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Review Articles

Research Articles

Research Article

EFFECT OF PLANTING DATES OF MAIZE ON THE INCIDENCE OF BORER COMPLEX IN CHITWAN, NEPAL

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ABSTRACT

Borer complex (*Chilo partellus* Swinhoe and *Sesamia inferans* Walker) are the major pests of maize in Nepal. Infestation of maize borer complex as well as climatic variability of growing areas are the major causes for low production and productivity of maize as compared to neighboring countries. Therefore, an experiment was conducted to find out the effect of planting time on open pollinated and hybrid maize variety for the incidence of borer complex during winter, spring, and summer seasons at the experimental field of National Maize Research Program, Chitwan. The experiment was conducted using Randomized Complete Block design with a factorial combination of treatments, each replicated for three times, for two maize genotypes, at every 10 days interval. The results showed that borer incidence varied with maize planting dates and genotypes. The highest plant damage by stem borers was up to 29.9% in genotype S03TLEY-FM (open pollinated variety) and 29.0% in RML 95/RML 96 (hybrid variety) at May planting, respectively. The crop planted from January to February reached into knee height stage when the temperature ranged 25-28$^{\circ C}$ during February to March which was more favorable for the growth and development of borers. September planting was the best time for hybrids, and September as well as March planting was best time for open pollinated variety with respect to low borer incidence in Chitwan condition.

Key words: Maize, planting date, borer complex, temperature, season

INTRODUCTION

Maize (*Zea mays* L.) is the second most important staple food crop after rice and serves as a major food crop in the hills of Nepal. It is cultivated in terai to high hills up to 2500 meter above sea level in Nepal. It contributes 3.15% in national GDP, 9.5% in AGDP and 26.06% to total cereal crop production in the country (MoAD, 2014). In spite of diverse cultivation areas and seasons of maize in Nepal, the productivity of maize is 2.55 ton/ha (MoAD, 2017). One of the important constraints responsible for low productivity is undoubtedly the attack of various insect pests particularly the stem borer complex limiting maize yield as compared to other developed nations (Achhami et al., 2015). Maize stem borer complex include; *Chilo partellus* (Swinhoe), *Sesamia inferans* Walker and *Chilo suppersalis* Walker, which are the serious insect pests (Neupane et al., 1984) and attack all parts of the plant except roots and cause damage by the destruction of the growing point in the whorl (dead heart), loss of photosynthetic leaf area due to foliar feeding, lodging due to burrowing in the stem, and extensive damage to young kernels due to feeding of larvae from the second and third generations (Thakur et al., 2013). Damage is critical when the growing points of young plants are completely damaged, when there is extensive lodging due to stem boring, and when second and third generation larvae feed directly on the cob. The larvae after entering the stem, feed on the internal tissues (pith) and tunnels are formed (Siddiqui and Marwaha, 1993). Mallapur et al. (2012) recorded maize stalk infestation by stem borers at the time of harvest in the farmer's fields. Yield loss as high as 40% has been attributed to stem borers (Chabi et al., 2005). About 20 to 80% of plants damaged due to maize stem borer were recorded in various studies in Nepal (Thakur et al., 2013; Neupane et al.,1984a). In severe cases, "dead hearts" are formed and such plants do not bear the ears. The extent of damage due to stem borer complex vary significantly with changing weather, such as temperature, relative humidity and rainfall (Achhami et al., 2015).

Chitwan represents central terai region of Nepal where maize can be grown during three seasons: spring, summer and winter (Nayava and Gurung, 2010). The time of maize planting was reported to have a distinct effect on the levels of infestation and successive yield loss caused by stalk borers in maize (Van Rensburg et al., 1985; 1987). The first generation moth flight results in stalk borer infestation of maize in the whorl stage of plant development while the second and third generations infest older maize plants. The main

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objective of this study was to determine the effect of time of planting of maize and the levels of infestation and damage caused by borer complex with particular seasonal variation over the year. Assessment of crop losses due to insect attack is essential in determining pest status, economic threshold levels and suppression strategic options for pest management. It is also a tool in decision making in agricultural planning and forecasting.

MATERIALS AND METHODS

Experimental site and design: This research was carried-out at the Maize Research Farm of the National Maize Research Program, Rampur, Chitwan, Nepal. The geography of the experimental site is latitude 27^0 40'N, longitude 84^0 19' E, and 228 m mean sea level. The experiment was conducted using Randomized Complete Block design with a factorial combination of treatments, each replicated for three times, for two maize genotypes, at every 10 days interval. Accordingly, two promising maize genotypes- SO3TEY-FM (open pollinated genotype) and RML-95/RML-96 (Hybrid genotype) were planted throughout the year at 10 days intervals. Each planting was done in two rows of five meter length with a cropping geometry of 60 cm×25 cm. All the agronomic practices, such as fertilizer application, weeding, side-dressing, and other necessary management practices were done as per the recommendation to maintain good crop stand except any application of plant protection measure.

Data collection: Individual sample plant in each genotype was thoroughly examined and damage done by stem borers including other major and minor pests were recorded. Plant damage was recorded at 10 days interval; stem tunneling, exit hole, cob length, cob diameter, and grain yield were taken from the tested genotypes at harvest.

Plant sampling: Ten plants from each tested genotype at each date of planting were collected for exit hole and tunnel length measurement. Similarly, five cobs from each date of planting from each tested genotype were taken to measure cob diameter and cob length, respectively.

Plant damage parameters: Plant damage percentage was observed visually during the vegetative (V8 leaf stage) and just before tasseling (V12 leaf stage) by counting healthy and damaged plants of both tested genotypes at each date of planting. However, the exit holes made by stem borer complex from the sampled plants were counted visually after removing the intact leaves on stem, and then each stalk was longitudinally dissected to record length of tunnel made by the borer inside the stalk and scored as given in Table (1).

