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Studies on culturing and identification of cowpea weevil in *Vigna* species (*Vigna radiata* and *Vigna mungo*) under laboratory condition

Nootan Singh[1*], Veena P Swami[2]
[1] Research Scholar, Department of Zoology, BSNV PG College, University of Lucknow, Lucknow, Uttar Pradesh, India
[2] Professor, Department of Zoology, BSNV PG College, University of Lucknow, Lucknow, Uttar Pradesh, India

Abstract
Studies on culturing and identification of *Callosobruchus maculatus* (Bruchidae: Coleoptera) in *Vigna radiata* and *Vigna mungo,* the present lab work was carried out at the Department of Zoology of BSNV PG College, Lucknow during 2024. Bean beetles is an important stored grain pest distributed in Asia and Africa from tropical and subtropical world. *C. maculatus* also feed on other legumes but the cowpea and chickpea are the favourite hosts for cowpea weevil. Grains were collected from various shops of local market of Lucknow and also Indian Institute of Pulse Research Kanpur. Grains of *Vigna radiata* and *Vigna mungo* were kept in jars (5 lit. capacity) and covered with muslin cloth fastened with rubber bands with 28±2ºC and 70±5 % RH with a photoperiod of 12h L:12h D in laboratory. The adult pulse beetles were ready to mate, oviposit, and grow their progeny, and observe adult emergence in daily basis, (0-1 day old) adults from the F1 progeny were used in the experiments. In this experiment we find out the result of oviposition, number of adults emerged, mean developmental period of *C. maculatus, C. chinensis and C. analis.* The number of eggs laid, number of adults emergence was seen highest in *C. maculatus and C. chinensis* while lowest in *C. analis* in both *Vigna mungo* and *Vigna radiata*. The mean developmental period was lowest in *C. maculatus* and *C. chinensis* while in *C. analis* mean developmental period for both *Vigna* species are highest.

Keywords: Bruchids**,** *Callosobruchus* species, black gram, green gram, legumes, stock culture

Introduction

In worldwide, one of the most economically important agricultural products for human, are pulses. Grain legumes are rich in protein, carbohydrates, magnesium, zinc, calcium and iron [7, 26]. In human diet, legumes play an important role therefore, they become the major contributors towards food and nutrition security. India is the country processing the greatest advantage of growing more than a dozen pulse crops in comparison to other countries of the world. Among them, mung bean is one of the most important pulse crops belonging to family Fabaceae [22]. It is an excellent source of protein and other micronutrients [6, 15]. It is used as food, feed, fodder. It also improves soil health by fixing the atmospheric nitrogen in to soil through symbiosis with *Rhizobium* [1, 17] economic importance, the productivity is still low due to erratic climatic conditions [8, 9, 10, 24, 20] and various biotic stresses [19, 23, 21, 13, 12]. The black gram an important leguminous crop, is commonly cultivated in different parts of Bangladesh and used as important protein supplement of diet as food item. The beetles infest it in the field condition and often make severe damage in storage condition which is one of the major limitations for increasing pulses production.

