regarding UAV (drone) use during the wet season (if permitted), using beneficial insects, increasing the pest-monitoring frequencies, and considering the stage of the crop when making insecticide decisions (see Appendix 2).

The improved knowledge and skills learned from these demonstration sites will help vegetable businesses select and time insecticide applications to achieve optimum FAW control and conserve beneficial insect activities. In addition, knowledge and understanding of the importance of rotating between new generation chemistries with biological products such as NPV is expected to delay the development of FAW populations with resistance to the new chemical groups.

Senior agronomists and consultants working for the major sweet corn companies were directly involved and contributed to the planning and designing of all pest and disease management options in sweet corn. They gained a better understanding of how the softer management options worked on FAW and other pests and impact on the number of marketable cobs. Other participants were technical specialists and agronomists working for chemical and seed companies, agro-industries represented horticulture, broad-acre, and cotton.

4. Changes in KASAP (knowledge, Attitude, Skills, Aspiration and Practice)

During the early phase of FAW detection and establishment in the 2020 season, we informally documented the FAW management practices used on local sweet corn farms, and the knowledge level and skills of farm agronomists when dealing with the new pest and applying management strategies. Most of the growers and service providers had limited knowledge and skills in confidently identifying FAW stages from other lepidopteran caterpillars and moths infesting their crops. They also had trouble selecting appropriate insecticides and timing. Some experienced severe damage of up to 100% losses due to the use of ineffective insecticides or poor timing.

In the 2021 season, most of the local farm agronomists and crop monitors gained knowledge and skills for recognising FAW egg and larval stages in the field, and greater understanding of the relationship between the pest's life cycle and seasonal activity relative to local weather conditions. This helped them make better decisions about applying control measures on time. This was evidenced by the changes in practices, which included, improved spray applications and the willingness to use biopesticides such as NPV, the number of applications, and increased confidence in using insecticide spray rotations. A better understanding of the existing FAW management strategies adopted by the sweet corn and vegetable industry is essential for designing the research and extension activities for the future.

In 2022, the growers displayed awareness of the risk of insecticide resistance and showed interest in testing for insecticide resistance. They also gained knowledge of endemic parasitoid and predators and learned the prospects of conserving them for FAW management. In addition, industry started to have a better understanding of the management practices and asking the researchers to address their questions like: how to identify the right time for the application of synthetic insecticides and biopesticides, and what are the appropriate release rates for biological control agents. The growers gained knowledge that insecticide application timing (based on crop stages and insect developmental stages) is important. Further, the growers appeared to be leaning towards the use of trap crops for suppressing the FAW population (see Appendix 3).

5. Co-design workshop

In 2022, several key grains and vegetable industry stakeholders came together to co-design the next steps in the response to FAW for the Australian Vegetable industry (Appendix 8). During the co-design workshop, the participants reviewed the FAW extension project "VG20003 Co-developing and extension integrated *Spodoptera frugiperda* (fall armyworm) management systems for the Australian vegetable industry" together with the outcomes from FAW RD&E in horticulture since early 2020 in Australia. A timeline of the FAW incursion, the industry response and management activities was captured for the period January 2020 to November 2022 to provide a shared understanding of the progress made in FAW management over three years. The timeline information was collated by Olive Hood and distributed to the participants to support discussions about the next steps for industry (Appendix 7).

The participants agreed on a shared goal of achieving 'Sustainable area wide management of FAW for Australian Vegetables' and worked as groups to develop four key areas for FAW R,D and E:

1. Efficient program management – including management committee, funding allocation, and establishing private, cross commodity and inter-governmental relationships;

2. Nationally coordinated regional area-wide management – industry commitment and investment, awareness and preparedness, E-hub engagement and communication, establishing local AWM group involving multiple commodity groups, stakeholders research;
3. Efficient integration of multiple management tools including resistance monitoring, female attractants, automatic direction tools, efficient insecticide application, and biopesticide and biological control;
4. Effective monitoring and evaluation of progress

The next steps, opportunities and challenges for realizing these objectives were identified as part of the workshop. As a result of the workshop, the project VG22006 'National fall armyworm innovation system for the Australian vegetable industry' was initiated to address the extension objective of nationally coordinated regional area-wide management.

6. FAW RD&E compendium for vegetable crops (detail in Appendix 4)

FAW research, development and extension projects and activities undertaken in Australia with government agencies, industry organisations, universities and private companies were documented and summarised. We also reviewed documents from Plant Health Australia, the Plant Biosecurity Research Initiative, Hort Innovation and GRDC. The following gaps in the research:

- Identification and utilisation of FAW parasitoid and predators for biological control
- Identification of alternative FAW hosts that support and maintain FAW populations
- Investigation of attractants and lure and kill products, and their potential efficacy within farm wide IPM programs
- Extension of the generated good practices through face-to-face meetings (field days, monitoring), publications and digital communications (newsletter, web)
  Investigation of the best way to incorporate biopesticides under field conditions within IPM programs, and their role in delaying insecticide resistance to conventional insecticides

In summary, this project used a PAR approach to bring together the knowledge and experience of researchers, industry and service providers to co-develop and demonstrate three BMOs for managing FAW in sweet corn in the Bowen region. Findings from the demonstration sites were shared nationally to build vegetable industry capacity to manage FAW across regions and crops. Two new horticulture focused communications channels—the FAW newsletter and eHub—were established to extend the reach of FAW information generated through the project and to keep industry up to date with the latest developments in FAW R&D. The FAW RD&E compendium that was developed for vegetable crops will be used by the new FAW extension project VG22006 to identify and address RD&E gaps and needs. Reflection upon these project achievements during the co-design workshop helped formulate the next steps needed to reach sustainable area wide management of FAW for the Australian vegetable and broadacre cropping industries. The further refinement of FAW BMOs through monitoring insecticide resistance and developing IPM systems will guide industry towards that sustainable goal.

Outputs

Table 1. Output summary

Output	Listed in M&E Plan: •Yes • No	Description	Evidence and data
Engagement of PAR group		Over 20 (PAR group members) vegetable industry agronomists, researchers, and representatives from chemical and seed companies were engaged in facilitating the knowledge and co-development of the interim FAW management strategy.	Meeting minutes and field visit records. Development of FAW management options (Appendix 5 and 6)
FAW extension and communication	Yes	FAW information on integrated and sustainable management practices were extended among the sweet corn growers, industry leaders, researchers, VegNET RDOs, extension officer, service providers through industry meetings, FAW newsletter, engagement hub on FAW RD&E for horticulture nationally. Sixty participants representing agronomists, chemical companies, with representatives from Hort Innovation, VegNET RDOs, DAF and the project team attended project meetings. We have published and distributed 3 issues of FAW newsletters to 204 individuals (printed and digital), additionally it is available at the FAW eHub. The engagement hub is monitored monthly based on its views, unique visitors and downloads (Figure 2). From the date of its publication, 5124 page views have been recorded with 1656 unique visitors. Likewise, the video has been viewed 25 times and 245 downloads are made until 04/01/2023. Monitoring of the project meetings, engagement hub and newsletter is conducted using google form, engagement hub analytics and newsletter reports (Attached appendices 1,2).	FAW presentation at project meetings (3), industry meeting at Ayr (1), published eHub on FAW RD&E, published FAW newsletter in June and October 2022. All these activities are published in FAW eHub latest news and updates, and archived in project resources in the ehub. Appendix 1: FAW extension and communication activities Appendix 2: Monitoring and Evaluation
Demonstration blocks on FAW management and field day	Yes	Twenty-two agronomists, researchers, and representatives from sweet corn and chemical companies, and seed industries participated. The field day event was published in eHub, FAW newsletter (October 2022). A virtual field day video will be available on the	Field day details in FAW eHub. The outcome of the demonstration is summarized in Appendix 5.

		Queensland Agriculture YouTube channel and the FAW eHub.	The virtual field day video will be available after inclusion of sub-titles and approval for release by DAF and Hort Innovation.
Early KASAP (knowledge, Attitude, Skills, Aspiration and Practice) changes achieved and/or projected for life of project	Yes	The interview questions were prepared and interviews of key industry people were conducted to capture the KASAP changes.	The results were summarized in Appendix 3.
Co-design workshop on FAW extension project	Yes	In 2022, several key grains and vegetable industry stakeholders came together to co-design the next steps in the response to FAW for the Australian Vegetable industry (Appendix 8). During the co-design workshop, the participants reviewed the FAW extension project "VG20003 Co-developing and extension integrated *Spodoptera frugiperda* (fall armyworm) management systems for the Australian vegetable industry" together with the outcomes from FAW RD&E in horticulture since early 2020 in Australia.	Publication on situation report DAF. Notes from the Co-design Workshop 17-18 November 2022, Brisbane (Appendix 7)
FAW management RD&E compendium for vegetable crops		Research gap related to vegetable crops identified and reported to Hort Innovation and state agencies	Appendix 4

Outcomes

Table 2. Outcome summary

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
Access to new information and control strategies for decision making.	**OUTCOME 3:** Extension and capability Building capability and innovative culture **STRATEGY 2:** Identify and support opportunities to improve productivity and sustainability through effective integrated pest and disease management (IPDM), weed control, soil health and cover	Knowledge on FAW management in sweet corn crops were extended to industry through grower/consultant events. The information delivered to the stakeholders were monitored and evaluated through different tools (feedback survey forms, vision 6 platform and	Feedback form survey for the project meetings and field days, vision6 platform analytics and engagement hub report. Appendix 2

	crops. **KPIs:** • Establishment of a baseline and then increased share of industry (hectares) with positive change in knowledge, attitude skills aspiration and practice change and implementation of targeted high priority areas. • Grower satisfaction with growth in cooperation from within and across vegetable industries leading to adoption of innovative practices and outcomes benefiting multiple stakeholders along the supply chain	engagement hub).	
Change in knowledge, awareness, skills, aspirations and practices (KASAP) on FAW management options across the vegetable industry, growers and agronomists.		Agronomists and crop monitors gained better knowledge and skills on recognising FAW egg and larval stages in the field, and more knowledge of the relationship between the pest life cycle and local weather conditions. This helped them make better decisions about applying control measures on time.	This was evidenced by the changes in practices, increased confidence in using insecticide spray rotations, the number of applications, and the willingness to use slow acting and softer products (for example, NPV products). Appendix 3
Co-design workshop on FAW extension project		'*Sustainable Area Wide Management of fall armyworm nationally*' was identified as the primary RD&E goal, with effective monitoring and evaluation of insects, multiple integrated management options, and a nationally coordinated effort at an area wide level identified as key objectives.	Situation report article in internal DAF communications. Notes from the Co-design Workshop 17-18 November 2022, Brisbane (Appendix 7)

Monitoring and evaluation

Key evaluation questions	Project-specific questions	Project performance	Continuous improvement opportunities
Effectiveness			
1. To what extent has the project achieved its expected outcomes?	To what extent has the project identified and developed an integrated FAW management system?	The project has demonstrated potential of conventional insecticides, integrated with bio-pesticide agents such as Fawligen and Spordovir	Refinement of management treatments under various climatic conditions in other production areas
	To what extent has the project delivered information and improved knowledge and awareness of growers?	Regular project and industry meetings, webinars, demonstration sites and field days, FAW newsletter and engagement hub has provided information on the FAW management options to the growers and industry. The changes in KASAP measured through informal interviews discussions with participants and agronomists.	Demonstrations and field days with other extension activities need to be continued to deliver integrated and sustainable FAW management practices.
	Has the project identified FAW management techniques that are now available for industry uptake?	Tested and validated seed treatment options for enabling seedling establishment. Collaborated with chemical companies - another Group 28 product Vayego gained registration for FAW control in sweet corn.	Testing the efficacy and need for each spray during the growing period. Another chemical mode of action is required for rotation to minimise insecticide resistance development.
Relevance			

