



Research Article

Survey and surveillance of fall armyworm, *Spodoptera frugiperda* (J. E. Smith) and its associated natural enemies (Lepidoptera: Noctuidae) in maize in Anand district of Gujarat

P. H. PATEL^{1*}, D. B. SISODIYA², B. L. RAGHUNANDAN³, N. B. PATEL³, D. R. PATEL and K. M. CHAVADA²

¹Department of Agricultural Entomology, N. M. College of Agriculture, NAU, Navsari – 396450, Gujarat, India

²Department of Agricultural Entomology, BA College of Agriculture, Anand Agricultural University, Anand – 388110, Gujarat, India

³AICRP on Biological Control of Crop Pests, Anand Agricultural University, Anand – 388110, Gujarat, India

*Corresponding author E-mail: piyushh195@gmail.com

ABSTRACT: Field surveys were conducted during *kharif*, 2019 and *rabi*, 2019-20 to document the fall armyworm (FAW) incidence and damage in maize fields of Anand district of Gujarat. The highest pest incidence and damage was recorded in maize fields of Khambhat taluka of Anand district during the study, while the lowest pest incidence and damage was recorded in Tarapur taluka. During *kharif* season, the highest pest incidence and damage was recorded in August month and during *rabi* season, the highest incidence of FAW and its damage in various maize fields was observed in November. It was noticed that the pest incidence was high in *kharif* season compared to *rabi* season. The significant differences were noticed with regard to FAW larval population and plant damage levels between the two seasons of the study. During the survey, the natural enemies of FAW viz., *Chelonus* sp., Coccinellids, *Forficula* sp., *Eocanthecona* sp., *Cosmolestes* sp., Spider (*Oxyopes* sp.) and *Geocoris* sp. were recorded. Similarly, *Bacillus thuringiensis*, *Metarhizium (Nomuraea) rileyi* and Nucleo Polyhedrosis Virus (NPV) infected FAW larvae were also noticed.

KEY WORDS: Fall armyworm, Gujarat, natural enemies, *Spodoptera frugiperda*

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INTRODUCTION

Maize (*Zea mays* L.) is the third most important grain crop, which is widely cultivated all over the world. As many as 130 insect pest's species cause varying degree of damage to maize crop right from sowing till harvest (Atwal and Dhaliwal, 2002). Apart from these, the recently introduced pest, fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is of serious concern due to its polyphagous behaviour. It is a major pest native to tropical and subtropical regions of America (Sah *et al.*, 2019). In early 2016, it was reported in West and Central Africa for the first time (Goergen *et al.*, 2016). The caterpillar voraciously feeds not only on cereal crops (maize, wheat, sorghum, millet, rice) and pasture grasses but also on sugarcane, cotton, potato, sweet potato, ginger, chrysanthemum, tomato, tobacco, spinach, crucifers, cucurbits, cucumber, cowpea, common bean, soybean, groundnut, banana, *etc* (Anonymous, 2018). Thus, it is a highly polyphagous pest, known to feed on 353 host plants (Montezano *et al.*, 2018). During June 2018,

Sharanabasappa *et al.* (2018) first reported the occurrence of fall armyworm in maize fields of Karnataka. This pest has been reported on maize from different parts of the country. In Gujarat, Sisodiya *et al.* (2018) first reported the occurrence of fall armyworm on maize at Anklav taluka of Anand district. According to the recent studies, fall armyworm can cause maize yield losses ranging from 8.3 m to 20.6 million tonnes per year in absence of management practices (Day *et al.*, 2017).

Fall armyworm is known to be susceptible to 16 species of entomopathogens including viruses, fungi, protozoa, nematodes and bacteria (All *et al.*, 1996 and Wayne *et al.*, 1980). Several predators and parasitoids were also reported worldwide for the biological control of this pest. Since last three years, this pest has become serious issue in maize growing area of Gujarat affecting the production and productivity of the crop. Further, severe damage of maize crop grown for fodder purpose has also been noticed.

With this background, an attempt was made to survey the incidence and infestation levels of fall armyworm and also the occurrence of its associated natural enemies in maize fields of Anand district of Gujarat during *kharif* and *rabi* seasons of the year 2019-20.

MATERIALS AND METHODS

The survey was conducted in eight talukas *viz.*, Anand, Borsad, Petlad, Khambhat, Umreth, Anklav, Sojitra and Tarapur of Anand district of Gujarat state. In each taluka, five villages were randomly selected, and in each village, one maize field was selected to record the incidence and plant damage caused by FAW. Thus, total 40 villages (fields) were surveyed in a month during the study period. To record the pest incidence in the field, 10 plants were randomly selected for recording the incidence and plant damage. The survey was carried out during *kharif* (from July 2019 to September 2019) and *rabi* (from October 2019 to January 2020) seasons at monthly interval. The larval population as well as number of plants damaged (in randomly selected 10 plants/field) by *S. frugiperda* were recorded in the selected field and percent plant damage was calculated. During survey, the natural enemies of FAW were also recorded. The dead or infected larvae were brought to the laboratory and further observed for the presence of parasitoids or insect pathogens.

