Research Article

SPATIAL AND SEASONAL DISTRIBUTION OF FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (J.E. SMITH) IN NEPAL

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ABSTRACT

Fall armyworm detection survey was conducted in summer and winter/spring maize in 24 districts of Nepal during 2019 and 2020. The main objective of the study was to find out its spatial and seasonal distribution within the country after its first record in May 2019 from Nawalpur district. Fall armyworm was found spread in 21 districts indicating it had covered country from east to west. Winter temperature in terai, inner terai region of Nepal is suitable for survival of fall armyworm. *Spodoptera frugiperda* and *Mythimna separata* can cohabit in same field in winter and spring maize.

Key words: *Spodoptera frugiperda, fall armyworm, distribution, maize*

INTRODUCTION

Fall armyworm *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is an invasive insect pest of cereal crops native to tropical and subtropical regions of American continents. *S. frugiperda* is a destructive pest of maize and more than 353 plant species belonging to 76 families were recorded as larval host (Debora, 2018). *S. furgipeda* larvae were estimated to cause maize yield losses of 20.15 percent in African countries (Abrahams *et al*., 2017) and 34 percent in Brazil (Cruz *et al*., 1999).This pest is strong flier with both migratory and localized dispersal habit and can fly up to 500 km before oviposition (Prasanna *et al*., 2018). *S. frugiperda* recorded for travelling 1600 km from southern U.S. state Mississippi to southern Canada in 30 hours with assistance of proper wind pattern (Rose *et al*., 1975).

S. frugiperda confined to American continent till 2015, was reported from West and Central Africa in 2016 (Goergen *et al*., 2016) and was found spread into all sub-Saharan countries in 2018 (Prasanna *et al*., 2018). *S. frugiperda* had been confirmed from 46 sub-Saharan and North African countries by February 2020 (CABI, 2020). First time in Asia *S. frugiperda* was recorded from Shivamogga district of Karnataka, India in May 2018. Since then, the insect had been spread into Asian countries: Bangladesh, China, Indonesia, Japan, Laos, Malaysia, Myanmar, Nepal, Pakistan, Philippines, South Korea, Sri Lanka, Thailand, United

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Arab of Emirates, Vietnam and Yemen (CABI, 2020). The *S. frugiperda* had been reported for the first time in Nepal from Gaindakot of Nawalpur district (N 27°42'16.67", E 084°22'50.61") in May 2019 (Bajracharya *et al*., 2019).

Maize is second most important staple food crop in Nepal and cultivated in 891,583 ha with production of 2,231,517 metric tons (MoALD, 2017). Among cultivated area 18.95 percent fall in plain areas and 81.04 percent in hills and mountains (MoALD, 2017). Maize is grown under rainfed condition during summer months as a mono crop or relayed by millet in hills and mountains. Maize is also grown during winter and spring seasons with irrigation in terai, inner- terai, valleys and low–lying river basins in Nepal (Paudyal *et al*., 2001). In short period after first report of *S. frugiperda* in Nepal various organizations and people were reporting its spread into different regions of the country without appropriate scientific identifications. The pheromone lures used for trapping male moths of *S. frugiperda* were either ineffective or cross attracting moths of other species. Although *S. frugiperda* disappeared from mid and high hills during winter season, its survival in low lying plain regions of Nepal need to be ascertained. Lack of clear picture on geographical and seasonal distribution of *S. frugiperda* within the country reflected into difficulties in program planning among researchers and extension agents of various organizations working on *S. frugiperda* management. Considering these facts detection survey of *S. frugiperda* in summer and winter/spring maize was conducted in 24 districts of Nepal and paper highlights on various findings.

