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Comparative resistance of mungbean genotypes against pulse beetles, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) under temperate condition of Kashmir valley

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Abstract
The present investigations on monitoring, screening and assessment of population of pulse beetle on mungbean under free choice conditions of twenty three genotypes of mungbean obtained maximum number of eggs (2.2 grain^{-1}) of pulse beetle on genotype ML-818 and minimum (0.80 grain^{-1}) on COGG-912. The survival percentage was also found highest on ML-818 (77.42%) and lowest in COGG-912 (41.60%). Minimum seed damage was recorded on COGG-912(53.33%) while maximum in ML-818 (96.66%). This resulted minimum per cent weight loss in COGG-912 (43.71%) while maximum in ML-818(66.91%). Least number of adults of pulse beetle were attracted towards COGG-912 (1.0%) while highest in Market Sample (9.0%). The susceptibility index was found highest in ML-818 (10.57%) and lowest in COGG-912 (3.67%). The maximum germination was found in COGG-912 (43.67%) while minimum in ML-818(24.66%), sixty days after release. The five genotypes *viz.*, COGG-912, T-44, MH 2-15, KM-2262 and KM-2266 registered promising on the basis of eggs laid, survival %, mean developmental period and susceptible index in free choice test were re-evaluated by no choice test.

Keywords: *Callosobruchus maculatus*, mungbean, pulse beetle, resistance and screening

Introduction
Mungbean or Green gram is one of the most important grain legume crop which is widely grown in South east Asia and other parts of the world. Green gram is the third most important pulse crop in India, grown in an area of 3.8 million hectares with a production of 1.6 million tonnes accounting about 45 per cent of total world green gram production. The average productivity is 421.05 kg per hectare (Ali and Gupta, 2012) [2]. The area, production and productivity of pulses in Jammu and Kashmir is 28.90 thousand hectares, 169 thousand quintals and 584.5 kg/ha respectively (Anonymous, 2010) [3].
In field, most serious insect pests are pod borers (*Helicoverpa armigera* Hubner and *Maruca testulalis* Geyer), pod sucking bugs (*Clavigralla* spp.) and pod fly (*Melanagromyza* spp.) (Minja *et al*., 1996) [11]. In storage, bruchids (Coleoptera: Bruchidae) are the major source of losses to pigeon pea (Singh and Jambunathan, 1990) [20]. Belonging to family Bruchidae, the genus *Callosobruchus* causes maximum damage (Mphuru, 1978; Lateef and Reed, 1990) [13, 10]. *Callosobruchus* spp. has been considered as a most dreaded stored grain pest with an estimated loss of 0.21 million tonnes (Rathore and Sharma, 2002) [18]. Loss of seed yield in mungbean and other legume crops during storage due to bruchids (seed beetles) is a very serious problem for farmers and traders (Rees, 2004) [19] Nahdy (1994) [14] estimated economic losses attributed to bruchid infestation in stored grain legumes as 35% in Central America, 7–13% in South America, and as high as 73% in Kenya. Bruchid infestation results in substantial reduction in the quantity and quality of the seed. The most destructive bruchid species of mungbean are *Callosobruchus chinensis* (L.) and *C. maculatus* (F.). Although bruchids start attacking seeds of host plants in the field, but cause minor damage. However, when infested seeds with larvae at varying stages of development are stored, infestation to fresh seeds rises with the emergence of adults (Talekar, 1988) [23]. These secondary infestations are considerably damaging and often lead to complete loss of a seed both quantitatively and qualitatively (Rees, 2004) [19]. A number of workers have attributed the texture of seed coat as main reason for ovipositional attractant or deterrent (Horber, 1983; Lambrides and Imrie,

2000; Sulehrie *et al.*,) [5, 9]. Size of seeds, increased surface area and weight have been documented to have relevance with ovipositional preference (Sulehrei *et al.*, 2003; Teoitia and Singh, 1966; Lambrides and Imrie, 2000) [24, 9]. Presence of anti-nutritional factors has also been linked with resistant property of some seeds like green gram (Dongre *et al*., 1996) [8].

Material and Methods

The present study was conducted in the Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar (Jammu and Kashmir).

The bruchids were collected from field by using sweep net on the crop. Collected material was brought to laboratory for identification and mass culturing of *Callosobruchus maculatus.*

C. maculatus was reared on fresh green gram seeds following the procedure of Strong *et al.* (1968) [21]. About 200 gms. Of green gram seeds were placed in 500 ml plastic bottles, into which approximately 50 pairs of freshly emerged *C. maculatus* adults were introduced. The bottles were covered with muslin cloth and placed in dark to facilitate maximum oviposition. Rearing was done at room temperature of 28 ± 2 ºC and 65 ± 5% RH. After 25-30 days, adults emerging from the culture were utilized for maintenance of subcultures following the same procedure. Sub culturing was done at weekly interval so as to get continuous supply of insects for experiments. Species identification was done as per Raina (1970) [17]. Before sub culturing, the beetles were examined for the conspecifics. Mixed-up cultures were instantly destroyed. Sub cultured *C. maculatus* was used for all experiments.