Larval specimens collected during the survey were identified by morphological features of larvae as it had a dark head with a pale, upside-down ‘Y’ shape on the front. The grownup larva was dark brown with granulated cuticular

texture all over the body. The dorsal pinacula present on one to eight abdominal segments were large and greater than the diameter of the corresponding spiracle. The dorsal pinacula on the 8th abdominal segment were arranged in a square and the pinacula on each segment except 8th segment were arranged in a trapezoid pattern, it was a typical mark of identification of *S. frugiperda* larva. On the 9th abdominal segment, a pinaculum with a ring shaped dark sclerotization was visible (Plate I). Maize plants damaged by the early instar larvae showed semi-transparent patches (scrapping) on the leaves, a characteristic windows or pin holes symptoms on the leaves. While, grown up larvae were confined to the deep whorls and fed extensively on inner whorl. Such plants appeared to have been torn. Feeding through the whorl cause a line of identical parallel “shot” holes, the leaf whorl and upper leaves to be a mass of holes, ragged edges, and frass matter (Plate I). The above larval characters and damage symptoms were matched with the pest and its damage descriptions mentioned in bulletin OEPP/EPPO (2015), CABI (2019) and Ganiger *et al.*, (2018).

RESULTS AND DISCUSSION

The data pertaining to FAW incidence and plant damage in maize during *kharif* and *rabi* season has been presented in the Tables 1 and 2, respectively and taluka-wise data on FAW incidence and plant damage has been depicted in the Fig. 2 and 3, respectively. Further, the correlation between the larval population and plant damage documented during two different seasons has been given in the Table 3. Further, natural enemies recorded during the survey have been catalogued in the Table 4.

Kharif season, 2019

Among the different maize fields surveyed in various talukas of Anand district, the highest larval population and plant damage was recorded in Kodva village (6.5 larvae/ 10 plants and 90% plant damage) of Khambhat taluka in August month. Whereas, the lowest larval population and plant damage (0.5 larvae/ 10 plants and 10-15%) was recorded during July month in the villages *viz.*, Bhadran village of Borsad taluka, Bilpad village of Anklav taluka, Pandoli village of Petlad taluka, Kothavi village of Sojitra taluka, Rinj and Isarwada village of Tarapur taluka. Overall, during *kharif* season the maize fields of Kodva village of Khambhat taluka recorded the more pest incidence and damage (4.0 larvae/10 plants, 56.67%), whereas, the lower pest incidence and damage was documented in Isarwada village (0.25 larvae/10 plants, 15 %) of Tarapur taluka (Table 1).

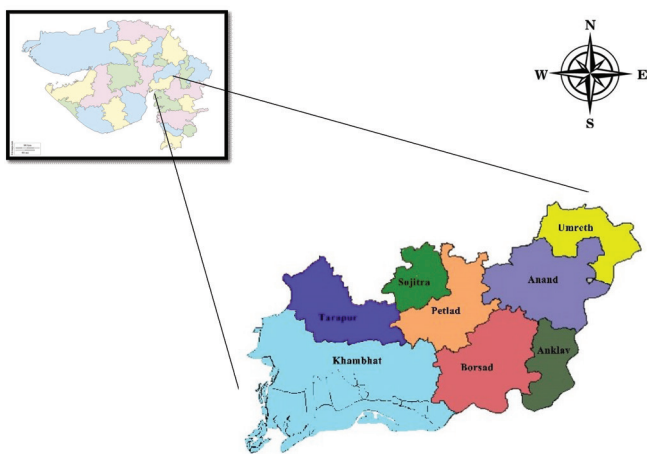


Fig. 1. Map of the survey in Anand district.

Table 1. Incidence and plant damage of fall armyworm in maize during *kharif*, 2019 in Anand district

| Taluka | Village | No. of larvae/10 plants | | | | Plant damage (%) | | | |
|-------------|--|-------------------------|-------------|-------------|-------------|------------------|-----------|-----------|--------------|
| | | July | August | Sept. | Mean | July | August | Sept. | Mean |
| Anand | Bakrol (22°33'39"N) (72°54'29"E) | 1.50 | 1.50 | 2.00 | 1.67 | 30 | 15 | 30 | 25.00 |
| | Navli (22°29'54"N) (72°57'20"E) | 2.00 | 2.00 | 0.00 | 1.33 | 40 | 30 | 15 | 28.33 |
| | Vadod (22°30'32"N) (73°00'15"E) | 2.50 | 2.50 | 1.00 | 2.00 | 40 | 25 | 10 | 25.00 |
| | Boriavi (22°36'47"N) (72°56'06"E) | 0.00 | 0.00 | 3.00 | 1.00 | 10 | 25 | 45 | 26.67 |
| | Samarkha (22°36'11"N) (72°59'15"E) | 2.00 | 3.50 | 1.50 | 2.33 | 25 | 55 | 25 | 35.00 |
| Mean | | 1.60 | 1.90 | 1.50 | 1.67 | 29 | 30 | 25 | 28.00 |
| Borsad | Santokpura (22°26'19"N) (72°51'22"E) | 0.00 | 4.00 | 2.50 | 2.17 | 10 | 60 | 40 | 36.67 |
| | Dhundakuva (22°27'38"N) (72°52'55"E) | 3.50 | 0.00 | 2.00 | 1.83 | 45 | 10 | 35 | 30.00 |
| | Nahapa (22°28'49"N) (72°54'50"E) | 1.50 | 1.50 | 1.50 | 1.50 | 30 | 20 | 35 | 28.33 |
| | Napa-vata (22°28'31"N) (72°55'10"E) | 0.00 | 2.50 | 0.00 | 0.83 | 00 | 45 | 00 | 15.00 |
| | Bhadran (22°21'23"N) (72°53'49"E) | 0.50 | 2.00 | 2.50 | 1.67 | 15 | 30 | 40 | 28.33 |
| Mean | | 1.10 | 2.00 | 1.70 | 1.60 | 20 | 33 | 30 | 27.67 |
| Anklav | Bilpad (22°18'46"N) (72°58'39"E) | 0.50 | 0.00 | 1.00 | 0.50 | 15 | 10 | 20 | 15.00 |
| | Navakhal (22°22'29"N) (72°59'32"E) | 0.00 | 3.50 | 1.50 | 1.67 | 00 | 50 | 25 | 25.00 |
| | Kinkhlod (22°20'16"N) (72°58'01"E) | 1.50 | 4.00 | 2.50 | 2.67 | 25 | 60 | 45 | 43.33 |
| | Anklav (22°23'06"N) (73°00'16"E) | 2.00 | 2.00 | 0.00 | 1.33 | 30 | 30 | 10 | 23.33 |
| | Joshikuva (22°23'11"N) (72°58'36"E) | 1.00 | 4.00 | 2.50 | 2.50 | 20 | 50 | 40 | 36.67 |
| Mean | | 1.00 | 2.70 | 1.50 | 1.73 | 18 | 40 | 28 | 28.67 |