Key evaluation questions	Project-specific questions	Project performance	Continuous improvement opportunities
2. How relevant was the project to the needs of intended beneficiaries?	To what extent has the project delivered new knowledge and information to the FAW management system?	Local knowledge on biology and behavior of FAW supported the growers to improve their control measures.	Information be extended to other growing locations and adaptation of control measures as appropriate
Process appropriateness			
3. How well have intended beneficiaries been engaged in the project?	To what extent was the engagement of the industry levy payers achieved?	Industry was regularly engaged through project meetings (online, face-face), the eHub, field days.	The engagement continues through the next project VG22006
	Have regular project updates been provided through linkages (face to face and digital platforms/forums) with the industry communication project?	Regular project meetings (online, face-face), newsletter and engagement hub (both digital and printed), events information. They were published in industry communication.	Continuous engagement and co-design with industry on a national basis
4. To what extent were engagement processes appropriate to the target audience/s of the project?	Did the project engage with industry levy payers through a participatory approach?	Demonstration sites establishment were conducted jointly by industry and DAF researchers. Field days were conducted in a participatory approach.	Continue the participatory approach at a national scale, including Gippsland, Lockyer Valley and Sydney Basin
	How accessible were extension events to industry levy payers?	Events were widely circulated to industry participants. Participants from the industry attended the events (field days, demonstration sites) at DAF Bowen.	Extend demonstration sites to key growing regions
Efficiency			
5. What efforts did the project make to improve efficiency?	What efforts did the project make to improve efficiency? What has the project achieved to assist growers manage FAW?	Regular industry meetings and field visits to communicate latest research information. New	Continue to monitor insecticide resistance development and communicate results to industry in a timely

Key evaluation questions	Project-specific questions	Project performance	Continuous improvement opportunities
		BMOs were developed and communicated. Insecticide resistance results delivered to guide industry in insecticide selection.	manner to guide use. Further develop integrated pest management systems and implement on an area wide basis.

Learnings and challenges of the PAR approach in this project

The PAR approach in the vegetable industry helped better to understand the industry's experiences and their existing management practices. It allowed the industries to share general information on FAW management, issues, and identification of research needs through facilitated meetings, field visits, field days, and farm walks. Additionally, the demonstration sites provided a medium for the growers to visit the sites and interact with the researchers about the performance of the co-developed FAW management options. This project has also broadened its concern beyond horticulture industry and initiated a discussion on Area-Wide Management of FAW.

Besides this, there are challenges to better understanding the industry’s comprehensive FAW management options in a group, mainly due to the competitiveness in the business. The demonstration site establishment on a commercial farm and access to other industries is also challenging.

Recommendations

The PAR approach fast tracked knowledge exchange between industry, researchers, service providers and associated rural companies. Recommendations going forward include:

- This methodology could be used as a model to guide industries in dealing with other exotic pest incursion responses.
- Future RD&E strategies and tools to develop various management options for a range of crops and crop cycles to enable effective area wide management of FAW.
- Development and adoption activities that would ensure full value from the project's findings for industry.
- Continued engagement of the growers, industry and relevant stakeholders in co-designing and co-development phase helps to build confidence for the sweet corn growers.
- Engagement hub on FAW RD&E for horticulture is effective in terms of delivering information and engagement.
- Networking with VegNET RDOs and extension projects nationally helped to deliver the information effectively and efficiently in a national context.
- Demonstration blocks on FAW management in sweet corn is effective in terms of engagement and on-ground extension. The post field day feedback survey revealed that the field day was useful and intending to make changes in their practices.
- FAW management and extension approaches need to scale up in area wide management concept including horticulture and grains.

Refereed scientific publications

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Intellectual property

No project IP or commercialisation to report.

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Also like to acknowledge the expert advice provided by Dr Olive Hood on extension principles and practices.

Appendices

Appendix 1: Extension and communication activities 2021 and 2022.

Appendix 2: Monitoring and evaluation activities with results

Appendix 3: Industry practice changes in FAW management in sweetcorn

Appendix 4: FAW management RD&E compendium for vegetable crops

Appendix 5: Co-design and testing of best management options for fall armyworm in sweetcorn (Nov 2021).

Appendix 6: Fall armyworm management options and demonstrations, Bowen Oct 2022

Appendix 7: Virtual field day – Video (DAF YouTube link to be provided)

Appendix 8: Notes from the Co-design Workshop 17-18 November 2022

Appendix 9: Extension paper publication (submitted)

Appendix 1: Extension and communication activities

According to the communications and extension strategy that was developed for this project, the project team have communicated and extended FAW management strategies and FAW RD&E across the Australian vegetable industry. The major activities include:

Field days and workshops

- Field-walk to view field trials of chemical and biological control options for FAW. National agronomic team from E.E Muir. (Bowen| 4 May 2022 by Siva Subramaniam, John Stanley and Verni Sivasubramanim).
- Field walks and demonstration on different management options for FAW in sweet corn. Participants from Mulgowie farming company, Bugs for bugs and Bayer crop science. (DAF Bowen 4 Aug 2022 |Siva Subramaniam and team.
- Field demonstration on insecticide rotation options including Bayer's new chemistry. Bayer crop science technical team visit to DAF Bowen|24 August 2022| Siva Subramaniam & team
- Fall Armyworm: Research, Development and Extension in Horticulture. Ologist Workshop at ESP Brisbane| 6-7 October 2022. John Stanley and team.
- Spay application workshop for sweet corn and horticulture industry. Two-day training on spray techniques for improving FAW control. Bowen| 11 and 12 Oct 22| Organised by Siva Subramaniam; Delivered by Graham Betts Agricultural Spraying Kare Pty Ltd.
- Farm visits – assessment of spray machines and provide reports for improvements. Bowen and Ayr| 13 and 14 Oct 22| Graham Betts and Siva Subramaniam
- Bowen Field day on FAW management demonstration sites was organized by FAW project at DAF, Bowen on 19 October 2022. Attendees: 22 agronomists, researchers, and representatives from sweet corn and chemical companies, and seed industries. Details in Fall armyworm engagement hub.
- Co-design workshop on fall armyworm project extension at ESP, Brisbane on 17-18 November 2022. Presentation by Dr Siva Subramaniam and Dr Ramesh Puri on FAW Research, Development, Extension and Communication. Attendees: 15 including sweetcorn companies, Hort Innovation, DAF.

Media and Industry publications

- Management of fall armyworm in vegetable crops in Australia (Nov 2021). Zali Mahony (AUSVEG) and Siva Subramaniam (DAF). https://ausveg.com.au/app/uploads/2021/12/Final-pdf-standard-faw-guide_compressed.pdf
- *Managing fall armyworm: a destructive, fast-moving pest* in the Vegetable Australia magazine Summer 2021/22 (page 88-89). Siva Subramaniam interviewed; https://ausveg.com.au/app/uploads/2021/11/AUSVEG_VegetablesAustralia_2021_Summer_WEB_100DPI_F01v1.pdf
- BOWEN researchers are fighting a battle to contain an insect that is ravaging sweet corn crops in the region. Whitsunday News |25 Oct 22 |Siva Subramaniam

Newsletters, eHub and online resources

- An engagement hub on "Fall armyworm research, development and extension for horticulture" was published nationally on 19 August 2022. This engagement hub is designed to keep up to date on the latest information on fall armyworm research, development and extension in horticulture, and engage with industry and stakeholders. Link: Fall armyworm engagement hub

- A new communications channel for the horticulture industry nationally was developed and delivered. Two issues (June and October 2022) of ***Fall armyworm news,*** a research and development update for horticulture was emailed to stakeholders through the Vision6 platform. The newsletter delivered regular communications to industry on R & D outcomes, resistance monitoring, pheromone trap catches, event information, and links to extension resources. Available in Project Resources tab in Fall armyworm engagement hub.

Conference and on-line presentations

- FAW management in vegetable crops; Hort Connection Conference, Brisbane Jun 2021. Oral presentation by Siva Subramaniam (DAF).
- Webinar presented by Siva Subramaniam (30 Sep 2021) *FAW management research update* as part of DAF's Vegetable Industry Webinar series hosted by Heidi Parkes. https://www.youtube.com/watch?v=2DENdz440sY&list=PL3dFDqBJiUG3iJV6LMh4BR4GMxnn6ePRh&index=6
- Presentation on FAW monitoring and management with Q & A. AgLink Australia Horticulture Agronomy Forum, Brisbane (On-line presentation |9 Nov 2022 | Siva Subramaniam)

Industry and project meeting and presentations

-
- FAW armyworm: Opportunities for integrated management. Queensland Horticulture Pest & Disease Workshops (AusVeg). Presentation by Siva Subramaniam at Ayr 20 July and Gumlu 21 Jul 2022
- Project meetings (forums for peer-to-peer learning) were held on 25 August 2021, 13 October 2021 and 25 November 2021 with Hort Innovation, and industry and DAF team members to share FAW situation reports, management experiences and learnings, chemical resistance updates, and co-develop the FAW interim management strategies for trialling.
- Presentation on FAW research update and management strategies. National agronomic team from E.E Muir. (Bowen| 4 May 2022 by Siva Subramaniam.
- Project meetings (forums for peer-to-peer learning) were held virtually on 12 May 2022 and 15 September 2022, and face-face on 22 June 2022 with Hort Innovation, sweet corn industry, researchers, chemical companies, VegNET RDOs and DAF team members to share FAW situation reports, management experiences and learnings, chemical resistance updates, and co-develop the FAW interim management strategies for trialling. Attendees: 15-24 including of agronomists, chemical companies, with representatives from Hort Innovation, VegNET RDOs, DAF and the project team. Details in Fall armyworm engagement hub.
- Melon Australia Road Show: "Fall armyworm Research, Development and Extension. Presentation by Dr Ramesh Puri at Ayr 10-10-2022. Attendees: 30 researchers, growers, service providers and industry leaders. News article published in Fall armyworm engagement hub. Details in Fall armyworm engagement hub.
- Portfolio approach to Australian vegetable, potato and onion extension. 10 November 2022 AUSVEG, Melbourne. Dr Ramesh Puri, DAF extension officer for the Hort Innovation / DAF (vegetable levy-funded) national fall armyworm management project participated in a meeting hosted by AUSVEG with the relevant Hort Innovation staff, delivery partner, and project leads of several levy-funded national vegetable, onion and potato extension investments. Attendees: 15. Details in Fall armyworm engagement hub.
- Bowen Gumlu Growers Association organized an Innovation field day at DAF Bowen. FAW R, D and E was demonstrated on 4 November 2022 at DAF Bowen. Dr Siva Subramaniam presented on FAW parasitoid and predators. Attendees: 150 growers, students, government agencies and industry stakeholders nationally. Details in Fall armyworm engagement hub.

Appendix 2. Monitoring and Evaluation

The project activities monitored and evaluated using web-based analytics (engagement hub and newsletter) and feedback forms (meetings, field days).

1. Monitoring engagement hub on FAW R, D & E using web analytics

The engagement hub was monitored monthly, recording the number of views, unique visitors and downloads (Figure 2). From the date of its publication, 5124 page views were recorded with 1656 unique visitors. Likewise, the video was viewed 25 times and 245 downloads were made until 04/01/2023.