Among the twenty three genotypes of mungbean under present study, Pusa-105, Pusa- 9072 and Pusa-9531, COGG-912, Hum-6, MH 2-15 and T-44 were obtained from Indian Institute of Pulse Research, Kanpur; ML-134, ML-818 and PAU-911 from Punjab Agriculture University, Ludhiana; KM-2262, KM-2263, KM-2264, KM-2265, KM-2266 and KM-2267 from C.S. Azad Agriculture University Kanpur ; Shalimar moong-1, SKUAM- 300, SKUAM-301, SKUAM-302, SKUAM- 353 and SKUAM- 365 from SKUAST-Kashmir and Market sample from local market.

Preliminary screening of mungbean genotypes against *C. maculatus* by Free-Choice and No-Choice test

All the twenty three mungbean genotypes were screened by Free-choice test for their comparative resistance against *C. maculatus* by subjecting each genotype separately to the attack of *C. maculatus*. For this test, three free choice chambers made of plywood (diameter 60 cm.) with 28 number of holes, each of 2.5 cm diameter were used. Ten seeds of each of twenty three mungbean genotype were placed in each hole. Each free choice chamber was considered as one replication. Fifteen pairs of 0-24 hours old adults of *C. maculatus* were collected from the stock culture and released in the each free choice chamber. The free choice chambers were covered with the muslin cloth held tightly with a band (Plate 3). The adults were removed after 72 hours and seeds of each genotype examined at 10, 30 and 60 days after release (DAR).

From the above free choice test, the promising mungbean genotypes rated as resistant to moderately resistant on the basis of eggs laid, survival %, mean developmental period and susceptible index, were re-evaluated under No-choice test (Temperature 28 ± 2^0 and 70 ± 5 RH). In this test, *C. maculatus* were allowed access to only one genotype. Ten seeds of each genotype were placed in culture tube and each tube was considered as one replication. One pair of 0-24 hours old adults of *C. maculatus* was released in each tube, replicated thrice. The adults were allowed to remain there for 72 hours for oviposition then removed. The genotypes were examined on 10 DAR, 30 DAR and 60 DAR.

Host preference

Host preference was determined in free choice chamber. Ten seeds of each of the 23 genotypes were kept randomly in different holes of chamber. Fifteen pairs of *C. maculatus* (0-24 hours old adult) were released in each chamber. The number of insects inside or out was counted after 24 hours. Adults which remained outside holes were considered as wanderers.

Ovipositional preference

Ten seeds of each genotype were randomly placed in each hole of free chamber. Fifteen pairs of freshly emerged adult beetles were introduced into the centre of the chamber and covered with a muslin cloth. The total number of eggs laid on each genotype was counted after three days. Average number of eggs laid on each genotype was taken as the criterion for assessment of ovipositional preference.

Germination or seed viability

The viability of genotypes was tested by drawing 10 seeds randomly following damage by bruchids. The selected seeds were placed in petri dishes containing moist filter paper and arranged in CRD. The number of emerged seedlings from each genotype from each petri plate were counted and recorded at 28±2 ^{0}C. The per cent germination (viability index) was computed according to Ogendo *et al.* 2004 [15], adopted from Zibokere, 1914 [25], as below:

$$VI = \frac{NG}{TG} \times 100$$

Where; VI = Viability index or germination percentage. NG = number of seeds germinated from each Petri plate, TG = total number of seeds in each Petri plate

Per cent weight loss

Per cent weight loss due to bruchid damage was estimated by using an electronic top pan balance, after Adams and Schulten (1978) formula, after sixty days of release of *C. maculatus.*

$$\text{Per cent weight loss of grains} = \frac{UND - DNU}{U(ND + NU)} \times 100$$

Where ND = No. of damaged grains, D = Weight of damaged grains, NU = No. of undamaged grains, U = weight of undamaged grain

Index of susceptibility

The index of susceptibility of each genotype was calculated using the formula (Dobie, 1977).

$$I = \frac{Log_e F_1}{MDP} \times 100$$

Where; I = Index of susceptibility, F_1 = Total no. of F_1 adults, D = Mean developmental period (days)

Reproductive success

Per cent reproductive success was worked out using the following formula:

$$\text{Reproductive success (\%)} = \frac{\text{No. of adult emerged}}{\text{No. of eggs laid}} \times 100$$

Growth index

$$\text{Growth Index} = \frac{\text{Reproductive success (\%)}}{\text{Development period (days)}} \times 100$$

Mean Developmental period

It was calculated by the time taken for 50 per cent of the adults to emerge (Howe, 1971).

$$\text{Mean development period} = \frac{d_1a_1 + d_2a_2 + d_3a_3 \text{---------} + d_na_n}{\text{Total number of adults emerged}}$$

Where; d_1 = day at which the adults started emerged, a_1 = number of adults emerged on d_1 day

Statistical analysis

The data was based on three replications, subjected to analysis of variance after appropriate transformation for Completely Randomized Design (CRD) at 5 per cent significance level (P=0.05).

