Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(2): 1300-1305

Received: 21-01-2019
Accepted: 25-02-2019

Anil Kumar Cholla
Division of Entomology, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi, India

Pradyumn Kumar
ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi, India

Subhash Chander
Division of Entomology, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi, India

Abhijit Kumar Das
Division of Genetics, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi, India

Suby SB
ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi, India

Sunil Chandra Dubey
NBPGR, Pusa Campus, New Delhi, India

JC Sekhar
ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi, India

Correspondence
Anil Kumar Cholla
Division of Entomology, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi, India

Identification of key damage parameters and plant morphological traits associated with *Chilo partellus* resistance in maize (*Zea mays* L.)

Anil Kumar Cholla, Pradyumn Kumar, Subhash Chander, Abhijit Kumar Das, Suby SB, Sunil Chandra Dubey and JC Sekhar

Abstract
Damage parameters *viz.*, leaf injury rating (LIR), dead hearts (DH, %), stem tunnelling (ST, %) and exit holes per plant as well as data on plant morphological traits such as leaf glossiness, seedling vigour, plant height, number of nodes, leaf length and leaf width were noticed to identify key damage parameters and plant morphological traits associated with *Chilo partellus* resistance in 30 maize genotypes. Principal component analysis (PCA) identified the stem tunnelling, deadhearts and leaf injury rating as the most important traits with regard to genotypic response to stem borer resistance/susceptibility. Eleven genotypes, WNZPBTL 2, P 72 CL BRASIL 1177-2-2-1, CM-501, HKI-170 (1+2+3), HKI-488, CM-202, AEB (Y) C5 F43-1, YCY 2-2-4-1, HKI-193-1, PFSR R3-7 and HK I-PC-5 were found to be source germplasm for stem borer resistance. Correlation study between morphological traits and damage parameters revealed negative association of seedling vigour with leaf injury rating and deadheart, plant height with leaf injury rating, and photosynthetic area (leaf width) with deadheart.

Keywords: Maize, spotted stem borer, damage parameters, morphological traits, PCA, correlation

1. Introduction
The maize spotted stem borer, *Chilo partellus* (Swinhoe) (Order: Lepidoptera; Family: Pyralidae) is widely distributed in Southeast Asia and African Continent. It is a serious pest of maize (*Zea mays* L.) in India and distributed throughout the country and poses a serious threat to maize cultivation. With the release of new high yielding varieties/hybrids/composites accompanied with new production technology, maize is grown round the year in one or the other regions of the country under irrigated as well as rainfed conditions. During *Rainy season*, maize is grown predominantly in northern parts, whereas in south and east India, continuous cropping is practiced during *Rainy season* and *winter* seasons. Maize is staple food of people of Asia and is also utilized in starch, oil, food and feed industries. It is also being used as green as well as dry fodder for cattle and yellow maize is used in the poultry industry.

The high yields in maize could not be realized due to large number of insect pests associated with maize, right from sowing until harvest. As many as 130 insects have been recorded causing damage to maize crop in India. All the parts of maize plants are attacked and damaged by these pests resulting in either partial or total grain loss. Barring half a dozen species, others are sporadic and minor pests in nature. Although, inadequate application of fertilizers, low plant stand, improper weed and water management practices and other factors deserve due consideration, but in many situations even with use of adequate level of various production inputs, insects especially maize stalk borer, *C. partellus* becomes a major bottleneck in realizing yield potential and sometimes may cause total crop failure. The present investigation was undertaken to identify most important damage parameters that can be utilized in resistance breeding against *C. partellus.*

2. Material and Methods
a. Plant material: The experiment was conducted at the ICAR-Indian Institute of Maize Research (IIMR), Pusa campus, New Delhi during *Rainy season* 2012. Experimental material consisted of 30 maize genotypes along with resistant check, CM 500 and susceptible check, Basilocal Selection. Each entry was sown in 2 row plots of 4 m length, and rows were 60 cm apart. There were three replications in a randomized block design (RBD).

b. Rearing of *Chilo partellus* culture: Larvae of *Chilo partellus* were collected after splitting infested maize stalks from the field. They were reared on cut pieces of maize stems (7.5 cm long) until pupation. Pupae thus collected were kept in glass rearing jars (10 cm X 15 cm) for the emergence of adults. The moths (1 Male: 1 Female) were transferred to oviposition jars kept at 27± 1^0 c [1]. Ovipostion was examined on alternate days and portions of butter paper containing the egg mass were cut and incubated at 27 ± 1^0 C. Live moths were again transferred to fresh egg-laying jars and kept in the BOD at 21 ± 1^0 C for further egg laying. The eggs thus obtained served as a nucleus for the mass rearing of *C. partellus* on an artificial diet in the laboratory. As natural infestation is often confounded by oviposition preference and uneven distribution of the *C. partellus* within the field, it was thus deemed necessary to artificially infest the maize plants with neonate larvae of the pest to ensure an equal selection pressure on all plants.