In the field and store houses pests are a major problem. They cause losses of more than half of the expected yield [25]. Presently, on the use of synthetic insecticides and fumigants, which control pest in quickest methods [18, 27]. During storage conditions, food commodities are attacked by the number of insect pest like *Sitophilus granarius*, *Callosobruchus maculatus*, *Callosobruchus chinensis*. Among them, *Callosobruchus maculatus*, is an important stored grain insect pest distributed in Asia and Africa, ranges from tropical to subtropical world. It has been reported that the favourite hosts for cowpea weevil are cowpea, mung bean, black gram, chickpea, but it also feed on other legumes as well [2]. Bruchid attack of pulses begins in the field and rapidly builds up during storage. Bruchid can cause an infestation from 60 to 100% during four to six months storage. In mature legume seeds development of *C. maculatus* was seen. The larvae upon hatching enter into the cotyledons and spends the entire larval stage within the seeds [4]. As the larvae of these beetles are unable to migrate between seeds, the oviposition behaviour of the female parent is crucial in determining the survival prospect of progeny [26]. According to recent studies sample evidence to suggest that natural selection has moulded the oviposition behaviour and related life history traits such as fecundity, adult emergence etc. of these insects in a way that maximizes the individual fitness. The larvae of cowpea beetles is totally dependent on the seed of legumes but the adults of this pest do not require water and feed but instead spend their limited life on mating and laying eggs. The eggs are being laid by an adult female on the surface of seed which are attached on its surface as if glued on the surface of seed at 30-35℃ and 70-90% R.H, are considered as ideal conditions for the egg laying and after 6 days of oviposition hatching takes place. Within 3-4 weeks under favourable conditions adult emergence takes place [14]. Under laboratory condition males and females *C. maculatus* have an average life time of 7 days, and only few of them can survive more than 2 weeks [5, 11]. During their life time both male and female can mate soon after their emergence and both can mate sever times. Oviposition rates are being adjusted by the females in order to handle the changes in host availability and thus laying few eggs when host availability is low. Biological control has not been widely used against *Callosobruchus* species, although natural populations of cowpea beetles are often subject to high levels of parasitism, particularly in west Africa. The objective of this study is to identify the pest insect and their growth and development period on *Vigna radiata* and *Vigna mungo* against *Callosobruchus* species.

Materials and methods

Collection of germplasms

Germplasms were collected from National seed corporation LTD India and ICAR pulse research institute Kanpur and some local seed shop of Lucknow. Grains were kept in 5 lit jars and placed in BOD chamber at (28℃±2℃ and RH of 70±5%.) and covered with muslin cloth in order to supply adequate humidity to the grains. The jars were examined after separate jar.

Stock culture of *C. maculatus*

Maintenance of the stock culture of *C. maculatus* green gram and black gram was used as a host. Seeds of *Vigna radiata* and *Vigna mungo* were kept in the jars and covered with muslin clothes and placed at 28℃±2℃ and RH of 70±5%. The culture was observed regularly for the presence of cowpea beetles and any other insects. The stock culture was maintained by providing host and optimum laboratory conditions for further research studies.

Preparation of the seeds for study

In this study, firstly seeds were picked out and all debris and dust particles were removed. Only mature and healthy intact seeds were used for the experiment. Before experiment, the seed of pulses were kept in a freezer for a week to kill any life phases of the pest if they are previously found on them and dried for 24 h in laboratory conditions.

Ovipositional preference

For the evaluation of oviposition preference, 100 seeds were carried off randomly from one of each jar which containing 100 g of seeds and after five days the number of eggs were counted, which was oviposited on the seeds after numbering seeds were put into respective jars carefully. Numbering was continued from 1st generation to 3rd generations.

Percent adult emergence

Adult emergence was recorded at a regular time interval of 24 hrs. After 23-35 days, the number of adults emergence were recorded depending upon the different pulse seeds. According to Sharma and Thakur (2014) [19], the following formula was used to calculate the adult emergence.

$$\text{Adult emergence (\%)} = \frac{\textit{Number of adult emeged}}{\textit{Number of eggs laid}} \times 100$$

Developmental period

From egg laying to mature adult stage period was recorded as developmental period (Sharma and Thakur, 2014) [19].

Statistical analysis

The data was statistically analysed as per standard procedure to determine the different parameters. The treatment means were compared to Least Significant Difference at p=0.5 level of significant.

