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Evaluation of maize genotypes for resistance to rice weevil, *Sitophilus oryzae* Linnaeous (Coleoptera: Curculionidae)

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Abstract
An experiment was conducted to study the resistance in fifteen maize genotypes against rice weevil, *Sitophilus oryzae* (L.) at Chaudhary Charan Singh Haryana Agricultural University, Hisar during 2017-2018 and 2018-2019 under laboratory conditions (28±2 °C and 70% RH). Susceptibility index, percent grain damage and percent weight loss were taken as parameters for this study. The results revealed that maximum pooled mean susceptibility index (5.0) was found in sweet corn against *S. oryzae*, therefore, it was categorized as moderately resistant genotype while minimum pooled mean susceptibility index (1.6) was recorded for HKi 161, so it was categorized as resistant. The minimum (8.72) pooled mean percent grain damage and minimum (8.26) pooled mean percent weight loss of was recorded in HKi 161 and HQPM 1, respectively. The results of experiment will be useful to improve maize protection in storage and varietal improvement/release program.

Keywords: Biology, brinjal, *Leucinodes orbonalis*, morphometry

Introduction

The maize, *Zea mays* (L.) belong to family Poaceae, is the third most important annual cereal crop of the world. It is known as queen of cereals due to highest genetic yield potential, wider adaptability to grow in varied seasons and ecologies for diverse purposes. Maize is cultivated primarily in subtropical, tropical and temperate region of the globe. It is the stable food resource in many parts of Asia including India. The local people use it mainly as flour for making chapatti but also consume it directly in roasted form or as popcorn. It is also an important food of livestock mainly for poultry and pigs. The watery by-product of maize called as steep liquor is widely used in biochemical industry and in research activity as culture medium for growing microorganisms [14]. The maize has so much utilization for domestic consumption as well as industrial purposes. Therefore, it has to be stored for longer period of time for using as animal feed, seed, grain and for processing for next seasons. But during storage maize are to be attacked by insect-pests, mites and rodents etc., which results in significant loses to the farmers.

Among all these enemies, insect-pests cause maximum losses by reducing quality, quantity and germination percentage of maize grains. The 20 to 40 percent losses were reported in many African countries which results in significant decrease in agricultural production [1]. The major insect pests of stored maize are maize weevil (*Sitophilus zeamais* Motsch), rice weevil (*Sitophilus oryzae* Linnaeous), lesser grain borer (*Rhyzopertha dominica* Fabricius) and larvae of the Angoumois grain moth (*Sitotroga cerealella* Olivier) they are internal feeder whereas, Indian meal moth (*Plodia interpunctella* Hubner), khapra beetle (*Trogoderma granarium*), red flour beetles (*Tribolium castaneum* Herbstand) *Tribolium confusum* Jacquelin Du Val are external feeder [15]. Among all these insects, *Sitophilus* spp. are major pest of maize in India because of its polyphagous nature. It causes damage by making cavity inside the grain and later on adult emerges out by making regular exit hole in grain. Under favourable conditions it can cause 80 percent damage in stored maize [12]. The damaged maize has low economic value [18] and seed germination percentage [10].

In India, traditional methods of preventing damage to stored grains are sun drying, application of vegetable oils, mixing of botanical materials etc. All these methods are easy, cheap and eco-friendly for preventing post-harvest losses due to insect pest infestation. The synthetic insecticides chiefly fumigants like phosphine, methyl bromide, cyanogen's, sulfuryl fluoride have been used extensively for preventing and curing insect-pests infestation in storage. But, the development of resistance against phosphine and malathion have been reported in India [13, 17, 2] whereas, ozone layer depletion was reported by Methyl bromide so, it was banned in developed and developing countries. Though insecticides are very effective in insect-pests management but residual effect has negative impact on environment, food commodity and human health [11,9]. All these problems can be solved by screening genotypes for susceptibility index, percent grain damage and percent weight loss. On the basis of screening, the test genotypes can be categorized as resistant and susceptibly.

