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Influence of stem morphological traits on the incidence of spotted stem borer, *Chilo partellus* in different maize genotypes

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Abstract
Spotted stem borer, *Chilo partellus* is the most ubiquitous and key pest of maize. Once the pest enters the plant tissue, it becomes almost impossible for biological control agents and pesticides to reach the target. Hence, keeping this in view the research trials were conducted during two consecutive years *i.e. Kharif* 2018 and 2019 at CRC of SVPUA&T, Meerut to know influence of stem morphological traits on the incidence of spotted stem borer in different maize genotypes. The results of the study revealed that the genotypes Vivek Hybrid 9, Vivek Hybrid 25, Wasc, Vivek Hybrid 39, HQPM 4, HQPM 8, Vivek Hybrid 43, HQPM 1 were recorded minimum (< 2) per cent of dead hearts and number of exit holes. From the correlation matrices of stem morphological traits with incidence of *C. partellus*, it was noted that more number of nodes per plant, stem diameter, internodal distance and plant height contributed for resistance in maize genotypes against the pest attack.

Keywords: *C. partellus*, dead hearts, exit holes, internodal length, number of nodes per plant, plant height and stem diameter

1. Introduction
Maize (*Zea mays* L.) belongs to family Poaceae is a cereal grain, also known as queen of cereals due to its diverse usages. In India, maize is the third most important staple food crop after rice and wheat. Depending on the regions and socio-economic conditions of the population, the maize is used for various purposes including food, feed, fodder, sweet corn, baby corn, popcorn, starch and several industrial products (Kumar *et al*., 2014) [14]. The multiple pest complex of maize crop poses serious limitation in the maize cultivation in different agro-climatic regions of India. Among the different insect pests affecting maize crop, the spotted stem borer was the most serious. It also infests sorghum, millets, rice, sugarcane, bajra and some other grasses. This pest has been reported to be the most destructive pest of maize at its early growth stage worldwide (Sharma and Sharma, 1987; Polaszek and Khan, 1998) [29, 28]. The spotted stem borer causes dead heart in seedling and early whorl stage, leading to total loss of the crop. It has been reported by different workers that *C. partellus* caused 4-97 per cent maize yield losses in different countries all over the world (Reddy and Walker 1990) [23]. The losses caused by *C. partellus* in maize were reported to be 26.70 to 80.40 per cent in yield in different agro climatic zones of India (Chatterji *et al*., 1969 and Panwar 2005) [9, 19]. Different maize genotypes exhibit varied reaction to the stem borer infestation (Mallapur *et al*. 2012) [16]. The differences in stem morphological traits of maize genotypes deter insect feeding and oviposition, rendering them resistant or less susceptible. Keeping this in view, influence of stem morphological traits on the incidence of spotted stem borer in different maize genotypes has been studied.

2. Materials and Methods
A field experiment was conducted with 18 maize genotypes at Crop Research Centre (CRC) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh for two consecutive seasons (*Kharif* 2018 and 2019) in a randomized block design with three replications. Each genotype was accommodated in two rows each of 6 m length with 60 and 30 cm spacing between rows and plants, respectively. Sowing was done in last week of June for both the seasons.

All the agronomic practices were adopted as per the package of practices, except the plant protection measures.

Observations on the damage parameters like per cent dead hearts and number of exit holes were recorded to know the incidence of *C. partellus* in different genotypes. Data on total number of dead heart infected plants and total number of plants per plot was counted at 45 days after sowing and converted into percentage. Data on number of exit holes made by *C. partellus* was counted on stem after removing the sheath leaves, at the time of harvest on ten randomly selected plants per each replication and the average number of exit holes per plant was calculated.

The observations on stem morphological traits such as stem diameter, internodal length, number of nodes per plant and plant height in each genotype were recorded on 75 days old crop. These biophysical traits were recorded on five randomly selected plants of each genotype in each replication and the average was calculated. The node above ground was considered as node one. Total number of nodes was recorded starting from node one. The stem diameter was recorded with the help of vernier caliper by measuring from the centre of 3rd internode. The length of third internode was measured with a measuring tape. Above ground plant height was recorded with the help of a measuring tape. These stem morphological traits were correlated with the per cent dead hearts and number of exit holes caused by *C. partellus* to determine their role towards resistance/susceptibility.

The data collected on various parameters were analyzed statistically following the procedure described by Gomez and Gomez (1984) [27]. The data in numbers were transformed into square root values and the data in percentages were transformed into arc sine values when needed before analyzing. The "F" test was used at 5 per cent level of significance. The data on correlation studies when needed were analyzed by using SPSS software.