c. Artificial infestation of maize plants with *C. partellus* in field: Infestation with neonates was done after 15 days of seedling emergence (DAE). Freshly hatched larvae of *C. partellus* were carefully picked up with the help of fine brush and placed in the whorl of the plant. The plant leaf whorl was gently tapped before infestation to avoid drowning of the larvae in water retained in the leaf whorl. Five neonates were placed in the whorl of each plant without causing any injury to them. After 25 days of infestation (DAI), all the plants in each of the replicates were observed for leaf injury using Leaf Injury Rating (LIR) scale from 1 (healthy plant) to 9 (dead heart) [2]. Data on traits important for *C. partellus* resistance, *viz.* Leaf Injury Rating (LIR), dead heart (DH,%), stem tunneling (ST,%) and exit holes per plant, six agronomic and morphological traits including leaf glossiness (LG), seedling vigor (SV), plant height (PH), number of nodes (NN), leaf length (LL) and leaf width (LW) were recorded on 30 maize genotypes under field condition.

$$\text{Dead heart incidence (\%)} = \frac{\text{Total number of plants with deadhearts in an entry}}{\text{Total number of plants in the entry}} \text{X } 100$$

The leaf injury by the stem borer was assessed two weeks after artificial infestation. Data on number of plants with *C. partellus* dead hearts were recorded at 25 days after infestation for each entry as:

Stem tunneling was recorded at maturity. The main stem of plants infested with the stem borer larvae were split open from the base to the apex and the tunnel length was measured. Mean tunnel length/plant was computed. Exit holes were also recorded at maturity. Number of exit holes was counted per plant in five randomly selected plants in each replication

d. Agronomic and Morphological traits

Each entry was evaluated visually for seedling vigor based on the height, leaf growth and robustness of the seedlings 7 days after seedling emergence (DAE) and was scored on a rating scale of 1-5. Seedlings showing maximum height, leaf expansion and robustness were scored as 1 and those showing poor growth, low leaf expansion and poor adaptation were scored as 5. Leaf glossiness was recorded 7 DAE on a scale of 1 to 5 (1= highly glossy light green, shining, narrow and erect leaves), and 5= non glossy (dark green, dull, broad, and drooping leaves). Plan height was measured on randomly selected five plants per entry from ground level to the point of initiation of panicle of main stem and average height of the plant was computed. Number of nodes was counted from the base of the stem to the point of initiation of panicle on five plants in each entry. Data on leaf length was taken from the leaf at cob node in five randomly selected plants with the help of measuring tape where as Data on leaf width was taken from the leaf at cob node in five randomly selected plants with the help of measuring tape.

e. Statistical analysis

Before statistical analysis, statistical experimental data were transformed following square root transformation in case of leaf injury rating, exit holes, leaf glossiness, seedling vigour and number of nodes, arc sign transformation in case of Dead heart and stem tunneling. Transformed data were then subjected to Duncan's Multiple Range Test (DMRT), correlation and principal component analysis (PCA) using SAS version 9.3.[3].

3. Results and Discussion

a. Expression of resistance to *C. partellus*

Results pertaining to four *C. partellus* resistant component traits *viz*., leaf injury rating (LIR), dead heart (%), Stem tunneling (%) and exit holes per plant are presented in table 1. The leaf injury rating score 1-9 scale indicated significant differences among the genotypes. The mean leaf injury rating score ranged from 2.2 to 7.7 in different genotypes. Genotypes WNZPBTL 2 (2.7) and PFSR 51016/1 (2.2) recorded lowest LIR. There were significant differences among the genotypes for dead heart damage and ranged from 14.0% in WNZPBTL 2 to 55.9% in HKI-1378. Genotype WNZPBTL 2 was rated as highly resistant as it was close to the resistant check, CM-500 (14.5%) in dead heart damage. Genotypes HKI-1378 and HKI-1352 were on par with the susceptible check, Basilocal selection, which recorded 54.8% dead-hearts. The tunneling ranged between 13.8% – 44.8%. There were significant differences in tunneling of the stem in various genotypes. Genotype WNZPBTL 2 recorded 13.8% stem tunneling that was proximal to the resistant check (14.5%). Significant differences were observed in the number of exit holes/ plant made by stem borer in different genotypes, and ranged from 5.1 to 10.9 holes/ plant. Genotype WNZPBTL 2 recorded 5.1 exit holes/plant followed by susceptible check (5.4).