Material and Methods

The present investigation was conducted at Storage Laboratory, Department of Entomology, Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar during 2017-2018 and 2018-2019. The experimental material consisted of 15 genotypes, namely, HKi 1105, HKi 193-1, HKi 1128, HKi 163, HKi 193-2, HKi 161, HM 11, HM 10, HM 9, HQPM 1, HQPM 4, HQPM 5, HQPM 7, sweet corn and baby corn. The clean, disease and insect free, 13 genotypes of maize were taken from CCS HAU, Regional Research Station, Karnal, Haryana and 2 genotypes from local market. The seeds of various genotypes were stored separately in individual plastic container (6.5 × 6.5 × 10 cm^3) at Storage Laboratory, Department of Entomology. For initiation of experiment, the culture of rice weevil, *S. oryzae* was taken from Department of Entomology, CCSHAU. As per the requirement of experiment the culture of test insect was maintained separately in BOD incubator at the temperature ranges of 28±2 °C and relative humidity of 70 percent in the Department of Entomology. The pure culture of test insect was maintained on wheat grains, which were sterilized at 50 °C for 4 hours. The sterilized grains were brought to room temperature before inoculation of test insect. The culture was observed at regular intervals for observing contamination by other insect species as well as pathogens. The male and female of test insect was identified from pure culture and used for various experimental studies The experiment was replicated thrice in Completely Randomized Design (CRD). The following parameters were evaluated:

Index of susceptibility: A sample of 50 g seeds of each maize genotype were taken separately in plastic container and ten pairs of test insect was released for oviposition. After thirty five days adults of test insect was removed and maize grains were retained in the containers for recording observations on F1 progeny emergence and their development period [7].

$$I = \frac{\text{Log F}}{\text{M. D.}} \times 100$$

Where,
I= Index of susceptibility
F= Total number of F1 adult
M.D. = Median development time

Calculation of median development period (days): The period from the middle of oviposition period to 50 percent emergence of F1 progeny [8].

Classification of susceptibility index (rating 0-11)
0-3=Resistant, 4-7= Moderately resistant, 8 -10=Susceptible and 11= Highly susceptible Damage potential estimation:- A sample of 50 g maize seeds from each genotype was taken separately in plastic containers and ten pairs of newly emerged adults of *S. oryzae* was released in each container. The number based damage estimation was done by randomly selecting 100 grains from infested sample of each genotype. On the basis of damage symptoms the healthy and infested grains were separated from randomly selected 100 grains at intervals of 30, 60 and 90 days after infestation. The percent grain damage was calculated by using following formula:

$$\text{Grain damage (\%)} = \frac{\text{Number of damaged grains}}{\text{Total number of grains}} \times 100$$

For estimation of percent weight loss, damaged and undamaged grains selected above were also weighted by using electric balance. The following formula was used for percent weight loss estimation [3].

$$\text{Weight loss (\%)} = \frac{(Wu \times Nd) - (Wd \times Nu)}{Wu \times (Nd + Nu)} \times 100$$

Where,
Wu= Weight of undamaged grains
Wd= Weight of damaged grains
Nu= Number of undamaged grains
Nd= Number of damaged grains

Statistical analysis

The data recorded in various experiments were subjected to statistical analysis. The OPSTAT software was used for analysis of data. For determination of significance in data, critical difference (C.D.) was calculated at 5 percent level of significance. The suitable transformations like log10 transformation (size data), angular (percentage data), square root (count data) were applied on the obtained data.

Results and Discussion

Susceptibility Index: The data presented in table 1 revealed that maximum F1 emergence of rice weevil adults was found in baby corn followed by HKi 1105 and sweet corn whereas minimum F1 emergence was recorded for genotype HKi 161 during 2017-2018. The minimum susceptibility index was recorded in HKi 161 and it was found at par with HM 11 whereas maximum susceptibility index was recorded for baby corn and HKi 1105. The genotypes HKi 161 and HM 11 having minimum susceptibility index showed maximum median development period.

