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Report of the invasive fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) and its natural enemies on maize and other crops from Andhra Pradesh, India

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Abstract

Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) was first noticed on maize crop at Regional Agricultural Research Station, Anakapalle, Visakhapatnam, Andhra Pradesh. Severe damage by *S. frugiperda* was recorded in several villages of Vizianagaram, Srikakulam and Visakhapatnam districts of Andhra Pradesh state during August and September, 2018. The incidence of fall armyworm ranging from 5 to 100 per cent was observed in all maize growing areas. Grown up larvae damaging maize whorls were collected from four locations and reared in the laboratory till adult stage. Species were identified based on morphological characters as *S. frugiperda*. Furthermore, molecular identification of the pest was done and Gen bank accession numbers were obtained for the pest from four locations of Andhra Pradesh (MH 822831, MH 822832, MH 822833 and MH 822834) and DNA barcodes were generated. Though the pest caused serious damage to maize during August - September, 2018, it was also found to cause 20-30% damage on sorghum, ragi, bajra during October and November, 2019. Furthermore, the pest was found to feed on young sugarcane crop (30 to 45 days old) and caused infestation around 5% during April, 2019 at Anakapalle, Visakhapatnam district, Samalkota, East Godavari district and Vuyyur, Krishna district of Andhra Pradesh. Egg parasitoids, *Trichogramma* sp. and *Telenomus* sp were found to parasitize the pest on maize and *T. chilonis* was found to parasitize eggs of the pest in sugarcane.

Keywords: Fall armyworm, *Spodoptera frugiperda*, *Trichogramma chilonis*

1. Introduction

Fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is native to America and is considered as the most important pest of corn in Brazil, the third largest corn producer in the world after USA and China. It is considered as a serious polyphagous pest of voracious nature with a wide host range of approximately more than 100 recorded plant species including maize, rice, sorghum, sugarcane, cabbage, potato, tomato, soybean, cotton and cause significant losses to agricultural crops (Goergen *et al.*, 2016)^[4]. This pest invaded Africa in 2016^[4]. Causing serious damage on maize crop and in Ghana during 2017 causing wide spread crop damage (CABI, 2016, Pogue, 2002, FAO, 2017)^[1, 6, 2]. In Brazil, *S. frugiperda* causes up to 34 per cent reduction in maize grain yield that amounts to an annual loss of US\$ 400 million.

Spodoptera frugiperda has been reported for the first time on the Indian subcontinent in maize fields University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka detected in 18th May, 2018 (Sharanabasappa and Kalleswara Swamy, 2018)^[8]. Subsequently occurrence of the pest and its natural enemies was reported (Shylesha *et al.*, 2018)^[9]. Maize is an emerging second most important cereal crop after rice in Andhra Pradesh and North coastal districts (Srikakulam, Vizianagaram and Visakhapatnam) account for 25.0 per cent production of maize in Andhra Pradesh. Keeping the above in view, surveys were conducted to monitor the pest and the occurrence of natural enemies in maize and other crops grown in north coastal zone of Andhra Pradesh state.

2. Material and Methods

As per the CABI alert and ICAR-NBAIR pest alert on invasive pest fall armyworm, the scientists at All India Coordinated Research Project on Biological control scheme noticed the incidence of *S. frugiperda* in maize at Regional Agricultural Research Station, Anakapalle on 10th August, 2018 and was confirmed through morphological characters (quote reference). Massive surveys were conducted on war footing basis on the occurrence of fall armyworm in maize crop in Vizianagaram, Srikakulam and Visakhapatnam districts of Andhra Pradesh covering 9 mandals of 20 villages grown with maize crop at 20-75 days age during August to November, 2018 along with the scientists of District Agricultural Advisory and Transfer of Technology Centres. Maize fields were devastated by fall armyworm caterpillars in Vizianagaram, Srikakulam and Visakhapatnam districts and the incidence of FAW was noticed at severe level (30-50%) in maize during first fortnight of August, 2018. In each field, twenty plants at five randomly selected spots were monitored for fall armyworm incidence and the larvae collected were reared in the laboratory to adult stage, adults were collected to mate and all the stages in the next generation (egg, larval, pupal and adult stages) were closely examined.