b. Agronomical and Morphological traits

Results on agronomical and morphological traits in different genotypes are presented in table 2. Genotype WNZPBTL 2 recorded highest seedling vigor followed by genotypes WNZPBTL 9, V 351, WNZPBTL 6, CM-500 and PFSR R3-7. Genotype genotypes HKI-1352, HKI-1378, HKI-170 (1+2+3) and WNZPBTL 3 were on par with the susceptible check. Genotype WNZPBTL 2 recorded lowest leaf glossiness and it was proximal to the resistant check followed by PFSR 51016/1, WNZPBTL 2, WNZPBTL 8, WNZPBTL 10 (9 F) and WNZPBTL 11 (57 D). On the other hand genotypes, HKI-1352, HKI-1378, HKI-295 and WNZPBTL 9 were on par with the susceptible check. Genotypes CM-501 and YCY 2-2-4-1 recorded highest plant height. Followed by genotypes PFSR R3-7, PFSR 51016/1 and WNZPBTL 2. On the other hand, WNZPBTL 3 recorded lowest plant height among all the genotypes followed by HKI-1354-2 and HKI-1352. Genotypes PFSR R3-7 and, PFSR 51016/1 recorded highest number of nodes followed by CM-501, YCY 2-2-4-1, WNZPBTL 10 (9 F), P 72 CL BRASIL 1177-2-2-1, HKI-170 (1+2+3) and HKI-1354-2, whereas AEB (Y) C5 F43-1 and HKI-295 recorded the lowest number of nodes followed by WNZPBTL 3 and HKI-335. Genotypes CM-501, YCY 2-2-4-1 and WNZPBTL 9 recorded highest leaf length among the test genotypes followed by WNZPBTL 8, WNZPBTL 11 (57 D), HKI-170 (1+2+3) and HKI-335, while lowest leaf length was recorded in HKI-1354-2 followed by CM-202, PFSR R3-7, Basilocal Selection (Susceptible check), WNZPBTL 3, AEB (Y) C5 F 38-1, AEB (Y) C5 F43-1, V 351 and HKI-488. Genotype WNZPBTL 8 recorded highest 10.15 leaf width, followed by genotypes CM-501, WNZPBTL 2, HKI-193-1 and HKI-1354-2, whereas AEB (Y) C5 F43-1 recorded highest leaf width (5.87) followed by susceptible check (Basilocal Selection) HKI-1378 and HKI-295.

c. Analysis of variance (ANOVA)

Genotypes chosen in this study were significantly diverse from each other for all the damage parameters except exit holes (Table 3). Variation for the all the morphological traits was also significant among the genotypes, which indicated diverse germplasm base of selected materials.

d. Correlation between damage parameters and morphological traits: Correlation analysis of damage parameters *viz*., leaf injury rating, dead hearts (%), stem tunnelling (%) and exit holes and morphological traits revealed highly significant negative association of seedling vigour with leaf injury rating (0.48^{**}) and dead heart (%) (0.50^{**}); though positive sign in the table is because the scale used for seedling vigour (1=highly glossy, 5= non glossy). Significant negative correlation was revealed by plant height (-0.46^{*}) and leaf width (-0.38^{*}) with leaf injury rating and dead hearts (%), respectively. None of the morphological parameters showed significant association with stem tunnelling (%) and exit holes (Table 4). Negative association of seedling vigour with leaf injury rating and dead hearts (%) could be due to inhibition of first instar larvae to reach the growing tip because of the rapid seedling growth. [4] Seedling vigour inhibited the establishment of the shoot fly larva which was one of the most essential traits of shoot fly resistance in sorghum. High leaf glossiness and seedling vigor were used as morphological markers for selecting genotypes for their resistance against stem borer damage in maize. [5, 6] Highly trichomed and vigorous maize genotypes suffered less deadheart compared to less vigourous and trichomless due to C. *partellus* damage. In contrast, poor seedling vigour resulting in slow growth, environmental stress and low fertility increased the chance of shoot fly damage in sorghum [7]. It has also been recorded earlier that reduced plant height due to increase in LIR in screened genotypes was possibly due to less translocation of nutrients through the conducting vessels damaged due to borer tunnelling [8,9]. Total photosynthesis and crop yield has been reported to increase as a result of increase in leaf area [10]. Negative association of dead hearts with leaf width indicated that infestation of *C. partellus* affected maize yield by reducing net photosynthetic area. [11] Positive correlation of leaf glossiness with dead hearts whereas adult insects were more attracted by glossy leaves. In present investigation leaf glossiness did not resulting in any association with any of the damage parameters. As neonates were placed in the whorl of each plant artificially irrespective of leaf glossiness, it excluded the criteria of adult attraction. Morphological traits showing association with damage parameters can assist in identifying potential resistant genotypes without exposing them to the pest attack. Negative association of seedling vigour, plant height, and photosynthetic area (leaf width) with damage parameters makes them suitable morphological selection criteria for resistance breeding against stem borer.

