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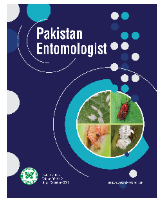

REARING AND RELEASE TECHNOLOGY OF TWO NATURAL ENEMIES (*CRYPTOLAEMUS MONTROUZIERI* AND *AENASIUS BAMBAWALEI*) FOR THE MANAGEMENT OF COTTON MEALYBUG

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ABSTRACT

Cotton mealy bug (*Phenacoccus solenopsis* Tinsley) is a serious threat to sustainable production of cotton in Pakistan. Biological control is known one of the best strategies for its control. The *C. montrouzieri* and *A. bambawalei* under laboratory conditions was successfully reared at 70% relative humidity and 28°C temperature. The consumption of higher instar/adults /more pairs reflected maximum effectiveness than earlier ones. Adults releases for *C. montrouzieri* and mummies with host for *A. bambawalei* had more impact on cotton mealy bug suppression and establishment of natural enemies. For quick control of pest, farmers of developing countries rely completely on pesticides. The pesticides not only kill pests but also harmful for beneficial fauna present in the field. The biological based IPM is the most effective and environment friendly tactic to manage this pest insect. This study will not only provide baseline but may also be proved very effective in conserving natural enemies and keeping hazardous chemicals away from the environment in the long run.

Keywords: Cotton mealybug, Natural enemies, *C. montrouzieri, A. bambawalei*

INTRODUCTION

Phenacoccus solenopsis damages field, forage and ornamental crops (Arif *et al*., 2012) including 154 plant species belonging to various families such as: Malvaceae, Solanaceae, Asteraceae, Euphorbiaceae, Amaranthaceae and Cucurbitaceae. However, economical damage has been observed on cotton, brinjal, okra, tomato, sesame, sunflower and china rose (Arif *et al*., 2009). In addition to this, cotton mealy bug consistently damages 52 plant families. These plant families serve as a bridge or carry-over place to spread on economic crops such as cotton to infest and ultimately destroy it.

Tropical and subtropical climate with summer rains and mild winters enhanced mealy bug breeding to remain present throughout the year. It has many overlapping generations damaging plant parts such as leaves, shoots, twigs, branches flowers and roots. Infestation occurs in patches that make huge loss to cotton yield. Severely damaged cotton plants suffer premature dehydration and defoliate (Mahmood *et al*., 2011).

For the management of mealy bug the farmers in developing countries mostly rely on pesticides for their quick control (Joshi *et al*., 2010). These pesticides not only kill pests but also harm the beneficial fauna prevalent in the field. The Integrated Pest Management (IPM) approach sounds effective and environment friendly to manage this insect. The important component of IPM i.e., the biological control has not proved very effective in these regions unlike the developed countries. Therefore, little is known about biological agent of *P. solenopsis* in Pakistan.

Biological control is known best strategy worldwide but it takes time and vast area to launch. But once it is established, becomes long-lasting and self-perpetuating. The bio-control agents such as predators, parasitoids and pathogens feeds on prey. Among predators, *Chrysoperla carnea*, Coccinellid beetles such as *Cryptolaemus montrouzieri* and *Brumoides suturalis* are of great economic importance and reacted numerically by consuming pest population in aggregation manner. Thus pest population is suppressed in short duration. But this bio-control system works well against both larvae and adults when it is developed before the damaging stage of pest sets in (Agarwal *et al*., 1988; Gautam, 1996; Ali *et al*.., 2014). Members of Coccinellid family such as *Cryptolaemus montrouzieri* (known as mealybug destroyer), *Brumoides suturalis, C. septumpunctata*, *Hippodamia variegata*,

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Menochilus sexmaculatus and *Hyperaspis maindron*, are great destroyer of mealy bugs (Ali *et al*., 2014). This predatory fauna whenever established in an ecosystem devour all stages of mealy bug in self-regulating manner. Among parasitoids, *Aenasius bambawalei* has high searching ability, high parasitism rate and short life cycle.

