General approach to quantitative and qualitative changes in the stored maize genotypes ecosystem infested by *Sitophilus zeamais* (L.) under variable thermal thresholds

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Abstract: Stored product pests are serious threats to stored grain commodities especially in under developed countries like Pakistan. Insects cut down the grains quantity and also deteriorate the grain nutrients leaving unfit for germination and food. Study was carried out to estimate losses (quantitative and qualitative) to screen out the eight advanced maize genotypes viz: NK-8441, MMRI-Yellow, 30K08, Agati-2002, SWL-2002, EV-6098, EV-1098 and Pak-Afghan against maize weevil (*Sitophilus zeamais*) at 28, 32 and 35°C. In physical losses, progeny development, frass weight, damage grain percentage and weight loss but in nutritive losses crude Protein, fat, fiber and ash was included. Results showed that in MMRI-Yellow proved most susceptible genotype following by NK-8441, Agati-2002, SWL-2002, EV-6098, EV-1098 and Pak-Afghan at 32°C. While, hybrid 30K08 genotype was highly resistant and least infested by weevil development. Similar results were estimated for qualitative losses where crude fat, fiber and ash contents were highly deteriorated in MMRI-Yellow and low in 30K08. Present research can help in breeding program.

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1. Introduction

Zia maize (Maize) among C4 plants shares a major portion of human food. (**Borchart *et al.*, 2009**)A single cob produces plenty of seeds used to make a number of palatable products. Vegetative part like leaves and stem of plant is nourishing domestic herbivores (**Danjumma *et al.*, 2009, Mugo *et al.*, 2012**). Both in developing and under developing countries maize is successfully cultivated. In Pakistan, it is among those major cereal crops that are sown at large area. Every year during the production and storage of maize grains certain insect pests attack both at field and storage level(**Shafique and Chaudry., 2007, Annonymous, 2011**). Numerous insect pests of stored products which attack on different stored grain commodities are *Sitophilus zeamais*, *Rhizopertha dominica*, *Tribolium castaneum*, *Tribolium confusum*, *Trogoderma granarium and Sitotroga cerealella*, *Sitophilus oryzae*, *Sitophilus granaries*, *Plodia interpunctella* and *Oryzaephilus surinamensis* etc (**Shafique and Chaudry., 2007, Sori and Ayana., 2012, Tasiane *et al.*, 2011, Prasanna *et al.*, 2011**). Losses estimated by different scientists are 10-15% in developing countries. Some insects attack on sound grain as early feeders like fresh or unbroken grains are known as primary insects(**Shafique and Chaudry., 2007, Tonjura *et al.*, 2010**). While secondary insects feed on already damaged or broken grains. Maize grain endosperm is rich in nutrients so plenty of stored product pests are attracted towards it(**Umoetok, 2004, Osipitan and Lawal, 2012**). Among weevil insects especially maize weevil infest more than others. Weevil chews grain with its long snout or rostrum like mouth parts making unfit for germination, reducing weight, digestibility and palatability and producing odor and frass(**Visarathanonth *et al.*, 2010, Ojo and Omoloye, 2012**). Insect attack also varies with genotypes and its genetic characteristic of the maize. So some advanced hybrid maize genotypes were selected to screen out their potential against quantitative and qualitative losses against maize weevil (*Sitophilus zeamais*)(**Prasanna *et al.*, 2011, Osipitan and Lawal, 2012**).

2. Materials and Methods

Research work was carried out in the Grain Research, Training and Storage Management Cell of the Department of Agri. Entomology, University of Agriculture Faisalabad in order to evaluate the relative resistance of eight maize genotypes viz: NK-8441, MMRI-Yellow, 30K08, Agati-2002, SWL-2002, EV-6098, EV-1098, Pak-Afghan against maize weevil (*Sitophilus zeamais*) at different temperatures. The samples of different maize genotypes varieties were taken from Maize and Millet Research Institute Yousafwala Sahiwal. In the laboratory, grains were treated with heat treatment to eliminate any prior infestation before starting the experiment. Samples were washed with water and dried grains moisture contents were maintained at 10-12%. The experiment was performed using Completely Randomized Design with three replications for each treatment. Sample of each genotype weighing 50g were taken in 150g capacity glass jars. Adults *Sitophilus zeamais* (M.) obtained from the reared stock cultures and batches of 30 weevil insects were released separately in each jar. For estimation of losses, jars of grains were placed in incubators at 28, 32 and 35^{o}C. The data for quantitative and qualitative losses by insect infestation were recorded for each genotype after 45, 90 and 120 days.