Survey and surveillance of fall armyworm, *Spodoptera frugiperda* and its associated natural enemies

| | | | | | | | | | |
|-------------|--|-------------|-------------|-------------|-------------|-----------|-----------|-----------|--------------|
| Umreth | Untkhari (22°40'09"N) (73°03'15"E) | 0.00 | 4.00 | 1.00 | 1.67 | 10 | 55 | 15 | 26.67 |
| | Pansora (22°41'46"N) (73°01'59"E) | 1.50 | 2.50 | 0.00 | 1.33 | 30 | 35 | 00 | 21.67 |
| | Vansol (22°41'14"N) (73°00'13"E) | 3.00 | 1.00 | 2.00 | 2.00 | 40 | 25 | 25 | 30.00 |
| | Badapura (22°39'17"N) (73°01'03"E) | 0.00 | 2.00 | 2.50 | 1.50 | 00 | 45 | 50 | 31.67 |
| | Bharoda (22°38'46"N) (73°08'28"E) | 1.50 | 0.00 | 1.50 | 1.00 | 30 | 00 | 30 | 20.00 |
| Mean | | 1.20 | 1.90 | 1.40 | 1.50 | 22 | 32 | 24 | 26.00 |
| Petlad | Bandhani (22°33'01"N) (72°49'32"E) | 2.50 | 2.50 | 1.50 | 2.17 | 50 | 35 | 15 | 33.33 |
| | Mahelav (22°33'54"N) (72°49'09"E) | 0.00 | 3.50 | 2.00 | 1.83 | 15 | 40 | 35 | 30.00 |
| | Vishnoli (22°31'29"N) (72°49'28"E) | 2.00 | 0.00 | 2.50 | 1.50 | 25 | 15 | 40 | 26.67 |
| | Pandoli (22°27'45"N) (72°44'41"E) | 0.50 | 4.50 | 1.50 | 2.17 | 10 | 75 | 30 | 38.33 |
| | Dharmaj (22°25'08"N) (72°47'55"E) | 1.50 | 3.50 | 2.50 | 2.50 | 30 | 45 | 50 | 41.67 |
| Mean | | 1.30 | 2.80 | 2.00 | 2.03 | 26 | 42 | 34 | 34.00 |
| Khambhat | Kodva (22°23'25"N) (72°39'14"E) | 2.00 | 6.50 | 3.50 | 4.00 | 30 | 90 | 50 | 56.67 |
| | Malasoni (22°23'05"N) (72°35'39"E) | 1.00 | 4.00 | 2.00 | 2.33 | 15 | 60 | 40 | 38.33 |
| | Metpur (22°18'50"N) (72°38'11"E) | 0.00 | 2.00 | 1.00 | 1.00 | 05 | 25 | 25 | 18.33 |
| | Jinaj (22°24'08"N) (72°36'37"E) | 2.00 | 3.00 | 2.00 | 2.33 | 40 | 30 | 30 | 33.33 |
| | Kanisha (22°23'02"N) (72°41'09"E) | 2.50 | 2.50 | 2.50 | 2.50 | 40 | 40 | 45 | 41.67 |
| Mean | | 1.50 | 3.60 | 2.20 | 2.43 | 26 | 49 | 38 | 37.67 |

| | | | | | | | | | |
|---------------------|--|-------------|-------------|-------------|-------------|--------------|--------------|--------------|--------------|
| Sojitra | Limbali (22°33'17"N) (72°42'33"E) | 1.00 | 1.50 | 0.00 | 0.83 | 25 | 25 | 00 | 16.67 |
| | Kothavi (22°30'18"N) (72°43'14"E) | 0.50 | 2.00 | 1.00 | 1.17 | 20 | 35 | 05 | 20.00 |
| | Runaj (22°29'48"N) (72°42'06"E) | 2.50 | 0.00 | 1.50 | 1.33 | 30 | 00 | 25 | 18.33 |
| | Viol (22°26'05"N) (72°49'41"E) | - | 3.50 | 2.00 | 2.75 | - | 55 | 45 | 50.00 |
| | Khansol (22°30'00"N) (72°43'26"E) | - | 2.00 | 1.50 | 1.75 | - | 30 | 35 | 32.50 |
| Mean | | 1.33 | 1.80 | 1.20 | 1.44 | 25 | 29 | 22 | 25.33 |
| Tarapur | Untwada (22°26'12"N) (72°37'39"E) | 1.00 | 3.00 | 2.50 | 2.17 | 20 | 45 | 40 | 35.00 |
| | Rinj (22°28'46"N) (72°38'58"E) | 0.50 | 2.00 | 0.00 | 0.83 | 15 | 35 | 00 | 16.67 |
| | Tarapur (22°28'57"N) (72°39'26"E) | 0.00 | 0.00 | 1.50 | 0.75 | 20 | 30 | 30 | 26.67 |
| | Isarwada (22°29'58"N) (72°37'07"E) | - | 0.50 | 0.00 | 0.25 | - | 20 | 10 | 15.00 |
| | Sansej (22°27'16"N) (72°40'20"E) | - | 1.00 | 1.50 | 1.25 | - | 20 | 20 | 20.00 |
| Mean | | 0.75 | 1.30 | 1.10 | 1.05 | 18.33 | 30.00 | 20.00 | 22.78 |
| Overall mean | | 1.22 | 2.25 | 1.58 | 1.69 | 23.04 | 35.63 | 27.63 | 29.02 |

