MANAGEMENT OF PULSE BEETLE, *Callosobruchus maculatus* (FAB.) (COLEOPTERA: CHRYSOMELIDAE) INFESTING COWPEA, *Vigna unguiculata* (L.)

THESIS

Submitted in partial fulfilment of the requirements

for the Degree of

MASTER OF SCIENCE

IN

AGRICULTURE

(AGRICULTURAL ENTOMOLOGY)

By

WAMAN ABHIJIT GOKUL
(ADPM/20/2729)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE, DAPOLI

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VIDYAPEETH, DAPOLI, RATNAGIRI (MS) 415712

NOVEMBER, 2022

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Under the Guidance of

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NOVEMBER, 2022

DECLARATION OF STUDENT

I hereby declare that the experimental work and its interpretation of the Thesis entitled **"MANAGEMENT OF PULSE BEETLE, *Callosobruchus maculatus* (FAB.) (COLEOPTERA: CHRYSOMELIDAE) INFESTING COWPEA, *Vigna unguiculata* (L.)"** or part thereof has neither been submitted for any other degree or diploma of any University, nor the data have been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged and that no part of the thesis has been submitted for any other degree or diploma.

Place: Dapoli

Date: / /2022

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CERTIFICATE

This is to certify that the thesis entitled, **Management of pulse beetle, *Callosobruchus maculatus* (fab.) (Coleoptera: Chrysomelidae) infesting cowpea, *Vigna unguiculata* (L.)"** submitted for the degree of M. Sc. (Agri.) in Agricultural Entomology of the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, is a bonafide research work carried out by **Waman Abhijit Gokul (ADPM/20/2729)** under my supervision and that no part of this thesis has been submitted for any other degree. The student had completed all the Course and Research requirement as per the norms in regular mode and has published / submitted one research paper from his M. Sc. work.

The assistance and help received during the course of investigation have been fully acknowledged.

Place: Dapoli

Date: / /2022

Chairman

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Head

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THESIS APPROVAL BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER

This is to certify that the thesis entitled, **"Management of pulse beetle, *Callosobruchus maculatus* (fab.) (Coleoptera: Chrysomelidae) infesting cowpea, *Vigna unguiculata* (L.)"** submitted by **Waman Abhijit Gokul (Enrolment No. ADPM/20/2729)** to the College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, in partial fulfilment of the requirements for the degree of M.Sc. (Agricultural Entomology) in the subject having Agrometeorology and crop weather forecasting, Plant virology, Seed production technology of vegetable crops as Minor subject of Department of Agronomy, Department of Plant pathology and Department of Horticulture has been approved by Student's Advisory Committee, Board of Studies of the Department and Evaluated by One External Examiner after an open Viva Voce examination in the presence of External Examiner on the same held on dated 15 / 11 / 2022.

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Place: Dapoli

Date: / / 2022 (Mr. Abhijit Gokul Waman)

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List of Abbreviations

%	:	Per cent
Dr. B. S. K. K. V.	:	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth
@	:	At the rate of
/	:	Per
&	:	And
°C	:	Degree centigrade
C.D.	:	Critical Difference
cm	:	Centimetre
DAT	:	Days after treatments
hrs.	:	Hours
et al.	:	And others
Fig.	:	Figure
g	:	grams
ml	:	milliliter
i.e.,	:	That is
kg	:	Kilogram
km	:	Kilometre
mm	:	milli metre
No.	:	Number
S. E. m. ±	:	Standard error mean
Sr. No.	:	Serial number
viz.,	:	Namely

Glossary

Identification of sexes of *Callosobruchus maculat*us (Fab.)

There is a marked difference in appearance between males and females of pulse beetles, *C. maculatus*. One of the most distinctive characteristics by which male and female *C. maculatus* can be easily identified is the light coloured plate covering the abdomen's end. There is an enlargement of the plate in the female and both sides are darkly coloured. Unlike the female, males have a smaller plate without stripes. The size of females is generally larger than that of males, but there is considerable variation. (As depicted in Plate VIII: adults of *C. maculatus*, a) male and b) female) Some strains have brown males and black females, but others have brown males and fem

INTRODUCTION

CHAPTER I

INTRODUCTION

1.1 Background Information

Pulses are the most cost-effective source of protein, along with all necessary amino acids. They also supply nutrient-rich food for cattle, as well as nitrogen to the soil which improves soil fertility and increases productivity of the farmland. They are packed with nutrients and have a high protein content, making them an ideal source of protein particularly in regions where meat and dairy are not physically or economically accessible. It contains almost twice the protein percentage than cereals *i.e.*, up to 20-24 per cent protein. For more than 80 % people, pulses are an important source of protein for the vegetarian population of India. Pulses are low in fat and rich in soluble fibre, which can lower cholesterol and help in the control of blood sugar. Because of these qualities they are recommended by health organizations for the management of non-communicable diseases like diabetes and heart problems. Pulses have also been proved effective in obesity (Parca *et al*., 2018).

As per Indian Institute of Pulses Research, in worldwide scenario the total area under pulses is 81 million hectors (Anonymous, 2013). India has the world's largest area under pulses. Pulses are grown on 29.03 million hectares in India, with yearly production of 23.40 million tonnes with the average productivity of 806 kg/ha. In the state of Maharashtra, pulses are grown on an area of 3.51 million hectares, with the average production of 2.16 million tonnes per year and the average productivity is 616 kg/ha (Anonymous, 2019). Major pulses producing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka, Andhra Pradesh, Gujrat, Tamilnadu, Jharkhand, Bihar (Anonymous, 2013). According to Agriculture Contingency plan of Ratnagiri district, the entire area under pulses in the district is 8800 hectares, comprising 6700 hectares of rainfed *kharif* pulses and 2100 hectares of irrigated *rabi* pulses (Anonymous, 2010).

The cowpea, *Vigna unguiculata* (L.) is one of the several species of widely cultivated genus *Vigna*. There are five cultivar groups of cowpeas *viz*., *biflora, melanophthalmus, sesquipedalis, textilis* and *unguiculata* (Pasquet, 2000). It is one of the most important leguminous crops in the tropics. It is a drought-resistant and warm-weather plant. Cowpea is a versatile crop that grows well in both wet and dry climates. Other legumes do not function well in the tropics. Cowpea provides one of the most variable species in case of plant growth, maturity, morphological characters, grain types, *etc*. among different cultivated crop plants (Singh, 2014). The cowpea crop has the ability to fix nitrogen from the atmosphere through the root nodules. It thrives well in poor soils, producing more than 85 per cent of normal seeds in less than 0.2 per cent organic matter, low sand content and high phosphorus levels. Due to its shade tolerant and drought tolerant capacity, it is effectively employed for conventional intercropping programs as fundamental component. It is a good intercrop for maize, millet, other cereals, cotton, sorghum and sugarcane, etc. (Olufajo and Singh, 2002).

1.2 Importance of study

The post-harvest losses in legumes have been reached to 8.5 per cent (FAO, 1977), out of which insects alone are responsible for about five per cent losses. Amongst several insect pests, bruchids are serious pests of stored pulses especially stored cowpea, which are commonly called as pulse beetles. The different species of pulse beetle *viz.*, *Callosobruchus chinensis* (L.), *Callosobruchus maculatus* (Fab.), *Callosobruchus analis* (Fab.) and *Callosobruchus phaseoli* (Gyllenhal), (Coleoptera: Chrysomelidae) are commonly occurring and considered to be the most serious insect pests of stored pulses. Every year, over 8.5 per cent of all pulses in India are wasted during post-harvest and storage (Agarwal *et al*, 1988). Eggs are glued to seed coats by ovipositing females. Grubs chew up the seed directly underneath the oviposition site, on hatching the grubs penetrate into the seed leaving upper shell intact. Grub destroys the endosperm completely, leaving only seed coat. In storage, pulse beetles multiply rapidly as they are internal feeders. There may be eight or ten grubs in a single seed. Severely damaged legume seeds are marked with multiple emergence holes. It not only causes the quantitative losses in the pulse industry but also nutritional losses and poor germination, which undermines the use of pulses as food. Average per cent damage of pulse beetle in cowpea is found to be 16.8 per cent (Bhaduria and Jakhmola, 2006).

From decades, farmers are using different kinds of botanicals for management of store grain pests (Araya and Emana, 2009). It is proved that the seed treatment with botanicals before storage is effective for controlling storage pests and are also helpful in improving seed quality. Botanicals such as neem leaf powder, *karanj* leaf powder, turmeric powder, *vekhand* powder, wood ash, eucalyptus oil, fine sand etc. are being used by many farmers to protect the pulses from store grain pests.

Neem leaves have insecticidal property for control of different storage pests. It contains active ingredients such as limonoids; amongst them azardirachtin, nimbin, meliantroil, salanin are the major components. These limonoids have growth regulatory, antifeedant, ovicidal, insecticidal, adult sterility and repellent action against many insects and store grain pests (Makanjoula,1989, Schmutterer,1990). Addition of fine powder of neem leaves in grains during storage is a well known practice to repel the store grain pests.

As a natural pest repellent, *karanj* leaf powder is also used to protect the store grains due to its insecticidal properties. It contains karanjin as an active ingredient which acts as both insecticide as well as acaricide. The *vekhand* (*Acorus calamus* L.) powder contains active ingredient, β- asarone, which has toxic and sterilising effect and effective against pulse beetle while storage.

Ash and fine sand, easily available natural products are used in management of pulse beetle in stored pulses. Sand is most effective as it affects development of eggs of pests. Wood ash has been found effective in protecting grains against store grain pests. Turmeric powder has good insecticidal effects on storage pests. The international literature and different efforts of researchers proved the satisfactory strength of turmeric powder as natural pesticide (Javaid and Poswal, 1995 and Jadhav *et al*., 2015b). It is a cheap and environment friendly option to chemical pesticides for controlling pests of store grains. Eucalyptus oil has repellent as well as lethal action on storage pests (Idoko and Ileke, 2020). It also arrests the oviposition by pulse beetle on treated seeds of pulses. Therefore, some of the available plant products have been selected for present study.

1.3 Objectives of study

For management of *C. maculatus,* under laboratory condition, present investigation was carried out to study 'Management of pulse beetle, *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae) infesting cowpea, *Vigna unguiculata* (L.)' with following objectives:

1) To study the ovipositional preference of *C. maculatus* to different cowpea genotypes.
2) To study the developmental period of *C. maculatus* on different cowpea genotypes.
3) To study the effect of different 'Indigenous Traditional Knowledges' (ITK's) for management of *C. maculatus.*

1.4 Hypothesis

The inorganic pesticides are having long residues, hence, cannot be used for storing pulses. Therefore, it is necessary to search the safer alternatives to inorganic insecticides which are effective against store grain pests with no harmful residues. With this view and on the basis of available information, the different ITKs (Indigenous Traditional Knowledge) were selected for the management study.

A lot of germplasms of cowpea are available at different Agriculture Universities. Therefore, it was decided to study the ovipositional preference of *C. maculatus* to cowpea germplasm. Also, the developmental period of *C*. *maculatus* on different cowpea genotypes have been studied which will give a clear idea about the biology of this pest. Based on the results of present study, the cowpea germplasm which was less preferred by *C. maculatus* for oviposition can be made available to the farmers.

1.5 Scope and Limitations:

Currently, indiscriminate use of synthetic pesticides has found to damage the ecosystem with intoxication of the non-target organisms. There is also the possibility of developing insecticide resistance. The long-term residual insecticides can enter the food chain, posing a major health risk to consumers. To avoid the side effects of toxic chemicals, plant-based pesticides have been created as a pest control alternative to synthetic insecticides. Bio pesticides generated from plants are safe, eco-friendly and less hazardous to mammals and less expensive alternatives for pest management of store grain insect pests. Therefore, some of the available plant products have been selected for present study under the head 'Indigenous Traditional Knowledge' (ITKs).

Bio-pesticides, herbal extracts, oils and local botanicals have gained importance recently due to their high adequacy against a wide range of pests without any adverse effect on the environment (Varma and Pandey, 1978 and Jane *et al.*, 2009). Plants with insecticidal properties appear to have distinct advantages over other agents, such as being environmentally friendly, biodegradable, non-toxic and non-targeting. Their affordability and accessibility make them an attractive choice for management of store gain pests.

It has been reported all over the world that, protecting stored pulses against insects is a major problem. The conventional methods include only the chemical and fumigant treatments. These hazardous chemicals and fumigants are having several side effects like exposure of consumers and users to health hazards, toxic residues and higher costs, contaminated seeds making it unfit for human consumption and cattle feed. Legislation discourages the mixing of pesticides with stored pulses. Hence pulses must be stored in alternative and safe ways. The farming community and seed industry will be greatly benefited if the seeds can be stored for a longer period without affecting quality by using indigenous traditional knowledge (ITK).

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

Pulse beetle is one of the most serious pests of stored cowpea. World-wide, bruchids cause enormous loss of stored pulses due to their destructive nature. They begin their life cycle in the field during the maturity stage of the crop. It is important to note that *Callosobruchus maculatus* (Fab.) attack a wide range of leguminous seeds, but the damage is not the same for all seeds. The available literature regarding pulse beetle infesting pulses have been reviewed under different heads and presented below.

2.1 To study the ovipositional preference of *C. maculatus* to different cowpea genotypes

Booker (1967) reported that, *C. maculatus* bred on a variety of hosts. When offered the option of smooth or rough testa seeds for oviposition, there was a clear preference for smooth testa seeds, but no preference for colour. He further reported that, a single beetle can lose 3 to 5 per cent weight of cowpea seed.

Dabi *et al*. (1979) studied ten varieties of cowpea and reported that genotype RS-9 had the lowest susceptibility, while RS-42, RS-118 and NO-5-19-4-1 had the highest susceptibility to *C. maculatus*. They also reported that the seed characters such as colour, weight, volume and hardness contribute to susceptibility.

Satyavir (1981) performed screening of 24 promising varieties of cowpea against pulse beetle and reported that these varieties of cowpea are not equally susceptible to *C. maculatus*. He also found that, seed weight and seed colour did not affect their susceptibility to *C. maculatus*.

Messina and Renwick (1985) found that, the different cowpea genotypes which are resistant to cowpea bruchids, differed from each other mostly in the acceptability of seeds for oviposition. They reported two rough-seeded lines (IT81D-985 and IT81D-1137) as resistant to bruchid larvae with non-preference resistance to ovipositing adults.

Singh *et al.* (1985) screened over 8000 cowpea germplasm lines against *C. maculatus*. They identified the germplasms *viz.* TVu2027, TVu11952, and TVu11953 as resistant source against *C. maculatus*. The observations were taken up to 50 days after infestation. The damage percentage of seeds varied from 25 to 26 per cent in resistant lines at 103 days after infestation as compared to 95 per cent for brown line.

Khokhar and Singh (1987) reported that, beetle laid an average of 34.7 eggs per pigeon pea variety and ICPL-143 and ICPL-148 were the most preferred varieties for egg laying, while ICPL-289 was more preferred for egg laying and provided optimal conditions for adult development.

Dias and Yadav (1989) conducted laboratory studies on female *C. maculatus, C. chinensis,* and *C. analis* to determine their preference for oviposition on seeds of four legumes and reported that all the three species of bruchids preferred cowpea seeds for oviposition.

Mueke (1991) tested ten varieties of cowpea for oviposition preference to *C. maculatus* and reported that the variety VITA 5 was less preferred for oviposition by *C. maculatus.*

Mabata (1992) conducted studies on soybean, cowpea, *Vigna subterranean* and *Sphenostylis stenocarpa* seeds to determine how seed characteristics interact with ovipositional markers of *C. maculatus* and concluded that the female bruchids were able to differentiate the egg-laid seeds from that of fresh seeds.

Chavan *et al.* (1997a) tested a cowpea line against *C. Chinensis* for its ovipositional preferences. During oviposition, pulse beetles showed a distinct intra-varietal response and reported that oviposition preference was more on lines with brown, black, grey and red seeds than with white seeds.

Boeke *et al.* (2003) investigated the reproductive success of *C. maculatus* and reported that it may vary between strains of the beetle and between varieties of the host seeds. All beetle strains were assayed in a no-choice and a two-choice test. In a no-choice situation, the developmental period from egg to adult was prolonged on the bean variety Kpodjiguegue. In a two-choice situation, the beetles showed a strong preference to oviposition for the Californian black eyed bean variety.

Singh and Sharma (2003) studied ovipositional preference and developmental period of *C. chinensis* on eight cowpea varieties and reported that pulse beetles prefer all cowpea varieties for egg laying. The seed coat texture of grain being the leading component of egg laying in these varieties ranging from 98.1 to 99.5 per cent.

Patel *et al*. (2005) studied the biology of pulse beetle (*C. chinensis*) under laboratory conditions on different pulses *viz*., green gram, Bengal gram, red gram, lentil, grass pea or cowpea. Host grain pulses differed significantly in their incubation periods, larval and pupal periods, and overall developmental periods. The most favoured hosts were green gram and cowpea. Colour, texture and seed volume all had an influence on oviposition. For oviposition and egg laying, brightly coloured, smooth-surfaced seeds with a greater size were considerably chosen.

Jha *et al*. (2009) studied preference of *C. maculatus* to 24 varieties of cowpea and reported that only two *i.e.,* BG-1103 and BG-1101of the 24 cultivars showed resistance to the infestation of *C. maculatus.*

Shinde (2019) studied the orientation of *C. maculatus* during developmental studies on different pulses at college of agriculture, Dapoli. She noted that, 3 and 4 number of adults were oriented on seeds of cowpea at 24hrs and 48 hrs. after release. Whereas, green gram was found to be most oriented by *C. maculatus i.e., 8 and 8* adults at 24 hrs. and 48 hrs. after release respectively, among all the pulses.

Shivanna *et al.* (2011) evaluated reaction of different cowpea varieties to *C. maculatus* and reported that the variety CP-17 was less preferred for oviposition.

Fawki *et al.* (2012) studied the resistance of various cowpea varieties such as Aswany, Local, Dokki-33 and Kareem 7 to the bruchid, a serious pest of stored pulses *(C. maculatus*). The results indicated that the variety Aswany reduced the growth and development of *C. maculatus* in case of adult emergence rate, total developmental period and growth index. They recorded the highest adult emergence of 90.42 % on dokki-331 which was followed by varieties Local (67.5 %), kareem-7 (55.0%) and finally Aswany (32.5%) cultivars respectively They also reported that, the protein content of seeds and the susceptibility index exhibited a negative correlation.

Rosemond and Khan (2013) studied the comparison of oviposition preferences between 18 cultivars of pigeonpea and *C. maculatus* was conducted. In comparison to the other cultivars tested, B9, B35, B26PL2, B52 and B59 appear to be more resistant to attack by *C maculatus*. Cultivar B35 had the shortest distance to adult emergence from oviposition (33 days), followed by cultivars B59 and B200 that had the longest distance (34 days).

Radha and Susheela (2014) studied the ovipositional preference and life history of pulse beetle on different pulses. They reported that the oviposition period did not differ considerably from one individual to the next in the pulse. Adults showed the highest preference for oviposition on seeds that are smooth and bold. The cowpea was shown to have the highest ovipositional preference among all the pulses chosen.

Chakraborty and Mondal (2016) determined the susceptibility of *C chinensis* through its preference for egg laying in five different stored pulses under a "free choice" test in a laboratory experiment. There are number of factors which may be responsible for the ovipositional preference of bruchids towards different pulses, including texture, seed size, seed weight, seed volume, and seed colour. The darkest and brownest seeds have the greatest potential for oviposition when given the choice between them and white seeds.

Kebe *et al.* (2020) studied oviposition preference and adult emergence of *C. maculatus* on cowpea seeds of three cowpea varieties *viz.*, BayeNgagne, MameFama, and Ndiaga Aw. They used both free choice and no-choice test to assess fecundity and adult emergence rate. They reported that the variety MameFama was most preferred for oviposition (fecundity rate = 30.50) and the variety Ndiaga Aw was least preferred (fecundity rate = 19.85). The adult emergence rate was greater on BayeNgagne and MameFama varieties.

Tripathi *et al*. (2020) assessed 103 different cowpea accessions for resistance to *C. maculatus* and reported that the accessions, EC528387 was least preferred by *C. maculatus* with only 52.7 eggs on 20 seeds. The minimum number of exit holes were observed in accession EC528425, also the least adult emergence was reported in the same accession.

2.2 To study the developmental period of *C. maculatus* on different cowpea genotypes

El Halfwy *et al.* (1972) studied the biology of *C. maculatus* on black eyed cowpea (*Vigna unguiculata* Sinensis), fertriate cowpea (a local variety of *V. unguiculata*) in the laboratory in Egypt. On the above two types of seeds, the oviposition period lasted for 4 and 5 days; the numbers of eggs/female averaged 62.4 and 39.4; the life span of adult males was 9.5 and 4.9 days respectively; the life span of adult females was 12.1 and 4.9 days and life cycle from egg to adult lasted for 26 and 29 days, respectively.

Seddiqi (1972) studies the biology of pulse beetle on cowpea, green gram, chickpea, garden-pea and reported that the average incubation period of pulse beetle was 5.5 days. The larval periods were 23.0, 23.5, 25.5 and 36 days and the pupal periods were 5.7, 5.6, 6.0 and 6 days on cowpea, green gram, chickpea and garden-pea, respectively. The mean adult longevity on cowpea, mung bean, chick pea, garden pea was 6.5, 6.2, 5.5, 5.65 and 6.1 days respectively. The egg to adult development was 95.5, 96.0, 89.9 and 58.9 on cowpea, green gram, chickpea, and garden-pea, respectively.

Wright (1986) studied the reproductive biology of three strains of *C. maculatus*, and reported that the cowpea seed beetle is a serious pest of stored grain pulses. As the female gets older, the energy reserves got depleted due to which there is decline in number of eggs laid. Various factors affected the fecundity of females. The initial adult weight of females showed a strong positive relationship with the number of eggs laid.