MATERIALS AND METHODS

Fall armyworm detection survey was conducted at eight locations of six districts in summer maize during 2019 and 29 locations of 21 districts in winter/spring maize during 2020. Survey in summer maize was conducted in Nawalpur, Chitwan, Lalitpur, Kavrepalanchowk, Sindhupalchowk and Sindhuli districts during May to August 2019. Similarly, in winter/spring maize was conducted in 21 terai districts during February 2020. The districts surveyed for *S. frugiperda* detection in winter/spring maize were, Jhapa, Morang, Sunsari, Saptari, Siraha, Dhanusha, Mahottari, Sindhuli, Sarlahi, Rautahat, Bara, Parsa, Makawanpur, Chitwan, Nawalpur, Nawalparasi, Rupandehi, Kapilvastu, Dang, Banke and Bardiya.

Visual observation was made at each location for typical damage symptoms of *S. frugiperda* on leaves and whorl of maize plants. When the damage symptoms were observed, larvae of *S. frugiperda* were collected and visually confirmed in the field itself with the help of hand lens. These larvae were brought to Entomology Division laboratory in plastic boxes. These samples were further confirmed under binocular microscope, BestScope BS-3040B and BS-3040T. The larvae were reared individually into adult in round plastic rearing boxes with 100 ml capacity (5 cm diameter). External morphology of pupae and adults were studied for further confirmation of *S. frugiperda*. The external morphology of larvae, pupae and adult

moths were compared with earlier finding (Bajracharya *et al*., 2019; Sharanabasappa *et al*., 2018; Ganiger *et al*., 2018; EPPO, 2015; Brambila, 2013). GPS coordinates and altitudes were recorded with GARMIN (GPS map 62sc) from each site. The GPS coordinates were used to prepare *S. frugiperda* distribution map in Google Earth.

At each site, 50 plants were sampled in order to determine percent *S. frugiperda* infestation. Sampling was done at five points walking in 'W' pattern at each site described by Prasanna *et al*. 2018. At each point 10 plants were sampled and observed for sign of fall armyworm damage symptoms. Percent plant infestation by *S. frugiperda* was calculated from number of plants infested against number or plants sampled. Scoring was done for damaged plants at same five points with the help of foliar damage scoring scale modified from Davis and Williams (1992) described in Table 1.

Table 1. Scoring scale (0-5) for assessment of foliar damage due to fall armyworm.

Score	Damage symptoms/description
0	No visible feeding symptoms on upper leaves and whorl.
1	Papery window damage symptoms on upper leaves and whorl.
2	Few small holes on upper leaves and whorl.
3	Ragged holes on upper leaves and partially whorl damaged.
4	Whorl and upper leaves extensively damaged.
5	Whorl completely destroyed and plant drying due to extreme defoliation

RESULTS AND DISCUSSION

Fall armyworm detection survey was conducted at eight locations of six districts in summer maize during May to August 2019. The detail information of surveyed locations along with GPS coordinates (latitude and longitude), altitudes, stages of fall armyworm and district are given in Table 2. Fall armyworm was detected in all the locations surveyed and confirmed by morphological study of larva, pupa and adult moths. The *S. frugiperda* was detected from altitudes of 165 m asl to 1471 m asl. The insect was detected from altitude of 1471m asl at Dhulikhel area of Kavrepalachowk district. Previously, *S. frugipeda* had been confirmed from altitude of 1700 m asl at Mainapokhari area of Dolakha district. The sample was received in Entomology Division from Hill Crop Research Program, NARC (Bajracharya *et al*., 2019). Fall armyworm had also been reported from altitude of 2000 m asl in Mexico though it is less important pest in those high land areas (Andrews, 1988).

Table 2. Fall armyworm occurrence in summer maize at different districts in 2019.