Note: 1. '-' Maize field was not found during survey
 2. Figures in parenthesis indicate GPS coordinates of surveyed maize fields

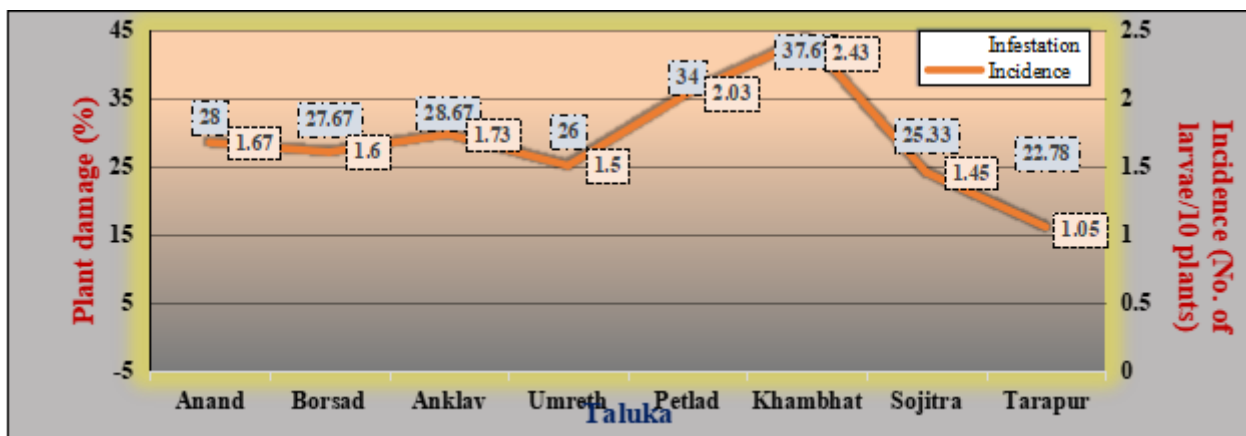


Fig. 2. Taluka-wise incidence and plant damage of fall armyworm in maize during kharif, 2019 in Anand district

The data analysed over the basis of taluka/blocks comprising different villages of survey revealed that the Khambhat taluka documented the highest larval population and plant damage (2.43 larvae/10 plants, 37.67%) followed by Petlad taluka (2.03 larvae/10 plants, 34 %), The lowest pest incidence and damage was recorded in Tarapur taluka (1.05 larvae/10 plants, 22.78%) (Fig. 2). The mean data over month basis depicts the highest larval population during the month of August (2.25 larvae/10 plants), followed by September (1.58 larvae/10 plants) and July (1.22 larvae/10 plants). Similarly, the highest plant damage was reported in the month of August (35.63%), followed by September (27.63%) and July (23.04%).

Rabi season, 2019–20

During *rabi* season, the data revealed the variation in the pest incidence and infestation levels when compared with *kharif* season data. Among the different maize fields

surveyed in various talukas, highest pest incidence and damage was noticed during November month in Metpur village of Khambhat taluka (4.0 larvae/ 10 plants and 60% plant damage) and Mahelav village (4.0 larvae/ 10 plants and 60%) of Petlad taluka. Whereas, maize fields of Vadod village (in October) of Anand taluka, Navakhal village (in December) of Ankjav taluka, Untkhari (in October) and Bharoda (in December) villages of Umreth taluka, Mahelav village (in December) of Petlad taluka, Limbali village (in January) of Sojitra taluka, Untwada (in October) and Rinj (in December) villages of Tarapur taluka were recorded with lowest larval population and plant damage (0.5 larvae/10 plants and 10-20% plant damage).

The data analysed over the basis of different talukas of Anand district, highest pest incidence and damage was documented in Khambhat taluka (1.85 larvae/10 plants, 42% plant damage). Whereas, lowest values were recorded in