Molecular based identification of fall armyworm

DNA extraction and sequencing

DNA extraction was done using a small part of the larvae of *S. frugiperda* and single adult of *Trichogramma* sp. using Qiagen DNeasy® kit, following the manufacturer's protocols. The DNA extracts were subjected to polymerase chain reaction (PCR) amplification of a 658bp region near the 5' terminus of the COX1 gene following standard protocol (Hebert *et al.* 2003). Primers used were: forward primer (LCO 1490: 5'- GGTCACAAATCATAAAGATATTGG-3'), and reverse primer (HCO 2198: 5'- TAAACTTCAGGGT GACCAAAAATCA-3'). PCR reactions were carried out in 96-well plates, 50µL reaction volume containing: 5 µL GeNei™ Taq buffer, 1 µL GeNei™ 10mM dNTP mix, 2.5 µL (20 pmol/µL) forward primer, 2.5 µL (20 pmol/µL) reverse primer, 1 µL GeNei™ Taq DNA polymerase (1 U/µL), 2µL DNA (50 ng/µL), and 36µL sterile water. Thermocycling consisted of an initial denaturation of 94°C for 5 min, followed by 30 cycles of denaturation at 94°C for 1 min, annealing at 46°C for 1 min and extension at 72°C for 1 min. PCR was performed using a C1000™ Thermal Cycler. The amplified products were analyzed on a 1.5% agarose gel electrophoresis as described by Sambrook and Russell (2001) [7].

The amplified products were sent to M/s Chromous Biotech, Bangalore, India, for sequencing. The species was bidirectional sequenced and checked for homology, insertions and deletions, stop codons, and frame shifts by using NCBI BLAST and ORF finder. The sequence was uploaded to GenBank and the Barcode of Life Database (BOLD, <http://www.boldsystems.org>).

3. Results and Discussion

Incidence of fall armyworm in Andhra Pradesh

The fall armyworm incidence on maize was first noticed on 10th August, 2018 at Regional Agricultural Research Station farm, Anakapalle,

Visakhapatnam district on 45 days old crop of variety, DHM117 with an infestation level of 7.34%. Infestation of fall armyworm on maize grown in kharif and rabi seasons during 2018 ranged from 5 to 100 per cent with maximum incidence recorded in Vizianagaram district followed by Srikakulam district. Fall army incidence on sorghum, ragi and bajra was 20 to 30 per cent in rabi season, 2018 in Visakhapatnam and Vizianagaram districts. Occurrence of fall armyworm was observed on sugarcane from April to May, 2019 with 2.0 per cent infestation in 30-45 days age crop at RARS farm, Anakapalle. FAW damage was reported in sugarcane farms of sugar factories at Samalkota, East Godavari District and Vuyyur, Krishna district during April, 2019. The field collected FAW larvae from Anakapalle, Samalkota, Vuyyur were reared in the laboratory on sugarcane seedling bits till adult stage.

Nature of fall armyworm damage on maize and other crops

Egg laying of the pest was observed mostly on the lower side of leaf as mass of 80-90 eggs in early stages of crop growth, sometimes egg laying was also noticed on upper side of leaf. Eggs are small in size, circular, shiny white in colour and covered with scales. Newly hatched larvae was green in colour with black spots having black head. Early instar caterpillars initially feed on the opened leaves by scraping and skeletonizing epidermis as silvery transparent membrane, later enter in to the whorl and feed between the leaves resulting in characteristic row of holes like symptoms in the form of pin holes or small window panes (Fig. 1). Usually within a whorl, one or two larvae are present feeding voraciously damaging the whorl.

The damage often results in extension of defoliation and damage to the growing points (leaf whorls). The nature of the damage indicating moist saw dust like frass observed near the funnel and upper leaves was observed in most of the locations during August, 2018

(Fig.2). the fall armyworm caterpillars feed on various plant parts including leaves, stems, tassel and immature cobs. Heavy defoliation similar to grasshopper damage was noticed in certain areas due to overlapping generations with egg to adult stages in 50-70 days age crop (Fig.3).

Older larvae burrow into maize cobs causing extensive damage was noticed in sweetcorn (Fig. 4).

Similarly, fall armyworm damage on sorghum, ragi and bajra crops was noticed at vegetative stage *viz.*, 15-45 days age with scraping, boring whorls, cutting leaf edges symptoms

(Fig. 5, 6, 7). FAW was found to infest the whorl and feed on tender leaf tissue of young plants. When leaves unfold, irregular, elongate feeding areas or rows of holes were visible. In sugarcane, FAW egg mass was noticed on underside of leaves and incidence was noticed in young sugarcane crop of 30-45 days old (Fig.8). FAW infested sugarcane plants shows typical symptoms of scraping chlorophyll of leaves in young crop by early instar larvae, irregular holes or windows on leaves in the form of pin holes or small window panes and feeding on leaf margins by grown up larvae was observed. In few plants nibbling and shearing of central shoot was observed due to damage by grown up larvae. The affected plants with fresh frass pellets were seen in the whorl with grown up larvae in the whorl and older leaves showed patches of dry frass (Fig. 8).