3. Results and Discussion

The data regarding damage parameters caused by *C. partellus* and stem morphological traits of various maize genotypes recorded during *Kharif* 2018, *Kharif* 2019 and pooled data are given in table 1, 2 and 3, respectively. The effect of stem morphological traits on the *C. partellus* damage parameters was also determined by processing the data into simple correlation and presented in Table 4.

Table 1: Damage parameters caused by *C. partellus* and stem morphological traits in different genotypes of maize during *Kharif* 2018

S. No	Genotypes	Damage parameters		Stem morphological traits			
		Dead hearts (%)^^	Exit holes (No./plant)^	Number of nodes per plant	Stem diameter (mm)	Internodal length (cm)	Plant height (cm)
1	African Tall	19.17 (25.89)	4.13 (2.02)	16.47	25.72	12.62	228.19
2	Narmada Moti	5.83 (13.91)	2.87 (1.69)	13.53	26.44	10.78	191.67
3	Wasc	0.00 (0.39)	1.03 (1.00)	14.07	27.59	11.57	201.42
4	DHM 117	16.67 (24.00)	2.73 (1.65)	13.93	21.30	10.92	196.53
5	Parkash	20.83 (27.10)	4.10 (2.02)	11.73	18.90	9.50	171.53
6	HQPM 1	2.50 (9.10)	1.07 (1.02)	13.27	27.88	10.97	189.25
7	HQPM 4	0.84 (3.29)	1.23 (1.10)	15.53	28.49	12.47	209.42
8	HQPM 5	15.00 (22.74)	3.27 (1.80)	12.33	20.58	9.25	174.93
9	HQPM 8	1.67 (6.19)	1.37 (1.15)	14.00	28.17	11.48	198.15
10	Vivek Hybrid 9	0.00 (0.39)	0.97 (0.97)	15.47	26.09	11.74	203.48
11	Vivek Hybrid 25	0.00 (0.39)	1.23 (1.10)	15.20	27.46	12.00	207.50
12	Vivek Hybrid 27	8.33 (16.74)	2.73 (1.65)	13.60	20.53	10.33	188.85
13	Vivek Hybrid 33	10.83 (19.19)	2.60 (1.61)	14.67	20.74	11.41	198.67
14	Vivek Hybrid 39	0.00 (0.39)	0.93 (0.96)	16.13	24.00	12.07	211.79
15	Vivek Hybrid 43	1.67 (6.19)	1.80 (1.33)	15.80	23.87	11.77	207.33
16	Shaktiman 2	23.33 (28.88)	4.47 (2.11)	12.87	18.72	10.00	181.01
17	Shaktiman 3	6.67 (14.90)	2.33 (1.53)	15.73	23.75	11.45	203.20
18	Shaktiman 5	21.67 (27.73)	4.47 (2.11)	12.40	19.00	9.81	178.21
SEm±		1.44	0.09	0.37	0.61	0.31	4.09
CD (P=0.05)		4.14	0.27	1.08	1.75	0.90	11.76

^^Values in parentheses are arc sine transformed values;
^Values in parentheses are square root transformed value

Table 2: Damage parameters caused by *C. partellus* and stem morphological traits in different genotypes of maize during *Kharif* 2019

S.No	Genotypes	Damage parameters		Stem morphological traits			
		Dead hearts (%)^^	Exit holes (No./plant)^	Number of nodes per plant	Stem diameter (mm)	Internodal length (cm)	Plant height (cm)
1	African Tall	16.67 (24.08)	3.17 (1.78)	16.87	25.12	13.17	234.71
2	Narmada Moti	3.33 (10.37)	1.37 (1.16)	13.40	25.72	10.68	188.13
3	Wasc	0.00 (0.39)	0.83 (0.90)	14.00	28.72	11.70	198.68
4	DHM 117	11.67 (19.95)	1.67 (1.28)	14.73	22.50	10.62	192.98
5	Parkash	18.33 (25.31)	4.13 (2.03)	12.73	20.38	10.18	177.04
6	HQPM 1	0.84 (3.29)	1.07 (1.02)	13.07	28.36	10.23	184.95
7	HQPM 4	0.00 (0.39)	0.80 (0.89)	15.60	28.74	12.31	212.80
8	HQPM 5	9.17 (17.59)	2.67 (1.62)	12.33	20.51	10.04	180.27
9	HQPM 8	0.00 (0.39)	0.93 (0.95)	14.13	26.74	10.83	191.34
10	Vivek Hybrid 9	0.00 (0.39)	0.87 (0.91)	15.40	26.97	12.40	208.04
11	Vivek Hybrid 25	0.00 (0.39)	0.83 (0.90)	16.00	28.55	12.90	215.29
12	Vivek Hybrid 27	4.17 (11.65)	2.43 (1.56)	14.87	20.84	11.08	195.58