Table 2. Incidence and plant damage of fall armyworm in maize during *rabi*, 2019–20 in Anand district

| Taluka | Village | No. of larvae/10 plants | | | | | Plant damage (%) | | | | |
|--------|--|-------------------------|------|------|------|------|------------------|------|------|------|-------|
| | | Oct. | Nov. | Dec. | Jan. | Mean | Oct. | Nov. | Dec. | Jan. | Mean |
| Anand | Bakrol (22°33'33"N) (72°54'27"E) | 1.00 | 2.00 | 0.00 | 0.00 | 0.75 | 10 | 25 | 15 | 00 | 12.50 |
| | Navli (22°29'50"N) (72°57'40"E) | 2.00 | 1.50 | 1.00 | 1.50 | 1.50 | 30 | 30 | 20 | 25 | 26.25 |
| | Vadod (22°30'32"N) (73°00'00"E) | 0.50 | 0.00 | 2.50 | 0.00 | 0.75 | 20 | 10 | 40 | 00 | 17.50 |
| | Boriavi (22°36'33"N) (72°56'24"E) | 1.50 | 1.50 | 1.50 | 1.00 | 1.38 | 25 | 25 | 15 | 15 | 20.00 |
| | Samarkha (22°36'35"N) (72°58'45"E) | 2.00 | 2.50 | 0.00 | 2.00 | 1.63 | 35 | 40 | 05 | 20 | 25.00 |
| Mean | | 1.40 | 1.50 | 1.00 | 0.90 | 1.20 | 24 | 26 | 19 | 12 | 20.25 |
| Borsad | Santokpura (22°26'05"N) (72°51'32"E) | 2.50 | 1.50 | 0.00 | 1.50 | 1.38 | 45 | 25 | 05 | 30 | 26.25 |
| | Dhundakuva (22°27'28"N) (72°54'28"E) | 2.00 | 0.00 | 0.00 | 0.00 | 0.50 | 20 | 20 | 20 | 00 | 15.00 |
| | Nahapa (22°28'25"N) (72°54'43"E) | 1.00 | 2.00 | 2.50 | 0.00 | 1.38 | 10 | 35 | 20 | 00 | 16.25 |
| | Napa-vata (22°28'52"N) (72°55'05"E) | 2.00 | 3.00 | 1.50 | 2.00 | 2.13 | 30 | 45 | 15 | 25 | 28.75 |
| | Bhadran (22°21'35"N) (72°53'42"E) | 0.00 | 2.00 | 2.00 | 1.50 | 1.38 | 05 | 30 | 30 | 25 | 22.50 |
| Mean | | 1.50 | 1.70 | 1.20 | 1.00 | 1.35 | 22 | 31 | 18 | 16 | 21.75 |

| | | | | | | | | | | | |
|--------|---|------|------|------|------|------|----|----|----|----|-------|
| Anklav | Bilpad (22°18'37"N) (72°58'44"E) | 1.50 | 2.00 | 1.50 | 2.50 | 1.88 | 30 | 30 | 25 | 35 | 30.00 |
| | Navakhal (22°22'48"N) (72°59'44"E) | 0.00 | 3.00 | 0.50 | 0.00 | 0.88 | 10 | 45 | 15 | 00 | 17.50 |
| | Kinkhlod (22°20'22"N) (72°58'13"E) | 1.50 | 0.00 | 1.50 | 1.50 | 1.13 | 15 | 00 | 30 | 25 | 17.50 |
| | Anklav (22°22'28"N) (73°00'23"E) | 1.50 | 3.50 | 0.00 | 1.00 | 1.50 | 35 | 50 | 00 | 15 | 25.00 |
| | Joshikuva (22°23'19"N) (72°58'54"E) | 2.00 | 1.50 | 2.50 | 0.00 | 1.50 | 20 | 35 | 35 | 15 | 26.25 |
| Mean | | 1.30 | 2.00 | 1.20 | 1.00 | 1.38 | 22 | 32 | 21 | 18 | 23.25 |
| Umreth | Untkhari (22°39'52"N) (73°02'11"E) | 0.50 | 0.00 | 2.00 | 0.00 | 0.63 | 15 | 10 | 35 | 00 | 15.00 |
| | Pansora (22°42'05"N) (73°01'54"E) | 1.50 | 2.00 | 1.00 | 2.00 | 1.63 | 15 | 30 | 20 | 15 | 20.00 |
| | Vansol (22°40'55"N) (72°59'59"E) | 2.00 | 1.00 | 0.00 | 0.00 | 0.75 | 40 | 25 | 00 | 10 | 18.75 |
| | Badapura (22°39'11"N) (73°00'49"E) | 2.00 | 1.50 | 1.50 | 1.00 | 1.50 | 35 | 20 | 25 | 20 | 25.00 |
| | Bharoda (22°37'33"N) (73°08'21"E) | 0.00 | 3.00 | 0.50 | 1.00 | 1.13 | 00 | 40 | 15 | 20 | 18.75 |
| Mean | | 1.20 | 1.50 | 1.00 | 0.80 | 1.13 | 21 | 25 | 19 | 13 | 19.50 |
| Petlad | Bandhani (22°33'34"N) (72°49'41"E) | 0.00 | 1.50 | 1.00 | 1.50 | 1.00 | 00 | 25 | 20 | 25 | 17.50 |
| | Mahelav (22°34'00"N) (72°48'51"E) | 1.50 | 4.00 | 0.50 | 1.00 | 1.75 | 30 | 60 | 20 | 20 | 32.50 |
| | Vishnoli (22°31'32"N) (72°49'14"E) | 2.50 | 0.00 | 2.00 | 2.50 | 1.75 | 45 | 20 | 25 | 25 | 28.75 |
| | Pandoli (22°27'57"N) (72°44'59"E) | 2.00 | 3.00 | 0.00 | 0.00 | 1.25 | 25 | 40 | 10 | 00 | 18.75 |
| | Dharmaj (22°25'10"N) (72°47'09"E) | 1.50 | 2.50 | 2.50 | 0.00 | 1.63 | 30 | 45 | 35 | 10 | 30.00 |
| Mean | | 1.50 | 2.20 | 1.20 | 1.00 | 1.48 | 26 | 38 | 22 | 16 | 25.50 |