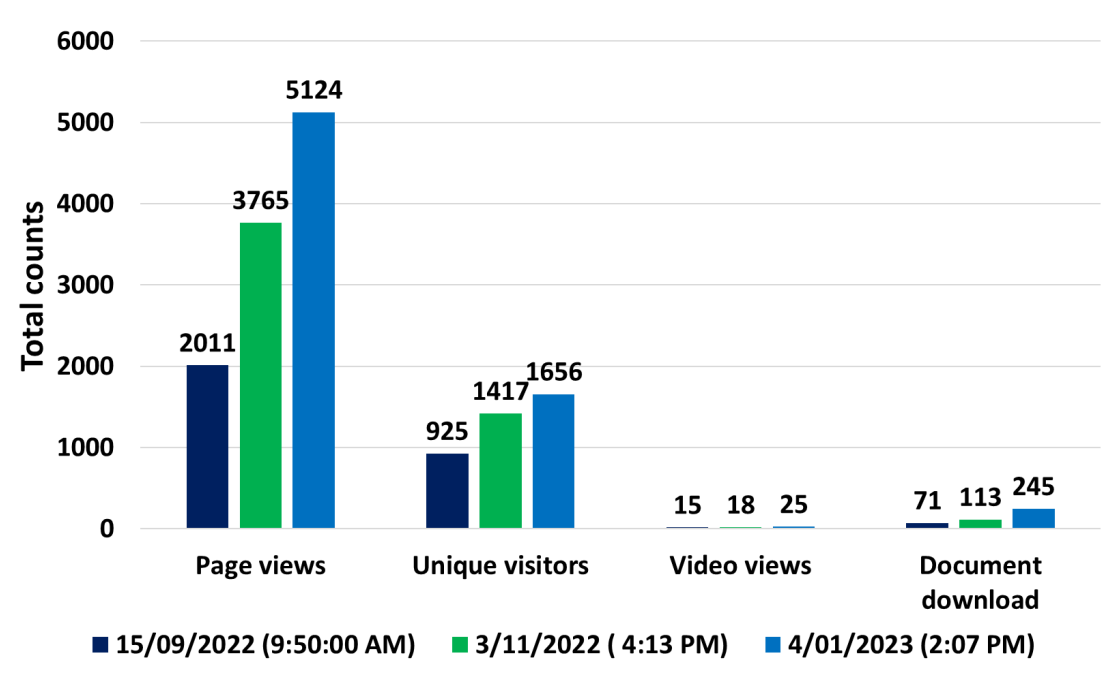

Figure 2. Engagement hub on FAW RD&E web analytics.

2. Fall armyworm newsletter analytics

Newsletters were distributed nationally in a digital form through vision6 platform. We tracked the number of recipients opening the newsletter through the platform (Figure 2). We distributed the first issue of the newsletter in June 2022, to 39 growers, industry and stakeholders, and second issue to 85 stakeholders nationally. The opening rate for first and second issues was 90% and 78%, respectively.

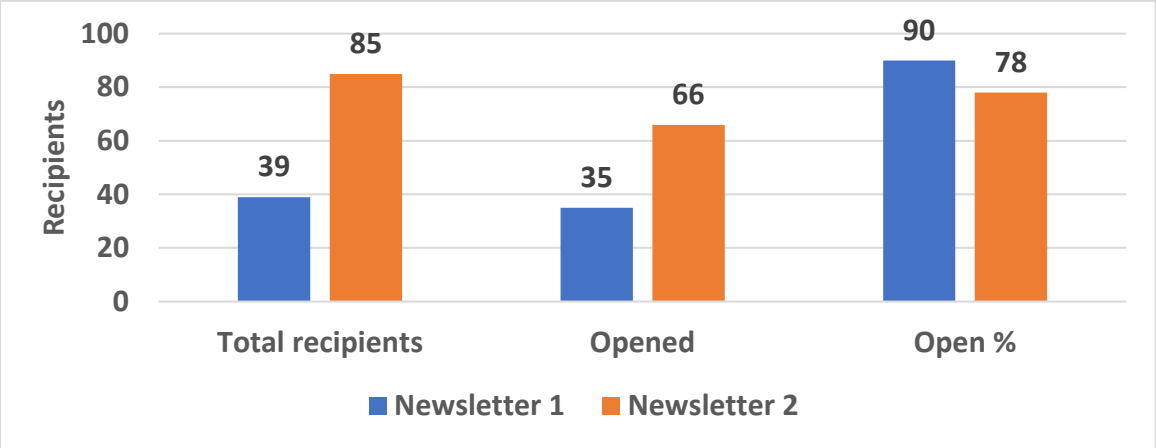

Figure 2. Monitoring of the newsletter through vision6 platform.

3. Feedback form and results: Project meeting 6 (15/09/2022)

Feedback Form

Thank you for attending the meeting.

Please provide feedback on this meeting by completing a survey.

1. Do you find FAW project updates useful? *

	1	2	3	
Not useful	○	○	○	Very useful

2. What additional information / tools / strategies are needed to manage fall armyworm? *

- [ ] Fall armyworm diagnostics
- [ ] Trapping and monitoring
- [ ] Chemical control
- [ ] Biological control
- [ ] Integrated pest management / Area wide management
- [ ] Insecticide resistance
- [ ] Lure and kill technology
- [ ] Spray application

3. What aspects of this meeting did you find the most useful or valuable to you? How could we improve? *

Long answer text

Thank you !!!!!

Results:

Feedback was received from 70.8% of the participants (17/24). 82.4% and 17.6% of the participants responded that the project updates information was very useful and useful, respectively (Figure 3).

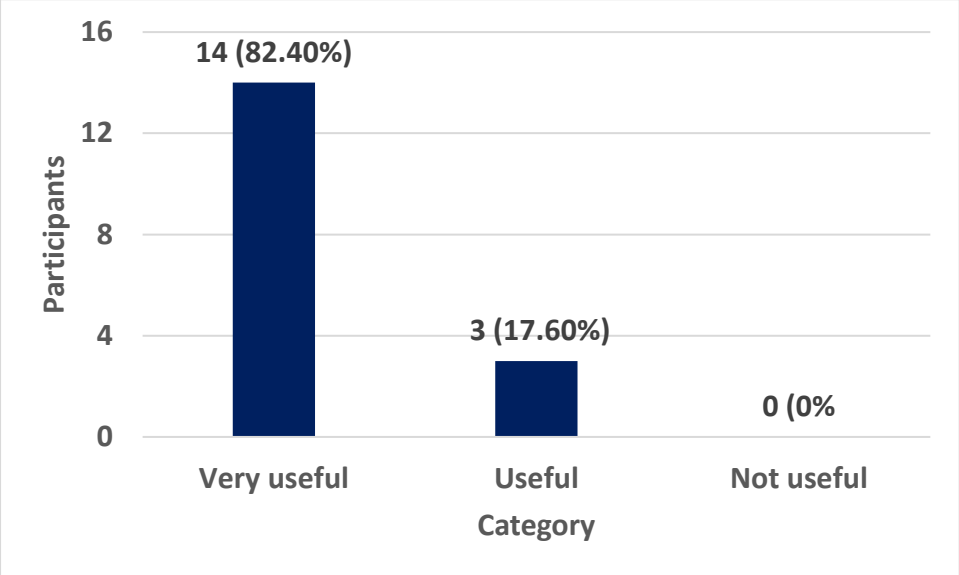

Figure 3. Response on usefulness of the project updates.

Similarly, participants requested additional information, tools and strategies to manage fall armyworm on: biological control (70.6%); spray application (64.7%); integrated pest management (58.8%); trapping and monitoring (58.8%); chemical control (52.9%) and lure and kill technology (52.9%).

Finally, the attendees reflected:

- Practical research findings, encouraging extension information
- Timing of spray applications, types of chemicals used and adjuvant additives and how weather/temperatures affect FAW pressure.
- Limited time
- Very good to have the broad but succinct industry overview. Better understanding of PowerPoint by the presenters or just have one central presenter that will improve efficiency.
- Updates on the FAW research, extension products. Darabug : where can we find its link. Is it coming on eHub. Will contact Ramesh for further information on darabug.
- The content was very good in helping me understand what the regions are doing, what works and what doesn't. Devastating but exciting to understand the good work going on
- Regional updates and chemical & biological advances are always great bits of information to share with my regions growers
- Very thorough but also very technical, making it easier to understand and apply.
- Am yet to have FAW officially detected in my region. Building knowledge before it arrives is valuable. Learning from the research occurring in other states and regions is valuable.

4. Feedback form: Field day on FAW management demonstration sites (19/10/2022)

Field day feedback

Thank you for attending the field day

Please provide feedback on this event by completing a survey.

1. How did you find the field day on fall armyworm management on sweet corn? *

	1	2	3	
Not useful	○	○	○	Very useful

2. What aspects of this field day did you find the most useful or valuable to you? *

- [ ] Fall armyworm management options
- [ ] Knowledge and understanding of beneficials
- [ ] On-ground delivery of the technologies
- [ ] Engagement with researchers and extensionist
- [ ] Extension and communication resources
- [ ] Drone spray application
- [ ] Other...

3. Are you considering or intending to make any changes to your management practices / business from what you have seen / heard today? *

- [ ] Yes
- [ ] No

Please tell us what you intend to do differently? *

Short answer text

4. Would you like this type of demonstration sites and field day event for next year? *

- [ ] Yes
- [ ] No

5. Any other feedbacks and comments / suggestion to improve ? *

Short answer text

Results:

Feedback was received from 68.2% of the participants (15/22).

86.6% and 13.3% of the responded participants reflected that the information presented at the field day was very useful and useful, respectively (Figure 4).

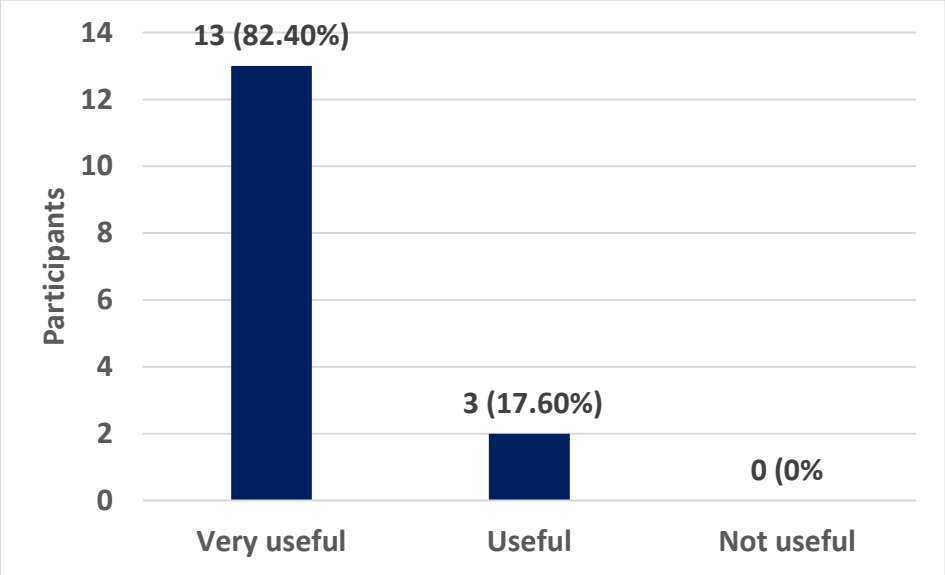

Figure 4. Response on usefulness of the project updates.

