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Improved method of screening maize germplasm for resistance against *Chilo partellus* (Swinhoe)

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Abstract

Thirty diverse maize genotypes were evaluated by infesting them artificially by stem borer (*Chilo partellus*) under field conditions during *kharif*, 2014. The stem borer infestation was measured in terms of leaf injury rating (LIR), dead hearts and stem tunneling. The damage by *C. partellus* indicated significant differences among the genotypes in respect of all the three traits measured. The leaf injury rating ranged from 2.16 in PFSR51016/1 to 8.74 in HKI 1352. The genotype WNZPBTL2 recorded minimum (14.03%) dead hearts while the genotypes HKI 1378 recorded maximum (55.94%) dead hearts. The larval feeding inside the stem resulted in minimum stem tunneling in WNZPBTL2 and maximum in Basi local i.e., 13.75 and 44.75% respectively. The correlations among damage parameters revealed significant positive association of leaf injury with dead hearts and stem tunneling. Thus these traits proved to be visual indicators of stem borer resistance. A selection index was constructed Division of Entomology, Indian Agricultural Research Institute, New Delhi 110012 India based on LIR and percent stem tunneling for selecting the best genotypes in the test population. The selection index led to the identification of WNZPBTL2 and PFSR 51016/1 as the resistance sources for *C. partellus*.

Keywords: *Chilo partellus*, maize germplasm screening, leaf injury, tunnel length, susceptibility index

Introduction

Utilizing diverse crop genetic resources that confer insect and disease resistance in crop breeding has long been one of the most effective strategies for the integrated pest management programs on crops for decades (Quisenberry and Clement 2011). Host plant resistance is the most practical and environmentally safe method of pest control if properly roped in IPM program. It is often regarded as the hub in any integrated crop or pest management strategy.

Maize is an important crop of global importance, which holds a unique position in world agriculture as a food, feed and industrial raw material require boost in productivity and production. Insect pests constitute an important biotic stress among various limiting factors that affect maize production. Stem borers are a major threat to maize yield globally. The challenge therefore, is to breed cultivars having inbuilt mechanism of resistance so as to have minimum crop losses due to stem borer infestation. Breeding for resistance is greatly enhanced when genotypes are screened efficiently against these pests. The leaf injury rating scale to evaluate the damage caused by stem borer which could be used for screening maize germplasm was first developed by Sarup (1983). To develop crop cultivars with durable resistance to insect pests, it is important to identify germplasm with diverse factors associated with resistance to the target pests and then to combine identified components/ mechanisms of resistance in the same genetic background. Some of the factors associated with resistance to insects can be quantified or monitored in plant populations and such characters can be used as "marker traits" to screen and select for resistance to insect pests (Chamarthi 2008). Leaf feeding damage, which is the first larval feeding symptom, is an important marker trait which has been used by various workers in order to distinguish resistant from susceptible genotypes (Kumar 1994). Odiyi (2007) and Singh et al. (2011) observed that the direct effect of stem tunneling on loss in maize grain yield was greater

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than the effect of leaf feeding. To achieve an overall improvement in the level of genotypic resistance that protects all stages of plant growth, resistance to more than one damage variable is required. Thus, it is important to develop approaches that eventually improve the efficiency of selecting borer-resistant genotypes in a high-yielding background. The selection criteria should consider measuring the combined effect of different components of host plant resistance, an approach that requires the use of appropriate indices that result in selection for resistance as well as grain yield performance.To maintain the continuity in adding new sources of resistance, maize germplasm belonging to different maturity groups are evaluated for their relative resistance to *C. partellus* from time to time. The present study was therefore, conducted to develop an improved method of screening maize germplasm for resistance against *C. partellus*.