The current study was designed to establish a baseline for the future biological control programs in Pakistan and monitoring the natural enemies of *P. solenopsis*. As an effort towards classical biological control of *P. solenopsis*, laboratory rearing techniques of exotic *C. montrouzieri* (Coccinellidae) were developed using local resources. For strengthening the study goals, laboratory rearing techniques of native *A. bambawalei* (Encyrtidae), with view point of their future on-farm conservation was also established.

MATERIALS AND METHODS

Establishment of mass rearing and release techniques

Materials required:

Efficient and economical rearing techniques of mealy bug and their different natural enemies (*C. montrouzieri* (Coccinellidae) and the parasitoid *A. bambawalei* (Encyrtidae)) was developed. Available inexpensive materials were selected such as plastic cages, plastic jars, plastic rearing trays and tested for rearing techniques.

Cotton mealy bug collection and culture establishment:

The cotton mealy bugs (both nymphs and adults) were collected from different infested hosts such as pumpkin, potato and okra, in district Multan. The collection was brought in the Biological Control Lab, CABI, Multan and kept at 26±2ºC temperature and 60±10% relative humidity (RH), to rear cotton mealy bug. For mealy bug culture establishment, potatoes were put in the baskets to sprouts in few days. The collection of mealy bug samples from field were put on these sprouts. Then fresh pumpkins were used to rear mealy bug. After mealy bug culture establishment, rearing techniques for the predator *C. montrouzieri* and the parasitoid *A. bambawalei* was standardized (Khan, 2013 and 2014) and further, released under field conditions.

Rearing techniques for the predator and the parasitoid:

Adults of *C. montrouzieri* were collected from CABI. Thirty adult beetles were released into each cage (48 x 17 x 14 cm) made of transparent celluloid sheets with provision of sleeves and mesh windows. The net material afforded increased aeration and thus prevented the development of sooty moulds. The pumpkins infested with mealy bugs were placed as food and oviposition until they perished. The adults can prey on all stages of mealy bug (Kaur and Virk, 2012). The grubs started appeared after one week, pupae after two to three weeks and adults after forty days (Kaur *et al*., 2010; Siddhapara *et al*., 2013). Each cage was placed under different ecological conditions (five different temperatures 20, 24, 28, 32, 36 ºC and relative humidity 50, 60, 70, 80 %), with five replications, to know the recovery of beetles.

Firstly, for egg laying purpose, cotton pieces, green cloth pieces and folding papers were put into the cage and temperature was maintained properly. Secondly, when the larvae of *C. montrozieri* were observed in the rearing cage, they were shifted on potato sprouts having mealy bug. After counting of *C. montrozieri* and of mealy bugs the potato sprouts along with *C. montrozieri* were shifted into the jars which were properly maintained for pupation. These larvae were also separated from cages and after counting were put into the petri dishes and mealy bugs were given as a food into these petri dishes. During this, observations were made for pupation. It was also observed that cannibalism was present in *C. montrouzieri*. To overcome cannibalism a plastic sheet apparatus was designed (1×1 feet) having 144 blocks of 1 square inch. Under this apparatus, a wire gauze was fitted as ventilation source and a moving lid was tilled at the top to prevent the larval movement from one to another block. With this modified apparatus, one larvae and mealy bug were put into each box until pupation and lid was placed / put on them. In this way, more than 95% recovery was observed.

The reared population of third instar mealy bug (250) and newly emerged *A. bambawalei* pair were placed in plastic jar, under different ecological conditions (five different temperatures 20, 24, 28, 32, 36 ºC and four relative humidity 50, 60, 70, 80 %) were maintained under lab conditions in five replications. Each replication consisted of three jars of each treatment. The honey was given on daily-basis. The parasitism was recorded after 07, 15 and 22 days, from each jar, in terms of counting mummified mealy bugs and emerged parasitoids.