Fig 1: Fall armyworm eggs, newly hatched larvae and damage as scrapping of leaves, small window panes in maize



Fig 2: *S. frugiperda* damage indicating moist saw dust like frass near the funnel and leaves in maize



Fig 3: Fall armyworm damage in maize whorl with overlapping generations, leaf damage similar to grasshopper and tassel damage



Fig 4: Fall armyworm extensive damage on cobs in sweet corn



Fig 5: Fall armyworm damage as scrapping and feeding on leaves in sorghum



Fig 6: Fall armyworm larva scrapping on leaves and leaf whorls in ragi.



Fig 7: *S. frugiperda* damage in bajra.

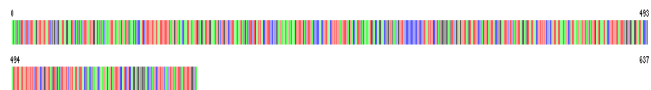


Fig 8: Fall armyworm egg mass and damage symptoms in sugarcane as scrapping, pin holes, feeding on leaves in central shoot and cutting leaf margins.

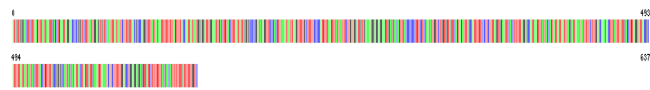
Sequence analysis of New Invasive pest in maize

FAW larvae collected from four locations i.e., Anakapalle, Chinthapalli, Vizianagaram and Srikakulam submitted to ICAR-NBAIR, Bangalore during August, 2018. Molecular identification by ICAR-NBAIR, Bangalore confirmed the occurrence of *S. frugiperda* in different parts of Andhra Pradesh and was 100% match through BLAST sequence analysis and the sequences were submitted to NCBI and accession numbers were retrieved and DNA barcoding was obtained from BOLD systems.

S. frugiperda (Anakapalle Population) GenBank Accession No.: MH822831
Barcode Image



S. frugiperda (Nelivada Population) GenBank Accession No.: MH822834
Barcode Image



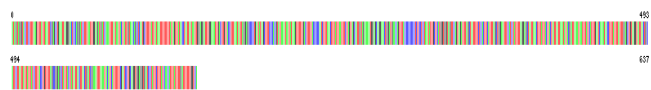
S. frugiperda (Chinthapalle Population) GenBank Accession No.: MH822832
Barcode Image