SN	Districts	Locations	GPS coordinates		Altitude (m asl)	*FAW stages confirmed
			Latitude	Longitude		
1	Kavrepalanchowk	Dhulikhel	N 27°35'25.99"	E 085°36'01.72"	1471	L, P, A
2	Kavrepalanchowk	Panchakhal	N 27°39'22.45"	E 085°37'30.41"	867	L, P, A
3	Kavrepalanchowk	Roshi Khola	N 27°31'02.71"	E 085°41'51.58"	832	L, P, A
4	Sindhupalchowk	Pokhare	N 27°39'56.41"	E 085°42'20.97"	930	L, P, A
5	Sindhuli	Jhangajholi	N 27°25'09.33"	E 085°51'47.15"	517	L, P, A
6	Lalitpur	Khumaltar	N 27°39'03.74"	E 085°19'38.59"	1308	L, P, A
7	Chitwan	Bhandara	N 27°36'08.84"	E 084°37'41.88"	199	L, P, A
8	Nawalpur	Gaindakot	N 27°42'16.67"	E 084°22'50.61"	165	L, P, A

*L = Larva, P = Pupa, A = Adult

Similarly, fall armyworm detection survey was conducted in winter and spring maize at 29 locations of 21 districts during February 2020. The detail information of surveyed locations along with GPS coordinates (latitude and longitude), altitudes, and stages of fall armyworm confirmed and districts are given in Table 3. Fall armyworm infestation in maize was confirmed from all surveyed locations in 18 districts (out of 21) based on morphological characters of larva and/or adult moths. Samples from Rautahat and Parsa districts were confirmed only on the basis of morphological characters of larva as larvae from these districts could not reared into adults. Thus, *S. frugiperda* infestation in winter and spring maize was confirmed from Jhapa, Morang, Sunsari, Saptari, Siraha, Dhanusha, Mahottari, Sindhuli, Sarlahi, Rautahat, Bara, Parsa, Makawanpur, Chitwan, Nawalpur, Dang, Banke and Bardiya districts of Nepal. Morphological character of pupa was also studied and confirmed from all above districts except Rautahat and Parsa. The *S. frugiperda* was not found from surveyed locations of Nawalparasi, Rupandehi and Kapilbastu districts.

Location wise stage of maize plants at survey time along with percent plant damaged by fall armyworm and its damage score is given in Table 4. The percent maize plants damage by *S. frugiperda* ranged from five to 56 percent in different locations and damage score ranged from one to three. Winter and summer maize was also found infested with oriental armyworm *Mythimna separata* (Wlk.) at most of the surveyed locations. *M. separata* infestation along with *S. frugiperda* infestation was recorded form Jhapa, Morang, Sunsari, Saptari, Siraha, Dhanusha, Rautahat, Bara, Parsa, Makawanpur and Bardiya districts. However, only *M. separata* infestation was observed from Nawalparsi, Rupandehi and Kapilvastu districts. *M. separata* infestation in maize plants was high in Rautahat (80%) and Dhanusha (30%) districts while, infestation in other districts recorded below 20%.

Table 3. Fall armyworm occurrence in winter and spring maize at different districts in 2020.