Results

Host preference on the basis of per cent attraction (Fig. 1) revealed highest number of adults attracted to market sample (9.0%) followed by ML-818, KM-2267, SKUAM-301 and Shalimar moong-1 (6.0%). COGG-912 (1.0%) followed by SKUAM-353, Pusa-9072 and Pusa-9531 with (2.0%) each recorded showed least host preference. 11.0% of released adults were recorded as wanderers *i.e.* remained outside the holes in which seeds were placed. Ovipositional preference among different genotypes was found statistically significant in free choice test. Mean number of eggs laid ranged 8.00 to 22.00 with highest on ML-818 (22.00) and at par with SKUAM-301 (20.00), Pusa-9531 (19.66), Market Sample (19.66) and Pusa-9072 (19.33). The lowest number of eggs was recorded on COGG-912 (8.0 eggs) which was statistically at par with T-44 (10.66) (Table 1 and Fig. 2). In no choice test, mean number of eggs laid ranged 13.00 to 28.66 with highest on KM-2266 (28.66 eggs) and at par with KM-2262. The least number of eggs were recorded on COGG-912 (13.0) which was statistically at par with T-44 (14.00), followed by MH 2-15 (22.33) (Table 3). Adult emergence in no choice test (Table-3) ranged 5.66 to 17.0 with maximum in KM- 2262 (17.00), followed by KM-2262 (16.00) and MH 2-15 (11.00). Genotype COGG-912 showed minimum adult emergence (5.66), followed by T-44 (6.33 adults). In free choice test on the other hand statistically significant differences among genotypes were obtained for adult emergence (Table 1 and Fig. 2). The maximum emergence was recorded in ML-818 (17.00) followed by KM-2264 (13.33) and Market Sample (12.66). The least emergence was noticed in COGG-912 (3.33) which was at par with T-44 (4.66) and was followed by KM-2262 (5.66), MH 2-15 (6.00) and KM-2266 (6.33). Survival percentage in free choice test was highest (77.42) (Table-1 and Fig-2) in genotype ML-818 which was at par with Pusa-9072 (72.36), SKUAM-301 (71.65), Shalimar moong-1 (70.95) and KM-2264 (70.03) followed by SKUAM-365 (68.23), PAU-911(67.12), KM-2265 (66.39) and ML-134 (66.12). The lowest survival percentage (Fig. 3) was seen in genotype COGG- 912 (41.60) and was at par with T-44 (43.93), MH 2-15 (46.15), KM-2262 (47.95) and KM-2266 (48.71) followed by Hum-6 (60.12), SKUAM-353 (61.80) and KM-2263 (63.64). In no choice test, the survival percentage (Table-3) varied from 43.56 to 59.29 with maximum in KM-2266 (59.29) which was at par with KM-2262 (56.45). The lowest survival percentage was recorded in genotype COGG- 912 (43.56) which was at par with T-44 (43.93) followed by MH 2-15 (49.27).

The mean developmental period in free choice test ranged 26.79 to 32.42 days (Table 1 and Fig.2) with maximum duration in COGG-912 (32.42), which was at par with T-44 (31.27). Minimum developmental period was found in ML-818 (26.79) and was at par with Pusa-105 (27.16), Pusa-9072 (27.55), Pusa-9531 (27.58), ML-134 (28.10), KM 2263(27.38), KM 2265 (27.83), SKUAM-301 (27.33), SKUAM-302 (27.16) and SKUAM-365 (27.66). In no choice test, mean developmental period (Table-3) highest mean developmental period was recorded in COGG-912 (30.20) which was at par with T-44 (29.98). The least developmental period was recorded in KM-2262 (26.88) being at par with KM-2266 (27.11) followed by MH 2-15 (27.53). The Growth Index ranged from 1.44 - 2.18. In free choice test (Table 1 and Fig. 2) it varied significantly among genotypes from 1.28 to 2.89. The least growth index value was found in COGG-912 (1.28) which was at par with T-44 (1.41), and MH 2-15(1.55), followed by KM-2262 (1.56) and KM-2266 (1.58). The highest growth index value was 2.89 in ML-818, which was at par with SKUAM-301 (2.63) and Pusa-9072 (2.62). In no choice test**,** highest growth index (Table 3) was observed in KM-2266 (2.18), which was at par with KM-2262 (2.10). The least growth index value was found in COGG-912 (1.44) and was at par with T-44 (1.50) followed by MH 2-15 (1.79). The susceptibility index ranged 5.73 to 10.45 (Table 3). In free choice test, the highest susceptibility index value was seen in ML-818 (10.57), which was at par with SKUAM-301 (9.79) followed by Pusa-9072 (9.57), Pusa-9531 (9.18) and SKUAM-365 (9.17) (Table 1 and Fig. 2) and least value was recorded in COGG-912 (3.67) followed by T-44 (4.91), KM-2262 (5.56), MH 2-15(5.99) and KM-2266 (5.99). In no choice test, highest susceptibility index value was recorded in KM-2266 (10.45), which was at par with KM-2262(10.34) and least value was found in COGG-912 (5.73) and was at par with T-44 (6.15), followed by MH 2-15 (1.79).

