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Occurrence of maize stem borer complex influenced by weather conditions along with an altitudinal gradient in Nepal

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ABSTRACT

Newly constructed black light traps (BLT) were placed in an open maize cropping area at Rampur in Chitwan (228 masl), Puranchaur (900 masl) and Lumle (1750 masl) in Kaski district of Nepal. Traps were operated at weekly interval from dusk to dawn in fixed day throughout the year for two consecutive years 2017 and 2018, and trapped borer insects recorded. Stem borers complex (*Chilo partellus* Swinhoe and *Sesamia inferens* Walker) were found in the study areas. Maximum number of *C. partellus* (103) moths was trapped in the month of March at Rampur, followed by Lumle (28) and Puranchaur (25) during the month of April with mean temperature ranged 18-24ºC. Similarly, the highest numbers of *S. inferens* (51 and 33) moths were trapped during the month of November at Rampur and Puranchaur; 22 at Lumle area during October at mean temperature range of 14-21ºC, respectively. This study clearly indicated that *C. partellus* was mostly active in summer and *S. inferens* in winter season in all three ecological regions. These results clearly showed that the incidence of borer complex was found more in the lower elevation>300 masl than in the foot hill, 900-1000 masl and the high hill, 1700-1800 masl. Occurrence of the adult of *C. partellus* was positively correlated with maximum temperature **(**r=0.248) and minimum temperature (r=0.751) but negatively corrected with rainfall (r=-0.172) while negatively correlated with maximum temperature (r =-0.652), minimum temperature (r=-0.233) and rainfall (r=-0.575) in the case of *S. inferens.*

INTRODUCTION

Maize (*Zea mays* L.), is an important cereal crop ranked at second after rice in terms of area and production, occupying 956447 ha of land with the production of 2713635 mt (MoAD 2018/19), contributing 3.15% in national gross domestic product (GDP) and 9.5% in agricultural gross domestic product (AGDP) in Nepal (MoAD 2017/18). It contributes 25.39% to total cereal crop production in the country. In spite of diverse cultivation areas and seasons of maize in Nepal, its productivity is only 2.84 mt/ha (MoAD 2018/19). Both biotic and abiotic constraints play a major role in limiting maize yield as compared to other developed nations (Achhami et al. 2015). Among the biotic pests, maize stem borer complex, striped stem borer [*Chilo partellus* (Swinhoe)], pink stem borer, *Sesamia inferens* (Walker) and rice stem borer, *Chilo suppersalis* (Walker) are major ones found in Nepal (Sharma and Gautam 2010; Bhandari et al. 2018). Also, in other countries, striped stem borer (Kavita et al. 2016) and pink stem borer (Deole et al. 2013) are the most damaging insect pests and causes tremendous damage to maize crop. Maize crop loss due to these pests in summer and winter season varies from 60 to 81.7% and 25.7 to 78.9%, respectively (Sekhar et al. 2009). About 20 to 80% of plants sustained damage due to maize stem borers in Nepal (Thakur et al. 2013; Sharma and Gautam, 2010; Achhami et al. 2015). Distribution, relative abundance, status of the pests and yield reduction vary with environmental conditions and ecological gradient. Various researchers noticed that the incidence of the borer complex assorted based on the ecological domain. Farid et al. (2007) reported that the activity of *C. partellus* moths started after the middle March and continued until the middle of May, after which a decline in population was observed in June. Timaru et al. (2012) had opined that the most suitable condition for *C. partellus* development was

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26 to 30ºC temperature. Sidar et al. (2015) reported that the active period of *S. inferens* was end of July to end of November and pick activity period was end of October. Striped stem borer, *C. partellus* has been found at low to mild altitudes commonly occurring below 1500 masl, found up to 1900 masl (Getu, 2002) but predominantly in the low elevation (<600 masl) (Ntambo et al. 2015).