Giga and Smith (1987) studied the egg production and development of *C. rhodesianus* and *C. maculatus* on several pulses like gram, green gram, pigeon pea, black eye cowpea and soybean at two different temperatures *i.e*., 20°C and 30°C. They reported that developmental period of *C. rhodesianus* was significantly shorter than *C. maculatus* on all hosts at 20^0C. At 30^0C, however, *C. maculatus* develops faster and on an average the difference between the species varied only between 1-3 days.

Manohar and Yadav (1990) concluded that on various pulses number of eggs produced were ranging from 104 to 170 by female *C. maculatus*. Cowpea showed the highest of 72 to 96 per cent adult emergence of *C. chinensis*. According to their observations on different pulses, the growth index of *C chinensis* and *C maculatus* ranged between 2.63 to 5.17 and 2.59 to 4.14, respectively.

Ramzan *et al.* (1990) studied the damage by *C. maculatus* to seeds of different pulses of genus *Vigna* under natural storage conditions. They reported that, *V. unguiculata* had the greatest damage in terms of exit holes (69.2 %) and weight loss (34.5 %), followed by *V. aconitifolia* (53.7 and 21.9 %) and *V. radiata* (50.3 and 19.4 %).

Javaid *et al.* (1993) studied the different land races of cowpea in Botswana for adult emergence based on the number of exit holes. The land races *viz*., B067, B041 and B016-E did not provide a satisfactory diet for *C. Maculatus* as compared with other land races evaluated in this study. The adult emergence on the black eye variety of cowpea was comparatively higher and more significant than on other land races evaluated. The viability of eggs on different land races also varied, but none of them provided complete resistance to *C. maculatus* during storage. There was wide variation in susceptibility among the cultivars tested.

Allotey and Dankwah (1995) reported that the egg hatchability of *C. maculatus* was over 90 per cent on all legumes tested. According to the studies, the mean developmental period of *C. maculatus* on cowpea was 23.7days and 28.5 days on the PieleKargu variety of groundnut. In case of damage caused, a significant difference was occurred between the brown cowpea and Bambara varieties of groundnut.

Ofuya and Credland (1995) studied the response of seed beetle, *C. maculatus* to different varieties of cowpea. Eleven resistant and two susceptible varieties were evaluated against three populations of the beetle. The result revealed that the mean developmental period was significantly ($P < 0.05$) longer in the resistant than in the susceptible cowpea varieties.

Chavan *et al.* (1997b) evaluated a variety of cowpea lines for their effect on the growth and development of *C. chinensis*. The emergence rate, larval-pupal period, and larval-pupal survival of *C. chinensis* on these different lines were significantly influenced by these lines. Those lines with growth indexes greater than 1.656 formed the less susceptible group along with 258/85, EC-340-10088, EC-59321, 597185, and V-70-3-3-1.

Gill and Ramzan (1998) reported variation in egg hatching of *C. maculatus* from 57.9% in November to 93.1% in September when observed on green gram. In Punjab, the life cycle of *C. maculatus* was determined to be 19.0 days in June-July and 35.35 days in October-November. The larval and pupal stages varied from 10.60± 0.06 to 5.03± 0.66 days, respectively.

Singal (1998) concluded that *C. chinensis* completed its life cycle from egg laying to adult emergence within 35.5 days in cowpea under laboratory conditions.

Singal and Borah (2001) observed that *C. chinensis* has a larval period of 16.2± 0.16 days and a pupal period of 7.2± 0.18 days. In addition to this, while studying the biology of *C. chinensis* on pigeon pea pods, they reported that males and females lived an average of 6.8± 0.25 days and 6.2± 0.36 days, respectively. Furthermore, they observed an average 30.4± 0.62 days total developmental period.

Nagaraja (2006) concluded that, pigeon pea genotypes ICPL 2008-1, DEPS-9, GS-1, DEPS-3 and PG-12 showed relative resistance to *C. maculatus* compared to other susceptible genotypes, PG-44, ICPL-2009-1, GPS-2003, and ICPL-87119, and had the lowest percentages of adult emergence, germination, weight loss, and developmental period. TV X 944, KM-1, Goa local, and T-1 cowpea genotypes, which had the lowest percentages of adult emergence, weight loss, growth index value, developmental duration and germination percentage, which exhibited the least susceptibility to *C. Chinensis.*

Kazemi *et al*. (2009) studied the biology of *C. maculatus* on chickpea (variety Jam), cowpea (variety Parastoo), lentil (variety Mardom) and green gram (variety Gohar) in a growth chamber at temperature of 25±1^{0}C and relative humidity 20±5%. The results revealed that the net reproductive rate of *C. maculatus* on cowpea was 15.37±0.72. The generation time was shortest on cowpea (29.77±0.07 day). The adult longevity of *C. maculatus* was recorded longest on green gram (8.29±0.38 days) and shortest on cowpea (5.87±0.08 days). Also, the shortest doubling time was obtained on cowpea (7.55±0.12 days). They concluded that the cowpea was more sensitive host to *C. maculatus* in comparison with others.

Deshpande *et al.* (2011) Recorded the per cent apparent weight loss was significantly maximum was in IC202806 (31.17%), which was on par with IC198361, IC259159-1, IC253181 and IC214757 with 31.03, 29.09, 29.07, and 28.84 per cent weight loss, respectively. While significantly minimum was in IC20278 with 8.87 per cent.

Obopile *et al*. (2011) evaluated several genetic races of Botswana cowpea for the resistance to cowpea bruchid, *C. maculatus.* They reported that the land races B013-F, B339, B261-B and B383 had significantly reduced adult emergence and oviposition percentages as compared to the land races B001-B, B154, B109-C and B055. A significant delay in the development period of beetles was also observed in the land races B339, B261-B, B013-F and B383. These land races possess an inherent level of resistance against pulse beetles as evidenced by the reduction in oviposition, adult emergence, and prolonged development period.

Badii *et al.* (2013) accessed the twenty-two cowpea genotypes in case of their relative susceptibilities based on oviposition, mean developmental period, adult emergence and seed weight loss. The results showed that more eggs were laid on seeds of SARC 3-122-2, Marfo-Tuya and SARC 1-119-2 (71.5-149.5), while SARC 1-132-1, SARC 1-91-1 and SARC1-13-2 recorded the least egg laid (16-24.5). The average total life cycle was also significantly higher on SARC 3-122-2, SARC 4-75 and Marfo-Tuya genotypes (21.1-21.5 days), and lower on SARC 1-57-2, SARC 1-136-2 and Apabgaala genotypes (18.4-18.9 days). Significantly more adults emerged from the genotypes SARC 3-122-2, Marfo-Tuya, SARC 1-36- 1, SARC 4-75 and IT97K-499-35 (111.3-54.0 days), while the genotypes SARC 1-132-1, SARC 1-91-1, SARC 1-13-2, SARC 3-90-2 and SARC 1-94A-2 recorded the least adult emergence (28.5- 8.3days), with the rest of the genotypes being in between. Moreover, genotypes Apabgaala, SARC 1-36-1 and Marfo-Tuya recorded the highest percentage weight loss (24.0-29.4%) while SARC 1-132-1, SARC 3-90-2 and SARC 3-103-1 recorded the least (4.3-9.6%).

Castro *et al*. (2013) studied the characterization resistance of 50 cowpea (*Vigna unguiculata*) genotypes to *C. maculatus*, and reported that genotypes SanziSambili, Canapuzinho-1-2, MN05-841, B-49, and MNC99-508-1 showed reduction in the number of adult emergences. This was probably due to the low viability of eggs. However, the genotypes IT81D-1045 Ereto, IT81 D-1045, Enramador, and IT85 F-2687 even with high percentages of viable eggs, had decreased number of adult emergences.

Amusa *et al.* (2014) studied the developmental period of *C. maculatus* on cowpea and reported that the mean development period of *C. maculatus* was 32-47 days. There were nine varieties of cowpea that showed percentage seed damage above 80 per cent and percentage pest tolerance below 50 per cent. TVU 11953 was the most resistant variety of all, with the susceptible index of 1.78, which indicates seven of the varieties studied were moderately resistant and the remaining three were resistant to bruchid infestations.

Barde *et al*. (2014) studied the pattern of oviposition, female adult longevity and F1 progeny emergence of *C. maculatus* (Fab.). The results of this investigation revealed that over 60 per cent of the total number of eggs laid by the female cowpea bruchids, *C. maculatus* occurred within the first 3 days (72 hrs.) after the initiation of the oviposition. This was followed by a decrease in the oviposition rates of the female adults. While, about 60 per cent of the adult females *C. maculatus* survived to the 4th day from the commencement of oviposition but only about 10 per cent survived to the 9th day. However, 100 per cent mortality of adult females was recorded from the 10th day. Also, F1 adult progeny emerged from the infested cowpea seeds was found to depend on the time at which the eggs were laid. With regards to adult females, longevity of *C. maculatus*, mortality rate was reduced, when noticed from the first to the third day from the commencement of oviposition. There was drastic increase in the mortality rates of the female cowpea bruchids particularly between the third and fourth day of oviposition.

Jadhav *et al.* (2015a) studied the ovipositional preference and development of *C. maculatus* on different cowpea cultivars. They reported egg incubation and larval-pupal period of bruchids ranging between 3.86 to 4.41 days and 22.86 to 26.60 days, respectively. They also found that, egg laying by *C. maculatus* on cowpea ranged between 26.67 to 54.00 eggs/30 seeds.

Sharma *et al.* (2016) studied the experiment of performance of different pulses in a laboratory condition on developmental biology of pulse beetle, *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) on five different pulses. In case of V-578 variety of cowpea, the number of eggs laid by C. maculatus ranged from 88-91 eggs. Also recorded the adult longevity of *C. maculatus* ranged in between 8-15 days in V-578 variety of cowpea. The incubation period of *C.*

maculatus ranged from 4-5 days. The hatching percentage was recorded 94.3 ± 0.3 per cent in V-578 variety of cowpea. Total life cycle was recorded in the range from 26-38 days. Adult emergence was recorded 85.8 ±1.6 per cent.

Adenekan *et al*. (2018) studied the effect of varying temperature regimes on the developmental stages of F1 progeny *of C. maculatus* on cowpea seeds. Total number of eggs laid, number of hatched eggs and total number of adults that emerged from each treatment were recorded and analysed. There were significant differences in the mean number of eggs oviposited, ecloded and mean number of adults that emerged at different temperature regimes by the insect. It was revealed that a temperature regime of 30^0C significantly supported the highest egg hatch of 44.0 ± 4.1, while, the least number of egg hatch (3.5 ± 1.0) was recorded at 10^0C. There was a significant reduction in the mean number of *C. maculatus* adults that emerged at 10 and 20^0C when compared to the adults that emerged at 30^0C. The mean number of eggs oviposited and ecloded decreased considerably as the temperature under which the F1 adults developed increases. Temperature has a marked effect on the egg laying and development of *C. maculatus*. The highest fecundity recorded on F1 adults under low temperature (10 and 20^0C) regimes, with longer developmental periods clearly showed that egg laid by individual female *C. maculatus* depended on the reserve built up during the larval stages.

Jaiswal *et al*. (2018) studied the biology of the pulse beetle, *C. chinensis* on the stored chickpea. The results revealed that the insect completed one generation from late March to first week of May. Biological studies of *C. chinensis* on chickpea revealed that it took 4.15 ± 0.87 days to incubate, larval period completed within 22.30 ± 3.06 and the pupal period completed within 6.70 ±0.87 days. Males had an adult life span of 9.30 ± 1.08 days while females had an adult life span of 10.15 ± 0.98 days. The total developmental period was 32.85 ± 3.42 days. A pre-oviposition period was 6.55 ± 0.94 hours, an average oviposition period was 8.10± 1.25 days, and the post-oviposition period was 1.85 ± 0.48 days. An average of 84.15 eggs was laid by a female with the hatching percentage of 88 per cent and the sex ratio between males and females was 1:0.88.

Augustine and Balikai (2019) studied biology of *C. chinensis* on cowpea varietyDC-15. The results of study revealed that the pre oviposition period was on an average of 6.10 ± 1.66 hours. The oviposition period lasted for 5 to 10 days with the mean of 7.10 ± 1.66 days. Incubation period ranged from 4 to 6 days with the mean of 4.6 ± 0.70 days. The duration of first instar grub ranged from 3 to 5 days with the mean of 3.50 ± 0.71 days. The second instar larval duration ranged from 3 to 6 days with an average of 4.40 ± 1.17 days. The third instar grub took 4 to 6 days for its development with a mean of 4.80 ± 0.92 days. The duration of fourth instar was 4 to 7 days with an average of 5.50 ± 1.08 days. The total development period occupied 26 to 40 days with the mean of 30.90 ± 4.28 days. It was observed that the females of *C. chinensis* lived longer than the male beetles. The females lived for a period of 8 to 12 days with the mean of 9.50 ± 1.58 days, whereas, the males lived for 7 to 11 days with the mean of 8.30 ± 1.25 days.

Nisar *et al*. (2021) studied developmental preference of *C. maculatus* in different legumes. Five different legumes *viz*., *kabuli* chickpea, *desi* chickpea, cowpea, mung bean and red kidney bean were used with three replications in completely randomized design. The maximum 23.33 egg count was recorded in cowpea. The shortest developmental period was observed in mung bean (22.66 days) followed by cowpea (24.33 days). Increased count of male *C. maculatus* was observed in mung bean (39) subsequently in cowpea (37.33). The maximum number of holes in seeds was observed in cowpea (19.33). Increased weight loss percentage was observed in cowpea (19.58%). The shortest larval and pupal period was recorded on mung bean and cowpea grains. Cowpea and mung bean promoted the development of more females than males. The increased adult population was observed on mung bean grains, followed by cowpea grains.

Bidar *et al*. (2021) studied the effect of various legume species including chickpea (*Cicer arietinum* L.), cowpea (*Vigna unguiculata* L.), green gram (*Vigna radiata* L.), lentil (*Lens culinaris* Medikus) on the life history and life table parameters of *C. maculatus* at the temperature 30 ± 1^0C, relative humidity of 65 ± 5% and complete darkness and reported that the developmental period was shortest on cowpea cultivar-1057.

Senthilraja and Patel (2021) Tested the performance of 14 cowpea varieties against *Callosobruchus maculatus* (F.) under the no-choice artificial infestation condition. They reported that mean number of eggs laid on cowpea varieties per 100 seeds was ranged from 59.67 to 119.00. The per cent weight loss due to feeding of *C. maculatus* ranged in between 13.03 to 24.92 per cent. The total life cycle of *C. maculatus* was noted in the range of 19.67 to 22.67 days in the different varieties of cowpea.

2.3 To study the effect of different 'Indigenous Traditional Knowledges' (ITK's) for management of *C. maculatus*

Radhakrishnan *et al*. (1983) reported that unlike neem kernel powder and other synthetic insecticides, wood ash and red earth slurry treatment did not affect the increasing number of insects infesting stored pulse, but neem kernel powder was found effective to check the population of pulse beetles.

Reddy and Reddy (1987) studied the use of powdered *Acorus calamus* (L.) rhizome to protect pulse seeds against pulse beetle and reported that the treated pulses showed promising results over 3 to 6 months at 2% rhizome content without adverse effects on seed viability/organoleptic qualities.

Thawatsin (1987) studied the effect of neem leaf and neem seed kernel powder on growth and development of *C. maculatus* on cowpea 22-37°C temperature, 98.6% relative humidity and 14 per cent moisture content of grains and reported the reduction in oviposition capacity, lengthened larval and pupal periods, reduction in adult emergence and growth index of *C. maculatus*.

Gidaganti (1990) observed that, *vekhand* powder treated cowpea seeds at 5g/kg for 210 days under ambient conditions maintained higher uniform seed weight, germination, emergence of adults, seedling length and vigour index with appropriate moisture content.

Chiranjeevi (1991) evaluated the efficacy of neem leaf powder, lantana leaf powder, sweet flag rhizome powder, neem seed powder, cow dung ashes, and casuarina ashes on the percentage of damaged grains, per cent protection over control and viability of seeds treated with these powders. The results revealed that sweet flag rhizome powder, neem seed powder and neem leaf powder showed promising results in reducing damage and infestation percentage of *C. maculatus* in green gram. The seed germination was not adversely affected by any of the treatments.

Javaid and Poswal (1995) conducted a study to evaluate the effectiveness of commonly-used spices as well as other plant products against *C. maculatus* in cowpea seeds in Botswana. Spices such as clove, ginger, turmeric, black pepper, chilli, garlic, and wood ash were administered as treatments. The results revealed that there were significant differences in weight loss and oviposition between the treatments. Wood ash, clove and black pepper did not seem to affect the number of eggs laid by females. In addition, the wood ash treatment resulted in less weight loss.

Chiranjeevi and Sudhakar (1996) investigated the effect of indigenous plants on the development of *C. chinensis* and reported that cow dung ash and *A. calamus* powder prevented egg laying at 0.5 per cent; however, other treatments reduced development at 1.5 and 2.0 per cent. As compared to the untreated control samples, the treated samples had a longer development period.

Javaid and Ramatlakapela (1996) evaluated the effectiveness of ashes and sands in preventing *C. maculatus* on cowpea seeds. Cow dung ash and "motswere" tree ash were statistically similar to malathion dust in preventing incidence of *C. maculatus.* The results of the cow dung ash were more consistent than those of the "motswere" tree ash. While, the sand was not as effective as ashes.

Dharmasena *et al.* (1998) evaluated eight plant species under no-choice and free choice conditions for insecticidal activity against *C. maculatus*. *V. altissima* at a rate of 5% w/w was highly effective as an ovipositional deterrent, and *Tamarindus indicus* (L.) was an effective larvicide. Under free choice conditions, *T. indicus* proved effective as both a deterrent and a repellent for oviposition.

Kumari *et al* (1998) reported that black pepper, neem, and mangrails powders were equally effective in terms of number of eggs laid, amount of adult emergence and reduction in damage to grains caused by *C chinensis* under laboratory.

Rajapakse *et al*. (1998) studied the effect of leaf powder of pepper, annona, neem, chillies and lemon peel powder on management of *C. maculatus* and reported that lemon leaf powder reduced the oviposition of *C. maculatus* by 37.50 per cent, followed by annona. They also observed that adult emergence was reduced by 20.30 per cent.

Shrivale and Borikar (1998) evaluated neem leaf powder (1% concentration) against *C. chinensis* in chickpea. They reported that 1.25 per cent adult population died 48 hours after release and 10.78 per cent of mortality was observed after 20 days of treatment.

Patil (2000) studied the effect of seed treatments on the storability of chickpea and it had been reported that chickpea seeds treated with neem leaf powder germinated more readily (65.91%), had highest seedling dry weight (149.00 mg) and a higher vigour index (1282) after ten months of storage than control seeds (64.17%, 144.00 mg and 1208 respectively).

Mulatu and Gebremedhin (2000) evaluated seven plant species for their toxic effects against *C. chinensis* and found that *Azadirachta indica* (A. Juss.), *Milletia ferruginea* (Hochst.) and *Chrysanthemum cinerarfacium* (Trevir.) were effective in preventing egg laying with no bruchid emergence seen from laid eggs.

Prasantha *et al.* (2002) exposed the adults of *C. maculatus* and *Acanthoscelides obtectus* (Say) to the diatomaceous earth 'Fossil-Shield®' on treated mung beans *(Vigna radiate* L) and common beans *(Phaseolus vulgaris* L.) @ 1020 mg/kg and 1080 mg/kg, respectively. *A. obtectus* was less susceptible to Fossil-Shield® than *C. maculatus.*

Shaheen and Khaliq (2005) conducted studies on management of pulse beetle, *C. chinensis* in stored chickpea using different ashes, red soil powder and turpentine oil as postharvest grain protectants for their insecticidal potency. They reported that, fly ash @ 1.0 g per 50 g of grains showed the less time for 100 per cent mortality of released adults, minimum fecundity (0.86 eggs per grain), minimum holes (0.41 per grain), lowest number (3.14) of F1 adult emerged, maximum inhibition (78.62 %) of F1 adults, minimum weight loss (9.63 %) and also showed the 100 % mortality in 2.86 and 4.19, of F1 adults. Fly ash and turpentine oil were the most effective at all application rates compared to other materials.

Swain and Baral (2005) evaluated the effectiveness of various ashes for controlling pulse beetles (*C. chinensis*). They used wood ash, rice straw ash, ash of rice husk, and fly ash @ 0.5 g of ash per 100 grams of pulse seeds. The results revealed that insects grew slowly in the presence of the ashes, indicating that the ashes significantly hampered the normal growth of *C. chinensis*.

Shukla *et al*. (2008) reported 100 per cent mortality of pulse beetle when chickpea treated with *vekhand* rhizome powder (5 mg/g seed). Also, 100 per cent ovicidal activity was observed in the same treatment. During storage of pulse seeds, *A. calamus* rhizome powder (*vekhand*) was highly effective in reducing beetle infestations.

Khatun *et al* (2012) observed the effects on quality of lentil seeds preserved with the help of various botanicals. It was recorded that the seeds stored with neem leaf powder produced the highest germination rate of 86.0% and 87.2% over two years, statistically the same as seeds stored with bishkatali treatment. However, the Seeds treated with dholkalmi and seeds left untreated which showed lowest and similar germination rates. There is a possibility that lentil seeds are more likely to germinate when stored with bishkatali and neem because of their lower moisture content.

Asawalam and Anaeto (2014) conducted a laboratory study to evaluate the effectiveness of some indigenous botanical powders and one essential oil extract as grain protectants against C. maculatus in cowpea. They reported the significant difference in mortality in all the treatments and control at 7 DAT, but garlic powder recorded significantly high mortality at 81.2%, next to it mortality in the treatments with turmeric powder and ginger oil was found more and were not significantly different from each other

Mishra *et al.* (2015) conducted studies on management of *C. chinensis* in green gram using various plant products. Among the different plant products tested neem leaf powder @ 2g/100g of seed was superior to rest of the treatments. The lowest seed damage (2.33 %) was observed in neem leaf powder @ 2g/100g of seed. However, it was at par with begonia leaf powder with 3.66 per cent seed damage and *bael* leaf powder with 4.00 per cent seed damage. Other treatments *viz.*, lemon grass, tulsi, custard apple, *karanja* and *L. camara* leaf powder @ 2g/100g of seed were significantly superior to untreated check. The *L. camara* leaf powder proved to be the least effective (5.33 % seed damage) but it was significantly superior to untreated check.

