Biological control efforts for the management of Fall Armyworm in India

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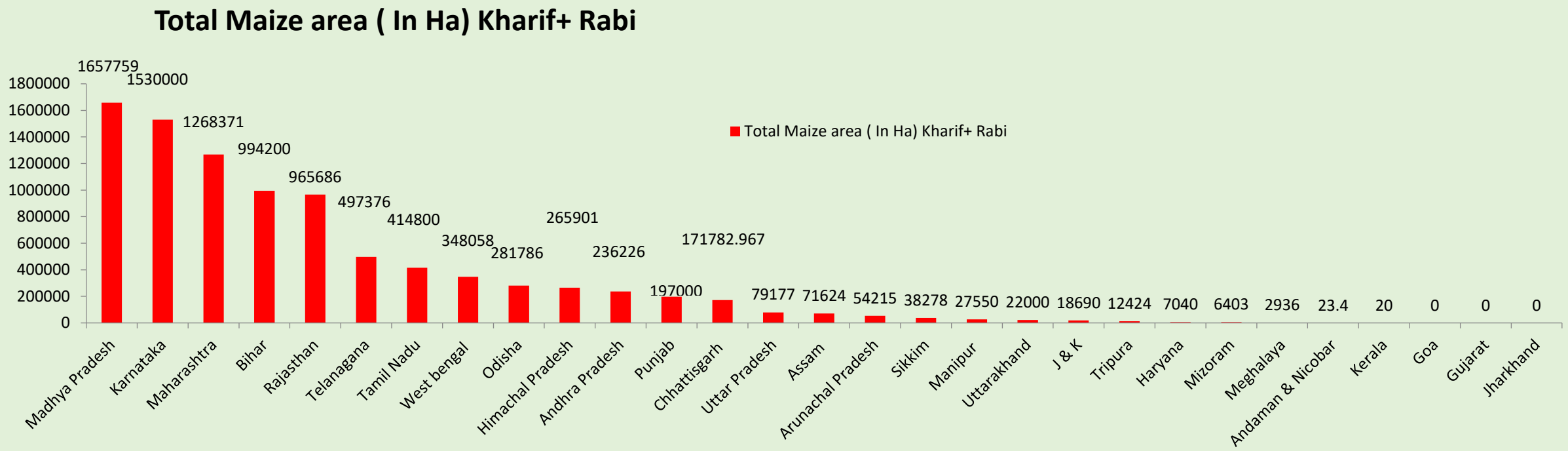
the facts….

- FAW was first recorded in May 2018 in India in southern most part (Shylesha et al. 2018) and later spread to other states (except Kashmir).
- First recorded on maize, later on sorghum
- Occasionally on sugarcane, cotton, rice, ginger etc.
- Maize cobs also damaged occasionally.
- Incidence in 2018: upto 70% plant damage.
- Incidence in 2022-23: low to moderate (6-20%) in all states as per AICRP-BC report.



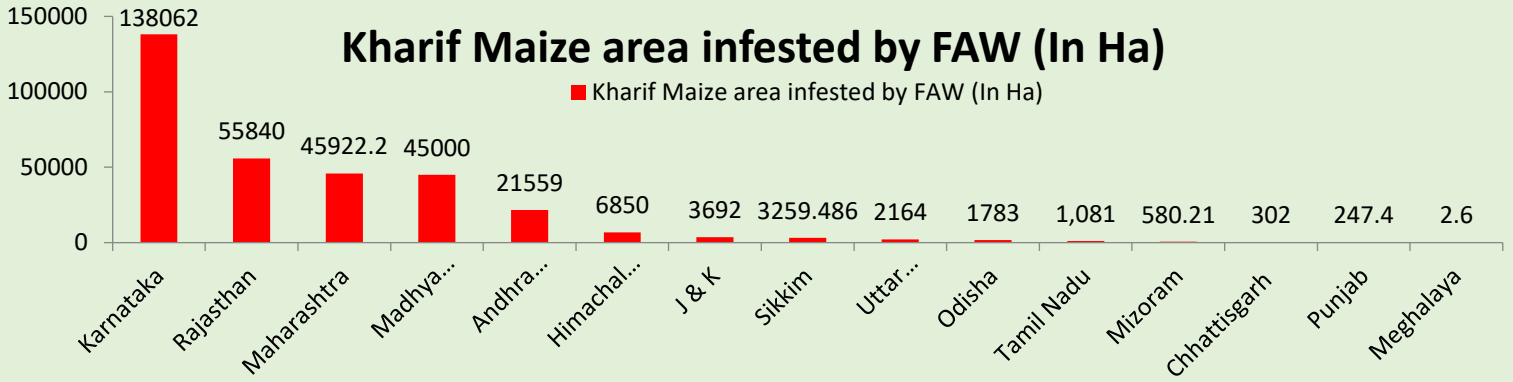
Maize Cultivation Scenario in India (2022-23)

