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Variations in the Life Cycle of Legume Pod Borer, *Maruca vitrata* Fabricius (Lepidoptera: Crambidae) on Different Pulses

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ABSTRACT

Legume or spotted pod borer, Maruca vitrata, is an important insect pest that causes severe economic damage in pulses. As the continuous mass culturing of this insect on different pulses is found to be difficult, comprehensive studies have not been done earlier. In keeping this, a comparison was made on its biology in different pulses viz., pigeon pea, green gram, black gram, cowpea, and lablab at the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, during 2012–13. Maximum fecundity of M. vitrata was recorded (61.0 eggs) in lablab with a mean of 15.3 eggs/female/day in an oviposition period of 3.4 days followed by pigeon pea (14.0 eggs). The mean incubation period of the egg was minimum on pigeon peas (2.33 days) as against 3.07 days on lablab. Five larval instars were recorded with a mean developmental period of 2.19–2.47 days in different instars. The total larval period ranged from 10.76 days in cowpea to 13.19 days on the black gram with a mean of 11.81 days irrespective of the host studied. The pupal period ranged from 6.07 (green gram) to 6.67 days (lablab) with maximum pupation of 83.0% on pigeonpea. The total life cycle was minimum in cowpea (19.50 days) compared to 21.47 days on the black gram and the mean of 20.58 days irrespective of hosts studied. The mean longevity of females (3.64 days) was higher than male moths (3.15 days). The highest growth index of 7.45 was recorded on pigeonpea compared to 5.09 days on the black gram. The sex ratio (:) favoured females in all hosts and ranged from 1.0:2.13 in lablab to 1.0:2.34 on pigeonpea except on cowpea where it was male-biased (1.0:0.65). Hence, it is that clear the host preference was maximum on cowpea followed lablab, green gram, pigeon pea, and black gram. Lablab and cowpea found to be ideal hosts for quick development of M. vitrata.

Keywords: *Biology, cowpea, lablab, legumes, legume pod borer, Maruca vitrata, oviposition, pigeonpea, total life cycle*

INTRODUCTION

Pulses are the most important cultivated crops in Indian agriculture and play a vital role in food production and to overcome the problem of malnutrition. As they are mostly grown under rainfed conditions to use the available soil moisture and to restore soil fertility, not much emphasis is given to improving their productivity across India. They are affected by many biotic impediments and legume pod borer, Maruca vitrata Fabricius being perhaps the most nefarious insect pest [1]. M. vitrata infest during flowering and pod formation stages. Larvae feed on floral buds, flowers, and pods of pulses [2], causing huge economic losses [3]. This pest is known to be infested on 39 host plants in Asia [4,5] and its wide host range, distribution, and voracious feeding nature make it the most significant constraint in increasing the productivity of grain legumes [6]. This pest shows a wide degree of polyphagia and is known to infest legumes such as pigeon pea (Cajanus cajan (L.) Millsp.), green gram (Vigna radiata (L.) R. Wilczek), black gram (Vigna mungo (L.) Hepper), cowpea (Vigna unguiculata (L.) Walp.), lablab (Lablab purpureus (L) Sweet.), and common bean (Phaseolus vulgaris L.) from tropics to temperate zones across the world [7,8]. This pest is known to inflict a grain yield loss of around 20.0–100.0% on various leguminous crops [9-12].

The infestation of this pest on various pulses is gradually increasing every day. Hence, farmers mainly rely on synthetic pesticides to ward off them [13]. The hidden nature of feeding by M. vitrata larvae diminishes the entry of pesticides [14] and thereby reduces their efficacy [15]. Even repeated application of pesticides induces the production of many detoxifying enzymes in their gut [15] and causes the development of resistance against pesticides [16,17], which leads to their major outbreaks in recent years [10]. Because of a wide range of adaptability to the nutritional status of different pulses and to different agroecosystems, they have developed a capacity to produce successive generations throughout the year. In spite of the increasing importance of M. vitrata, the preliminary data on

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Materials and Methods

Location and hosts used

A comparative study on bionomics of M. vitrata was carried out on five pulses under laboratory conditions at a mean temperature of 26.5 ± 2 °C and 83.50 ± 3.5% relative humidity (RH) at the Department of Agricultural Entomology, Tamil Nadu Agricultural University (TNAU), Coimbatore, during 2012–13. Flowers and pods of pigeon pea (cv. CO-RG-7), green gram (cv.CO-GG-7), black gram (cv. CO-BG-6), cowpea (cv. CO 7), and lablab (cv. Rohini) were used as hosts.