Table 1. Stem borer leaf damage scoring scale (1-9)

Scale	Description	Host reaction
1	No visible leaf feeding damage	Highly resistant (RH)
2	Few pin holes on older leaves	Resistant (R)
3	Several shot-holes injury on a few leaves	Resistant (R)
4	Several shot-hole injuries common on several leaves or small lesions	Moderately resistant (MR)
5	Elongated lesions (> 2 cm long) on a few leaves	Moderately resistant (MR)
6	Elongated lesions on several leaves	Susceptible (S)
7	Several leaves with elongated lesions or tattering	Susceptible (S)
8	Most leaves with elongated lesions or severe tattering	Highly susceptible (HS)
9	Plant dying as a result of foliar damage	Highly susceptible (HS)

Source: Ampofo and Saxena (1987).

Pest incidence was calculated using following formulae:

$$\text{Percent infestation} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

$$\text{Length of tunneling (\%)} = \frac{\text{Length of tunneling (cm)}}{\text{Total length of stem (cm)}} \times 100$$

Yield attributes: Cob diameter, cob length, 1000 grain weight were measured after harvesting of five sample cobs from each date of planting of each tested genotype. Cob diameter was measured by using Vernier caliper.

In case of grain yield estimation, all harvested cobs were converted into mt/hectare by using the formula: field weight (kg) × (100-moisture content) × (10,000 × 0.8)/ (net plot area ×shelling percentage ×1000).

Grain yield measurement: Grain yield (kg per plots) at 15 percent moisture was converted into mt/ha and calculated with the help of following formula:

$$\text{Grain yield (ton/ha)} = \frac{\text{Grain yield}\left(\frac{\text{kg}}{\text{plot}}\right) \times \text{selling\%} \times 10\left(100 - \text{moisture\%}\right)}{\text{Not plot area (m}^2) \times 85}$$

Data analysis: All the collected data were analyzed by using Excel and GenStat software and subjected to correlation analysis with the weather parameters.

Weather parameters

Climate and weathers can significantly influence the growth and development and distribution of insects. Weather parameters were recorded during the experimental period from the weather station established at National Maize Research Program, presented as below in figure (1).

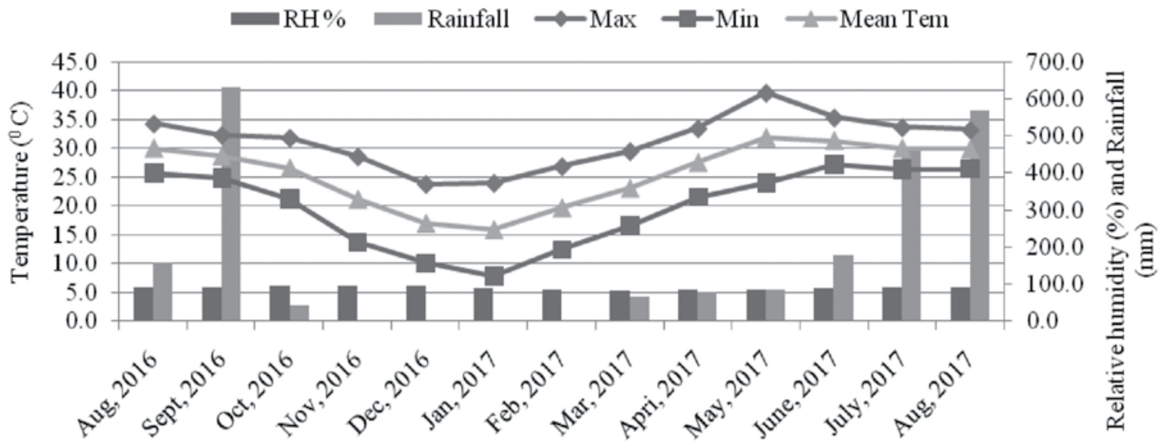

Figure 1. Meteorological data during experimental period (2016/ 2017) at Rampur, Chitwan, Nepal

RESULTS AND DISCUSSION

Leaf damage and dead heart

Stem borer damage on leaves and dead heart of the tested genotypes (2016/2017) is presented in Table (2). There was highly significant difference with planting date irrespective of the genotypes. However, no significant difference occurred between genotypes and interaction with genotype × planting date in all cases. The observation indicated that leaf damage and dead heart of both genotypes gradually increased with the progress of planting date from first week of October to mid of December and slightly declined from first week of January to mid February, which again gradually increased for both the genotypes from 3rd week of February to end of July. Among the genotypes tested, RML-95/RML-96 (hybrid genotype) was more sensitive to maize stem borers in terms of mean leaf damage (14.2%) and dead heart (1.7%) than S03TLEY-FM (open pollinated full season genotype) where leaf damage and dead heart recorded 13.7% and 1.6%, respectively. In this study, maximum infestation (50.8%) was recorded in RML-95/RML-96 genotype at mid May planting followed by 47.6% damage in S03TLEY-FM in the same date. Similarly, the minimum infestation (4.1-4.5%) was recorded in mid February planting in both the genotypes.

The lowest range of leaf damage (6.0-9.3%) was recorded in the planting months from end of December to mid February in both the genotypes and the lowest range of dead heart (0.7-1.0) was recorded from first week of September to mid of October (Table 2).

Among the seasons within the year, more infestation was observed in summer (17.4%) than spring (11.55%) and winter (11%) in term of leaf damage for both genotypes. Similarly, more or less same result was obtained in spring (1.1%) and summer (1.09%) than winter (1.03%) for dead heart calculation (Table 2).