Regular monitoring with respect to ecological niche is an important tool to investigate impacts of elevation and seasonal variation on the distribution and abundance of the pests. It is an established fact that population dynamics of any insect is greatly influenced by weather fluctuations and thereby the location specific studies have become more important (Sharma et al. 2017). For developing any pest management strategies, specific agro-ecosystem information on abundance and distribution of pest in relation to weather parameters is a basic requirement. The seasonal abundance of the stem borers using light traps was studies by earlier researchers, but influence of weather factors on population fluctuation of borer complex was scanty. Hence, the present study was carried out to investigate population dynamics of maize stem borer complex in different geographical elevation with prevailing weather conditions.

MATERIALS AND METHODS

Study site

The study was done at three sites having diverse agro-ecological conditions, which represent the major maize growing areas, from Inner Terai to High Hill of Nepal (Table 1).

Light trap setting and monitoring of maize stem borers

Locally developed black light trap (Bhandari et al. 2017) (Figure 1) was installed at each location and maize borer complex associated with maize-based cropping system recorded at weekly interval in fixed date regularly for two consecutive years (2017-2018). The black light traps (BLT) were placed in an open maize cropping area at experimental plots at Rampur, Chitwan; Puranchaur and Lumle, Kaski district. Light was turned on from dusk to dawn every week in a fixed day throughout the year. Trapped insects were identified, and the numbers of each species were averaged for each month. The insect species collected from each sampling site were annually average on their relative abundance and frequency of occurrence computed.

Abundance and Relative abundance

Abundance is the relative representation of a species in a particular ecosystem. It is usually measured as the number of individuals found per sample. Relative species abundance is calculated by dividing the number of species from one group by the total number of species from all groups.

$$\text{Relative abundance (\%)} = \frac{\text{The abundance of one species}}{\text{Total all species counted}} \times 100$$

Meteorological data and analysis

Monthly meteorological data (temperature and rainfall) was obtained from the Department of Hydrology and Meteorology (DHM), Kathmandu, Nepal. A simple correlation study between number of adult borers trapped and the weather data (maximum temperature, minimum temperature and rainfall) were done. All the collected data were analyzed by using Excel and GenStat software and subjected to correlation analysis with the weather parameters.

Figure 1. Black light trap (BLT)

Table 1. Geographical location and weather condition of the study sites

Locations	Landscapes	Latitude	Longitude	Altitude (masl)	AMT (˚C)	AMP (mm)
NMRP, Chitwan	Inner Terai	27.63ºN	84.31ºE	176-228	24.3	166
Puranchaur, Kaski	Foot hill	28.31ºN	83.97ºE	900-1000	20.9	311
Lumle, Kaski	Mid hill	28.38ºN	83.83ºE	1700-1800	16.1	454

AMT=Annual mean temperature, AMP=Annual mean precipitation, masl=meter above sea level, mm=millimeters, ˚C=degree centigrade

RESULTS AND DISCUSSION

Relative abundance of maize stem borers

The study clearly showed that striped stem borer (SSB), *Chilo partellus* and pink stem borer (PSB), *Sesamia inferens* were major pests in the study area. Relative abundance of both stem borer species was highest (PSB-62.3% and SSB-45.2%) in Rampur followed by Puranchaur (PSB-19.9% and SSB-31.0%) and Lumle, Kaski (PSB-17.8% and SSB-23.7%) in pooled analysis over the locations (Table 2). These results clearly showed that the incidence of maize stem borers was found more in lower elevation (inner terai) than in the foot hill and the high hill. These results clearly showed that the incidence of borer complex was found more in the lower elevation>300 masl than in the foot hill, 900-1000 masl and the high hill, 1700-1800 masl. The present findings are in agreement with that of Mwalusepo et al. (2015) reported that distribution of *C. partellus* was more at low altitudes than at high altitudes (above 1100 m). It has been found at low to mild altitudes commonly occurring below 1500 masl, found up to 1900 masl (Getu 2002), but predominantly in the low elevation (<600 masl) (Ntambo et al. 2015).