Quantitative Analysis

Adult emergence

Thirty healthy insects were released in each sample jar and data was recorded three times at 45days intervals. All the adult weevils were counted that were produced in each jar.

Weight of Frass (g)

Powdery material collected at the bottom of the jar in the form of insect feces, debris and broken food particles is known as frass was taken three times after 45 90 and 120days. LD model digital electronic electrical balance was used for this purpose to minimize the equipment error.

Percentage weight loss

Infected grains in each jar was subjected to sieving to split frass, grain dust and other excretion added due to *Sitophilus zeamais* (M). A sample weighing 50 gram was taken from the cleaned maize for assessment of percent weight loss. For this purpose, number and weight of damaged and undamaged grains were recorded and put in the next given equation for determination of weight loss (**Gwinner *et al.*, 1996**).

$$\text{Weight loss (\%)} = \frac{(Wu.Nd)-(Wd.Nu)}{Wu\ X\ (Nd+Nu)} x100$$

Where

Wu = Weight of undamaged grains

Nd = Number of damaged grains

Wd = Weight of damaged grains

Nu = Number of undamaged grains

Percentage damaged grains

Percentage damaged grains were determined by counting the damaged grains with following formula

Percentage damage grains = No of damage grains/ Total number of grains× 100.

Qualitative analysis

Crude fat

Crude fat contents were determined by using "Soxhlet Apparatus" along hexane as solvent (AOAC, 2006). The crude fat was determined according to the given formula.

Crude fat (%)= (Weight of original sample – Weight of sample after extraction) x 100/(Weight of original sample)

Crude protein

Crude protein was determined by Kjeldal method in (AOAC, 2006). The sample (3 g) was first digested with 25 mL concentrated sulphuric acid in the presence of digestion mixture for 5-6 hours or till light green or transparent color of the sample. The sample was diluted to 250 mL with distilled water. The distillation was done by taking 10 mL of diluted sample and 10 mL of 40% NaOH solution in distillation apparatus. The ammonia thus liberated was collected in 2% boric acid solution containing methyl red as indicator. Finally the sample containing ammonium burate was titrated against 0.1 N H_2SO_4 solutions till golden brown end point. The crude protein percentage was calculated by multiplying nitrogen with a factor 6.25 as given below.

Crude protein = nitrogen (%) x 6.25

Fiber content

The crude fiber contents were estimated by taking 3g fat free sample of each treatment. Firstly it was allowed to digest in 1.25% H_2SO_4 for 30 mints followed by washing and filtering the residue in distilled water. This material was again digested in another solution containing 1.25% NaOH for 30 mints followed by same washing and filtering treatment. Then received residue was allowed to dry and ignite in muffle furnace 3-5 hours at temperature of 550-650°C till grey or white ash as described in AOAC (2006). The percentage of crude fiber was calculated according to the expression given below.

Crude fiber (%) = Weight loss on ignition x 100/Weight of sample

Ash content

The ash content is total inorganic matter of a grain. It was estimated by using oven dried 3g sample of each treatment were charred on the burner and then ignite prior to place in muffle furnace at the temperature of 550-600ºC for 5-6 hours or till to grayish or whitish ash formed. As given by AOAC (2006). The ash contents were calculated with the help of following given formula.