In 2018-2019 similar trend was followed with maximum F1 emergence for baby corn followed by sweet corn whereas minimum F1 emergence was recorded for HKi 161. Similarly, maximum susceptibility index recorded in baby corn and minimum for HKi 161. On the basis of pooled susceptibility index data of both years the various genotypes were categorized as resistant, moderately resistant, susceptible and highly susceptible. Almost all the tested genotypes were found in resistant to moderately resistant category. The findings were similar [12, 16] who also found all the test varieties of maize resistant or moderately resistant on the basis of Dobie susceptibility index against maize weevil, *Sitophilus zeamais* while [6] observed maize lines MPQ-13, CML 469, CM 119 as least susceptible whereas CML 334 and CML 339 were highly susceptible to *S. oryzae* infestation on the basis of adult emergence.

Percent grain damage: The percent grain damage of rice weevil was recorded at various intervals 30, 60 and 90 DAI (Table 2). During 2017- 2018 no significant difference in percent grain damage was recorded among genotypes at 30 DAI. The maximum percent grain damage was recorded for sweet corn followed by HKi 1105 and baby corn whereas no grain damage was recorded for HM 9 and HQPM 4. The maximum percent grain damage was recorded for genotype HKi 1105 followed by baby corn and sweet corn at 60 DAI. The minimum percent grain damage was recorded for genotypes HKi 161 and it was found at par with HQPM 1 at 60 DAI. The sweet corn and baby corn showed maximum percent grain damage at 90 DAI. The minimum percent grain damage was recorded for HM 11 and HKi 161 which was at par with HQPM 1. During 2017-2018, the mean percent grain damage was maximum in sweet corn followed by baby corn, HKi 1105, HM 10, HKi 193-2 and HKi 163 whereas minimum percent seed damage was recorded for HKi 161.

During 2018-2019, no significant difference was found for percent grain damage in various maize genotypes at 30 DAI although at 60 and 90 DAI significant difference was recorded with respect to percent grain damage. The maximum percent grain damage was recorded for sweet corn followed by baby corn whereas minimum percent grain damage was recorded for HQPM 1 and it was at par with HKi 161 at 60 DAI. The percent grain damage at 90 DAI had also showed similar trend as that of 60 DAI. Maximum percent grain damage was recorded for sweet corn and baby corn whereas minimum percent grain damage was found in genotype HKi 161 and it was on par with HQPM 1 and HM 11.

The pooled percent grain damage for 2017-18 and 2018-19 showed that minimum percent grain damage was recorded HKi 161 followed by HM 11 and HQPM 1whereas maximum percent grain damage was recorded for sweet corn and baby corn. The results were in accordance with [19] who reported that composite maize (Hunius) was found least susceptible with 12.00 percent grain damage whereas the hybrid Ganga safed-2 was found highly susceptible with maximum grain damage (49.33%) due to infestation of rice weevil.

Percent weight loss: The percent weight loss by rice weevil was presented in table 3 for years 2017-2018 and 2018-2019. During 2017-18, the minimum percent weight loss was recorded for HKi 161 which was followed by HQPM 1 and HM 11 while maximum percent weight loss was recorded in sweet corn followed by baby corn, HKi 1105 and HM 10 at 60 DAI. Minimum percent weight loss was recorded in high quality protein maize, HQPM 1 followed by HKi 161 which was at par with HM 11 whereas maximum percent weight loss was recorded in sweet corn which was followed by baby corn, HKi 1105 and HKi 193-2. The mean percent weight loss for 2017-18 showed that maximum weight loss was recorded in sweet corn whereas minimum in HQPM 1.