Seasonal occurrence of maize stem borers

Their results (Table 3) showed that *C. partellus* was mostly active in summer (February to July) and *S. inferens* generally active in winter (September to December) in all study sites. The present finding are in accordance with that of Siddiqui and Marwaha (1993) reported that *C. partellus* was mostly active during rainy season and *S. inferens* during post rainy season. Similarly, Zhang et al. (2019) agreed that *S. inferens* has cold tolerance mechanisms; therefore, it is an emerging pest, which causes economic importance for winter maize (Sharma et al. 2017). Periodical observation on the occurrence of *C. partellus* revealed that the adults were first trapped in the month of February in both the years 2017 and 2018. There was increase in population in subsequent weeks and reached its peak numbers (43 and 44) in the month of March in the same years when mean temperature ranged 15ºC-30ºC. Similarly, second peak numbers (33 and 36) were also observed in the month of May in both of the years. After that its population started declining slowly from June to October. Similarly, the adult of pink stem borer, *S. inferens* appeared in the month of January and the adult population was 4 in 2017 and 2 in 2018. Reports of earlier workers confirm the present finding that Ishtiyaq et al. (2008) observed that maize stem borer appeared in light trap maximum (47adults/trap) at maximum and minimum temperature of 29.3ºC and 16.5ºC with 82.6% relative humidity in upper Himalaya of Jammu region. Similarly, Khadioli et al. (2014) reported that *C. partellus* population's development within the temperature range 18-35ºC. The first peak adult populations were 12 during March in 2017 and 21.3 during same month in 2018. Thereafter, the adult population gradually decreased up to July then, gradually increased the adult population onward December and the maximum number of adults (32) were trapped during October in 2017 and 37 during November in 2018 when mean temperature was 12-24ºC respectively (Table 3). Likewise, the peak populations of 44 and 34 adults were trapped during March and October for *C. partellus* and *S. inferens* respectively in combined analysis. In season wise comparision, *C. partellus*

Table 2. Relative abundance of stem borer complex at with altitudinal gradients

Altitude	Stripe stem borer						Pink stem borer					
	2017		2018		Combined		2017		2018		Combined	
	A	RA	A	RA	A	RA	A	RA	A	RA	A	RA
Rampur, Chitwan (176-228 masl)	249	62.9	254	61.7	252	62.3	137	32.7	223	49	180	45.2
Puranchaur, Kaski (900-1000 masl)	80	20.2	81	19.7	81	19.9	122	34.1	125	26.4	124	31.0
Lumle, Kaski (1700-1800 masl)	67	16.9	77	18.7	72	17.8	98	33.2	91	24.6	95	23.7
Mean	132	33.3	137	33.3	135	33.3	119	33.3	146	33.3	133	33.3
Total	396	100	412.0	100	404	100	357	100	455	100	398	100
SD	101.5	25.6	101	24.5	101.4	25.1	19.7	0.7	79	13.6	48.5	11.9
SEM±	58.6	14.8	58.3	14.2	58.5	14.5	11.4	0.4	45.6	7.9	28	6.9

A=Abundance (no.), RA=Relative abundance (%)

Table 3. Number of maize stem borer complex occurrence in different month and seasons