Ash content (%) = Weight of ash x100/Weight of flour

3. Results

For Quantitative Losses

After 45 days

Data collected for quantitative analysis for Weight loss, frass weight, undamaged grains and insect emergence was significant in maize genotypes after 45 days as in Table no.1. In relation to thermal effect maximum (51.542) insect development was recorded at 32°C followed by (35.708) (4.667) at 28 and 35°C respectively. While among genotypes high (43.44) number of insects emerged in MMRI-Yellow and lowest (22.556) number of insect emerge in 30K08. Significantly frass weight calculated as shown in Table no.1 varied with temperature fluctuations among all maize genotypes. Proving optimum temperature 32°C was more infested with high frass weight (0.58g) followed by (0.27g) at 28°C and (0.20g) at 35°C. MMRI -Yellow (1.32g) was more susceptible and as compare to other genotypes but 30K08 (0.0312g) proved high resistant level. Percentage damaged grains was high in SWL-2002 (16.30%) and MMRI-Yellow (15.98%) and heavily infested by maize weevil but least in 30K08 (3.42%). Overall More percentage damage grains (16.15%) was recorded at 32°C followed by 28°C (3.96%) and 35°C (1.89%) as given in Table no.2. Weight loss calculated by using weight loss formula indicated maximum percentage weight loss due to weevil infestation in MMRI-Yellow (6.90%) and minimum in 30K08 (0.21%). Optimum thermal thresh hold was observed 32°C with mean value of (4.35%) then 28°C (1.13%) and 35°C (0.41%).

After 90 Days

Losses calculated after 90 days of storage for all above mentioned parameters are given individually in tabular form. Data recorded for insect multiplication showed that high F1 progeny was recorded at 32°C (100.67) and less population at 28°C (66.08) and 35°C (11.79). Progeny was recorded in all sorghum genotypes but low number of insects emerged in 30K08 (42.44) and high number of insect emerge in MMRI-Yellow (88.44). Rest of the genotypes showed almost similar kind of weevil population. Among all sorghum genotypes high frass weight was recorded in EV-6098 (2.94%) and lowest weight of frass was recorded in 30K08 (0.06g) as in Table no.3. While, more frass weight was recorded at 32°C as compare to other thermal conditions. Weight loss calculated by Gwinner's formula is given in Table no.3. Similarly as data recorded after 45 days and with the passage of time due to high infestation rate maximum, minimum percentage weight loss was recorded in MMRI-Yellow (7.55%) and 30K08 (0.33%) respectively. Both peak temperature conditions (28°C (1.90%) and 35°C (5.17%)) were not as favorable as at 32°C (5.17%). Genotypic and phenotypic characters of grain like seed coat and quantity of endosperm effected the weevil infestation variably as shown in Table no.4. 30K08 (6.04%) was best among all verities but MMRI-Yellow (23.83%) was severely infested by weevil especially at 32°C.

After 120 Days

Observations made after 120 days were miraculous indicated highly significant results as in Table no.5 indicating that number of insect emergence varied from each other in different varieties at different temperature. Massive insect population emerged in hybrid MMRI-Yellow (171.0) but hybrid 30K08 (76.22) did not allowed weevil to flourish. Maximum F1 progeny development recorded at optimum thermal thresh hold (32°C) (170.46) and least at 28°C (129.21) and 35°C (26.25). Frass collected and weighted after 120 days after removal of all other materials was high in MMRI-Yellow (6.38g) proving most susceptible genotype and lowest as resistant genotype in 30K08 (0.10gg). Maximum infestation was observed at 32°C as given in Table no.5. In similar trend as observed after 90 days for weight loss was again repeated with more severity as given in Table no.6. Genotype showed best genetic traits in 30K08 (0.10g) least losses were occurred as compared to NK-8441, Agati-2002, SWL-2002, EV-6098, EV-1098 and Pak-Afghan. Among all these genotypes MMRI-Yellow (6.38g) was voraciously infested by weevil especially at 32°C. More damaged grains were counted at 32°C (17.1%) as compared to rest of the temperature conditions. More number of damaged grains was counted in MMRI-Yellow among all sorghum genotypes as shown in Table no.6.