Per cent seed weight loss among different genotypes ranged 53.04 to 66.03 (Table 3). In free choice test, highest seed weight loss was recorded in ML-818 (66.91) which was at par with SKUAM-301 (65.94), Pusa-105 (65.83), Pusa-9531(65.01), KM-2264 (63.5) SKUAM-365 (63.42), Hum-6 (62.53), ML-134 (62.49), Pusa-9072 (62.27), KM, 2267, (61.35), KM-2263, (62.19). Least seed weight loss was recorded in COGG- 912 (43.71%) and was at par with T-44 (47.79) followed by KM-2266 (55.91), MH 2-15 56.40, KM-2262 (56.47), SKUAM-353 (57.41), KM-2265 (58.25), and Market sample (58.48) (Table 2 and Fig.2). In no choice test on the other hand, highest per cent seed weight loss was seen in KM-2266 (66.03) which was at par with KM- 2262 (65.26) and MH 2-15 (63.11). The least per cent seed weight loss was observed in COGG- 912 (53.04%) followed by T-44 (58.57). Germination percentage in free choice test was observed highest in COGG- 912 (43.67) and was at par with T-44 (40.66), KM-2262 (39.66), Market sample (39.33), KM-2266 (38.33) and MH 2-15 (38.33). The lowest per cent germination was noticed in ML-818 (24.66) being at par with SKUAM- 301 (26.00), SKUAM-365 (28.66) and Shalimar moong-1 (29.00) (Table 2, Fig. 2). In no choice test, the per cent germination (Table 3) was observed significantly high in COGG- 912 (33.66) and was at par with T-44 (30.66) followed by MH 2-15. The least per cent germination was noticed in KM-2266 (21.66) which was at par with KM- 2262 (24.66). Per cent seed damage in free choice test was highest in ML-818 (96.66) which was at par with ML-134 (96.99), SKUAM-365 (96.66), SKUAM-301 (93.33), Pusa-9531 (93.33), Shalimar moong-1 (93.33) PAU- 911(90.00), Pusa-9072 (90.00), KM-2264 (90.00) and SKUAM-300 (90.00). The lowest seed damage was seen in genotype COGG- 912 (53.33), and was at par with MH 2-15 (56.66), KM-2262 (45.66) T-44 (60.00), and KM-2266 (60.00) (Table 2, Fig. 2). In no choice test, the highest per cent seed damage was found in KM-2266 (93.33) and was at par with KM-2262 (86.66) and MH 2-15 (86.66) while lowest in COGG-912 (63.33) being at par with T-44(70.00) (Table 3). Adults' weight (milligrams) in free choice test was maximum on ML-818 (4.91 mg) and at par with Pusa-9531 (4.74), KM-2264 (4.69), SKUAM-301 (4.64), KM-2267(4.60), SKUAM-365 (4.51), Market sample (4.48) and Pusa-105 (4.47) followed by PAU-911 (4.45) and KM-2265(4.32). The least adult weight was found in COGG-112 (3.86) being at par with SKUAM-353 (3.90), MH 2-15 (3.92), T-44 (3.94), KM-2266 (3.95) and KM- 2266 (3.95) (Table 2). In no choice test on the other hand, the maximum weight of adults was recorded in KM-2266 (4.60) which differed significantly from other genotypes. The least adult weight was found in T-44 (3.95) and was at par with COGG-112 (3.97) and MH 2-15 (4.02) (Table 3). The five genotypes *viz.*, COGG-912, T-44, MH 2-15, KM-2262 and KM-2266 registered promising on the basis of survival, mean developmental period and susceptible index eggs laid in free choice test, were re-evaluated by no choice test.

The correlation revealed moderate to strong relationship among the variables under observation. The correlation of protein with oil content in grains, mean developmental period and germination per cent were moderately significant (r = <0.7). Protein content showed significantly strong correlation (r = > 0.7) with susceptibility index (0.79), growth index (0.77) and seed damage (0.76) [Table 4]. Seed weight loss was also found positively correlated with the protein content (r= 0.68). However, with oil content all the variables except development period and germination per cent showed significantly negative correlation. Growth index, susceptibility index, seed damage and weight loss showed strongly positive correlation with survival percentage (r > 0.9). However, the mean development period (r= 0.82) and germination per cent (r= 0.78) showed significant negative correlation with survival percentage. Mean development period showed significant and strongly positive correlation with oil content (0.81) and germination percentage (0.83) whereas other variables like growth index, susceptibility index, seed damage and weight loss showed strong negative correlation. Growth index showed very strong and significantly positive correlation with susceptibility index, seed damage and weight loss. Germination per cent also recorded strong positive correlation with oil content and development period, while as other variables showed significantly strong negative correlation.