Survey and surveillance of fall armyworm, *Spodoptera frugiperda* and its associated natural enemies

| | | | | | | | | | | | |
|--------------|--|------|------|------|------|------|-------|-------|-------|-------|-------|
| Khambhat | Kodva (22°23'20"N) (72°38'14"E) | 2.00 | 3.00 | 1.50 | 1.00 | 1.88 | 25 | 45 | 35 | 15 | 30.00 |
| | Malasoni (22°23'16"N) (72°35'35"E) | 2.50 | 2.00 | 2.00 | 2.00 | 2.13 | 45 | 25 | 25 | 30 | 31.25 |
| | Metpur (22°18'36"N) (72°38'22"E) | 2.00 | 4.00 | 3.00 | 1.50 | 2.63 | 30 | 55 | 50 | 25 | 40.00 |
| | Jinaj (22°24'13"N) (72°36'26"E) | 0.00 | 3.00 | 1.00 | 0.00 | 1.00 | 00 | 50 | 20 | 00 | 17.50 |
| | Kanisha (22°23'09"N) (72°41'09"E) | 2.00 | 2.50 | 0.00 | 2.00 | 1.63 | 50 | 35 | 00 | 25 | 27.50 |
| Mean | | 1.70 | 2.90 | 1.50 | 1.30 | 1.85 | 30 | 42 | 26 | 19 | 29.25 |
| Sojitra | Limbali (22°33'30"N) (72°42'50"E) | 1.00 | 0.00 | 1.00 | 0.50 | 0.63 | 25 | 00 | 25 | 10 | 15.00 |
| | Kothavi (22°30'16"N) (72°43'23"E) | 0.00 | 1.50 | 0.00 | 1.50 | 0.75 | 00 | 30 | 00 | 25 | 13.75 |
| | Runaj (22°29'56"N) (72°42'19"E) | 2.00 | 2.00 | 1.50 | - | 1.38 | 20 | 40 | 30 | - | 22.50 |
| | Viol (22°26'32"N) (72°50'39"E) | 1.50 | 2.50 | - | - | 2.00 | 40 | 40 | - | - | 40.00 |
| | Khansol (22°29'56"N) (72°43'29"E) | - | - | - | - | - | - | - | - | - | - |
| Mean | | 1.13 | 1.50 | 0.83 | 0.67 | 1.03 | 21.25 | 27.50 | 18.33 | 11.67 | 19.69 |
| Tarapur | Untwada (22°26'39"N) (72°37'58"E) | 0.50 | 1.00 | 1.00 | 1.00 | 0.88 | 15 | 20 | 20 | 15 | 17.50 |
| | Rinj (22°28'51"N) (72°39'09"E) | 2.00 | 1.50 | 0.50 | - | 1.00 | 35 | 20 | 10 | - | 16.25 |
| | Tarapur (22°28'54"N) (72°39'43"E) | 0.00 | 3.00 | - | - | 1.50 | 00 | 45 | - | - | 22.50 |
| | Isarwada | - | - | - | - | - | - | - | - | - | - |
| | Sansej | - | - | - | - | - | - | - | - | - | - |
| Mean | | 0.83 | 1.83 | 0.75 | 0.50 | 0.98 | 16.67 | 28.33 | 15.00 | 07.50 | 16.88 |
| Overall mean | | 1.32 | 1.89 | 1.09 | 0.90 | 1.35 | 22.87 | 31.23 | 19.79 | 14.15 | 22.83 |

Note: 1. '-' Maize field was not found during survey

2. Figures in parenthesis indicate GPS coordinates of surveyed maize fields

Tarapur taluka (0.98 larva/10 plants, 7.50% plant damage) (Fig. 3). The mean data of larval population on monthly basis indicated the highest larval population in the month of November (1.89 larvae/10 plants), followed by October (1.32 larvae/10 plants) and December month (1.09 larvae/10 plants). Whereas, the lowest larval population was observed in January month (0.90 larva/10 plants).

Correlation between the pest incidence and plant damage:

The mean data of larval population recorded in *kharif* (1.69 larvae/10 plants) and *rabi* (1.35 larvae/10 plants) seasons revealed the significant difference in the pest incidence (t-test 2.40*). Similar observations were also documented with regard to damage caused by the pest.

Significant difference was observed in the plant damage recorded in *kharif* (29.02%) and *rabi* season (22.83%). The significant positive correlation (0.925) between larval population and plant damage was noticed during the study period. The results of this present study are in accordance with the findings of Anandhi *et al.* (2020), they reported the higher average larval population of FAW during *kharif* (0.99 to 3.66 larvae per plant) as compared to *rabi* (0.66 to 2.60 larvae per plant) in all the locations of the survey.

Natural enemies of fall armyworm:

During survey, activity of several natural enemies were recorded in maize fields of different villages of Anand district. Among them, the identified natural enemies of fall armyworm recorded were presented in the Table 4 (Plate II).

Table 3. Correlation between the larval incidence and the plant damage caused by fall armyworm in different seasons of the year 2019

| Season & Year | No. of larvae/10 plants | Plant damage (%) | Correlation co-efficient (r) |
|-----------------------|-------------------------|------------------|------------------------------|
| <i>Kharif</i> , 2019 | 1.69 | 29.02 | 0.929** (40) |
| <i>Rabi</i> , 2019-20 | 1.35 | 22.83 | 0.904** (37) |
| Pooled | 1.52 | 25.92 | 0.925** (77) |
| T-test | 2.40* | 3.18** | - |

Note: * Significant at 5 % level, ** Significant at 1 % level, Figures in parenthesis are no. of observations.