Feeding potential of bio-agents:

The most effective ecological conditions for *C. montrouzieri* were further maintained in the laboratory and effectiveness was tested for different life stages of cotton mealy bug. For this purpose, each instar of beetle was fed on 1st instar, 2nd instar, 3rd instar and adult of cotton mealy bug, until moulting of each stage of beetle. The experiment was replicated four times.

Five hundred third instar of cotton mealy bug with one pair of parasitoid; *A. bambawalei* was placed in jar 1, 2 pairs in jar 2, 3 pairs in jar 3, 4 pairs in jar 4 and 5 pairs in jar 5, respectively. Each jar was considered as one treatment and each treatment was replicated 5 times. The honey was also given on daily-basis as food. The parasitism was recorded after 07, 15 and 22 days, from each treatment/jar.

Then the percentage of host's mealy bug parasitized or adults emerged from parasitized mealy bug was determined.

Mass rearing of bio-agents:

For *C. montrouzieri*, a plastic sheet apparatus was designed (1×1 feet) having 144 blocks of 1 inch square. A wire gauze was fitted for ventilation source (underside this apparatus). Moreover, a moving lid was present at the top to prevent the larvae movement to another block. One larvae and mealy bug were put into each box and lid was placed on them. The mealy bugs were given to each and every box until adults emerge. The experiment was repeated five times.

In case of mass rearing of *A. bambawalei*, plastic petri dishes along with potato sprouts having mealy bug on it, were then, placed on the small plastic racks and these racks were put into the plastic cages. One or two pumpkins previously established with mealy bug culture were placed into the cages. Once the mealy bug culture was introduced and acclimatized into the cage. The adult mealy bug parasitoids *A. bambawalei,* of uniform age, were released into this cage for further multiplication @ 200 parasitoids per cage. Honey was given to these parasitoids regularly. Tissue paper was also used for mummies because sometime when mealy bug become parasitized, few detaches from pumpkin and went under the tissue and most of them are on pumpkin where mummies were formed. The data were taken after 07, 15 and 22 days.

Techniques for releases of bio-agents:

Two techniques were used for releases of *C. montrouzieri*, because both larvae as well as adults were predaceous in nature. For this purpose, 1000 adults or larvae were released (Mani and Krishnamoorthy, 2008; Sarwar, 2016) in one (01) acre in the mealy bug infested field and data were collected after one, three and seven days.

Three techniques (1. Adults in test tubes, 2. Cards, 3. Mummies with host) were used to release the *A. bambawalei* under field conditions. Cards were prepared in the Biological Control Laboratory, CABI, Multan, at 26±2ºC temperature and 60±10% relative humidity (RH). Each card consisted of a white paper (4 inch square) and 100 mummies were pasted with gum. The adults were reared in the lab and uniform aged adults are released in the field with the help of test tube / jar. In case of third technique, host plant with mummies were shifted to the field. Thirty-five hundred (3500) mummies / adults were released under field conditions. The data were recorded on the basis of mummified mealy bugs after seven, fifteen and twenty-two days.

Statistical analysis of data

All the experiments were designed under CRD (Complete Block Design) except 4th experiment which was designed under RCBD. The replicated data were put in Microsoft excel spread sheet and standard error was calculated. Further, this data was analyzed by using computer based software, Statistix 8.1 to calculate analysis of variance (ANOVA) and finally means were compared using LSD test at α 0.05 (Analytical software, 2005).

RESULTS

The rearing of different life stages (Table 1) of *C. montrouzieri* under four levels of relative humidity and five levels of temperature showed that 70% relative humidity and 28 °C temperature recorded was the most optimum that exhibited duration, i.e., 2.71, 2.486, 1.828, 60 and 75.2 days to complete 1st, 2nd, 3rd instars, adult male and adult female its life stage whereas 2.352 days taken by 4th instar at 70% relative humidity and 24 °C temperature. In case of fecundity, the most suited conditions were 70% RH and 28 °C recorded in producing maximum eggs (238.4 eggs) in a complete life stage. While minimum number of eggs were recorded under conditions with 50% RH and 36 °C temperature.