SN	Districts	Locations	GPS coordinates		Altitude (m asl)	*FAW stage confirmed
			Latitude	Longitude		
1	Jhapa	Damak	N 26°39.312'	E 087°44.020'	120	L, P, A
2	Morang	Belbari	N 26°39.909'	E 087°24.044'	115	L, A
3	Morang	Salakpur	N 26°39.742'	E 087°21.182'	117	L, P, A
4	Sunsari	Inaruwa	N 26°38.259'	E 087°10.551'	76	L, P, A
5	Saptari	Kanchanpur	N 26°38.693'	E 086°53.831'	85	L, P, A
6	Saptari	Mahuli	N 26°38.613	E 086°51.404'	98	L
7	Siraha	Bayarbuni	N 26°53.784'	E 086°09.256	93	L, P, A
8	Dhanusha	Ratu	N 26°58.987'	E 085°54.756'	201	L, P, A
9	Mahottari	Bardibas	N 27°02.401'	E 085°49.396'	234	L, P, A
10	Sindhuli	Mulkot	N 27°25.139'	E 085°51.758'	534	L, P, A
11	Sarlahi	Bagmati	N 27°07.201'	E 085°29.485	109	L, P, A
12	Rautahat	Chandrapur	N 27°07.497'	E 085°21.199	116	L
13	Bara	Jitpur	N 27°04.755'	E 084°55.990'	94	L, P, A
14	Parsa	Tedha	N 27°09.103'	E 084°56.909'	98	L
15	Makawanpur	Manahari	N 27°32.934'	E 084°44.583'	239	L, P, A
16	Chitwan	Gitanagar	N 27°37.156'	E 084°23.605'	168	L, P, A
17	Nawalpur	Gaindakot	N 27°42.392'	E 084°22.957'	163	L, P, A
18	Nawalparasi	Bardaghat	N 27°29.282'	E 083°47.769'	99	-
19	Nawalparasi	Parasi	N 27°30.900'	E 083°47.260'	96	-
20	Nawalparasi	Sunawal	N 27°36.477'	E 083°38.182'	116	-
21	Rupandehi	Chhapiya-A	N 27°33.468'	E 083°21.070'	86	-
22	Rupandehi	Chhapiya-B	N 27°33.020'	E 083°22.071'	92	-
23	Rupandehi	Sainamaina	N 27°41.752'	E 083°17.200'	113	-
24	Kapilbastu	Badgaon	N 27°41.471'	E 083°09.125'	121	-
25	Dang	Lalmatiya	N 27°50.430'	E 082°44.174'	292	L, P, A
26	Dang	Lamahi	N 27°51.973'	E 082°33.083'	243	L, P, A
27	Banke	Rapti sonari	N 28°07.397'	E 081°48.775'	144	L, P, A
28	Banke	Khajura	N 28°05.119'	E 081°32.362'	129	L, P, A
29	Bardiya	Gulariya	N 28°11.334'	E 081°22.231'	120	L, P, A

*L = Larva, P = Pupa, A = Adult

Table 4. Location wise stage of maize plants with percent plant and damage score.

SN	Districts	Locations	Maize season	Maize stage	% plant infested by *S. frugiperda*	Damage score of *S. frugiperda*	*M. seperata* infestation	% plant infested by *M. seperata*
1	Jhapa	Damak	Winter	V6	14	2-3	Yes	10
2	Morang	Belbari	Winter	V5	20	2	Yes	NA
3	Morang	Salakpur	winter	V6	18	1-2	Yes	NA
4	Sunsari	Inaruwa	Winter	V9	12	1-3	Yes	10
5	Saptari	Kanchanpur	Winter	GF*	30	2-3	Yes	NA
6	Saptari	Mahuli	Winter	GF	30	2-3	Yes	NA
7	Siraha	Bayarbuni	Spring	V3	23	2-3	Yes	20
8	Dhanusha	Ratu	Winter	V6	56	2-3	Yes	30
9	Mahottari	Bardibas	Winter	V9	26	2-3	-	-
10	Sindhuli	Mulkot	Spring	V3	10	1-2	-	-
11	Sarlahi	Bagmati	Winter	V6	12	2	-	-
12	Rautahat	Chandrapur	Winter	GF	6	2	Yes	80
13	Bara	Jitpur	Winter	V6	16	1-2	Yes	20
14	Parsa	Tedha	Winter	V-8	6	1-2	Yes	NA
15	Makawanpur	Manahari	Winter	VT	14	1-2	Yes	NA
16	Chitwan	Gitanagar	Spring	V5	10	1-2	-	-
17	Nawalpur	Gaindakot	Winter	V7	14	2-3	-	-
18	Nawalparasi	Bardghat	Winter	GF	-	-	Yes	NA
19	Nawalparasi	Parasi	Winter	GF	-	-	-	-
20	Nawalparasi	Sunawal	Winter	V6	-	-	Yes	NA
21	Rupandehi	Chhapiya-A	Spring	VE	-	-	-	-
22	Rupandehi	Chhapiya - B	Winter	V7	-	-	Yes	NA
23	Rupandehi	Sainamaina	Winter	V7	-	-	-	-
24	Kapilbastu	Badgaon	Winter	GF	-	-	Yes	NA
25	Dang	Lalmatiya	Winter	V8	10	2	-	-
26	Dang	Lamahi	Winter	V9	16	2	-	-
27	Banke	Rapti sonari	Winter	V7	10	2	-	-
28	Banke	Khajura	Spring	VE	5	1	-	-
29	Bardiya	Gulariya	Winter	V8	16	2	Yes	NA