Table 1: Screening of Mungbean genotypes by free choice test

S. No.	Genotype	Eggs laid (No.)	Adults emerged (No.)	Survival (%)	Mean Development period (Days)	Growth index (%)	Susceptibility index (SI) (%)	Classification Dobie's SI
1.	COGG-912	8.00±0.57 (2.99)	3.33±0.33 (2.07)	41.60±2.10 (6.52)	32.42±0.99	1.28±0.03	3.67±0.18	R
2.	Hum-6	15.00±1.15 (3.99)	9.00±0.57 (3.16)	60.12±0.78 (7.81)	28.33±0.47	2.12±0.08	7.73±0.13	MS
3.	MH 2-15	13.00±0.57 (3.74)	6.00±0.57 (2.64)	46.15±3.84 (6.85)	29.80±0.78	1.55±0.17	5.99±0.39	MR
4.	T- 44	10.66±0.33 (3.41)	4.66±0.33 (2.37)	43.93±4.01 (6.69)	31.27±0.29	1.41±0.13	4.91±0.27	MR
5.	Pusa- 105	17.33±0.88 (4.27)	11.33±0.88 (3.50)	65.21±1.72 (8.13)	27.16±0.25	2.40±0.05	8.91±0.26	S
6.	Pusa- 9072	19.33±0.33 (4.50)	14.00±0.57 (3.87)	72.36±2.01 (8.56)	27.55±0.22	2.62±0.09	9.57±0.22	S
7.	Pusa-9531	19.66±1.20 (4.54)	12.66±0.88 (3.69)	64.39±2.14 (8.08)	27.58±0.70	2.33±0.07	9.18±0.04	S
8.	ML-134	18.66±1.20 (4.43)	12.33±0.82 (3.64)	66.12±2.75 (8.18)	28.10±0.22	2.35±0.08	8.92±0.20	S
9.	ML-818	22.00±1.15 (4.79)	17.00±0.57 (4.24)	77.42±1.44 (8.85)	26.79±0.40	2.89±0.10	10.57±0.05	HS
10.	PAU- 911	18.33±0.88 (4.39)	12.33±0.82 (3.64)	67.12±1.54 (8.25)	28.27±0.49	2.37±0.09	8.88±0.49	S
11.	KM-2262	11.66±0.88 (3.55)	5.66±0.88 (2.57)	47.95±4.12 (6.98)	30.61±0.70	1.56±0.11	5.56±0.46	MR
12.	KM-2263	16.66±1.20 (4.19)	10.66±1.20 (3.40)	63.64±2.49 (8.03)	27.38±0.62	2.32±0.03	8.59±0.20	S
13.	KM-2264	19.00±0.57 (4.47)	13.33±0.88 (3.78)	70.03±2.53 (8.42)	28.16±0.58	2.49±0.14	9.19±0.42	S
14.	KM-2265	18.00±1.15 (4.35)	12.00±1.15 (3.59)	66.39±2.17 (8.20)	27.83±0.34	2.38±0.10	8.90±0.43	S
15.	KM-2266	13.00±0.57 (3.74)	6.33±0.33 (2.70)	48.71±1.28 (7.05)	30.78±0.27	1.58±0.05	5.99±0.21	MR
16.	KM-2267	17.66±1.20 (4.31)	11.33±0.88 (3.50)	64.19±2.89 (8.07)	29.22±0.11	2.19±0.09	8.29±0.29	S
17.	SKUAM- 300	18.33±0.88 (4.39)	12.00±0.57 (3.60)	65.46±0.61 (8.15)	27.33±0.33	2.3±0.04	9.08±0.27	S
18.	SKUAM- 301	20.00±1.15 (4.57)	14.33±0.88 (3.91)	71.65±0.83 (8.52)	27.16±0.44	2.63±0.07	9.79±0.33	S
19.	SKUAM- 302	17.66±0.88 (4.31)	12.0±0.57 (3.60)	67.94±0.64 (8.30)	29.30±0.02	2.31±0.02	8.47±0.17	S
20.	SKUAM-353	16.33±0.88 (4.16)	10.00±0.57 (3.31)	61.80±5.93 (7.90)	28.50±0.25	2.16±0.18	8.06±0.14	S
21.	SKUAM-365	18.66±1.21 (4.43)	12.66±0.33 (3.69)	68.23±3.20 (8.31)	27.66±0.19	2.46±0.12	9.17±0.05	S
22.	Shalimar moong-1	17.33±1.20 (4.27)	12.33±1.20 (3.64)	70.95±3.44 (8.47)	29.11±0.30	2.43±0.10	8.59±0.26	S
23.	Market sample	19.66±1.21 (4.54)	12.66±0.33 (3.69)	64.72±2.86 (8.10)	30.29±0.65	2.13±0.06	8.38±0.18	S
CD (0.05)		2.77 (0.32)	2.17 (0.31)	7.78 (0.51)	1.36	0.27	0.77	-
±SEm		0.97 (0.11)	0.76 (0.11)	2.72 (0.18)	0.47	0.09	0.27	-
CV (%)		10.01 (4.68)	12.23 (5.69)	7.56 (3.93)	2.89	7.63	5.83	-

Values in parenthesis are square root transformation of mean values, R = Resistant, MR = Moderately Resistant, MS = Moderately Susceptible, S = susceptible, HS = Highly Susceptible

Table 2: Performance and assessment of mungbean genotypes based on adult weight, seed damage, per cent weight loss and germination percentage