13	Vivek Hybrid 33	5.83 (13.91)	3.00 (1.73)	13.93	22.65	10.66	190.42
14	Vivek Hybrid 39	0.00 (0.39)	1.27 (1.12)	16.53	26.27	13.25	217.51
15	Vivek Hybrid 43	1.67 (6.19)	1.43 (1.19)	14.33	25.49	11.43	200.45
16	Shaktiman 2	17.50 (24.69)	4.10 (2.02)	12.47	20.30	9.64	176.16
17	Shaktiman 3	4.17 (11.65)	1.23 (1.10)	15.47	25.46	11.84	203.39
18	Shaktiman 5	17.50 (24.73)	3.93 (1.98)	12.80	20.14	10.29	183.41
SEm±		1.15	0.10	0.48	0.44	0.39	4.35
CD (P=0.05)		3.31	0.28	1.37	1.26	1.11	12.51

^^Values in parentheses are arc sine transformed values;
^Values in parentheses are square root transformed value

Table 3: Pooled effect of damage parameters caused by *C. partellus* and stem morphological traits in different genotypes of maize during *Kharif* 2018 and 2019

S. No	Genotypes	Damage parameters		Stem morphological traits			
		Dead hearts (%)^^	Exit holes (No./plant)^	Number of nodes per plant	Stem diameter (mm)	Internodal length (cm)	Plant height (cm)
1	African Tall	17.92 (25.02)	3.65 (1.90)	16.67	25.42	12.90	231.45
2	Narmada Moti	4.58 (12.27)	2.12 (1.45)	13.47	26.08	10.73	189.90
3	Wasc	0.00 (0.39)	0.93 (0.97)	14.03	28.16	11.63	200.05
4	DHM 117	14.17 (22.08)	2.20 (1.48)	14.33	21.90	10.77	194.76
5	Parkash	19.58 (26.26)	4.12 (2.03)	12.23	19.64	9.84	174.28
6	HQPM 1	1.67 (7.32)	1.07 (1.03)	13.17	28.12	10.60	187.10
7	HQPM 4	0.42 (2.40)	1.02 (1.01)	15.57	28.62	12.39	211.11
8	HQPM 5	12.08 (20.32)	2.97 (1.72)	12.33	20.55	9.64	177.60
9	HQPM 8	0.84 (4.41)	1.15 (1.06)	14.07	27.45	11.16	194.74
10	Vivek Hybrid 9	0.00 (0.39)	0.92 (0.96)	15.43	26.53	12.07	205.76
11	Vivek Hybrid 25	0.00 (0.39)	1.03 (1.01)	15.60	28.00	12.45	211.40
12	Vivek Hybrid 27	6.25 (14.43)	2.58 (1.61)	14.23	20.69	10.70	192.22
13	Vivek Hybrid 33	8.33 (16.77)	2.80 (1.67)	14.30	21.69	11.04	194.54
14	Vivek Hybrid 39	0.00 (0.39)	1.10 (1.05)	16.33	25.14	12.66	214.65
15	Vivek Hybrid 43	1.67 (7.32)	1.62 (1.27)	15.07	24.68	11.60	203.89
16	Shaktiman 2	20.42 (26.85)	4.28 (2.07)	12.67	19.51	9.82	178.58
17	Shaktiman 3	5.42 (13.44)	1.78 (1.33)	15.60	24.61	11.65	203.29
18	Shaktiman 5	19.58 (26.26)	4.20 (2.05)	12.60	19.57	10.05	180.81
SEm±		0.86	0.06	0.28	0.35	0.23	2.98
CD (P=0.05)		2.47	0.16	0.81	1.00	0.67	8.56

^^Values in parentheses are arc sine transformed values;
^Values in parentheses are square root transformed value

Table 4: Correlation coefficients between damage parameters caused by *C. partellus* and stem morphological traits of maize genotypes during *Kharif* 2018 and 2019

Year	Damage parameters caused by *C. partellus*	Stem morphological traits			
		Number of nodes per plant	Stem diameter (mm)	Internodal length (cm)	Plant height (cm)
Kharif 2018	Per cent dead hearts	-0.539*	-0.792**	-0.625**	-0.490*
	Number of exit holes	-0.507*	-0.759**	-0.615**	-0.467^{NS}
Kharif 2019	Per cent dead hearts	-0.378^{NS}	-0.787**	-0.439^{NS}	-0.330^{NS}
	Number of exit holes	-0.473*	-0.869**	-0.504*	-0.428^{NS}
Pooled data	Per cent dead hearts	-0.479*	-0.806**	-0.563*	-0.425^{NS}
	Number of exit holes	-0.511*	-0.850**	-0.592**	-0.464^{NS}