Jadhav *et al.* (2015b) studied the effect of different grain admixtures against *C. maculatus* in stored cowpea. They used turmeric powder @ 2gm/100gm, dried ginger powder @2gm/100gm,*vekhand* powder @ 2 gm/100gm, ash @ 2gm/100gm, *tisal* powder @ 2 gm/100gm, *adulsa* leaf powder @ 2 gm/100gm, *nirgudi* leaf powder @ 2 gm/100gm, tulsi leaf powder @ 2gm/100gm, *ghaneri* leaf powder @ 2gm/100gm, dried neem leaf powder @ 2gm/100 gm, *hinga* powder @ 2gm /100gm, black pepper powder @ 2 gm/100gm seeds for the study and reported that the treatment of *vekhand* powder @ 2gm/100gm seeds observed to be the most effective with only 50 per cent egg hatching. Whereas, *ghaneri* leaf powder failed to prevent egg hatching in which 100 per cent eggs were hatched. They reported minimum adult longevity in black pepper (4.10 days) followed by *vekhand* powder (4.20 days). The treatments of *vekhand* powder, black pepper and ash were observed most promising giving maximum protection to cowpea grains with the least grain infestation of 2.33, 4.33 and 6.00 per cent, respectively. Overall, they reported that the treatment of *vekhand* powder as the best surface protectant followed by black pepper powder for cowpea seed against pulse beetle.

Mofunanya and Namgbe (2016), Conducted an evaluation to determine the effects *Callosobruchus maculatus* (Coleoptera: Bruchidae) infestations on germination and nutrient quality of *Vigna unguiculata*. They observed that infested grains had lower germination rates than non-infested grains. The Infested seeds showed progressively lower germination percentage which ultimately leads to reduction in germination potential making them unsuitable for planting and also made them unfit for the human consumption.

Khinchi *et al.* (2017) evaluated the effectiveness of various plant part powders and reported that neem leaf powder @ 60 g/kg grains inhibited oviposition of *C. maculatus* up to 55.40 per cent and egg hatching and adult emergence was inhibited by 67.71 per cent.

Sharma *et al*. (2018) studied the effect of several botanicals *viz*., neem oil, mustard oil, turmeric powder and their mixture and surface protectants such as neem seed kernel powder, saw dust, sand, dung cake ash and wheat husk on pigeon pea seed against *C. maculatus*. Highest mortality of 84 to 100% was observed by neem oil @ 10ml/kg and lowest of 3.33% by turmeric powder @ 3.5g/kg seeds, after 135 days of storage. Neem oil @ 10ml/kg was found effective to inhibit the oviposition, adult emergence and seed damage. All the oils and inert materials prevented egg laying, reduced population build up of beetles and minimized seed damage as compared to control.

Swamy *et al.* (2018) carried out studies on Feasibility of sand layer technique for small scale storage of pulses seed and reported that, during 2017-18, When seed was stored under sand layer in modified bins for three months, germination of the three pulses *viz.*, was enhanced compared to conventionally stored seed in gunny bags, regardless of variety. After three months of storage, in gunny bags, 87.89 per cent of black gram seed germinated, while 93.45 per cent seeds germinated of blackgram when stored under sand layer in the modified bin. The modified containers kept pigeonpea seeds under a sand layer for three months showed 94.11 per cent germination. Furthermore, sand layer stored pulses had no grain damage or a negligible amount of grain damage. There was complete damage due to bruchids at a location where seeds were stored in gunny bags without any protection, and there was no germination.

Sousa Neto *et al*. (2019) conducted study to determine the effectiveness of neem powder against cowpea weevils and reported that weevils were repelled by neem powder at all the doses in cowpea seeds and on the basis of mortality curve of *C. maculatus* on cowpea they also concluded that neem leaf powder has insecticide action.

Idoko and Ileke (2020) evaluated the insecticidal activity of essential oils from seeds of *Tetrapleura tetraptera* (Schumach. & Thonn.), *Annona muricata* (L.), and *Aframomum melegueta* (K. Schum.) and leaves of *Ficus exasperate* (Vahl) and *Eucalyptus globulus* (Labill.) for the control of *C. maculatus* on cowpea seeds. The results revealed that *E. globulus* oil (Eucalyptus oil) significantly reduced oviposition of *C. maculatus* as the rate of essential oils applied to cowpea seeds increased. They reported that *C. maculatus* laid 85.7 eggs on cowpea seeds in the treatment of *E. globulus* @ 5 ml/kg as against 107.33 and 115.33 eggs at the dose of 1ml and 3ml of *E. globulus* oil per kg of cowpea seeds, respectively. Cowpea seeds treated with 5 ml of *E. globulus* essential oil per kg seeds significantly reduced ($P < 0.05$) oviposition as compared to other treatments. Thus, the oils of *E. globulus* leaves exerted oviposition deterrent effect on *C. maculatus,* the adult mortality of *C. maculatus* was more (73.33%) in the treatment of *E. globulus*@ 5ml/kg.

MATERIALS AND METHODS

Chapter III

MATERIAL AND METHODS

A laboratory study on "Management of pulse beetle, *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae) infesting cowpea, *Vigna unguiculata* (L.)" was undertaken at laboratory of Department of Agricultural Entomology, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. Dist. Ratnagiri (Maharashtra) during 2021-22. The information on material and methods adopted for conducting various experiments during the course of investigation is described in this chapter under following heads.

3.1 Material required

3.1.1 Inputs used

3.1.1.1 Seed

Seeds of eight different genotypes and one released variety of cowpea were obtained from Research and Education Farm, Department of Agricultural Botany, College of Agriculture, Dapoli.

List of different genotypes and varieties of cowpea used for experimentation

Genotypes: 8	Varieties: 1
1) CP-06	Konkan Safed
2) CP-08	
3) CP-13	
4) SNJ-11	
5) SNJ-22	
6) SNJ-27	
7) SNJ-32	
8) PP	

3.1.1.2 Culture of Pulse beetle

The initial culture of pulse beetle, *C. maculatus* was obtained from the cowpea grains already infested by bruchids from local market and godowns where old infested cowpea was available and kept in glass jar. For identification and isolation of desired species of pulse beetle i.e., *C. maculatus*, the taxonomic keys given by Haines, 1988 were used. For initial culture, healthy and uninfested seeds of cowpea were procured from local market and kept in 32×22.5 cm size cylindrical jar and twenty adults isolated from original culture were released into the jar containing healthy grains. The top of the jar was covered with black muslin cloth secured firmly by rubber band. The newly emerged adults were introduced into the cowpea seed kept in a series of cylindrical jars for building up a homogenous population. A permanent colony was maintained as per procedure described by Strong *et al*. (1968). Adults of uniform age were used from this colony for the experiment. These studies were conducted at room temperature and relative humidity under ambient conditions.

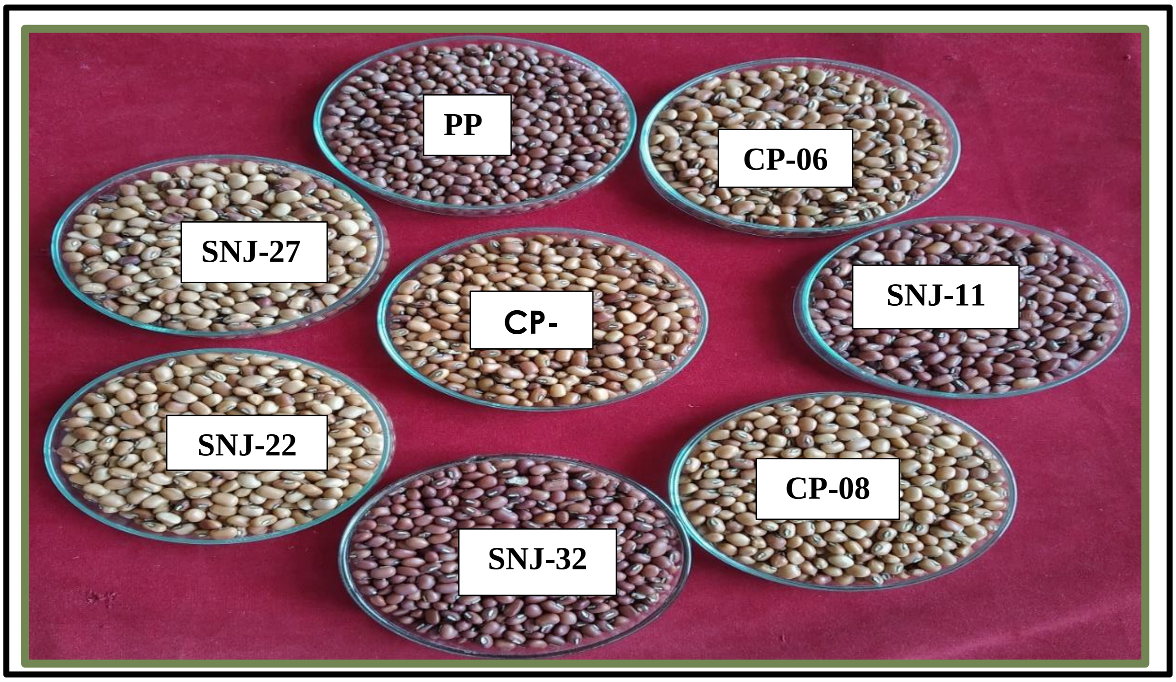

Plate 1: Different cowpea genotypes used for ovipositional preference and developmental studies

Plate 2: Permanent culture of *Callosobruchus maculatus* (Fab.)

3.1.1.3 Different products used under Indigenous Traditional Knowledge (ITK)

- **Neem leaf powder**

  Common name of plant: Neem
  Botanical name: *Azadirachta indica* (A. Juss.)
  Family: Meliaceae
  Used as seed protectant
  Plant part used for present study: Leaf powder

- **Karanj leaf powder**

  Common name of plant: Karanj
  Botanical name: *Pongamia pinnata* (L.)
  Family: Fabaceae
  Used as seed protectant
  Plant part used for present study: Leaf powder

- **Vekhand powder**

  Common name of plant: Sweet flag
  Botanical name: *Acorus calamus* (L.)
  Family: Acoraceae
  Used as seed protectant
  Plant part used for present study: Rhizome powder

- **Turmeric powder**

  Common name of plant: Turmeric
  Botanical name: *Curcuma longa* (L.)
  Family: Zingiberaceae
  Used as seed protectant
  Plant part used for present study: Rhizome powder

- **Wood ash**

  Used as seed protectant
  Plant part used for present study: Common wood ash

- **Eucalyptus oil**

  Common name of plant: Eucalyptus
  Botanical Name: *Eucalyptus globules* (Labill)
  Family: Myrtaceae
  Used as seed protectant
  Plant part used for present study: Oil from leaves.

- **Fine sand**

  Used as seed protectant
  Parts used for study: Sea shore sand

3.1.2 Machines used

Machines, equipment and instruments used during experiment

A) Equipments

The list of eqipments used for the experiment is given below

1) Working table	2) Plastic vials	3) Muslin cloth
4) Test tubes	5) Hand lens	6) Needles
7) Forceps	8) Plastic rearing containers	9) Round plastic boxes
10) Glass rearing containers	11) Rearing glass jars	12) Glass vials
13) Rubber bands	14) Slides	15) Trays
16) Cotton		

B) Instruments

The list of instruments used for the experiment is given below

1) Compound microscope	2) Electronic Weighing balance
3) Dino light microscope	

3.2 Methods Adopted

3.2.1 To study the ovipositional preference of *C. maculatus* to different cowpea genotypes

3.2.1.1 Locale of study

The experiment on ovipositional preference of *C. maculatus* conducted at the laboratory of Department of Agricultural Entomology, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. Dist. Ratnagiri (Maharashtra).

3.2.1.2. Standard procedure used

Preference of pulse beetle *C. maculatus* towards different cowpea genotypes was tested by conducting free choice test. In this test olfactometer was used for the study. The details are given below.

3.2.1.3. Free Choice Test:

Free choice test was implemented using olfactometer. The details of olfactometer are as follows:

Olfactometer:

An olfactometer designed by Gibson and Raina (1972) and subsequently modified by Jadhav *et al* (2015a) was prepared by using circular plastic box of 15 cm in diameter and 5 cm in height with a lid. Test tubes each of 2.5 cm in diameter and 15 cm in length were fixed at equidistance in a slanting position to outside wall of circular plastic box. The mouth of test tube was kept open just inside the sidewall of a box to have free choice for beetles to orient and oviposit. Three such olfactometers were prepared and used during present study (Plate.3).

3.2.1.4 Observations to be recorded:

Ten gram grains of different cowpea genotypes were kept in separate test tubes fixed to the container of olfactometer. Accordingly, all selected genotypes were examined. Three such olfactometers were used in order to maintain three replications. Eight pairs of freshly emerged adults were released in the centre of circular container. Orientation of these adults towards different cowpea genotypes was observed and eggs laid by them were counted and recorded at 24 and 48 hours after release.

3.2.2 To study the developmental period of *C. maculatus* on different cowpea genotypes

3.2.2.1 Research design used

To study the developmental period of *C. maculatus* on different cowpea genotypes, the laboratory experiment was laid out in randomized block design (RBD) with eight treatments consisting of different genotypes of cowpea, which were replicated thrice. Thus, there were total 24 treatment combinations.

3.2.2.2 Location of study

The experiment was conducted at the laboratory of Department of Agricultural Entomology, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. Dist. Ratnagiri (Maharashtra)

3.2.2.3. Standard procedure used

Year of study	:	2021-22
Name of insect	:	*Callosobruchus maculatus* (Fab)
No. of adults released per treatment/replication	:	5 mated adult female beetles.
Design	:	Randomised Block Design
Quantity of grains taken	:	50g
No. of replications	:	Three
No. of treatments	:	Eight cowpea genotypes

Treatment details

The different cowpea genotypes selected for the experiment are as given below

Cowpea genotypes

T_1- CP-06

T_2- CP-08

T_3- CP-13

T_4- SNJ-11

T_5- SNJ-22

T_6- SNJ-27

T_7- SNJ-32

T_8- PP

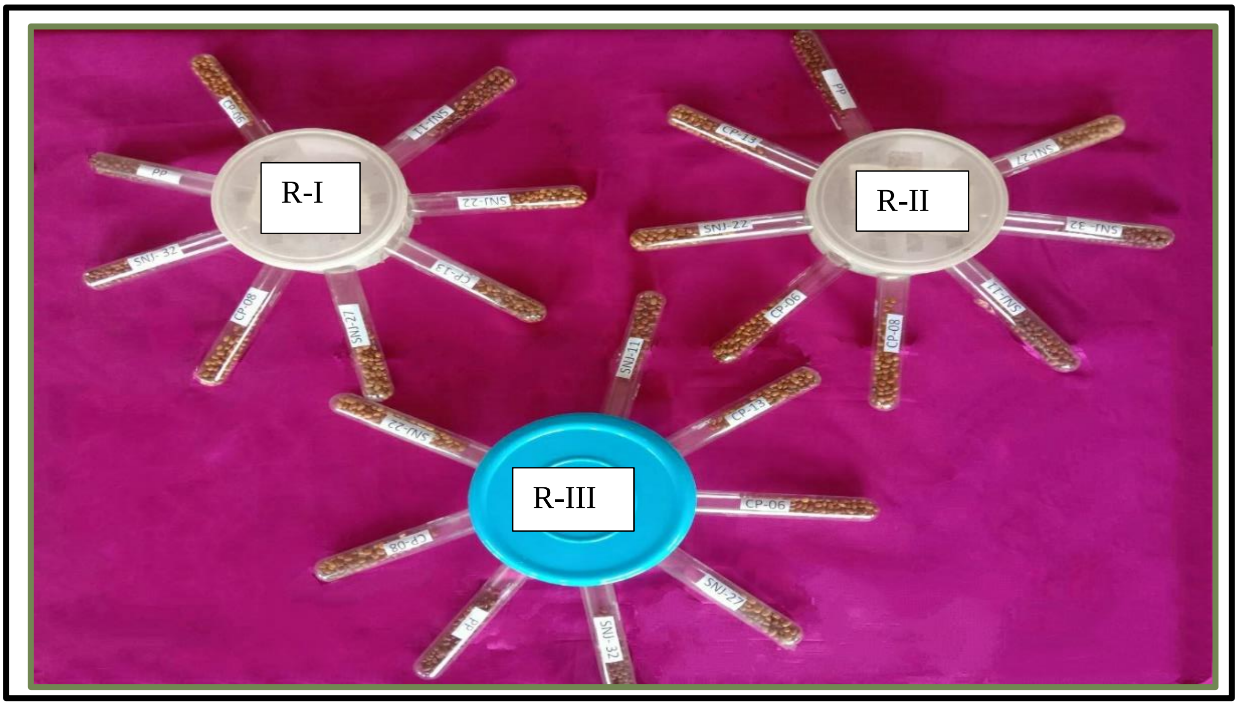

Plate 3: Olfactometer used for the study of ovipositional preference

Plate 4: Different Cowpea genotypes placed for developmental studies of *C. maculatus*

3.2.2.4 Observations to be recorded

Fifty gram seeds of above mentioned eight genotypes of cowpea were kept separately in the plastic bottles. Five mated adult females of *C. maculatus* were released in each plastic bottle. The mouth of plastic bottle was closed tightly with black muslin cloth with rubber band. The beetles were allowed to lay eggs on the cowpea seeds placed in plastic bottles until death. Three such replications were maintained for each genotype. The observations were recorded on following parameters for developmental period of pulse beetle.

1. Fecundity/ No. of eggs laid

The newly emerged adult beetles were allowed to oviposit on seeds of different genotypes of cowpea until death. The dead beetles were removed from each treatment. All seeds were observed carefully from each treatment and number of eggs laid were counted.

2. Incubation period and hatching percentage

The incubation period was worked out by counting the number of days from egg laying to eggs hatching. Ten eggs were observed continuously from egg laying till hatching to work out the incubation period. The incubation period of each egg was recorded and the average incubation period was worked out.

Ten eggs were kept separately to observe the hatching percentage. Three such sets were maintained. Hatching percentage was calculated on the basis of number of eggs hatched.

3. Adult emergence

Total number of adult insects emerged from each treatment (genotype) were recorded on the basis of number of seeds with exit holes which were counted on each alternate day from the date of emergence. The data obtained were analysed statistically and presented.

4. Adult longevity

Freshly emerged ten adult beetles were separated in another test tubes individually from each treatment. Same adults were observed regularly till the death of each adult. The date of adult emergence and date of death of adult was recorded to measure the average adult longevity in each genotype.

5. Total life cycle

Since the pulse beetle is internal feeder, it is difficult to take the observations of larval and pupal period by breaking the seeds of cowpea. Hence for the study of total life cycle of bruchid, the period required from egg laying to of adult emergence was recorded, which also includes larval and pupal period.

6. Per cent weight loss

Initially, known quantity (50g) of seeds of each genotype was taken (initial weight). After adult emergence, the seeds of each genotype were weighed (final weight) with the help of electronic balance. The per cent weight loss in seed of different genotypes was worked out using the formula.

3.2.2.5 Formulae and statistical methods used

1. Formulae used

To workout the hatching percentage and per cent weight loss, following formulae were used.

a. Hatching percentage

$$\text{Hatching Percentage} = \frac{\text{No. of eggs hatched}}{\text{Total no. of eggs observed}} \times 100$$

b. Per cent weight loss

$$\text{Per cent weight loss} = \frac{\text{Initial seed weight-Final seed weight}}{\text{Initial seed weight}} \times 100$$

2. Statistical method used

The data obtained on number of eggs laid, hatching percentage, adult emergence, per cent weight loss, adult longevity and total life cycle of *C. maculatus* was analysed by using randomized block design as per the statistical guidelines given by Gomez and Gomez (1984). The data was transformed to arc sin or square root values wherever necessary.

3.2.3. To study the effect of different 'Indigenous Traditional Knowledges' (ITK's) for management of *C. maculatus*

3.2.3.1 Research design used

Present laboratory experiment was undertaken using randomised block design with eight treatments in which seven treatments were different ITKs and one treatment was untreated control with three replications.

3.2.3.2. Location of study

The experiment was conducted at the laboratory of Department of Agricultural Entomology, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. Dist. Ratnagiri (Maharashtra).

3.2.3.3. Standard procedure used

The details of experiment conducted are as follows:

Year of study	:	2021-22
Variety used	:	Konkan Safed
Name of test insect	:	*Callosobruchus maculatus* (Fab)
No. of adults released per treatment/replication	:	10 adult beetles.
Quantity of grains taken	:	100 gm
No. of replications	:	Three
No. of treatments	:	Eight

Table 3.1 Details of treatments

Sr. No.	Treatment	Name of Treatments	Dose per kg seed
1.	T_1	Neem leaf powder	10g
2.	T_2	Karanj leaf powder	10g
3.	T_3	Vekhand powder	2.5g
4.	T_4	Turmeric powder	10g
5.	T_5	Wood ash	10g
6.	T_6	Eucalyptus oil	10ml
7.	T_7	Fine sand	1kg
8.	T_8	Untreated control	-

Plate 5: Different ITK treatments used for management of *C. maculatus*

Availability of plant products and their application to seeds of cowpea

For the present investigation, various plant products were used in the form of dried powder, wood ash, oil and fine sand, which were assessed their efficacy against pulse beetle in Konkan safed variety of cowpea. Healthy and uninfested seeds of cowpea were used for the experiment. For each treatment 100 g of seed was used. Same quantity of the untreated seed was also taken which served as an untreated control.

The details about different treatments are given below.