Similarly, the participants mentioned that the field day was useful as it had: engagement; on site demonstration sites observation; and interaction among researchers, agronomists, and stakeholders. Additionally, they found it useful in terms of getting knowledge and understanding of beneficials, drone spray applications and on-ground extension.

Participants were considering making changes on their practices like, use of drones during wet season, highly focussing on monitoring, and including beneficials in the management practices. Finally, all the respondents want to have demonstration sites and field day events next year.

Appendix 3: Industry practice changes in FAW management in sweet corn

The project team have conducted several FAW extension and communication activities which includes grower and project meetings, webinars, field walks, field visits, displays, publications, and field demonstrations. In consultation with industry agronomists, the following KASAP (knowledge, attitude, skills, aspiration and practice) changes in FAW management were observed and documented and with sweet corn and vegetable industries during the 2022 season. The current KASAP survey will be used as a baseline, and monitoring of changes will be reported throughout the new 4-year project VG22006:

- Improved knowledge and understanding of FAW biology, lifecycle, infestation patterns, recognition of larval stages, and seasonal activities related to local temperature and cropping conditions. Application of that knowledge into management practices.
- Better knowledge of the older chemistries that are ineffective or have developed resistance to FAW populations in their locations.
- Positive practice changes in minimising the use of ineffective chemistries such as synthetic pyrethroids, organophosphate and carbamates. Local research has indicated that fall armyworm has developed high-level resistance to these chemistries.
- Positive practice changes and adoption in choosing more effective insecticides for targeting FAW life stages. Choosing the right insecticide products and using them at the right time to target eggs or larvae.
- Positive practice changes in applying the chemical and biological products in a strategic manner to target critical crop stages of sweet corn and improved control levels.
- Better knowledge and understanding in recognising the endemic parasitoids, predators and pathogens attacking FAW eggs and larval stages. Local research has identified various endemic natural enemies (parasitoids, predators, and pathogens) that are known to have attacked fall armyworm eggs and larvae. This information is helping industry to conserve the natural enemies in their farms.
- Increased aspiration to incorporate beneficial insects and biopesticides within the existing IPM programme in sweet corn crops.
- Improved knowledge of various aspects of sprayer settings including nozzle selections, droplet sizes and spray volumes, following DAF's spray application workshops and on-farm spray evaluations and recommendations.
- Improved knowledge and understanding of the insecticide resistance testing program and increased aspiration to adopt the outcomes for FAW resistance management. The collaboration and participation of growers in the testing program is on-going.
- Improved knowledge and adoption of spray adjuvants for improving FAW control.
- Increased knowledge of insecticide seed treatments to protect early vegetative stages of sweet corn. In the 2022 season, sweet corn growers have participated in large-scale seed treatments trials (under commercial trial permit).

Appendix 4: Fall armyworm Management Research, Development and Extension compendium for vegetable crops - VG20003 (updated May 2022).

FAW RD&E	Research projects	Research focus	Implementing organization / Project leader	Industry focus	Funding source
Biological control	Investigate the use of biocontrol agents	Preliminary FAW survey in NT locations	NT gov Dr Brian Thistleton	Hort/ Grain	NT gov
	FAW in Western Australia	Evaluation of biocontrol agents	DPIRD WA, Dr Helen Spafford	Grain/ Hort	DPIRD WA
	Identifying potential parasitoids of the FAW	Survey of endemic parasitoids and predators	DAF QLD, WA, NT Dr Siva Subramaniam	Horticulture	Hort Innovation
Biopesticides	Surveying and testing locally occurring insect viruses for use in FAW management	Testing the efficacy of viruses in controlling FAW	DAF QLD, Ian Newton	All industries	Plant Health Australia
	Responding to FAW threats to Queensland's Agricultural Industries - Horticulture	Field evaluation of permitted biopesticides within sweet corn IPM	DAF QLD, Dr Mark Hickman/ Dr Siva Subramaniam	Hort	CBRC QLD Gov and DAF QLD
	Responding to FAW threats to Queensland's Agricultural Industries – Broadacre crops	Fawligen bioassays; field trials – maize / sorghum	DAF QLD, Dr Mark Hickman/ Dr Melina Miles	Grains	CBRC QLD Gov and DAF QLD
Chemical control	Responding to FAW threats to Queensland's Agricultural Industries – Horticulture	Insecticide control options; soil and seed treatments	DAF QLD, Dr Mark Hickman/ Dr Siva Subramaniam	Horticulture	CBRC QLD Gov and DAF QLD
	Pesticide efficacy trial	Trials to manage the larval FAW	DPIRD/WA	Forage	DPIRD/WA
Developing FAW IPM strategies	Development of management strategies for FAW	Study the biology, behaviour and management of FAW	NT gov Dr Brian Thistleton	Grain/ Hort	NT gov
	Responding to FAW threats to Queensland's Agricultural Industries – Broadacre crops	FAW management in the northern grains region	DAF QLD, Dr Melina Miles	Grains, Broadacre	DAF QLD
	Codeveloping and extending integrated FAW management systems for the Australian vegetable industry	Delivering sustainable integrated FAW management. Increased knowledge and awareness and extension	DAF QLD, Dr Siva Subramaniam	Horticulture	Hort Innovation; DAF QLD
Genetics	Characterisation of Fall armyworm populations in South-East Asia and Northern Australia	Diversity among the FAW populations in terms of genetic and pesticide resistance profiles.	ACIAR, Dr Tek Tay	Grain (Corn)	ACIAR and GRDC
	Insecticide response and genomic characterisation of FAW and parasitoids	Characterisation of FAW using whole genome sequencing	CSIRO, Dr Tek Tay	All industries	CSIRO
	Insecticide response and genomic characterisation of FAW and parasitoids	Whole genome sequencing characterization of resistance genes.	CSIRO	All industries	CSIRO/International
	LAMP assay for fall armyworm	Validation and testing of a FAW lamp assay detection	AgVIC	All industries	AgVIC
	LAMP assay for fall armyworm	Validation and testing of a FAW lamp assay detection	DPIRD, WA	All industries	DPIRD, WA
	Monitoring insecticide resistance	Developing markers to identify the FAW	DPI, NSW Dr Duong Nguyen	All industries	DPI NSW
	Genomic insight of FAW movement in Australia	Genomic analysis	CSIRO, Wee Tek Tay	All industries	Plant Health Australia

FAW RD&E	Research projects	Research focus	Implementing organization / Project leader	Industry focus	Funding source
Monitoring and surveillance	Pheromone trapping network	Develop trapping grids for pests in WA wheat belt and established a network of FAW traps	DPIRD WA and DPI NSW	Broadacre	DPIRD WA and DPI NSW
	Field trial for host preference	Host preference	NT gov	Hort crops	NT gov
	Assessment of host plant preference	Assessed for FAW ovipositional and larval feeding preferences	DPIRD WA	All crops	DPIRD WA
	Damage and impact study	Monitor FAW damage and impact on unmanage crops	DPIRD WA	All crops	DPIRD WA
	A review of ecological modelling	Identifying areas of using modelling in FAW	DAWE		DAWE
	Surveillance using pheromone traps	Monitor FAW distribution	NT gov	All crops	NT gov
	Responding to FAW threats to Queensland's Agricultural Industries	Establishing a network of pheromone traps Monitoring of FAW	DAF QLD Dr Melina Miles/ Dr Richard Sequeira	All crops	DAF QLD
	FAW distribution using climex / dymex	Exploring CLIMEX/Dymex FAW species distribution models	CSIRO	All crops	CSIRO
	Mapping risk of establishment and spread	Developing pragmatic maps of risk of establishment and spread	UoM, CEBRA		UoM, CEBRA
	Preparedness modelling GRDC gap analysis	Monitoring of FAW	Cesar Australia		Cesar Australia GRDC
	Responding to FAW threats to Queensland's Agricultural Industries – Horticulture	Pheromone traps, field monitoring	DAF QLD, Dr Siva Subramaniam	Horticulture	DAF QLD, Hort Innovation
	FAW risk to Australian horticulture	Economic analysis	DAF QLD, Dr Siva Subramaniam	Horticulture	DAF QLD, Hort Innovation
	Rapid real-time simulation of wind-assisted long-ranged dispersal of FAW in Australia.	Seasonal activity prediction models for FAW	Cesar Australia, James Maino	All crops	Plant Health Australia
Insecticide Resistance	Insecticide response and genomic characterisation of FAW and parasitoids	Bioassays of Australian FAW to better understand the resistance status to selected insecticidal compounds	CSIRO	All crops	CSIRO/GRDC/CRDC
	Insecticide resistance in Australian FAW and development of testing procedures	Develop DNA methods to detect insecticide resistance in FAW	DPI NSW Dr Lisa Bird	All crops	CRDC, DPI NSW
	Detection of genetic resistance in FAW populations	Genetic resistance to insecticide groups in FAW populations- focus on sweetcorn in Bowen/ Burdekin	DPI NSW Dr Duong Nguyen	Vegetables	DAF QLD/ NSW DPI
	Understanding the key market drivers that will underpin the development of an Insecticide Resistance Management Strategy for FAW	Industry consultation on insecticide resistance management	ICAN, Mark Congreve	All crops	Plant Health Australia
Taxonomy and diagnostics	Diagnostics through molecular techniques and genitalia examination	Identification using molecular techniques and genital examination	NT Gov	All crops	NT Gov
	Parasitoid taxonomy service	Identification of parasitoids associated with FAW	Uni of Adelaide, Dr Erinn Peta Fagan-Jeffries	Horticulture Grain crops	DAF QLD Hort Innovation
	High volume rapid species identification	High throughput sequencing approach to identify FAW	CSIRO H&B / L&W	All crops	CSIRO
	In field detection	Dipstick development	DPIRD, WA	All crops	DPIRD, WA
	Field-based testing for fall armyworm	Rapid identification of fall armyworm	DJPR Victoria	All crops	DAWE, Hort Innovation

Appendix 5: FAW demonstration block – Best management options 2021

(see attached PDF)

Appendix 6: Fall armyworm management options demonstrations and field day - 2022 .

The three FAW management options were co-designed by DAF researchers in consultation with sweet corn agronomists, chemical and seed companies, and spray operators. Sweet corn demonstration blocks were established at the Bowen Research Facility in August 2022 to test the three different improved management options for FAW in sweet corn.

FAW infestation and damage levels were monitored in all three demonstration blocks from seedling emergence to harvest at weekly intervals. FAW treatments were initiated based on the weekly monitoring results. Insecticides sprays were applied using a tractor mounted air-assisted sprayer (treatments are summarised in the Table below).

BMO 1 site: insecticide (cyantraniliprole) treated seeds were used to protect seedling from FAW damage and followed with conventional insecticide as foliar sprays. BMO 2 and 3: seeds were not treated with inscectides but received conventional and biopesticide (NPV) sprays based on the monitoring results.

FAW field day was conducted on the demonstration sites on 19 October 2022. For the field day, forty cobs per boarder were collected, stripped of their husk and displayed on benches next to the crop. This clearly exhibited the proportion of cobs with FAW damage at the tip and along the side of each cob. Participants had opportunity to view the FAW damage pattern, infestation levels and marketable quality of cobs. At the field day, another two blocks of sweet corn were used to demonstrate drone spray applications with three different spray volumes. Other activities included displays of endemic parasitoids, predators and pathogens that attack FAW in Australia.