For Qualitative Losses

Nutritive losses were significantly recorded after the completion of quantitative losses estimation as mention in Table no.7. Proximate analysis for crude protein content range was 6.51% to 6.11%. The highest protein content was recorded in 30K08 (6.51%) due to minute infestation and high protein content deterioration was recorded in MMRI-Yellow (6.11%) followed by NK-8441 (6.26%), Pak Afghan (6.26%), SWL-2002 (6.26%) and EV-6098 (6.26%). Feeding effect of *Sitophilus zeamais* (Motsch.) on fat content was significantly variable as in Table no.7. A wide range (0.74% to 0.34%) of crude fat was extracted from infested samples. The highest amount of fat contents were observed in 30K08 variety (0.74%) and lowest for MMRI-Yellow (0.34%). As compared to protein content, crude fiber was severely deteriorated by *Sitophilus zamias* presented in Table no.8. The least fiber contents were in MMRI-Yellow (0.15%) while highest amount was observed in genotype 30K08 (0.38%). The range of fiber contents was 0.38% to 0.15%. The results indicate the feeding effect of *Sitophilus zeamais* (Motsch.) on Ash content has been presented in Table no.8. It also indicates that there were significant differences for the Ash contents among the different maize varieties. The range of ash contents was 0.49% to 0.18%. The highest amount of

Ash contents were observed in 30K08 variety (0.49%) and lowest for MMRI-Yellow (0.18%).

Table 1: Comparative mean values for adult emergence and frass weight in Sorghum genotypes to estimate quantitative losses against *Sitophilus zeamais* (L.) after 45 days

Varieties	Adult emergence			frass weight (g)		
	Temperatures (Mean ± S.E)			Temperatures (Mean ± S.E)		
	28°C	32°C	35°C	28°C	32°C	35°C
MMRI-Yellow	46.67±1.45cde	72.33±1.41a	11.33±1.44g	0.63±0.09bc	2.22±0.08a	1.12±0.09b
Pak-Afghan	32.67±1.41ef	64.0±1.42ab	4.0±1.40g	0.32±0.07bc	0.81±0.05bc	0.14±0.06bc
EV-6098	40.0±1.42def	52.66±1.45bcd	2.3±1.39g	0.35±0.08bc	0.66±0.08bc	0.12±0.07bc
SWL-2002	33.0±1.47ef	59.3±1.46abc	1.6±1.45g	0.69±0.06bc	0.14±0.07bc	0.07±0.06c
EV-1098	38.0±1.40def	45.67±1.42cdef	9.33±1.38g	0.20±0.08bc	0.43±0.08bc	1.33±0.07c
Agati-2002	33. ±1.430ef	43.0±1.39def	7.33±1.41g	0.04±0.09c	0.17±0.09bc	0.11±0.08c
NK-8441	31.67±1.44ef	38.3±1.45def	1.33±1.42g	0.07±0.07c	0.13±0.08bc	0.02±0.07c
30K08	30.67±1.41f	37.0±1.35def	0.00±1.39g	0.02±0.05c	0.07±0.07c	0.0±0.06c

Any two means not sharing a letter in common differ significantly at 5% level of probability

Table 2: Comparative mean values for percentage weight loss and percentage damaged grains and frass weight in Sorghum genotypes to estimate quantitative losses against *Sitophilus zeamais* (L.) after 45 days

Varieties	Weight loss (%)			Percentage damaged grains		
	Temperatures (Mean ± S.E)			Temperatures (Mean ± S.E)		
	28°C	32°C	35°C	28°C	32°C	35°C
MMRI-Yellow	2.78±0.47bcd	16.26±0.44a	1.66±0.45cd	5.22±0.47cdefgh	36.36±0.45a	6.38±0.46cdefg
Pak-Afghan	0.98±0.47cd	5.78±0.44b	0.23±0.46cd	4.93±0.48defgh	19.6±0.46b	1.79±0.48fgh
EV-6098	1.43±0.49cd	3.57±0.47bc	0.38±0.48cd	6.72±0.48cdef	18.84±0.48b	0.65±0.48h
SWL-2002	1.51±0.49cd	3.31±0.48bcd	0.47±0.49cd	2.84±0.49fgh	16.30±0.47b	0.35±0.44h
EV-1098	0.94±0.48cd	2.85±0.47bcd	0.43±0.47cd	4.06±0.42efgh	9.20±0.43cde	2.79±0.47fgh
Agati-2002	0.59±0.44cd	1.99±0.40cd	0.04±0.41d	4.71±0.49defgh	9.60±0.48cd	1.50±0.45fgh
NK-8441	0.56±0.46cd	0.73±0.45cd	0.06±0.43d	1.94±0.47fgh	10.43±0.48c	1.68±0.48fgh
30K08	0.22±0.49cd	0.39±0.47cd	0.00±0.46de	1.34±0.46gh	8.92±0.46cde	0.00±0.46h