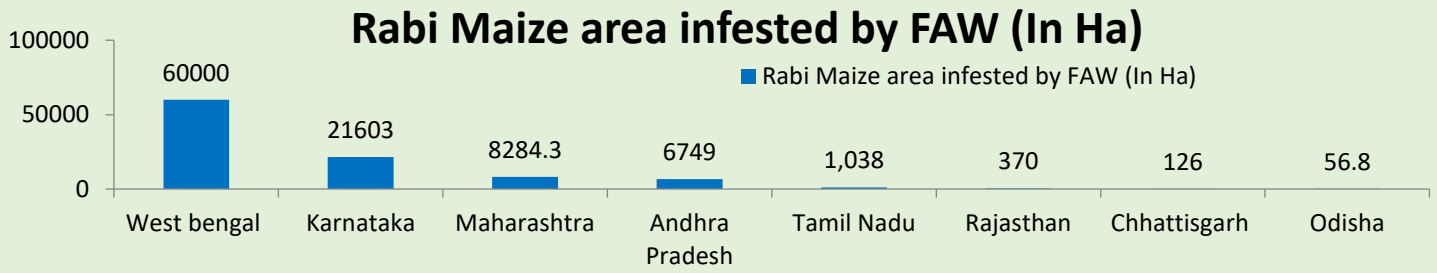


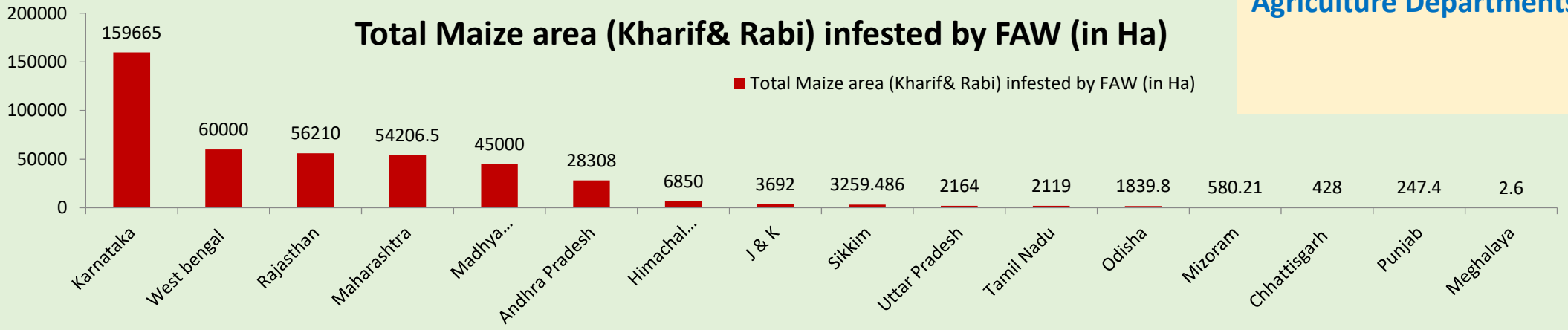
Kharif (Sowing in May-June) - 6.80 M Ha (74%)
Rabi - (Sowing in Oct-Nov) 2.36 M Ha (26%)
Total area - 9.17 M Ha

(Source: Data Submitted by State Agriculture Departments)

Maize Area (Ha) Infested by FAW in India (2022-23)







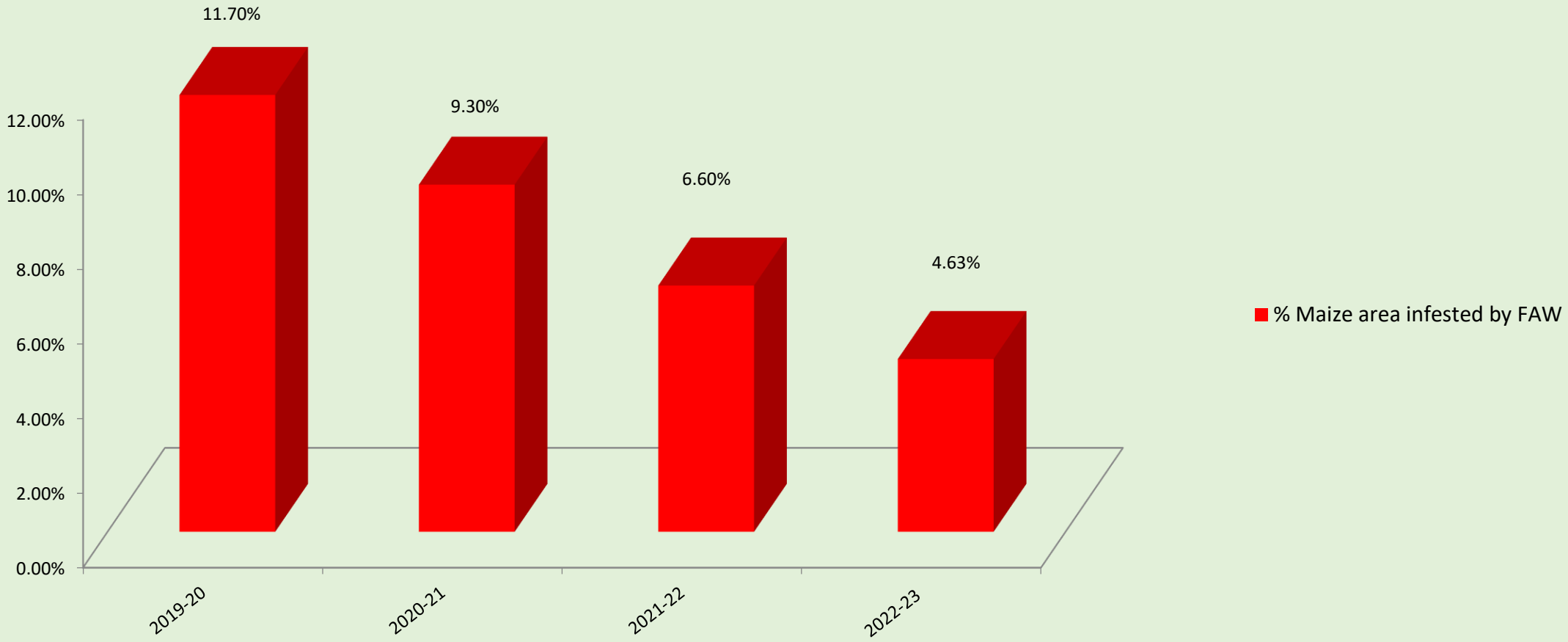
Kharif (Sowing in May-June) – 0.326 Million ha (4.79% area of Kharif)

Rabi - (Sowing in oct-Nov) 0.098 Million ha (4.15 % area of Rabi)

Total 0.424 Million ha (4.63% of Total Maize area)

Source: Data Submitted by State Agriculture Departments

Percent maize Area infested by FAW in India (2019--23)



Surveys conducted in states across India

Natural enemies recorded on fall armyworm (FAW) in India

	Scientific name	Taxonomic placement	Biological attribute	Collection locality (States)	Reference
	*Telenomus remus*	Hymenoptera: Platygastridae	Egg parasitoid	Karnataka and Tamil Nadu	Shylesha et al. 2018
	*Trichogramma chilonis*	Hymenoptera: Trichogrammatidae	Egg parasitoid	Karnataka	Shylesha et al. 2018
	*Chelonus formosanus* Sonan	Hymenoptera: Braconidae	Egg-larval parasitoid	Karnataka and Telangana	Gupta et al. 2020
	*Coccygidium transcaspicum*	Hymenoptera: Braconidae	Larval parasitoid	Karnataka and Telangana	Gupta et al. 2020
	*Cotesia ruficrus* (Haliday)	Hymenoptera: Braconidae	Larval parasitoid	Karnataka, Tamil Nadu, Rajasthan, Uttar Pradesh, Punjab, Meghalaya	Gupta et al. 2019

	*Glyptapanteles creatonoti* (Viereck)	Hymenoptera: Braconidae	Larval parasitoid	Karnataka	Shylesha et al. 2018
	*Campoletis chlorideae* Uchida	Hymenoptera: Ichneumonidae	Larval parasitoid	Karnataka	Shylesha et al. 2018 and Sharanabasappa et al. 2019
	*Eriborus* sp.	Hymenoptera: Ichneumonidae	Larval parasitoid	Karnataka	Sharanabasappa et al. 2019
	*Odontepyris* sp.	Hymenoptera: Bethylidae	Larval parasitoid	Tamil Nadu	Sharanabasappa et al. 2019
	*Phanerotoma* sp.	Hymenoptera: Braconidae	Larval parasitoid	Karnataka	Ballal et al. 2021
	*Exorista sorbillans* (Wiedemann)	Diptera: Tachinidae	Larval parasitoid	Karnataka	Sharanabasappa et al. 2019