Mass culturing of study insect

Larvae of M. vitrata were collected from different pulses raised in TNAU, Coimbatore, to establish the stock culture. Field-collected larvae were kept in a plastic basin (30 cm dia. and 10 cm height) on a dry filter paper, and pods of lablab were provided as food (Fig. 1a). During the process of rearing, inactive, sluggish, slow-growing, malformed and disease-affected larvae and pupae were removed and destroyed. Healthy pupae (Fig. 1b) were kept in plastic buckets (22.5 cm dia. and 25 cm height) for adult emergence (Fig. 1c). Ten pairs of healthy adults were maintained in each bucket. Fresh lablab pods were provided as a source for egg laying. The mouth of the plastic bucket was covered with a piece of black sterile muslin cloth, which also served as an oviposition substrate. Sugar solution (10%) with a drop of vitamin E was used as adult food in suitable sterile glass vials and absorbent cotton. The whole setup was kept in a culture room at a temperature of 27.9 ± 2.2 °C and RH of 76.6 ± 9.1%. The muslin cloth of each bucket cover and sugar solution were removed periodically and fresh lablab pods were provided daily. Each muslin cloth along with egg-laden lablab pods was labelled with the date and batch number. The fresh eggs were stored in a humidified (95% RH) plastic container. After hatching, the larvae were reared in the tender pods of lablab in groups until the pupation in plastic rearing trays (30 cm dia. and 10 cm height). The rearing trays carrying the fifth instar larvae were carefully examined for any disease symptoms for removal.

The larvae were allowed for pupation, and 4 days after pupation, the pupae were collected and all malformed or undersized pupae were discarded. Pupae thus obtained were placed in plastic buckets for adult emergence and other procedures, as described earlier, were followed for mass culturing. To study the biology of M. vitrata on pigeon pea, green gram, black gram, cowpea, and lablab, moths were incubated along with flowers and pods of respective hosts for egg laying and the larvae obtained were used for further studies.

Fecundity studies

To study the egg-laying potential of M. vitrata on different pulse hosts, 10 pairs of newly emerged adult moths were collected from the stock culture and released in a plastic bucket, and 10% sugar solution with absorbent cotton was placed to serve as food for adult moths. One day after mating, the mated individual female moths were confined in plastic buckets (22.5 cm dia. and 25 cm height) and fresh flowers and pods of lablab were provided separately for egg laying and this setup was replicated five times. The mouth of the buckets was covered with black muslin cloth and fastened with a rubber band. Fresh pods were replenished daily and the number of eggs laid by each female on lablab pods was counted until the death of moths. A similar methodology was adopted to study the fecundity potential of M. vitrata on pigeonpea, green gram, black gram, and cowpea also.

Egg, larval, and pupal periods

Flowers and pods of pigeon pea, green gram, black gram, cowpea, and lablab were collected from the field and inoculated with fertile female moths separately for oviposition. Totally 100 eggs were collected from each host and maintained separately in glass bottles (2.0 cm width and 3.5 cm height). The egg period was studied by introducing single, freshly laid egg containing flower or pod into the glass bottles, which were covered with muslin cloth for adequate aeration and fastened with rubber bands to prevent the escape of the developing larvae. Totally 10 replications were maintained for each host at a rate of 10 eggs/replication. The larvae were provided with fresh food from the corresponding host once in 2 days. Observation of different biological parameters such as egg period, number of larval instars, duration of each larval instar, total larval period, percent pupation, an incubation period of pre-pupa and pupa, total life cycle from egg to adult stage, percent adult emergence, and adult longevity were made for all replications and the mean developmental period of respective stages was worked out.