Materials and methods

The culture of *Chilo partellus* was collected from the maize fields of ICAR-Indian Institute of Maize Research, Pusa Campus, New Delhi and multiplied in laboratory. Thirty inbred lines (genotypes) of maize were obtained from Regional Maize Research Centre (CCSHAU, Karnal) and Winter Nursery Centre, Hyderabad. The experiment was conducted at the ICAR-IIMR, Pusa campus, New Delhi during *kharif* 2014. Fifteen seeds of each entry were sown in 2 rows of 3m length. The row to row distance was maintained as 60 cm. The experiment was replicated thrice in a randomized block design (RBD). Thinning was carried out one week after seedling emergence to maintain plant to plant spacing of 10 cm thereby leaving twelve plants per row for experimental purpose. The crop was raised following recommended agronomic practices.

Mass rearing and rtificial infestation of plants with neonates of Chilo partellus

The field collected larvae were reared under the constant rearing environment at a temperature of 26 ± 2.0^{o}C and relative humidity of 65 ± 5%. on fresh maize stalk till pupation. Further the culture was multiplied on artificial diet (Siddiqui et al. 1977) for experimental use. The plants were artificially infested 12 days after seedling emergence with neonates of *C. partellus.* Five freshly hatched neonates 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 dew accumulated in the leaf whorl. The observations of Leaf Injury Rating (LIR) were recorded after 25 days of infestation. Each entry was scored on 1 (healthy plant) to 9 (dead heart) scale based on the severity of injury on the leaves of the plant as evolved by Sarup 1983. Stem tunneling was recorded at crop maturity stage. The main stem of plants infested with the stem borer larvae were split open from the base to the apex and the length of tunnel was measured with scale.

Formation of selection index

Considering the 100 percent loss of yield at LIR 9, the data of genotypes was arranged on scale of 1-100. The following formula was used to calculate the weighted rank of genotype for each trait.

For LIR, $$X_i = \left(\frac{X_n}{9}\right) 100$$

where, X_i is the weighted rank of the i^{th} genotype for LIR on 1-100 scale.

X_n is the LIR recorded for nth genotype

For tunnel length = $$X_i = \left(\frac{X_n}{plant\ height}\right) 100$$

X_n = Tunnel length recorded for n^{th} genotype

The selection index was calculated by taking the average of values of these two traits.

$$SI_i = \frac{\{X_i(LIR) + X_i(Stream\ tunneling\}}{2}$$

Where SI_i is the selection index of i^{th} genotype

Results

Significant differences were observed in damage parameters due to stem borer in test genotypes during screening under artificial infestation. The detailed results have been presented in Table 1.

Different damage parameters

The analysis of variance indicated significant difference in maize genotypes with respect to leaf injury rating. The leaf injury rating ranged from 2.16-8.74 in the test genotypes (Table 1). The genotypes PFSR51016/1 and WNZPBTL 2 resulted in mean LIR of 2.16 and 2.65, respectively and were considered resistant against *C. partellus* infestation on the basis of LIR. The genotypes, WNZPBTL 8, PFSR R3-7, JCY 2-2-4-1, WNZPBTL 6, HKI-1332, WNZPBTL 9, CM-

202, CM-500, HKI-488, WNZPBTL 3, CM-501, HKI-170 (1+2+3), P 72, CL BRASIL 1177-2-2-1, V 351, HK I-PC-5 and HKI-335 HKI-161 were moderately susceptible with LIR value between 3.0 to 6.0. All other genotypes showed high susceptibility towards *C. partellus*.

Significant differences were recorded among the genotypes for tunnel length due to larval feeding and the extent of tunnel length ranged from 13.75 percent in WNZPBTL2 to 44.75 per cent in Basi local (Table 1). The number of plants with LIR 9 i.e., dead hearts was observed to vary significantly among the inbred