Any two means not sharing a letter in common differ significantly at 5% level of probability

Table 3: Comparative mean values for adult emergence and frass weight in Sorghum genotypes to estimate quantitative losses against *Sitophilus zeamais* (L.) after 90 days

Varieties	Adult emergence			frass weight (g)		
	Temperatures (Mean ± S.E)			Temperatures (Mean ± S.E)		
	28°C	32°C	35°C	28°C	32°C	35°C
MMRI-Yellow	80.0±0.19def	154.67±0.17a	30.66±0.18g	1.31±0.16bc	4.53±0.17a	2.30±0.19ab
Pak-Afghan	64.33±0.17ef	125.0±0.18b	9.00±0.17gh	0.64±0.17c	1.57±0.20bc	0.37±0.21c
EV-6098	64.33±0.18ef	115.0±0.17bc	7.33±0.16gh	0.70±0.19c	1.31±0.18bc	0.37±0.16c
SWL-2002	75.66±0.19def	88.0±0.18cde	21.66±0.17gh	1.16±0.18bc	0.27±0.19c	0.18±0.19c
EV-1098	60.0±0.16f	98.66±0.17bcd	7.00±0.18gh	0.40±0.19c	0.86±0.18c	0.13±0.20c
Agati-2002	63.33±0.18ef	83.0±0.17def	15.33±0.16gh	0.07±0.20c	0.34±0.17c	0.23±0.18c
NK-8441	61.0±0.15ef	73.66±0.16def	3.33±0.16gh	0.13±0.22c	0.26±0.21c	0.04±0.19c
30K08	60.0±0.17f	67.33±0.19ef	0.00±0.18h	0.04±0.17c	0.13±0.19c	0.00±0.18c

Any two means not sharing a letter in common differ significantly at 5% level of probability

Table 4: Comparative mean values for percentage weight loss and percentage damaged grains and frass weight in Sorghum genotypes to estimate quantitative losses against *Sitophilus zeamais* (L.) after 90 days

Varieties	Weight loss (%)			Percentage damaged grains		
	Temperatures (Mean ± S.E)			Temperatures (Mean ± S.E)		
	28°C	32°C	35°C	28°C	32°C	35°C
MMRI-Yellow	3.10±0.64b	15.49±0.64a	4.08±0.65b	13.78±0.65bcdef	43.29±0.66a	14.40±0.67bcdef
Pak-Afghan	3.0±0.65b	6.71±0.67b	3.75±0.64b	8.38±0.64def	36.35±0.65ab	6.97±0.63def
EV-6098	2.07±0.67b	6.42±0.66b	2.22±0.62b	11.4±0.63cdef	33.45±0.64abc	5.21±0.62def
SWL-2002	2.72±0.65b	3.32±0.65b	1.35±0.67b	14.1±0.65bcdef	26.0±0.66abcde	2.38±0.67ef
EV-1098	1.99±0.63b	3.82±0.63b	1.20±0.66b	6.95±0.62def	27.35±0.65abcd	3.55±0.65ef
Agati-2002	1.20±0.65b	3.75±0.65b	1.66±0.61b	9.45±0.61def	15.81±0.63bcdef	4.52±0.64def
NK-8441	2.11±0.66b	1.31±0.62b	0.91±0.64b	3.03±0.66ef	19.67±0.67abcdef	4.87±0.68def
30K08	0.49±0.64b	0.50±0.65b	0.00±0.63b	4.46±0.64def	13.65±0.63bcdef	0.00±0.62f

Any two means not sharing a letter in common differ significantly at 5% level of probability

Table 5: Comparative mean values for adult emergence and frass weight in Sorghum genotypes to estimate quantitative losses against *Sitophilus zeamais* (L.) after 120 days