Adult longevity

On emergence from the pupae, moths were observed for their longevity in both sexes. The freshly emerged moths of both sexes were confined separately in plastic bottles (9.0 cm dia. and 11 cm height) along with 10% sugar solution and covered with a muslin cloth. The longevity of the moths was recorded until their death and it was compared for all hosts.

Growth Index

The growth index (GI) of M. vitrata was studied using the following formula [18]:

$$\text{Growth Index} = \frac{\text{Mean percent pupation}}{\text{Mean larval period}}$$

Sex ratio (♂ : ♀)

The sex ratios of M. vitrata on different pulse hosts of biology studies were computed using the following formulae:

$$\text{Sex ratio} = \frac{\text{Number of female moths}}{\text{Number of male moths}}$$

Statistical analyses

For correcting zero values obtained in the study, 0.5 (X + 0.5) was added to all values and analyzed. To analyze data on percent fallen between 1.0 and 100.0, arcsine transformation was used [19]. Analysis of variance was conducted and means were separated by multiple comparisons test using Turkey's HSD [20] at 5% significance level [19].

Results

Duration of different life stages of *M. vitrata*

Egg period

The female moth laid pale white eggs on the flower buds, flower surface, and pods (Fig. 2A). Eggs of M. vitrata hatched into larvae within 2–4 days in all hosts. Eggs laid on pigeonpea took a minimum of 2.33 days to hatch into a larva, which was statistically significant than other hosts (Table 1). This was followed by 2.83, 2.88, 3.05, and 3.07 days on the black gram, green gram, cowpea, and lablab, respectively. The mean egg period was found to be 2.83 days irrespective of hosts.

Larval period

In total, five larval instars of M. vitrata were recorded on all hosts used in the study. The larvae (Fig. 2B) are found to be negatively phototrophic and highly active in the dark. The duration of the first instar larvae was found to be insignificant on all hosts, and recorded 1.92 to 2.32 days on pigeon pea and lablab, respectively (Table 2). In the second instar larvae, the least mean duration of 2.06 days was recorded in cowpea, which was highly significant from all other hosts. In other hosts, it ranged from 2.17 to 2.57 days. The significantly lowest mean duration of the third instar was recorded in cowpea followed by 2.24 days in lablab and 2.32 days in pigeon pea, which were statistically similar. The maximum duration of 2.75 days was recorded for green gram. The minimum mean longevity of the fourth instar larval duration of 2.15 days was recorded in cowpea followed by 2.21 and 2.31 days in lablab and pigeonpea, respectively, which were on par with each other. However, Maruca larvae took 2.98 days to complete the fourth instar stage on the black gram. The fifth instar larva recorded a significant minimum mean duration of 2.19 days in cowpea and 2.31 and 2.28 days in lablab and pigeon pea, respectively. However, the highest mean duration of 2.74 days was recorded on the black gram (Table 2).

The larvae fed on cowpea took a minimum of 10.76 days to complete their development, which was significant compared to the larvae on other hosts (Table 2). This was followed by 11.15 and 11.8 days on pigeonpea and lablab, respectively. The larvae fed on black gram developed slowly and reached the pupal stage after 13.19 days with a range of 10-17 days.

Prepupa and pupal period

The duration of the prepupal period was found to be insignificant in all pulses and completed with a mean period of 2.04 days on all hosts (Table 3; Fig. 2C–2D). Similarly, the pupal duration was also found statistically on par in all hosts studied (mean = 6.44 days). The lowest pupal duration of 6.07 days was recorded on green gram compared to 6.67 days on lablab. The pupation level of Maruca larvae was found to be statistically on par (mean = 72.2%) except on cowpea (65.0%) and ranged from 68.0 to 83.0%, from black gram to pigeon pea (Table 3).