e. Principal component analysis (PCA)

PCA was performed by taking into consideration four damaged parameters *viz*. leaf injury rating, dead hearts (%), stem tunnelling (%) and exit holes. The eigen value bar chart (Fig 1) shows, the accounted eigen value for these four principal components as 2.19, 0.92, 0.60 and 0.28, respectively. Scree plot test suggested that only first two principal components were meaningful and thus the PC1 and PC2 were retained. PC1 explained 57.4% of variation, whereas PC2 explained 23.1% variance and combined, components 1 and 2 accounted for 80.5% of the total variance among genotypes. Rest of the principal components explained only 22.2% of total variation. Factor loading of. 50 or greater for a variable was considered for loading a damage parameter on a given component. Three damage parameters *viz.* stem tunneling% (0.87), dead heart% (0.83) and leaf injury rating (0.77) were found related to PC1, whereas PC2 was more related to exit holes (0.91). All the four damage parameters showed positive factor loading on PC1, while, rest three damage parameters except exit holes showed negative factor loading in PC2. Thus stem tunnelling (%), dead heart (%) and leaf injury rating were favourable most important damage parameters in determining genotypic response to stem borer resistance or susceptibility. Principal component analysis (PCA) is a powerful tool to reduce the number of observed variables and to create lesser number of artificial variables that can explain most of the variance in the data set. Biplot of vectors corresponding to four variables classified stem tunnelling (%), dead hearts (%) and leaf injury rating in positive and negative quadrant of PC1 and PC2, respectively, whereas exit holes occurred at positive quadrant for both the PCs. Observed depiction of variable was because stem tunnelling (%), dead hearts (%) and leaf injury rating had high positive correlation with PC1 but negative correlation with PC2, in contrast, exit holes was positively associated with both the PCs. It has been reported earlier that among the damage parameters dead hearts, stem tunneling and exit holes/stalk are the most reliable parameters for characterization of resistance/susceptibility to *C. partellus* in sweet sorghum [12]. Two-dimensional projection of damaged parameter data plotted against PC1 and PC2 facilitated the classification of the genotypes into distinct, quadrants which indicated that there was substantial diversity in selected maize inbreds for resistance to *C. partellus*. Genotypes which were close together in the biplot, had recorded similar scores on these principal components. Although most of the genotypes were clustered near the origin, two genotypes (HKI-1378 and HKI-1352) in quadrant 1, one genotype each in rest of the three quadrants *viz.* Basilocal Selection (quadrant 2), CM 500 (quadrant 3) and WNZPBTL 2 (quadrant 4) appeared distant from the origin. WNZPBTL 2 positioned at extreme in negative quadrant (quadrant 4), was expected to be a superior genotype with least scores for damage parameters *viz*., stem tunnelling (%)13.75, dead hearts (%)14.03 and leaf injury rating (2.67). Quadrant 1 had 8 genotypes WNZPBTL 9, AEB (Y) C5 F 38-1, HKI-1378, HKI-1354-2, HKI-1352, HKI-335 and HKI-163, HKI-295, whereas, quadrant 2 had recorded five genotypes *viz*., Basilocal Selection, WNZPBTL 6, WNZPBTL 10 (9 F), WNZPBTL 11 (57 D) and HKI-161. Quadrant 3 had four genotypes *viz*., CM-500, PFSR 51016/1, V 351 and HKI-1332, whereas quadrant 4 had 11 genotypes *viz*., WNZPBTL 2, P 72 CL BRASIL 1177-2-2-1, CM-501, HKI-170 (1+2+3), HKI-488, CM-202, AEB (Y) C5 F43-1, YCY 2-2-4-1, HKI-193-1, PFSR R3-7 and HK I-PC-5 genotypes. All the genotypes clustered at quadrant 4 can serve as good source germplasm for resistance breeding against *C. partellus*. These genotypes can be exploited either by deriving second cycle inbreds through population improvement or immediate testing of hybrid combination.