Varieties	Adult emergence			frass weight (g)		
	Temperatures (Mean ± S.E)			Temperatures (Mean ± S.E)		
	28°C	32°C	35°C	28°C	32°C	35°C
MMRI-Yellow	148.33±1.75de	297.0±1.76a	67.67±1.77j	2.30±0.25cd	9.48±0.21a	6.66±0.23b
Pak-Afghan	128.0F±1.76ghi	213.0±1.75b	17.67±1.78lmn	1.22±0.24cde	3.20±0.22c	0.73±0.24de
EV-6098	143.33±1.74def	138.67±1.75defg	44.33±1.75k	1.35±0.26cde	1.76±0.25cde	0.76±0.22de
SWL-2002	121.68±1.76ghi	183.0±1.75c	17.0±1.77lmn	0.75±0.24de	1.65±0.26cde	0.03±0.26e
EV-1098	132.33±1.75efgh	138.33±1.74defg	31.33±1.3kl	0.14±0.28e	0.63±0.26de	0.44±0.25e
Agati-2002	126.0±1.77fghi	153.0±1.76d	21.0±1.75lm	0.21±0.27e	0.50±0.25e	0.31±0.22e
NK-8441	118.33±1.75hi	129.0±1.76fghi	9.67±1.74mn	0.26±0.26e	0.55±0.25e	0.06±0.24e
30K08	115.67±1.74hi	111.67±1.75i	1.33±1.76n	0.07±0.25e	0.22±0.24e	0.00±0.23e

Any two means not sharing a letter in common differ significantly at 5% level of probability

Table 6: Comparative mean values for percentage weight loss and percentage damaged grains and frass weight in Sorghum genotypes to estimate quantitative losses against *Sitophilus zeamais* (L.) after 120 days

Varieties	Weight loss (%)			Percentage damaged grains		
	Temperatures (Mean ± S.E)			Temperatures (Mean ± S.E)		
	28°C	32°C	35°C	28°C	32°C	35°C
MMRI-Yellow	14.96±1.57bcde	48.28±1.56a	7.42±1.52cde	41.07±0.83b	54.50±0.86a	31.09±0.85cde
Pak-Afghan	7.02±1.55cde	28.47±1.55b	2.58±1.51e	21.87±0.85fghi	37.21±0.85bc	10.27±0.86jklm
EV-6098	7.61±1.53cde	20.04±1.54bcd	3.97±1.54de	26.04±0.86defgji	33.38±0.83bcd	8.89±0.86klmn
SWL-2002	3.08±1.56e	21.62±1.52bc	3.109±1.56e	15.59±0.87ijklm	30.76±0.84cdef	10.53±0.84jklm
EV-1098	8.81±1.57cde	6.19±1.51cde	6.61±1.55cde	17.55±0.82hijk	27.03±0.85defg	9.85±0.86jklmn
Agati-2002	3.71±1.55de	9.22±1.54cde	4.80±1.57de	16.95±0.82ijkl	23.10±0.8efghi	11.39±0.83jklm
NK-8441	2.68±1.55e	1.73±1.55e	5.02±1.56de	7.05±0.84mn	29.05±0.87cdef	8.57±0.85lmn
30K08	2.37±1.57e	1.25±1.53e	0.33±1.53e	8.35±0.85lmn	18.11±0.86ghij	1.28±0.85n

Any two means not sharing a letter in common differ significantly at 5% level of probability

Table 7: Comparative mean values for Crude fat (%) and Crude fiber (%) in Sorghum genotypes to estimate qualitative losses against *Sitophilus zeamais* (L.)

Varieties	Crude fat (%)			Crude fiber (%)		
	Temperatures (Mean ± S.E)			Temperatures (Mean ± S.E)		
	28°C	32°C	35°C	28°C	32°C	35°C
MMRI-Yellow	0.79±0.06a	0.79±0.05a	0.63±0.06abcde	0.33±0.03bcde	0.49±0.02a	0.33±0.04bcde
Pak-Afghan	0.73±0.04Abc	0.37±0.03efg	0.49±0.05cdef	0.27±0.01bcdefgh	0.41±0.02abc	0.26±0.03cdefgh
EV-6098	0.75±0.04abc	0.44±0.05efg	0.39±0.04efg	0.26±0.04bcdefgh	0.23±0.06ab	0.42±0.02efgh
SWL-2002	0.73±0.03abc	0.44±0.04efg	0.39±0.05efg	0.28±0.05bcdefgh	0.37±0.04abcde	0.25±0.01cdefgh
EV-1098	0.76±0.05ab	0.46±0.02defg	0.33±0.06fg	0.26±0.03bcdefgh	0.31±0.05ab	0. 23±0.04efgh
Agati-2002	0.73±0.02abc	0.39±0.05efg	0.22±0.04g	0.26±0.02bcdefgh	0.27±0.04bcdefgh	0.26±0.05bcdefgh
NK-8441	0.72±0.06abcd	0.35±0.05fg	0.23±0.06g	0.24±0.05defgh	0.16±0.03fgh	0.22±0.06efgh
30K08	0.52±0.04bcdef	0.31±0.05fg	0.19±0.05g	0.22±0.04efgh	0.11±0.03h	0.13±0.05gh
Control	0.80±0.03a	0.80±0.04a	0.80±0.06a	0.40±0.02abcd	0.40±0.01abcd	0.40±0.03abcd