Neem and Karanj leaf powder

Leaves of neem and karanj tree were collected from plantations near local area and forests. The leaves were separated and dried in shade for four days. The dried leaves were grinded in grinder and the powder was sieved through muslin cloth to obtain fine powder. This powder was stored in plastic bags for easy handling and further use. One gram quantity of both the powders were weighed on electronic balance and mixed with 100g healthy cowpea seeds kept in a plastic bottle. Then the bottles were shaked well for uniform coating of neem and karanj powders on the seeds. Ten adult beetles of *C. maculatus* were released in each bottle. The mouth of the bottles was properly covered with black muslin cloth secured with rubber band. Three such bottles were prepared as three replications.

Turmeric and vekhand powder

The turmeric powder and vekhand (sweet flag) powder were made available by purchasing from general store in nearby market in Dapoli. These powders were weighed on electronic balance *i.e.,* turmeric powder @ 1 g /100 g seed and vekhand powder @ 0.25 g/100 g seed. The turmeric powder and vekhand powder were mixed thoroughly with seeds in respective bottles. Ten adult beetles of *C. maculatus* were released in each bottle containing cowpea seeds treated with turmeric powder and vekhand (sweet flag) powder. The mouth of bottles was properly covered with muslin cloth with the help of rubber band. Three such bottles were prepared as three replications.

Wood ash

For preparation of wood ash, common burning wood were collected from nearby locality. Fully dried wood was collected and burnt completely till the formation of ash. The ash was collected carefully and sieved with muslin cloth until fine ash was obtained. The sieved fine wood ash was stored in plastic bag for further usage. By using electronic balance, 1g ash was measured and mixed with 100 g healthy seeds of cowpea in plastic bottle. Then bottle was shaked well to mix the ash with seed grains uniformly. Ten adult beetles of *C. maculatus* were released in plastic bottle. The mouth of the bottle was properly covered with black muslin cloth secured with rubber band. Three such bottles were prepared for maintaining three replications.

Eucalyptus oil

The eucalyptus oil was made available by purchasing from general store from nearby market in Dapoli. By using micropipette, 1 ml quantity of oil was sampled from bottle and poured in the container containing 100g cowpea seeds. This mixture was shaked thoroughly so as to cover each grain with layer of oil. The treated seeds were then dried under shade for three hours. These seeds were placed in plastic bottle. Ten adult beetles of *C. maculatus* were released in plastic bottle. The mouth of bottle was properly covered with muslin cloth secured with rubber band. Three such bottles were prepared as three replications.

Fine sand

Fine sand used for treatment was collected from seashore. The sand was sundried completely for removal of moisture. This dried sand was finely sieved for getting uniform sized sand particles. By using electronic balance, 100 g of fine sand was measured. The sand was poured in the plastic bottle containing 100 g cowpea seeds. The sand acquires the spaces between the seeds and form layer on the seeds. The whole setup was made to prevent the insect entry and allow sufficient air required for seed respiration so that seed germination may not be affected. Ten adult beetles of *C. maculatus* were released in plastic bottle. The mouth of bottle was properly covered with muslin cloth and tied with rubber band to avoid escape of beetles. Three such bottles were prepared for three replications. The observations were recorded on the basis of following parameters for management of pulse beetle.

1) **Per cent mortality**

For calculating per cent mortality, the number of dead insects were collected and counted 3 and 5 days after release of beetles. Moribund insects were considered as dead. The per cent mortality was worked out using the formula.

2) **Per cent germination**

To observe the effect of test materials on germination of cowpea seeds, germination test of the treated pulses and untreated (control) seeds was carried out separately two months after seed treatment. From each treatment 50 seeds of cowpea were taken at random and placed in petri dishes (15cm diameter) lined with moistened blotting paper. These petri dishes were kept at room temperature (25-30^{o}C) for ten days to observe the germination. The number of sprouted and unsprouted seeds were counted and germination percentage was calculated by using the formula.

3.2.3.4. Formulae and statistical methods used

1. Formulae used

To workout the per cent mortality and per cent germination following formulae were used.

a) Per cent mortality

$$\text{Per cent mortality} = \frac{\text{No. of dead insects}}{\text{Total no. of insects released}} \times 100$$

b) Per cent germination

$$\text{Per cent germination} = \frac{\text{No. of seeds germinated}}{\text{No. of seeds taken}} \times 100$$

2. Statistical method used

The data on per cent mortality of adult beetles and per cent seed germination were transformed to arc sin values and analysed by using randomized block design as per the statistical guidelines given by Gomez and Gomez (1984).

Plate 6: Cowpea seeds treated with different seed protectants

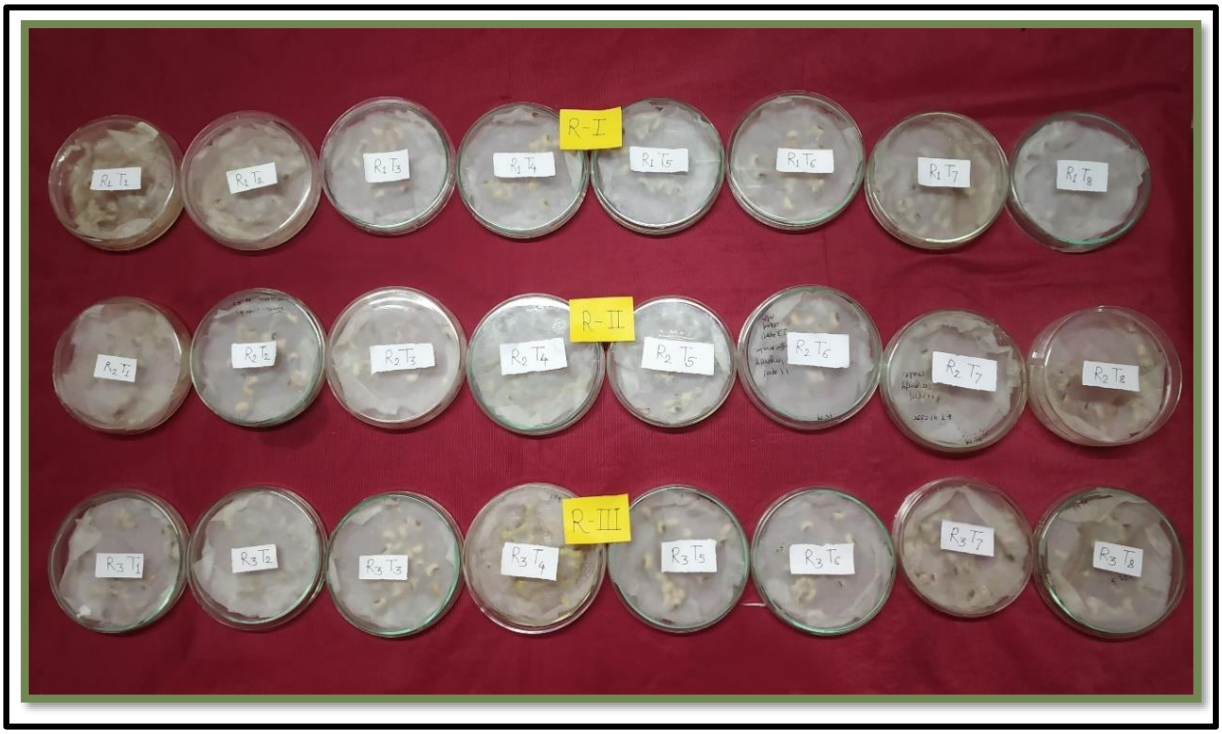

Plate 7: Germination test of cowpea seeds treated with different seed protectants

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

During the course of present investigation, the experiments were undertaken to study the ovipositional preference, developmental parameters and management of pulse beetle, *C. maculatus,* under the heading "Management of pulse beetle, *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae) infesting cowpea, *Vigna unguiculata* (L.)" during the year 2021-22 in the laboratory of Department of Agricultural Entomology, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. Dist. Ratnagiri (Maharashtra). The studies were carried out at temperature 22± 3˚C and relative humidity 85 ± 12 per cent.

The results of the experiments are presented and discussed under the following heading;

4.1 Study of ovipositional preference of *C. maculatus* to different cowpea genotypes.

4.2 Study of developmental period of *C. maculatus* on different cowpea genotypes.

4.3 Study of effect of different 'Indigenous Traditional Knowledges' (ITK's) for management of *C. maculatus.*

4.1 Study of ovipositional preference of *C. maculatus* on different cowpea genotypes

4.1.1 Orientation of released adult beetles of *C. maculatus* towards different cowpea genotypes

The data obtained on orientation of adult *C. maculatus* towards eight cowpea genotypes in olfactometer are presented in Table 4.1 and depicted in figures 4.1, 4.2 and 4.3.

From the data it is observed that the highest number of adults (12 adults) were attracted towards genotype CP-13 (6 at 24 hrs. and 6 at 48 hrs. after release) followed by genotype SNJ-32 (7 adults). Least adults were attracted towards genotype SNJ-11 (1 adult). The genotypes CP-06, SNJ-27 and PP attracted only 2 adults of *C. maculatus*.

Table 4.1 Orientation of adults of *C. maculatus* towards different cowpea genotypes

Sr. No.	Cowpea genotypes	No. of adult beetles oriented to different cowpea genotypes at		
		24 hours after release	48 hours after release	Cumulative data
1.	CP-06	1	1	2
2.	CP-08	1	2	3
3.	CP-13	6	6	12
4.	SNJ-11	1	0	1
5.	SNJ-22	2	1	3
6.	SNJ-27	1	1	2
7.	SNJ-32	3	4	7
8.	PP	1	1	2

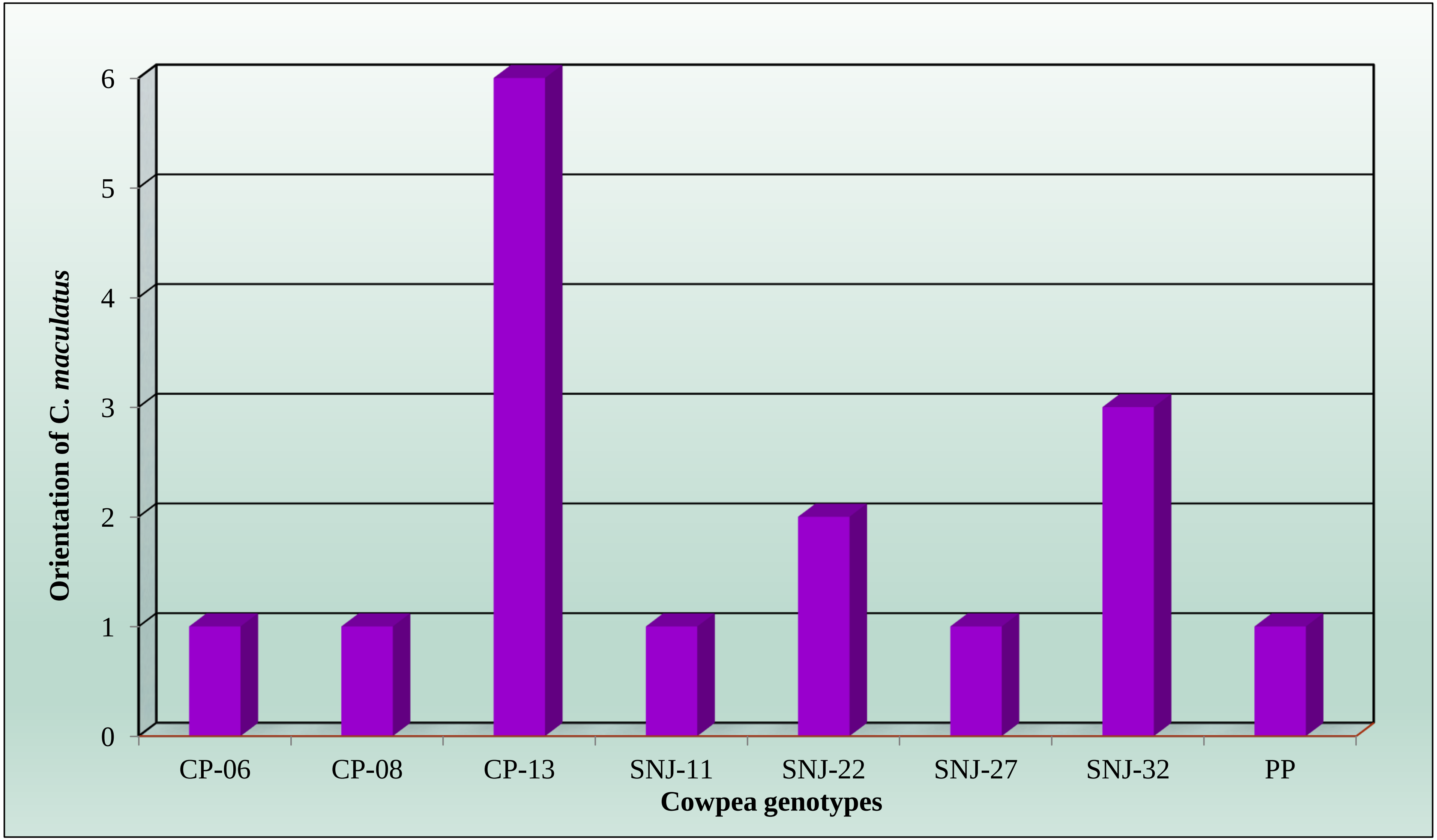

Fig 4.1 Orientation of *C. maculatus* towards different genotypes of cowpea at 24 hours after release

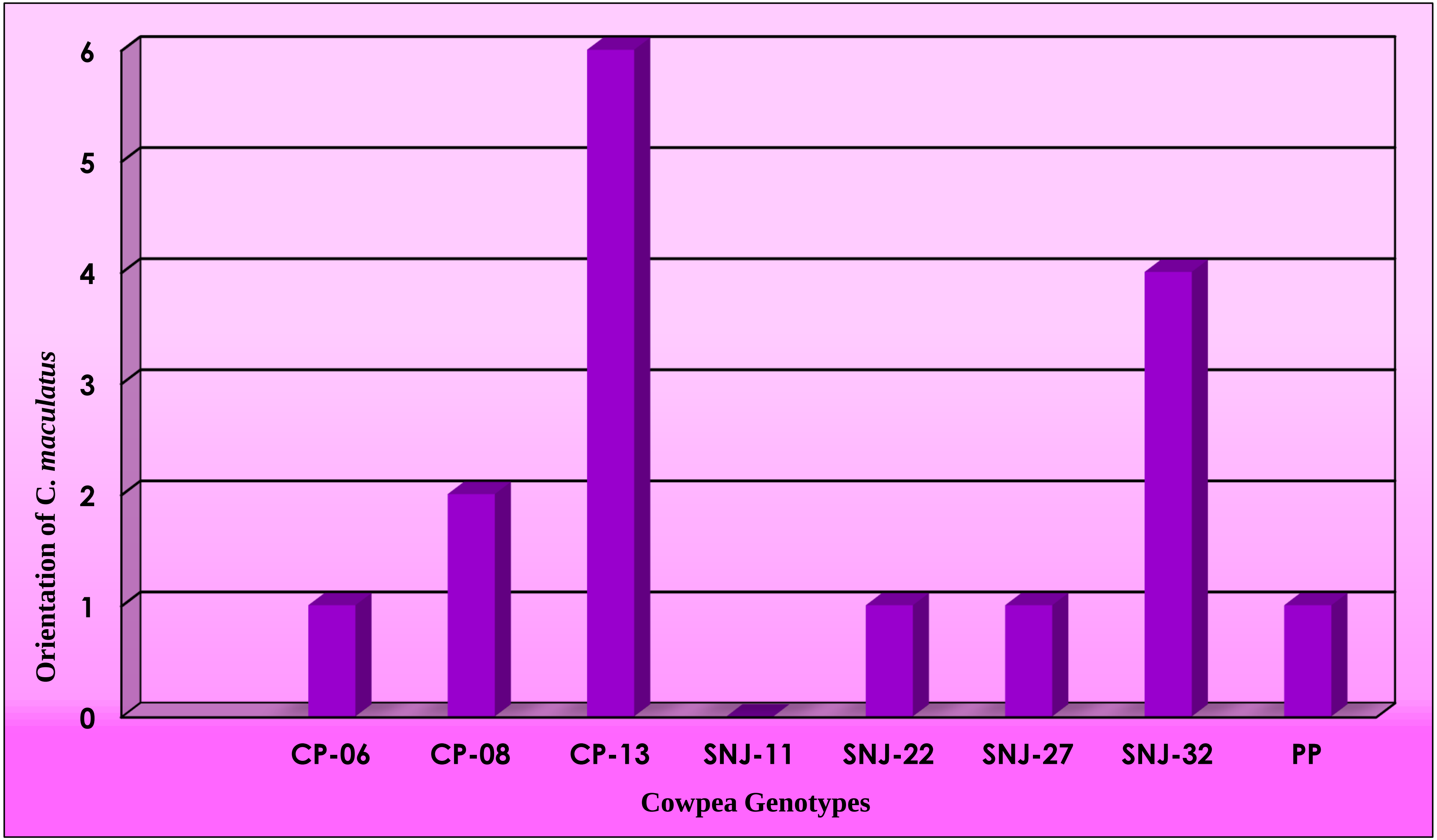

Fig 4.2 Orientation of *C. maculatus* towards different genotypes of cowpea at 48 hours after release.

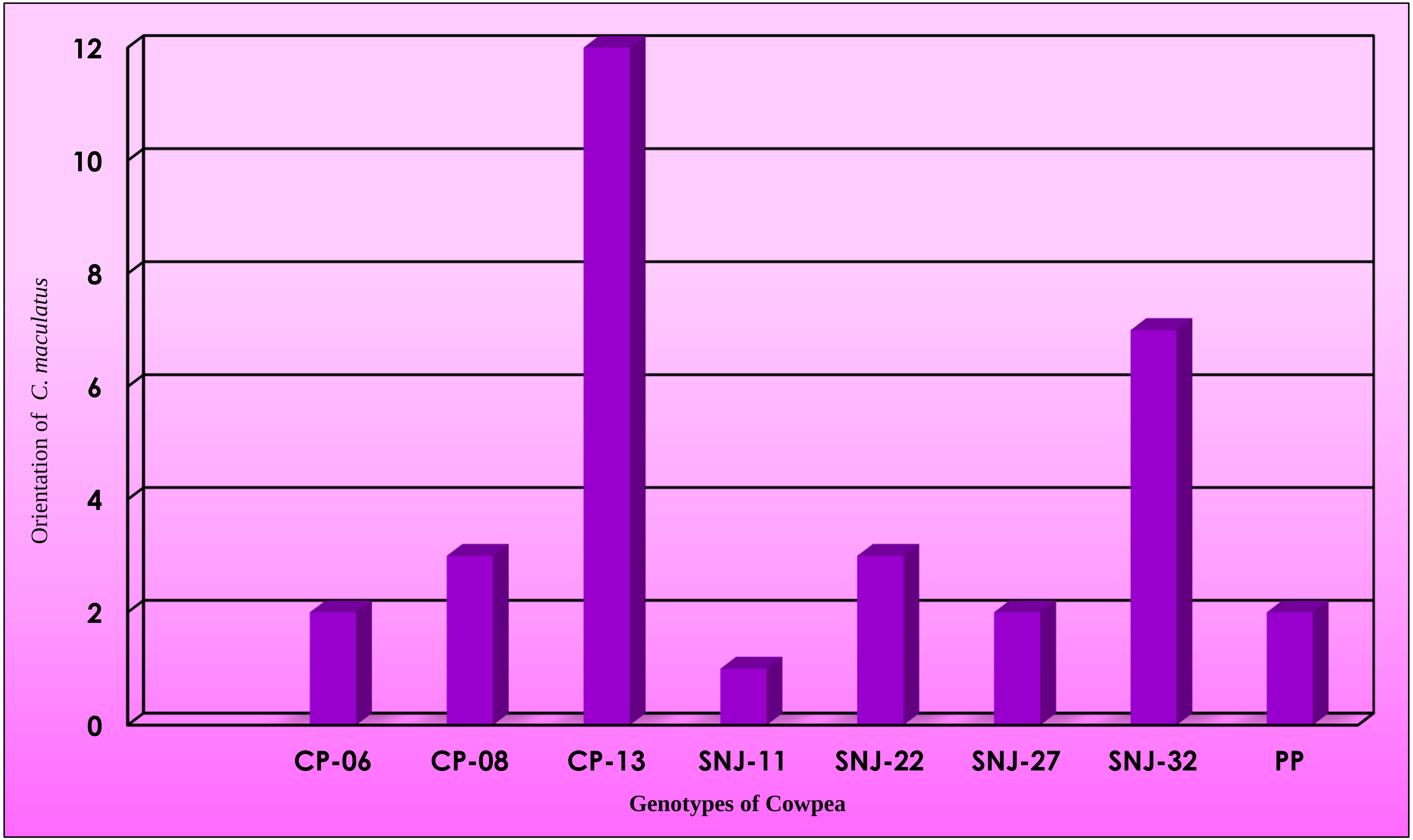

Fig 4.3 Orientation of *C. maculatus* on different genotypes of cowpea (Cumulative data- 24hrs.+ 48 hrs.)

4.1.2 Ovipositional preference of *C. maculatus* on different genotypes of cowpea under 'Free choice test'

The data recorded on ovipositional preference using free choice test is presented in Table 4.2 and depicted in Figure 4.4. From the data it is evident that, pulse beetle showed marked variation for oviposition to all tested cowpea genotypes. However, among the tested genotypes, SNJ-11 was observed to be the least preferred (11.67 eggs) by *C. maculatus* for oviposition which was significantly superior to rest of the genotypes. The genotypes CP-06 (15.33 eggs) and SNJ-27 (15.67 eggs) were found to be the next least preferred genotypes followed by SNJ-11. Whereas, the genotype CP-13 was the most preferred genotype for oviposition by *C. maculatus* with highest number of eggs laid (27.67 eggs).