Two BMOs were based on the approved products and currently available resources for industry. The third BMO had a promising unregistered product, (recently registered as Vayego® to use against FAW in sweet corn) and an improved hybrid sweet corn variety. FAW pressure was low to moderate during the vegetative stage and increased to moderate to high levels during tasselling and silking (19 to 54% infestation). The demo blocks were sprayed using an air-assisted boom with spray volume of 300 to 500 L/ ha. Approved biopesticides such as Fawligen and Spodovir were used during mid to late vegetative stages that were mainly worked against neonate and smaller size (less than 4 mm) stages.

Key outcomes

- At early crop establishment, sweet corn seeds treated with cyantraniliprole gave good protection against FAW damage up to three weeks from seed emergence. The results gave the industry confidence to participate in the large-scale trials conducted on their farms by the chemical company.
- The release of ladybird beetles (*Harmonia octomaculata*), just before tassel initiation, gave good control of aphids. The ladybird population established in the sweet corn blocks within two weeks.
- The participants gained a better understanding of the types of endemic predators and parasitoids associated with FAW, aphids and green vegetable bugs. No evidence of egg parasitism following the release of the egg parasitoid, *Trichogramma pretiosum.*
- Drone spray applications of a non-toxic dye at three different volumes (30, 40 and 50 L /ha) was demonstrated at the field day. Participants viewed the differences in spray droplet distribution and penetration throughout the crop canopy and discussed with the drone pilot to gain a better understanding of drone spray application details.
- The improved knowledge learned from these demonstration sites helped the vegetable businesses select and time insecticide applications to achieve optimum FAW control and conserve beneficial insect activities. In addition, knowledge and understanding of the importance of rotating between new generation chemistries with biological products such as NPV is expected to delay the development of FAW populations with resistance to the new chemical groups.

Appendix 6: Three management options tested against FAW in sweetcorn.

Sowing Date: 10 Aug 2022; Emergence Date: 15-16 Aug 2022

Date	Crop stage	Demo Option - 1	Demo Option - 2	Demo Option - 3
	Seed treatments	*Group 28 + Fungicides	Fungicides	Fungicides
19 Aug	**V1**	**No Insecticide sprays**		
25 Aug	**V2**	**No insecticide sprays**	Success Neo (Group 5)	**No insecticide spray**
31 Aug	**V3**	**No insecticide sprays**		Vayego
02 Sep	**V3/V4**	**No insecticide sprays**		NPV + Adjuvant (applied with rain)
8 Sep	V5	Success Neo	Success Neo	NPV + Optimol
14 Sep	V6	Success Neo	NPV + Adjuvant	Success Neo
21 Sep	V8/V9	Proclaim Opti	Coragen + NPV	Vayego + NPV
28 Sep	Tassel initiation	Coragen + NPV	Coragen + NPV Movento	Vayego + NPV
	Beneficial releases: Trichogramma Ladybird beetle Cotesia			
6 Oct	Full tassel, young silk)	Proclaim Opti + NPV	Success Neo	Proclaim Opti + NPV
13 Oct	Full silks, second cobs	Coragen + NPV	Coragen + NPV	Success Neo
18 Oct	Cob Maturing	**No insecticide sprays**		

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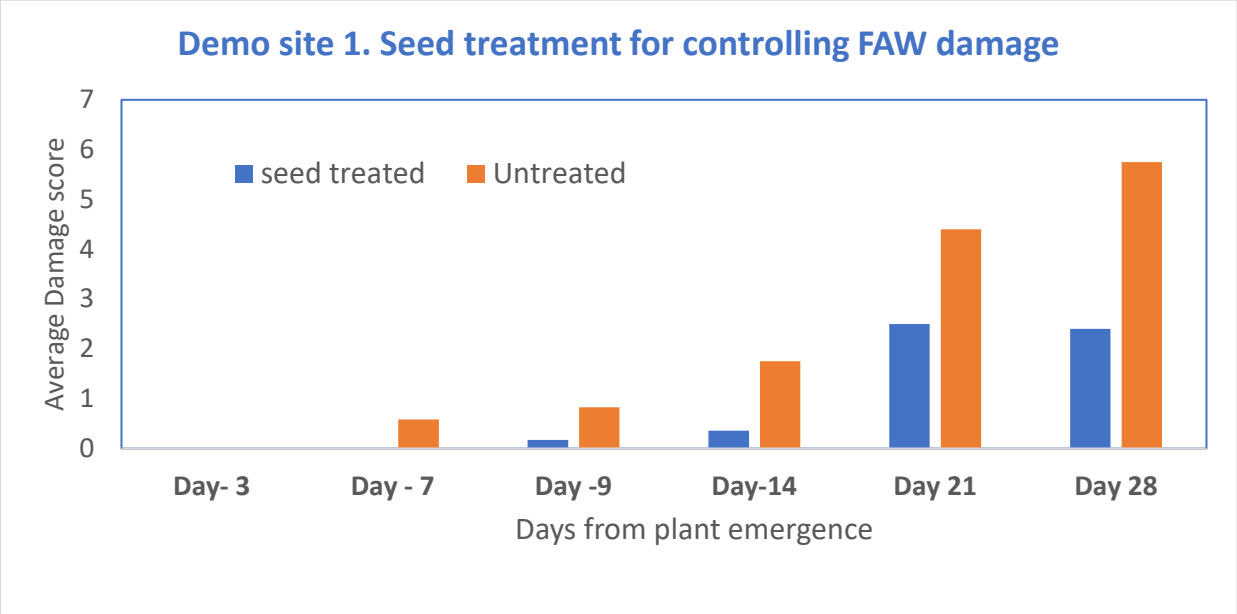
Hort Innovation Strategic levy investment | VEGETABLE FUND

Queensland Government

Results summary:

Date	Crop stages / treatments	Demo 1	Demo 2	Demo 3
		FAW damage levels (Davis scale: 0 to 9)		
25 Aug	Early vegetative (V2)	0.17	0.35	0.18
30 Aug	Vegetative (V3)	0.36	0.1	1.40
7 Sep	Vegetative V4/ V5	2.5	0.85	0.72
	Foliar sprays (8 Sep and 13 Sep)	Success Neo Success Neo	Success Neo NPV + Adjuvant	NPV + Optimol Success Neo
15 Sep	Foliage damage -V6	3.15	1.27	1.8
20 Sep	Pre-tassel (% plants with larvae)	33 %	54%	19 %
	Foliar sprays (21 Sep and 27 Sep)	Proclaim Opti Coragen	Coragen + NPV Coragen + NPV	DC-163 + NPV DC-163 + NPV
27 Sep	Tassel damage (% plants)	12.5 %	64%	27%
	Foliar sprays (6 Oct and 13 Oct)	Proclaim Opti Coragen + NPV	Success Neo Coragen + NPV	Proclaim Opti Success Neo
17 Oct	Cob with tip damage	14.5 %	46%	23%
17 Oct	Cob with side damage	2%	12.0 %	2 %
17 Oct	Undamaged cobs	83.5%	42%	75%



Final harvest of sweet corn cobs from the three demonstration sites Oct 2022.

Monitoring and activities of sweetcorn demonstrations and field day, Bowen

Participatory action research group of Bowen

Drone spray demonstration

Drone release of bio control agents

Appendix 8: Notes from the Co-design Workshop 17-18 November 2022, Brisbane

Our Goal and Plan:

<table>
<tr><th colspan="4">GOAL: Sustainable FAW AWM for <u>Australian</u> Vegetables</th></tr>
<tr><th>OBJECTIVE 1:

Efficient Program Management</th><th>OBJECTIVE 2:

<u>Nationally</u> Coordinated Regional AWM</th><th>OBJECTIVE 3:

Efficient Integration of Multiple Management tools</th><th>OBJECTIVE 4:

Effective Monitoring and Evaluation of Progress</th></tr>
<tr><td>Management Committee

Funding Allocation

Private sector relationships including chemical, equipment and biological suppliers, seed companies

Intergovernmental relationships

Cross Commodity relationships</td><td>Industry commitment and investment

Awareness and preparedness raising

E-Hub coordinates communication and engages across stakeholder groups – maps for industry too

Highly effective local AWM groups – develop sophisticated understanding of landscape, crop and FAW interactions and management that responds to these (i.e., systems approach)

AWM involves multiple commodity groups (needs resourcing)

Stakeholder research

Scheduled follow up meeting held</td><td colspan="2">International collaboration

Resistance Monitoring

Female attractants

Automatic detection tools

Cross commodity collaboration e.g., grains

GAP analysis of FAW AWM ASAP

Pressure definitions

Permit applications

Efficient chemical/spray management

Biologicals

Biopesticides

Resistant varieties and beneficials

Pastoral and cultural tools

Economic assessments

Habitat and behaviour of beneficials</td></tr>
</table>

		Weather effects (e.g., La Nina versus El Nino)	

Our Definitions:

Sustainable	Being able to produce and consume vegetable categories such as sweetcorn for eternity by protecting the resources (soil, water etc.), businesses (profitable) and technologies (e.g., varieties, chemistry, beneficials etc.) required to do so Not just looking after the earth, remaining profitable and managing chemical resistance are a part of it Social, economic, and environmental sustainability
Area Wide Management (AWM)	Management of an area, the boundary of which is determined by interdependent participants of that area when they consider climates, soils, cropping cycles and capacity to coordinate action It is not prescriptive but rather produces management systems through facilitated development of understanding, skills and practices amongst all stakeholders within the designated area It is more than horticulture as it involves other crops (e.g., grains) and other hosts (e.g., vegetation) It is a system of management that includes interactions across multiple pests, crops and the landscape
Research	Growers, industry oriented Undertaking studies into the management of pests and diseases either through trials, surveys or any other form of data collection from the field or growers leading to a better understanding and management of the pests and diseases in question
Extension	Leading, coordinating and brokering relationships and knowledge development Facilitate access of growers / industry and stakeholders to information, facilitate their interaction with researchers / relevant institutions and assist in bringing practice change; supporting

	growers to work with researchers to continuously improve their management of pest and diseases Overlaps with research in the process of knowledge, skill, technology development
Communication	Provides information to the growers / industry and stakeholders through various communication tools and some extension activities (e.g., newsletter, eHub, field days, demonstration sites); informing growers about the type of research that is being undertaken by various stakeholders Ability to produce material relevant to the research that has happened and deliver the research to growers in a user-friendly format without all the technical jargon

Barriers/Enablers:

What could frustrate progress towards our goal:	**Remedies**
The development of chemistry is too slow and/or excessive use	Include Croplife, APVMA and Chemical reps Keep Ausveg, Growcom and other advocacy groups informed
AWM groups failed	Ensure AWM & PAR capability in project teams, use appropriate engagement methods; ensure ongoing funding
Not enough funding – underestimated costs and resources	Start small and build as the resourcing knowledge gets developed
Unable to commercialise effective beneficials	Include commercial providers in the process, accelerate funding for this
Reduced capacity/staff turnover	Build understanding that the long term will be funded through evidence of impact, in a collaborative approach
Loss of social license	Include community groups in the process; keep informed
Ineffective planning	Have program steering committee up and running; continue to check in on progress and adapt
Poor communication and collaboration between groups	Establish, refine communication protocols and processes asap, building on VG20003, scheduled meeting led
Timing of pest arrivals	Through increased preparedness build resilience to incursions (e.g., prepare the list of potential exotic species and their risks to the industry, control options and resistance monitoring)
Unable to be responsive	Build capability through adaptive management in the program approach
Becomes too expensive to grow sweet corn profitably	
Disasters – flood/drought	Build capability through adaptive management in the program approach

Where to from here:

Short term (less than a year)	Medium term (2-3 years)	Long term 3-5 years
Program Management Team – form steering committee	More biological controls commercialised	Genetic modification of pest (e.g., sterilisation)
Gap analysis – independent assessment of FAW AWM knowledge, skill, technology gaps and its application in this context		Full functional coordination and collaboration
Lobby funding for R&D support		Genetically modify beneficials for chemical resistance; BT Corn trials
Identify and engage stakeholders		
Commercially rear egg parasitoid		
Identify softer options		
Emergency permit applications		
Monitoring pest		
Grow international partnerships		
Olive types up notes		

Timeline

Jan/Feb 2020	Mar/Apr 2020	May/Jun 2020	July/Aug 2020	Sep/Oct 2020	Nov/Dec 2020	Jan/Feb 2021	Mar/Apr 2021	May/Jun 2021
Ian Newton detected FAW in FNQ Stand-up of DAF staff to understand the fundamentals and work with growers to collect basic information and to craft ideas for management	Sampling Survey Extension of FAW – identification and life cycles Agronomists and growers ill-equipped to manage FAW – overuse of carbamates. Atherton hard hit Covid disruptions – hard to get overseas input Business Queensland FAW Fact Sheets	Establishment of population in Bowen Cool period in NQ First commercial losses recorded - 100% in organic sweetcorn and no options available Industry meetings with Bowen Gumlu and Bundy (online)	Further increase in numbers and damage reports, particularly NQ Temporary emergency use permit for Proclaim, Magnet, Success, Coragen, Avatar, Steward Expanded Pheromone trapping Different lures became available Hort Innovation REM appointed to Townsville	Field observations of life cycle in one month SEQ impacted, initially patchy Weekly pheromone trapping in Lockyer Detected group resistance genes First FAW meeting in Bowen	Serpentine Leaf Minor and FAW Arrived in Gippsland WA, NT VegNET heard of presence a and awareness DEC Field Day at Bowen – efficacy of pesticides, biological controls, Entrust became available, Started collecting samples for chemical resistance Metarhizium found in Kalbar Hort Innovation and QDAF facilitated an online forum	First Fawligen arrived First crop loss recordings in SEQ Qld government Funding Hort Innovation funding – MT19014 (field based detection) biological products, parasitoids Demonstration blocks, endo-pathogens – metarhizium mass produced Fawligen water volume impact – 200ml/l ok	Detected in Tasmania Sampling of Parasitoids – chelonus spp – egg larval endo-parasitoid, tachinid fly Commercial use of Fawligen started in Bowen area Bayer identified new product for trial Hort Innovation Funding MT19015 – (Beneficials)	Started finding cortesia in NQ QMFAW attractant available with good results Syngenta started seed treatment trials Damages found in Capsicum NQ Hort Innovation Funding VG20003 – (Extension)

Jul/Aug 2021	Sep/Oct 2021	Nov/Dec 2021	Jan/Feb 2022	Mar/Apr 2022	May/Jun 2022	Jul/Aug 2022	Sep/Oct 2022	NOV 2022
Peak FAW numbers Treatment options vs crop (sweetcorn cob) damage Insecticide resistance testing – carbamate/ organophosphate resistance found (Bowne/Burdekin) high homozygous susceptibility Extension project Initiated VegNET seminar Early pressure in Aug 21 in Lockyer	Ausveg/DAF FAW Management guide Bundaberg had FAW Issues in Sept Some damage also noted in Ginger and Turmeric Recognition that Hort needed a better mechanism to get news out on FAW – initially distributed online via Beatsheet	High pressure in Lockyer – continued through to Mar 2022 Chemical resistance results available to industry Drone spraying in commercial operations to check performance Boom spray – improving spray performance – air assist boom sprayer vs McGrow electromagnetic spray system	More damage in capsicum Evaluation of biological products IPM strategies Insecticide resistance testing Breeding key parasitoids Ramesh engaged to drive extension activities Extension project meetings Parasitoid sampling survey SEQ and N-NSW	MT19015 Final report John Stanley joined CBRC project Field trials established Crop damage in N-NSW Mulgowie learnt to manage with current chemistry to keep yield loss to a minimum	Timing of insecticides and spray options Development of E-Hub Newsletters – first Volume June Hort Innovation Funding AS1000 – Pheromone Blends	3 days 10 degrees maximum in NQ and rainfall = FAW reprieve FAW damage in sugarcane confirmed FAW damage in Heliconia	Spray application field days Sweetcorn seed treatment options 2nd newsletter Oct Trial with Vantacor (Coragen) for overhead irrigation and drone Spray performance improvement – water rate and adjuvant	Portfolio approach to extension Baseline KASAP E-Hub views Crop losses in Home Hill following high temps and wet weather

VG20003 Review:

Positive	Negative	Change
Beneficial Insects survey (MT19015 actually) e-Hub Networking for information deliver Engaging stakeholders Demonstration sites/field days Information generated Industry engagement Communication Adequate extension in production regions (Qld) Biological identification Emergency permits Collaborative approach Monthly meetings Good relationships on project team, open and sharing Local relationships Access to properties In-kind contribution from industry Communication framework Network of companies nationally Private sector collaboration Co-design of demonstration sites and strategies Resistance Monitoring • Very good sampling	RDOs – information on basics of FAW nationally Basic identification of pest nationally Getting information resources to growers in a timely fashion Regular project review/planning meeting annually Limited access to beneficial insects, biopesticides, new groups Loss of emergency pest status Not enough country wide engagement Limited resistant varieties Limited cultural control Spray performance of equipment Failure of R&D findings – not enough Trials in low pressure conditions Timing of applications not always optimal Define PAR and develop a working document New research – where is the pipeline of new knowledge – cannot go any further without more research Can't get all new information from private sector Perception of extension as not with researchers Resistance developing Not focused on research, need funds to invest more time	More beneficial surveys Commercial availability of beneficials e-Hub – include other pests Workshops – FAW, SLM, other pests identification/ management Build linkages among relevant projects nationally Farm walk Focus on pest rather than crop Commercialise beneficial insects Resistance strategies of chemicals (including helothis) IPM Need more new chemistry Extend info into area wide and country wide Work with seed companies Cultural techniques (trap crops. Push/pull crops, companion crops) Accelerate extension effort to other regions Lobby for more R&D funds Defined measures of pressure Stakeholder research Outside of Queensland Extension not supporting the development of the evidence to drive further investment in gaps Overall IPM requires a different mindset and capabilities that need to be built (Gap analysis) Consider cover or non-host crops etc Inclusion of beneficials into crop management programs

• Multiple regions e-hub Biocontrols working when softer options used		National reach Integration of all research PHA, CSIRO. Macquarie, other RDCs etc Integration of e-Hub with other key information interfaces Leveraging resources across other investments (joint initiatives) Improve trapping Monitor heliothis in growing regions System approach to crop/pest/landscape management - AWM

Workshop Review:

Element	Positive	Change
Participants	• Key industry representatives	• Involve chemical; representatives, APVMA, Croplife • Involve Hort Innovation R&D team • Involve other industries
Process	• Facilitation • Split across two days • Voices respected – co-design • All had a say	• Condense intro presentations • Noisy neighbours – venue change • Allow more time
Activities	• Dinner! • Timeline • Bear cards	
Outcomes	• Focus on Area Wide Management	

Appendix 9. Oral presentation at APEN conference in Launceston, Tasmania on 16th November 2023. The paper submitted to Rural Extension and Innovation Systems Journal (unpublished version attached)

The use of participatory approaches in the development and extension of fall armyworm management practices for the Australian vegetable industry

The use of participatory approaches in the development and extension of fall armyworm management practices for the Australian vegetable industry

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Abstract. Fall armyworm (FAW; *Spodoptera frugiperda*) was first detected in Northern Australia in February 2020. It quickly established and caused economic losses to sweet corn and maize. We used Participatory Action Research methods (PAR, plan, act, observe and reflect) to co-develop and deliver FAW best management options (BMOs) for the sweet corn industry and extend FAW information to the broader Australian vegetable and grains industry. Multiple extension methods were deployed, including facilitated meetings, demonstration sites, field days, newsletters, videos, and an online interactive engagement hub (eHub). Three prospective FAW BMOs in sweet corn were co-developed and demonstrated. A total of 402 vegetable industry participants and service providers engaged in the project's activities. Over 60% rated the field day as a valuable resource for engaging, sharing, learning, and accessing BMOs. Surveys showed that the PAR approach improved the participant's knowledge (understanding FAW biology, insecticide resistance and endemic parasitoids and predators), skills (identification of FAW larvae and adult moths, increasing the frequency of monitoring crops), aspirations (to incorporate beneficial insects into their management practices, adopt the FAW resistance strategy and UAV technologies) and changed the practices (minimise the use of ineffective chemistries and number of sprays by targeting the specific FAW stages) on FAW management.

Keywords: fall armyworm, participatory action research, co-development, extension, best management options, eHub

Introduction

The fall armyworm (FAW; *Spodoptera frugiperda*), a highly polyphagous noctuid moth native to the tropical and subtropical regions of the Americas, was officially reported in Western Africa in early 2016 (Goergen et al. 2016). Since 2016, this highly invasive species has become a global pest, expanding into Asia, the Pacific, and Australia (Kearns et al. 2020).

FAW was first detected in Queensland's Bowen, Burdekin, and Mareeba agricultural production regions in March 2020. Subsequent detections were reported in the Northern Territory (Darwin and Katherine), Western Australia (Broome and Kununurra), Queensland (Bundaberg and Lockyer Valley), Northern NSW, Victoria (Gippsland) and Tasmania (Wynyard). Within a short period of detecting FAW, significant crop damage (up to 50%) was recorded in organic and conventional sweet corn crops (Subramaniam 2022). Discussions with growers and agronomists indicated that the invasion of FAW has greatly increased the use of pesticides on these crops disrupting the Integrated and Pest Management (IPM) practices currently being used by the horticultural industry in the Bowen and Burdekin regions.

In Australia, growers largely rely on chemical intervention to suppress populations of FAW because there is limited availability of non-chemical options for management. However, extensive chemical use can harm non-target organisms, and flare secondary pests (natural enemies of FAW and beneficial insects released through biological control programs) (Desneux et al. 2007). Globally, reliance on chemical control strategies for FAW has led to resistance to at least 29 insecticidal active ingredients in six mode of action groups (Wu et al. 2019). Scientists have confirmed that FAW populations in Australia (NT, NSW, QLD and WA) have gene alleles associated with organophosphate and carbamate resistance (Nguyen et al. 2021). Judicious use of selective chemical options and non-chemical control measures within an IPM framework is the most effective strategy for minimising the risk of resistance and managing FAW sustainably (Bateman et al. 2018).

In response to FAW, several research projects were funded through governments and industry to

understand and address this new threat to Australian horticulture and grain crops. Hort Innovation Australia funded a project MT19014, where the Agriculture Victoria researchers validated FAW Loop-Mediated Amplification Technology (LAMP) for in-field detection of the FAW in Australia (Blacket 2022). Similarly, Hort Innovation funded MT 19015 project, where the Queensland Department of Agriculture and Fisheries (QDAF) collaborated with the Western Australia Department of Primary Industries and Regional Development (DPIRD), and the Northern Territory Department of Industry, Tourism and Trade (DITT) and discovered 18 endemic parasitoid species that attack egg and larval stages of FAW (Subramaniam 2022). Duong et al. (2021) reported that the Australian invasive *Spodoptera frugiperda* carried a resistance gene to organophosphate and carbamate insecticide. Similarly, a baseline screening of the Australian FAW populations (2020-2021) identified moderate resistance to carbamates and organophosphates and high resistance to synthetic pyrethroids. (Bird et al. 2022). Economic modelling was also used to assess the economic impact of FAW in Northern Australia and the potential benefit of IPM to horticultural crops. This modelling study reported that, in the first year of the FAW incursion (2020), losses in the horticultural crops across Northern Australia were estimated to be $AUS409 million or 23 per cent of total losses over 30 years. However, losses were dramatically reduced once the industry adjusted its pest management (conventional and Integrated pest management, IPM), reducing losses to an estimated $AUS59 million (Subramaniam 2022).