Table 1: Expression of resistance to spotted stem borer *C. partellus* in 30 maize genotypes screened under field condition during *Rainy season* 2012

Sr. No	Name of the genotype	* leaf injury rating (LIR)	* Exit holes/plant	**Dead Heart (%)	** Stem Tunnelling (%)
1	CM-202	4.07(2.14)a-g	6.84(2.69)f-i	35.66(36.51)hi	22.5(28.3)e-h
2	CM-500	4.23(2.15)a-h	10.88(3.37)j	14.48(22.19)de	14.52(22.23)ef
3	CM-501	4.75(2.24)a-i	6.13(2.52)f-h	28.46(32.10)d-i	20.22(26.41)e-g
4	Basilocal Selection	7.71(2.85)ij	5.43(2.43)fg	54.82(47.78)j	44.75(41.92)j
5	YCY 2-2-4-1	3.90(2.08)a-e	7.17(2.74)f-i	30.64(33.38)e-i	32.56(34.77)g-j
6	PFSR R3-7	3.73(2.01)a-d	6.77(2.67)f-i	28.87(32.44)d-i	36.12(36.88)g-j
7	PFSR 51016/1	2.16(1.63)a	8.22(2.94)f-j	33.28(34.88)f-i	25.02(29.74)e-h
8	WNZPBTL 2	2.67(1.77)ab	5.06(2.35)f	14.03(21.95)d	13.75(21.74)e
9	WNZPBTL 3	4.38(2.19)a-h	7.81(2.87)f-j	34.65(35.88)g-i	29.74(32.67)f-j
10	WNZPBTL 6	3.91(2.09)a-f	7.10(2.71)f-i	31.95(33.83)f-i	39.26(38.66)h-j
11	WNZPBTL 8	3.26(1.93)a-c	6.57(2.62)f-i	28.02(31.83)d-i	33.25(34.98)g-j
12	WNZPBTL 9	3.99(2.11)a-f	7.89(2.89)f-j	35.99(36.74)hi	37.34(37.64)h-j
13	WNZPBTL 10 (9 F)	7.34(2.76)g-j	6.79(2.67)f-i	28.04(31.56)d-i	34.76(36)g-j
14	WNZPBTL 11 (57 D)	7.24(2.78)h-j	6.48(2.63)f-i	26.46(30.86)d-i	37.15(37.44)h-j
15	AEB (Y) C5 F 38-1	6.50(2.64)d-j	8.06(2.92)f-j	34.33(35.71)g-i	34.29(35.62)g-j
16	AEB (Y) C5 F43-1	6.11(2.56)c-j	7.06(2.73)f-i	29.39(32.65)d-i	23.28(28.61)e-h
17	V 351	5.50(2.42)c-j	7.25(2.76)f-i	20.91(27.10)d-i	26.51(30.89)e-i
18	P 72 CL BRASIL 1177-2-2-1	5.10(2.36)b-i	5.97(2.52)f-h	18.09(25.12)d-g	28.61(32.32)f-j
19	HK I-PC-5	5.56(2.41)b-j	7.24(2.76)f-i	16.87(23.96)d-f	32.34(34.52)g-j
20	HKI-161	6.74(2.67)e-j	7.00(2.74)f-i	22.88(28.5)d-i	39.94(38.99)h-j
21	HKI-163	7.12(2.72)f-j	8.03(2.91)f-j	27.31(31.01)d-i	32.88(34.97)g-j
22	HKI-193-1	6.43(2.62)d-j	6.49(2.61)f-i	19.62(26.19)d-h	28.83(32.26)f-j
23	HKI-170 (1+2+3)	4.86(2.24)a-i	6.51(2.61)f-i	22.14(27.75)d-i	24.33(29.46)e-h
24	HKI-1378	8.62(3.02)j	9.51(3.16)ij	55.94(48.41)j	44.37(41.71)ij
25	HKI-1354-2	6.65(2.66)e-j	8.59(3.01)g-j	29.02(32.48)d-i	35.94(36.77)g-j
26	HKI-1352	8.74(3.04)j	9.25(3.12)h-j	55.11(47.93)j	43.44(41.14)ij
27	HKI-335	5.91(2.51)c-j	7.97(2.89)f-j	37.46(37.66)i	37.06(37.34)h-j
28	HKI-295	6.13(2.55)c-j	8.55(3)g-j	34.12(35.61)g-i	30.39(33.38)g-j
29	HKI-1332	3.91(2.08)a-f	7.60(2.84)f-j	26.52(30.74)d-i	28.50(32.16)f-j
30	HKI-488	4.28(2.16)a-f	6.94(2.71)f-i	35.72(36.61)hi	28.66(32.30)f-j
S.Em±		0.23	0.22	3.27	3.12
C.D (5%)		0.64	0.61	9.25	8.84

*Values in parenthesis are square root transformed values,
** Values in parenthesis are arc sign transformed values.
Means followed by same letter do not differ significantly (*P*=0.01) DMRT