Season	Month	2017		2018		Pooled analysis	
		C. partellus	*S. inferens*	*C. partellus*	*S. inferens*	*C. partellus*	*S. inferens*
Spring	January	0.0(0.7)^{a}	0.0(0.7)^{a}	0.0(0.7)^{a}	1.8(1.3)^{abc}	0.0(0.7)^{a}	1.8(1.3)^{a}
	February	7.0(2.6)^{abc}	9.0(2.9)^{bcd}	8.8(2.8)^{abc}	15.7(3.4)^{bcde}	8.8(2.8)^{abc}	13.7(3.3)^{bc}
	March	42.7(5.8)^{d}	12.3(3.5)^{cd}	44.0(5.9)^{d}	21.3(4.5)^{def}	43.5(5.9)^{d}	17.2(4.1)^{cde}
	April	20.7(4.4)^{cd}	9.3(3.0)^{bcd}	20.3(4.5)^{cd}	14.2(3.5)^{cde}	20.8(4.5)^{cd}	12.8(3.4)^{bc}
Mean		17.6(3.4)	7.7(2.5)	18.3(3.5)	13.3(3.2)	18.3(3.5)	11.4(3.0)
Summer	May	33.0(5.5)^{d}	6.0(2.5)^{abcd}	35.5(5.8)^{d}	5.0(2.2)^{abcd}	33.8(5.6)^{d}	5.2(2.3)^{abc}
	June	12.0(3.5)^{bcd}	0.0(0.7)^{a}	13.3(3.7)^{bcd}	0.0(0.7)^{a}	12.8(3.6)^{bcd}	0.0(0.7)^{a}
	July	8.0(2.9)^{abc}	0.0(0.7)^{a}	6.3(2.5)^{abc}	0.0(0.7)^{a}	7.0(2.7)^{abc}	0.0(0.7)^{a}
	August	0.0(0.7)^{a}	2.0(1.3)^{ab}	1.3(1.3)^{ab}	0.8(1.1)^{ab}	0.7(1.1)^{ab}	1.6(1.4)^{ab}
Mean		13.3(3.1)	2.0(1.3)	14.1(3.3)	1.45(1.2)	13.6(3.2)	1.7(1.3)
Winter	September	1.7(1.3)^{ab}	15.0(3.9)^{de}	3.3(1.6)^{ab}	9.5(3.1)^{abcd}	3.3(1.6)^{ab}	13.3(3.7)^{cd}
	October	4.3(1.7)^{ab}	32.0(5.6)^{e}	4.2(1.7)^{ab}	29.8(5.5)^{ef}	4.2(1.7)^{ab}	30.5(5.5)^{de}
	November	0.0(0.7)^{a}	28.0(5.3)^{e}	0.0(0.7)^{a}	36.7(5.9)^{f}	0.0(0.7)^{a}	33.8(5.7)^{e}
	December	0.0(0.7)^{a}	5.3(1.8)^{abc}	0.0(0.7)^{a}	1.0(1.1)^{ab}	0.0(0.7)^{a}	2.8(1.6)^{ab}
Mean		1.5(1.1)	20.1(4.2)	1.9(1.2)	19.3(3.9)	1.9(1.2)	20.1(4.1)
Grand mean		10.8(2.5)	9.9(2.7)	11.4(2.6)	11.3(2.7)	11.2(2.6)	11.1(2.8)
CV, %		53.7	38.6	50.3	46.6	51.2	38.8
T-test		*	**	*	**	*	**
LSD $_{(0.05)}$		28.20	11.28	27.41	17.6	27.61	13.76

(*= P<0.05; **P< 0.01), means with same letter are not significantly different at 0.05 level of significance.

was mostly active in summer season and *S. inferens* generally active in winter season in all ecological gradients.

Population dynamic of striped stem borer in relation to weather

The average number of maize stem borer complex has been illustrated in figures (2, 3 and 4). The study clearly showed that *Chilo partellus* moth first appeared in January and reached maximum in number during the month of March (134 adults). Then after the population declined gradually to minimum (1 adult) during January when the maximum and minimum temperatures were 22.5ºC and 8.0ºC respectively at Rampur, Chitwan (Figure 2). The present findings are in agreement with Thakur et al. (2013) who reported that an average stem borer damage was more in the month of April (58.2%) and gradually decreased in the month of November to February with decrease in temperature. The finding of Singh and Singh (2013) is consistent with the results of the present study. Similarly, the adult of *C. partellus* moth was first appeared in February and reached to its peak in April at the temperature of 29.7ºC and minimum rainfall (9.5 mm) at Purachaur, Kaski (Figure 3). Tamiru et al. (2012) presented his opinion that the most suitable condition for the development of *C. partellus* was 26 to 30ºC temperature, and according to Zulfiqar et al. (2010) it was 32.5ºC. Likewise, the moth activity started in February and continued up to August with a peak population (37 adults) in April at the mean temperature (17.7ºC±2ºC) and lower rainfall (64 mm±5 mm) at Lumle, Kaski (Figure 4). The findings of Kumar et al. (2017) also support the present results. The present study clearly indicated that activity of *C. partellus* moth has been shifted with the climatic variation from Terai (tropical) to Mid Hill (upper sub-tropical) of Nepal. Likewise, the present findings are in agreement with Mwalusepo et al. (2015) that *C. partellus* was found in cooler and higher altitude areas, in contrast to its known optimal ecological conditions indicating an expansion of its geographical ranges.