Table 1. Damage parameters in maize due to *Chilo partellus* in *kharif* 2014

S.No.	Genotype	LIR	LIR* (out of 100)	Tunnel length (Per cent)	Dead hearts (%)	Selection index
1	CM-202	4.07(2.14)$^{d-j}$	45.22	22.5(28.3)$^{c-f}$	35.66(36.51)^{bc}	33.86
2	CM-500	4.23(2.15)$^{c-j}$	47.00	14.52(22.23)^{ef}	14.48(22.19)^{fg}	30.76
3	CM-501	4.75(2.24)$^{b-j}$	52.78	20.22(26.41)$^{d-g}$	28.46(32.1)$^{b-g}$	36.50
4	Basilocal Selection	7.71(2.85)^{ab}	85.67	44.75(41.92)^{a}	54.82(47.78)^{a}	65.21
5	JCY 2-2-4-1	3.9(2.08)$^{f-j}$	43.33	32.56(34.77)$^{a-d}$	30.64(33.38)$^{b-f}$	37.95
6	PFSR R3-7	3.73(2.01)$^{g-j}$	41.44	36.12(36.88)$^{a-d}$	28.87(32.44)$^{b-g}$	38.78
7	PFSR 51016/1	2.16(1.63)^{j}	24.00	25.02(29.74)$^{c-f}$	33.28(34.88)$^{b-e}$	24.51
8	WNZPBTL 2	2.67(1.77)^{ij}	29.67	13.75(21.74)^{f}	14.03(21.95)^{g}	21.71
9	WNZPBTL 3	4.38(2.19)$^{c-j}$	48.67	29.74(32.67)$^{a-e}$	34.65(35.88)$^{b-d}$	39.20
10	WNZPBTL 6	3.91(2.09)$^{e-j}$	43.44	39.26(38.66)$^{a-c}$	31.95(33.83)$^{b-e}$	41.35
11	WNZPBTL 8	3.26(1.93)$^{h-j}$	36.22	33.25(34.98)$^{a-d}$	28.02(31.83)$^{b-g}$	34.74
12	WNZPBTL 9	3.99(2.11)$^{e-j}$	44.33	37.34(37.64)$^{a-c}$	35.99(36.74)^{bc}	40.84
13	WNZPBTL 10 (9 F)	7.34(2.76)$^{a-d}$	81.56	34.76(36)$^{a-d}$	28.04(31.56)$^{b-g}$	58.16
14	WNZPBTL 11 (57 D)	7.24(2.78)$^{a-c}$	80.44	37.15(37.44)$^{a-c}$	26.46(30.86)$^{b-g}$	58.80
15	AEB (Y) C5 F 38-1	6.5(2.64)$^{a-g}$	72.22	34.29(35.62)$^{a-d}$	34.33(35.71)$^{b-d}$	53.26
16	AEB (Y) C5 F43-1	6.11(2.56)$^{a-h}$	67.89	23.28(28.61)$^{c-f}$	29.39(32.65)$^{b-g}$	45.58
17	V 351	5.5(2.42)$^{a-h}$	61.11	26.51(30.89)$^{b-f}$	20.91(27.1)$^{b-g}$	43.81
18	P 72 CL BRASIL 1177-2-2-1	5.1(2.36)$^{b-i}$	56.67	28.61(32.32)$^{a-e}$	18.09(25.12)$^{d-g}$	42.64
19	HK I-PC-5	5.56(2.41)$^{a-i}$	61.78	32.34(34.52)$^{a-d}$	16.87(23.96)$^{e-g}$	47.06
20	HKI-161	6.74(2.67)$^{a-f}$	66.06	39.94(38.99)$^{a-c}$	22.88(28.5)$^{b-g}$	53.00
21	HKI-163	7.12(2.72)$^{a-e}$	78.17	32.88(34.97)$^{a-d}$	27.31(31.01)$^{b-g}$	55.52
22	HKI-193-1	6.43(2.62)$^{a-g}$	71.44	28.83(32.26)$^{a-e}$	19.62(26.19)$^{c-g}$	50.14
23	HKI-170 (1+2+3)	4.86(2.24)$^{b-j}$	54.00	24.33(29.46)$^{c-f}$	22.14(27.75)$^{b-g}$	39.17
24	HKI-1378	8.62(3.02)^{a}	95.78	44.37(41.71)^{ab}	55.94(48.41)^{a}	70.07
25	HKI-1354-2	6.65(2.66)$^{a-f}$	73.89	35.94(36.77)$^{a-d}$	29.02(32.48)$^{b-g}$	54.91
26	HKI-1352	8.74(3.04)^{a}	97.11	43.44(41.14)^{ab}	55.11(47.93)^{a}	70.28
27	HKI-335	5.91(2.51)$^{a-h}$	65.67	37.06(37.34)$^{a-c}$	37.46(37.66)^{b}	51.36
28	HKI-295	6.13(2.55)$^{a-h}$	68.11	30.39(33.38)$^{a-d}$	34.12(35.61)$^{b-d}$	49.25
29	HKI-1332	3.91(2.08)$^{e-j}$	43.44	28.5(32.16)$^{a-e}$	26.52(30.74)$^{b-g}$	35.97
30	HKI-488	4.28(2.16)$^{e-j}$	47.56	28.66(32.3)$^{a-e}$	35.72(36.61)^{bc}	38.11