Feeding potential (Fig. 1) of *C. montrouzieri* showed that 1st, 2nd, 3rd, 4th instar and adult of *C. montrouzieri* consumed 16.34, 42.56, 128.86, 166.79 and 1616.3 number of 1st instar followed by 11.32, 27.73, 75.47, 77.68 and 392.2 number of 2nd instars, 1.69, 6.5, 14.17, 21.92 and 116.8 3rd instars and 0.83, 3.43, 9.17, 13.87 and 75.7 adults of CMB to complete respective stage.

Mass rearing was done in specialized cells where individual grubs were reared to avoid cannibalism. The data exhibited (Table 3) that maximum population obtained from tray 3, whereas the minimum from tray 5.

There are two stages larvae and adults; should be effectively released (Table 4). The results showed that 403.81 mealy bugs were recorded before adult release. The results indicated population decrease, i.e., 338.78 mealy bugs after 01 day followed by 237.96 and 166.37 mealy bugs after 03 and 07 days, respectively. In addition to this, no *C. montrouzieri* larvae was recorded before the release but 0.74, 0.89 and 0.93 larvae and 0.89, 1.370 and 1.64 adults were recorded after 01, 03 and 07 days, respectively.

***A. bambawalei* at different temperature and relative humidity**

The results for rearing of *A. bambawalei*. comprised that 70% relative humidity with 28 °C temperature was observed as the most suitable in terms of exhibiting high parasitism on CMB, i.e., 64.8 followed by 132.87 and 168.33, after 07, 15 and 22 days respectively. While minimum parasitism recorded was 9.267, 10.93 and 13.68 in conditions with 50% RH and 20 °C temperature, after 07, 15 and 22 days, respectively (Table 2).

The results from pairing release (Fig. 2) of *A. bambawalei* on CMB population exhibited that five pairs gave maximum CMB parasitism, i.e., 28, 51.8 and 31.2 followed by four (21.8, 43.8, 25) and three pairs (17.2, 31.2, 15.8), after 07, 15 and 22 days respectively. While the minimum parasitism recorded from one pair was 6, 15 and 10, after 07, 15 and 22 days, respectively.

The results for mass rearing (Table 3) of *A. bambawalei* on CMB population showed that cage five recovered maximum number CMB parasitism, i.e., 962, followed by cage one (953.8) and three (943.2), while minimum recorded in cage four (936.4), while after 15 days, cage five gave maximum CMB parasitism, i.e., 2709 followed by cage one (2707) and three (2702.4), while minimum recorded in cage four (2637.2). After 22 days, cage one gave maximum CMB parasitism, i.e., 1321 followed by cage three (1306) and five (1293.4), while minimum recorded in cage four (1262.2).

The results (on the basis of percent parasitism) exhibited that 406.33, 409.27 and 407.04 mealy bugs were recorded before the release of mummies, cards and adults (Table 4). The maximum parasitism found on mummies (with host) release field (40.305 %), followed by (31.155%) and (27.732%) after seven, fourteen (60.59, 44.466 and 39.328%) and twenty-one days (73.99, 56.612 and 49.89%) respectively.

DISCUSSION

The rearing of different life stages of *C. montrouzieri* under four levels of relative humidity and five levels of temperature showed that 70% relative humidity and 28 °C temperature recorded was the optimum and exhibited duration, i.e., 2.71, 2.486, 1.828, 60 and 75.2 days to complete 1st, 2nd, 3rd instars, adult male and adult female its life stage whereas 2.352 days taken by 4th instar at 70% relative humidity and 24 °C temperature. In case of fecundity, the most suited conditions are 70% relative humidity and 28 °C temperature recorded to produce maximum eggs, i.e., 238.4 eggs in a complete life stage. While minimum number of eggs were recorded under conditions with 50% RH and 36 °C temperature. The above findings are in partial agreement with Ghafoor *et al*. (2011), who conducted experiment in Cotton mealy bug Entomological laboratory, Ayub Agriculture Research Institute, Faisalabad and found that *C. montrouzieri* feeds voraciously on mealy bugs both in larval and adult stages at 30 ± 1°C temperature and 70 ± 5% R.H, on cotton mealy bug.