To strengthen linkages between FAW research projects and to optimise resources and research outcomes for the horticulture industry, Hort Innovation Australia funded the project “VG20003 Co-developing and extending integrated *Spodoptera frugiperda* (fall armyworm) management systems for the Australian vegetable industry”. The one-year extension project aimed to facilitate co-development of effective integrated FAW management strategies using a ‘Participatory Action Research’ approach’, and to communicate these strategies to the Australian vegetable industry. PAR involves collaborative research (Kindon et al. 2007), where the stakeholders (growers, researchers, consultants, extension officers, and service providers) are empowered to work together to investigate and develop solutions to shared issues and challenges. PAR enables the participants to build capacities and establish ownership and autonomy of the resulting innovations (Barbon et al. 2021).

A key reason for using this approach was to bring expert knowledge from growers and agronomists together with scientific knowledge to improve FAW management through active participation in planning, implementation, observation, and reflection stages (DHHS, 2012).

This paper describes the ‘Participatory Action Research’ approach to facilitate the co-development of knowledge and practice for FAW management in the Bowen-Gumlu region, North Queensland, Australia. Additionally, it describes the changes in knowledge, attitude, skills, aspiration and practice (KASAP) of growers in the region for FAW management. Identifying changes will let the current project review processes and methodology to “fill the gaps” and improve the project's focus.

Methodology

Participatory Action Research

The participatory action research (PAR) approach was used in VG 20003 project to co-develop knowledge and practices for FAW management. This is a collaborative approach (Kindon et al. 2007) where stakeholders, including growers, researchers, extension officers and consultants, work together in the planning, implementation, observation, and reflection stages to develop

knowledge and tools for FAW management. The project used four staged PAR frameworks (Figure 1) in objective setting, activity planning and delivery, and evaluation and reflection to build knowledge and skills in FAW management. The supporting prompts were used to encourage participation and engagement of PAR group members during the project period. Additionally, knowledge, attitude, skills, aspirations, and practice changes (KASAP) on FAW management were

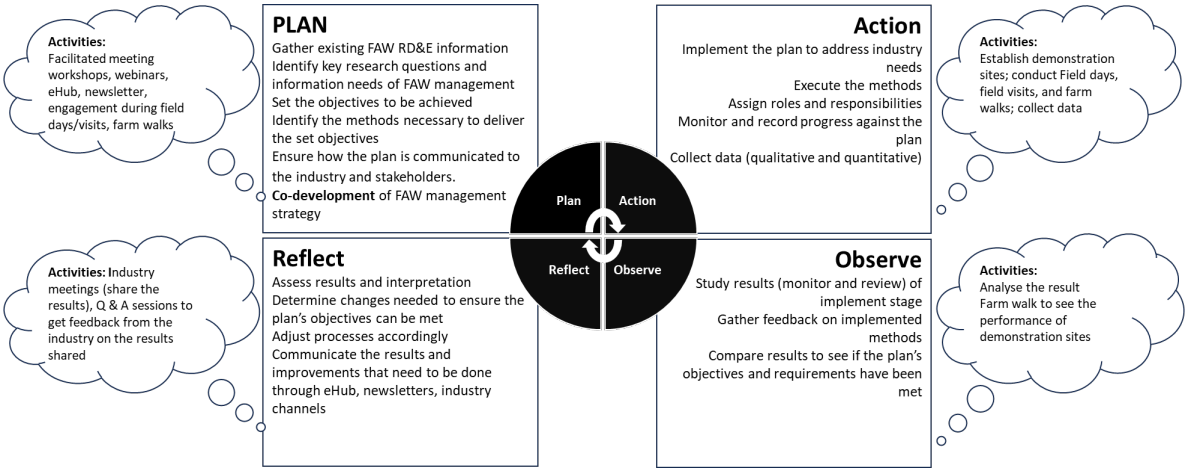

FIGURE 1. A framework to support Participatory action research (modified DHHS 2012)

documented in the PAR process (Table 1).

Table 1. Supporting prompts to engage participants and document KASAP changes on FAW management

Step 1. Plan	• What are we trying to do, learn or achieve in FAW management? • What is the FAW situation and pressure? How does it differ from last year? • What are our current practices for managing FAW? • What do we not know? (Insecticide resistance, where are FAW breeding during off-season?) • What are the likely changes in knowledge, attitudes, skills, aspirations, and practice **(KASAP)** due to the activity?
Step 2. Act	• What methods were used? • What are our current practices for managing FAW (biological, chemical, monitoring)? How do we study insecticide resistance and FAW sample collection (larvae size, treatment history)? • How do we proceed with the demonstration site establishment (commercial farm or research station)?
Step 3. Observe	• What were the results? • What was the effect of seed treatment and other treatments?
Step 4. Reflect	• What does the data say (interpretation)? • What is its application to the growers and other stakeholders? • What did we learn? • What will we do differently?

	• What is the impact on growers and stakeholders **(KASAP)**? • What do you want to see in the next meeting?

Step 1. Plan

Formation of Participatory Action Research Group

A regionally-based PAR group was formed in the Bowen-Gumlu, located in the North Queensland Dry Tropics (Figure 2) and is the largest winter vegetable growing region in Australia, with an annual value of $650 million. Key commodities produced in the region include sweet corn, tomato, capsicum, mangoes, cucurbits, and beans (D Shorten 2023, pers. Comm., 20 September). The PAR group in the Bowen-Gumlu region consisted of 12 members, including growers, consultants, VegNET RDOs (National Vegetable Extension Network, Regional development officers), researchers, extension officers, and service providers (seed and chemical companies).

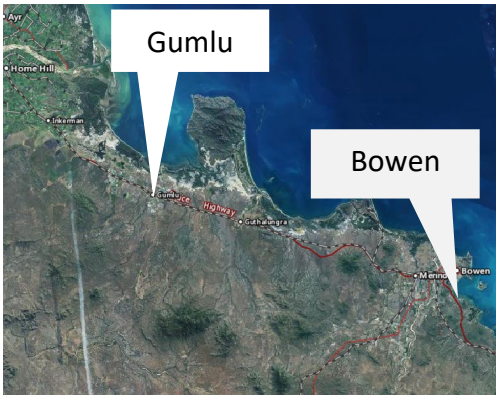

FIGURE 2. Bowen-Gumlu region in the North Queensland, Australia

Engagement with the PAR group and stakeholders nationally

The PAR group members and stakeholders collaborated in multiple facilitated meetings and field visits to understand the fall armyworm situation in the region, share the latest research updates, identify the industry needs and co-develop the FAW management strategy for establishing demonstration sites.

The half-day facilitated meetings were structured around the following sessions:

1. Growers and industry updates on the FAW situation, FAW pressure and possible management practices.
2. Updates from researchers.
3. Facilitated sessions on FAW knowledge and experiences followed by a ‘questions and answer’ session.
4. Identifying knowledge gaps and information needs to guide the project's next steps.
5. Evaluation survey to document feedback from the participants.

Co-development of demonstration sites

In consultation with PAR group members, fall armyworm best management options were co-developed in sweet corn crops. In designing the options, the team has considered best-performing chemistries and their impact on beneficial insects, crop phenology stages, fall armyworm and other pest pressures, spray application methods and varieties with industry standards. The two best management options were based on the approved products and currently available resources for the industry. The third-best management option had promising chemistry and improved sweet corn varieties.

The co-developed BMOs included conventional chemistries, similar to the industry practices, but a study to see their impact on beneficial insects differed from the industry practice. Likewise, the demonstration blocks were monitored weekly and sprayed using an air-assisted boom with a spray volume of 300 to 500 L/ ha, different from industry practice. Further, the release of larval parasitoids (*Cotesia* sp.) in a demonstration block was first practised in the region. Interestingly, *Cotesia* sp. was commonly detected in the FAW samples collected from sweet corn fields in the Bowen Research Facility. Specific prompts for growers and other stakeholders were asked to encourage participation and engagement (Table 1). This step helped identify the knowledge gaps and key research questions.

Step 2. Act

Establishment of demonstration sites and conduct a field day

Three prospective FAW BMOs were established at QDAF, Bowen Research Facility, with each block's 16 rows x 60 m size. The two best management options were based on the approved products and currently available chemistries for the industry. The third best management option had new promising chemistry and improved sweetcorn varieties. These options were identified from the facilitated meetings in Step 1. Likewise, the FAW field day was conducted on the demonstration sites on 19th October 2022.

On the field day, two blocks of sweet corn were used to demonstrate UAV spray applications with three different spray volumes. Other activities included displays of endemic parasitoids, predators and pathogens that attack FAW in Australia. Specific prompts for growers and other stakeholders were asked to encourage participation (Table 1).

Step 3. Observe

Observation of demonstration sites and field day

FAW infestation and damage levels were monitored from seedling emergence to harvest in all three demonstration blocks. At weekly intervals, 96 plants per block (16 rows x 60 m) were searched in a stratified random fashion for FAW egg masses and larval presence per plant (6 plants/row, one plant randomly from each 10 m interval of row). Plant damage scores were also recorded according to the Davis Scale (Davis & Williams 1992). The researcher and extension officer collected these data.

Growers were also invited to visualise the effect of seed treatments on sweet corn crops at 3-4 stage, around two weeks of emergence. FAW treatments were initiated based on the weekly monitoring results Insecticide sprays were applied using a tractor-mounted air-assisted sprayer.

For the field day, forty cobs per boarder were collected, stripped of their husk and displayed on benches next to the crop. This exhibited the proportion of cobs with FAW damage at the tip and along the side of each cob. Furthermore, a 10 m deep clearing was forged into the crop to display cobs while still attached to the plants. This allowed participants to access the crop and view the FAW damage pattern, infestation levels and marketable quality of cobs.

Specific prompts for growers and other stakeholders were asked to encourage participation in the observation step (Table 1).

Feedback from the participants was collected using a questionnaire:

- How did you find the field day on fall armyworm management on sweet corn? (Not useful, very useful)
- What aspects of this field day were the most useful or valuable to you? (FAW management options, beneficial, engagement, FAW resources, UAV spray)
- Do you intend to change your management practices/business from what you have seen/heard today? (Yes, No) if yes, please tell us what you intend to do differently.
- Would you like this type of demonstration site and/or field day event in the coming days? (Yes/No)
- Any other feedback and comments/suggestions to improve?

Step 4. Reflection

Facilitated meetings and feedback from growers and other stakeholders

The PAR group members and stakeholders were invited to facilitated meetings to share the results and their implications with the growers and other stakeholders. These meetings were organized after the crop season. The half-day facilitated meetings were structured around the following sessions as follows:

1. Growers' updates on the impact of FAW in sweet corn crops and other vegetable crops and share the possible management practices used.
2. Updates from researchers on results and their application to the growers.
3. Facilitated sessions driven by the prompt questions (Table 1).
4. Identifying knowledge gaps and information needs to guide the project's next steps.
5. Evaluation survey to document feedback from the participants.

Specific prompts for growers and other stakeholders were asked to encourage participation in the reflection step (Table 1).