Table 2: Agronomical and Morphological traits of thirty maize genotypes studied under field condition during *Rainy season* 2012

S. No	Name of genotype	Leaf Glossiness	Seedling Vigor	Plant Height (cm)	Number of nodes	Leaf length (cm)	Leaf width (cm)
1	CM-202	2.92(1.85)d-h	4.21(2.16)i-n	101.58(2.01)h-k	11.8(3.51)fh	55.87(1.75)mn	8.46(0.93)ef
2	CM-500	2.43(1.71)hi	2.03(1.59)a-e	128.93(2.11)c	12.08(3.55)e-g	65.7(1.82)h	8.44(0.93)ef
3	CM-501	3.17(1.90)c-h	3.39(1.96)g-m	143.33(2.16)ab	12.95(3.67)b-d	78.12(1.89)a	9.42(0.97)bc
4	Basilocal Selection	4.80(2.30)a	4.84(2.31)n	98.6(1.99)jl	10.21(3.27)k	57.65(1.76)kl	6.23(0.79)n
5	JCY 2-2-4-1	3.73(2.05)a-e	2.74(1.79)c-h	151.73(2.18)a	13.46(3.74)b	77.27(1.89)a	8.21(0.91)fg
6	PFSR R3-7	2.64(1.77)f-h	2.01(1.58)a-e	136.08(2.13)bc	14.22(3.84)a	57.18(1.76)lm	7.45(0.87)jk
7	PFSR 51016/1	2.43(1.71)hi	2.58(1.75)b-h	135.4(2.13)bc	14.52(3.88)a	65.15(1.81)h	7.59(0.88)ij
8	WNZPBTL 2	2.20(1.64)hi	1.47(1.39)a	137.93(2.14)bc	11.63(3.48)gh	67.62(1.83)fg	9.35(0.97)bc
9	WNZPBTL 3	3.15(1.90) c-h	4.43(2.22)l-n	74.63(1.87)o	9.23(3.12)l	58.4(1.77)kl	7.37(0.87)jk
10	WNZPBTL 6	4.25(2.17)a-c	1.94(1.56)a-d	92.93(1.97)l-n	10.26(3.28)k	66.1(1.82)gh	8.14(0.91)g
11	WNZPBTL 8	2.51(1.73)hi	4.45(2.22)l-n	107.33(2.03)f-j	10.32(3.29)k	74.47(1.87)b	10.15(1.01)a
12	WNZPBTL 9	4.17(2.16)a-c	1.57(1.42)ab	119.75(2.08)d	10.48(3.31)k	78.61(1.9)a	8.84(0.95)d
13	WNZPBTL 10 (9 F)	2.36(1.69)hi	4.82(2.31)n	114.92(2.06)d-f	13(3.67)bc	67.41(1.83)fg	8.73(0.94)de
14	WNZPBTL 11 (57 D)	2.45(1.71)hi	3.19(1.91)e-l	108.17(2.03)e-i	11.44(3.46)hi	72.66(1.86)c	8.68(0.94)de
15	AEB (Y) C5 F 38-1	2.72(1.79)e-h	3.69(2.04)h-n	104.22(2.02)g-j	11(3.39)ij	58.66(1.77)k	6.94(0.84)l
16	AEB (Y) C5 F43-1	4.84(2.31)a	4.35(2.20)k-n	90.4(1.96)mn	8.33(2.97)m	58.67(1.77)k	5.87(0.77)o
17	V 351	4.51(2.24)ab	1.8(1.51)a-c	106.67(2.03)f-j	12.41(3.59)e	57.56(1.76)kl	7.85(0.89)h