**Significant at 1% level
*Significant at 5% level
NS – Non significant

3.1 Damage parameters

3.1.1 Dead hearts (%)

The findings on per cent dead hearts during *Kharif* 2018, varied between 0.00 to 23.33 per cent. Among the 18 genotypes screened, Vivek Hybrid 9, Vivek Hybrid 25, Wasc and Vivek Hybrid 39 were found promising against *C. partellus* with no dead hearts formation. The next best genotypes were HQPM 4 (0.84%), Vivek Hybrid 43 (1.67%), HQPM 8 (1.67%) and HQPM 1 (2.50%). The highest per cent of dead hearts was recorded in Shaktiman 2 (23.33%) followed by Shaktiman 5 (21.67%), Parkash (20.83%), African Tall (19.17%) and DHM 117 (16.67%). Other genotypes Narmada Moti, Shaktiman 3, Vivek Hybrid 27, Vivek Hybrid 33 and HQPM 5 recorded 5.83, 6.67, 8.33, 10.83 and 15.00 per cent dead hearts, respectively.

Dead heart percentage ranged between 0.00 to 18.33 per cent in the succeeding year *i.e*., *Kharif* 2019. The genotypes Vivek Hybrid 9, Vivek Hybrid 25, Wasc, Vivek Hybrid 39, HQPM 4 and HQPM 8 were found promising against *C. partellus* with no dead hearts formation. The next best genotypes were HQPM 1 (0.84%), Vivek Hybrid 43 (1.67%), Narmada Moti (3.33%), Vivek Hybrid 27 (4.17%) and Shaktiman 3 (4.17%). The highest per cent of dead hearts was recorded in Parkash (18.33%) followed by Shaktiman 2 (17.50%), Shaktiman 5 (17.50%) and African Tall (16.67). Other genotypes Vivek Hybrid 33, HQPM 5 and DHM 117 recorded 5.83, 9.17 and

11.67 per cent dead hearts, respectively.

The cumulative mean of per cent dead hearts for *Kharif* 2018 and 2019, ranged from 0.00 to 20.42 per cent. Zero per cent dead heart was recorded in genotypes Vivek Hybrid 9, Vivek Hybrid 25, Wasc and Vivek Hybrid 39 were found promising against *C. partellus* susceptibility. The next best genotypes were HQPM 4 (0.42%), HQPM 8 (0.84%), Vivek Hybrid 43 (1.67%), HQPM 1 (1.67%) and Narmada Moti (4.58%). The highest per cent of dead hearts was recorded in Shaktiman 2 (20.42%) followed by Shaktiman 5 (19.58%), Parkash (19.58%) and African Tall (17.92%). Other genotypes Shaktiman 3, Vivek Hybrid 27, Vivek Hybrid 33, HQPM 5 and DHM 117 recorded 5.42, 6.25, 8.33, 12.08 and 14.17 per cent dead hearts, respectively.

The results are in agreement with Lella and Srivastav (2013) [15] and Rasool (2015) [22] who recorded zero per cent dead heart formation in some maize genotypes, but in addition the present finding on maximum dead heart formation are in close conformity with Patra *et al.* (2013) [20] who recorded 18.88 per cent but differs with the findings of Joshi *et al*. (2019) [10], Biradar *et al.* (2011) [8] and Anil *et al*. (2018) [5] who observed maximum dead heart formation of 5.14, 46.67 and 55.94 per cent, respectively. The variation could be attributed due to the different genotypes studied under different agro-climatic conditions during present and earlier studies.

Dead hearts has been reported to be one of the stable parameters for differentiating degrees of resistance (Singh *et al*., 1968) [26]. The low level of dead hearts recorded in the least susceptible and moderately susceptible lines of the present study suggest that limited migration of larvae of stem borers to the growing tip of maize. Dead hearts occurs when the feeding larvae migrates to the meristematic region to feed thus damaging the growing point (Kamiyo *et al*., 2011) [12].

3.1.2 Exit holes per plant

In *Kharif* 2018, the exit holes per plant for all the genotypes ranged from 0.93 to 4.47. Minimum number of exit holes per plant was found in the genotype Vivek Hybrid 39 (0.93) followed by Vivek Hybrid 9 (0.97), Wasc (1.03), HQPM 1 (1.07), Vivek Hybrid 25 (1.23), HQPM 4 (1.23), HQPM 8 (1.37) and Vivek Hybrid 43 (1.80) whereas, maximum number of exit holes per plant was found in the genotypes Shaktiman 2 (4.47) and Shaktiman 5 (4.47) followed by African Tall (4.13), Parkash (4.10) and HQPM 5 (3.27). On the other hand genotypes, Shaktiman 3 (2.33), Vivek Hybrid 33 (2.60), Vivek Hybrid 27 (2.73), DHM 117 (2.73) and Narmada Moti (2.87) recorded moderate number of exit holes per plant.

