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Present status and management of Fall Armyworm in India: mini-review

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ABSTRACT: Fall Armyworm (*Spodoptera frugiperda* (J. E. Smith)), a highly polyphagous and destructive pest of American origin, has recently invaded India. Its rapid establishment in diverse agro-ecologies of the country within a very short span of time presents a major challenge to both farming as well as local research needed to support their containment. This review covers its economic importance, temporal spread, biological characteristics, nature of damage, host preference and extent of yield loss, and population genetics in India. Further, use of various non-chemical management options like cultural practices, semio-chemicals, natural enemies (predators, parasitoids and entomopathogens) and botanicals, besides recommended dose regimes of synthetic pesticides applicable to its most preferred host *i.e.*, maize, are also discussed. Recognizing the lack of chance to eradicate *S. frugiperda* from our country, the scope to develop and implement ecologically more sustainable management strategies, which is appropriate to farming systems and socio-economic scenario of Indian farmers are discussed.

Key words: Invasive pest, *Spodoptera frugiperda*, maize, natural enemies, push-pull strategy, integrated pest management.

Introduction

The recent incursion of Fall Armyworm (FAW, *Spodoptera frugiperda* (J. E. Smith)) (Noctuidae: Lepidoptera), a native of tropical and subtropical Americas (FAO, 2018) and serious pest of corn and millets in USA, into Africa in late 2016 (Goergen *et al.*, 2016) and spread within two years across 40

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countries in Africa, more recently into India possibly through Yemen in 2018 (Chatterjee, 2019) is indeed remarkably unforeseen. Presently it has spread to most of the countries of South and South East Asia including China, South Korea and Japan (Lamsal *et al*., 2020). Very recently, its incursion has also been reported from Australia (CABI, 2020). This pest exhibits high degree of polyphagy as it can attack 353 plant species belonging to 76 botanical families, though preferring maize the most (Suby *et al*., 2020). It's phenomenal spread across the two continents in just 3-4 years is reckoned as great potential threat to food and nutritional security globally (FAO and CABI, 2019).

Temporal movement and host preference in India

In India, FAW was first detected from maize fields of Shivamogga (Karnataka) in May, 2018 (Sharanabasappa *et al*., 2018). It is quite probable that FAW arrived India through intercontinental trade (Lamsal *et al*., 2020), whereas possibilities of adult migration (Westbrook *et al*., 2015) or pest dispersal through wind currents in Indian Ocean (Perera *et al*., 2019), cannot be ruled out. In 2018 July, researchers from National Bureau of Agricultural Insect Resources (NBAIR) confirmed FAW incursion in South India, finding nearly 70 percent of maize fields in Chikkaballapur, about 60 km from Bengaluru being heavily infested. Since then, it has spread very rapidly to all maize growing ecologies of India within a span of just 16 months, except Himachal Pradesh, and Jammu and Kashmir, thereby casting a shadow on maize production in the country (Suby *et al*., 2020). Temporal spread of FAW from peninsular India to the North and North East has been particularly very fast during 2018 and 2019 monsoon (Naganna *et al*., 2020), resulting in a cumulative damage to 10,772 hectares of maize crop (Lamsal *et al*., 2020). High humidity and moderately high temperatures in these states are probably suitable for the multiplication and spread of FAW. While FAW has been primarily attacking maize crop, there are reports from peninsular and north eastern states that it has damaged paddy, sorghum, sugarcane, cotton, soybean, groundnut, chickpea, vegetables and ginger.

Biological characteristics and seasonal abundance

FAW moths are known to lay typically grayish white eggs in batches of 100-200 with a hairy covering from moth's abdomen. Incubation period ranges from 2-3 days during warm conditions and a female moth can lay about 1500 eggs in her entire life span (Tippannavar *et al*., 2019). The larval period is completed through six distinct instars, within 14-22 days. Distinguishing features of FAW caterpillars are the presence of a characteristic upside-down pale "Y" shaped marking on the front (Firake *et al*., 2019) of head capsule, and four raised dark spots in a square pattern on top of eighth abdominal segment. The presence of these spots distinguishes it from other armyworm species (CABI, 2020). The pupation usually occurs in soil, just like other noctuids, but may also occur on host plant, if the pest population density is high. Pupae are smooth textured and about 15 mm long. The moths emerge out from pupal cases in 9-12 days, come to the soil surface and then cling to the host plant or debris, nearby. These moths are considered very strong fliers and have the ability to migrate with capacity of 100 km overnight and 300 miles per generation (Westbrook *et al*., 2015). Sexual dimorphism is also clearly evident in the forewings of adults. The forewings of male FAW moths have distinct white patches at the lower outer edges, which are absent in comparatively dull-coloured wings of females (Lamsal *et al*., 2020). However, the total life span of females (34-46 days) is slightly longer than males

(32-40 days). Lack of diapause is a key driver to FAW's having at least 12 overlapping generations in a year, making it a major pest both during the rain-fed and winter cropping seasons (FAO and CABI, 2019). Limited studies on its' seasonal abundance from India revealed that the larval population build-up is positively correlated with rising temperatures in both *kharif* and *rabi* maize (Kumar *et al.*, 2020). High rainfall accompanied with cloudy conditions for more than a week can further shoot up the activity of this pest species (Suby *et al.*, 2020).