	*Forficula* sp.	Dermaptera: Forficulidae	Predator	Karnataka	Shylesha et al. 2018 and Sharanabasappa et al. 2019
	*Harmonia octomaculata* (Fabricius):	Coleoptera: Coccinellidae	Predator	Karnataka	Sharanabasappa et al. 2019
	*Coccinella transversalis* Fabricius	Coleoptera: Coccinellidae	Predator	Karnataka	Sharanabasappa et al. 2019
	*Andrallus spinidens* (Fabricius)	Hemiptera: Pentatomidae	Predator	Karnataka	Firake & Behere 2020
	*Eocanthecona furcellata*	Hemiptera: Pentatomidae	Predator	Karnataka	Keerthi et al. 2020

Egg and larval parasitoids

First year of invasion 2018

1. ***Trichogramma chilonis*** **Ishii**
2. ***Telenomus*** **nr.** ***remus***
3. ***Chelonus formosanus*** **Sonan**
4. ***Campoletis chloridae*** **Uchida**
5. ***Cotesia ruficrus*** **(Haliday)**
6. ***Glyptapanteles creatonoti*** **(Viereck)**

Gradually expanding native parasitoid bank….. post 2018

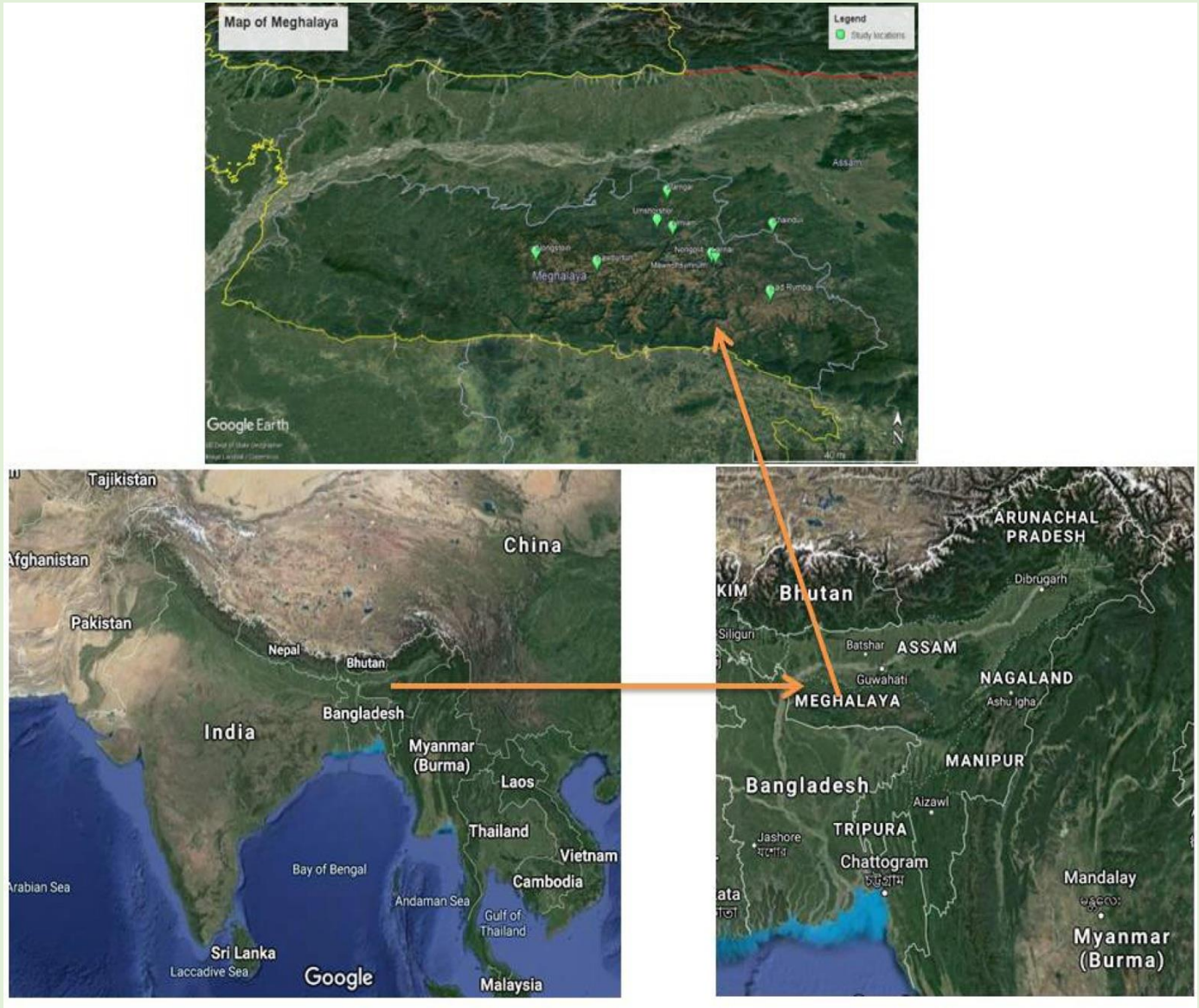
Two-Three years of invasion

1. Coccygidium transcaspicum (Kok.), *2. Phanerotoma* sp., *3. Aleiodes* sp., *4. Meteorus pulchricornis* (Wes.), 5. *Microplitis manilae* (Ashmead), 6. *Microplitis demolitor* (Wilk.), 7. *Netelia* sp., 8. *Metopius rufus* (Ashmead), 9. *Temelucha* sp., 10. *Ichneumon promissorius.*

Natural percent parasitism.....

Parasitoids	Percent parasitization	
	2018-19	2019-20
Trichogramma chilonis	3.7 - 12.43	15.81 - 23.87
Telenomus remus	1.8 - 9.4	8.0 - 11.6
Chelonus spp.	0.2 - 1.4	4.91 - 21.38
Cotesia sp.	-	0.14
Campoletis chlorideae	-	0.29
Exorista xanthaspis	-	1.86 - 6.63

Experiences from NE India……..



In Meghalaya (N-E India) : 56.6% to 73.1% of larvae were found to be parasitized /infected with entomopathogens.