Table 2. Response of maize genotypes to maize stem borer's incidence at Chitwan, Nepal during 2016/017

Season	Date	DKHS (25-30 DAS)		DBTS (45-50 DAS)		Dead heart (%)		Tunnel length (cm)		Exit holes (no.)	
		RML95/ RML96	S03TLE YFM	RML95/ RML96	S03TLE YFM	RML95/ RML96	S03TLE YFM	RML95/ RML96	S03TLE YFM	RML95/ RML96	S03TLE YFM
Winter	04-Sep-2016	9.7(3.0)	8.3(2.9)	9.9(3.1)	8.1(2.9)	0.8	0.8	4.1(0.9)	3.6(1.0)	0.9(2.0)	1.1(1.8)
	14-Sep-2016	10.7(3.2)	10.3(3.2)	12.5(3.5)	11.1(3.3)	0.9	0.7	1.0(0.6)	3.0(1.0)	0.5(0.8)	1.1(1.7)
	24-Sep-2016	9.0(3.0)	12.1(3.5)	9.0(3.0)	10.7(3.3)	0.7	1.0	0.9(0.4)	0.7(0.4)	0.2(0.8)	0.2(0.7)
	04-Oct-2016	14.7(3.8)	14.6(3.7)	14.7(3.8)	12.6(3.5)	0.9	0.7	0.1(0.3)	2.3(0.5)	0.1(0.0)	0.5(1.1)
	14-Oct-2016	17.4(4.2)	13.1(3.6)	17.4(4.2)	14.0(3.7)	1.0	0.7	0.8(0.4)	1.3(0.5)	0.2(0.7)	0.3(1.0)
	24-Oct-2016	14.9(3.8)	9.4(3.0)	12.4(3.5)	13.7(3.7)	1.1	1.2	1.2(0.6)	0.2(0.3)	0.3(1.1)	0.1(0.2)
	03-Nov-2016	25.5(5.0)	13.0(3.6)	9.7(3.1)	7.5(2.7)	0.7	0.7	2.2(0.5)	0.6(0.4)	0.4(1.4)	0.2(0.8)
	13-Nov-2016	26.7(5.1)	15.2(3.8)	7.9(2.8)	12.2(3.5)	1.2	1.0	4.0(0.6)	3.9(0.6)	0.5(1.6)	0.6(1.9)
	23-Nov-2016	19.9(4.4)	13.0(3.6)	7.8(2.8)	8.3(2.9)	1.1	1.1	5.3(0.7)	3.1(0.8)	0.6(2.3)	0.6(1.6)
	03-Dec-2016	8.3 (2.8)	9.1(3.0)	4.7(2.2)	5.5(2.3)	0.8	0.8	1.8(0.6)	2.9(0.7)	0.5(1.3)	0.5(1.6)
	13-Dec-2016	16.4(4.0)	10.5(3.2)	8.3(2.8)	6.8(2.6)	1.1	0.9	5.0(0.7)	2.3(0.6)	0.6(2.2)	0.4(1.5)
	23-Dec-2016	8.9(3.0)	6.7(2.6)	7.0(2.6)	5.2(2.3)	0.8	1.0	5.2(0.7)	10.2(1.0)	0.6(2.0)	1.2(3.2)
Spring	02-Jan-2017	8.5(2.9)	10.4(3.2)	9.2(3.0)	8.4(2.9)	1.0	0.8	15.9(1.5)	11.6(1.3)	2.2(4.0)	1.8(3.4)
	12-Jan-2017	7.1(2.7)	11.1(3.3)	7.9(2.7)	6.9(2.6)	0.9	1.0	15.4(1.5)	11.4(1.2)	2.3(3.9)	1.5(3.3)
	22-Jan-2017	8.3(2.7)	7.7(2.7)	10.2(3.1)	7.7(2.7)	1.0	0.7	7.8(1.1)	7.4(1.2)	1.4(2.7)	1.8(2.4)
	01-Feb-2017	5.5(2.3)	7.7(2.7)	7.6(2.7)	7.2(2.6)	1.0	1.1	10.4(1.2)	21.7(2)	1.6(3.0)	4.1(4.5)
	11-Feb-2017	4.1(2.0)	4.5(2.1)	12.3(3.4)	8.1(2.7)	1.0	1.0	12.3(1.6)	19.5(1.8)	2.7(3.4)	3.2(4.4)
	21-Feb-2017	11.4(3.4)	15.3(3.9)	26.4(5.1)	15.0(3.8)	1.3	1.5	14.0(2.1)	18.9(1.9)	4.3(3.7)	3.6(4.2)
	03-Mar-2017	12.4(3.5)	16.6(4.1)	32.3(5.7)	20.4(4.4)	1.4	1.5	8.2(1.5)	18.6(2.1)	2.2(2.8)	4.3(4.3)
	13-Mar-2017	8.3(2.8)	5.2(2.3)	20.2(4.4)	21.8(4.6)	1.1	1.1	6.4(1.3)	10.9(1.6)	1.7(2.5)	2.6(3.2)
	23-Mar-2017	11.4(3.4)	15.3(3.9)	10.8(3.2)	12.4(3.5)	1.1	1.4	6.6(1.2)	7.8(1.4)	1.4(2.5)	2.0(2.8)
Summer	02-Apr-2017	10.0(3.1)	10.3(3.2)	6.3(2.5)	6.9(2.6)	1.0	1.0	13.9(1.7)	8.7(1.5)	2.9(3.7)	2.3(2.9)
	12-Apr-2017	14.9(3.8)	17.2(4.0)	34.5(5.7)	17.8(4.2)	0.8	0.8	15.5(1.9)	7.8(1.3)	3.7(3.9)	1.7(2.8)
	22-Apr-2017	10.7(3.2)	9.7(3.1)	25.5(5.0)	24.4(4.9)	1.2	1.3	14.7(1.7)	14.1(1.5)	3.0(3.8)	2.5(3.4)
	02-May-2017	5.7(2.4)	5.9(2.4)	35.1(5.8)	31.5(5.6)	1.4	1.3	14.3(1.9)	21.0(2.2)	3.8(3.8)	4.9(4.6)
	12-May-2017	10.4(3.2)	9.0(3.0)	47.6(6.9)	50.8(7.1)	1.2	1.2	11.6(1.7)	12.5(1.6)	2.9(3.4)	2.7(3.4)
	22-May-2017	10.4(3.2)	8.3(2.8)	31.7(5.6)	39.0(6.2)	1.2	1.1	11.3(1.8)	13.6(1.9)	3.3(3.2)	3.7(3.5)
	01-Jun-2017	13.3(3.6)	14.7(3.7)	27.3(5.2)	34.0(5.8)	1.1	1.4	7.2(1.5)	18.7(2.3)	2.4(2.6)	5.3(4.3)
	11-Jun-2017	11.7(3.4)	11.9(3.4)	23.2(4.8)	21.0(4.6)	1.5	1.3	5.7(1.1)	10.3(1.7)	1.3(2.2)	3.1(3.1)
	21-Jun-2017	18.6(4.3)	25.4(5.0)	18.8(4.3)	23.1(4.8)	1.3	1.0	4.3(0.8)	5.3(1.1)	0.8(1.6)	1.3(2.3)
	01-Jul-2017	11.9(3.4)	20.2(4.4)	11.9(3.4)	20.3(4.5)	1.6	1.7	2.8(0.9)	0.7(0.4)	0.8(1.6)	0.2(0.7)
	11-Jul-2017	11.7(3.4)	15.5(3.9)	19.9(4.4)	18.0(4.2)	0.9	0.8	2.4(0.7)	1.9(0.5)	0.8(1.2)	0.3(1.1)
	21-Jul-2017	13.8(3.6)	14.5(3.7)	14.1(3.8)	14.1(3.8)	0.9	1.0	1.1(0.3)	2.5(0.9)	0.2(0.8)	1.3(1.3)
	31-Jul-2017	21.6(4.6)	17.0(4.1)	14.9(3.8)	13.6(3.7)	0.7	0.7	2.9(0.9)	2.0(0.7)	1.4(1.4)	0.5(1.1)
	10-Aug-2017	10.0(3.2)	11.8(3.4)	8.1(2.8)	12.0(3.4)	0.7	0.8	11.4(1.7)	13(1.9)	3.3(3.2)	3.7(3.5)
	20-Aug-2017	8.9(3.0)	9.7(3.1)	5.4(2.3)	9.0(3.0)	0.7	0.7	8.6(1.6)	8.7(1.6)	2.5(2.9)	2.9(2.9)
	Mean	12.3(3.4)	12.0(3.4)	16.2(3.8)	15.5(3.7)	1.0	1.0	7.1(1.1)	8.4(1.2)	1.6(2.3)	1.9(2.5)
Date		**		**		**		**		**	
Genotype		ns		ns		ns		ns		ns	
Date × Genotype		ns		ns		ns		ns		ns	
CV,%		17.8		17.1		21.7		36.1		37	
$LSD_{0.05}$		0.17		0.16		0.25		0.24		0.11	