Any two means not sharing a letter in common differ significantly at 5% level of probability

Table 8: Comparative mean values for Crude protein (%) and percentage damaged grains and Crude ash (%) in Sorghum genotypes to estimate qualitative losses against *Sitophilus zeamais* (L.)

Varieties	Crude protein (%)			Crude ash (%)		
	Temperatures (Mean ± S.E)			Temperatures (Mean ± S.E)		
	28°C	32°C	35°C	28°C	32°C	35°C
MMRI-Yellow	6.59±0.03a	6.52±0.05a	6.43±0.04ab	0.46±0.03abcd	0.48±0.06abc	0.53±0.02ab
Pak-Afghan	6.51±0.04a	6.44±0.04ab	6.12±0.03bcde	0.37±0.02abcdef	0.41±0.06abcde	0.36±0.05abcdef
EV-6098	6.51±0.05a	6.33±0.05abc	6.10±0.04cde	0.34±0.07abcdef	0.27±0.05bcdef	0.34±0.06abcdef
SWL-2002	6.48±0.03a	6.35±0.04ab	5.98±0.05de	0.34±0.04abcdef	0.24±0.04bcdef	0.26±0.05bcdef
EV-1098	6.50±0.03a	6.33±0.03abc	5.95±0.04e	0.34±0.08abcdef	0.25±0.07bcdef	0.25±0.06bcdef
Agati-2002	6.50±0.04a	6.34±0.05abc	5.94±0.05e	0.34±0.04abcdef	0.24±0.06cdef	0.26±0.07bcdef
NK-8441	6.51±0.05a	6.34±0.03abc	5.93±0.04e	0.35±0.03abcdef	0.17±0.04def	0.16±0.05ef
30K08	6.31±0.02abcd	6.12±0.04bcde	5.90±0.05e	0.31±0.07abcdef	0.11±0.08f	0.11±0.06f
Control	6.60±0.04a	6.60±0.04a	6.60±0.06a	0.60±0.05a	0.60±0.06a	0.60±0.07a

Any two means not sharing a letter in common differ significantly at 5% level of probability

4. Discussion

Significant investigation was made for percentage damage grains, weight loss and frass weight due to *Sitophilus zeamais* infestation in stored corn seeds after 45, 90 and 120 days (**Caneppele *et al.*, 2003**). Morphological effects of maize genotypes against growth and development of *S. zeamais* (**Vowoter *et al.*, 2005.**). They also observed losses caused by *P. truncatus* was 26% and by maize weevil 6%. It was observed that about 37 species of Arthropoda are closely associated with maize during storage (**Sori and Ayana., 2012**). After six months of storage significantly estimated mass loss due to weevils in the bin (0.4%) and control (2.1%) (**Demissi *et al.*, 2003**). It found that high rate progeny development 1000 adult insects per kg among different varieties and qualitative deterioration level was also significantly calculated (**Firoz *et al.*, 2007**). High insect populations was calculated in stored cereals (**Siwale *et al.*, 2009**). Single maize grain consist of 74% carbohydrates 5.7% fats contents 11.4% proteins 2.3% crude fiber 1.6% ash contents. 461 calories energy is obtained from 100 gram of maize grains (Rana and Khan. 1985). Qualitative estimation were calculated 15 to 56% of the daily calories energy is obtained from maize (**Prasanna *et al.*, 2011**).

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