34 different locations representing five major districts (viz., East Jaintia Hills, West Khasi Hills, East Khasi Hills, West Jaintia Hills and Ri Bhoi)

Firake and Behere, 2020

Genetic diversity of invasive FAW populations in India

- Two morphologically identical strains, designated as majority strain (*Tpi*-Corn & *COI*-Rice) and minority strain (*Tpi*-Corn & *COI*-Corn) most consistently found on Maize and less frequently in Sorghum, Finger Millet, Pearl Millet etc.

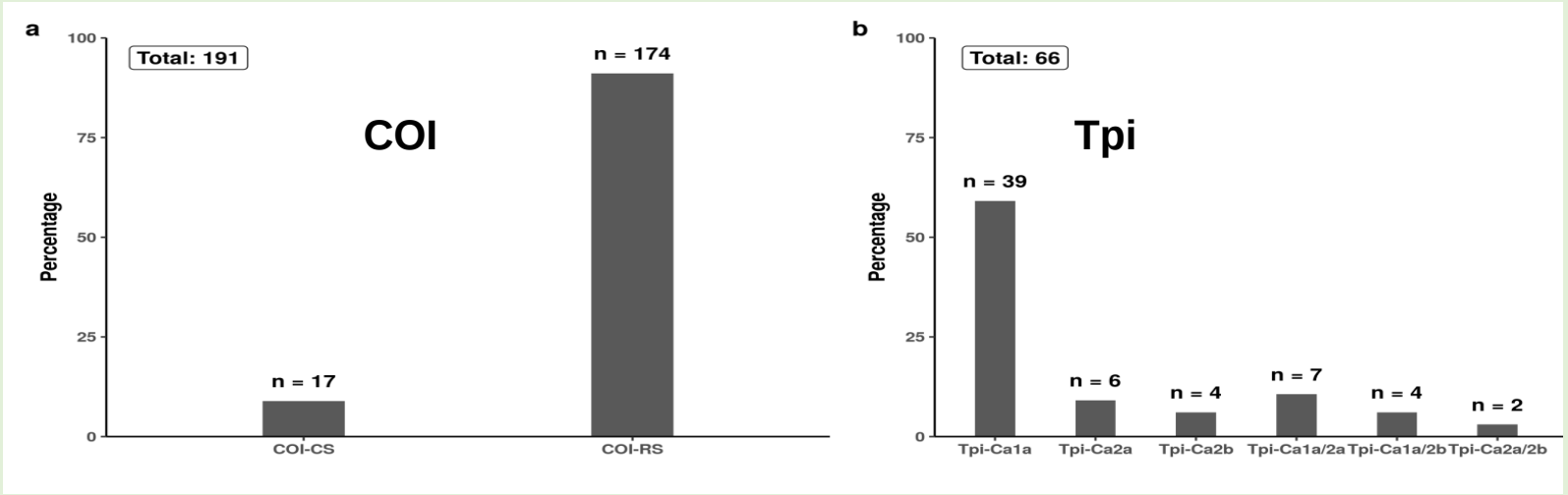
- Genetic diversity of the two strains was studied based on *Cytochrome c-oxidase subunit-1* (mitochondria) & *Triosephosphate isomerase* (nuclear) markers.

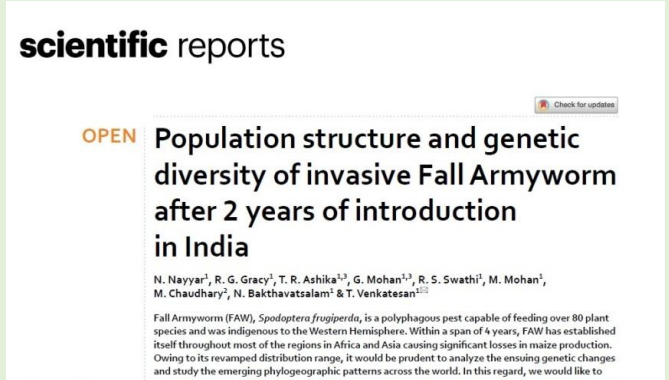
- The same trend was found in other invaded countries.

Genetic diversity of invasive FAW populations in India

- **Analyzed 191 mitochondrial COI gene sequences of FAW specimens from 101 different regions of India & Nepal**

- **In addition, 66 nuclear T*pi* gene sequences were also analyzed which is considered as a useful marker to ascertain the association of host plants in FAW.**





Distribution of FAW haplotypes in India (*COI* & *Tpi*)

- **<u>100% of the population exhibited 'Corn Strain' haplotype on the basis of Tpi gene sequences.</u>**

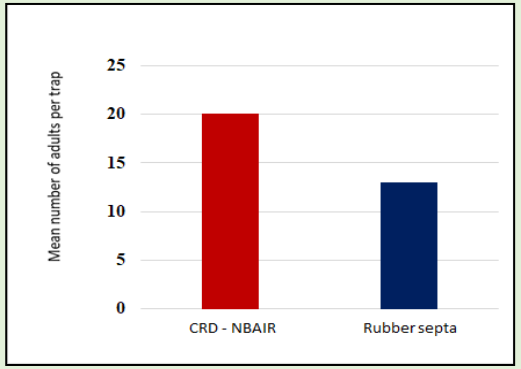
- **Thus, *Tpi* gene marker was more accurate in prediction of host association in India. Similar trend was observed in FAW from Africa & Asia, suggesting a common origin for invasive populations in all these places.**

Nayyar *et al*., 2021

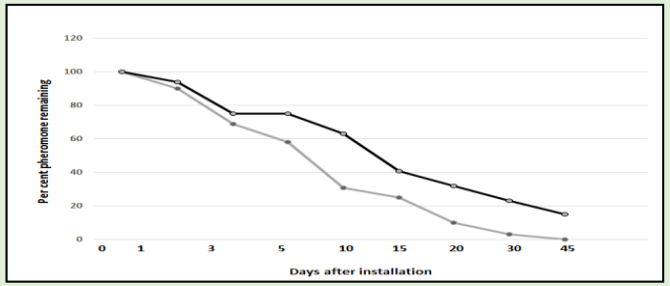
Controlled release matrix for delivery of FAW, *Spodoptera frugiperda* pheromone

- The Antennal response of adult *S. frugiperda* males to (*Z*)- *9-Tetradecen-1-ol acetate* (as major component) was established by electroantennography. This confirms the physiological response of the antennal neurons to pheromone.
- Field trials using the **NBAIR controlled release dispenser** at three locations trapped over 20 ± 3.13 adult males per trap as compared rubber septa that trapped less than 13 ± 2.82 moths per trap.
- Controlled released dispenser is effective for over 45 days.
- Identity of *S. frugiperda* adults trapped were confirmed by molecular and morphological techniques
- The technology developed has been commercialized to three firms

EAG trace of FAW adult



Field efficacy of FAW pheromone



Line in black : Pheromone loaded in controlled release matrix
Line in grey : Pheromone loaded in rubber septa