During 2018-2019, the maximum weight loss was recorded for baby corn and it was at par with sweet corn and HKi 1105 but minimum percent weight loss was recorded for HQPM 1 which was at par with HKi 161 and HM 11 at 60 DAI. At 90 DAI, maximum weight loss was recorded in baby corn which was at par with sweet corn while minimum percent weight loss was recorded for HQPM 1 followed by HM 11 and HKi 161. The mean percent weight loss during the year 2018-19 was maximum in baby corn and minimum in HM 11.

The pooled mean percent weight loss data of both years (2017-18, 2018-19) showed that maximum weight loss was in sweet corn followed by baby corn whereas minimum in HQPM 1 followed by HM 11. The similar finding for wheat against rice weevil and lesser grain borer [4] who reported that the wheat cultivars were (GW 322, HD 3117 and HI 1544) least susceptible with minimum (3.37, 3.33 and 2.70) percent weight loss, respective while PBW 343 showed maximum 8.86 percent weight loss against rice weevil. In case of lesser grain borer, wheat cultivar HD 3165 was found to be resistant with minimum weight loss (3.37%) whereas maximum 16.28 percent weight loss was found for susceptible cultivars.

Table 1: Evaluation of Susceptibility Index (S.I.) of various genotypes of maize against rice weevil, *Sitophilus oryzae.*

Genotypes	Susceptibility Index									
	2017 -2018			2018-2019			Pooled mean			
	F1 adult emergence (no.)	M.D	S.I.	F1 adult emergence (no.)	M.D	S.I.	F1 adult emergence (no.)	M.D	S.I.	Category
HKi 1105	113.67*(10.66)	41	5.0	97.00(9.84)	43	4.6	105.33 (10.26)	42.00	4.8	Moderately resistant
HKi 193-1	26.67 (5.16)	45	3.2	11.67(3.35)	44	2.4	19.17 (4.37)	44.50	2.9	Resistant
HKi 1128	28.33 (5.32)	46	3.2	10.67 (3.23)	47	2.2	19.50 (4.41)	46.50	2.8	Resistant
HKi 163	37.67 (6.13)	46	3.4	10.33 (3.15)	45	2.3	24.00 (4.89)	45.50	3.0	Resistant
HKi 193-2	42.00 (6.47)	42	3.9	13.33 (3.62)	41	2.7	27.67 (5.26)	41.50	3.5	Resistant
HQPM 1	24.67 (4.94)	50	2.8	20.67 (4.54)	47	2.8	22.67 (4.75)	48.50	2.8	Resistant
HKi 161	10.00 (3.13)	53	1.9	3.67 (1.88)	51	1.1	6.83 (2.60)	52.00	1.6	Resistant
HM 11	15.67 (3.94)	51	2.3	4.67 (2.12)	49	1.4	10.17 (3.17	50.00	2.0	Resistant
HM 10	96.33 (9.81)	44	4.5	42.00 (6.47)	42	3.9	69.17 (8.31)	43.00	4.3	Moderately Resistant
HQPM 7	32.33 (5.68)	42	3.6	6.00 (2.41)	43	1.8	19.17 (4.37)	42.50	3.0	Resistant
HQPM 5	62.33 (7.89)	45	4.0	88.33 (9.39)	44	4.4	75.33 (8.67)	44.50	4.2	Moderately Resistant
HM 9	38.00 (6.16)	45	3.5	15.67 (3.93)	45	2.7	26.83 (5.17)	45.00	3.2	Resistant
HQPM 4	39.00 (6.24)	46	3.5	15.67 (3.93)	45	2.7	27.33 (5.22)	45.50	3.2	Resistant
Sweet corn	106.67 (10.326)	42	4.8	106.67 (10.32)	43	4.7	106.67 (10.35)	42.50	4.8	Moderately Resistant
Baby corn	124.00 (11.13)	42	5.0	123.33 (11.10)	42	5.0	123.67 (11.11)	42.00	5.0	Moderately Resistant
CD (0.05%)	(0.45)			(0.77)			(0.36)			
SE(m) ±	(0.07)			(0.21)			(0.04)			

Figure in parentheses are square root transformed

*= Mean of three replications, M.D. = Mean development period in days, S.I. = Susceptibility index,

Table 2: Extent of percent grain damage by *Sitophilus oryzae* in various maize genotypes.