Solangi *et al*. (2012**)** and Siddhapara *et al*. (2013) observed biology *C. montrouzieri* on *P. solenopsis*. The former recorded pre-mating, pre-oviposition, oviposition incubation period, mean prepupal and pupal period, total development period from egg to adult and fecundity of *C. montrouzieri* (5.6±0.08, 9.9±0.19 and 76.4±1.30, 5.3±0.07, 2.9±0.07 and 8.5±0.2, 42.9±0.95, 80.9±0.89 and 84.4±0.9 days, 486.9 ± 1.417 per female respectively)., whereas incubation period notified later, hatching percentage, different instars development period and total larval period 5.12 ± 0.87, 92.61 ± 3.93 %, first (3.04 ± 0.28), second (2.34 ± 0.48), third (3.06 ± 0.24) and fourth instar larva (4.18 ± 0.48), and 12.62 ± 1.67 days, on cotton mealybug. Three different temperatures (24, 28 and 32°C) with constant 65 ±5% relative humidity 28°C proved an ideal temperature gradient to produce maximum female fecundity with high survival rate and egg to adult emergence. Concerning the other temperatures such as 32°C gave quick development and but highest death / capacity of feeding decreased in considerable amount (Saljoqi *et al*., 2014).

In case of feeding assessment, different instars such as 1^{st}, 2^{nd} , 3^{rd}, 4^{th} instar and adult of *C. montrouzieri* consumed 16.34, 42.56, 128.86, 166.79 and 1616.3 1^{st} instar followed by 11.32, 27.73, 75.47, 77.68 and 392.2 2^{nd} instars, 1.69, 6.5, 14.17, 21.92 and 116.8 3^{rd}instars and 0.83, 3.43, 9.17, 13.87 and 75.7 adult, of CMB to complete all respective life stage. These studies are in line with Kaur and Virk (2012) who recorded that 1^{st} instar nymphs of mealybug 15.56, 41.01, 125.38, 162.69 and 1613.81 consumed by 1^{st}, 2^{nd}, 3^{rd} and 4^{th} instar grub and adult beetles of *C. montrouzieri*, respectively whereas 2^{nd} and 3^{rd} instar grub indicated much increased consumption of nymphs of mealybug. Thus, clearly reflecting that *C. montrouzieri* has the potential and inoculative releases of 4^{th} instar larvae and adults might provide efficient control of *P. solenopsis*. These stages devour the mealybugs in less time and consume more number of mealybugs (Ahi *et al*., 2015) and hatching percentage is also increased remarkably.

Earlier investigations (Rosas-Garcia *et al*., 2002; Atif *et al*., 2011) evaluated different life stages of *C. montrouzieri* against citrus mealybug and concluded efficiency of all stages. But earlier instar had less demand to consume the administered feed, so these 1^{st} and 2^{nd} instar consumed lesser amount of mealybugs whereas later developmental stages such as 3^{rd} instar and adults showed more thrust of food.

Mass rearing was done in specialized cells/tray where individual grubs were reared to avoid canabolism. The data exhibited that maximum population obtained 11.33 (from tray 3), whereas the minimum (109.83) from tray 5. Kairo *et al*. (2013) reported that *C. montrouzieri* constantly used in classical and augmentative biological control programs and become effective and efficient among all natural enemy. It has rapid developmental rate, high reproductive potential and better adaptation to a wide range of tropical as well as subtropical climates. Moreover, it holds high prey consumption (both adults and larvae) and easy rearing technology. This statistics made introduction of *C. montrouzieri* possible into more than 60 countries for the management of eight Hemipteran families including more than 16 insect pest species.