DKHS=Damage at knee high stage (%), DBTS=Damage at before tasseling stage (%), DAS=Days after sowing, **= highly significant, ns=non significant

Tunnel length and exit holes

The tunnel length and exit hole made by the borer complex to the tested genotypes is presented in Table (2). The number of exit holes and tunnel length per stem varied across the seasons and planting date, but the variation was not significant due to genotypes. The study indicated that tunnel length and exit holes range of both genotypes gradually increased with the progress of planting date from first week of January to first week of March and remained constant during March and then again gradually increased till end of May for both genotypes. The tunnel length (8.4cm) and exit holes number (1.9) per plant made by borer complex were higher in S03TLEY-FM than in RML-95/RML-96 (7.1 cm tunnel length and 1.6 exit hole). Maximum infestation of 21.7 cm was observed in S03TLEY-FM in first week of February planting followed by 15.9 cm damaged by tunneling in RML-95/RML-96 at 24.4^0C whereas the lowest tunnel length (0.1cm and 0.2 cm) measurement was recorded on the October plantings RML-95/RML-96 and S03TLEY-FM genotypes, respectively. Here, the temperature about 25^0C at end of January was more favorable for growth and development of the borers.

Yield and yield attributes

There was highly significant difference between planting date and genotypes in case of plant height, cob length and grain yield (Table 3). However, there was no significant difference with respect to interaction of genotype × planting date for those traits and cob diameter in both genotypes. The higher mean grain yield was observed in case of single cross hybrids (RML-95/RML-96) during September planting (8.4-9.5 t/ha) and March to April planting (6.8-8.8 mt/ha). Similarly, the mean grain yield of open pollinated variety (S03TLEYFM) was fluctuated by the season. However, the higher grain yield was obtained in September planting (4.3-5.4 mt/ha) followed by February to April planting (4.2-5.3 t/ha). In both hybrid (3.6-4.7 t/ha) and OPV (1.8-2.8 t/ha), lower grain yield was recorded during May to August planting. Thousand grain weight of maize genotypes fluctuated according to the season which ranged from 265 to 408 g with mean 339g in hybrid and 226 to 389 g with mean 329g in OPV, respectively. In addition, cob length ranged from 10.8 to 15.2 cm with mean 13.3 cm in hybrid and 9.3 to 13.8 cm with mean 12.2 cm in OPV. Plant height ranged from 136 to 200 cm with mean 169 cm in hybrid and 118 to 188 cm with mean 156 cm in OPV.