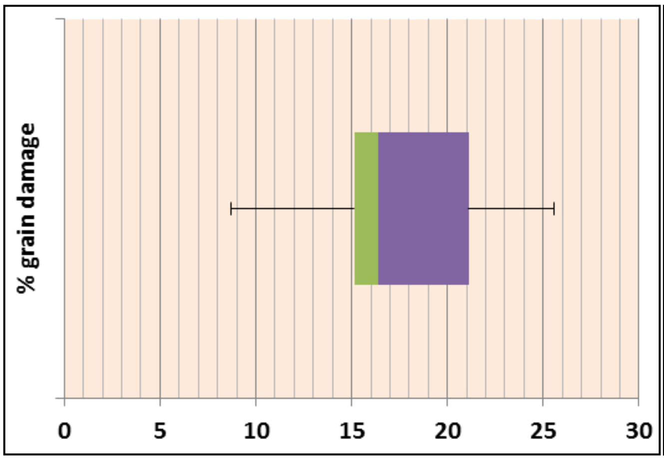
Genotypes	Percent Grain Damage								
	2017-2018				2018-2019				Pooled mean
	30 DAI	60 DAI	90 DAI	Mean	30 DAI	60 DAI	90 DAI	Mean	
HKi 1105	3.00* (7.15)	38.00 (36.86)	33.33 (35.25)	24.78 (29.84)	2.33 (8.46)	31.33 (34.02)	30.33 (33.41)	23.67 (29.09)	24.22(29.47)
HKi 193-1	1.33 (5.33)	16.33 (25.56)	28.67 (30.43)	15.44 (23.12)	2.00 (7.94)	19.33 (25.91)	25.33 (30.15)	15.22 (22.93)	15.33 (23.03)
HKi 1128	0.60 (4.71)	18.33 (27.49)	28.33 (29.76)	15.78 (23.39)	1.33 (6.53)	22.00 (27.91)	21.67 (27.71)	15. 67 (23.29)	15.72 (23.34)
HKi 163	0.60 (6.53)	21.33 (25.56)	32.00 (35.46)	18.00 (25.08)	1.00 (5.73)	21.33 (27.47)	31.67 (34.24)	17.89 (24.99)	17.94 (25.04)
HKi 193-2	0.60 (6.53)	27.33 (32.9)	33.00 (32.36)	20.33 (26.78)	1.33 (5.33)	26.33 (30.75)	29.33 (32.72)	19.89 (26.47)	20.11 (26.63)
HQPM 1	0.33 (6.53)	9.33 (17.68)	27.33 (25.08)	12.33 (20.54)	1.00 (4.71)	11.00 (19.33)	15.00 (22.69)	9.56 (17.99)	10.94 (19.30)
HKi 161	0.67 (5.73)	5.33 (15.65)	18.00 (26.54)	8.00 (16.41)	1.67 (7.15)	13.00 (20.84)	13.33 (21.39)	9.44 (17.86)	8.72 (17.15)
HM 11	1.00 (6.53)	11.33 (20.82)	17.33 (23.55)	9.89 (18.30)	2.00 (7.94)	13.67 (21.64)	15.00 (22.75)	10.0 (18.42)	9.94 (18.37)
HM 10	1.00 (7.11)	28.00 (31.56)	37.33 (37.26)	22.11 (27.96)	2.00 (7.94)	30.33 (33.41)	33.67 (35.44)	22.11 (27.96)	22.11 (27.96)
HQPM 7	0.67 (8.46)	19.67 (26.31)	26.33 (31.49)	15.56 (23.21)	1.33 (6.53)	21.67 (27.62)	27.67 (31.72)	16.4 (23.91)	16.00 (23.56)
HQPM 5	1.00 (7.94)	18.67 (25.79)	29.33 (32.13)	16.33 (23.81)	1.67 (6.13)	17.00 (24.29)	29.33 (32.78)	16.44 (23.90)	16.39 (23.86)
HM 9	0.00 (0.00)	19.67 (26.55)	30.33 (31.92)	16.89 (24.25)	1.67 (7.15)	20.33 (26.73)	29.67 (32.96)	16.44 (23.89)	16.67 (24.07)
HQPM 4	0.00 (0.00)	16.67 (23.28)	27.67 (31.93)	14.89 (22.68)	1.67 (7.15)	19.67 (26.25)	28.33 (32.13)	15.00 (22.77)	14.94 (22.73)
Sweet corn	3.33 (8.46)	32.67 (34.85)	41.67 (39.61)	25.89 (30.57)	2.00 (8.13)	30.67 (33.61)	39.00 (38.64)	25.22 (30.13)	25.56 (30.35)
Baby corn	2.33 (8.46)	33.33 (34.24)	40.00 (40.39)	24.67 (29.76)	3.00 (9.88)	30.57 (33.58)	39.00 (38.63)	25.33 (29.98)	25.00 (29.98)
CD (0.05%)	(N.S.)	(4.16)	(2.38)	(1.75)	(N.S.)	(4.94)	(3.44)	(1.91)	(1.66)
SE(m) ±	(9.09)	(6.24)	(2.04)	(0.60)	(7.52)	(8.78)	(4.27)	(0.66)	(0.57)