In *Kharif* 2019, the exit holes per plant for all the genotypes varied from 0.80 to 4.13. Minimum number of exit holes per plant was found in the genotype HQPM 4 (0.80) followed by Vivek Hybrid 25 (0.83), Wasc (0.83), Vivek Hybrid 9 (0.87), HQPM 8 (0.93), HQPM 1 (1.07), Shaktiman 3 (1.23), Vivek Hybrid 39 (1.27), Narmada Moti (1.37), Vivek Hybrid 43 (1.43) and DHM 117 (1.67) whereas, maximum number of exit holes per plant was found in the genotype Parkash (4.13) followed by Shaktiman 2 (4.10), Shaktiman 5 (3.93), African Tall (3.17) and Vivek Hybrid 33 (3.00). On the other hand genotypes, Vivek Hybrid 27 (2.43) and HQPM 5 (2.67) recorded moderate number of exit holes per plant.

The pooled analysis on exit holes per plant for *Kharif* 2018 and 2019, in all the genotypes ranged from 0.92 to 4.28. Minimum number of exit holes per plant was found in the genotype Vivek Hybrid 9 (0.92), Wasc (0.93), HQPM 4 (1.02), Vivek Hybrid 25 (1.03), HQPM 1 (1.07), Vivek Hybrid 39 (1.10), HQPM 8 (1.15), Vivek Hybrid 43 (1.62) and Shaktiman 3 (1.78) whereas, maximum number of exit holes per plant was found in the genotype Shaktiman 2 (4.28) followed by Shaktiman 5 (4.20), Parkash (4.12) and African Tall (3.65). On the other hand genotypes, Narmada Moti (2.12), DHM 117 (2.20), Vivek Hybrid 27 (2.58), Vivek Hybrid 33 (2.80) and HQPM 5 (2.97) recorded moderate number of exit holes per plant.

These results were more or less similar with the findings of Bhandari *et al.* (2016) [7] who reported that the exit holes due to stem borer was in the range of 0.90 to 4.20 and 2.00 to 7.00 for two consecutive years. However, higher range of exit holes (4.00 to 14.30) was reported by Kumar *et al*. (2017) [13], which might be due to the differences in genotypes, pest population pressure as well as the agro-climatic conditions. It was clear from the present studies that the higher number of exit holes indicated the higher borer survivorship and higher infestation level and the fewer borer exit holes indicated the lower borer survival and infestation level.

3.2 Stem morphological traits

3.2.1 Number of nodes per plant

In *Kharif* 2018, the number of nodes per plant for all the genotypes varied from 11.73 to 16.47. Higher numbers of nodes were noticed in African Tall (16.47/plant) followed by Vivek Hybrid 39 (16.13/plant), Vivek Hybrid 43 (15.80/plant), Shaktiman 3 (15.73/plant), HQPM 4 (15.53/plant), Vivek Hybrid 9 (15.47/plant) and Vivek Hybrid 25 (15.20/plant) whereas, lower numbers of nodes were noticed in Parkash (11.73/plant) followed by HQPM 5 (12.33/plant), Shaktiman 5 (12.40/plant) and Shaktiman 2 (12.87/plant). However, moderate numbers of nodes were noticed in HQPM 1 (13.27/plant), Narmada Moti (13.53/plant), Vivek Hybrid 27 (13.60/plant), DHM 117 (13.93/plant), HQPM 8 (14.00/plant), Wasc (14.07/plant) and Vivek Hybrid 33 (14.67/plant).

In *Kharif* 2019, the number of nodes per plant for all the genotypes varied from 12.33 to 16.87. Higher numbers of nodes were noticed in African Tall (16.87/plant) followed by Vivek Hybrid 39 (16.53/plant), Vivek Hybrid 25 (16.00/plant), HQPM 4 (15.60/plant), Shaktiman 3 (15.47/plant) and Vivek Hybrid 9 (15.40/plant) whereas, lower numbers of nodes were noticed in HQPM 5 (12.33/plant) followed by Shaktiman 2 (12.47/plant), Parkash (12.73/plant) and Shaktiman 5 (12.80/plant). However, moderate numbers of nodes were noticed in HQPM 1 (13.07/plant), Narmada Moti (13.40/plant), Vivek Hybrid 33 (13.93/plant), Wasc (14.00/plant), HQPM 8 (14.13/plant), Vivek Hybrid 43 (14.33/plant), DHM 117 (14.73/plant) and Vivek Hybrid 27 (14.87/plant).