Table 3. Response of grain yield and yield attributing traits of maize genotypes during 2016/017

Season	Date	Plant height (cm)		Cob length (cm)		Cob diameter (cm)		Thousand grain weight (gm)		Grain yield (mt/ha)	
		RML95/ RML96	S03TLEY-FM	RML95/ RML96	S03TL E YFM	RML95/ RML96	S03TLEY-FM	RML95/ RML96	S03TLEY-FM	RML95/ RML96	S03TLEY-FM
Winter	04-Sep-2016	153.5	150.3	15.2	13.1	4.8	4.3	336.0	336.0	9.5	5.4
	14-Sep-2016	139.4	135.3	12.6	11.5	4.4	4.0	330.7	344.0	8.4	4.3
	24-Sep-2016	140.5	142.8	13.6	13.8	4.6	4.3	364.0	380.0	4.9	3.3
	04-Oct-2016	145.3	163.5	12.7	13.7	4.1	4.2	265.3	333.3	5.4	4.6
	14-Oct-2016	150.0	148.2	11.4	11.3	4.1	4.3	364.0	357.3	4.4	3.7
	24-Oct-2016	150.9	148.0	10.8	11.2	3.9	3.6	373.3	346.7	4.7	3.4
	03-Nov-2016	146.5	140.6	12.9	13.3	4.6	6.9	349.3	360.0	7.4	4.8
	13-Nov-2016	152.0	148.6	12.4	13.0	4.5	4.4	349.3	389.3	5.6	4.1
	23-Nov-2016	155.9	153.7	12.8	11.7	4.0	4.1	316.0	286.7	5.8	3.4
	03-Dec-2016	189.3	164.3	11.5	11.6	4.5	4.3	346.7	354.7	5.7	3.5
	13-Dec-2016	166.6	152.7	11.5	12.9	4.2	4.4	346.7	358.7	5.8	4.4
	23-Dec-2016	168.3	157.4	13.4	13.0	4.4	4.4	349.3	368.0	5.9	4.5
Spring	02-Jan-2017	164.5	162.2	13.8	13.1	6.4	4.5	349.3	346.7	5.8	4.1
	12-Jan-2017	175.3	175.1	12.2	13.5	4.0	4.1	338.7	332.0	5.1	3.9
	22-Jan-2017	172.0	160.3	13.8	12.7	4.3	4.2	341.3	336.0	5.3	3.1
	01-Feb-2017	173.7	174.0	13.8	11.8	4.3	4.1	336.0	296.0	5.3	3.9
	11-Feb-2017	167.4	170.8	13.6	12.7	4.1	4.2	301.3	309.3	6.6	4.3
	21-Feb-2017	163.2	165.9	14.5	12.2	4.3	4.1	345.3	314.7	5.3	4.3
	03-Mar-2017	168.3	149.3	12.1	12.0	4.3	3.9	390.7	378.7	6.8	4.2
	13-Mar-2017	178.4	144.0	14.0	12.8	4.3	4.5	349.3	373.3	8.2	4.6
	23-Mar-2017	188.0	155.0	14.1	12.4	4.2	4.0	309.3	365.3	8.8	4.9
Summer	02-Apr-2017	194.3	168.6	14.9	12.4	3.9	3.9	353.3	346.7	7.7	5.1
	12-Apr-2017	172.2	160.0	14.9	13.5	4.1	3.9	408.0	352.0	7.8	5.3
	22-Apr-2017	182.7	165.5	14.5	13.8	4.0	3.9	322.7	304.0	5.1	4.2
	02-May-2017	198.8	186.0	14.6	12.3	4.2	3.8	400.0	336.0	4.6	2.4
	12-May-2017	200.3	181.0	14.2	13.1	4.0	3.9	376.0	341.3	4.2	2.8
	22-May-2017	198.8	187.8	13.8	12.7	4.3	4.4	282.7	293.3	3.9	2.5
	01-Jun-2017	189.8	177.2	13.5	11.7	4.1	4.8	336.0	320.0	4.5	2.6
	11-Jun-2017	183.8	165.8	11.8	9.9	3.9	3.8	330.7	373.3	6.0	4.1
	21-Jun-2017	178.7	175.0	11.8	9.9	3.9	3.5	373.3	380.0	6.1	3.6
	01-Jul-2017	164.4	153.3	12.6	11.9	3.8	3.8	306.7	264.0	3.6	2.6
	11-Jul-2017	140.0	143.3	13.6	12.0	3.9	4.0	357.3	285.3	3.9	2.4
	21-Jul-2017	224.1	120.8	13.7	9.3	4.1	3.0	272.0	248.0	4.6	2.6
	31-Jul-2017	146.5	117.7	13.9	11.5	4.0	4.2	306.7	249.3	4.1	2.2
	10-Aug-2017	156.6	119.3	14.0	11.5	4.2	3.4	317.3	226.7	4.7	1.8
	20-Aug-2017	136.6	123.3	13.9	10.6	4.1	3.3	318.7	273.3	4.2	1.8
	Mean	168.8	155.7	13.3	12.2	4.2	4.1	339.3	329.4	5.7	3.7
F-test (Date)		**		**		ns		**		**	
F-test (Genotypes)		**		**		ns		ns		**	
CV (%)		11.4		8.5		17.6		10.5		16.1	
$LSD_{0.05}$		21.06		1.235		0.839		40.01		0.864	

** Significant at 0.01,and ns non-significant

Correlation among the parameters

The correlation coefficients of various parameters, namely: percent of damage plant, exit hole, tunnel length and grain yield were measured in the genotypes SO3TLEY-FM and RML-95/RML-96 with weather parameter, such as mean temperature, average maximum temperature, average minimum temperature, rainfall and relative humidity (Tables 4, 5). The damage percentage, exit holes and tunnel length in SO3TLEY-FM were negatively correlated with average maximum, minimum, mean temperature and rainfall, whereas grain yield was positively correlated except rainfall. Exit holes, leaf damage, tunnel length and damaged plants as well as tunnel length and exit holes showed positive correlation. Achhami et al. (2014) reported that percentage of damaged plants and damage score, as well as exit holes and tunnel length of S99TLYQ-B and Across 9942/Across 9944 were highly positively correlated.