Adults and Larva of *C. montrouzieri* were not present under the infested CMB fields. However, their population was evident and recorded to decrease the CMB population. Releases of adults and larvae *C. montrouzieri* was referenced by earlier scientists (Mani and Krishnamoorthy, 2008; Sarwar, 2016). These releases along with certain conservation (such as abiotic conditions; temperature, relative humidity and rainfall) and inundation releases must be followed to sustain the predator population to such a level that must consume / feed the pest population to a sub-economic level. Larval release had some canabolistic impact that induce reduction in population level of the above predator. Under this portfolio, adult release might be effective and recommended.

The rearing of *A. bambawalei* was evaluated at different levels of temperature and relative humidity. The results showed maximum mealy parasitization 64.8 followed by 132.87 and 168.33, after 07, 15 and 22 days, at 70% relative humidity with 28 °C temperature whereas minimum parasitism recorded was 9.267, 10.93 and 13.68 in conditions (50% RH and 20 °C temperature), after 07, 15 and 22 days respectively. In case of results from pairing releases of *A. bambawalei*, five pairs exhibited maximum CMB parasitism, i.e., 28, 51.8 and 31.2 followed by four pairs (21.8, 43.8, 25) and three pairs (17.2, 31.2, 15.8), after 07, 15 and 22 days respectively. While the minimum parasitism recorded from one pair.

The mass rearing results on CMB population showed that cage five recovered maximum number of CMB parasitisation, i.e., 962, followed by cage one (953.8) and three (943.2), while minimum recorded in cage four (936.4), while after 15 days, cage five gave maximum CMB parasitism, i.e., 2709 followed by cage one (2707) and three (2702.4), while minimum recorded in cage four (2637.2). After 22 days, cage one gave maximum CMB parasitism, i.e., 1321 followed by cage three (1306) and five (1293.4), while minimum recorded in cage four (1262.2).

These findings are in consonance with Badshah *et al*. (2015) and Shahzad *et al*. (2016). The former reported that the most suitable host as cotton mealy bug for mass culturing of parasitoid (*A. bambawalei*) under lab conditions. Furthermore, they assessed five different host plants including shoe flower, tomato, potato, okra and brinjal to compare basic life parameters. The shoe flower was the most preferred host followed by potato because cotton mealy bug gained maximum weight when fed on this plant. While latter parasitization rate host physiology development and reproduction. Nalini (2015) compared sex ratio and percent parasitism of *A. bambawalei* and *A. advena*. The results indicated that *A. bambawalei* produced higher number of female progeny, the sex ratio (females) percent parasitism than *A. advena*.

Zain-ul-Abdin *et al*., 2013; Iqbal *et al*., 2016 and Zhang *et al*., 2016 studied biology and development of *A. bambawalei* on the basis of laboratory conditions, parasitoid age and host age. They found 3^{rd} instar, 5 day old parasite and 3^{rd} instar of host as suitable for rearing of *A. bambawalei*.

Table 1
Rearing of *C. montrouzieri* at different temperatures and relative humidity.