The pooled analysis on number of nodes per plant for *Kharif* 2018 and 2019, in all the genotypes ranged from 12.23 to 16.67. Higher numbers of nodes were noticed in African Tall (16.67/plant) followed by Vivek Hybrid 39 (16.33/plant), Shaktiman 3 (15.60/plant), Vivek Hybrid 25 (15.60/plant), HQPM 4 (15.57/plant), Vivek Hybrid 9 (15.43/plant) and Vivek Hybrid 43 (15.07/plant) whereas, lower numbers of nodes were noticed in Parkash (12.23/plant) followed by HQPM 5 (12.33/plant), Shaktiman 5 (12.60/plant) and Shaktiman 2 (12.67/plant). However, moderate numbers of nodes were noticed in HQPM 1 (13.17/plant), Narmada Moti (13.47/plant), Wasc (14.03/plant), HQPM 8 (14.07/plant), Vivek Hybrid 27 (14.23/plant), Vivek Hybrid 33 (14.30/plant)

and DHM 117 (14.33/plant).

Correlation studies between number of nodes per plant and *C. partellus* damage parameters resulted a negative relationship. The correlation coefficient values showed significance with all damage parameters during both seasons and pooled data except with per cent dead hearts during *Kharif* 2019. Correlation coefficient values (r) for number of nodes per plant was -0.539, -0.378 and -0.479 with per cent dead hearts and -0.507, -0.473 and -0.511 with number of exit holes, during *Kharif* 2018, *Kharif* 2019 and pooled data, respectively. This may be due to the fact that the larvae spent more time in entering and exiting plants with more number of nodes as compared to plants with fewer nodes. The results of present investigation were in conformity with the findings of Ali *et al*. (2015) [4], Jyothi (2016) [11], Nadeem *et al.* (2016) [18] and Rasool *et al*. (2017) [21] who observed significant and negative correlation between number of nodes and pest infestation. Similarly, Afzal *et al.* (2009) [2] also observed negative but non-significant correlation between number of nodes and pest damage.

3.2.2 Stem diameter (mm)

During *Kharif* 2018, mean stem diameter in various genotypes ranged from 18.72 to 28.49 mm. The genotype HQPM 4 (28.49 mm) possessed the maximum stem diameter followed by HQPM 8 (28.17 mm), HQPM 1 (27.88 mm), Wasc (27.59 mm), Vivek Hybrid 25 (27.46 mm), Narmada Moti (26.44 mm), Vivek Hybrid 9 (26.09 mm) and African Tall (25.72 mm) whereas, minimum stem diameter was observed in Shaktiman 2 (18.72 mm) followed by Parkash (18.90 mm), Shaktiman 5 (19.00 mm), Vivek Hybrid 27 (20.53 mm), HQPM 5 (20.58 mm), Vivek Hybrid 33(20.74 mm), DHM 117 (21.30 mm), Shaktiman 3 (23.75 mm), Vivek Hybrid 43 (23.87 mm) and Vivek Hybrid 39 (24.00 mm).

In the succeeding year *i.e*., *Kharif* 2019, mean stem diameter in various genotypes ranged from 20.14 to 28.74 mm. The genotypes HQPM 4 (28.74 mm) and Wasc (28.72 mm) possessed the maximum stem diameter followed by Vivek Hybrid 25 (28.55 mm), HQPM 1 (28.36 mm), Vivek Hybrid 9 (26.97 mm), HQPM 8 (26.74 mm), Vivek Hybrid 39 (26.27 mm), Narmada Moti (25.72 mm), Vivek Hybrid 43 (25.49 mm), Shaktiman 3 (25.46 mm) and African Tall (25.12 mm) whereas, minimum stem diameter was observed in Shaktiman 5 (20.14 mm) followed by Shaktiman 2 (20.30 mm), Parkash (20.38 mm), HQPM 5 (20.51 mm), Vivek Hybrid 27 (20.84 mm), DHM 117 (22.50 mm) and Vivek Hybrid 33 (22.65 mm).

The cumulative data of both years reveal that mean stem diameter in various genotypes ranged from 19.51 to 28.62 mm. The genotype HQPM 4 (28.62 mm) possessed the maximum stem diameter followed by Wasc (28.16 mm), HQPM 1 (28.12 mm), Vivek Hybrid 25 (28.00 mm), HQPM 8 (27.45 mm), Vivek Hybrid 9 (26.53 mm), Narmada Moti (26.08 mm), African Tall (25.42 mm) and Vivek Hybrid 39 (25.14 mm) whereas, minimum stem diameter was observed in Shaktiman 2 (19.51 mm) and Shaktiman 5 (19.57 mm) followed by Parkash (19.64 mm), HQPM 5 (20.55 mm), Vivek Hybrid 27 (20.69 mm), Vivek Hybrid 33 (21.69 mm), DHM 117 (21.90 mm), Shaktiman 3 (24.61 mm) and Vivek Hybrid 43 (24.68 mm).