Similarly, tunnel length, exit holes and grain yield of RML-95/RML-96 showed negative correlations with weather parameters (Table 5). Exit holes, tunnel length and grain yield exhibited positive correlation with the damaged plants.

Table 4. Correlation coefficient for the traits in SO3TLEY-FM with weather parameters

SO3TLEY-FM									
	Av. max tempera-ture	**Av. min tempera-ture**	**RH**	**Rainfall**	**Mean temperature**	**Damaged plant %**	**Exit hole**	**Tunnel length**	**Yield**
Av. max temperature	-								
Av. min temperature	0.94**	-							
RH	0.21*	0.24*	-						
Rainfall	0.69**	0.76**	-0.05^{ns}	-					
Mean temperature	0.98**	0.99**	0.23*	0.75**	-				
Damaged plant %	-0.67^{ns}	-0.68^{ns}	-0.67^{ns}	-0.39^{ns}	-0.68^{ns}	-			
Exit hole	-0.51**	-0.54**	-0.76**	-0.28*	-0.53**	0.95^{ns}	-		
Tunnel length	-0.64**	-0.65**	-0.70**	-0.39**	-0.66**	0.99^{ns}	0.97^{ns}	-	
Yield	0.14^{ns}	0.28^{ns}	-0.15*	0.48^{ns}	0.24^{ns}	0.14^{ns}	0.17^{ns}	0.15^{ns}	-

* Significant at 0.05, ** Significant at 0.01; and ns non-significant

Table 5. Correlation coefficient for the traits in RML-95/RML-96 with weather parameters

RML-95/RML-96									
	Av. max temp.	**Av. min temp.**	**RH**	**Rainfall**	**Mean temp**	**Damaged plant (%)**	**Exit hole**	**Tunnel length**	**Yield**
Av. max. temperature									
Av. min temperature	0.94**								
RH	0.21*	0.24*							
Rainfall	0.69**	0.76**	-0.05^{ns}						
Mean temperature	0.98**	0.99**	0.23*	0.75**					
Damaged plant %	-0.66^{ns}	-0.67^{ns}	-0.59^{ns}	-0.41^{ns}	-0.67^{ns}				
Exit hole	-0.47*	-0.51*	-0.70*	-0.32*	-0.50**	0.90^{ns}			
Tunnel length	-0.68**	-0.68**	-0.59**	-0.42*	-0.69**	1.00^{ns}	0.89^{ns}		
Yield	0.04^{ns}	0.03^{ns}	0.06^{ns}	0.13^{ns}	0.03^{ns}	0.18^{ns}	0.21^{ns}	0.16^{ns}	

* Significant at 0.05, ** Significant at 0.01; ^{ns} non-significant, RH= Relative humidity; and Temp= Temperature

Relation between leaf damage with temperature and rainfall

Leaf damage by stem borers gradually increased with the increase in temperature in both the genotypes (Figure 2). The range of temperature from 25 to 29˚C during September to November and March to July was suitable for growth and development of stem borers. This finding is supported with the work of Tamiru et al. (2012) that the most suitable condition for *C. partellus* development was 26-30˚C. Similarly, Mallapur et al. (2012) reported that the percent infestation of stem borers varied during different months. The highest infestation (19.22%) was recorded in August followed by July (15.80%) and September (15.10%), respectively. Furthermore, Muhammad et al. (2010) supported the role of increasing temperature that the infestation of *C. partellus* was found highest at higher temperature (32.5^{0}C). It is clear that about 28-31^{0}C temperature at the first week of May to mid of July was the most favorable for the growth and development of borers. Zahid (2009) reported that maximum dead hearts due to stem borer on maize were noticed during July (62%) and minimum during June, December and January (32%). Biradar et al. (2011) reported that the lower number of pin holes due to stem borers were noticed lowest during the months of December and June.

This experiment revealed that the maize stem borer damage in tested genotypes were higher in vegetative stages than later stage under natural field conditions. Thakur et al. (2013) reported similar findings and recorded vegetative stages (below knee high) more vulnerable than older stage of maize crop.

