Hexapoda (*Insecta indica*)

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Fall armyworm management - Experiences in Karnataka

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ABSTRACT: Fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) has emerged as a major constraint to the production of maize in India and is currently the major constraint in reducing the grain and fodder yield. Karnataka is the major maize growing state in India and the FAW was first noticed in May 2018 in Shivamogga district and later spread in different districts of Karnataka on maize causing between 20 per cent and 100 per cent leaf damage in different districts of Karnataka. Fall armyworm completes its biology in a period of 32 46 days and it completes 2- 3 generations on a single crop. Among the natural enemies recorded, *Metarrhizium rileyi* caused 80 to 90 per cent natural mortality of FAW during August and September in 2019 and 2020 in kharif sown maize crop. The native natural enemy's activity was more in kharif 2019 and 2020 as compared to kharif 2018. Use of non-chemical methods such as silica, plant growth regulators and biorationals is being explored. The different management tools for the fall armyworm management under R&D in Karnataka state are discussed.

Keywords: Fall armyworm, host plants, biology, *Metarrhizium rileyi*, management

Introduction

Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. In India, maize is the third most important cereal crop and cultivated

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with an area of 9.5million ha with a production of 27.23 million tons (Anonymous, 2019). Maize is an important staple food for millions of people having a wide diversity of uses such as food for humans and feed for animals. Karnataka is the leading maize producer in India contributing 13.70 per cent of total countries production with the production of 3.73 MT and productivity of 2.90 MT per ha (Anonymous, 2019).

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) has emerged as a major constraint to the production of maize in India and causing reduction in the grain and fodder yield. It is a transboundary migratory pest native to the Americas (Luginbill 1928), was first detected in Africa in early 2016 (Goergen *et al.*, 2016; Prasanna *et al.*, 2018), arrived later in Asia in May 2018 (Sharanabasappa *et al.*, 2018a) and now spread to Australia (FAO, 2020). The fall armyworm is a highly polyphagous pest which feeds on more than 353 cultivated and wild host plants including maize and sorghum as primary hosts (Montezano *et al.*, 2018). FAW has the potential to destroy up to 80 million tonnes of maize worth USD 18 billion per year, affecting about 600 million people in Africa, Asia-Pacific and the Near East (FAO, 2020).

Karnataka is the major maize growing state in India and FAW was first noticed in May 2018 in Shivamogga and subsequently noticed in different districts of Karnataka on maize causing damage 20 per cent to 100 per cent leaf damage in different districts of Karnataka (Ganiger *et al.*, 2018; Mallapur *et al.*, 2018; Shylesha *et al.*, 2018) and later spread to southern states (Mahadevaswamy *et al.*, 2018). When FAW was first observed in May 2018 on maize, it was in early instars and was mistakenly assumed to be *Mythimna seperata* but when brought and reared under laboratory conditions, based on the morphological and molecular approaches, it was confirmed as arrival of FAW in India. After confirming the species identification, many studies were targeted across various organizations in India. In Karnataka, we studied its biology, incidence, its natural enemies and management options in two maize growing districts (Davanagere and Shivamogga) during Kharif 2018, 2019 and 2020.

Host range

In Karnataka, it mainly fed on maize and on other hosts also recorded *viz*, sorghum, pearl millet, finger millet, fodder sorghum. The larvae were also noticed on groundnut and marigold hosts the damage was meager (the population migrated from nearby maize field, personal observation). The maximum extent of damage was noticed on maize as compared to other hosts.

Biology of fall armyworm

The female adult lays about 1000 eggs in clusters on below or above the leaf surface of the maize plant, base of the plant, and also in whorls. The eggs are ventrally flattened and the incubation period was 2-3 days. There were six larval instars with 14 -19 days of larval duration and color changes from instar to instar. First instars were green with a black head but it turns greenish brown during second instar. From third instar onwards, larvae turn brown with three dorsal and lateral white lines. Pupation took place in the soil and pupal period ranges from 9 to 12 days. A female moth laid an average of about 1000 eggs. The total life cycle of male and female fall armyworm ranged 32-43 and 34-46 days, respectively (Sharanabasappa *et al.*, 2018b).