Documentation of Knowledge, Attitude, Skills, Aspiration and Practice changes (KASAP)

The KASAP documentation was conducted by asking pre-defined questions (Table 1) to the PAR members during 2021-2022, mainly at PAR's planning and reflection stages. KASAP documentation was conducted during the engagement activities (Figure 1, meetings, field days, field visits and one-on-one communication). The documentation was mainly focused on qualitative information based on the discussion and the KASAP questions. The qualitative data collected from facilitated meetings and field visits were compiled and qualitatively analysed to compare KASAP differences.

Communication of FAW Research, Development & Extension (RD&E) nationally

The FAW engagement hub (FAW eHub) and newsletters were managed to provide regular updates on FAW Research, Development and Extension (RD&E), project activities and share learnings to the vegetable industry development managers, growers, and agronomists, and provide a forum for feedback and discussion, nationally.

Results and discussion

Engagement of PAR group

A total of 402 vegetable industry agronomists, researchers, and representatives from chemical and seed companies, nationally were engaged in facilitating the knowledge and co-development of the interim FAW management strategy. The participants were engaged through PAR group facilitated meetings, field visits by industry participants representing different Australian States and through the newsletters. The facilitated meetings were useful in identifying the research and information needs on three broad topics: biological control, insecticide resistance and sustainable integrated FAW management and monitoring.

The highest-rated needs of the industry were:

- To know whether adjuvants are adding to the efficacy of insecticides or not for FAW management
- To know the best time to spray (crop stage, time of the day, insect stage)

- To know the method to control FAW in the whorl
- To know where are FAW coming from in the production system
- To know how and where FAW survives during the off-season to initiate infestation in the immediate season
- To fast-track commercialisation of beneficial insects (predators and parasitoids) and biologicals (fungi, viruses), if they are effective in managing FAW
- Toxicity of insecticides on beneficial insects and biologicals
- To communicate FAW RD&E information to the industry

New knowledge and research needs identified from the meetings were communicated nationally to the researchers and other vegetable industries using the project's communication channels (FAW newsletter and engagement hub).

The facilitated discussion was critical, allowing PAR group members, extension officers and researchers to understand the industry practices and share the research updates on FAW management. A similar report was suggested by Sewell et al. (2017), where it is mentioned that, researchers and extension officers' engagement with the growers and industry provides an opportunity to engage with the science, and interactions help span the world of science and farm decision-making.

Co-design of FAW management options

Co-development of three BMOs

The three BMOs were demonstrated at the Bowen Research Facility in 2022. Demonstration sites were established by planting three sweet corn blocks in August 2022 to target moderate to high fall armyworm pressures. The demonstration blocks were monitored weekly and sprayed using an air-assisted boom with a 300 to 500 L/ ha spray volume. The commercially available egg parasitoid, *Trichogramma pretiosum* for *Heliothis* and ladybird beetles (*Harmonia octomaculata*) for aphids were released using an unmanned aerial vehicle (UAV). Larval parasitoids (*Cotesia* sp.) were released to observe their impact on fall armyworm. The data and information collected from this demonstration site were summarised and distributed to participants at a field day.

A field day was organised on the demonstration sites in October 2022. Twenty-two agronomists, researchers, and representatives from sweetcorn, chemical companies, and seed industries participated. UAV spray applications with three different volumes (30, 40 and 50 L /ha) using non-toxic dye were demonstrated at the field day. Participants viewed the differences in spray droplet distribution and penetration patterns with three spray volumes, engaged with displays of natural enemies of fall armyworm, and discussed fall armyworm management issues facing the industry.

Over 60% of the field day participants responded that it was a valuable forum for engaging, sharing, learning, and accessing BMOs. Similarly, the respondents intended to change their practice regarding UAV use during the wet season (if permitted), using beneficial, and increasing the monitoring frequencies considering the crop stages (Figure 2). Demonstration sites and field days helped translate research into application by allowing participants to observe innovations and making it simpler for researchers and extension officers to communicate the innovation, as reported by Singh (2018) and Boleman & Dromgoole (2007).

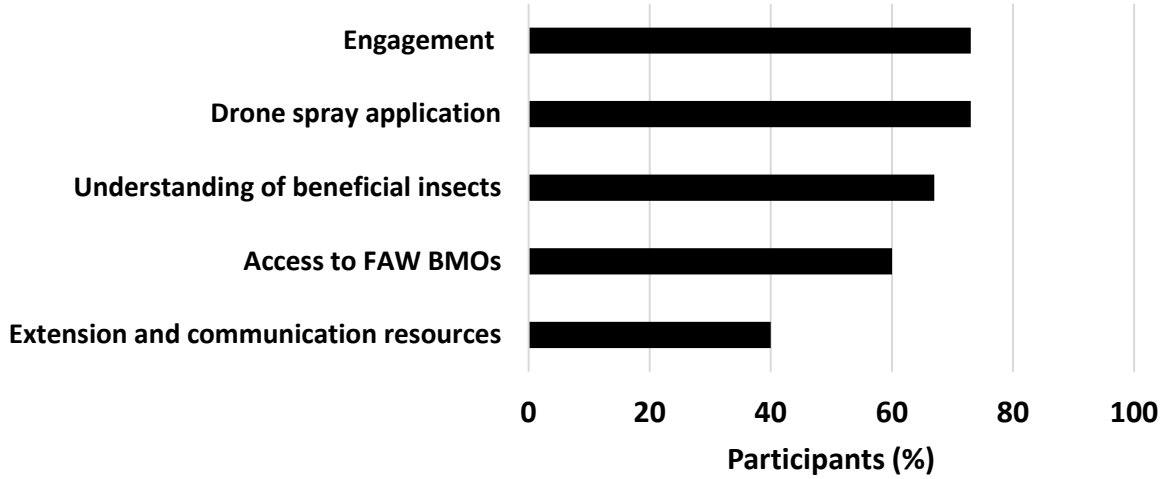

Figure 2. Participants respond to their valuable useful aspects of the field day (top five in order)

Changes in KASAP

Repeating the meetings across the project period (6-7) effectively improved participants' knowledge, skills, and intentions to improve their management practices in the future. The project has demonstrated that the PAR methods can help build rapport and trust with the industries to bring change in practice.

The key insights from the evaluation (KASAP) are summarised below:

The highest-rated impacts on participants' knowledge were:

- understanding of FAW biology and seasonal activities relating to local temperature and cropping conditions
- understanding the efficacy of chemistries and resistance to FAW populations in their locations
- understanding the endemic parasitoids, predators and pathogens attacking FAW eggs and larval stages
- understanding various aspects of sprayer settings, including nozzle selections, droplet sizes and spray volumes
- understanding the effective spray adjuvants for improving FAW control
- understanding of insecticide resistance
- understanding insecticide seed treatments to protect the early vegetative stages of sweet corn.

The highest-rated impacts on participants' skills were:

- skills to identify FAW eggs and larvae in the field condition
- skills to manage FAW in the commercial farm
- skills to identify the endemic parasitoids and predators
- skills to monitor FAW in the crop

The highest-rated impacts on participants' aspirations were:

- aspiration to adopt the outcomes for FAW resistance management
- aspiration to incorporate beneficial insects and biopesticides within the existing management practices.

The highest-rated impacts on participants' practice changes were:

- Adoption in minimising the use of ineffective chemistries such as synthetic pyrethroids, organophosphate and carbamates. Local research has indicated that fall armyworm has developed high-level resistance to these chemistries.
- Adoption in choosing more effective insecticides for targeting FAW life stages. Choosing the right insecticide products and using them at the right time to target eggs or larvae.

Sweet corn growers also showed interest in FAW IPM to minimise the risk of insecticide resistance and adopt the research findings to achieve sustainable and integrated FAW management. These results indicate that participants

improved their knowledge and skills in managing FAW. The results suggest that the growers have increased their confidence in growing sweet corn in the region.

Communication of FAW RD&E nationally

The FAW eHub was published, and FAW newsletters were produced and distributed nationally using the digital platform. The engagement hub allowed the stakeholders to keep up to date on the latest information on FAW RD&E activities for horticulture and engage with industry and stakeholders. Since its release, the eHub web analytics has shown impressive results in engaging stakeholders (Figure 3).

The FAW eHub has 5367 page views with 1721 unique visitors in the portal. Likewise, 1334 and 443 stakeholders became aware (number of unique visitors who have viewed the project page, minus any visitors who have undertaken any activity, e.g. downloaded a document, viewed a video, completed a survey etc.) and were informed (Any unique visitor who has viewed the latest news item, viewed a document, viewed a video, viewed a FAQ minus any user that has engaged e.g. done a poll, survey, ideas wall, interactive mapping, interactive document, forum), respectively, by the eHub.

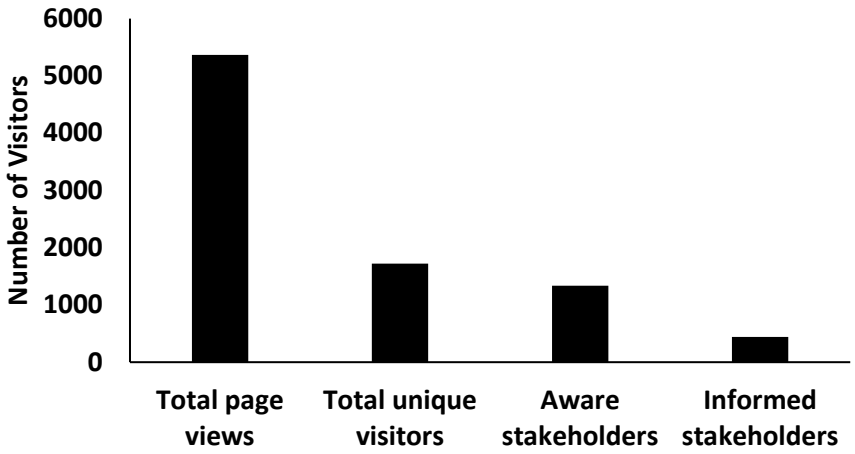

Figure 3. Stakeholders' engagement in FAW eHub.

Learnings and challenges of the PAR approach in this project

The PAR approach in the vegetable industry helped better to understand the industry experiences and their existing management practices. It allowed the industries to share general information on FAW management, issues, and identification of research needs through facilitated meetings, field visits, field days, and farm walks. Additionally, the demonstration sites provided a medium for the growers to visit the sites and interact with the researchers about the performance of the co-developed FAW management options. This project has also broadened its concern beyond horticulture industry and initiated a discussion on Area-Wide Management of FAW.

Besides this, there are challenges to better understanding the industry's comprehensive FAW management options in a group, mainly due to the competitiveness in the business. The demonstration site establishment on a commercial farm and access to other industries is also challenging. Likewise, a practice change on replacing the existing cover crops needs effort for the Area-Wide Management of FAW.

Conclusion

This extension has engaged 402 horticulture growers, agronomists, researchers, and representatives from chemical and seed companies nationwide to co-develop and deliver the sweet corn FAW BMOs for industries and communicate FAW RD&E information to the Australian vegetable industry. The industries have developed their knowledge, attitude, skills, aspirations and practice change on FAW management, suggesting increased confidence in sweet corn cultivation in the Bowen-Gumlu region. The FAW engagement hub has been useful in communicating the FAW RD&E to the industry and stakeholders nationally and has been able to engage them through this platform. The involvement of stakeholders from different Australian states has increased their interest in FAW RD&E to be prepared for pest identification, monitoring and management before it economically impacts the vegetable and grain crops, suggesting an Area-Wide Management of FAW.

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