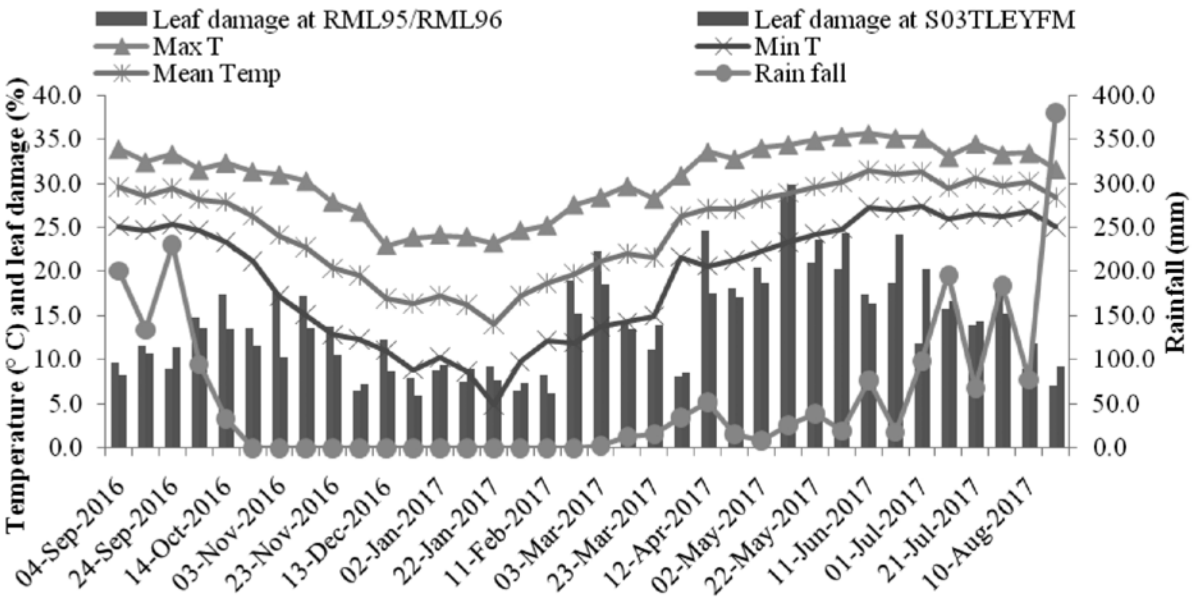

Figure 2. Influence of weather parameter on leaf damage by stem borers in Chitwan, Nepal

Relation of tunnel length and exit hole with temperature

The effect of temperature on insect activity for stem tunneling and exit holes are shown in Figure 3 and 4. The tunnel length and the number of exit holes in SO3TLEY-FM genotype increased with the rising temperature during fourth week of January to first week of June where mean temperature ranged from 18 to 31˚C (figure 3). Likewise, RML-95/RML-96 genotype showed more or less similar trend (Figure 4). The leaf damage was about 3% higher in SO3TLEY-FM than in RML-95/RML-96 genotype. Achhami et al. (2015) also recorded 14.38 cm tunnel length in the January planting and 15.43 cm in December planting in the genotypes Across 9942/Across9944 and S99TLYQ-B, respectively. Similarly, Thakur et al. (2013) recorded higher tunnel length per plant in December to January planting in Chitwan, Nepal. The lower tunnel length and exit holes were recorded in the planting months at third week of September to end of October in both the genotypes.

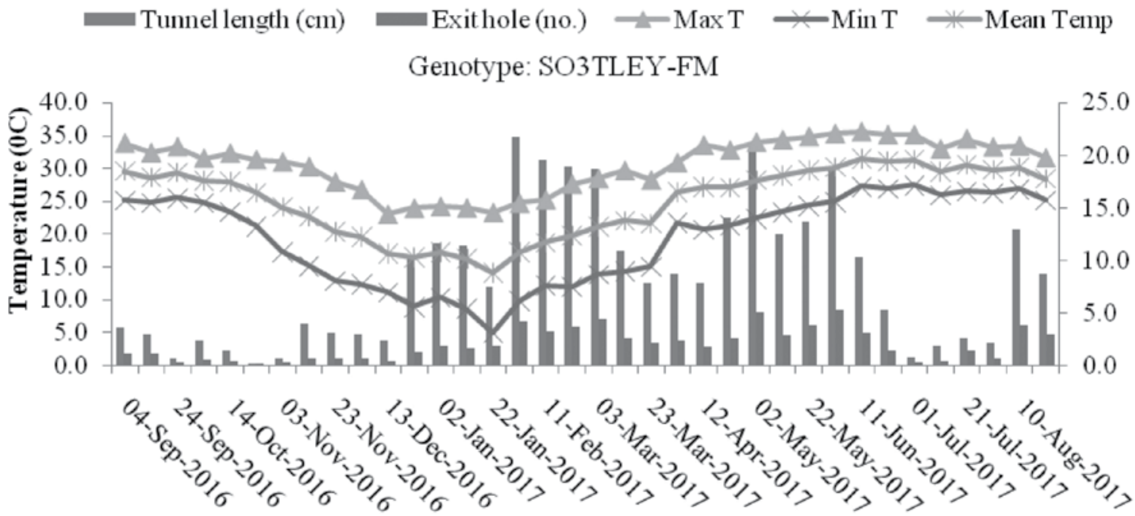

Figure 3. Influence of weather parameter on tunnel length and exit holes made by stem borers on OPV genotype (SO3TLEY-FM) during 2016/017 in Chitwan, Nepal