Table 4.2 Ovipositional preference of *C. maculatus* on different cowpea genotypes placed in olfactometer under 'free choice test'

Sr. No.	Cowpea genotypes	No. of eggs laid
1.	CP-06	15.33(4.039) *
2.	CP-08	19.00 (4.471)
3.	CP-13	27.67 (5.353)
4.	SNJ-11	11.67 (3.555)
5.	SNJ-22	17.33 (4.279)
6.	SNJ-27	15.67 (4.080)
7.	SNJ-32	24.33 (5.027)
8.	PP	17.00 (4.242)
	Mean	18.50(4.381)
	S.E.m.±	0.089
	C.D.@5%	0.274

(*Figures in parenthesis are square root transformed values)

4.2 Study of developmental period of *C. maculatus* on different cowpea genotypes

Observations on different parameters regarding development of pulse beetle *viz.*, fecundity, hatching percentage, adult emergence, per cent seed weight loss, adult longevity and total life cycle were recorded separately. The results of the present study were statistically analyzed and presented under following subheadings.

4.2.1 Fecundity

The adult female laid eggs singly on the surface of cowpea seed. The eggs were oval or spindle shaped which were clear, shiny and firmly adhered to the seed (Plate No. VIII).

The observations recorded on average number of eggs laid by *C. maculatus* until death on 50gram seeds of different genotypes of cowpea are presented in Table 4.3 and depicted in figure 4.5.

From the data it is evident that, there were significant differences among the different treatments. The average number of eggs laid by *C. maculatus* ranged from 113.67 to 147.33 eggs per 50g seeds. The lowest number of eggs (113.67 eggs/50g seed) were laid on the genotype

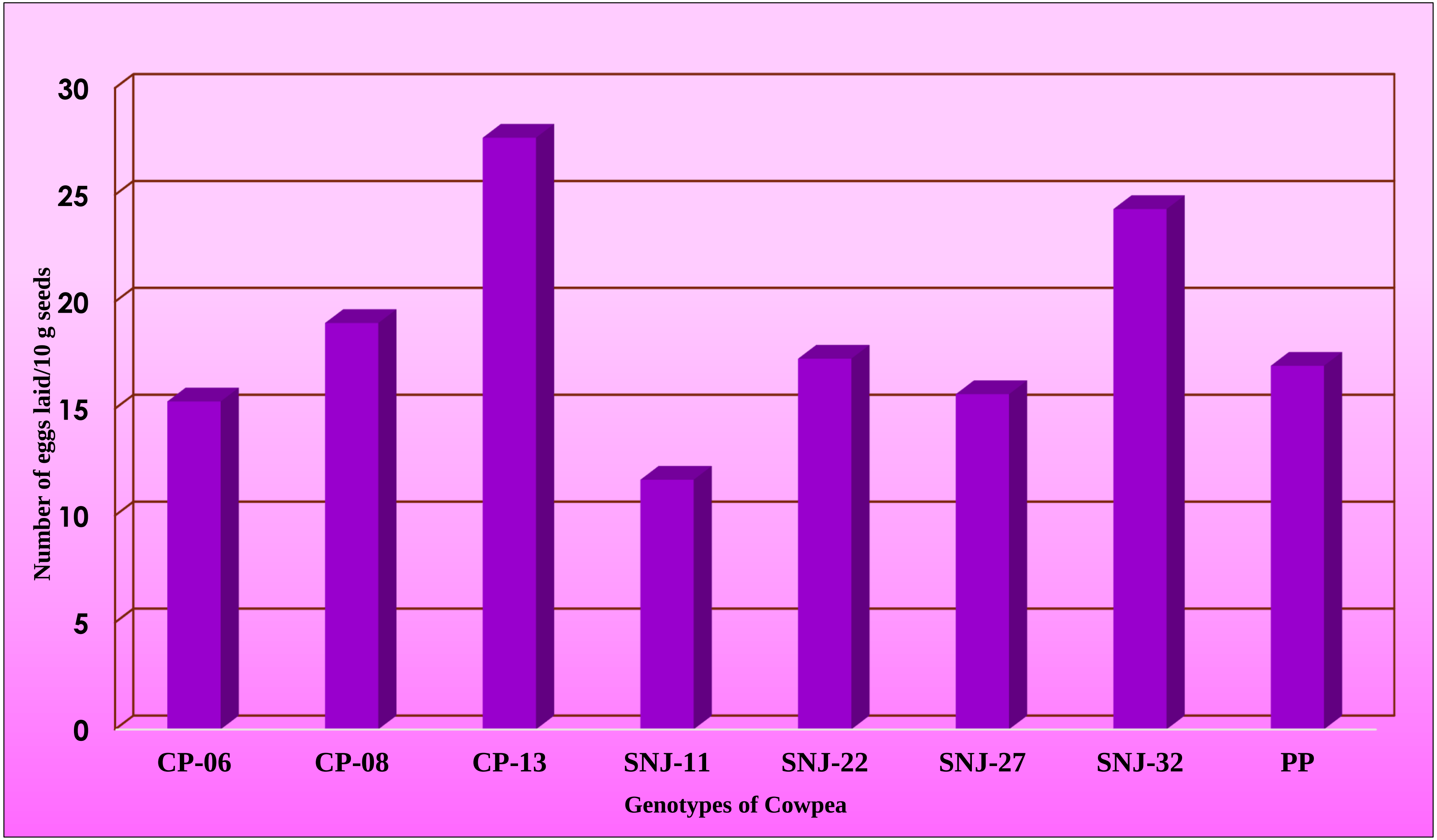

Fig 4.4 Ovipositional preference of *C. maculatus* on different cowpea genotypes placed in olfactometer under 'free choice test.

SNJ-11 which was significantly superior to rest of the treatments, followed by genotype CP-06 (125.33 eggs/50g seed), however, it was at par with SNJ-27 (129.33 eggs/50g seeds).

Genotype CP-13 recorded the highest egg laying (147.33 eggs/50g seed), followed by genotype SNJ-32 (143.33 eggs/50g seed), CP-08 (140.67 eggs/50g seed) and SNJ-22 (138.33 eggs/50g seed).

Table 4.3 Fecundity of *C. maculatus* on different genotypes of cowpea

Sr. No.	Cowpea genotypes	Average No. of eggs laid/ 50g seeds
1.	CP-06	125.33 (11.240) *
2.	CP-08	140.67 (11.902)
3.	CP-13	147.33 (12.179)
4.	SNJ-11	113.67 (10.707)
5.	SNJ-22	138.33 (11.804)
6.	SNJ-27	129.33 (11.416)
7.	SNJ-32	143.33 (12.014)
8.	PP	131.67 (11.518)
	Mean	133.71 (11.598)
	S.E.m.±	0.071
	C.D.@5%	0.217

(*Figures in parenthesis are square root transformed values)

4.2.2 Incubation period and hatching percentage

Data recorded on incubation period of *C. maculatus* on eight different genotypes of cowpea are presented in Table 4.4 and depicted in Figure 4.6.

From the data it is seen that, the incubation period of *C. maculatus* was ranged between 3.25 to 5.50 days in all the tested genotypes. The maximum incubation period was observed in genotype SNJ-32 (5.50 days) however it was significantly at par with genotype PP (5.25 days). The minimum incubation period was observed in genotype SNJ-22 (3.25 days). The average incubation period was found to be 4.38 days.

The grub hatched out from the egg, bored through the seed coat and entered into seed endosperm by directly boring into the seed. As the grub entered into the seed, the egg became opaque white.

The observations regarding number of eggs hatched were recorded and presented in Table 4.5 and depicted in Figure 4.7. From this data the hatching percentage was calculated, statistically analyzed and presented in Table 4.5 and depicted in Figure 4.8.

The data presented in Table 4.5 indicated that, there is marked variation (50% to 86.67%) in hatching percentage in the tested genotypes of cowpea and the overall average percentage of hatching was 70.83 per cent. The lowest hatching percentage was observed in genotype SNJ-11 (50.00 %) which was at par with genotype PP (56.67%), CP-06 (66.67%), SNJ-22 (70.00%) and significantly superior over rest of the genotypes. The highest hatching percentage was recorded in genotype CP-13 (86.67%), followed by genotypes SNJ-32(83.33%), CP-08(76.67%), SNJ-27(76.67%), SNJ-22(70%) and CP-06(66.67%).

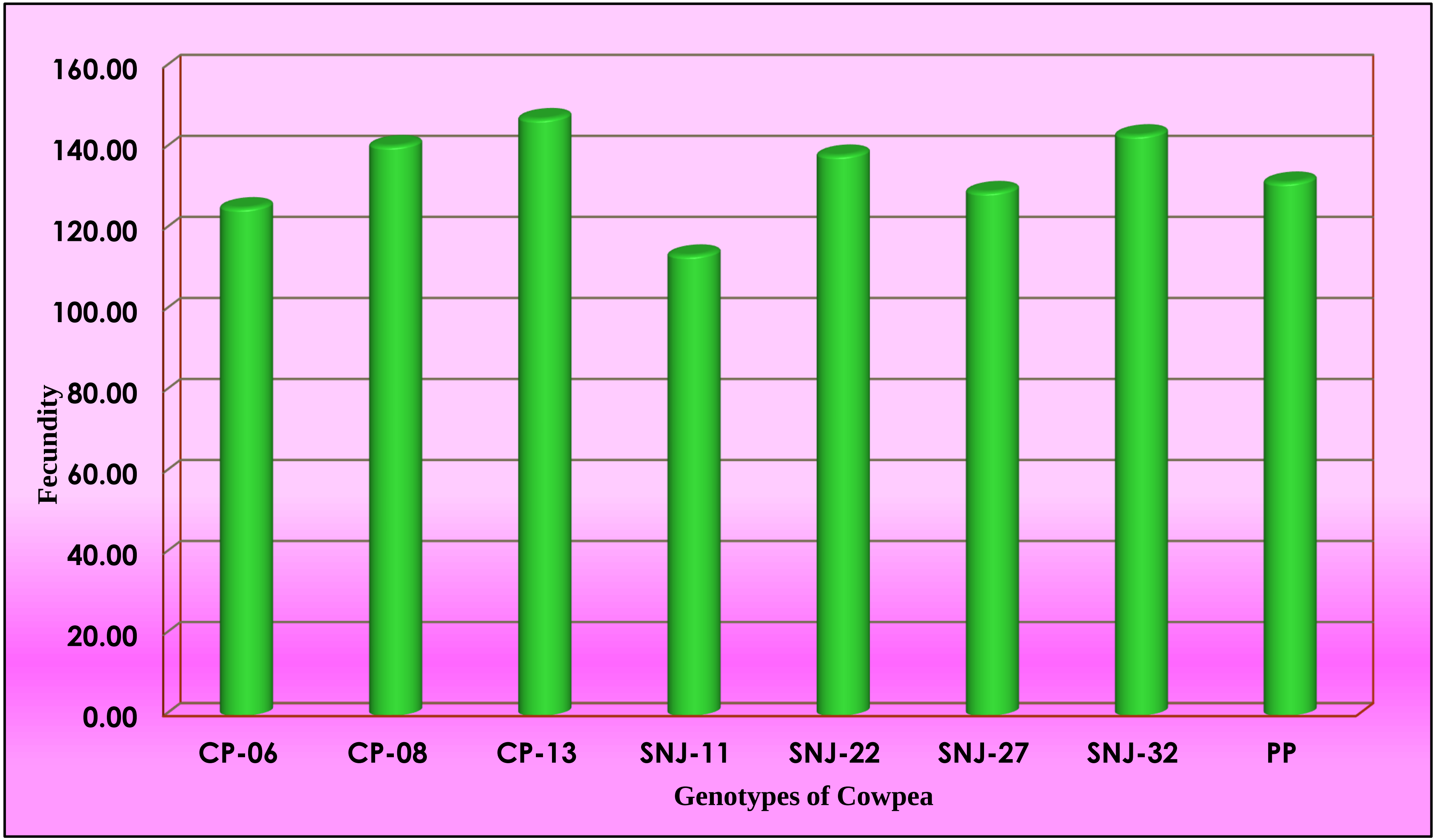

Fig 4.5 Fecundity of *C. maculatus* on different genotypes of cowpea

Table 4.4 Incubation period of *C. maculatus* on different genotypes of cowpea.

Sr. No.	Cowpea genotypes	No. of eggs observed	Incubation Period (Days)	
			Range	Average
1.	CP-06	10	3-6	4.25 (2.18) *
2.	CP-08	10	3-6	3.50 (2.01)
3.	CP-13	10	3-6	3.75 (2.06)
4.	SNJ-11	10	3-6	5.00 (2.34)
5.	SNJ-22	10	3-6	3.25 (1.94)
6.	SNJ-27	10	3-6	4.50 (2.24)
7.	SNJ-32	10	3-6	5.50 (2.45)
8.	PP	10	3-6	5.25 (2.40)
	Mean			4.38 (2.21)
	S.E.m.±			0.03
	C.D.@5%			0.09

(* Figures in parenthesis are square root transformed values)

Table 4.5 Number of eggs hatched and hatching percentage of *C. maculatus* eggs on different genotypes of cowpea.

Sr. No.	Cowpea genotypes	Eggs hatched (per 10 eggs)	Hatching percentage
1.	CP-06	6.67(2.759) *	66.67(55.053) **
2.	CP-08	7.67(2.936)	76.67(61.898)
3.	CP-13	8.67(3.108)	86.67(68.898)
4.	SNJ-11	5.00(2.444)	50.00(44.982)
5.	SNJ-22	7.00(2.828)	70.00(56.766)
6.	SNJ-27	7.67(2.936)	76.67(61.898)
7.	SNJ-32	8.33(3.051)	83.33(66.613)
8.	PP	5.67(2.58)	56.67(48.826)
	Mean	7.83(2.83)	70.83(58.108)
	S.E.m.±	0.119	4.39
	C.D.@5%	0.365	13.45

(*Figures in parenthesis are square root transformed values)
(**Figures in the parentheses are arc sine values)

4.2.3 Adult Emergence

The data recorded on adult emergence of *C. maculatus* from eight different cowpea genotypes are presented in Table 4.6 and depicted in Figure 4.9. From the data it is evident that, the adult emergence of *C. maculatus* ranged between 27.00 to 49.72 per 50 g seeds of different genotypes of cowpea. The least number of adults (27.00) emerged in the genotype SNJ-11 which was significantly superior over rest of the genotypes. The maximum numbers of adults (49.72) were found emerged in the genotype CP-13. None of genotype was found to be totally resistant to bruchid attack.

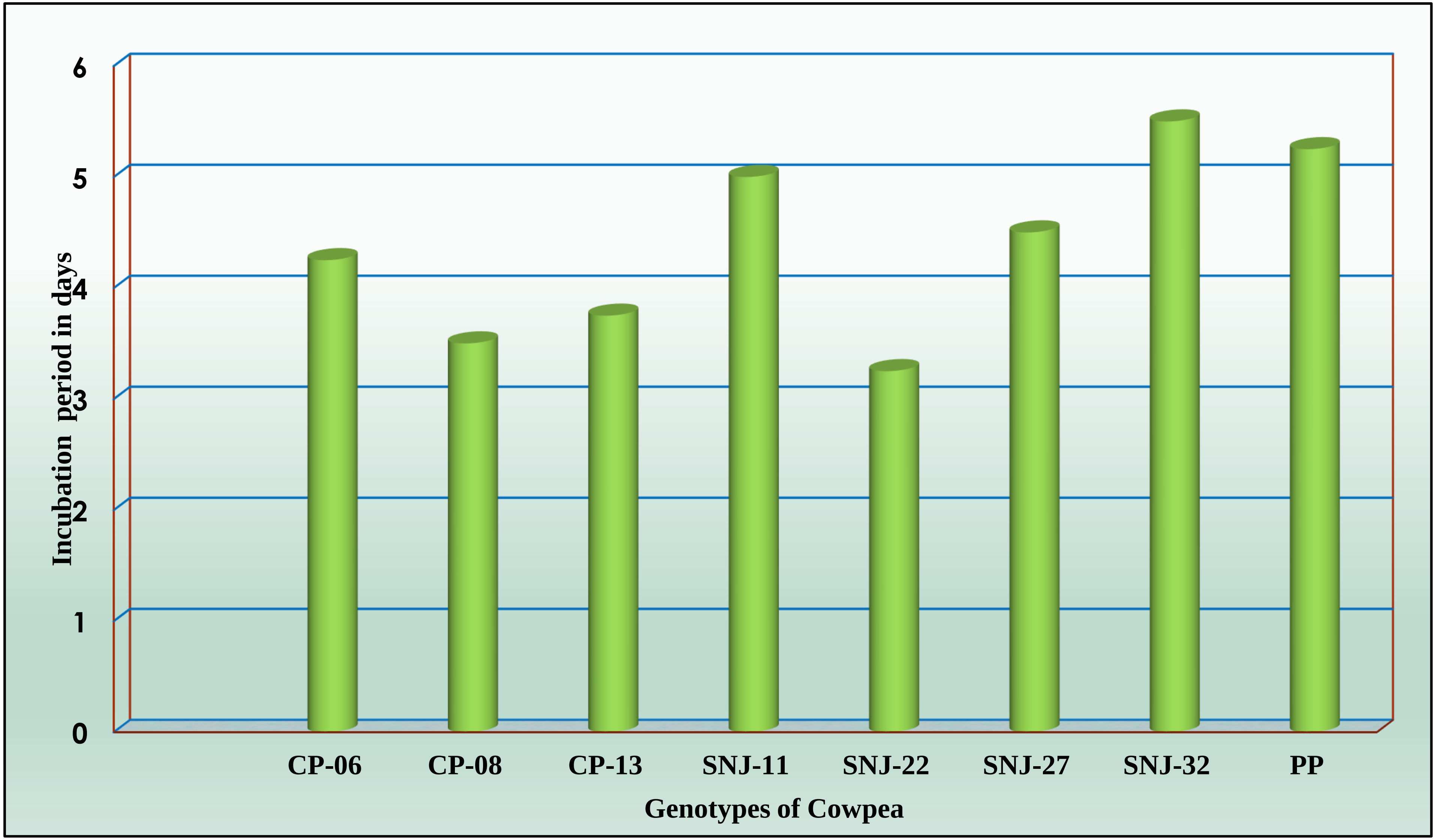

Fig 4.6 Incubation period of *C. maculatus* eggs on different genotypes of cowpea.