Total life cycle

The total life cycle of M. vitrata from egg to adult was completed within a mean duration of 20.58 days. The significantly lowest duration was recorded on cowpea (19.50 days) followed by 19.74, 20.76, and 21.41 days on lablab, green gram, and pigeonpea, respectively (Table 3). The maximum life span of 21.47 days was registered on the black gram. During the experimental period, no diapause was observed in any life stages of M. vitrata reared irrespective of host plants.

Longevity of adult moths

The longevity was insignificant (mean = 3.15 days) on all hosts and ranged from 2.73 to 3.42 days, from black gram to green gram (Table 3). However, the mean longevity of female moths was 3.64 days. Significant minimum longevity of female moths was observed on cowpea (3.17 days) followed by black gram (3.35 days) and pigeon pea (3.72 days). In green gram and lablab, it was 3.91 and 4.03 days, respectively. Male and female moths could be clearly distinguished. In the male, the abdomen was tapered towards the end (Fig. 2 E) and the tip of the female abdomen was long, and slightly bulged with a prominent copulatory pore (Fig. 2F).

Growth index)

A maximum GI of 7.45 was observed in pigeonpeas and was statistically significant in other hosts (Table 4). This was followed by 6.86 and 6.16 on lablab and cowpea, respectively, as against the minimum GI on the black gram (5.09).

Adult emergence

Adult emergence ranged from 58.0 and 68.0% on cowpea and pigeon pea, respectively. A significant maximum emergence of male moths of M. vitrata was recorded on cowpea (41.0 %) followed by 28.0 and 27.0% on pigeonpea and green grams, respectively, when compared to 19.0% on the black gram. However, the percent female emergence was insignificant on all hosts and ranged from 34.0 on the green gram to 41.0 on pigeon pea except on cowpea (17.0%).

Sex ratio

Data on sex ratio (♂:♀) revealed that they were biased towards females (Table 4). A significant maximum sex ratio was recorded on pigeonpea (1.0:2.34) followed by 1.0:2.23 on the black gram, 1.0:2.19 on the green gram, and 1.0:2.13 on the lablab. On cowpea, the sex ratio favoured the males (1.0:0.65).

Figure 1a: Mass culturing of Maruca vitrata under laboratory conditions

Figure 1b: Pupae of M. vitrata

Figure 1c: Rearing of M. vitrata adults for egg laying

Figure 2a: Eggs of M. vitrata

Figure 2b: Larvae of M. vitrata

Figure 2c: Various stages of Pre-pupal development in M. vitrata

Figure 2d: Various stages of pupal development in M. vitrata

Figure 2e: Adult male moth of M. vitrata

Figure 2f: Adult female moth of M. vitrata

Discussion

The laboratory studies revealed that the highest ovipositional preference of M. vitrata was on lablab compared to other pulses. Maximum eggs were laid on lablab (61.0) followed by pigeon pea (14.0), and in other hosts, the fecundity was found to be very low (<10.0). These results were in consonance with an earlier finding that female moths of M. vitrata could lay up to 400 eggs on different pulses [21]. According to Hanabar and Hegde (2018) [22] female moths of M. vitrata laid up to 97.50 eggs on groundnut. Similarly, a fecundity of 62.34 eggs per female was observed in the refined D-OOD diet [23]. On the contrary, there were recorded mean fecundity of 38.8 and 41.8 eggs per female on black gram [24] and cowpea [25], respectively. On pigeonpeas, the fecundity was reported to be 28.7 [23] and 37.24 eggs [26] by female moths, which was comparatively lesser than that found in the present study. The higher fecundity due to the availability of more preferred flowers coincides with maximum volatile emission, which elicits maximum oviposition of M. vitrata. Female moths of M. vitrata reared on lablab showed the lowest pre-oviposition period of 1.2 days and spent more time (3.4 days) in laying eggs than all other hosts tested.