Damage symptoms and severity of infestation

Being polyphagous, FAW causes damage to a diverse range of crops, including cereals, millets, legumes, oilseeds, sugarcane, cotton, vegetables and ornamentals (FAO, 2018). This pest can affect the crop at different stages of growth, from early vegetative to physiological maturity. In case of maize, larvae usually feed on leaves, creating a characteristic "window pane" damage and ragged leaf edges. Late instars even feed inside developing silks, tassels or cobs, thereby limiting fertilization of the ear, and grain filling process. Badly infested fields may look as if they have been hit by a severe hailstorm (FAO and CABI, 2019). It has been estimated that FAW has the potential to cause maize yield losses of 8.3 to 20.6 million tons annually, valued at between US$2.5 to US$6.2 billion, in the absence of proper control methods (CABI, 2020). In India, 5 to 40 percent loss in maize production has been roughly estimated in the FAW affected areas (Suby *et al.*, 2020), except Karnataka where severe yield losses of over 95 percent was recorded (Mallapur *et al.*, 2018). In addition to maize, crop losses of up to 30 percent in sugarcane and 10 percent in sorghum (Chormule *et al.*, 2019), have also been reported.

Population genetics

There are two known strains of FAW, namely 'C-strain' (corn strain) which feeds predominantly on maize, sorghum and cotton, and 'R-strain' (rice strain) which prefers rice, millets and turf grass (Sharanabasappa *et al.*, 2018). These two strains are morphologically indistinguishable and capable of cross hybridization. Preliminary molecular diversity studies of Indian FAW populations suggest that it comprises of both 'C' and 'R' strains, based on *Tpi* and *COI* gene markers, respectively (Nagoshi *et al.*, 2019); however possibilities of existence of inter-strain hybrids cannot be discarded. The Indian collections also showed nearly identical haplotype profiles with populations from South Africa, Kenya and Tanzania, suggesting a close relationship and recent interactions between these populations. Recently, a notable expansion of gene families associated with pesticide detoxification and tolerance like cytochrome P450 and glutathione S-transferase has also been reported from Asian populations, with C-strains being more tolerant (Gui *et al.*, 2019).

Determination of action threshold

In case of maize, for determination of FAW infestation thresholds, scouting is to be done by a leisure walking in "W" pattern in the field after leaving 3-4 outer rows (FAO and CABI, 2019). Randomly 20-50 plants are selected around the 5 stopping points of the corners of "W" and the number of newly damaged plants is counted based on 3-4 leaves emerging from the whorls, with infestation level of 5-10 percent requiring immediate action, an such details are available for other crop stages also (Firake *et al.*, 2019).

Management strategies

Since this species is known to develop resistance against synthetic pesticides fairly soon when exclusively applied repeatedly (FAO, 2018), there is need to shift to eco-safe alternatives. Such options which could be chosen to manage FAW, particularly in maize are discussed below:

Cultural practices: There appears to be good scope for intercropping or companion cropping of maize with other crops (non grass species), whereby the diversity of plants in the crop ecosystem could confuse FAW moths in selecting preferred host. Some common intercrops may include legumes such as cowpea, pigeonpea, blackgram, greengram, lab-lab bean, etc (FAO, 2018; Tippannavar *et al.*, 2019). Adoption of push-pull strategy by intercropping of maize with a "push" plant, such as *Desmodium* or *Tephrosia*, which repels FAW from the field, and planting a "pull" crop along the field boundary (like Napier grass or *Brachiaria*) that attracts FAW away from the maize, can reduce the number of larvae per plant and plant damage per plot by 83 and 87 percent, respectively (Midega *et al.*, 2018). Avoiding staggered planting could also prevent continuous feeding and local buildup of FAW (Lamsal *et al.*, 2020).