The relationship between stem diameter and *C. partellus* damage parameters showed a highly significant negative correlation. Correlation coefficient values (r) for stem diameter was -0.792, -0.787 and -0.806 with per cent dead hearts and -0.759, -0.869 and -0.850 with number of exit holes, during *Kharif* 2018, *Kharif* 2019 and pooled data, respectively. In other words, genotypes with thicker stem resulted in more resistance. This may be related to the point that plants with thicker stems, can provide more food and shelter for larvae so that they prefer to remain at the same location where they have entered after hatching. In case of thinner stems larvae might have migrated to other parts of the stem due to insufficient food and thus the damage might have increased in thinner stems. Results of the present study are comparable to those of Afzal *et al.* (2009) [2], Jyothi (2016) [11], Nadeem *et al.* (2016) [18], Rasool *et al*. (2017) [21] and Singh (2018) [25] who had discussed the role of stem diameter towards resistance of *C. partellus* on maize.

3.2.3 Internodal length (cm)

The data generated on internodal length of various maize genotypes during *Kharif* 2018, ranged between 9.25 to 12.62 cm. The maximum internodal length was recorded in African Tall (12.62 cm) followed by HQPM 4 (12.47 cm), Vivek Hybrid 39 (12.07 cm), Vivek Hybrid 25 (12.00 cm), Vivek Hybrid 43 (11.77 cm), Vivek Hybrid 9 (11.74 cm), Wasc (11.57 cm), HQPM 8 (11.48 cm), Shaktiman 3 (11.45 cm) and Vivek Hybrid 33 (11.41 cm). The minimum internodal length was recorded in HQPM 5 (9.25 cm) and Parkash (9.50 cm) followed by Shaktiman 5 (9.81 cm), Shaktiman 2 (10.00 cm), Vivek Hybrid 27 (10.33 cm), Narmada Moti (10.78 cm), DHM 117 (10.92 cm) and HQPM 1 (10.97 cm).

During the next year *i.e*., *Kharif* 2019, the internodal length of various maize genotypes ranged between 9.64 to 13.25 cm. The maximum internodal length was recorded in Vivek Hybrid 39 (13.25 cm) and African Tall (13.17 cm) followed by Vivek Hybrid 25 (12.90 cm), Vivek Hybrid 9 (12.40 cm), HQPM 4 (12.31 cm), Shaktiman 3 (11.84 cm), Wasc (11.70 cm), Vivek Hybrid 43 (11.43 cm) and Vivek Hybrid 27 (11.08 cm). The minimum internodal length was recorded in Shaktiman 2 (9.64 cm) followed by HQPM 5 (10.04 cm), Parkash (10.18 cm), HQPM 1 (10.23 cm), Shaktiman 5 (10.29 cm), DHM 117 (10.62 cm), Vivek Hybrid 33 (10.66 cm), Narmada Moti (10.68 cm) and HQPM 8 (10.83 cm).

The pooled data pertaining to internodal length during two seasons ranged between 9.64 to 12.90 cm. The maximum internodal length was recorded in African Tall (12.90 cm) followed by Vivek Hybrid 39 (12.66 cm) Vivek Hybrid 25 (12.45 cm), HQPM 4 (12.39 cm), Vivek Hybrid 9 (12.07 cm), Shaktiman 3 (11.65 cm), Wasc (11.63 cm), Vivek Hybrid 43 (11.60 cm), HQPM 8 (11.16 cm) and Vivek Hybrid 33 (11.04 cm). The minimum internodal length was recorded in HQPM 5 (9.64 cm) followed by Shaktiman 2 (9.82 cm), Parkash (9.84 cm), Shaktiman 5 (10.05 cm), HQPM 1 (10.60 cm), Vivek Hybrid 27 (10.70 cm), Narmada Moti (10.73 cm) and DHM 117 (10.77 cm).

A negative correlation was observed between internodal length and *C. partellus* damage parameters. The correlation coefficient values showed significance with all damage parameters during both seasons and pooled data except with per cent dead hearts during *Kharif* 2019. Correlation coefficient values (r) for internodal length was -0.625, -0.439 and -0.563 with per cent dead hearts and -0.615, -0.504 and -0.592 with number of exit holes, during *Kharif* 2018, *Kharif* 2019 and pooled data, respectively. It indicates that longer internodes resulted in more resistance and less damage and might be related to the fact that genotypes with longer internodes have inheritable vigour of growth which in turn

can exhibit negative effect on larval activities inside the maize stem. Sharma and Chatterji (1972) [24], Arabjafari and Jalali (2007) [6], Abdalla and Raguraman (2014) [1], Rasool *et al*. (2017) [21] and Singh (2018) [25] reported that the maize genotypes having longer internodes were more resistant to the attack of *C. partellus*, which can be corroborated with the present findings. In contrast a positive correlation between *C. partellus* infestation and internodal length was reported by Ahmad *et al*. (1990) [3] and Jyothi (2016) [11].