Population dynamic of pink stem borer in relation to weather

Pink stem borer (*Sesamia inferens*) activity started in February and continued up to June then after gradually declined up to August at Rampur. Population increased again from September to November, with peak (42 adults) in mid-November when maximum and minimum temperature was 28.3ºC and 15.1ºC respectively (Figure 2). The present finding is in consistence with Singh and

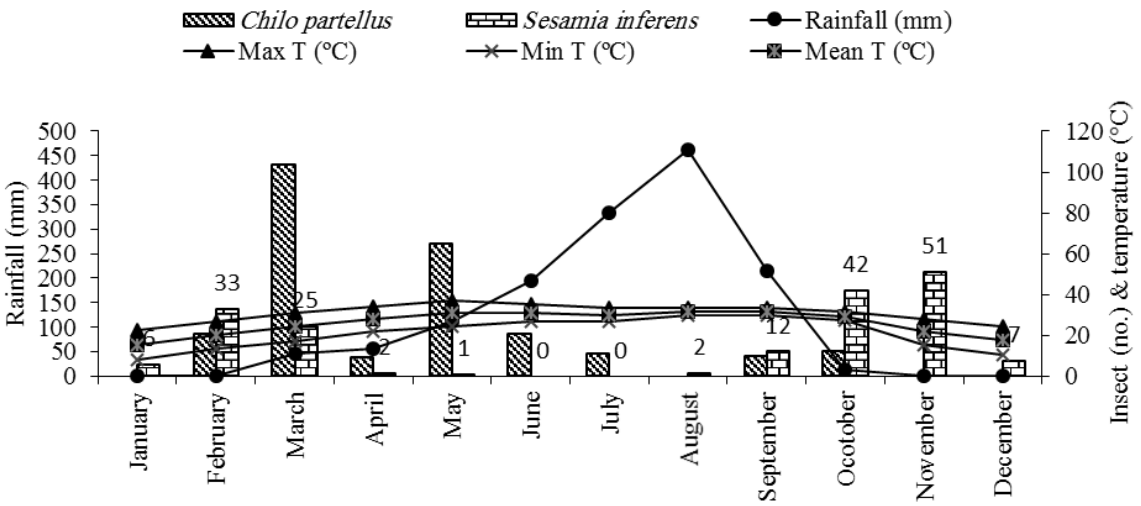

Figure 2. Effect of temperature and rainfall on incidence of stem borers at Rampur, Chitwan during 2017/18