Incidence of fall armyworm

Roving surveys were carried out to record the per cent plant infestation in maize due to fall armyworm during 2018, 2019 and 2020 in Shivamogga Davanagere, Chitradurga, Chikkamagalore and Haveri districts .The observation on plant infestation was recorded by counting infested plants to the total number of plants observed at two different stages of the crop (10-30 and 31 to 60 days old crops) and converted into per cent plant infestation. The data was subjected univariate ANOVA performed using SPSS version software. The results revealed that there were no significant differences between the districts with respect to plant infestation in all the three years ($F_{4,742}$, 0.102 $P = 0.982$) but there was a significant difference between the stages of the crops ($F_{1,742}$, 910.17 < P 0.10). For instance, our roving surveys data showed that in 2020 the level of infestation was less as compared to 2018 and 2019 ($F_{2,}$ 2742, 38 <P 0.10) (Table 1). The fall armyworm incidence was noticed on other crops like sorghum, bajra, ragi and sugarcane (Deshmukh et al., 2021) The FAW infestation on other crops like sorghum ranged from 845 % and 10- 40 % reported on finger millet.

Table 1: Three year summary of survey on fall armyworm incidence on maize in five districts of Karnataka, 2018-20.

District	Crop age	Plant infestation (%)					
		2018		2019		2020	
		Range	Mean ± SEm	Range	Mean ± SEm	Range	Mean ± SEm
Shivamogga	10-30 days	38-100	82.68 ± 3.55	10-95	81.36 ±4.21	15-80	63.28 ±3.95
	31- 60 days	20-96	46.56 ±3.98	10-69	45.08 ±3.68	9-55	36.56 ±3.68
Davanagere	10-30 days	43-100	84.40 ±3.20	26-90	81.76 ±3.76	22-86	65.04 ±4.12
	31- 60 days	18-80	45.72 ±3.65	10-48	44.24 ±3.54	15-45	33.60 ±1.83
Chitradurga	10-30 days	40-93	81.44 ± 3.12	20-85	81.36 ±3.90	22-90	65.20 ±4.16
	31- 60 days	25-66	46.60 ±2.70	10-65	44.92 ±3.64	18-45	36.76 ±1.31
Haveri	10-30 days	36-95	84.12 ±3.15	21-89	80.52 ±2.72	15-80	71.96 ±3.82
	31- 60 days	18-48	39.20 ±1.79	16-69	37.80 ±2.79	9-55	40.20 ±2.57
Chikkamagalore	10-30 days	26-90	81.72 ±3.09	20-85	77.24 ±2.90	21-82	69.56 ±3.07
	31- 60 days	18-60	43.24 ±2.40	15-55	42.08 ±2.49	16-55	35.88 ±2.52

Natural enemies

During our survey few natural enemies were recorded in different seasons of the crop. During 2018-19, the parasitoids namely *Coccygidium melleum* (Roman) (Hymenoptera: Braconidae), *Odontepyris* sp (Hymenoptera: Bethylidae) and *Eriborus* sp. (Hymenoptera: Ichneumonidae) were identified (Sharanabasappa *et al.*, 2019). During *kharif* 2019, we recorded the activity of other egg parasitoids, *Telenomus* sp and *Trichogramma* sp, larval parasitoids viz., *Campoletis chlorideae*, tachinids were found. In the August September 2019 and 2020, more activity of the entomopathogen, *Metarrhizium rileyi* was recorded during our survey (Palam Pradeep, 2021; Deshmukh et al., 2021).