*data converted to 1-100 scale considering 9 as 100; Similar letters indicate non-significance of data lines. The minimum number of dead hearts (14.03 per cent) was recorded in WNZPBTL9 while the maximum number of dead hearts (55.94 per cent) was observed in HKI-1354-2 (Table 1).

Selection index and coorelations

The selection index (SI) was formulated based on two damage parameters i.e., LIR and Stem tunneling. The results of SI ranged from 21.71 to 70.28 in test genotypes (Table 1) Based on SI, the most resistant genotype WNZPTL2 was found with LIR 2.67 and stem tunneling of 13.75 per cent followed by PFSR 51016/1 with LIR 2.16 and stem tunneling of 25.02 per cent. The most susceptible genotype HKI 1352 was observed to be with LIR 8.74 and stem tunneling of 43.44 per cent followed by HKI 1378 with LIR 8.62 and stem tunneling of 44.37 per cent.

Correlation of different combinations of damage parameters caused by *C. partellus* at different plant-age was calculated using Pearson's correlation coefficient (r) for LIR, dead hearts and tunnel length among the genotypes were calculated. Significant positive correlation was found in all the combinations of damage parameters caused by *C. partellus*. The correlation of LIR with dead hearts percentage and stem tunnel length was 0.41 and 0.58, respectively. The correlation of per cent dead hearts with tunnel length was still better (0.65).

Discussion

The maize germplasm offers reservoir of genes with potential for maize improvement that needs to be exploited (Pressoir and Berthaud 2004). An understanding of the response of genotypes to *C. partellus* could add information on the selection process of maize lines. In the present study the genotypes depicted considerable variation in LIR due to damage by *C. partellus*. Different plant and insect traits have been used to discern the susceptible genotypes while screening maize for resistance against *C. partellus* by various workers. However, leaf injury rating has been the widely used criterion for evaluating the genotypes against stem borers for the last four decades. Vishvendra et al. (2017) screened maize cultivars against *C. partellus* under field conditions based on LIR and per cent dead hearts formation. Sekhar et al. (2016) screened 212 maize inbred lines against *C. partellus* during rainy season, 2012 under artificial infestation in field conditions. Various other parameters have been in use to differentiate the genotypes between resistant and susceptible along

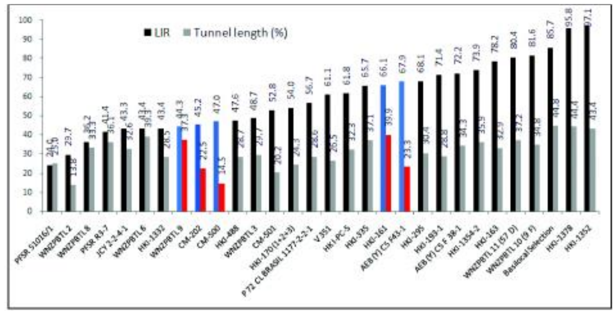

Fig. 1. Trend of tunnel length with increasing Leaf Injury Rating (LIR) in maize genotypes