*Grain filling stage.

The result showed that fall armyworm can survive in winter season in terai and inner terai districts of Nepal where maize crop is cultivated. Foster and Cherry (1987) reported eggs of fall armyworms were most tolerant to cold temperature even surviving at -10°C. They also found adult moths were most susceptible stage to cold temperature and can survive up to -5°C. The minimum normal temperature of terai districts: Biratnagar, Janakpur, Simara, Bhairahawa and Nepalgunj ranged between 7.7°C to 11.3°C over 30 years of period from 1980 to 2010 in Nepal (DHM, 2020). *S. frugiperda* was recorded to survive in mild winters of south-western Texas and southern Florida (Johnson, 1997) though developmental threshold temperature was recorded 10.9°C with requirement of 559 day-degrees centigrade to complete life cycle (Gracia *et al*., 1987). Plesis *et al*., (2020) reported minimum temperature threshold for egg and larva development was 13.01 and 12.12°C, respectively, 13.06°C for pupae and 12.57°C for egg-to-adult development. Thus, *S. frugiperda* can survive during winter in various developmental stages in terai region of Nepal though development period will be prolonged.

The survey confirmed presence of *S. frugiperda* in 21 districts of Nepal in summer and winter maize. The absence of fall armyworm during winter season does not mean that insect might be absent in summer season in Nawalparasi, Rupandehi and Kapilvastu districts as insect is recorded from adjacent districts and they are migratory in nature. Long distance migration by fall armyworm with sustained flight of 16-30 hours had been reported by Van Handel (1974). Fall armyworm cannot diapauses (Johnson, 1987) so it may not survive in harsh cold climate of mid and high hills in Nepal. However, the small population survived in terai region will multiplies as soon as temperature starts to rise in spring. The fall armyworm population multiplied in terai region might migrate to hills as soon as temperature will become suitable.

One of the interesting finding from survey was that both *M. separata* and *S. frugiperda* cohabitated in the same field of winter and spring maize. Competition between two species of noctuidae may occur due to niche overlap as feeding on same resources, leaf and whorl in early stage of plant and reproductive parts in later stage. This competition may cause reduction in larval density of both species per plant. *M. separata* larvae are cannibalistic in late instar larvae (Li *et al*., 2018). *S. frugiperda* larvae are cannibalistic in early instar and have the ability to dominate interspecific competition and reduce intraspecific rivals (Chapman *et al*., 1999). *S. frugiperda* has a competitive advantage against the *Helicoverpa zea* and *Spodoptera albicosta* in the intraguild competition on non-Bt maize under laboratory and field conditions (Bentivenha *et al*., 2016). But conclusion cannot be drawn without study on interspecific competition of *S. frugiperda* and *M. seperata*. This association may result into positive or negative effect from management perspective.

In general, the survey indicated *S. frugiperda* had nearly spread into country from east to west after its first record in May, 2019 from Gaindakot of Nawalpur district (Fig. 1). Winter temperature in terai, inner terai region of Nepal is suitable for survival of fall armyworm in Nepal. This terai population of fall armyworm will migrate to mid and high hills as soon as temperature increases in spring season. Oriental armyworm and fall armyworm can infest same field in winter and spring maize.