Trapping FAW adult males

S. frugiperda genetalia dissected to confirm the sp. trapped

Microbial pathogens on FAW in India

Quantification of Natural occurrence of microbial pathogens of FAW in Karnataka (India)

Fungal pathogens : 74.07 %
Bacterial pathogens : 9.87%
NPV : 13.58%
Others : 3.70%

- **Natural epizootics of *Metarhizium rileyi* (=*Nomuraea rileyi*) were reported to cause significant larval mortality ranging from 1.87% to 18.30% in Karnataka.**
- **Natural epizootics of an NPV of *S. frugiperda* have been reported from Gujarat in Western India (Raghunandan et al., 2019).**

Metarhizium anisopliae ICAR-NBAIR Ma 35 for the management FAW

- Talc/oil based formulation was developed
- Field trials- 3 Foliar sprays @ 20, 30 and 40 days after sowing (10 days interval)
- Locations: Andhra Pradesh , Karnataka, Gujarat, Tamil Nadu
- Field trials - 50-76% reduction in the plant damage caused by the FAW
- Yield enhancement- 20-40%

FAW mortality under lab conditions

Ma35 spraying in maize plots

Ma-35 dead cadaver after foliar application

Consortia of bacteria for the Management of FAW in hybrid Maize under Field Conditions

- A consortium of *Pseudomonas fluorescens* (NBAIR-PFDWD) and *Bacillus albus* (NBAIR-BATP) was found to be effective against FAW.
- More than 80 % reduction in FAW infestation in maize.
- One hundred per cent recovery observed on maize plants infested with fall armyworm after four sprays of bacterial consortium.
- Plant growth promotion activity also observed.
- Yield enhancement: 30-45%

Bacterial biopesticides sprayed maize field

Maize field inspection by experts

Aqueous formulation of *Spodoptera frugiperda* nucleopolyhedrovirus (SpfrNPV ICAR -NBAIR1) for the management of FAW

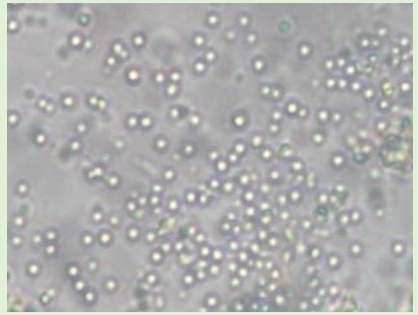
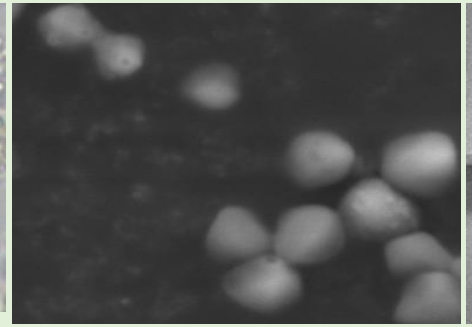
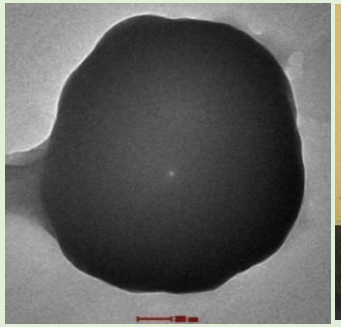
Shatpada FAW Kill

- **SpfrNPV is a host specific NPV and is effective against FAW**
- **Shelf life: 2 years**
- **Occlusion Bodies count in the formulation : $1x10^9$ OBs/ml**
- **Technology transferred for wide area demonstration.**

Spodoptera frugiperda NPV ICAR-NBAIR1(FAW Kill)





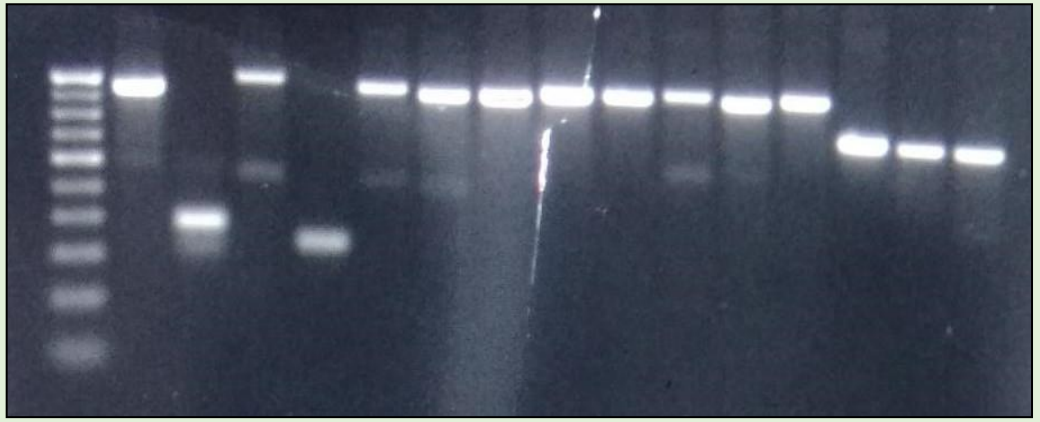





Size of the Occlusion body	1.64 µm
Shape of the Occlusion body	Tetrahedral
Molecular confirmation	NCBI GenBank acc.no. MT422725 (Polyhedrin gene)
Laboratory larval mortality	80%
LC_{50} Value	4.12 OB/mm^2
Pest reduction recorded in field evaluation	72%

Shatpada Armour (NBAIR Bt25)

Bioefficacy of *B. thuringiensis* strain NBAIR BT25 against *Spodoptera frugiperda* after four days of inoculation

Isolates	LC50 (µg/ml)	95%FL	LC90 (µg/ml)	95%FL	Slope± SE	Chi-Square value	P-value
Bt25	42.92	33.30-54.63	132.49	96.26-221.9	2.61± 0.38	4.29	0.23