S. No.	Genotype	Adult weight (mg)	100 seeds weight (g)	Seed damage (%) (60 DAR)	Per cent weight loss (60 DAR)	Germination (60 DAR)
1	COGG-912	3.86±0.093	3.06	53.33±3.333 (7.36)	43.71±0.895	43.67±0.882
2	Hum-6	4.08±0.189	3.57	80.00±5.774 (8.98	62.53±1.371	33.33±5.812
3	MH 2-15	3.92±0.095	3.37	56.66±3.333 (7.58)	56.40±1.621	38.33±1.202
4	T-44	3.94±0.072	3.59	60.00±5.774 (7.79)	47.79±2.135	40.66±1.764
5	Pusa-105	4.47±0.257	3.21	90.00±5.774 (9.53)	65.83±3.080	30.66±3.528
6	Pusa-9072	4.40±0.185	3.05	90.00±5.774 (9.53)	62.27±1.452	35.66±1.155
7	Pusa-9531	4.74±0.095	3.20	93.33±6.667 (9.71)	65.01±0.827	30.00±1.453
8	ML-134	4.04±0.072	3.34	96.66±3.333 (9.88)	62.49±2.755	30.33±1.202
9	ML-818	4.91±0.232	3.61	96.66±3.333 (9.88)	66.91±3.080	24.66±1.155
10	PAU-911	4.45±0.397	3.84	83.33±8.819 (9.15)	58.90±2.627	36.00±2.309
11	KM-2262	3.97±0.112	3.18	56.66±3.333 (7.58)	56.47±2.641	39.66±0.882
12	KM-2263	4.45±0.218	3.45	86.66±8.819 (9.33	62.19±0.968	36.00±1.155
13	KM-2264	4.69±0.103	3.81	90.00±5.774 (9.53)	63.5±1.282	34.33±1.202
14	KM-2265	4.32±0.187	4.20	86.66±8.819 (9.33)	58.25±0.116	35.66±1.453
15	KM-2266	3.95±0.041	3.81	60.00±5.774 (7.79)	55.91±0.584	38.33±1.528
16	KM-2267	4.60±0.075	3.86	93.33±3.333 (9.71)	61.35±1.118	34.00±0.882
17	SKUAM-300	4.02±0.107	3.46	90.00±5.774 (9.53)	60.41±4.180	29.33±0.882
18	SKUAM-301	4.64±0.116	3.54	93.33±3.333 (9.71)	65.94±1.833	26.00±0.882
19	SKUAM-302	4.19±0.135	3.92	90.00±5.774 (9.53)	60.86±2.180	30.66±0.882
20	SKUAM-353	3.9±0.061	2.94	80.00±5.774 (8.98)	57.41±2.027	33.33±2.603
21	SKUAM-365	4.51±0.073	4.45	96.66±3.333 (9.88)	63.42±1.135	28.66±0.882
22	Shalimar moong-1	4.14±0.090	3.92	93.33±3.333 (9.71)	61.08±1.633	29.00±0.882
23	Market sample	4.48±0.074	4.68	90.00±5.774 (9.53)	58.48±1.732	39.33±1.764
	CD (0.05)	0.447	-	15.88 (0.876)	5.77	5.519
	±SEm	0.156	-	5.56 (0.307)	2.02	1.932
	CV (%)	6.307	-	11.61 (5.83)	5.84	9.886

Values in parenthesis are square root transformation of mean values, DAR = Days after release

Table 3: Screening of promising mungbean genotypes by no-choice test

S. No.	Genotype	Eggs laid (No.)	Adults emerged (No.)	Survival (%)	Mean Development period (Days)	Growth Index (%)	Susceptibility index (SI) (%)	Classification Dobie's SI	Adult weight (mg)	100-seeds weight (g)	Seed damage (%) (60 DAR)	Per cent weight loss (60 DAR)	Germination (%) (60 DAR)
1	COGG-912	13.00±0.577 (3.74)	5.66±0.333 (2.58)	43.56±1.340 (6.67)	30.20±0.441	1.44±0.066	5.73±0.247	Moderately Resistant	3.97	3.06	63.33±3.33 (8.01)	53.04±1.551	33.66±0.567
2	MH 2-15	22.33±1.202 (4.82)	11.00±0.577 (3.46)	49.27±0.723 (7.09)	27.53±0.416	1.79±0.035	8.69±0.073	Susceptible	4.02	3.37	86.66±3.33 (9.36)	63.11±1.483	28.66±1.202
3	T-44	14.00±0.577 (3.87)	6.33±0.333 (2.70)	45.22±1.193 (6.79)	29.98±0.289	1.50±0.043	6.15±0.227	Moderately Resistant	3.95	3.39	70.000±5.77 (8.41)	58.57±0.369	30.66±0.602
4	KM- 2262	28.33±0.667 (5.41)	16.00±0.577 (4.12)	56.45±1.091 (7.57)	26.88±0.948	2.10±0.118	10.34±0.505	Highly Susceptible	4.14	3.18	86.66±3.33 (9.36)	65.26±1.583	24.66±0.782
5	KM- 2266	28.66±0.882 (5.44)	17.00±0.577 (4.24)	59.29±0.399 (7.76)	27.11±0.588	2.18±0.047	10.45±0.106	Highly Susceptible	4.60	3.81	93.33±3.33 (9.71)	66.03±0.846	21.66±0.82
	CD (0.05)	2.60 (0.27)	1.57 (0.22)	3.22 (0.23)	1.85	0.21	0.88	-	0.28	-	12.58 (0.71)	4.02	3.047
	±SEm	0.81 (0.08)	0.49 (0.07)	1.00 (0.07)	0.58	0.06	0.27	-	0.08	-	3.944 (0.22)	1.26	0.955
	CV (%)	6.65 (3.24)	7.64 (3.54)	3.44 (1.74)	3.56	6.59	5.80	-	3.71	-	8.539 (4.34)	3.57	5.933