This showed their preference for lablab and helps them to lay more eggs on lablab than other hosts. Next to the lablab, a low preoviposition period of 1.4 days was recorded on pigeonpea. On other hosts, the oviposition period was only less than 2.5 days. Earlier it was reported a slightly high pre-ovipositional period of 3.56 days and an oviposition period of 4.83 days [21]. Controversially, on the black gram, a higher oviposition period of 3.8 days was recorded [24]. The maximum oviposition period and fecundity of M. vitrata in lablab might be due to the positive influence of the host and release of strong physiochemical cues, which make them the most preferred host to female moths.

The incubation period of M. vitrata egg was minimum (2.33 days) on pigeonpea with a mean egg period of 2.83 days irrespective of hosts. This was in agreement with the earlier observations on pigeonpea at 2.50 [27], 2.85 [23], and 2.63 days [21] of the oviposition period. On semisynthetic and refined D-OOD diets, larvae of M. vitrata emerged within 2.4-3.0 [28] and 2.60 days [23] from eggs. Similarly, an egg period of 2.47, 2.80, and 3.65 days was recorded on pigeonpea [26], cowpea [29], and green gram [30], respectively. However, egg incubation periods of 3.0 to 4.0 days on cowpea, lablab, green gram, and pigeon pea also reported in earlier studies [31].

A mean larval period of 10.76 days was registered in cowpea compared to a maximum of 13.19 days on the black gram. The present finding is in line with the earlier studies revealed that larval development ranged from 8.0 to 16.3 days in different pulses [5]. On a refined D-OOD diet, the total larval duration lasted 14.28 days [23]. Similarly, M. vitrata larva took 12.20 to 14.80 days to develop into pupa when reared on a semi-synthetic diet [28]. The larval life span of M. vitrata on cowpea was shorter (11.1 days) compared to that of cowpea flour diets (16.5 days) and soybean flour diets (14.4 days) [32]. In South India, it was recorded the completion of the larval period within 10 days [33]. Similarly, the larval cycle ranged from 12.7 to 16.4 days in pigeonpea [34]. However, on groundnut, the mean larval duration was 16.21 days [22]. On contrary, M. vitrata larva turned into a pupa within 7.3 days on cowpea and took 21 days on sunn hemp [35]. Nevertheless, earlier reports [21, 23, 27, 36] are also in line with the present findings on various pulses. The slight variation in the total larval period with earlier findings might be attributed to the variation in the nutrition of the host plants.

The mean duration of prepupa and pupal periods of M. vitrata were found to be 2.04 and 6.44 days, respectively, in different pulses. These observations are in line earlier reports that the prepupal and pupal period of l.2 to 2.0 days and 6.4–11.0 days, respectively [5]. Similarly, in pigeonpea slightly a higher prepupal (2.5–3.0 days) and pupal (7.0–8.5 days) durations [23, 26] were recorded. Similarly, in pigeon pea and sunn hemp, it was registered 11.1 and 11.6 days of pupal periods [34]. On the refined D-OOD and semisynthetic diet, pupal duration lasted for 9.41 [23] and 9.0–11.0 days [28], respectively. The variation in temperature and RH of the rearing room might have played a significant role and caused the difference in the pupal duration in the present experiments from the earlier studies.