RH (%)	Temp. (°C)	1st instar	2nd instar	3rd instar	4th instar	Male Adult	Female adult	Fecundity
50	20	5.116a	4.112bc	5.19ab	5.92a	102.6a	113.6a	79.6mn
50	24	4.666a-e	4.112bc	4.006e	5.474a-d	93.4bc	100.4cd	88.2klm
50	28	4.014fgh	3.552efg	3.694 ef	4.914def	77.2fg	86.2fg	193.6c
50	32	4.92ab	4.004cd	4.598 cd	5.302a-e	45.6kl	67.8i	86.6lm
50	36	4.326c-g	4.444b	5.426a	5.736ab	42.6klm	50.2lm	69.8n
60	20	4.758a-d	3.472fgh	4.926 abc	5.032c-f	97.8ab	108.6ab	94.8kl
60	24	4.268d-g	3.472fgh	3.87 e	4.676efg	87.8cde	97.4de	110.6hij
60	28	3.77ghi	2.988ij	3.272 fg	4.452fgh	68.8gh	81.6gh	217.4b
60	32	4.12e-h	3.374ghi	4.16 de	5.218b-e	58.4ij	63.2ij	102.8ijk
60	36	4.854abc	3.894cde	4.584 cd	5.59abc	50.4jk	44.4mn	90.2klm
70	20	3.942fgh	3.942cde	3.694 ef	3.942hi	90.4bcd	99.4cde	132.4fg
70	24	3.554hij	3.942cde	2.922 g	2.352k	81.6ef	92.6ef	141.6ef
70	28	2.714k	2.486k	1.828 h	2.624k	60.2hi	75.2h	238.4a
70	32	3.05jk	2.794jk	2.178 h	2.862jk	39.2lmn	58.2jk	138.8d
70	36	3.3ij	3.078hij	2.838 g	3.388ij	31.2no	41.8no	152.2e
80	20	5.162a	4.92a	5.162 ab	4.134gh	95.6abc	105.8bc	109.8hij
80	24	4.75a-d	4.87a	4.75 bc	4.234gh	84.4def	94.8de	120.8gh
80	28	3.822ghi	3.612d-g	3.19 fg	4.458fgh	55.2ij	79.2gh	227.4ab
80	32	4.442b-f	3.804c-f	3.896 e	4.658efg	34.4mn	53.4kl	115.2hi
80	36	4.914ab	4.478ab	4.106 de	5.086b-f	25.2o	35.2o	100.2jkl

Table 2
Rearing of *A. bambawalei* at different temperatures and relative humidity.

RH (%)	Temp. (°C)	Population after 07 days	Population after 15 days	Population after 22 days
50	20	9.267 l	10.93 k	13.67 k
50	24	14.733 ijk	16.2 hij	19.47 ijk
50	28	18.667 ghi	20.47 gh	23.8 ghi
50	32	17.2 hij	18.47 ghi	21.87 hij
50	36	10.867 kl	12.33 jk	14.2 k
60	20	12.267 kl	14.53 ijk	15.47 jk
60	24	16.267 ij	18.73 ghi	20.87 h-k
60	28	26.33 e	41.93 d	47.6 de
60	32	13.53 jk	14.13 ijk	18.33 ijk
60	36	11.67 kl	13.13 jk	17.13 ijk
70	20	14.267 jk	21.27 g	27.2 fgh
70	24	41.4 c	51.27 c	61.2 c
70	28	64.8 a	132.87 a	168.33 a
70	32	47.73 b	68.67 b	96.93 b
70	36	21.67 fg	28.07 ef	47.2 de
80	20	14.67 jk	19.93 gh	32 f
80	24	25.467 ef	30.27 e	42.2 e
80	28	31.6 d	39.13 d	49.93 d
80	32	20.33 gh	23.2 fg	30.67 fg
80	36	11.73 kl	14 ijk	20.13 h-k

CONCLUSION

Rearing of *C. montrouzieri* was suitable in tray with 144 wells and adult release was the best than larvae whereas in case of *A. bambawalei* rearing was effective on pumpkin and releases were efficient with mummies on host than cards and adults in jars.