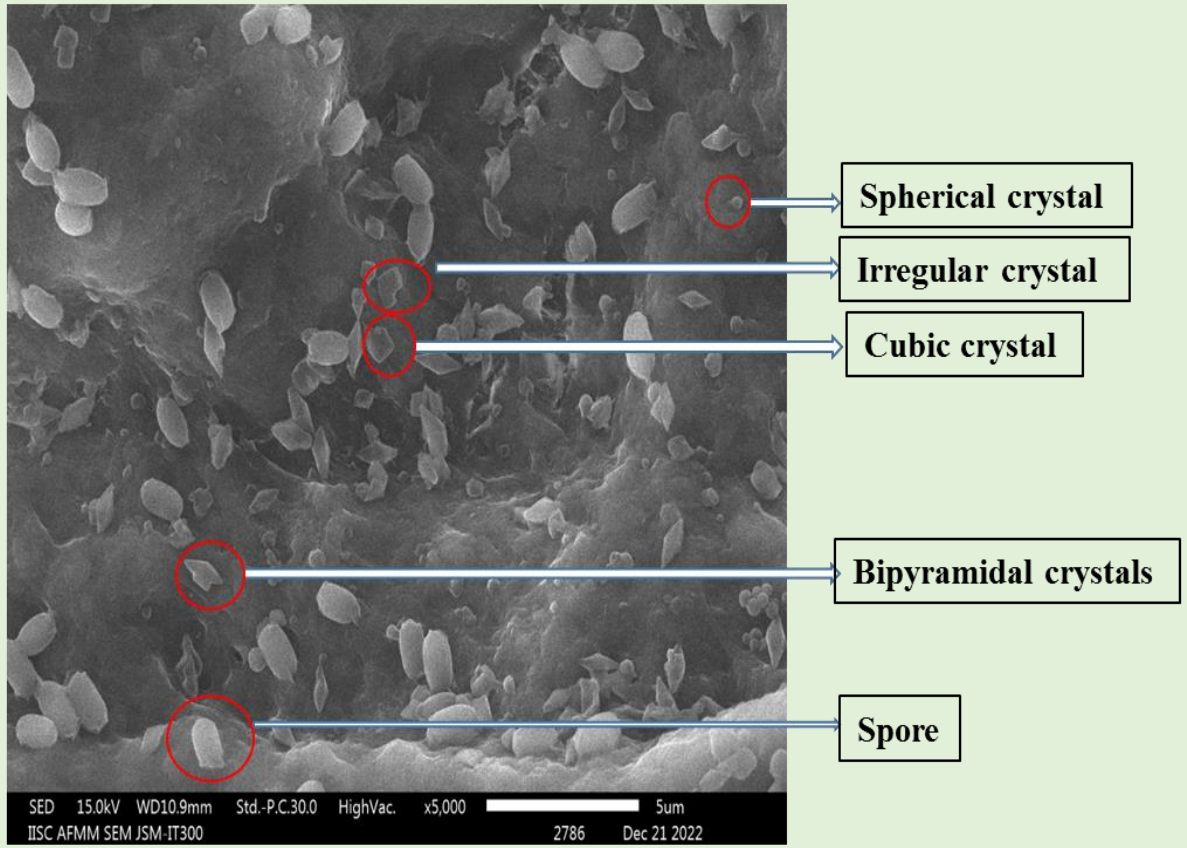
Gel picture showing the insecticidal genes profiling of NBAIR BT25. Lane M: Ladder (100bp). Lane 1: *cry*1Ab9, Lane 2: *cry*1Ab14, Lane 3: *cry* 1Ea10, Lane 4: *cry*1Gc1, Lane 5: *cry*1Aala44, Lane 6: *cry*2Aa9, Lane 7: *cry*2Ab4, Lane 8: *cry*8Aa1, lane9: *cry*70Aa1, Lane10: *cyt*1Da2, Lane 11: *vip*3Aa59, Lane 12: *vpb*4Aa1, Lane 13: *zwa*5A, Lane 14: *zwa*5B, Lane 15: *zwa*6

Field efficacy of *B. thuringiensis* strain NBAIR BT25 at multi-locations

Multi-environment phenotyping of *B. thuringiensis* strain against FAW of maize was done in the year 2019-2020 where mean of average reduction of FAW larvae by **NBAIR BT25 for different locations in 2019 was 57.47 % and in 2020 was 58.58 %.**

Shatpada Armour (NBAIR Bt25)

Scanning Electron Microscopy



Multi Locus Sequence Typing

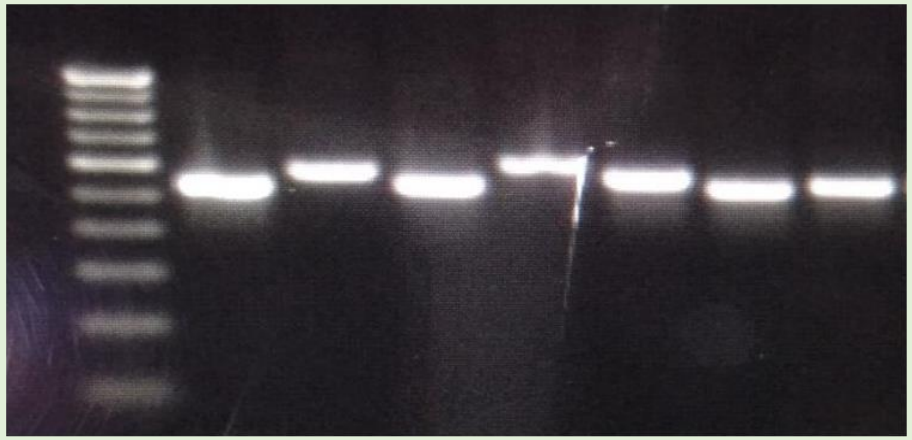


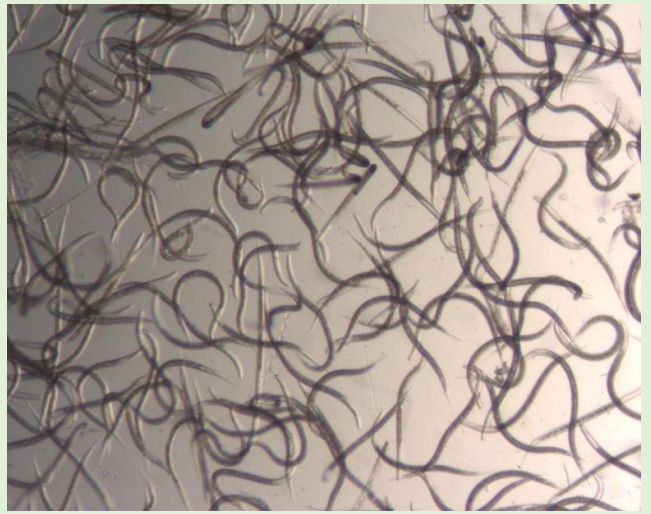
Fig. 2: Gel picture showing the amplification of housekeeping genes of *Bacillus thuringiensis* strain NBAIR BT25 in MLSA study. Lane M: Ladder (100bp). Lane 1: *glp*, Lane 2: *gmk*, Lane 3: *ilv*D, Lane 4: *ilv*D2, Lane 5: *pur*, Lane 6: *pta*, Lane 7: *pyc*A, Lane 8: *tpi*

Entomopathogenic nematodes

- ***Heterorhabditis indica*** **1 NBAIIH38 (ICAR NBAIR strain),** ***Steinernema carpocapsae*** **NBAIRS59 (ICAR NBAIR strain), (2.5 × 10^8 IJs ha^{-1}) were tested.**

- **The second round of spraying of *H. indica* 1 NBAIIH38 (ICAR NBAIR Strain) at a concentration of 2.5 × 10^8 IJs ha–1; Four releases of *T. chilonis* at weekly intervals (100 000 *T. chilonis* parasitized eggs ha–1) significantly reduced the larvae of *S. frugiperda* (87.56%), which is close to the value for emamectin benzoate treatment (98%).**

- **Technology approved for commercialization**



Patil et al., 2022

Trichogrammatid Cultures at ICAR-NBAIR

Live cultures (*Trichogrammatoidea* spp. (4 nos.) & *Trichogramma* spp. (20 nos.)