Results

Green gram varieties

The results revealed that number of eggs laid, number of adults emergence, and mean developmental periods (days) significantly differed between 10 green gram genotypes (Table 1). The genotypes, EC520041, AKM96-4, CO-4 recorded less number of eggs (4.68, 7.20 and 7.36 eggs/100 seeds) while PDM-54, PDM-139, IPM-02-3 recorded highest number of eggs (25.33, 19.33 and 15.34 eggs/ 100 seeds) and number of adult emerged was lowest in EC520041, AKM96-4, CO-8 (3.68, 5.69,7.68/100 seeds), while highest in PDM-54, IPM-02-3, IPM-02-14 (19.68,13.66,12.36/100 seeds). Mean developmental period was highest in IPM-02-3 (27.10 days), while lowest in HUM-12 (12.10 days) in *C. maculatus*. In *C. chinensis* highest number of eggs laid on PDM-54 (24.31), and lowest in EC520041(3.67), and number of adults emergence was lowest in EC520041(2.67) and highest in PDM-54 (18.6). Mean developmental period was highest in IPM-02-3 (28.0 days), while lowest in HUM-12 (24.0 days). In *C. analis* highest number of eggs laid on PDM-54 (23.30) while lowest in EC520041(2.67). Adult emergence was highest in PDM-54 (17.66) as comparison to EC520041(1.67), while mean developmental period was found in IPM-02-3(29.10), and lowest in PDM-139 (25.05).

Table 1: Evaluation of *Vigna radiata* germplasms for resistance to *Callosobruchus maculatus*, *C. chinensis*, *C. analis*

S.no	*V. radiata* varieties	*C. maculatus*			*C. chinensis*			*C. analis*		
		No. of eggs laid±SEM	No. of adult emerged±SEM	Mean developmental period (days)±SEM	No. of eggs laid±SEM	No. of adult emerged±SEM	Mean developmental period (days)±SEM	No. of eggs laid±SEM	No. of adult emerged±SEM	Mean developmental period±SEM
1.	PDM-54	25.33±0.88	19.68±0.68	25.69±0.33	24.31±0.88	18.6±0.67	26.6±0.33	23.30±0.87	17.66±0.66	27.68±0.33
2.	PDM-139	19.33±0.68	9.67±0.35	23.20±0.59	17.32±0.67	8.67±0.33	24.0±0.58	16.31±0.65	7.65±0.33	25.05±0.59
3.	IPM-02-3	15.34±0.69	13.66±0.34	27.10±0.02	14.3±0.67	12.6±0.33	28.0±0.01	13.32±0.66	11.64±0.32	29.10±0.02
4.	IPM-02-14	18.35±0.89	12.36±0.68	26.94±0.54	16.3±0.88	11.3±0.67	27.9±0.52	15.33±0.87	10.3±0.68	28.94±0.54
5.	CO-8	12.68±0.34	7.68±0.35	25.68±0.89	11.6±0.33	6.67±0.33	26.6±0.88	10.65±0.32	5.65±0.34	27.68±0.89
6.	AKM 96-4	7.20±1.00	5.69±0.69	24.69±0.35	6.10±1.00	3.67±0.67	25.6±0.33	5.00±1.00	2.66±0.67	26.69±0.35
7.	CO-4	7.36±0.67	8.35±0.65	23.58±0.33	6.33±0.66	7.31±0.67	24.5±0.30	6.32±0.65	6.22±0.69	25.58±0.33
8.	EC 520041	4.68±0.33	3.68±0.34	25.67±0.33	3.67±0.33	2.67±0.33	26.6±0.33	2.65±0.32	1.65±0.35	27.67±0.34
9.	HUM-12	12.69±1.20	12.10±1.00	23.12±0.00	11.6±1.20	11.0±1.00	24.0±0.00	9.68±1.19	10.05±1.00	25.07±0.00
10.	ML-515	14.34±0.33	9.33 ±0.33	24.35±0.88	12.3±0.33	8.31 ±0.33	25.3±0.88	11.30±0.31	7.30 ±0.32	26.34±0.89

Table 2: Evaluation of *Vigna mungo* germplasms for resistance to *Callosobruchus maculatus*, *C. chinensis*, *C. analis*