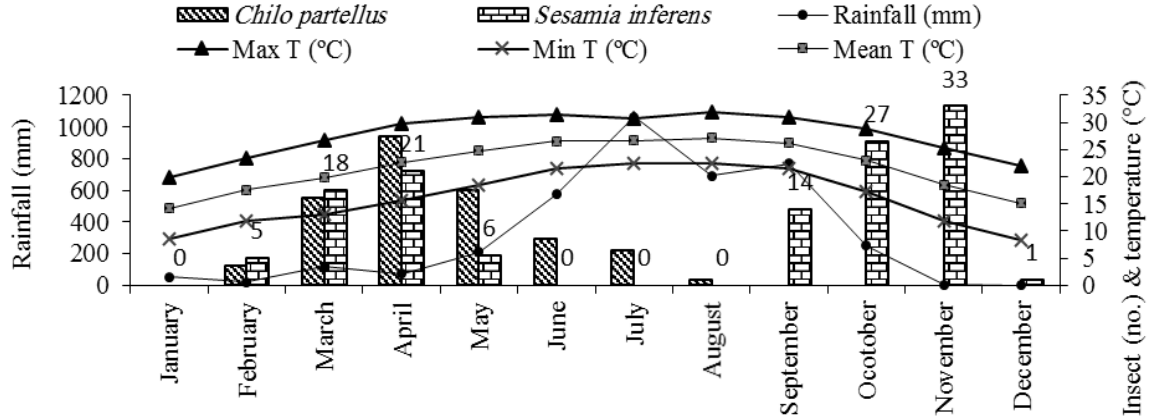

Figure 3. Effect of temperature and rainfall on incidence of stem borers at Puranchaur, Kaski during 2017/18

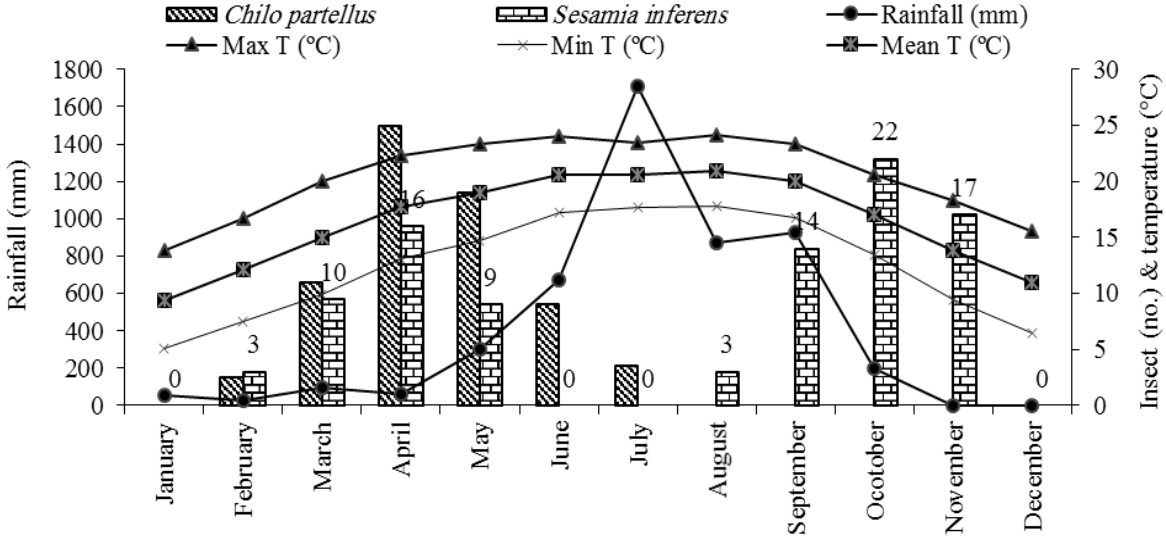

Figure 4. Effect of temperature and rainfall on incidence of stem borers at Lumle, Kaski during 2017/018

Kular (2015) as they noted that maximum incidence of *S. inferens* was observed in the months of September-October when maximum and minimum temperature ranged from 31.9 to 33.9ºC, 22.2 to 26.3ºC, respectively.

At Puranchaur, the initial occurrence of *S. inferens* started in February and continued up to June with peak (21adult) in April when maximum and minimum temperature were 29.7ºC and 15.7ºC respectively and rainfall was 74 mm (Figure 3). Deole et al. (2017) also found that the maximum adult population was trapped during third and fourth week of March when the maximum temperatures ranged from 29.7ºC to 36.4ºC and minimum temperatures ranged from 16.4ºC to

Table 4. Correlation of population of maize stems borers with temperature and rainfall at different altitude in 2017 and 2018