The total life cycle from egg to adult was minimum (19.5 days) in cowpea against the maximum (21.47 days) on the black gram and completed in a mean period of 20.58 days irrespective of pulses tested. These findings are in concordance with the earlier reports on different pulses [5, 29, 27, 21]. However, a slightly higher total life cycle of 28.12, 29.36, 33.30, 34.03, and 36.5 days was reported on black gram [24], cowpea [25], groundnut [22], green gram [30], and pigeon pea [23], respectively, than the present study. Similarly, it was also evidenced 28.20 days of total life cycle by M. vitrata on pigeon pea [26]. These differences might be due to variations in laboratory growing conditions, nutrition, and the variety of hosts used in the study.The mean longevity period of Maruca females was found to be more (3.64 days) than the males (3.15 days) irrespective of the hosts. Similar results were also recorded in black gram [24], green gram [30], pigeon pea [21, 23], and groundnut [22] also. Hence, it is very clear that female moths survived slightly longer than males. This was mainly because females spent extra time in the selection of a host for egg laying and further oviposition processes. Also, it is well known that freshly emerged moths are more prone to healthy mating and generation development activities than older ones. Already, more number of matings recorded in 2 to 5 days old adult moths of M. vitrata than 6 and 7 days aged moths [37]. Hence, it is clear that the frequency of mating between the two sexes of M. vitrata influences fecundity. Adult moth emergence of 58.0 and 68.0% were recorded on cowpea and pigeon pea, respectively. This high level of adult emergence may be a positive trait for this species to sustain their generation to proceed further. However, on the green gram, about 76.0% of adult emergence was observed [30].

The maximum GI was observed in pigeonpea (7.45) followed by 6.86 in lablab and 6.16 in cowpea, and this revealed a sustainable GI and development of Maruca larvae on pigeonpea than other hosts. Similarly, a GI of 5.71 was recorded on cowpea [25]. In contrast, a lower GI was reported on pigeonpea (4.14), cowpea (4.63), and hyacinth beans (5.17) [36]. Diverse agro-climatic conditions, varietal differences, and host plant nutrition could be reasoned out for this variation. More than 50% of adult emergence was recorded irrespective of all pulses. The results on sex ratio (♂:♀) revealed that in all hosts it favoured females which ranged from 1.0:2.13 in lablab to 1.0:2.23 in black gram except in cowpea wherein it biased towards males (1.0:0.65). However, on pigeonpea and cowpea, it was recorded the sex ratio (♀:♂) of 1.0:0.50 and 1.0:0.84, respectively [38]. Optimum mating and oviposition were recorded at 1:1 ratio [39]. Similarly, earlier laboratory studies revealed that the sex ratio (♂:♀) of M. vitrata and Conogethes punctiferalis Guenee was female-biased on different pulses [40] and castor [41], respectively. This higher female moth population helps this species to produce more offspring in the next generation and strengthen their stage-specific generation survival and GI of the successive cohorts.

In general, the selection of an ideal host by any insect species is triggered by nutrition, morphological parameters, and host plant volatile composition [42]. Likewise, in the presently studied host plants, these factors played an important role in the biological variations and ecology of M. vitrata. In the present results, shorter development of M. vitrata on cowpea followed by lablab and pigeon pea may be due to higher adaptation to the nutrition and host plant volatiles of these hosts. Earlier it was reported that lablab was a highly suitable host for mass rearing of M. vitrata followed by cowpea and pigeon pea by supporting adequate levels of nutrition for optimum growth and development [43] and these give strong emphasis to the present findings. In Lepidoptera, host plant selection for oviposition is mainly chosen by female moths and this is referred to as the 'mother-knows-best hypothesis' [44]. Hence, female moths of M. vitrata lay their eggs in the vicinity of hosts (on flowers and pods) in clusters so that their neonates can readily feed ideal hosts upon hatching.

The management of any phytophagous insect pests should not focus only on a single major host crop but on different cropping systems across a wide area [45]. Hence, the availability of other related host crops near the vicinity of the major food source is important [46] and plays a major role in determining population dynamics and outbreaks of many polyphagous herbivores. In concomitant to this, the existence of proximity was recorded between larval populations of cowpea and lablab [47] and hence, this could make a developmental variation in M. vitrata when reared on the above pulses. In view of all these reasons, it is very clear that different adaptive and host selection mechanisms of M. vitrata might have influenced variations in the life cycle of the host plants studied.