Host plant resistance: A parallel initiative to screen maize germplasms for FAW resistance at ICAR-Indian Institute of Maize Research (ICAR-IIMR), Hyderabad, with infestor rows by early planting of susceptible lines has identified seven promising maize lines, viz. DMR E63/CML 287-5-4-1B, DMR E63/CML 287-4-14-2B, DMR E63/CML 287-4-14-3B, DMR E63/CML 287-4-89-4B, DMR E63/CML 287-3-3-, DMR E63/CML 287-2-3-2-, and P31C4S5B-85-##-1-4-5-B*5-1-B-1 as resistant to FAW (Anonymous, 2019). In the interim, cultivars with tight husk cover, especially for sweet corn could be cultivated in FAW prone areas. Few FAW resistant lines of sorghum and pearl millet have also been identified.

Semiochemicals: The major component of FAW pheromone has been identified as (Z)-9 tetradecenyl acetate (Sekul and Sparks, 1967). In India, funnel traps with FAW lure are presently being used for monitoring @ 4/acre in maize field, while pheromone traps @ 15/acre are adequate for mass trapping, with lures being changed once in 20 to 30 days (Firake *et al.*, 2019). Presently, research efforts are also being made to select suitable pheromone blends for FAW, besides for mating disruption (Suby *et al.*, 2020).

Natural enemies: The scope for local natural enemies with potential to reduce FAW population substantially is the main focus. The common FAW predators found in maize ecosystem include mirid bugs, rove beetles, earwigs, predatory wasps, ladybird beetles and spiders (FAO and CABI, 2019), among which *Orius insidiosus* appears to be primary preying upon both eggs and larvae (Tippannavar *et al.*, 2019). Among more than 100 species of parasitoids so far recorded, the parasitoids promising from India are *Telonomus remus*, *Trichogramma pretiosum*, *Cotesia marginiventris*, *Coccygidium melleum*, *Chelonus insularis*, *Glyptapanteles creatanoti*, *Exorista sorbilans* and *Tachina sobria* (Shylesha *et al.*, 2018). Recently, ICAR-IIMR has recommended release of egg parasitoids, *T. pretiosum* @ 16000/ acre or *T remus* @ 4000/acre, twice at weekly intervals, starting within a week of maize germination till six leaf stage (Lamsal *et al.*, 2020). Entomopathogens such as bacteria (*Bacillus thuringiensis* v. *aizawai* HD68), virus (*Colombian multicapsid nucleopolyhedrovirus - SfMNPV*), fungi (*Beauveria bassiana* strains Bb19, Bb21, Bb23, Bb 27, Bb39 and Bb40; *Metarhizium anisopliae* strains Ma22, Ma 41 and Mr8; *Nomuraea rileyi*) and nematode (*Heterorhabditis indica*) have also shown potential for bio-control of FAW (Cruz-Avalos *et al.*, 2019; Suby *et al.*, 2020).

***Botanicals*:** The extracts from over 69 plant species have shown insecticidal potential against FAW. Very high larval mortality (above 95 percent) has been reported in extracts of *Azadirachta indica*, *Phytolacca dodecandra* and *Schinnus molle* (Sisay *et al.*, 2019), besides extracts of *Nicotiana tabacum* and *Lippia javanica* showing moderate mortality (up to 66 percent) in maize (Phambala *et al.*, 2020). Suchefficacy is also known with combined extract of garlic and neem against FAW (Lamsal *et al.*, 2020). However, there is need for multi-location field studies and compatibility of botanical pesticides with other pest management options.

***Chemical insecticides*:** As emergency response, the Central Insecticide Board and Registration Committee (CIBRC) has recommended some chemical insecticides, namely chlorantraniliprole 18.5 SC @ 0.4 ml/l, spinetoram 11.7 % SC @ 0.5 ml/l, thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC @ 0.25 ml/l for minimizing FAW damage in maize. Recently, use of cyantraniliprole 19.8% + thiamethoxam 19.8% FS @ 6 ml/kg has also been recommended as seed treatment against FAW (Suby *et al.*, 2020).

Poison baiting: It is found to be effective for late instar larvae (Firake *et al.*, 2019), for which 10 kg rice bran and 2 kg of jaggery is first mixed with 3 litres of water and kept for 24 hours to ferment. 1 kg of sand and insecticide is also mixed with the fermented content just before use, and applied in form of small pellets into infested whorls.

Conclusion

In a world of climate change and increased global trade, the risks of invasive pest attacks are increasing which calls for more strict quarantine efforts to prevent such transboundary movement of pests. In case of FAW invasion in India, if timely management interventions are initiated as described earlier, this problem can be nipped off easily. As a long term solution, we need to develop an effective integrated management strategy on area-wide basis, incorporating host plant resistance (through breeding), biological and cultural control, and use of bio-pesticides and environmentally safer chemicals, compatible with our farming system and farmer's socio-economic scenario.

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