Weather parameters	Altitudinal gradients (masl)						Pooled analysis	
	176-228		900-1000		1700-1800			
	SSB	PSB	SSB	PSB	SSB	PSB	SSB	PSB
Max T (°C)	0.157	-0.393	0.341	0.060	0.348	0.106	0.248	-0.120
Min T (°C)	0.036	-0.327	0.116	-0.174	0.156	-0.044	0.751*	-0.233
Mean T (°C)	0.036	-0.361	0.218	-0.072	0.242	0.022	0.112	-0.189
Rainfall (mm)	-0.137	-0.594*	-0.150	-0.445*	-0.167	-0.456*	-0.172	-0.575*

*Significant at P = 0.05, SSB=Stripe stem borer, PSB=Pink stem borer, masl=Meter above sea level Max T=maximum temperature, Min T=minimum temperature

19.4ºC. The borer reappeared from September and continued up to November with peak (33 adults) in November with maximum and minimum temperature of 25.2ºC and 11.8ºC respectively. Similar finding was reported by Chaudhary and Sharma (1992) that the moth populations of *S. inferens* were highest in March and October; and also emerged in February and November, as the borer requires lower temperature for emergence.

At Lumle, the adult moth was first trapped in February and continued up to June with peak emergence (28 adults) in the month of April when maximum and, minimum temperature were 22.3ºC and 13.2ºC, respectively and rainfall was 64 mm (Figure 4). Again next cycle of moth activity started during the month of September and continued up to November with peak emergence (30 adults) during November with maximum and minimum temperature of 18.4ºC and 9.4ºC respectively. Similar finding was reported by Deole et al. (2017) and Sharma et al. (2017). Sidar et al. (2015) reported that the active period of *S. inferens* was at the end of July to end of November and pick activity period was the end of October. Deole (2016) observed highest larval population of *S. inferens* during last week of February on maize field and peak activity of adult moths was found during second week of March in Chandigarh. Mahesh et al. (2013) recorded the seasonal incidence of *S. inferens* which indicated that its infestation started in March, peaked by third week of May, gradually declined after the onset of monsoon and reached the minimum by the second week of June. Akhter et al. (2015) in Pakistan trapped *S. inferens* in light trap below 32ºC in all winter season.

Correlation between occurrence of stem borers and weather conditions

The interactions between the adult population of *Chilo partellus* and weather parameter during 2017-2018 revealed positive correlation with maximum temperature (r=0.248), highly significant in minimum temperature (r=0.751), while the interaction with rainfall showed negative correlation (r=-0.172). Hamid et al. (2019) also found that adult moth catch of *C. partellus* showing positive and significant correlation with maximum and minimum temperature. The interactions between the adult population of *Sesamia inferens* and weather parameters during (2017-2018) revealed negative and significant correlation with maximum temperature (r =- 0.6519), minimum temperature (r=-0.233) and rainfall (r=-0.575) (Table 4). Similar observation was noted by Deole et al. (2017) which showed negative and significant correlation of *S. inferens* with maximum temperature (r =-0.4964) and minimum temperature (r =-0.566). Joshi et al. (2009) also found significant negative correlation with maximum and minimum temperatures. Singh and Kular (2015) reported negative correlation between the incidence of *S. inferens* and maximum and minimum temperatures and Sharma et al. (2017) reported significant negative correlation with rainfall.

CONCLUSIONS

The incidence of striped stem borer (*Chilo partellus*) started from February and continued up to August with peak incidence in March at study sites. Similarly, pink stem borer (*Sesamia inferens*) adult activity started from February and continued up to July and decreased in August. It again increased from September to December with peak incidence in October. This study clearly indicated that striped stem borer; *C. partellus* was mostly active from February to July but pink stem borer, *S. inferens* from February to June and September to November in all three ecological regions. The relationship between *C. partellus* adult population with maximum and minimum temperature showed positive correlation and negative correlation with rainfall. Similarly, the interactions between the adult population of *S. inferens* and weather parameters (maximum, minimum temperature and rainfall) showed negative correlation. In

conclusion, study of the maize borer population dynamics is useful in developing strategy to manage borer complex during the maize growing seasons at different geographical regions of Nepal.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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