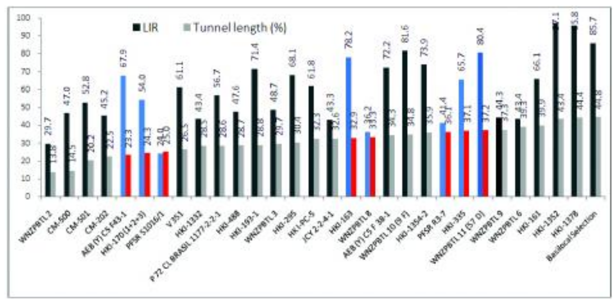

Fig. 2. Trend of Leaf Injury Rating (LIR) with increasing tunnel length in maize genotypes

with LIR. In order to know the relative susceptibility of different maize genotypes to maize stem borer, the genotypes were screened based on leaf damage, dead heart formation, number of exit holes, number of larvae and pupae recovered from the stem and mean tunnel length (Lella and Srivastava 2013).

During maize germplasm screening using artificial infestation, we concluded from the observations that while leaf feeding reduces the photosynthetic area of the plant, stem tunneling contributes to reduced maize grain yield through destruction of vascular bundles. According to Afzal (2009), stem tunneling lowered the plant growth and reduced potential yield through interruption of the flow of water and nutrients. Songa et al. (2001) observed that stem borer damage greatly reduced maize yield with tunnel lengths greater than 20 cm that caused a 40% reduction of potential yields. Furthermore, tunnel feeding reduces stem strength and predisposes the plant to lodging further compounding the yield losses. Significant differences in per cent stem tunneling among resistant and susceptible lines have also been reported by Kumar (1994). Ajala and Saxena (1994) had earlier reported this interrelationship between leaf damage and tunnel length.

The significant correlation (0.580) obtained between foliar damage and stem tunneling in our study strongly suggest that these two damage parameters are important for resistance identification. The selection for resistance to stem borers based on a single parameter may not be reliable since a resistant genotype may have some other damage parameter(s) which significantly contributes to yield loss (Ajala et al. 1993; Alghali, 1987). In the present study, the genotypes CM 500 and WNZPBTL6 expressed same (moderately susceptible) reaction based on LIR towards *C. partellus* but their tunnel length vary enormously i.e., 39.26 and 14.52 per cent proving the variation among genotypes for these damage parameters. Conversely, the genotypes WNZPBTL 9 and WNZPBTL 11(57) D have variable response in terms of LIR i.e., of 3.99 (moderately susceptible) and 7.24 (highly susceptible), but their tunnel lengths were almost on par i.e., 37.37 and 37.15 per cent respectively which again support the view of variation among genotypes for these parameters. In the light of observations, where genotypes with almost equal tunnel lengths varied greatly in LIR, and, genotypes with varied tunnel length have almost equal LIR (Figs. 1 and 2), it becomes imperative to include the contribution of both the damage parameters in deciding the resistance reaction of the genotype. Since the resistance level indicated by LIR and stem tunneling in the current study showed similar trend, it strongly suggests that these two parameters together provide robust measures of resistance in a germplasm. The weightage of dead heart was not included in selection index as it is inclusive in LIR (LIR 9 is dead heart). The expression of resistance in germplasm varies because of considerable interaction among the damage parameters associated with reduction in grain yield. The selection based solely on leaf injury may not infer the actual response of genotype for loss in grain yield because it does not account for the damage caused by second generation of borer whereas the tunnel length does. Therefore, the susceptibility index taking account of both the parameters, refine the screening method to identify the resistance level of maize germplasm. However, a fundamental limitation of this selection index is to maintain the crop till harvest to arrive at the selection decision.

Authors' contribution

Conceptualization of screening method (PK, JK); Designing of the experiments (AKC); Contribution of experimental materials (PK, SBS); Execution of field and laboratory experiments and data collection (AKC, JK); Analysis of data and interpretation (PK, JK); Preparation of manuscript (PK, JK, SC)

Declaration

The authors declare no conflict of interest

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