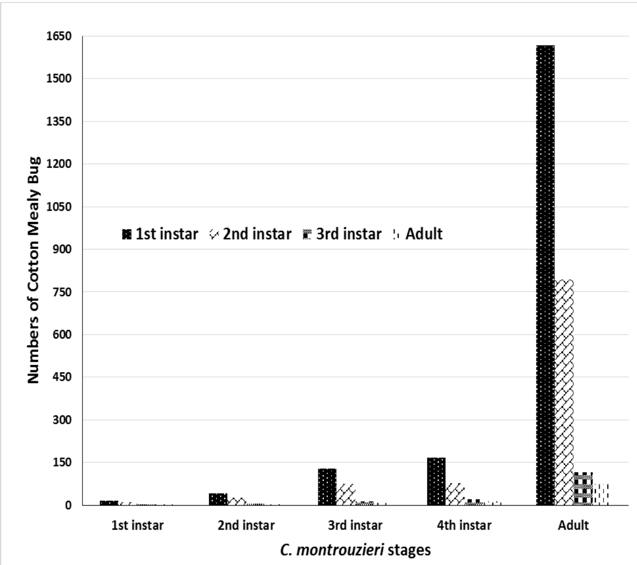

Fig. 1
Feeding potential of different life stages of *C. montrouzieri* on different instars of CMB

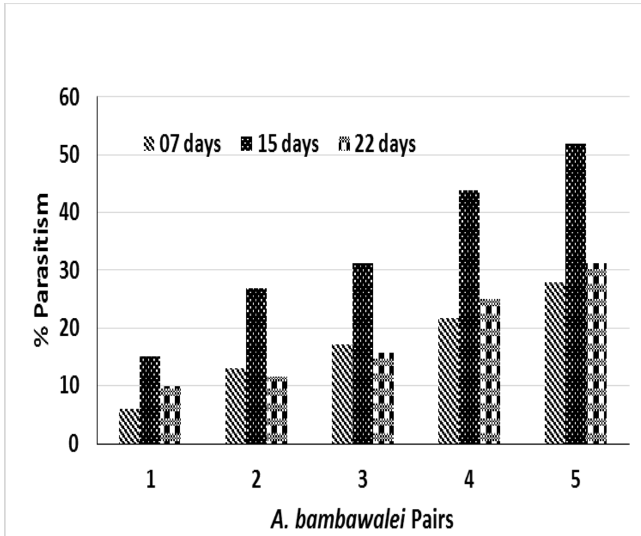

Fig. 2
Percent Parasitism of different pairs of *A. bambawalei* on CMB

Table 3
Mass rearing of *C. montrouzieri* and *A. bambawalei.*

Trays / Cages	*Population of *C. montrouzieri*	Population of *A. bambawalei*		
		07 days	15 days	22 days
1	110.67 a	953.8 c	2707 a	1321.6 b
2	110.15 a	937.2 c	2680.6 a	1287.2 b
3	111.33 a	943.2 c	2702.4 a	1306.6 b
4	110.7 a	936.4 c	2637.2 a	1262 b
5	109.83 a	962 c	2709 a	1293.4 b

*Means showing same letter are similar with each other

Table 4
Releasing techniques of *C. montrouzieri* ,*A. bambawalei* and CMB trends.

	Population Level			
C. montrouzieri	Pre -treatment	After 01 days	After 03 days	After 07 days
Larvae	0 (403.81)	0.7407 b (338.78 b)	0.889 a (237.96 c)	0.9259 a (166.37 d)
Adults	0 (402.74 a)	0.889 b (315.56 b)	1.3704 a (162.663 c)	1.64 a (97.56 d)
	Parasitism (%)			
A. bambawalei	Pre -treatment	After 07 days	After 15 days	After 22 days
Adults	0 (409.27)	32.155 a	44.466 b	54.612 c
Cards	1 (406.33)	27.732 c	39.328 b	49.89 a
Mummies with host	0 (407.04)	40.305 c	60.59 b	73.99 a

*Means showing same letter along the rows are similar with each other
Figure in parenthesis represented CMB population

AUTHORS' CONTRIBUTION

M. Naeem Aslam contributed regarding taking data, analysis and writing the manuscript. Ehsan-ul-Haq helped in planning and execution of research and reviewed the manuscript. Muhammad Aslam reviewed the manuscript.

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