S.no	*V. mungo* varieties	*C. maculatus*			*C. chinensis*			*C. analis*		
		No. of eggs laid ±SEM	No. of adult emerged±SEM	Mean developmental period (days)±SEM	No. of eggs laid±SEM	No. of adult emerged±SEM	Mean developmental period (days)±SEM	No. of eggs laid ±SEM	No. of adult emerged ±SEM	Mean developmental period (days)±SEM
1.	1/98	48.1±5.1	25±1.3	30.0±0.8	46.1±5.0	24±1.2	31.0±0.9	44.1±4.0	23±1.3	35.0±0.8
2.	9/14	57.3±4.2	33±1.0	30.0±0.5	56.2±3.1	32±1.2	31.1±0.4	51.3±2.0	31±1.4	32.2±0.5
3.	KU-415	47.9±2.2	37±2.1	32.0±0.2	45.8±1.2	35±1.2	33.0±0.3	41.7±0.2	32±1.0	34.1±0.4
4.	KU-312	59.0±4.1	47±3.1	32.0±0.6	58.0±3.1	46±2.0	32.0±0.6	52.0±2.1	43±1.0	33.2±0.7
5.	KU-319	61.8±4.3	31±1.1	32.1±1.8	60.6±3.2	29±1.2	33.3±1.9	57.5±2.1	28±0.2	35.4±1.8
6.	KU-814	63.5±3.1	25±0.7	31.0±0.1	62.4±2.1	24±0.8	32.2±0.2	58.3±2.3	22±0.7	34.3±0.4
7.	KU-315	35.6±3.4	27±2.5	28.0±0.1	33.5±2.5	26±1.3	29.0±0.1	30.5±1.4	23±1.2	31.3±0.3
8.	IC- 11925	60.2±5.3	27±1.3	29.0±0.3	59.1±4.2	25±0.2	30.0±0.4	55.1±3.1	24±0.1	33.2±0.6
9.	IC-1572	45.6±2.2	30±2.7	30.0±0.2	44.5±1.2	28±1.6	31.2±0.3	42.4±1.0	26±1.5	34.5±0.4
10.	NG-2119	59.8±4.2	29.4±2.2	25.0±0.1	58.7±3.3	27.4±2.1	26.0±0.2	53.6±2.2	25.4±1.0	31.6±0.3

Black gram varieties

This given data clear that number of eggs laid, number of adult emergence, and mean developmental periods (days) significantly differed between 10 black gram genotypes (Table 2). The genotypes, KU-315, IC-1572 and KU-415 recorded less number of eggs (35.6, 45.6 and 47.9eggs/100 seeds) while KU-814, KU-319 recorded highest number of eggs (63.5 and 61.8 eggs/100seeds) and number of adult emerged was lowest in KU-814, KU-315 (25,27/100seeds), while highest in KU-312, KU-415 (47,37/100seeds). Mean developmental period was highest in KU-319 (32.1days), while lowest in NG-2119 (25.0 days) in *C. maculatus*. In *C. chinensis* highest number of eggs laid on KU-814 (62.4/100 seeds), and lowest in KU-315 (33.5/100 seeds), and number of adult emerged was lowest in KU-814 (24.8/100 seeds) and highest in KU-312 (46.2/100 seeds). Mean developmental period was highest in KU-319 (33.3 days), while lowest in NG-2119 (26.0 days). In *C. analis* highest number of eggs laid on KU-814 (58.3/100 seeds) while lowest in KU-315 (30.5/100 seeds). Adult emergence was highest in ku-312 (43.1/100 seeds) as comparison to KU-814(22.0/100 seeds), while mean developmental period was found in KU-319 (35.4 days), and lowest in KU-315 (31.3 days).

Morphological characters of *Callosobruchus* species

The members of Bruchid family are granivores and typically damage various kinds of germplasm or beans, living for most of their life cycle inside a single seed. In worldwide these family includes about 1,350 species. Cowpea weevils are generally compact and oval in shape, with small heads somewhat bent under. Sizes ranges from 1 to 22 mm for some tropical species. Colours are usually black or brown, often with mottled patterns. Although their mandibles may be elongated, they do not have the long snouts characteristics of true weevils. Adults deposit eggs on seeds, then the larvae chew their way in to seed. When the stage of pupation starts, larvae cut and made a exit hole, then return to feeding chamber. Adult beetles have a habit of feigning death and dropping from a plant when distributed.