Table 1. Fecundity of M. vitrata on different pulses

Host	Preoviposition Period*	Oviposition Period*	Mean Number of Eggs Laid/Female/Day*	Total Eggs Laid/Female
Pigeon pea	1.4^{a} ± 0.5 (1.4)	2.8^{ab} ± 0.4 (1.8)	3.4^{b} ± 1.4 (2.0)	14.0
Green gram	2.0^{a} ± 0.4 (1.6)	2.2^{ab} ± 0.4 (1.6)	2.0^{b} ± 1.1 (1.6)	6.0
Black gram	1.8^{a} ± 0.8 (1.5)	1.8^{b} ± 0.8 (1.5)	1.1^{b} ± 0.6 (1.3)	4.0
Cowpea	2.2^{a} ± 0.4 (1.6)	2.6^{ab} ± 0.4 (1.8)	2.6^{b} ± 2.1 (1.8)	10.0
Lablab	1.2^{a} ± 0.5 (1.3)	3.4^{a} ± 1.3 (2.0)	15.3^{a} ± 3.9 (4.0)	61.0
SEd	0.4899	0.6449	2.3894	-
CD (p = 0.05)	1.0219	1.3453	4.9843	-

** Mean and standard deviation of five replications.*
Figures in the parentheses are $\sqrt{X + 0.5}$ transformed values.
In a column mean(s) followed by a common letter are not significantly different at 5% in Tukey's HSD.

Table 2. Developmental periods of eggs and larvae of M. vitrata on different pulses

Host	Egg	Period of Larval Instars* (Days)					Total Larval Period
		I Instar	II Instar	III Instar	IV Instar	V Instar	
Pigeon pea	2.33^{a} ± 0.45 (1.68)	1.92^{a} ± 0.29 (1.55)	2.29^{c} ± 0.23 (1.67)	2.32^{b} ± 0.32 (1.68)	2.31^{ab} ± 0.50 (1.68)	2.38^{abc} ± 0.53 (1.70)	11.15^{b} ± 1.14 (3.41)
Green gram	2.88^{b} ± 0.51 (1.84)	2.25^{a} ± 0.39 (1.66)	2.50^{d} ± 0.23 (1.73)	2.75^{d} ±0.43 (1.80)	2.61^{b} ± 0.55 (1.76)	2.64^{bc} ± 0.44 (1.77)	12.77^{c} ± 1.16 (3.64)
Black gram	2.83^{b} ± 0.48 (1.82)	2.13^{a} ± 0.43 (1.62)	2.57^{d} ± 0.31 (1.75)	2.73^{c} ± 0.32 (1.80)	2.98^{c} ±0.36 (1.87)	2.74^{c} ± 0.51 (1.80)	13.19^{d} ± 1.20 (3.70)
Cowpea	3.05^{b} ± 0.35 (1.88)	2.31^{a} ± 0.37 (1.68)	2.06^{a} ± 0.32 (1.60)	2.05^{a} ± 0.41 (1.60)	2.15^{a} ± 0.17 (1.63)	2.19^{a} ± 0.20 (1.64)	10.76^{a} ± 1.09 (3.36)
Lablab	3.07^{b} ± 0.43 (1.89)	2.32^{a} ± 0.23 (1.68)	2.17^{b} ± 0.27 (1.63)	2.24^{b} ± 0.29 (1.65)	2.21^{a} ± 0.43 (1.65)	2.31^{ab} ± 0.42 (1.68)	11.18^{b} ± 1.13 (3.42)
Mean	2.83	2.19	2.32	2.42	2.45	2.47	11.81
SEd	0.0553	NS	0.0366	0.0472	0.0546	0.0564	0.0738
CD (p = 0.05)	0.1114	NS	0.0736	0.0950	0.1100	0.1136	0.1487

NS- non significant
**Mean of 10 replications and each replication consisted of 10 individuals.*
**Figures in the parentheses are $\sqrt{X + 0.5}$ transformed values.*
In a column mean(s) followed by a common letter are not significantly different at 5% in Tukey's HSD.