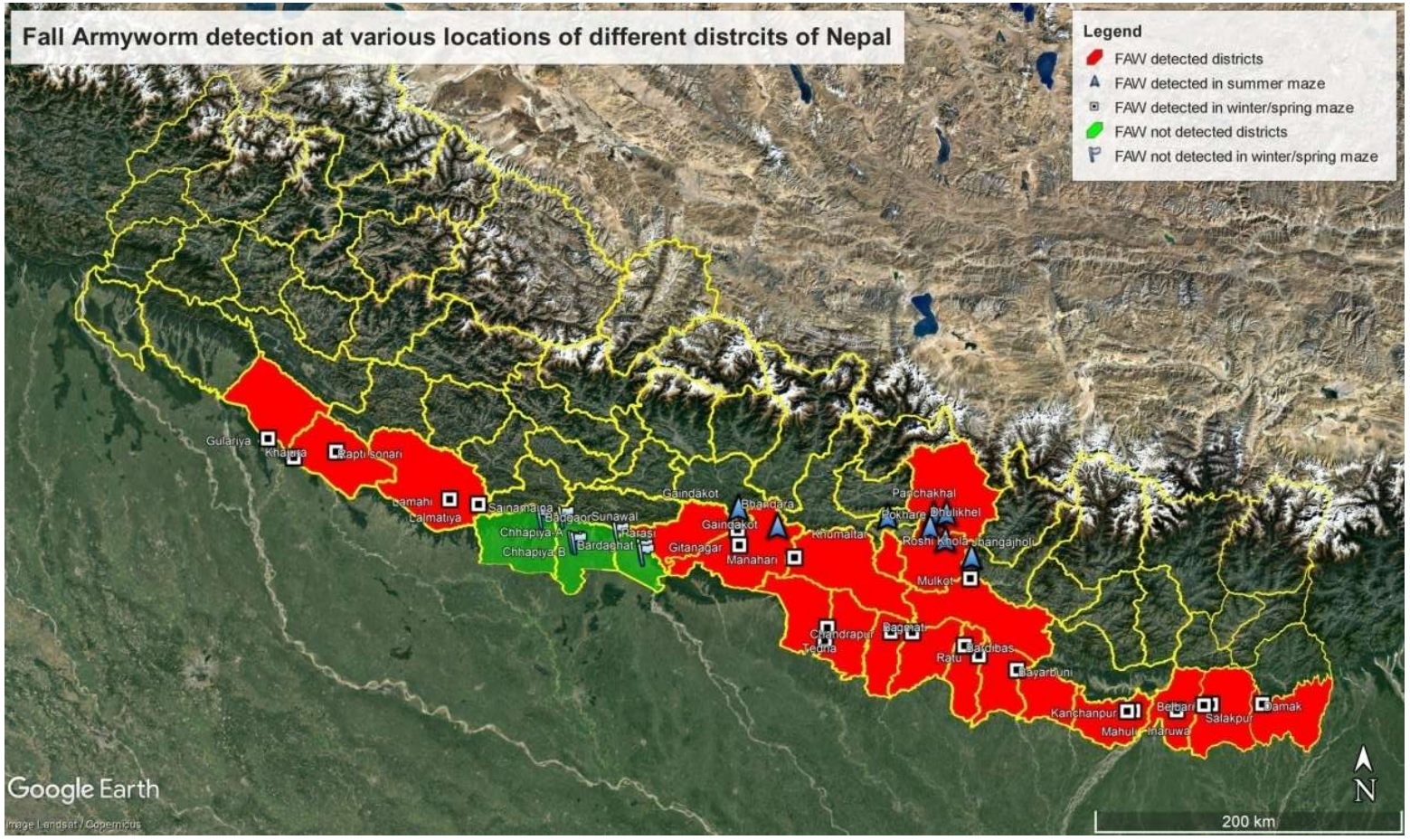

Fig. 1: Detection of fall armyworm at various locations of different districts in Nepal.

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