***Trichogrammatoidea* spp.**	
Trichogrammatoidea armigera Manjunath	***Tr. bactrae*** Nagaraja
Tr.* sp. nr. *robusta	***Tr. robusta*** Nagaraja

***Trichogramma* spp.**	
Trichogramma achaeae Nagaraja & Nagarkatti	***T. chilonis*** Ishii
T. chilotraeae Nagaraja & Nagarkatti	***T. danausicida*** Nagaraja
T. hebbalensis Nagaraja	***T. japonicum*** Ashmead
T. pieridis Nagaraja & Mohanraj	***T. semblidis*** (Aurivillius) (France)
T. brassicae Bezdenko (Italy)	***T. brassicae*** (Canada)
T. cacoeciae Marchal (France)	***T. cordubense*** Vargas & Cabello (France)
T. dendrolimi Matsumura (Germany)	***T. embryophagum*** (Hartig) (Germany)
***T. evanescens* (Ar)** (France)	***T. evanescens* (Th)** Westwood (France)
T. pretiosum Riley (Colombia)	***T. mwanzai*** Schulten & Feijen (Kenya)
T. pretiosum (France)	***T. pretiosum*** (Germany)

Multiple insecticide tolerant strain of egg parasitoid *Trichogramma chilonis* for the management of FAW (NBAIR-MITS-FAW)

- **The strain of the parasitoid, *Trichogramma chilonis* (MITS-FAW) is tolerant to multiple insecticides (organo-phosphate, pyrethroids, oxadiazine & spinosyn) with a high resistance factor and can be used against FAW and other pests in a pesticide stressed crop conditions including IPM.**
- **Technology approved for transfer.**

Fall armyworm infesting maize

***T. chilonis* (MITS-FAW) parasitizing Fall armyworm eggs**

Awareness programmes

GOI Initiatives…….

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सत्यमेव जयते

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कृषि, सहकारिता एवं किसान कल्याण विभाग
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Government of India
Ministry of Agriculture & Farmers Welfare
Department of Agriculture, Cooperation & Farmers Welfare
Krishi Bhawan, New Delhi-110001

D.O. No.12080/37/2018-PP.I

Dated: 05.08.2019

o/c

Subject: Management of Fall Armyworm in maize.

We are aware that Fall Armyworm caterpillar a native to North America landed in Africa in 2016 and in India and many other Asian Countries in 2018. Since then, it has wreaked havoc in ravaging crops, especially maize. In fact, FAO has already declared FAW as a food security threat. In a short span, in India its presence has been observed in ten states and Fall Armyworm infestation has

Management strategies of
Fall Armyworm (FAW), *Spodoptera frugiperda* on maize

Monitoring: Installation of pheromone traps @ 5/acre in the current and potential area of spread in crop season and off-season.

Scouting:

Start scouting as soon as maize seedlings emerge

1. At Seedling to early whorl stage (3-4 Weeks after emergence)- Action can be taken if 5% plants are damaged.
2. At Mid whorl to late whorl stage (5-7 weeks after emergence) –Action can be taken if 10 % whorls are freshly damaged in mid whorl stage and 20% whorl damage in late whorl stage.
3. At tasseling and post tasseling (Silking stage)- Do not spray chemical insecticides. Suitable bio-pesticide may be used in the event of ear/cob damage.

Cultural Measures

1. Deep ploughing is recommended before sowing. This will expose FAW pupae to predators.
2. Timely and uniform sowing over a large area is advised. Avoid staggered sowings.
3. Intercropping of maize with suitable pulse crops of particular region. (eg. Maize + pigeon pea/black gram /green gram).
4. Erection of bird perches @ 10/acre during early stage of the crop (up to 30 days).
5. Sowing of 3-4 rows of trap crops (eg. Napier) around maize field and spray with 5% NSKE or azadirachtin 1500 ppm as soon as the trap crop shows symptom of FAW damage.
6. Clean cultivation and balanced use of fertilizers.
7. Cultivation of maize hybrids with tight husk cover will reduce ear damage by FAW.

Mechanical control:

1. Hand picking and destruction of egg masses and neonate larvae in mass by crushing or immersing in kerosine water.
2. Application of dry sand in to the whorl of affected maize plants soon after observation of FAW incidence in the field.
3. Application of Sand + lime in 9:1 ration in whorls in first thirty days of sowing.
4. Mass trapping of male moths using FAW specific pheromone traps @ 15/acre.

Bio Control:

1. *In situ* protection of natural enemies by habitat management: Increase the plant diversity by intercropping with pulses, oil seeds and ornamental flowering plants which help in build-up of natural enemies.
2. Augmentative release of egg parasitoid *Trichogramma pretiosum* or *Telenomus remus* @ 50,000 per acre at weekly intervals or based on trap catch of 3 moths/trap.
3. Bio-pesticides: If infestation level is at 5% damage in seedling to early whorl stage and 10% ear damage, then use following entomopathogenic fungi and bacteria

Metarhizium anisopliae *Metarhizium rileyi (Nomuraea rileyi)* *Beauveria bassiana* *Verticilium lecani*	1 × 10^8cfu/g) @ 5g/litre whorl application. Repeat after 10 days if required.

- *Bacillus thuringiensis* v. *kurstaki* formulations @ 2g/l (or) 400g/acre.
- NPV
- EPN

Chemical Control:

1. **Seed treatment:** Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS @ 6 ml/kg of seed will be effective for 15-20 days.
2. **First Window (seedling to early whorl stage):** To control FAW larvae at 5% damage to reduce hatchability of freshly laid eggs, spray 5% NSKE / Azadirachtin 1500ppm @ 5ml/l of water.
3. **Second window (mid whorl to late whorl stage):** To manage 2nd and 3rd instars larvae having more than 10% foliar damage the following chemicals may be used upto early tasselling stage: Spinetoram 11.7% SC or Chlorantraniliprole 18.5% SC or Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC.
4. **Poison baiting:** Poison baiting is recommended for late instar larvae of second window. Keep the mixture of 10 kg rice bran + 2 kg jaggery with 2-3 litres of water for 24 hours to ferment. Add 100g Thiodicarb or ------do------ just half an hour before application in the field. The bait should be applied into the whorl of the plants.
5. **Third Window (8 weeks after emergence to tasseling and post tasseling):** Insecticide management is not cost effective at this stage. Bio-pesticides as recommended above to be applied. Hand picking of the larvae is advisable.