3.2.4 Plant height (cm)

Plant height of various genotypes during *Kharif* 2018, varied between 171.53 to 228.19 cm. The maximum plant height was recorded in African Tall (228.19 cm) followed by Vivek Hybrid 39 (211.79 cm), HQPM 4 (209.42 cm), Vivek Hybrid 25 (207.50 cm), Vivek Hybrid 43 (207.33 cm), Vivek Hybrid 9 (203.48 cm), Shaktiman 3 (203.20 cm) and Wasc (201.42 cm). The minimum plant height was recorded in Parkash (171.53 cm) followed by HQPM 5 (174.93 cm), Shaktiman 5 (178.21 cm), Shaktiman 2 (181.01 cm), Vivek Hybrid 27 (188.85 cm), HQPM 1 (189.25 cm), Narmada Moti (191.67 cm), DHM 117 (196.53 cm), HQPM 8 (198.15 cm) and Vivek Hybrid 33 (198.67 cm).

Plant height of various genotypes varied between 176.16 to 234.71 cm in the succeeding year *i.e*., *Kharif* 2019. The maximum plant height was recorded in African Tall (234.71 cm) followed by Vivek Hybrid 39 (217.51 cm), Vivek Hybrid 25 (215.29 cm), HQPM 4 (212.80 cm), Vivek Hybrid 9 (208.04 cm), Shaktiman 3 (203.39 cm) and Vivek Hybrid 43 (200.45 cm). The minimum plant height was recorded in Shaktiman 2 (176.16 cm) followed by Parkash (177.04 cm), HQPM 5 (180.27 cm), Shaktiman 5 (183.41 cm), HQPM 1 (184.95 cm), Narmada Moti (188.13 cm), Vivek Hybrid 33 (190.42 cm), HQPM 8 (191.34 cm), DHM 117 (192.98 cm), Vivek Hybrid 27 (195.58 cm) and Wasc (198.68 cm).

The cumulative mean of plant height for *Kharif* 2018 and 2019, varied between 174.28 to 231.45 cm. The maximum plant height was recorded in African Tall (231.45 cm) followed by Vivek Hybrid 39 (214.65 cm), Vivek Hybrid 25 (211.40 cm), HQPM 4 (211.11 cm), Vivek Hybrid 9 (205.76 cm), Vivek Hybrid 43 (203.89 cm), Shaktiman 3 (203.29 cm) and Wasc (200.05 cm). The minimum plant height was recorded in Parkash (174.28 cm) followed by HQPM 5 (177.60 cm), Shaktiman 2 (178.58 cm), Shaktiman 5 (180.81 cm), HQPM 1 (187.10 cm), Narmada Moti (189.90 cm), Vivek Hybrid 27 (192.22 cm), Vivek Hybrid 33 (194.54 cm), HQPM 8 (194.74 cm) and DHM 117 (194.76 cm).

Plant height showed a negative correlation with *C. partellus* damage parameters. However, the effects were significant with per cent dead hearts during *Kharif* 2018, whereas non-significant results were observed with per cent dead hearts during *Kharif* 2019 and pooled data and number of exit holes during both seasons and pooled data. Correlation coefficient values (r) for plant height was -0.490, -0.330 and -0.425 with per cent dead hearts and -0.467, -0.428 and -0.464 with number of exit holes, during *Kharif* 2018, *Kharif* 2019 and pooled data, respectively. The damage due to borer tunneling might have obstructed the translocation of nutrients through the conducting vessels and thus the shorter plant height resulted in susceptible genotypes. These findings were more or less similar with the findings of Afzal *et al.* (2009) [2], Abdalla and Raguraman (2014) [1], Ali *et al*. (2015) [4], Nadeem *et al.* (2016) [18], Rasool *et al.* (2017) [21] and Singh (2018) [25] who reported non-significant and negative correlation with *C. partellus* damage parameters, whereas Jyothi (2016) [11] reported significant and negative correlation. The present findings cannot be compared with those of Ahmad *et al*. (1990) [3] and Munyiri *et al.* (2013) [17] because they observed positive correlation with *C. partellus* damage.

4. Conclusion

The damage parameters caused by *C. partellus* and stem morphological traits of maize genotypes based on pooled data revealed that per cent dead hearts, exit holes, number of nodes per plant, stem diameter, internodal length and plant height ranged from 0.00 to 20.42 per cent, 0.92 to 4.28, 12.23 to 16.67, 19.51 to 28.62 mm, 9.64 to 12.90 cm and 174.28 to 231.45 cm, respectively. The correlation studies revealed that number of nodes per plant, stem diameter, internodal length and plant height had negative correlation with *C. partellus* damage parameters. On the basis of above discussion some of the results showed contrary results to the present findings with respect to correlation studies. Hence this conclusion needs to be examined through further studies. Further these parameters should be studied at different locations.

5. References

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