18	P 72 CL BRASIL 1177-2-2-1	4.52(2.24)ab	3.77(2.05)h-n	99.7(2)i-l	12.96(3.67)b-d	62.36(1.79)i	6.75(0.83)l
19	HK I-PC-5	3.99(2.11)a-d	2.15(1.62)a-f	108.93(2.04)e-h	10.51(3.32)jk	66.4(1.82)gh	8.77(0.94)d
20	HKI-161	3.57(2.01)b-g	3.09(1.88)d-k	104(2.02)h-k	12.56(3.61)c-e	65.4(1.82)h	9.25(0.97)c
21	HKI-163	2.82(1.82)e-h	3.33(1.94)f-m	95.9(1.98)k-m	12.32(3.58)ef	48.57(1.69)o	7.31(0.86)k
22	HKI-193-1	1.63(1.45)i	2.24(1.63)a-g	113.33(2.05)d-g	11.47(3.46)hi	68.58(1.84)f	9.57(0.98)b
23	HKI-170 (1+2+3)	4.82(2.31)a	4.58(2.25)l-n	117.47(2.07)de	13.43(3.73)b	70.66(1.85)d	7.35(0.87)jk
24	HKI-1378	4.11(2.14)a-c	4.29(2.18)j-n	113.4(2.05)d-g	11.47(3.46)hi	68.88(1.84)ef	6.5(0.81)m
25	HKI-1354-2	3.77(2.06)a-e	3.51(2.00)h-n	88.08(1.94)n	13.3(3.71)b	55.59(1.74)n	9.26(0.97)bc
26	HKI-1352	4.82(2.31)a	4.39(2.21)k-n	86(1.93)n	12.26(3.57)ef	66.31(1.82)gh	8.25(0.92)fg
27	HKI-335	2.74(1.76)gh	3.62(2.03)h-n	105(2.02)g-j	9.38(3.14)l	70.29(1.85)de	8.7(0.94)de
28	HKI-295	3.65(2.04)a-f	2.92(1.85)d-i	68(1.83)p	8.29(2.96)m	60.37(1.78)j	6.48(0.81)m
29	HKI-1332	3.95(2.11) a-d	2.93(1.85)d-i	105.67(2.02)f-j	12.43(3.6)de	60.77(1.78)j	7.79(0.89)hi
30	HKI-488	2.63(1.77)f-h	2.98(1.86)d-j	99.93(2)i-l	10.28(3.28)k	58.21(1.77)kl	7.79(0.89)hi
S.Em±		0.1	0.12	0.01	0.03	0.0	0.01
C.D (5%)		0.28	0.33	0.03	0.07	0.01	0.01

Values in parenthesis are square root transformed values.
Means followed by same letter do not differ significantly (*P*=0.01) DMRT

Table 3: ANOVA for damage parameters and morphological traits

Source of variation	MSS	F value	*P* value
Dead hearts (%)	134.18	4.19	0.000
Exit holes/plant	0.15	1.04	0.441
Leaf injury rating	0.38	2.48	0.002
Stem tunnelling (%)	77.57	2.65	0.001
Leaf glossiness	0.17	6.01	0.000
Seedling vigour	0.22	5.59	0.000
Plant height	1132.27	40.04	0.000
Number of nodes	0.16	82.86	0.000
Leaf length	164.18	162.57	0.000
Leaf width	3.527	150.46	0.000

Table 4: Correlation between damage parameters and morphological traits

Parameters	lir	eh	dh	st	lg	sv	ph	nn	ll	lw
Leaf injury rating (lir)	1									
Exit holes/plant (eh)	0.204	1								
Dead hearts (%) (dh)	0.406*	0.254	1							
Stem tunnelling (%) (st)	0.580**	0.128	0.651**	1						
Leaf glossiness (lg)	0.275	0.060	0.319	0.312	1					
Seedling vigour (sv)	0.479**	-0.018	0.500**	0.296	0.225	1				
Plant height (ph)	-0.463*	-0.212	-0.302	-0.351	-0.327	-0.399*	1			
Number of nodes (nn)	-0.167	-0.043	-0.234	-0.108	-0.120	-0.129	0.607**	1		
Leaf length (ll)	-0.182	-0.116	-0.059	0.003	-0.064	-0.137	0.537**	0.075	1	.
Leaf width (lw)	-0.242	-0.150	-0.384*	-0.134	-0.479**	-0.306	0.341	0.238	0.502**	1

*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed).