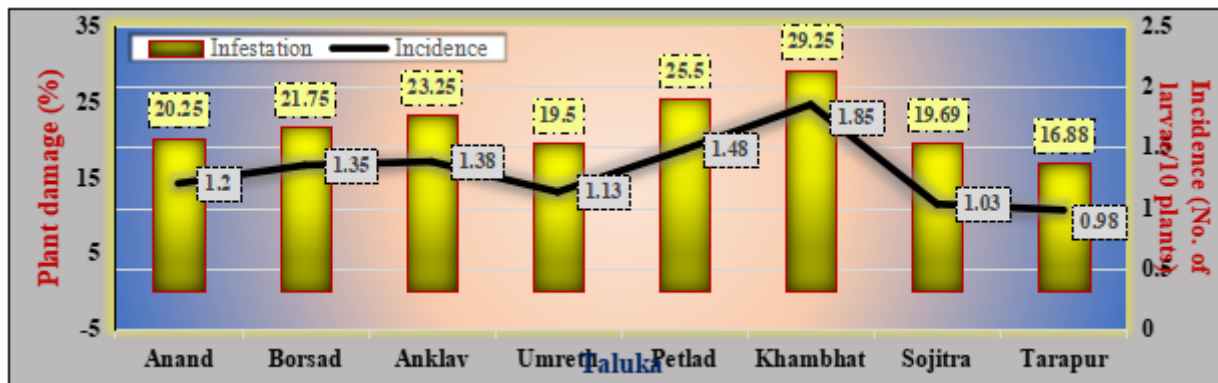


Fig. 3. Taluka-wise incidence and plant damage of fall armyworm in maize during *rabi*, 2019-2020 in Anand district

Table 4. Natural enemies of fall armyworm recorded during the survey of FAW in Anand district of Gujarat

| Taluka | Village | Natural enemies | | |
|--------|----------|--------------------------------|------------|--|
| | | Pathogens | Parasitoid | Predator |
| Anand | Bakrol | | | Coccinellids, Spider, <i>Forficula</i> sp. |
| | Vadod | | | <i>Forficula</i> spp., <i>Eocanthecona</i> sp. |
| | Boriavi | | | Coccinellids, |
| | Samarkha | Nucleopolyhedrosis virus (NPV) | | Spider, <i>Forficula</i> sp. |

| | | | | |
|----------|------------|--------------------------------------|---------------------|---|
| Borsad | Santokpura | <i>Bacillus thuringiensis</i> | | Coccinellids, <i>Eocanthecona</i> sp. |
| | Nahapa | | | Spider, <i>Cosmolestes</i> sp. |
| | Napa-vata | Nucleopolyhedrosis virus (NPV) | | Coccinellids, <i>Geocoris</i> sp. |
| Anklav | Bilpad | <i>Bacillus thuringiensis</i> | | Spider, <i>Forficula</i> sp. |
| | Kinkhlod | <i>Metarhizium (Nomuraea) rileyi</i> | | Coccinellids, <i>Geocoris</i> sp. |
| | Anklav | Nucleopolyhedrosis virus (NPV) | | Coccinellids, Spider |
| | Joshikuva | | | Spider, <i>Geocoris</i> sp. |
| Umreth | Untkhari | | | Coccinellids, <i>Eocanthecona</i> sp. |
| | Pansora | Nucleopolyhedrosis virus (NPV) | | Coccinellids, <i>Cosmolestes</i> sp. |
| | Bharoda | | | Coccinellids, <i>Geocoris</i> sp. |
| Petlad | Bandhani | <i>Metarhizium (Nomuraea) rileyi</i> | | |
| | Mahelav | <i>Bacillus thuringiensis</i> | | Coccinellids, Spider |
| | Vishnoli | | | <i>Forficula</i> sp. |
| | Pandoli | | | Spider, <i>Forficula</i> sp. |
| Khambhat | Kodva | <i>Metarhizium (Nomuraea) rileyi</i> | | <i>Eocanthecona</i> sp. |
| | Malasoni | | | Coccinellids, Spider, <i>Geocoris</i> sp. |
| | Metpur | Nucleopolyhedrosis virus (NPV) | <i>Chelonus</i> sp. | Coccinellids, Spider |
| | Kanisha | Nucleopolyhedrosis virus (NPV) | | Spider, <i>Geocoris</i> sp. |
| Sojitra | Limbali | <i>Metarhizium (Nomuraea) rileyi</i> | | Coccinellids, Spider, |
| | Kothavi | | | Coccinellids, <i>Forficula</i> sp. |
| | Runaj | Nucleopolyhedrosis virus (NPV) | | Coccinellids, Spider, <i>Geocoris</i> bug |
| | Khansol | | | Spider, <i>Geocoris</i> bug, <i>Forficula</i> sp. |
| Tarapur | Untwada | <i>Metarhizium (Nomuraea) rileyi</i> | | Spider |
| | Rinj | | | Coccinellids, |
| | Tarapur | | | Coccinellids, <i>Geocoris</i> sp. |
| | Sansej | | | Coccinellids, Spider, <i>Forficula</i> sp. |

CONCLUSION

This study clearly documented the highest FAW incidence and damage in maize fields of Khambhat taluka of Anand district during *kharif* and *rabi* seasons of the year 2019, while the lowest pest incidence and damage was recorded in Tarapur taluka. During *kharif* season, highest pest incidence and damage was recorded during August month while in *rabi*, it is in November month in various maize

fields of Anand district of Gujarat. The significant differences were noticed with regard to FAW larval population and plant damage levels between the two seasons of the study. During the survey, the natural enemies of FAW viz., *Chelonus* spp., Coccinellids, *Forficula* sp., *Eocanthecona* sp., *Cosmolestes* sp., Spider (*Oxyopes* sp.) and *Geocoris* sp. were recorded. Similarly, *B. thuringiensis*, *N. rileyi* and nucleopolyhedrosis virus (NPV) infected FAW larvae were also observed and are documented.