Differences among *maculatus* and other species *Callosobruchus*

C. maculatus
Inner carina of hind femur smooth, inner tooth typically as long as, or very slightly longer than, outer tooth. Pronotum of mature specimens with black cuticle, and with golden setae, except on the basal median gibbosities, which extend well beyond the posterior margin and are covered with white scale- like setae. Eyes very deeply emarginate, prominent and bulbous. Male genitalia distinctive median lobe with two longitudinal sclerotized denticulate areas near its middle, parameters rather stout and broadly spatulate.
C. chinensis
Male antennae pectinate, segments 4-10 conspicuously expanded antero- laterally, female antennae serrate, antennae of both sexes usually with segments 4-11 dark brown. Female and male pygidium covered with white or silver setae. Inner tooth of hind femur with sides more or less parallel, converging near apex. Male genitalia; median lobe more elongate, apex with exophallic valve spearhead-shaped and base with two sclerotized plates; parameters normal and rather broadly spatulate.
C. analis
Inner carina of hind femur with numerous irregularly-spaced small denticles along its proximal two- thirds; inner tooth rather shorter than, or as long as outer tooth. Pronotum with uniformly reddish -brown cuticle, and with sparse golden setae, except on the basal median gibbosities, which extend only slightly beyond the posterior margin and have sparse white setae. Eyes less deeply emarginate, rather flattened and less prominent. Male genitalia; median lobe without sclerotized areas near it middle, parameters rather slender and narrowly spatulate.

Discussion

C. maculatus is an important stored grain insect pest. In mature legume seeds, growth and developmental period of cowpea weevils was seen. On the surface of seed eggs being laid by adult adults male and female have average life time of 7 days and only few of them can survive more than 2 weeks. It belongs to family *Bruchidae* of the order Coleoptera, genus *Callosobruchus*. The most distinguishing characteristic is the coloration on the plate is enlarged and darkly colored on both sides. The plate is smaller and lack stripes is generally seeing in male. As comparison to male females are larger in size, but there is much variation. In some strains, females are black in coloration and males are brown in colour, but in other sexes are brown, *calandrae* is larval as parasitoid of *Callsobruchus maculatus*. In this experiment we find out the result of oviposition, number of adult emergences, mean developmental period of *C. maculatus, C. chinensis and C. analis.* The number of eggs laid, number of adult emerged was seen highest in *C. maculatus and C. chinensis* while lowest in *C. analis* in both

Vigna mungo and *Vigna radiata*. The mean developmental period was lowest in *C. maculatus* and *C. chinensis* while in *C. analis* mean developmental period for both *Vigna* species are highest. The genotypes, EC520041, AKM96-4, CO-4 recorded less number of eggs (4.68, 7.20 and 7.36 eggs/100 seeds) while PDM-54, PDM-139, IPM-02-3 recorded highest number of eggs (25.33, 19.33 and 15.34 eggs/ 100 seeds) and number of adult emerged was lowest in EC520041, AKM96-4, CO-8 (3.68, 5.69,7.68/100 seeds), while highest in PDM-54, IPM-02-3, IPM-02-14 (19.68,13.66,12.36/100 seeds). Mean developmental period was highest in IPM-02-3 (27.10 days), while lowest in HUM-12 (12.10 days) in *C. maculatus*. In *C. chinensis* highest number of eggs laid on PDM-54 (24.31), and lowest in EC520041(3.67), and number of adults emergence was lowest in EC520041(2.67) and highest in PDM-54 (18.6). Mean developmental period was highest in IPM-02-3 (28.0 days), while lowest in HUM-12 (24.0 days). In *C. analis* highest number of eggs laid on PDM-54 (23.30) while lowest in EC520041(2.67). Adult emergence was highest in PDM-54 (17.66) as comparison to EC520041 (1.67), while mean developmental period was found in IPM-02-3(29.10), and lowest in PDM-139 (25.05). The genotypes, KU-315, IC-1572 and KU-415 recorded less number of eggs (35.6, 45.6 and 47.9eggs/100 seeds) while KU-814, KU-319 recorded highest number of eggs (63.5 and 61.8 eggs/100seeds) and number of adult emerged was lowest in KU-814, KU-315 (25,27/100seeds), while highest in KU-312, KU-415 (47,37/100seeds). Mean developmental period was highest in KU-319 (32.1days), while lowest in NG-2119 (25.0 days) in *C. maculatus*. In *C. chinensis* highest number of eggs laid on KU-814 (62.4/100 seeds), and lowest in KU-315 (33.5/100 seeds), and number of adult emerged was lowest in KU-814 (24.8/100 seeds) and highest in KU-312 (46.2/100 seeds). Mean developmental period was highest in KU-319 (33.3 days), while lowest in NG-2119 (26.0 days). In *C. analis* highest number of eggs laid on KU-814 (58.3/100 seeds) while lowest in KU-315 (30.5/100 seeds). Adult emergence was highest in ku-312 (43.1/100 seeds) as comparison to KU-814(22.0/100 seeds), while mean developmental period was found in KU-319 (35.4 days), and lowest in KU-315 (31.3 days).