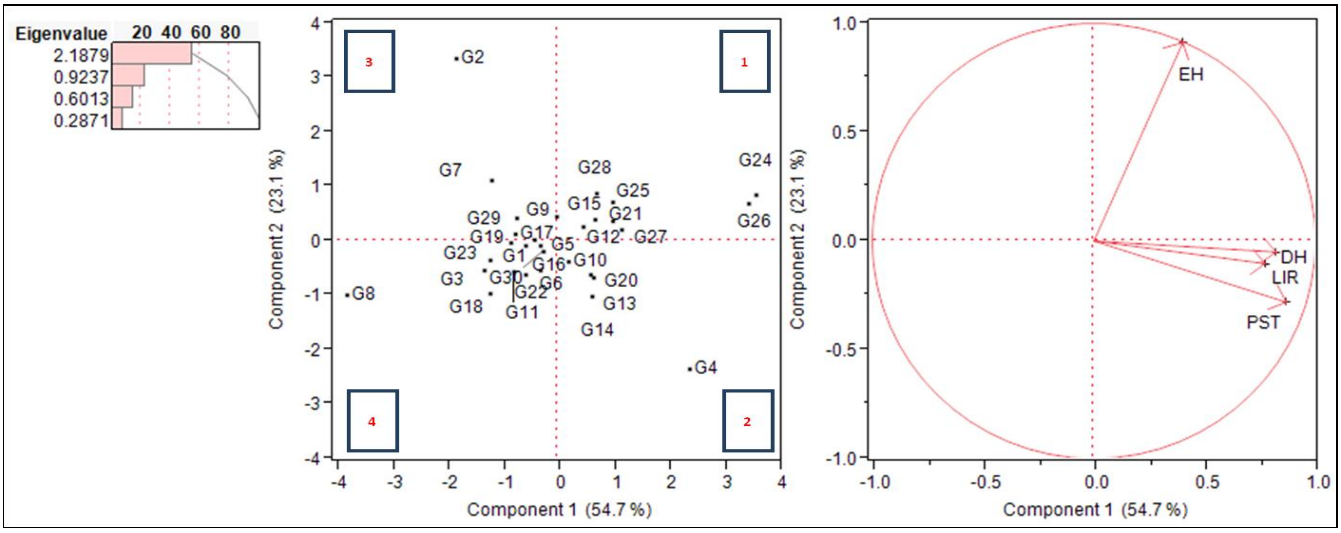

Fig 1: Eigen value bar chart, ballot of genotypes and vectors revealed by Principal component analysis (PCA)

4. Conclusion
Principal component analysis (PCA) identified the stem tunnelling, dead hearts and leaf injury rating as most important traits with regard to genotypic response to stem borer resistance. Eleven genotypes were found to be source germplasm for stem borer resistance. Correlation between plant morphological traits and damage parameters reveal negative association of seedling vigour with LIR and DH, plant height with LIR, and photosynthetic area (leaf width) with DH. Morphological traits, such as seedling vigour, plant height and photosynthetic area thus can serve as easily visible traits for resistance breeding against stem borer.

5. References
1. Siddiqui KH, Sarup P, Panwar VPS, Marwaha KK. Evolution of base-ingredients to formulate artificial diets for the mass rearing of *Chilo partellus* (Swinhoe). J Entomol Res 1977; 1(2):117-31.
2. Sarup P, Marwaha KK, Panwar VPS, Siddiqui KH. Evaluation of some exotic and indigenous maize germplasm for resistance to *Chilo partellus* (Swinhoe) under artificial infestation. J Entomol Res. 1978; 2(1):98-105.
3. SAS Institute Inc SAS/STAT 9.3 Cary, NC, USA: SAS Institute, 2009.
4. Jayanthi PDK, Reddy BVS, Gour TB, Reddy DDR. Early seedling vigour in sorghum and its relationship with resistance to shoot fly *Atherigona soccata* (Rond). J Entomol Res. 2002; 26:93-100.
5. Muturi PW. Resistance to the African and spotted stem borers in sorghum in Kenya PhD thesis submitted to Makerere University, Uganda, 2013.
6. Muhammad A, Zahid N, Muhammad HB, Bilal SK. Analysis of host plant resistance in some genotypes of maize against *Chilo partellus* (Swinhoe) (Pyralidae: Lepidoptera). Pak J Bot. 2009; 41(1):421-428.
7. Taneja SL, Leuschner K. Resistance screening and mechanisms of resistance in sorghum to shoot fly, pp. 115-129. In: Proceedings of the international sorghum entomology workshop, Texas A&M University, College Station, Texas, USA, International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502324, Andhra Pradesh, India, 1985.
8. Dass S, Mehla JC, Moudgal RK, Dhanju KS, Pal DM, Singh DP. Identification of morphological traits in maize for its least susceptibility to *Chilo partellus*. Ann Plant Protect Sci. 2006; 14(1): 33-37.
9. Rao CN, Panwar VPS, Morphological plant characters affecting resistance to *Chilo partellus* in Maize. Ann Plant Protect Sci. 2000; 8:145-149.
10. Richards RA. Selectable traits to increase crop photosynthesis and yield of grain crops. J Exp Bot 2000; 51**:**447-458.
11. Singh BU, Sharma HC, Rao KV. Mechanisms and genetic diversity for host plant resistance to spotted stem borer, *Chilo partellus* in sorghum, *Sorghum bicolour*. J Appl Entomol. 2011; 136:386-400.
12. Shyamprasad G, Bhagwat VR, Kalaisekar A, Subbarayudu B, Umakanth AV, Rao SS *et al*. Assessment of resistance to stem borer, *Chilo partellus* (Swinhoe) in sweet sorghum [*Sorghum bicolor* (L.) Moench]. Indian J Entomol. 2011; 73(2):116-120