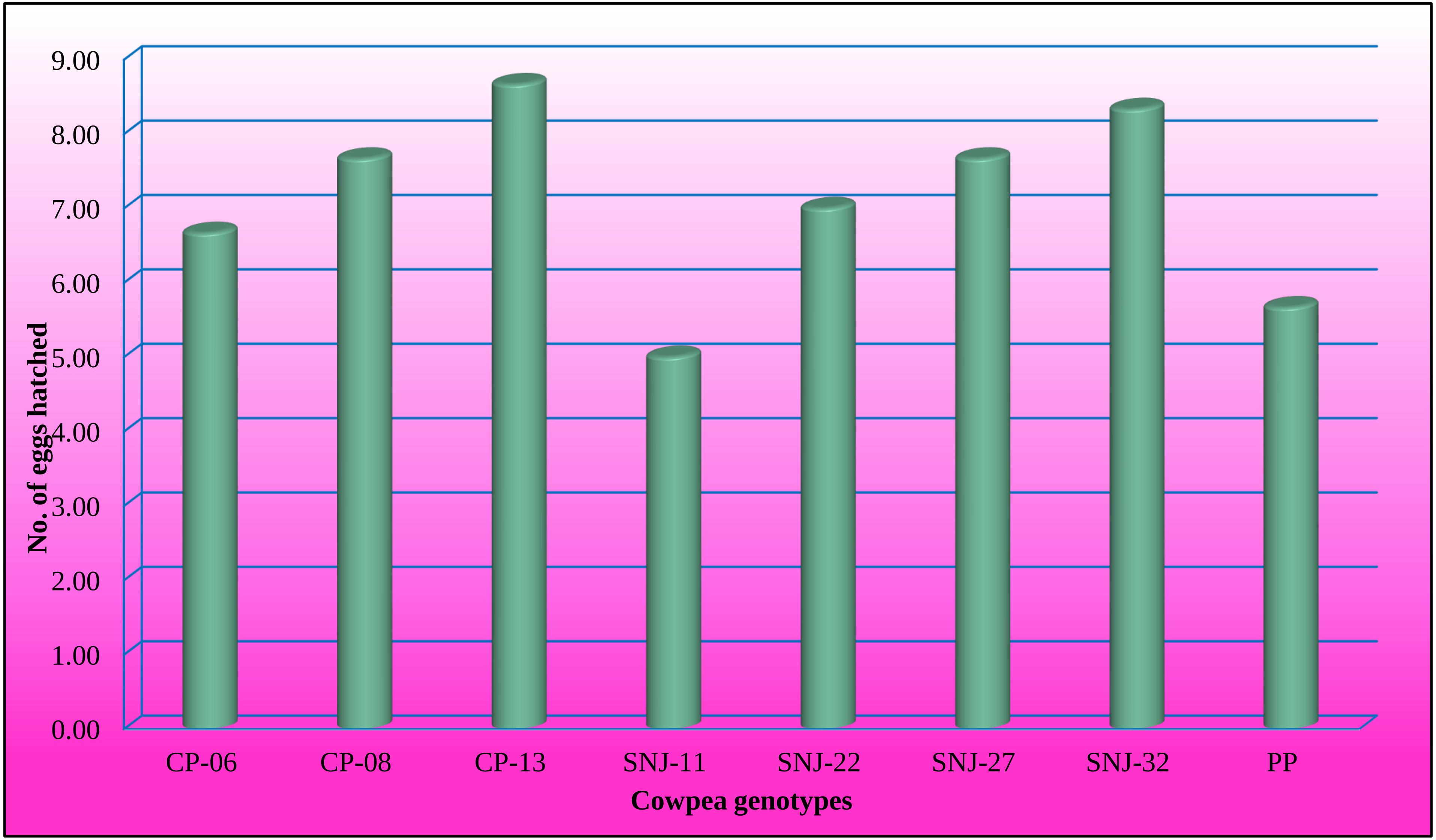

Fig 4.7 Number of eggs hatched on different genotypes of cowpea

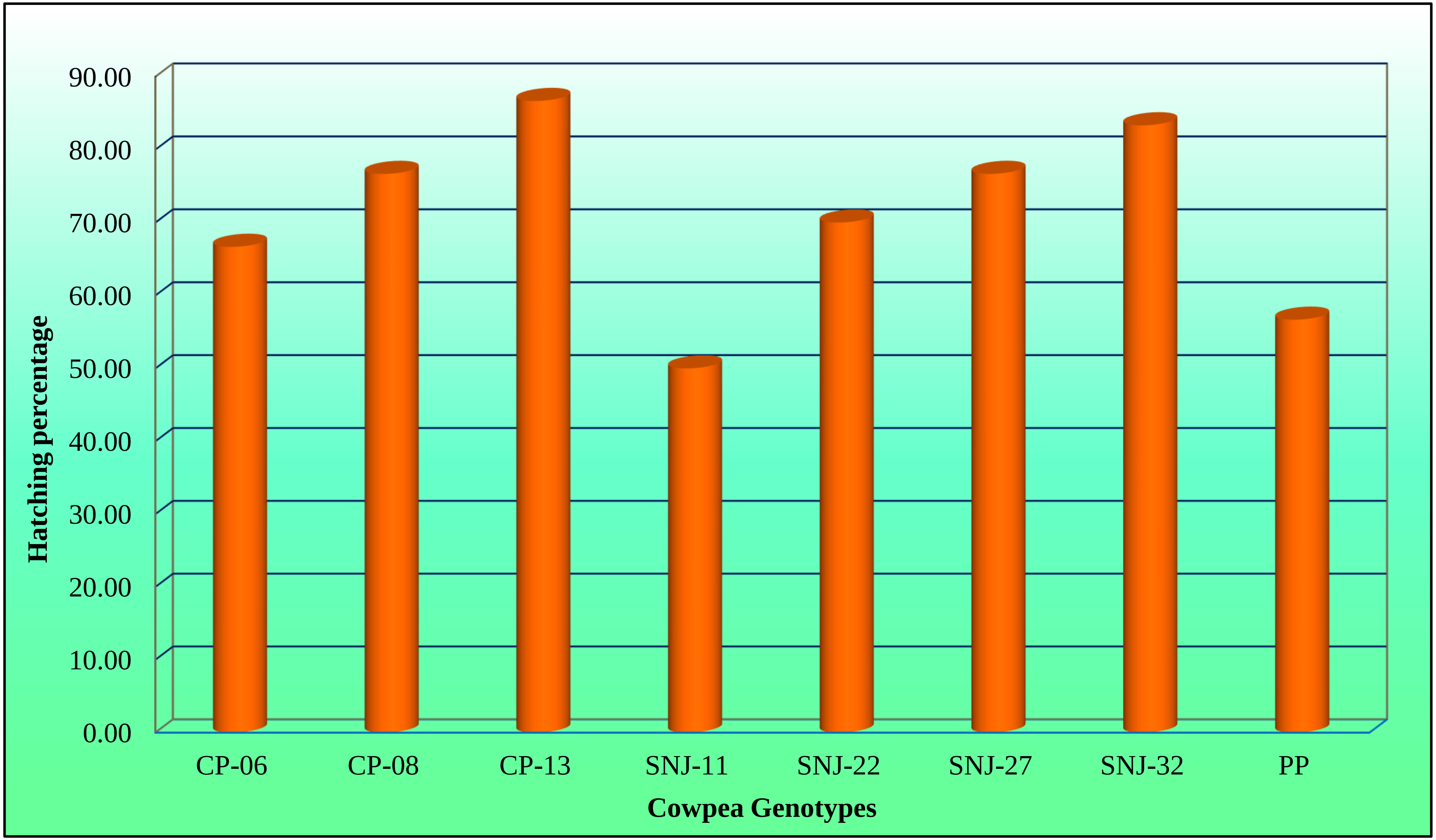

Fig 4.8 Hatching percentage of *C. maculatus* on different genotypes of cowpea

Table 4.6 Adult emergence of *C. maculatus* in different cowpea genotypes

Sr. No.	Cowpea genotype	Mean no. of adults emerged/ 50g seeds
1.	CP-06	37.33 (6.16) *
2.	CP-08	38.33 (6.27)
3.	CP-13	49.72 (7.09)
4.	SNJ-11	27.00 (5.24)
5.	SNJ-22	37.33 (6.15)
6.	SNJ-27	38.00(6.21)
7.	SNJ-32	36.12(6.05)
8.	PP	37.21(6.14)
	Mean	37.73(6.16)
	S.E.m.±	0.101
	C.D.@5%	0.306

(*Figures in parenthesis represents square root transformed values)

4.2.4 Adult longevity

The data obtained on adult longevity of pulse beetle, *C. maculatus* on different cowpea genotypes is presented in Table 4.7 and depicted in Figure 4.10. The data showed that the adult longevity varied in the range of 7.40 to 9.20 days. In CP-13 genotype, the mean adult longevity of 7.4 days was observed which was the lowest amongst all other genotypes but it was at par with CP-08(7.80 days) and SNJ-32 (7.90 days) and significantly superior over rest of the treatments. The highest adult longevity of 9.2 days was observed in genotype SNJ-22.

Table 4.7 Effect of different genotypes of cowpea on longevity of adults of *C. maculatus*

Sr. No.	Cowpea genotypes	Total no. of adults observed	Average Adult longevity (In days)
1.	CP-06	10	8.34
2.	CP-08	10	7.80
3.	CP-13	10	7.40
4.	SNJ-11	10	8.30
5.	SNJ-22	10	9.20
6.	SNJ-27	10	8.53
7.	SNJ-32	10	7.90
8.	PP	10	8.40
	Mean		8.23
	S.E.m.±		0.27
	C.D.@5%		0.83

4.2.5 Total life cycle

The bruchid undergo different life stages such as egg, grub, pupa, adult. The total life cycle of pulse beetle completed inside the seed itself. Upon hatching from the egg, the grub entered in the grain. The grub burrowed into the seed endosperm and embryo, undergone a series of moults, and burrowed just beneath the seed coat before pupation. At the location where the beetle pupated, there was a round window of 1-2 mm visible through the seed coat. In order to emerge from the

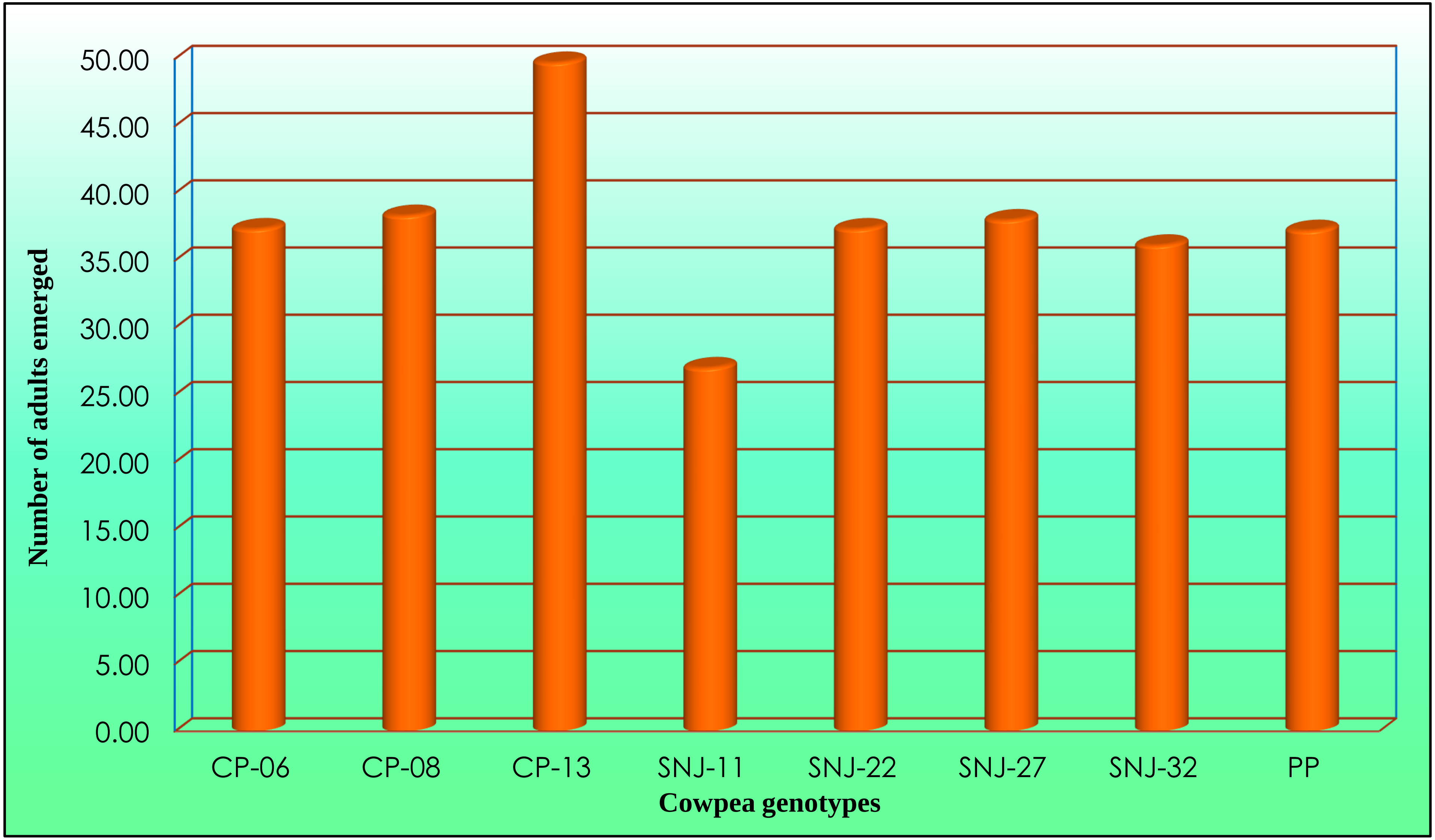

Fig 4.9 Adult emergence of *C. maculatus* in different cowpea genotypes

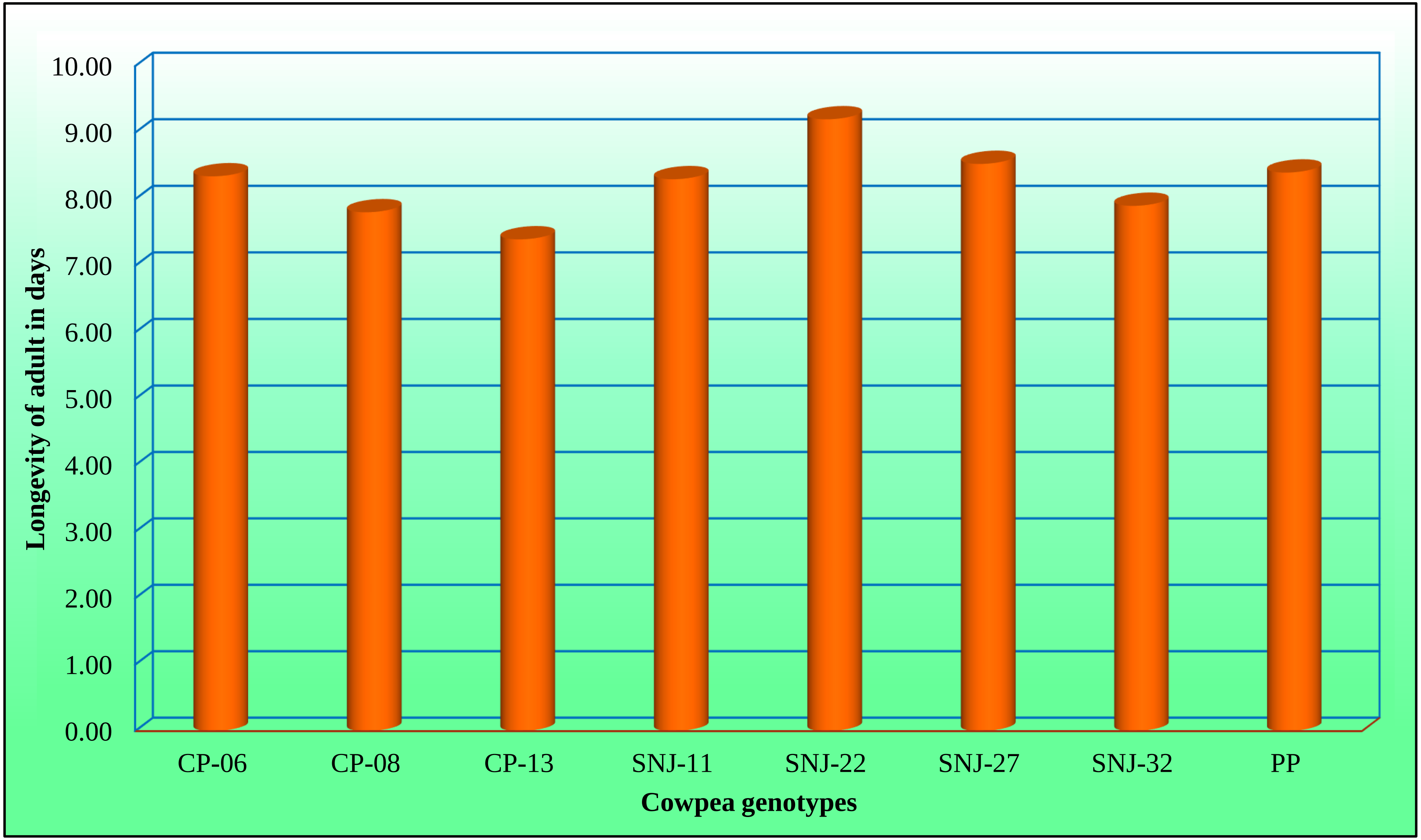

Fig 4.10 Effect of different genotypes of cowpea on longevity of adults of *C. maculatus*.

cowpea seed, the adult came out by breaking the seed coat. The total life cycle of *C. maculatus* includes days required from egg laying to emergence of adults from the seed. In the current study, the observations regarding total time needed to complete the total life cycle in eight cowpea genotypes was recorded and presented in Table 4.8 and depicted in Figure 4.11.

From the data it is evident that, the average number of days to complete life cycle of *C. maculatus* on different cowpea genotypes ranged from 22.63 to 27.77 days. The minimum life cycle period of *C. maculatus* was observed on genotype CP-13 (22.63 days) which was at par with genotype SNJ-22 (23.68 days), SNJ-11 (24.58 days) and SNJ-32 (24.89 days) and significantly superior over rest of the genotypes. The maximum life cycle period was recorded in genotype PP (27.77 days) followed by CP-06 (27.62 days).

Table 4.8 Effect of different genotypes of cowpea on total life cycle of *C. maculatus*

Sr. No.	Cowpea genotypes	Total life cycle (in days)
1.	CP-06	27.62
2.	CP-08	25.49
3.	CP-13	22.63
4.	SNJ-11	24.58
5.	SNJ-22	23.68
6.	SNJ-27	26.38
7.	SNJ-32	24.89
8.	PP	27.77
	Mean	25.41
	S.E.m.±	0.85
	C.D.@5%	2.63

4.2.6 Per cent seed weight loss

The data recorded on per cent weight loss in the seed weight of different genotypes of cowpea due to *C. maculatus* are presented in Table 4.9 and depicted in Figure 4.12.

The data on mean per cent weight loss ranged from 3.88 to 8.48 per cent which was found statistically significant. The minimum weight loss in cowpea seed was recorded in genotype CP-06 (3.88 %) which was at par with genotypes PP (4.51 %), SNJ-22 (4.56 %), SNJ-32 (4.61%), SNJ-27 (4.74%) and significantly superior over rest of the treatments. The maximum weight loss (8.48%) was observed in genotype CP-13.

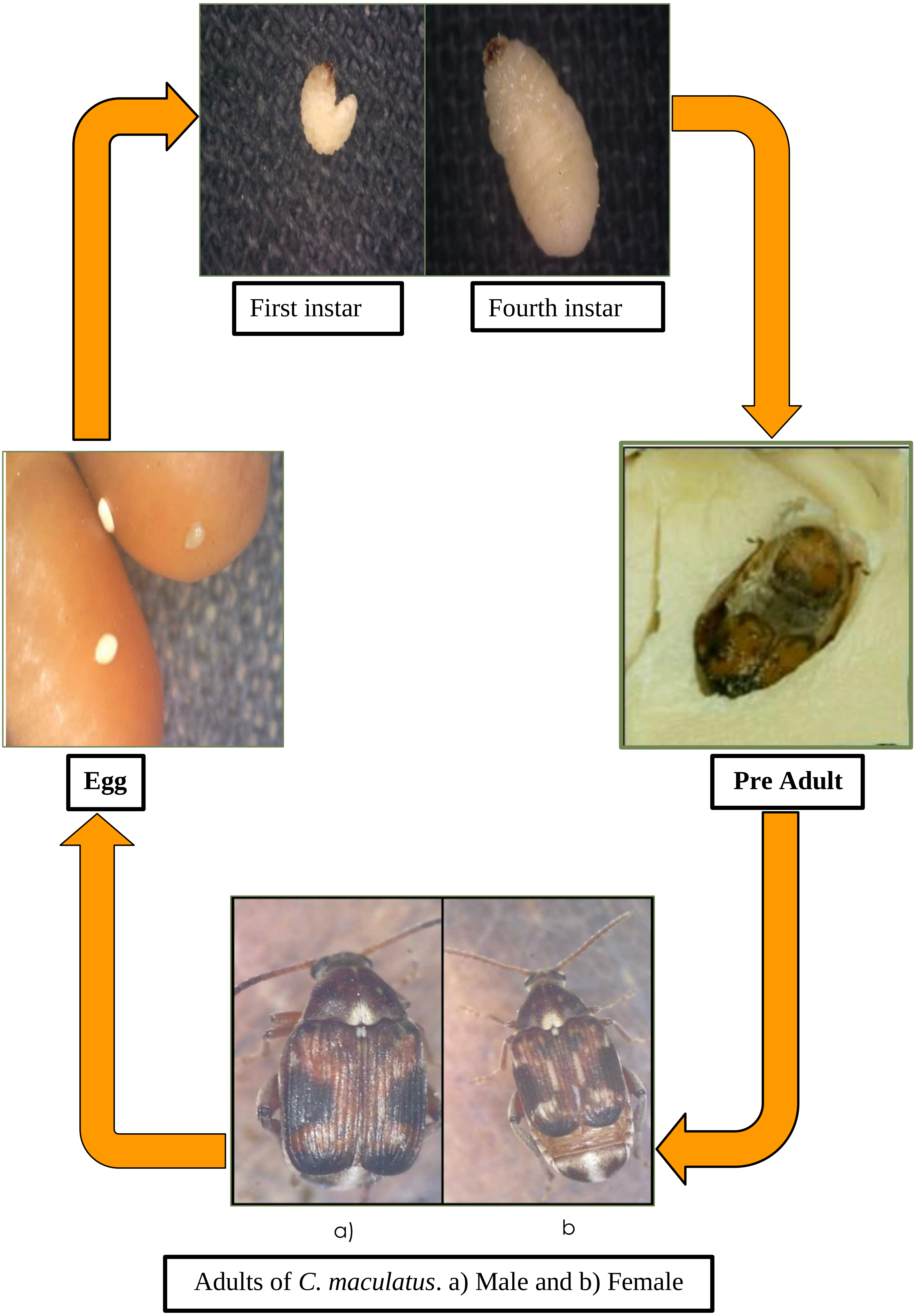

Plate 8. Different stages in life cycle of pulse beetle, *C. maculatus*.

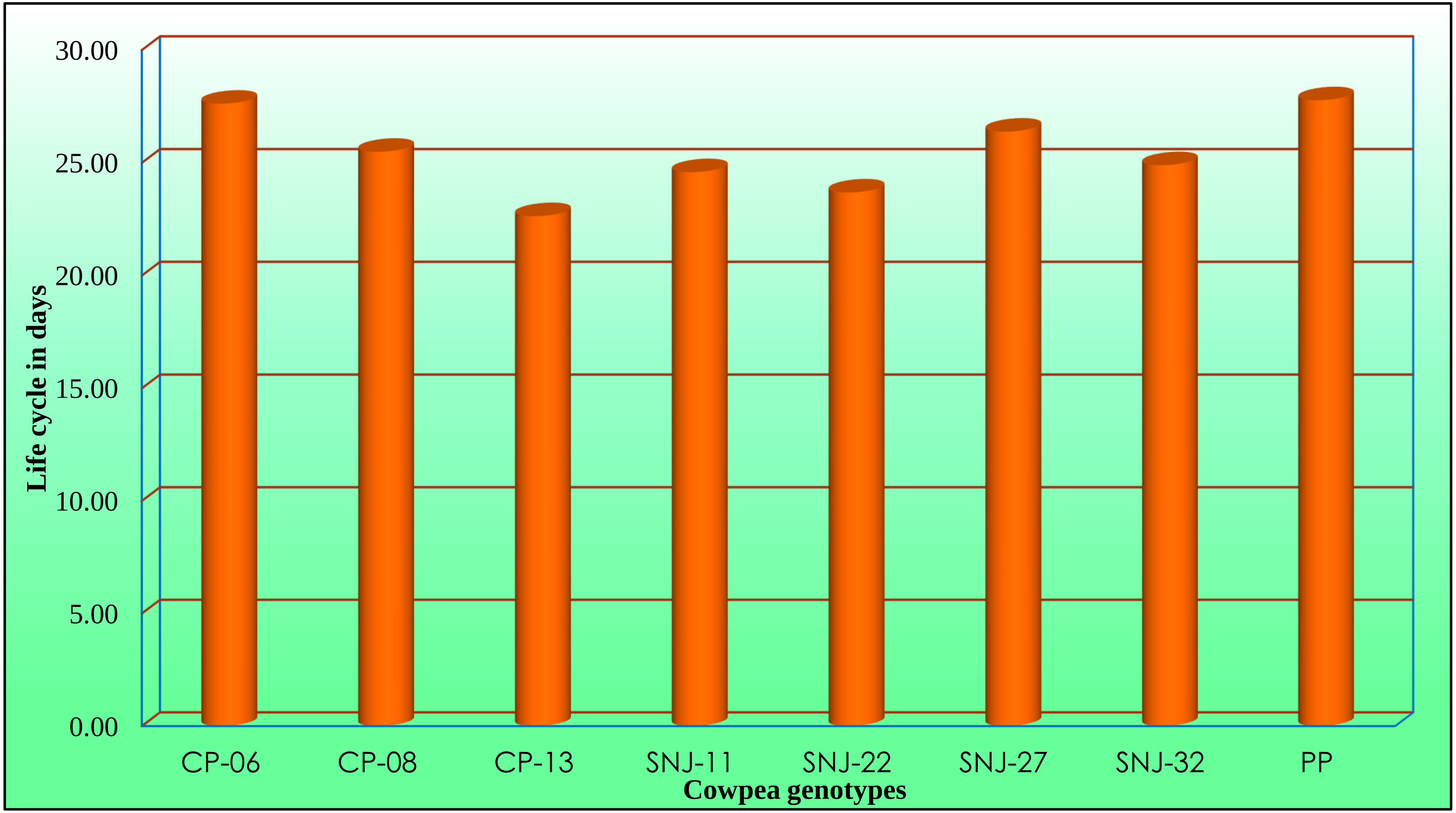

Fig 4.11 Effect of different genotypes of cowpea on total life cycle of *C. maculatus.*

Table 4.9 Per cent weight loss in different genotypes of cowpea due to *C. maculatus* infestation.