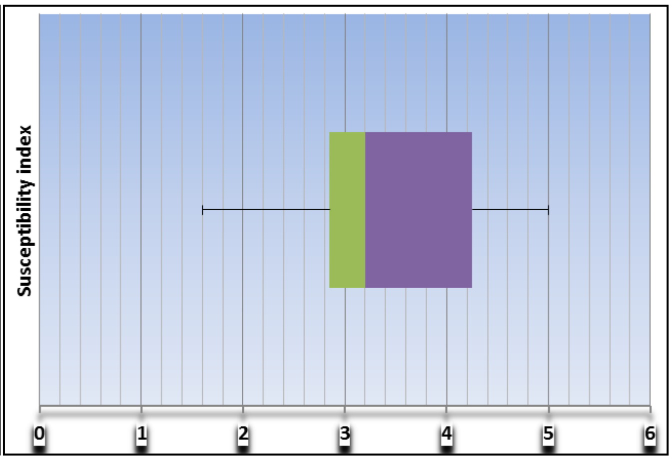
Figure in parentheses are angular transformed, N.S. = non-significant
*=Mean of three replications, DAI= days after infestation

Table 3: Extent of percent weight loss by *Sitophilus oryzae* in various maize genotypes.

Genotypes	Percent Weight Loss						
	2017-2018			2018-2019			Pooled mean
	60 DAI	90 DAI	Mean	60 DAI	90 DAI	Mean	
HKi 1105	48.27* (44.00)	54.43 (47.57)	51.35 (45.77)	49.61 (44.77)	50.67 (45.38)	50.14 (45.08)	50.75 (45.43)
HKi 193-1	10.02 (18.44)	21.63 (27.71)	15.825 (23.43)	17.50 (24.72)	26.87 (31.21)	22.19 (28.10)	19.01 (25.84)
HKi 1128	22.77 (28.49)	36.31 (37.05)	29.54 (32.92)	27.68 (24.72)	38.21 ((38.17)	32.95 (35.03	31.24 (33.98)
HKi 163	20.81 (27.14)	28.70 (32.39)	24.755 (29.83)	18.32 (31.74)	45.57 (42.46)	31.95 (34.41)	28.35 (32.17)
HKi 193-2	39.42 (38.88)	54.10 (47.35)	46.76 (43.14)	40.46 (25.33)	45.23 (42.26)	42.85 (40.88)	44.80 (42.01)
HQPM 1	7.17 (15.52)	7.23 (15.57)	7.20 (15.56)	6.14 (39.50)	12.49 (20.68)	9.32 (17.77)	8.26 (16.70)
HKi 161	6.22 (14.44)	9.02 (17.46)	7.62 (16.02)	6.58 (14.25)	17.09 (24.41)	11.84 (20.12)	9.73 (18.17)
HM 11	7.23 (15.59)	9.15 (17.60)	8.19 (16.62)	6.67 (14.85)	11.43 (19.75)	9.05 (17.50)	8.62 (17.07)
HM 10	38.62 (38.41)	48.07 (43.89)	43.34 (41.17)	37.13 (14.93)	54.97 (47.85)	46.05 (42.73)	44.70 (41.95)
HQPM 7	14.70 (22.54)	22.25 (28.14)	18.47 (25.44)	12.48 (37.53)	31.06 (33.86)	21.77 (27.81)	20.12 (26.65)
HQPM 5	19.81 (26.42)	31.91 (34.39)	25.86 (30.56)	13.59 (20.62)	38.82 (38.53)	26.21 (30.53)	26.03 (30.67)