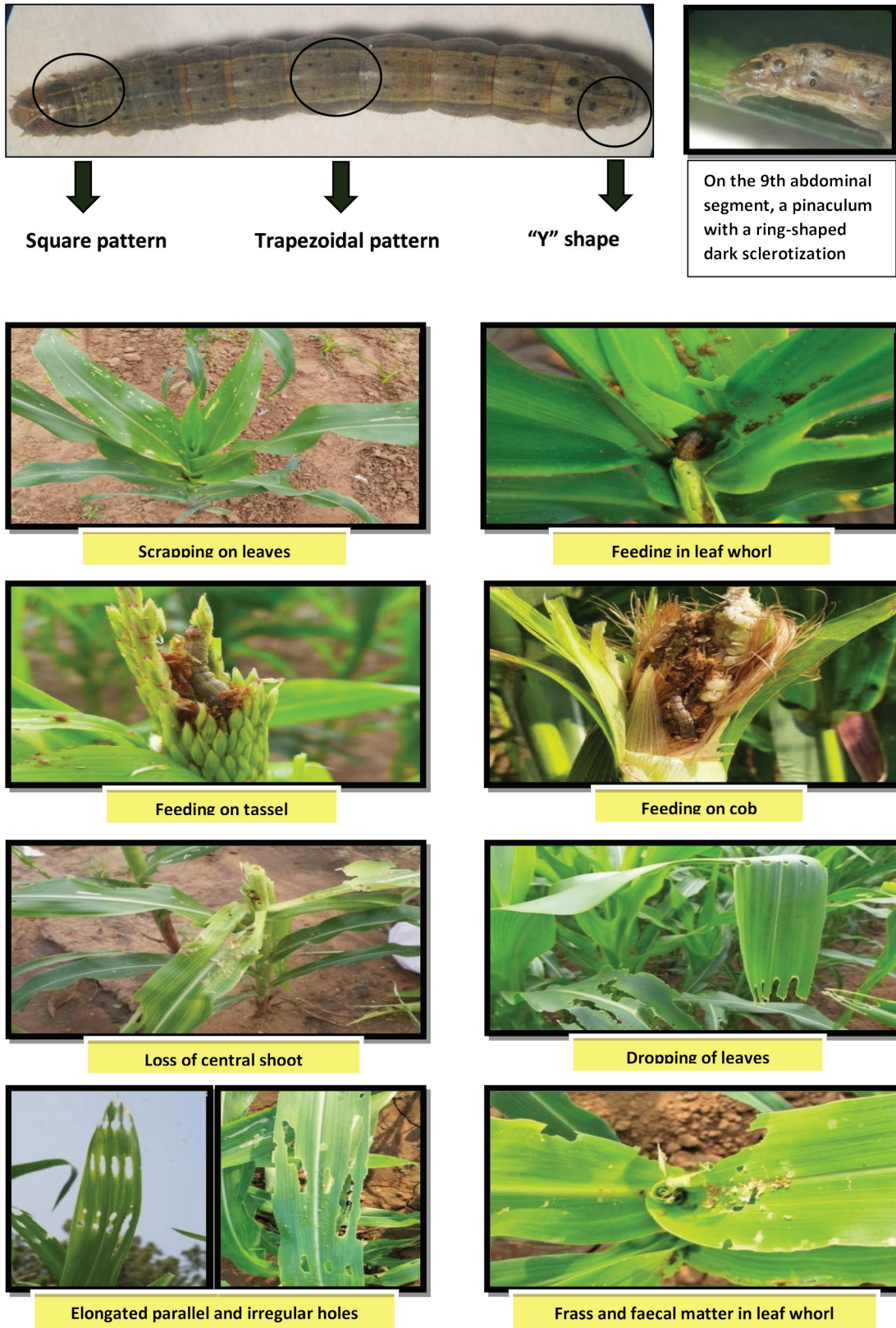


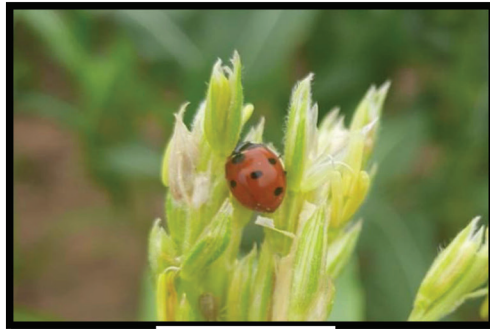
Plate I. Marks of identification and nature of damage



Larva of *Chelonus* sp. emerging from parasitized FAW larva



Adult of *Chelonus* sp.



Coccinelli



Cosmolestes



Geocoris sp.



Spider (*Oxyopes* sp.)



Eocanthacona sp.

Plate II. Natural enemies of fall armyworm documented during survey

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