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References

1. Allito BB, Ewusi-Mensah N, Alemneh AA. Rhizobia strain and host-legume interaction effects on nitrogen fixation and yield of grain legume: A review. Mol Soil Biol,2014:2:1–12. doi: [CrossRef].
2. Applebaum SW, Tadmor U, Podoler H. The effect of starch and of heteropolysaccharide on fecundity of *Callosobruchus chinensis*. Entomol Exp Appl,1970:13:61-70.
3. Cope JM, Fox CW. Oviposition decisions in the seed beetle *Callosobruchus maculatus* (Coleoptera: Bruchidae): effects of seed size on super parasitism. J Stored Prod Res,2003:39:355-65.
4. Credland PF, Wright AW. Oviposition deterrents of *Callosobruchus maculatus* (Coleoptera: Bruchidae). Physiol Entomol,1990:15:285-98.
5. Fox CW. Multiple mating, lifetime fecundity and female mortality of the bruchid beetle *Callosobruchus maculatus* (Coleoptera: Bruchidae). Funct Ecol,1993:7:203-8.
6. Foyer CH, Lam HM, Nguyen HT, Siddique KH, Varshney RK, Colmer TD, *et al*. Neglecting legumes has compromised human health and sustainable food production. Nat Plants,2016:2:16112. doi: [CrossRef] [PubMed].
7. Franca AFJ, Araujo JN, Santos YQ, Carelli GSC, Silva DA, Amorim TML, *et al*. Vicilin from Anadenanthera colubrina seeds: An alternative tool to combat *Callosobruchus maculatus*. Saudi J Biol Sci,2021:28(9):5229-37. doi: 10.1016/j.sjbs.2021.05.041.
8. Kumar C, Mishra S, Singh CM. Evaluation of selection indices for improving terminal heat tolerance in green gram (*Vigna radiata* L. Wilczek). J Agrometeorol,2016:18:216–21. doi: [CrossRef].
9. Kumar C, Mishra S, Singh CM. Investigating morpho-physiological traits and agro-meteorological indices in green gram (*Vigna radiata* (L.) Wilczek) for terminal heat tolerance. Legume Res,2017:40:271–6. doi: [CrossRef].
10. Kumar R, Singh CM, Arya M, Kumar R, Mishra S, Singh U, *et al*. Investigating stress indices to discriminate the physiologically efficient heat tolerant genotypes of mungbean (*Vigna radiata* (L.) Wilczek). Legume Res,2020:43:43–9.
11. Messina FJ. Heritability and evolvability of fitness components in *Callosobruchus maculatus*. Heredity,1993:71:623-9.
12. Mishra GP, Dikshit HK, Sv R, Tripathi K, Kumar RR, Aski M, *et al*. Yellow mosaic disease (YMD) of mungbean (*Vigna radiata* (L.) Wilczek): Current status and management opportunities. Front Plant Sci,2020.
13. Nair R, Schreinemachers P. Global status and economic importance of mungbean. In: The Mungbean Genome. Berlin: Springer, 2020, 1–8.
14. Oke OA, Akintunde EM. Reduction of nutritional values of cowpea infested with *Callosobruchus maculatus*. Int J Agri Sci,2013:3(1):30-6.
15. Pratap A, Dhaliwal I, Singh CM, Mahalingam A, Manivannan N, Basavaraja T, *et al*. Biofortification of Mungbean. In: Biofortification of Staple Crops. Singapore: Springer, 2022, 295–333. doi: [CrossRef].
16. Qi YT, Burkholder WE. Sex pheromone biology and behaviour of the cowpea weevil *Callosobruchus maculatus* (Coleoptera, Bruchidae). J Chem Ecol,1982:8:527-34.
17. Sehrawat N, Yadav M, Bhat KV, Sairam RK, Jaiwal PK. Effect of salinity stress on mungbean (*Vigna radiata* (L.) Wilczek) during consecutive summer and spring seasons. J Agric Sci Belgrade,2015:60:23–32. doi: [CrossRef].
18. Shaheen FA, Khaliq A. Management of pulse beetle *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) in stored chickpea using ashes, red soil powder and turpentine oil. Pak Entomol,2005:27(2):19-24.