Values in parenthesis are square root transformation of mean values

Table 4: Correlation studies of all tested parameters

Parameters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
X_1-Protein content (%)	1.00	-	-	-	-	-	-	-	-
X_2-Oil content (%)	-0.54**	1.00	-	-	-	-	-	-	-
X_3-Survival (%)	0.77**	-0.75**	1.00	-	-	-	-	-	-
X_4-Mean development period (Days)	-0.67**	0.81**	-0.82**	1.00	-	-	-	-	-
X_5-Growth index (%)	0.77**	-0.80**	0.99**	-0.89**	1.00	-	-	-	-
X_6-Susceptibility index (%)	0.79**	-0.77**	0.97**	-0.90**	0.99**	1.00	-	-	-
X_7-Seed damage (%)	0.76**	-0.65**	0.91**	-0.83**	0.91**	0.95**	1.00	-	-
X_8-Weight loss (%)	0.68**	-0.81**	0.87**	-0.86 **	0.90 **	0.88**	0.82**	1.00	-
X_9-Germination (%)	-0.57**	0.78 **	-0.78**	0.83 **	-0.82**	-0.83**	-0.80**	-0.82**	1.00

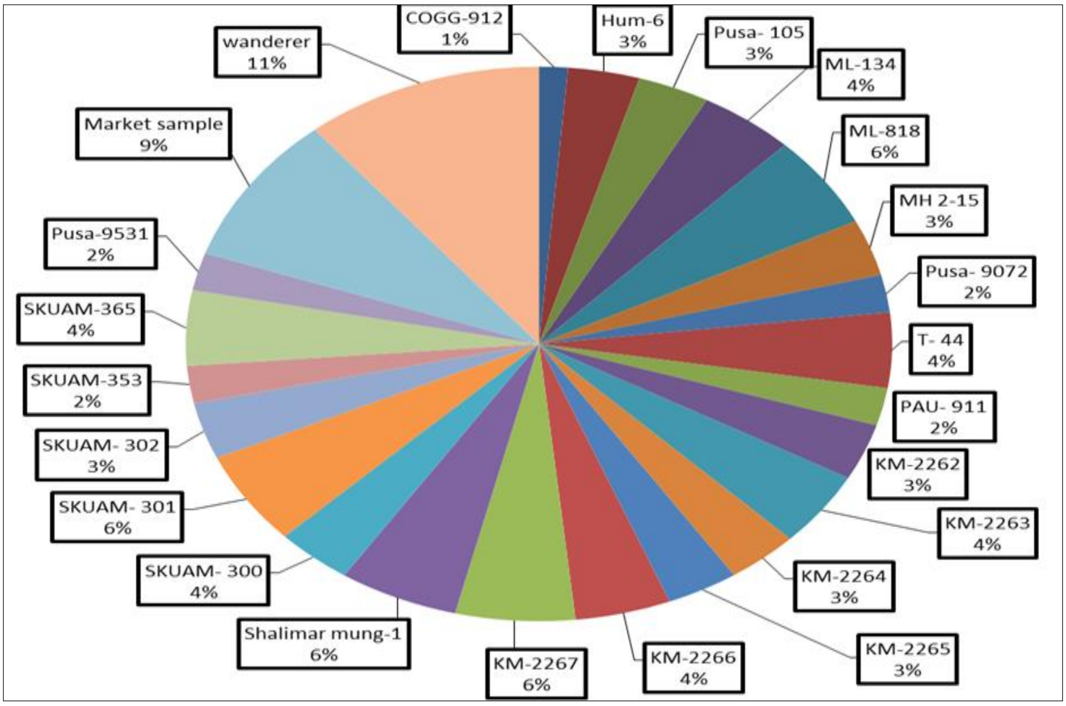

Fig 1: Host preference for oviposition of pulse beetle (*Callosobruchus maculatus* F.) to different mungbean genotypes