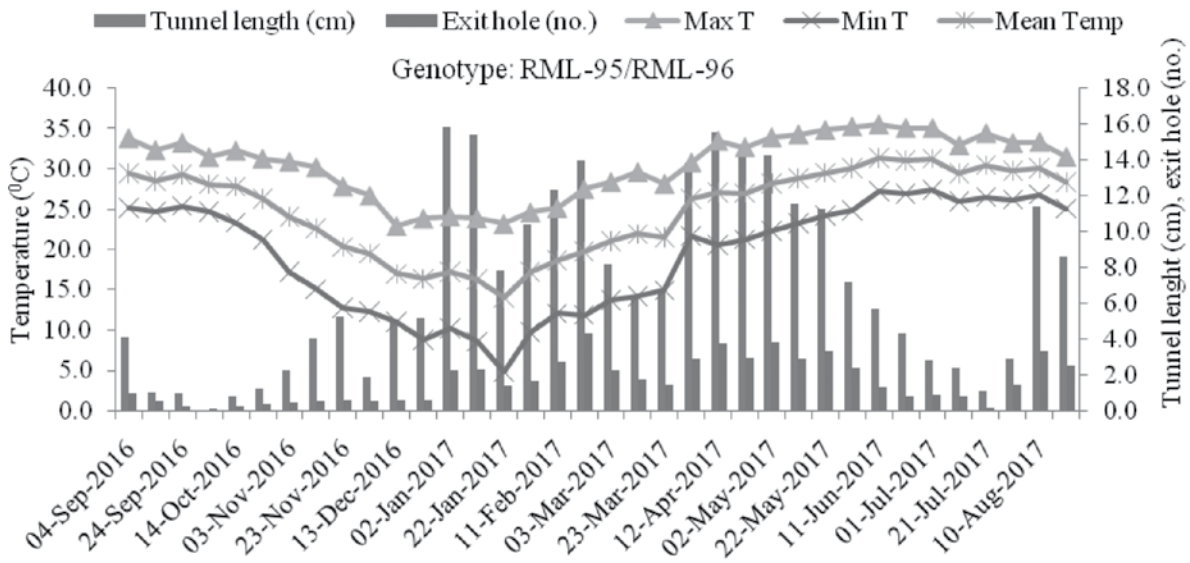

Figure 4. Influence of weather parameter on tunnel length and exit holes made by stem borers on hybrid genotype RML-95/RML-96 during 2016/017 in Chitwan, Nepal

Relationship between borer damage, temperature and grain yield

As observed the unclear relationships of damages by stem borers on gain yield in the present study, similar kinds of finding have also been reported by Sehu Reddy and Sum (1991), Songa et al. (2001) and Achhami et al. (2014). The study depend on natural infestation of stem borer, which may not have been constant/uniform across seasons and plantings. Likewise, the two populations studied were genetically heterogeneous, hybrid and open-pollinated variety, with possible inclusion of tolerant and susceptible lines. Composites have been reported to be tolerant to stem borer infestation in previous studies (Neupane et al., 1984b; Ampofo and Saxena, 1989).

Other insect pests and natural enemies of maize

Beside borer complex, sporadic infestation of some other insects, such as armyworm, leaf beetles, white grubs and pollen beetle were observed in winter plantings (September to December). Similarly, leaf folder, grasshopper and aphid, field cricket and cutworms were observed in December to February plantings (Table 6). At the same time, beneficial insects, like spider, hover fly, preying mantid, long horned grasshopper, ladybird beetle, reduviid bug, minute parasite wasps were also observed during the maize growing season (Table 7).

Table 6. Other insect pests occurring at different growth stage of maize at NMRP, Rampur, Chitwan, Nepal

Common name	Damage level	Family	Stage of crops
White grubs (*Phyllophaga* spp.)	M	Scarabidae	Seedling to maturity
Leaf folder (*Marasma trapizalis* Hampson)	M	Pyralidae	Vegetative to Maturity
Stem fly (*Atherigona soecata* Rondani)	L	Anthomyiidae	Seedling stage
Grasshopper *(Heiroglyphus banions)*	L	Acrididae	Vegetative to Maturity
Aphids (*Rhopalosiphum maidis*(Fitch)	H	Aphididae	Silking to maturity
Field cricket (*Brachytrupes portentosus)*	L	Pyrgomorphidae	Vegetative
Bihar hairy caterpillar (*Spilaractia casignata*	L	Noctuidae	Vegetative to Maturity
Hadda beetle (*Epilachna vigintioctopunctata)*	L	Coccinellidae	Vegetative
Mole cricket *(Gryllotalpa africana)*	M	Gryllotalpidae	Seedling to vegetative stage
Armyworm *(Mythimna separata*)	H	Noctuidae	Vegetative to Maturity
Green bug *(Nazara virudula)*	L	Pentatomidae	Vegetative stage
Cutworm (*Agrotis* sp.)	M	Noctuidae	Seedling stage
Corn pod borer (*Helicoverpa armigera)*	M	Noctuidae	Silking to maturity
Hairy caterpillar (*Amsacta albestrica)*	M	Noctuidae	Vegetative stage
Blister beetle (*Mylabris phalerata)*	L	Meloidae	Silking to maturity stage
Corn flea beetle (*Monolepta signata)*	H	Chrysomelidae	Vegetative stage
Leaf hopper *(Pyrilla perpusilla)*	L	Lophopidae	Vegetative stage

Note: H: High, M: Medium, L: Low infestation

Table 7. Natural enemies recorded on maize crop at NMRP, Rampur, Chitwan, Nepal

Common name	Family	Stage of crops
heilomenes sexmaculata (Fabricius)	Coccinellidae	Vegetative –maturity
Coccinella transversalis	Coccinellidae	Vegetative –maturity
Coccinella septempunctata	Coccinellidae	Vegetative –maturity
Anegleis cardoni	Coccinellidae	Vegetative –maturity
Conocephalus longipennis	Tettigoniidae	Vegetative stage
Paederus fucipes	Staphylinidae	Vegetative –maturity
Geocoris sp.	Geocoridae	Vegetative
Neoscona oaxacensis	Araneidae	Vegetative –maturity
Lycosa sp.	Lycosidae	Vegetative –maturity
Thomisus sp.	Thomisidae	Vegetative
Argiope sp.	Araneidae	Vegetative –maturity

CONCLUSION

The findings of this study clearly indicated that infestation by stem borer complex was higher with higher temperature (25-31°C), and the early stage of maize was more susceptible to the stem borers than at the later stage. It can be thus concluded that farmers can take benefit by planting maize during September for winter season, end of January for spring season, and July for summer season to minimize maize stem borer damage under Chitwan condition. Further study is necessary to elaborate the relationships between stem borer damage to maize genotypes and role of changing climate at different elevations.

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