Sr. No.	Cowpea genotypes	Mean per cent weight loss
1.	CP-06	3.88 (11.379) *
2.	CP-08	6.82 (15.234)
3.	CP-13	8.48 (16.92)
4.	SNJ-11	5.73(13.85)
5.	SNJ-22	4.56 (12.32)
6.	SNJ-27	4.74(12.59)
7.	SNJ-32	4.61(12.39)
8.	PP	4.51(12.26)
	Mean	5.42(13.36)
	S.E.m.±	0.799
	C.D.@5%	2.422

(*Figures in parenthesis are arc sin transformed values)

4.3 Study of effect of different 'Indigenous Traditional Knowledges' (ITK's) for management of *C. maculatus*

To avoid the hazardous residues of chemical pesticides, farmers are using different plant products and locally available botanicals on the basis of Indigenous Traditional Knowledge. In the present investigation different botanicals including different plant products such as neem leaf powder, karanj leaf powder, vekhand powder, turmeric powder, eucalyptus oil and inert materials such as wood ash and fine sand were used for management of *C. maculatus* in Konkan Safed variety of cowpea. The data generated on per cent mortality and per cent germination of seed are presented in Table 4.10 and 4.11.

4.3.1 Effect of different ITKs on per cent mortality of pulse beetle, *Callosobruchus maculatus* (Fab.)

The observations on per cent mortality of *C. maculatus* were recorded at 3 and 5 days after treatment and presented in Table 4.10 and depicted in Figure 4.13 and 4.14.

4.3.1.1 Effect on adult mortality at 3 days after treatment

From the data recorded at 3 days after treatment, it is evident that all the ITK treatments were effective for management of *C. maculatus*. However, the maximum per cent mortality of *C. maculatus* (76.67%) was observed in the treatment T_6 (Eucalyptus oil) which was statistically at par with T_3 (Vekhand powder), T_2 (Karanj leaf powder), T_5 (Wood ash), T_1 (Neem leaf powder) and T_7 (Sand) and found significantly superior over T_4 (Turmeric powder). Vekhand powder treatment (T_3) was observed to be the second best treatment for management of *C. maculatus* at 3 days after treatment with 66.67 per cent mortality. The treatment T_4 (Turmeric powder) was observed to be the least effective treatment with only 50 per cent adult mortality of *C. maculatus* 3 days after treatment.

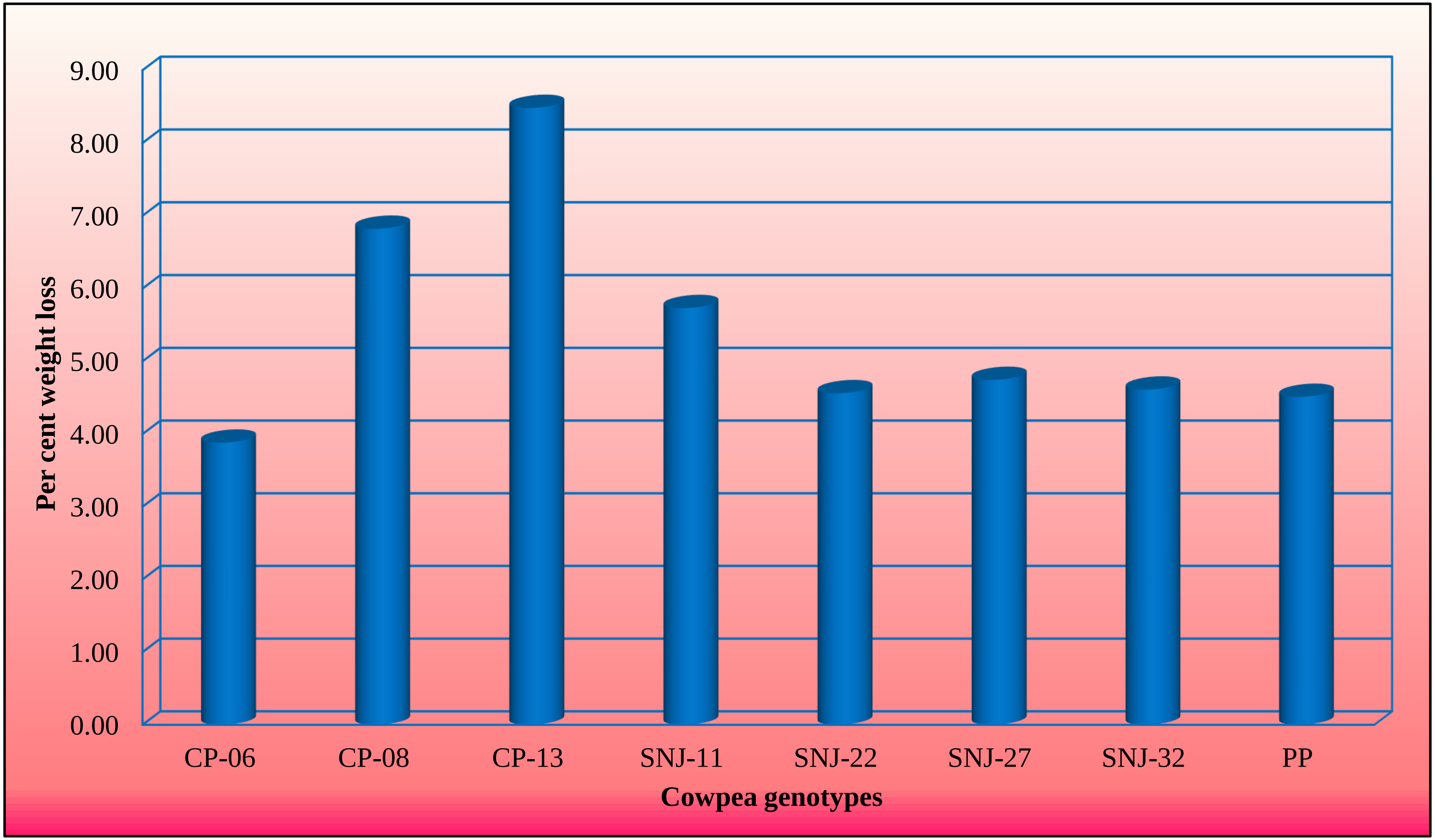

Fig 12. Per cent weight loss in different genotypes of cowpea due to *C. maculatus* infestation.

4.3.1.2. Effect on adult mortality at 5 days after treatment

The data recorded on per cent mortality of *C. maculatus* on treated cowpea seeds at 5 days after treatment is presented in Table 4.10. From the data it is found that at 5 days after treatment, complete mortality (100 %) of adults of *C. maculatus* was observed in the seeds treated with eucalyptus oil (T_6), however, it was statistically at par with T_3 (Vekhand powder), T_5 (Wood ash), T_7(Sand), T_1(Neem leaf powder) and T_2 (Karanj leaf powder). Vekhand powder treatment (T_3) was observed to be the second best treatments for management of *C. maculatus* at 5 DAT with 88.89 per cent mortality, however, it was statistically at par with all rest of the treatments.

Table 4.10 Effect of different ITKs on per cent mortality of *C. maculatus* in cowpea (Cultivar: Konkan safed)

Sr. No.	Treatments	Dose per kg seed	Per cent mortality	
			3DAT	5DAT
1.	Neem leaf powder	10g	53.33 (47.30) *	83.33 (70.21)
2.	Karanj leaf powder	10g	63.33 (52.78)	83.33 (70.21)
3.	Vekhand powder	2.5g	66.67 (54.78)	88.89 (78.25)
4.	Turmeric powder	10g	50.00(45.00)	67.94 (55.76)
5.	Wood ash	10g	60.00 (50.85)	85.00 (71.14)
6.	Eucalyptus oil	10ml	76.67 (61.92)	100 (90.00)
7.	Fine sand	1kg	53.33 (47.30)	72.22 (63.25)
8.	Untreated control	-	0.0 (00.00)	0.0 (00.00)
	Mean		52.92 (44.99)	72.59 (62.33)
	S.E.m.±		4.89	9.2
	C.D.@5%		14.82	27.92

(*****Figures in parenthesis are arc sin transformed values)
(DAT- Days after treatment)

4.3.2 Effect of different ITKs on germination percentage of cowpea seed

The effect of different ITKs was studied on germination of cowpea seeds. On the basis of seed germination, the germination percentage was calculated and recorded in Table 4.11 and Figure 4.15.

From the data it is evident that, there are no significant differences observed in germination percentage. The germination percentage in different treatments ranged from 84.67 to 88.00 per cent. The maximum seed germination (88.00%) was observed in treatment of wood ash and the minimum seed germination (84.67%) was observed in the treatment of untreated control.

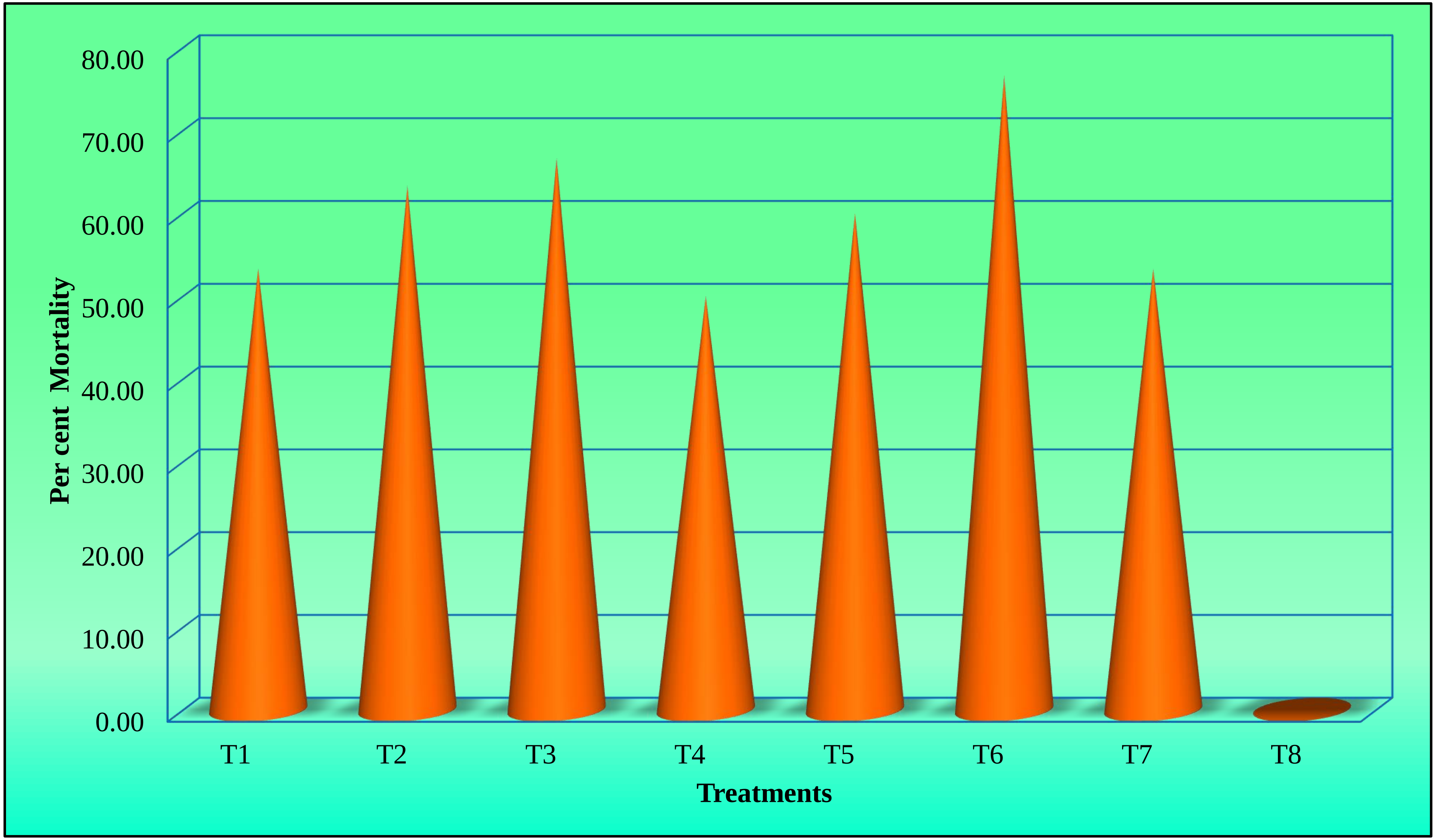

Fig 4.13 Effect of different ITKs on per cent mortality of *C. maculatus* three days after treatment in cowpea

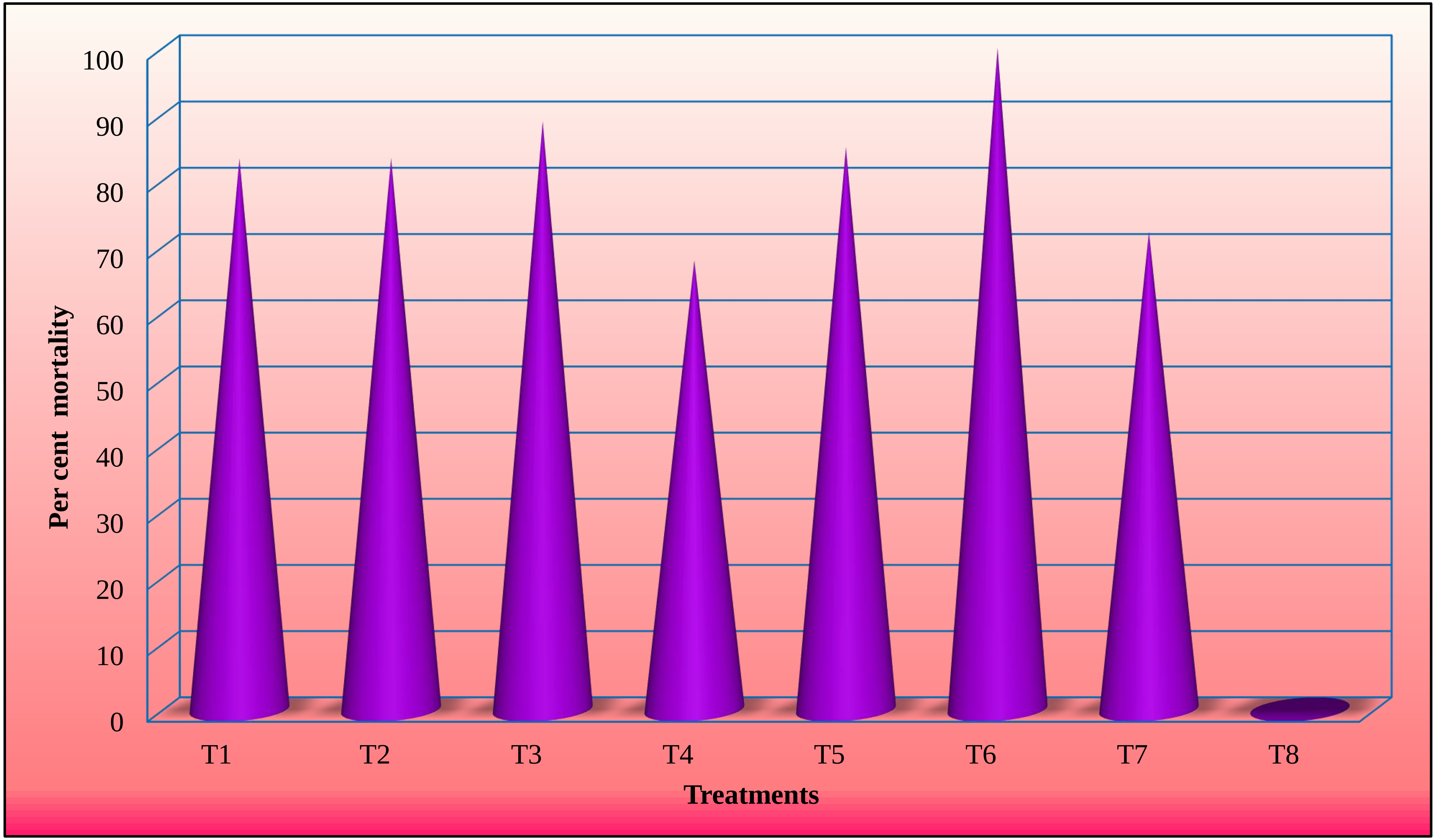

Fig 4.14 Effect of different ITKs on per cent mortality of *C. maculatus* five days after treatment in cowpea .

Table 4.11 Effect of different ITKs against *C. maculatus* on per cent germination of cowpea seeds (Cultivar: Konkan safed)

Sr. No.	**Treatments**	**Dose per kg seed**	**Mean seed germination (%)**
1.	Neem leaf powder	10g	87.29 (69.33)
2.	Karanj leaf powder	10g	87.82(69.80)
3.	Vekhand powder	2.5g	87.33 (69.39)
4.	Turmeric powder	10g	87.00 (69.02)
5.	Wood ash	10g	88.00 (69.90)
6.	Eucalyptus oil	10ml	87.76 (69.64)
7.	Fine sand	1kg	85.33 (67.61)
8.	Untreated control	-	84.67 (66.98)
	Mean		86.90 (69.06)
	S.E.m.±		2.65
	C.D.@5%		NS

(*Figures in parenthesis are arc sin transformed values).

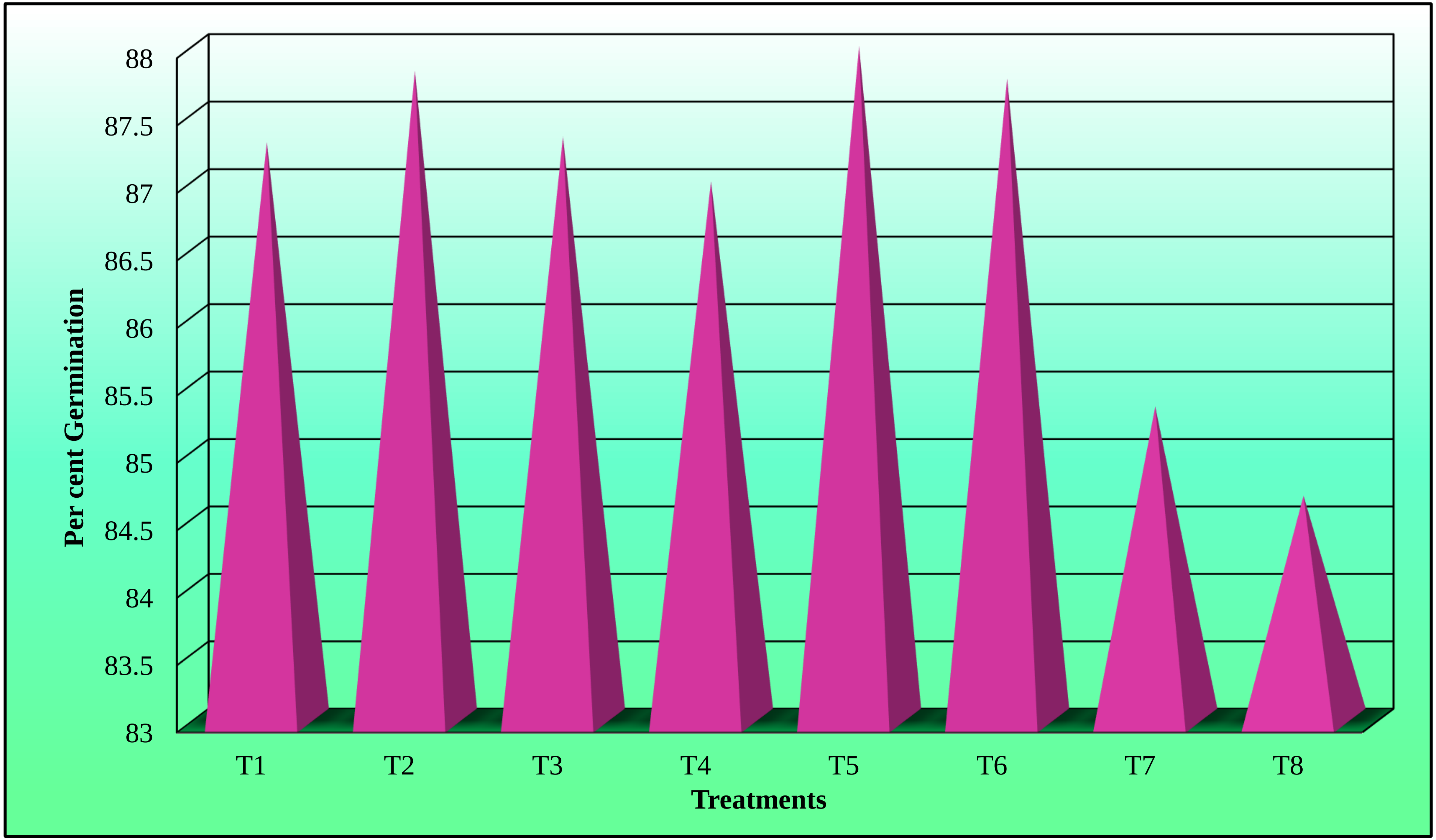

Fig 4.15 Effect of different ITKs used against *C. maculatus* on per cent germination of cowpea seeds.