Extension activities

A workshop on fall armyworm was also organized at the main University of Agricultural and Horticultural Sciences, Shivamogga campus to create awareness and for management of fall armyworm

in the month of May 2019.Another program in association with South Asia Biotechnology Centre (SABC), New Delhi organized one day program on management of fall armyworm in maize June 2019. University of Agricultural Sciences Bangalore, Commonwealth Agricultural Bureaux International (CABI), India and National Bureau of Agriculturally Important Resources Bangalore, University of Agricultural Sciences, Dharwad and UAHS Shivamogga jointly brought a publication on common management practices for fall armyworm. In September 2020, UAHS Shivamogga in collaboration with South Asia Biotechnology Centre, New Delhi also organized a webinar on fall armyworm management. The participants were state department agriculture officers, Krishi Vigyanan Kendra Scientists, private company employees, farmers and students. We also did extension work and conducted off campus trainings to the farmers at village level in collaboration with state department of agriculture. We developed folders on fall armyworm and its management on maize a technical bulletin in English and in Kannada and developed video clip in local language identification and management of fall armyworm.

Bio-control based integrated pest management

Varshney *et al.,* (2020) evaluated the biocontrol-based integrated pest management (BIPM) and farmer's practice during rabi and kharif season (20182019). BIPM strategy comprised installation of FAW pheromone traps, four releases of *Trichogramma pretiosum* Riley, two sprays of neem oil, one spray of each *Bacillus thuringiensis* (NBAIR-BT25) and *Metarrizium anisopliae* (NBAIR Ma-35) resulted in 76 and 72% reduction in egg mass, besides 80 and 74 % larval population reduction at 60 days after treatment during rabi and kharif season, respectively. Cob yield per acre in biocontrol-based IPM field was higher than the farmer's practice (67 sprays of emamectin benzoate 5% SG) during both the seasons, and it resulted in 38.3 and 42.3 % gain in yield per acre during rabi and kharif, respectively.

***Adhoc* recommendation for the management of FAW:**

The following are the key measures that can be applied in an integrated management approach (combining several intervention measures) since every positive action has an additive effect:

1. Ploughing before onset of rains to expose pupae to predators and sunlight.
2. Crop rotation with redgram, groundnut and sunflower.
3. Intercropping with redgram (8:2).
4. Area wide sowing early in June and avoid late sowing in the month of August or September.
5. Seed treatment with cyantraniliprole 19.8 % + thaimethoxam 19.8 % FS @ 6 ml per kg of seed offers protection for 15-20 days of crop growth.
6. Installation of pheromone traps (5 traps per ac) at the time of sowing.
7. Handpicking and squashing egg masses and neonates.
8. Conservation of egg parasitoids like *Trichogramma* and *Telenomusremus* the management of FAW.
9. Spraying of neem based insecticide 10000 ppm @ 2 ml per lit of water on the leaves and to the whorl region.
10. Spraying of *Metarrhizium rileyi* @ 3 g per lit of water.
11. The field efficacy of different insecticides both as sprays and poison baits.
    The insecticides, Spinetoram 11.7 SC, chlorantraniliprole 18.5 SC studied by Muralimohan and Dileepkumar (2019).The results indicated that greener molecules with a waiting period of < 3-5 days

were very efective as baits, and cost of plant protection was substantially low when used as baits

12. (up to 42 % cost reduction) as compared to sprays.
Use of insecticides like chlorantraniliprole 18.5 SC @ 0.4 ml per liter of water or spinetoram 11.7 SC @ 0.5 ml per lit of water or emamectin benzoate 5 SG @ 0.5 g per lit of water (Deshmukh *et al.*, 2020). Similarly, Dileep Kumar and Murali Mohan (2020) reported that among the different insecticides evaluated spinetoram recorded the highest grain yield (33.48 q/ha), followed by novaluron (32.07 q/ha) and chlorantraniliprole (31.13 q/ha). The spray should be directed to the plan whorls and top leaves.

Future line of work

The current focus needs to remain on use of insecticides in order to manage *S. frugiperda* such that the needs of food safety and the greater agricultural requirement for a growing human population. The further studies on development of economic thresholds, estimation of yield loss, spacing, irrigation intercropping with pulses oil seeds, systemic monitoring of pest, environmentally sustainable fall armyworm management requires effective integration of various approaches, including biological control, safe pesticides and agro-ecological management.

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