HM 9	19.25 (26.02)	28.73 (32.41)	23.99 (29.32)	24.44 (29.61)	32.47 (34.73)	28.46 (32.24)	26.22 (30.79)
HQPM 4	9.68 (18.12)	19.11 (25.91)	14.39 (22.29)	6.35 (14.56)	34.12 (35.74)	20.24 (26.72)	17.32 (24.59)
Sweet corn	56.76 (48.88)	65.52 (54.01)	61.14 (51.44)	45.64 (42.48)	66.51 (54.64)	56.08 (48.49)	58.61 (49.95)
Baby corn	49.18 (44.53)	60.65 (51.14)	54.91 (47.81)	49.61 (43.90)	67.90 (55.49)	58.76 (50.04)	56.84 (48.93)
CD (0.05%)	(1.07)	(1.01)	(1.15)	(2.43)	(2.75)	(1.13)	(0.74)
SE(m) ±	(0.41)	(0.36)	(0.38)	(0.91)	(1.07)	(0.46)	(0.19)

Figure in parentheses are angular transformed
*= Mean of three replications, DAI= Days after infestation





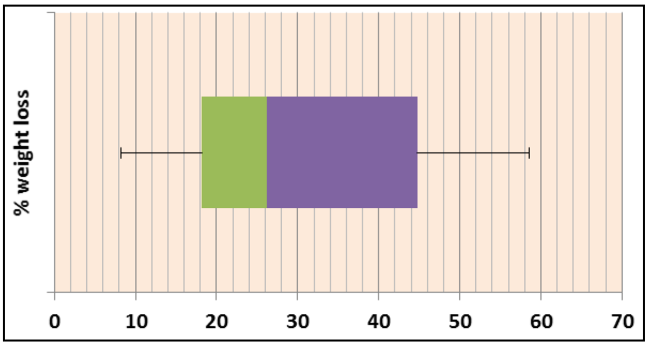


Fig 1: Box plots for *S.oryzae* infestation with percent grain damage, percent weight loss and susceptibility index of maize genotypes.

Conclusion

Observations on susceptibility index, percent grain damage and percent weight loss revealed that none of the genotype tested was immune against *S. oryzae* but the maize genotype, HKi161 showed minimum pooled susceptibility index as well as minimum percent pooled grain damage while minimum percent pooled weight loss was recorded in high quality protein maize genotype HQPM 1. Hence, there is ample opportunity to explore and utilize these genotypes with minimum susceptibility index, percent weight loss and percent grain damage in post-harvest insect pest management, maize breeding programs and varietal improvement/release.

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