Table 3. Developmental periods of prepupa, pupa, and adult longevity of M. vitrata on different pulses

Host	Period of Development (Days)					
	Prepupa*	Pupa*	Pupation# (%)	Total Life Cycle*	Adult Moth*	
					Male	Female
Pigeon pea	2.02^{a} ± 0.22 (1.59)	6.55^{a} ± 0.40 (2.66)	83.0^{a} (65.6)	22.05	3.28^{a} ± 0.90 (1.94)	3.72^{c} ± 0.60 (2.06)
Green gram	1.94^{a} ± 0.28 (1.56)	6.07^{a} ± 0.65 (2.56)	69.0^{a} (56.2)	23.66	3.42^{a} ± 0.92 (1.98)	3.91^{d} ± 0.80 (2.10)
Black gram	2.03^{a} ± 0.20 (1.59)	6.28^{a} ± 0.79 (2.60)	68.0^{a} (55.6)	24.33	2.73^{a} ± 0.56 (1.80)	3.35^{b} ± 0.56 (1.96)
Cowpea	2.20^{a} ± 0.20 (1.64)	6.62^{a} ±0.48 (2.67)	65.0^{b} (53.7)	22.63	3.14^{a} ± 0.32 (1.91)	3.17^{a} ± 0.81 (1.91)
Lablab	1.99^{a} ± 0.38 (1.58)	6.67^{a} ± 0.34 (2.68)	76.0^{a} (60.7)	22.91	3.16^{a} ± 0.38 (1.91)	4.03^{d} ± 0.51 (2.13)
Mean	2.04	6.44	72.20	23.12	3.15	3.64
Sed	NS	NS	8.0416	-	NS	0.0755
CD (p = 0.05)	NS	NS	16.3091	-	NS	0.1520

NS- non significant.
**&,#Mean of 10 replications and each replication consisted of 10 individuals.*
**Figures in the parentheses are $\sqrt{X + 0.5}$ transformed values.*
#Figures in the parentheses are arcsine transformed values.
In a column mean(s) followed by a common letter are not significantly different at 5% in Tukey's HSD.

Table 4. Growth index and sex ratio of M. vitrata on different pulses

Host	Growth Index*	Sex Ratio$ (? :?)	
		Mean	± SD
Pigeon pea	7.45[a] (2.82)	1.0:2.34[a]	2.27
Green gram	5.36[b] (2.42)	1.0:2.19[ab]	2.11
Black gram	5.09[b] (2.36)	1.0:2.23[ab]	1.02
Cowpea	6.16[ab] (2.58)	1.0:0.65[b]	0.34
Lablab	6.86[ab] (2.71)	1.0:2.13[ab]	1.02
SEd	0.7011	0.7268	-
CD (p = 0.05)	1.4123	1.4609	-

**,$Mean of 10 replications and each replication consisted of 10 individuals.*
**Figures in the parentheses are $\sqrt{X + 0.5}$ transformed values.*
#Figures in the parentheses are arcsine transformed values.
In a column mean(s) followed by a common letter are not significantly different at 5% in Tukey's HSD.

Conclusion

Hence, this study clearly demonstrated that host preference was in the order of cowpea followed lablab, green gram, pigeon pea, and black gram, and experimental results give an idea to understanding the variation in biology of M. vitrata on various pulses. Similarly, it is very clear that the selection of ideal host plants by M. vitrata is based on quick development, survival, and adaptation. This forms a strong base and attracts a great deal of attention for the management of M. vitrata through tracing any inimical factors on sturdy host recorded and finding the ideal host plant in terms of providing adequate nutrition for mass culturing. It is also helpful to gain knowledge on the degree of susceptibility of the above-studied host crops to M. vitrata with respect to growth and development. Also, more researches with respect to different hosts are to be carried out to get precise knowledge on the genetic-level influence on their biological variation with populations of different agro ecological conditions.

Conflict of interest

All the authors have approved the final manuscript submitted and do not have any conflict of interest in publication.

Authors contribution

SSK and CD initiated the work. CD and SMK advised on a filed collection of samples. SSK conducted all experiments and collected and analyzed the data. SSK, CD, and NG wrote the paper. All authors contributed and were involved in the overall preparation of the manuscript.

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