S. frugiperda (Anakapalle Population) from Sugarcane GenBank Accession No.: MN126574
Barcode Image



S. frugiperda (Pedabathivalasa Population) GenBank Accession No.: MH822833
Barcode Image



T. chilonis (Anakapalle Population) from Sugarcane GenBank Accession No.: MN116707
Barcode Image

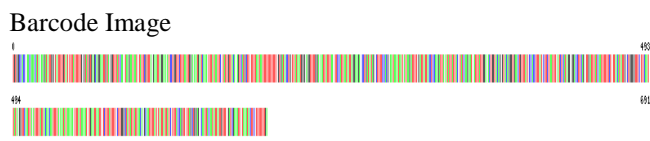


Table 1: Incidence of *S. frugiperda* on maize and other crops in Andhra Pradesh

Date	District	Mandal	Village	Crop	Variety	Age of the crop (days)	Level of infestation (%)	Natural enemies
10.8.18	Visakhapatnam	Anakapalle	Anakapalle (RARS)	Maize	DHM117	45	7.34	Coccinellid predators
		Chinthapalli	Chinthapalli (RARS)	Maize	VMH6474	45-50	8.0-10.0	Coccinellid predators
11.8.18	Vizianagaram	Pusapatirega	Pedabathivalasa	Maize	PAC-751	40-50	30.0-56.2	nil
13.8.18	Srikakulam	Ranastalam	Neliwada	Maize	PAC-751 Nuziveedu Pioneer	20-75	5.0-89.57	nil
17.8.18	Vizianagaram	Garividi	Kondalaxmipuram	Maize	PAC-751	50	75.0	nil
			Vedulavalasa	Maize	PAC-751	50	45.0	nil
			KL Puram	Maize	PAC-751	40	25.0	nil
			Kapusambham	Maize	PAC-751	40	28.0	nil
			Kumaram	Maize	PAC-751	50	50.0	Nil
20.8.18	Visakhapatnam	Ravikamtam	Thotakorapalem	Maize	Sweet corn Srikar 495	30 days	55.8	Coccinellid predators
23.8.18	Srikakulam	Ranastalam	Venkatarapeta	Maize	PAC751	50 days	27.0	Coccinellid predators
23.8.18	Vizianagaram	Pusapatirega	Pasupam	Maize	PAC-751	30-50 days	50-63	nil
24.9.18	Vizianagaram	Gurla	Gurla	Maize	PAC751	40 days	10.0	Spiders
		Garividi	Kondalaxmipuram	Maize	PAC-751	100 days	8.0	nil
			Vedulavalasa	Maize	PAC751	100 days	10.0	nil
		Cheepurupali	Kapusambham	Maize	PAC-751	30 days	20.0	nil
8.10.18	Visakhapatnam	Anakapalle	Anakapalle	Ragi	Chaitanya	50 days	23.0	Coccinellid Spider predators
30.10.18	Vizianagaram	Garividi	Vedulavalasa	Maize	PAC751	30-70 days	10.0-100	nil
				Bajra	Hybrid	50 days	20.0-30.0	Nil
		Cheepurupali	G.Agraharam	Maize	PAC751	60 days	70.0	nil
				Sorghum	Local	40 days	20.0-30.0	nil
	Gurla	Vallapuram	Maize	Pioneer	90 days	5.0-10.0	nil	
9.11.18	Visakapatnam	Anakapalle	Anakapalle	Maize	Sweet corn	20-70 days	5.0-70.0	Coccinellid Spider predators
22.12.18	Vizianagaram	Cheepurupali	Vedulavalasa	Maize	PAC751	90-100 days	5.0-10.0	nil
		Gurla	Gurla	Maize	PAC751	80-90 days	5.0	nil
9.1.2019	Vizianagaram	Gajapathinagaram	Pidisila	Maize	PAC751	10-50 days	<5.0	nil
19.1.19	Vizianagaram	Gajapathinagaram	Pidisila	Maize	PAC751	10-70	<5.0	nil
2.2.2019	Srikakulam	Ranasthalam	Patharlapalli	Maize	PAC751	30-50	5.0-10.0	nil
4.2.2019	Vizianagaram	Denkada	Chollangipeta	Maize	PAC751	50-60	<5.0	nil
18.2.19	Srikakulam	Ranasthalam	Patharlapalli	Maize	PAC751	20-30	<5.0	nil
19.2.19	Vizianagaram	Denkada	Chollangipeta	Maize	PAC751	30-40	<5.0	nil
9.4.19	East Godavari	Samalkota	Samalkota Sugar factory farm	Sugarcane	93V46	45-60	2.0	Coccinellids Spiders

15.4.19	Visakapatnam	Anakapalle	Anakapalle (RARS)	Sugarcane	87A298	30	1.0-2.0	Egg parasitoids, Coccinellid, beetle, bug, earwig predators
17.4.19	Krishna	Vuyyur	Vuyyur Sugar factory farm	Sugarcane	93V46	40-60	2.0-5.0	Coccinellids

4. Conclusion

Fall armyworm is the most destructive pest of maize noticed in Andhra Pradesh during August, 2018 as pestiferous populations and its spread to other crops viz., sorghum, ragi, bajra and sugarcane from October, 2018 to May, 2019. Extensive surveys were conducted in maize growing areas to document the spread and extent of damage by fall army worm. Diagnostic characters of fall army worm larvae and adults were provided to state department of agriculture extension personnel for easy identification and containment of the pest. Furthermore, eggs of the fall worm was parasitized by *T. chilonis* in sugarcane under natural condition is an interesting finding. Therefore, efforts may be made to mass rear the parasitoid and release against the pest as augmentative releases to contain the pest. Maize crop is recovering after initial damage by the larvae and farmers are advised to take timely plant protection by ecofriendly means. Emphasis is on early warning of the pest, awareness on damage, assessment of impact on maize yields and identifying suitable management practices for fall army worm.

5. Acknowledgement

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