All the sprays should be directed towards whorl and either in the early hours of the day or in the evening time.

Capacity building and mass awareness

1. Application and timely plant protection measures to avoid spread of the insect from the abandoned crop.
2. Creation of awareness among important stake holders through trainings /group discussions.
3. Community based and area-wide approach for implementing management strategies.

- **Regular surveys, surveillance and monitoring were conducted by the Central Integrated Pest Management Centres (CIPMCs) in collaboration with the State Department of Agriculture, SAUs and ICAR etc.**

- **Further, awareness programmes for the farmers were organized to advise them to adopt cultural and farm practices.**

- **Mass production of effective bio-control agents was promoted.**

- **The POP was circulated to all the States for its implementation. Timely advisories were issued to State Departments of Agriculture to adopt preventive measures.**

Efforts made by some State Agriculture Departments on management of FAW During 2022-23

State/UT	Details of Trainings held on FAW during 2022-23	
	No of Trainings Held	No of Farmers Participated
Andaman & Nicobar	12	350
Jharkhand	190	6850
Maharashtra	7245	118664
Mizoram	22	660
Punjab	231	7170
Uttar Pradesh	919	144675
Uttarakhand	24	4104

Training activities conducted by CIPMCs of DPPQ&S, Govt of India

Year	Farmers Field School		2 days HRD		5 days HRD		30 days SLTP	
	Number	Farmers Trained	Number	# trained *	Number	# trained *	Number	Master Trainer trained
2019-20	690	21040	101	4120	11	440	3	120
2020-21	351	10530	28	1120	5	200	0	0
2021-22	282	9870	80	4368	0	0	0	0
2022-23 (Kharif)	126	4410	56	3063	0	0	0	0
2022-23 (Rabi)	104	3640	59	3174	6	229	0	0

*AEOs, NGOs, Lead Farmers, Private Entrepreneurs etc.

Distribution of NBAIR-BT25 formulations to farmers against FAW

NBAIR-BT25 was distributed to farmers growing maize in Hindupur and Srikakulam for FAW management


ఈనాడు
శ్రీకాకుళం
మంగళవారం 7 జనవరి 2020 12 పేజీలు
రసాయనాలతో మిత్రపురుగులు నాశనం

Farmer Field days……

- At Kadalaveni village, Gouribidanur Taluq, Chikkaballapur district, Karnataka.
- At Chilamattur, Hindupur, Karnataka.
- A large number of farmers field days were organized by state & central agencies.

కత్తెర పురుగు నివారణపై అవగాహన సదస్సు

సమావేశంలో మాట్లాడుతున్న శాస్త్రవేత్త భక్తవత్సల

చిలమత్తూరు: మొక్కజొన్నలో ఆశించిన కత్తెర పురుగు నివారణపై రైతులకు స్థానిక వ్యవసాయ శాఖ కార్యాలయంలో సోమవారం అవగాహన కల్పించారు. హిందూపురం డివిజన్ స్థాయిలో నిర్వహించిన ఈ కార్యక్రమంలో వ్యవసాయశాఖ, బెంగళూరుకు చెందిన ఐసీఏఆర్-ఎన్‌బీఏఐఆర్ శాస్త్రవేత్తలు పాల్గొని, పలు అంశాలపై రైతులకు సూచనలు అందజేశారు. జీవ నియంత్రణ పద్ధతులు, రసాయనిక పురుగుల మందుల వినియోగంపై చైతన్య పరిచారు. జీవ నియంత్రణ పద్ధతిలో ఫిరమోన్‌ట్రాప్స్, వేపనూనె, మెటారైజియం, ఎన్‌పీవీ, బీటీ, ఈపీఎన్ పద్ధతుల ద్వారా తక్కువ పెట్టుబడితో ఎక్కువ శాతం కత్తెర పురుగును నివారించవచ్చునని సూచించారు. కార్యక్రమంలో ఏడీఏ రవి, వ్యవసాయ శాస్త్రవేత్తలు భక్తవత్సలం, రామానుజం, శైలేష్, మాళవిక, లలితా, రిచా, రంగేశ్వర, వ్యవసాయాధికారులు, సిబ్బంది పాల్గొన్నారు.

సాక్షి Tue, 17 December 2019
https://epaper.sakshi.com/c/46951400



Two days training on “Mass production of biocontrol agents for the management of fall armyworm (FAW)” (27-28 December 2019) under CABI funded project on FAW


International training programme on FAW

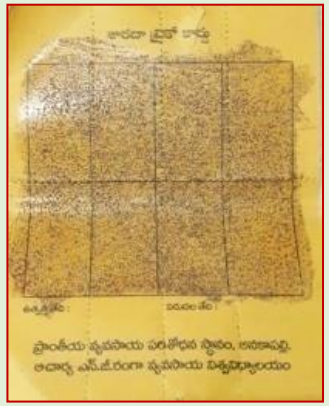
- Conducted **five days (22-26 May, 2023)** International training programme funded by **USAID** through the Feed the Future Nepal Integrated Pest Management **(FTFNIPM)** activity and the Feed the Future Bangladesh Integrated Pest Management **(IPMA)** activity being operated by, **Dr R Muniappan** Principal Investigator, FTFNIPM and IPMA, Virginia Tech, Blacksburg, USA.

- Seven officials from Nepal and Bangladesh were exposed to hands-on training on the "Production protocol of biocontrol agents for the management of Fall armyworm."

All India Coordinated research project on biological control of crop pests

Validation of BIPM against FAW-Pan India

- Installation of pheromone trap @ 10 /acre
- Release of *Trichogramma chilonis* (1,00,000 eggs/ ha) (2 releases, first release after one week of sowing & second one after one week of first release)
- 2 sprays of NBAIR Bt-25 @ 10 ml/L at 10 days interval
- 2 sprays of NBAIR *Metarhizium anisopliae* (Ma-35) @ 5g/L at 10 days interval.
- C:B ratio: 1.77-4.78 at different locations



Research Team at ICAR-NBAIR

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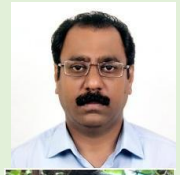

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Thank you

for

your kind attention