19. Sharma S, Thakur DR. Comparative developmental compatibility of *Callosobruchus maculatus* on cowpea, chickpea, and soybean genotypes. Asian J Biol Sci,2014:7(6):270-6.
20. Singh CM, Kumar R, Mishra S, Pandey A, Arya M. Characterization of mungbean genotypes against Mungbean Yellow Mosaic Virus and Cercospora leaf spot diseases under north east plain zone. Int J Agric Environ Biotechnol,2015:8:119–25. doi: [CrossRef].
21. Singh CM, Mishra SB, Pandey A, Arya M. Eberhart-Russell and AMMI approaches of genotype by environment interaction (GEI) for yield and yield component traits in *Vigna radiata* L. Wilczek. Int J Agric Environ Biotechnol,2014:7:277–92. doi: [CrossRef].
22. Singh CM, Pratap A, Gupta S, Biradar RS, Singh NP. Association mapping for mungbean yellow mosaic India virus resistance in mungbean (*Vigna radiata* L. Wilczek). 3 Biotech,2020:10:33. doi: [CrossRef] [PubMed].
23. Singh CM, Pratap A, Kumar H, Singh S, Singh BK, Prasad D, *et al*. Recent advances in omics approaches for mungbean improvement. In: Technologies in Plant Biotechnology and Breeding of Field Crops. Berlin: Springer, 2022, 181–200. doi: [CrossRef].
24. Singh CM, Singh P, Pratap A, Pandey R, Purwar S, Douglas CA, *et al*. Breeding for enhancing Legumovirus resistance in mungbean: Current understanding and future directions. Agronomy,2019:9:622. doi: [CrossRef].
25. Singh CM, Singh P, Tiwari C, Purwar S, Kumar M, Pratap A, *et al*. Improving drought tolerance in mungbean (*Vigna radiata* L. Wilczek): Morpho-physiological, biochemical and molecular perspectives. Agronomy,2021:11:1534. doi: [CrossRef].
26. Sirohi A, Tandon P. Assessment of insecticidal efficiency of neem sawdust on the pulse beetle (*Callosobruchus chinensis* L.). Asian J Agric Sci,2011:3(5):414-6.
27. Singh N, Swami V. Screening for ovipositional preference, growth and development of *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae) on different stored legumes. J Exp Zool India,2024:27:1067-73.
28. Smith RH. Oviposition, competition and population dynamics in storage insects. In: Proc 4th Int Conf Stored-Product Protection: 1986.
29. Swami V, Singh N. Screening and synergistic action of medicinal plant powders against cowpea weevil *Callosobruchus maculatus* as adulticidal and fecundity and fertility inhibitor. Int J Entomol Res,2023:8(9):48-53.