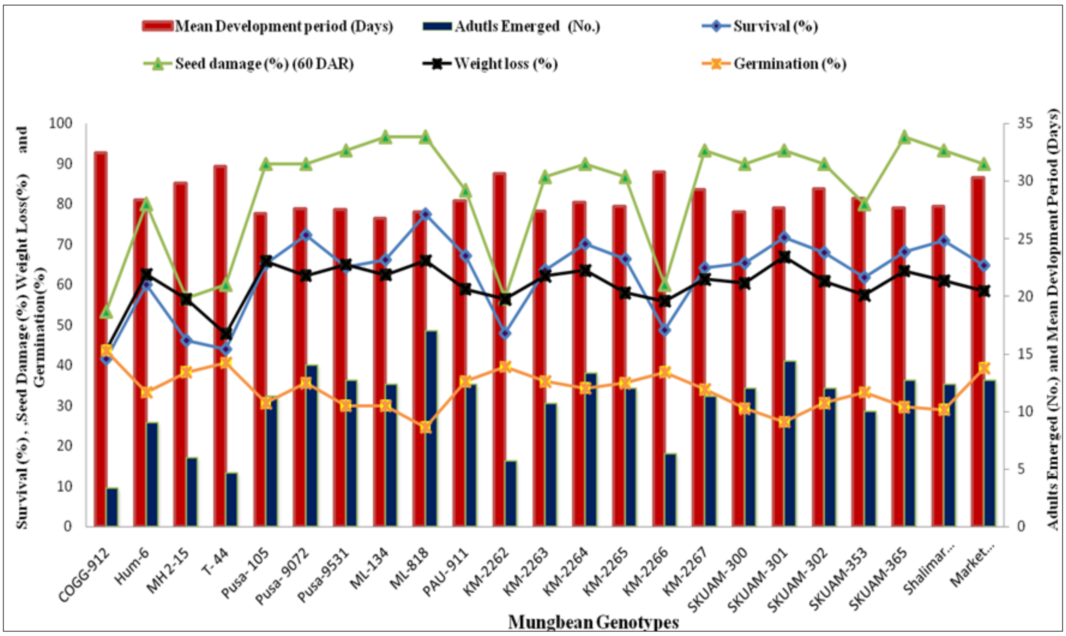

Fig 2: Relationship of survival (%), mean development period (Days), seed damage (%), weight loss (%), germination (%) and adults emerged (No.) among different mungbean genotypes

Discussion

Different host preference by *Callosobruchus maculatus* to different genotypes was because of the physical texture, seed coat and size of the seeds. Varying level of attraction of the bruchid towards market sample (9%) and COGG-912 (1%) is attributed to the smooth and rough seed coat of the genotypes. Similar observations have been made by Jha (2002) for chickpea cultivar of BG-267 (11.8%), and BG-256 (2.5%). Ovipositional difference in the 23 genotypes that ranged 8.00 to 22 eggs/10 seeds, alludes preferential selection by *C. maculatus*. ML-818 being the highly preferred (22.00 eggs) whereas COGG-912 as least (8.00 eggs). However, the low number of eggs laid on different genotypes did not reflect the level of resistance. This could be visualized from the fact that the genotype T-44 which recorded only 10 eggs/10 seeds was found moderately resistant with an index of Dobie's susceptibility of 4.91±0.27. This may be attributed to the reason that only one grub emerged from a seed even though multiple number of eggs were laid per seed, thus didn't not have any significant role on host suitability, which was also reported by Dobie *et al*. (1978).

In present study it was observed that seeds with smooth/rough surface and oval/drum shape were equally preferred for oviposition. The role of seed coat though on ovipositional preference by *C. maculatus* has been discussed by many workers. Antixenosis during oviposition seems to be associated with rough pericarp as also documented by Brewer and Horber (1983) [5]. Lambrides and Imrie (2000) [9] have also evaluated the effect of texture on egg laying and observed that the rough layer of the green gram acts as an ovipositional deterrent. Sulehrie *et al.* (2003) [22] observed smooth seed coat of green gram more preferred for oviposition.

Our finding with non-significant correlation between 100 seed weight and number of eggs laid, both under free and no choice test is in contrast with the observations with findings of many workers. Sulehrei *et al.* (2003) reported greater seed weight and higher surface area in green gram led to higher oviposition. Similar conclusion was drawn by Mitchell (1990) [12] who reported that large seeded varieties of green gram induced the bruchids to lay more eggs than smaller seeds. In our case, the smaller size of the seeds probably accounted for the obtained result.

Insignificant role of seed colour in relation to number of eggs laid, both under free and no choice test gets support from identical observations made by Ragupathy and Rathnaswami (1970) [16], who expressed colour of seed without any bearing on the resistance/susceptibility of grain to pulse beetle.

Present finding revealed that nearly all the genotypes favoured *C. maculatus* for the completion of life cycle. It was further observed that seeds of genotypes weighing more than 3.0 grams (Table 2) and with larger seed size were more conducive for adult development which is in line with the findings of Teoitia and Singh (1966) [24] Lambrides and Imrie (2000) [9]. Who also stated that larger seed size provide more substrate for supporting the developing larvae.

The delay in developmental period can be related to the presence of anti-nutritional factors or larval competition at initial stages. Dongre *et al*. (1996) [8] observed a prolonged mean development period in bruchid resistant green gram. Appleby and Credland (2004) [4] noticed that certain susceptible varieties of cowpea registered a shorter mean development period.

The reason for maximum seed weight loss in ML-818 (66.91) was on account of this genotype attracted maximum egg laying, ensuring highest percentage of adult emergence with maximum per cent survivalability in minimum duration of developmental period. On the contrary, lowest seed weight loss in COGG- 912 (43.71) under free choice test was because of unfavourable features of this genotype for the pest (Table 1). The present findings are in absolute agreement with Rustamani *et al.* (1985) who observed significantly higher weight loss caused by *C. chinensis* on moong than in gram seeds. They opined that moong was most susceptible crop to *C. chinensis*, on the basis of progeny, percentage weight loss, damage, adult lifespan and developmental period of *C. chinensis.*

Out of 23 genotypes, genotype ML-818 was found as as highly susceptible, 16 genotypes as susceptible and one genotype, Hum-6 as moderately susceptible. One genotype, COGG-912 was found resistant and four genotypes were found moderately resistant against *C. maculatus* (Table 1). Comparative resistance to *C. maculatus* by the genotypes COGG-912, T-44, MH 2-15, KM-2262, and KM-2266 was due to lowest per cent adult emergence, weight loss, growth index and highest developmental period. It is inferred that the screened promising genotypes i.e COGG-912 and T-44 can be incorporated in varietal improvement programme of mungbean against pulse beetle, C. *maculatus*.

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