DISCUSSION

The present experiment entitled, "Management of pulse beetle, *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae) infesting cowpea, *Vigna unguiculata* (L.)" was conducted at laboratory of Department of Agricultural Entomology, College of Agriculture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist- Ratnagiri 415 712 during the year 2020-21 and 2021-22. The results of the experiment are presented in the preceding part of this chapter and discussed under following sub-headings.

4.5 Study of ovipositional preference of *C. maculatus* to different cowpea genotypes.
4.6 Study of developmental period of *C. maculatus* on different cowpea genotypes.
4.4 Study of effect of different 'Indigenous Traditional Knowledges' (ITK's) for management of *C. maculatus.*

4.5 Study of ovipositional preference of *C. maculatus* to different cowpea genotypes.

Pulse beetle, *C. maculatus* (Fab.) is a major store grain pest infesting cowpea. The different genotypes of cowpea selected for present study were tested for orientation and ovipositional preference of pulse beetle to find out the most susceptible genotypes.

The data pertaining to orientation of *C. maculatus* on different genotypes of cowpea are presented in Table 4.1. From the data it was observed that the highest number of adults (12 adults) were attracted towards genotype CP-13 (6 at 24 hrs. and 6 at 48 hrs. after release) followed by genotype SNJ-32 (7 adults). The least adults were attracted towards genotype SNJ-11 (1 adult). The genotypes CP-06, SNJ-27 and PP attracted only 2 adults of *C. maculatus*.

These observations on orientation of *C. maculatus* are in accordance with Shinde (2019) who recorded the orientation of 3 and 4 adults towards cowpea seeds at 24 hrs. and 48 hrs. after release.

The data recorded on ovipositional preference of *C. maculatus* towards different genotypes of cowpea under free choice test in olfactometer are presented in Table 4.2. From the data, it is evident that, the genotype SNJ-11 was observed to be the least preferred (11.67 eggs) by *C. maculatus.* Whereas, the most preferred genotype for oviposition by *C. maculatus* was CP-13 with the highest number of eggs laid (27.67).

Many other workers have studied the ovipositional preference of *C. maculatus* on different cowpea varieties/genotypes. Dabi *et al*. (1979) examined the reaction of different cowpea varieties to *C. maculatus* and reported that, the genotype RS-9 was the least susceptible, whereas, the varieties RS-42, RS-118 and NO-5-19-4-1 were the most susceptible to *C. maculatus*. Messina and Renwick (1985) reported that, among the different cowpea genotypes tested against cowpea bruchids, two lines (IT81D-985 and IT81D-1137) of cowpea with rough seed coat were resistant to bruchid larvae with non-preference resistance to ovipositing adults. Mueke (1991) reported that among the ten different cowpea varieties tested, VITA-5 was the least preferred for oviposition by

C. maculatus. Shivanna *et al.* (2011) reported that, the cowpea variety CP-17 was the least preferred for oviposition by *C. maculatus*. Tripathi *et al.* (2020) reported that among different cowpea varieties tested, EC528387 variety was the least preferred by *C. maculatus* for oviposition. The differences observed in the ovipositional preference of *C. maculatus* reported by other workers may be due use of different cowpea genotypes.

4.6 Study of developmental period of *C. maculatus* on different cowpea genotypes

Different developmental parameters of *C. maculatus viz.*, fecundity, incubation period, hatching percentage, adult emergence, adult longevity and total life cycle were studied during present investigation. The per cent seed weight loss was also recorded separately on different cowpea genotypes.

4.6.1. Fecundity

The observations recorded on average number of eggs laid by *C. maculatus* until death on 50g seeds of different genotypes of cowpea are presented in Table 4.3. From the data it is evident that, the average number of eggs laid by *C. maculatus* ranged from 113.67 to 147.33 eggs per 50g seeds. The lowest number of eggs (113.67 eggs/50g seed) were laid on the genotype SNJ-11, followed by genotype CP-06 (125.33 eggs/50g seed). Genotype CP-13 recorded the highest egg laying (147.33 eggs/50g seed), followed by genotype SNJ-32 (143.33 eggs/50g seed), CP-08 (140.67 eggs/50g seed) and SNJ-22 (138.33 eggs/50g seed).

The present results are more or less in conformity with Singh and Sharma (2003) who reported the fecundity of 98.1 to 99.5 egg in eight different varieties of cowpea. Tripathi *et al.* (2020) assessed 103 different cowpea varieties and reported that *C. maculatus* laid eggs ranging from 52.7 to 437 per 20 seeds. The lowest number of egg laying was observed in variety EC528387 (52.7 eggs). El Halfwy (1972) reported that, the average number of eggs laid by *C. maculatus* on blackeyed cowpea and fertriate cowpea were 62.4 and 39.4 eggs, respectively. Badii *et al.* (2013) reported the highest egg laying of *C. maculatus* in cowpea genotype SARC 3-122-2 (149.5 eggs) and the least number of eggs were laid on genotype SARC 1-132-1 (16 eggs). Ofuya and Credland (1995) studied the lifetime fecundity of *C. maculatus* on cowpea and inferred that, the fecundity was lowest in IT84S-275-9 cowpea variety. The differences observed in the fecundity of *C. maculatus* reported by other workers may be due use of different cowpea genotypes.

4.6.2. Incubation period and hatching percentage

Data recorded on incubation period of *C. maculatus* on eight different genotypes of cowpea are presented in Table 4.4. From the data it is seen that, the incubation period of *C. maculatus* was ranged between 3.25 to 5.50 days in all the tested genotypes. The maximum incubation period was observed in genotype SNJ-32 (5.50 days). The minimum incubation period was observed in genotype SNJ-22 (3.25 days). The average incubation period was found to be 4.38 days.

These observations are in accordance with Seddiqi (1972) who reported the average incubation period of *C. maculatus* as 5.50 days on cowpea. Also, Jadhav *et al.* (2015a.) reported that, the incubation period of *C. maculatus* on different cowpea varieties ranged from 3.86 to 4.41 days. Sharma *et al.* (2016) recorded the average incubation period of 4 to 5 days in V-578 variety of cowpea. Jaiswal *et al*. (2018) reported the incubation period of *C. maculatus* as 4.15 ± 0.87 days in chickpea. Augustine and Balikai (2019) studied the incubation period of pulse beetle in DC-15 variety of cowpea which was ranged from 4 to 6 days with the mean of 4.6 ± 0.70 days. The differences observed in the incubation period of *C. maculatus* reported by other workers may be due use of different cowpea genotypes.

The observations regarding hatching percentage are presented in Table 4.5. The data on hatching percentage indicated that, there is marked variation (50% to 86.67%) in hatching percentage in the tested genotypes of cowpea and the overall average percentage of hatching was 70.83 per cent. The lowest hatching percentage was observed in genotype SNJ-11 (50.00 %) and the highest hatching percentage was recorded in genotype CP-13 (86.67%).

Adenekan *et al*. (2018) reported the highest egg hatching of 44 ± 4.1 at 30 ^{o}C. and the lowest hatching of 3.5 ± 1.0 eggs at 10 ^{o}C. The differences observed in the hatching percentage of *C. maculatus* reported by other workers may be due use of different cowpea genotypes.

4.6.3 Adult emergence

The data recorded on adult emergence of *C. maculatus* from eight different cowpea genotypes are presented in Table 4.6. From the data it is evident that, the adult emergence of *C. maculatus* ranged between 27.00 to 49.72 per 50 g seeds of different genotypes of cowpea. The least number of adults (27.00) emerged in the genotype SNJ-11, whereas, the maximum number of adults (49.72) were found emerged in the genotype CP-13. None of genotype was found to be totally resistant to bruchid attack.

These results are more or less in conformity with Fawki *et al.* (2012) who reported the highest adult emergence of 90.42% in cowpea variety dokki-331. Badii *et al.* (2013) studied the adult emergence of *C. maculatus* in twenty two genotypes of cowpea and reported the adult emergence in the range of 8.3 to 11.3. Manohar and Yadav (1990) concluded that among different pulses tested, cowpea showed highest adult emergence (70 to 90 %) of pulse beetle. Also, Javaid *et al.* (1993) reported the comparatively higher adult emergence of *C. maculatus* on black eye variety of cowpea than other evaluated land races. The differences observed in the adult emergence of *C. maculatus* reported by other workers may be due use of different cowpea genotypes.

4.6.4 Adult longevity

The data obtained on adult longevity of pulse beetle, *C. maculatus* on different cowpea genotypes is presented in Table 4.7. The data showed that the adult longevity varied in the range of 7.40 to 9.20 days. In CP-13 genotype, the mean adult longevity of 7.4 days was observed which was the lowest amongst all other genotypes. The highest adult longevity of 9.2 days was observed in genotype SNJ-22.

These results are nearly matching with some earlier workers. Seddiqi (1972) reported the adult longevity of pulse beetle as 6.5 days in cowpea. Also, Kazemi *et al*. (2009) noted the adult longevity of 5.87 ± 0.08 days of *C. maculatus* in cowpea. Sharma *et al.* (2016) recorded the adult longevity of *C. maculatus* ranging from 8-15 days in V-578 variety of cowpea. The differences observed in the adult longevity of *C. maculatus* reported by other workers may be due use of different cowpea genotypes.

4.6.5 Total life cycle

The observations regarding total time needed to complete the life cycle in eight cowpea genotypes was recorded and presented in Table 4.8. From, the data it is evident that, the average number of days to complete life cycle of *C. maculatus* on different cowpea genotypes ranged from 22.63 to 27.77 days. The minimum life cycle period of *C. maculatus* was observed on genotype CP-13 (22.63 days). The maximum life cycle period was recorded in genotype PP (27.77 days) followed by CP-06 (27.62 days).

These obtained results are more or less supported by Senthilraja and Patel (2020). They recorded total life cycle period of *C. maculatus* ranging from 19.67 to 22.67 days in different genotypes of cowpea. Sharma *et al.* (2016) recorded the average total life cycle of 8 to 15 days in different genotypes of cowpea. El Halfwy (1972) studied the total life of cycle *C. maculatus* in black eyed cowpea and fertriate cowpea from egg to adult which lasted for 26 and 29 days, respectively. Badii *et al.* (2013) reported the total life cycle of 21.5 days as the highest and 18.5 days as the lowest in different genotypes of cowpea. Gill and Ramzan (1998) reported the life cycle of *C. maculatus* on green gram as 35.35 days in the months of October- November. Singal (1998) reported the total life cycle period of pulse beetle as 35.5 days in laboratory conditions which is somewhat more than our findings. Jaiswal *et al*. (2018) recorded total developmental period of pulse beetle in chickpea was 32.85 ± 3.42 days. The differences observed in the total life cycle of *C. maculatus* reported by other workers may be due use of different cowpea genotypes.

4.6.6 Per cent weight loss

The data recorded on per cent weight loss in the seed weight of different genotypes of cowpea due to *C. maculatus* are presented in Table 4.9. The data on mean per cent weight loss ranged from 3.88 to 8.48 per cent. The minimum weight loss in cowpea seed was recorded in genotype CP-06 (3.88 %) and the maximum weight loss (8.48%) was observed in genotype CP-13.

Deshpande *et al.* (2011) recorded the least weight loss of 8.87 per cent in IC20278 variety of cowpea. Badii *et al.* (2013) recorded the weight loss of 4.3-9.6% in SARC 1-132-1, SARC 3-90-2 and SARC 3-103-1 genotypes of cowpea. Senthilraja and Patel (2021) reported little higher weight loss (13.03 to 24.92%) in different varieties of cowpea due to feeding of *C. maculatus*. The differences observed in the per cent weight loss of *C. maculatus* reported by other workers may be due use of different cowpea genotypes.

4.7 Study of effect of different 'Indigenous Traditional Knowledges' (ITK's) for management of *C. maculatus*

The data on effect of different ITKs against *C. maculatus* infesting seeds of cowpea on per cent mortality and per cent germination are presented in Table 4.10 and 4.11. These results are presents and discussed below.

4.7.1. Effect of different ITKs on per cent mortality of pulse beetle, *Callosobruchus maculatus* (Fab.)

The data on per cent mortality of *C. maculatus* was recorded at 3 and 5 days after treatment with different ITKs and presented in Table 4.10. At both intervals the treatment eucalyptus oil of @ 10 ml/kg was found to be the most effective with 76. 60 and 100 per cent mortality at 3 and 5 DAT, respectively which was followed by vekhand powder @ 2.5g/kg with 66.67 and 88.89 per cent mortality at 3 and 5 DAT, respectively. However, the other ITK treatments except turmeric powder were found equally effective for management of *C. maculatus*. Seed treatment with turmeric powder was found to be the least effective treatment (50.00 % at 3 DAT and 67.94 % at 5 DAT).

Similar results have been recorded by Idoko and Ileke (2020). They reported the highest mortality (73.33%) of *C. maculatus* when the seeds were treated with eucalyptus oil (*Eucalyptus globulus* Labill) to the cowpea seeds. Sousa Neto *et al*. (2019) reported neem leaf powder as effective treatment of management of *C. maculatus* in cowpea. Shukla *et al*. (2008) reported 100 per cent mortality of pulse beetle when treated with vekhand powder to chickpea seeds. Shaheen and Khaliq (2005) observed 100 per cent mortality of pulse beetle when treated with fly ash @ 1g/50g seeds of chickpea.

4.7.2. Effect of different ITKs on germination percentage of cowpea seed

The effect of different ITKs was studied on germination of cowpea seeds (Konkan Safed). On the basis of seed germination, the germination percentage was calculated and recorded in Table 4.11. From the data it is evident that, there are no significant differences observed in germination percentage. The germination percentage in different treatments ranged from 84.67 to 88.00 per cent. The maximum seed germination (88.00%) was observed in treatment of wood ash and the minimum seed germination (84.67%) was observed in the treatment of untreated control.

Chiranjeevi (1991) reported that, the seed germination of green gram seeds was not adversely affected by any of the treatments against *C. maculatus.* Patil (2000) recorded the highest germination of chickpea seeds which were treated with neem leaf powder. Also, Khatun *et al*

(2012) observed the same in case of lentil seeds which were treated with neem leaf powder, which produced the highest per cent germination (86.0 and 87.2%) over the two years. Gidanganti (1990) reported that cowpea seed treatment with 5g/kg vekhand powder maintained the higher seed germination along with the seed protection. Swamy *et al.* (2018) recorded the germination of 93.45 per cent in the seeds of blackgram, when stored under sand layer in the modified bin.

SUMMARY AND CONCLUSIONS

CHAPTER V

SUMMARY AND CONCLUSION

Pulses are proved to be the substantial source of digestible protein in our regular nourishment. In all the pulses, the cowpea is considered a smart food. Due to its superior nutritional properties, in this century, it is referred to as the food legume of the 21st century. However, due to the presence of different storage grain pests, substantial obstacles in the yield and storge of cowpea aroused in recent years. Among all the store grain pests, pulse beetle, *Callosobruchus maculatus* (Fab.) is main reason of annihilation of stored cowpea. For management of this pest farmers are using different chemicals which are having many side effects like resistance and residue, thereby causing pollution in the environment which makes them unsuitable for consumption and also, sometimes for sowing. In recent years, legislations are also made to discourage the use of chemicals for storage pest management. Therefore, considering the need for alternative and economic management of pulse beetle, the present investigation entitled 'Management of pulse beetle, *Callosobruchus maculatus* (Fab.) (Coleoptera: Chrysomelidae) infesting cowpea, *Vigna unguiculata* (L.)' was taken as research work in the laboratory of Department of Agril. Entomology, College of Agriculture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (Maharashtra) for the academic year 2021-22.

For this research work, the culture of pulse beetle, *C. maculatus* was collected and maintained properly on seeds of cowpea in the laboratory. The different stages of development of pulse beetle, *C. maculatus* on eight different genotypes of cowpea *viz.*, CP-06, CP-08, CP-13, SNJ-11, SNJ-22, SNJ-27, SNJ-32 and PP were studied. By using free choice test, the preference and orientation of pulse beetle was tested on the eight genotypes of cowpea. For management of pulse beetle in Konkan safed variety of cowpea, seven different ITK based products *viz.*, neem leaf powder (10g/kg), karanj leaf powder (10g/kg), vekhand powder (2.5g/kg), turmeric powder(10g/kg), wood ash(10g/kg), eucalyptus oil(10ml/kg), fine sand(1kg/kg) were tested. The results obtained by this study are summarized as under.

The data recorded on the orientation of adults of *C. maculatus* at the intervals of 24 hrs. and 48 hrs. to eight different genotypes showed that, the maximum *i.e.*, 12 adults were seen to be oriented to CP-13 genotype which was followed by SNJ-32 towards which 7 adults were oriented. On genotype SNJ-11 the least number of adults were found oriented (1 adult).

The ovipositional preference of *C. maculatus* to eight genotypes of cowpea was tested by using free choice test and the results revealed that the genotype SNJ-11 was found to be the least preferred by *C. maculatus* for oviposition (11.67 eggs), which was significantly superior to rest of the genotypes. Whereas, the most preferred genotype for oviposition was CP-13 on which maximum *i.e.*, 27.67 eggs were observed.

While studying the different developmental stages of *C. maculatus* on different genotypes of cowpea, the data recorded on fecundity of *C. maculatus* revealed that, the average number of eggs laid ranged from 113.67 to 147.33 eggs. The lowest number of eggs *i.e.*, 113.67 eggs were found laid on genotype SNJ-11. Whereas, the maximum number of eggs (147.33) were found laid on the genotype CP-13.

The observations recorded on incubation period of *C. maculatus* on different genotypes of cowpea indicated that, the incubation period ranged from 3.25 to 5.50 days in all the genotypes of cowpea with the overall mean of 4.38 days. Among all the tested genotypes, the minimum incubation period of 3.25 days was observed in genotype SNJ-22 and the maximum incubation period of 5.50 days was observed in genotype SNJ- 32.

On the basis of data recorded on hatching percentage of *C. maculatus* on different genotypes of cowpea it is seen that, the hatching percentage ranged from 50 to 86.67 per cent. The average hatching percentage was 70.83 per cent. In the genotype SNJ-11, the lowest hatching percentage of 50.00 per cent was observed and the maximum hatching percentage was recorded in genotype CP-13 (86.67%).

The observations recorded on adult emergence of *C. maculatus* on eight different genotypes of cowpea, revealed that the average adult emergence was 37.73 which was ranged from 27.00 to 49.72 per 50g seeds of cowpea. It was seen that in genotype SNJ-11, the least *i.e.,* 27 number of adults were emerged. While the maximum number of adults *i.e.,* 49.72 were emerged from genotype CP-13. From these observations it was also clear that, none of the genotype was completely resistant to the attack of pulse beetle.

The observations on adult longevity of *C. maculatus* on different cowpea genotypes revealed that, the variation in adult longevity was in the range of 7.40 to 9.20 days. The overall average adult longevity was 8.23 days. The least mean adult longevity (7.40 days) was observed in genotype CP-13. In genotype SNJ-22, the highest adult longevity of 9.2 days was recorded.

From the data recorded on total life cycle of pulse beetle, *C. maculatus* it is seen that, on an average 25.41 days were required to complete the total life cycle of *C. maculatus* in different genotypes of cowpea. The mean number of days required to complete the total life cycle of *C. maculatus* ranged from 22.63 to 27.77 days. On genotype CP-13, the minimum life cycle period of 22.63 days of *C. maculatus* was observed, whereas, the maximum life cycle period of 27.77 days was recorded in genotype PP.

The observations recorded on per cent weight loss of different genotypes of cowpea due to *C. maculatus* indicated that, the average per cent weight loss of all the genotypes of cowpea was 5.42 per cent. The mean per cent weight loss in cowpea genotypes due to *C. maculatus* ranged from 3.88 per cent to 8.48 per cent. The minimum weight loss of 3.88 per cent in cowpea seeds was observed in genotype CP-06, whereas, in genotype CP-13, the maximum weight loss of 8.48 per cent was observed.

For management trials the seeds of Konkan safed variety of cowpea were used. The data on per cent mortality of *C. maculatus* was recorded at 3 and 5 days after treatment with different ITKs. At both intervals the treatment of eucalyptus oil @ 10 ml/kg was found to be the most effective with 76. 60 and 100 per cent mortality at 3 and 5 DAT, respectively which was followed by vekhand powder @ 2.5g/kg with 66.67 and 88.89 per cent mortality at 3 and 5 DAT, respectively. However, the other ITK treatments except turmeric powder were found equally effective for management of *C. maculatus*. Seed treatment with turmeric powder was found to be the least effective treatment (50.00 % at 3 DAT and 67.94 % at 5 DAT).

The data recorded on effect of ITKs on per cent germination of cowpea seeds of Konkan safed variety revealed that, the maximum seed germination of 88 per cent was observed in the seeds treated with wood ash @ 10g/kg seeds and the minimum seed germination of 84.67 per cent was noticed in the treatment of untreated control.

On the basis of overall results obtained it can be concluded that,

The genotype SNJ-11 was observed to be the least preferred by *C. maculatus* for oviposition. Also, the minimum number of eggs were laid on the same genotype. The minimum hatching percentage, adult emergence was observed on the same genotype.

The genotype CP-13 was observed to be the most preferred by *C. maculatus for* oviposition. Also, the maximum number of eggs were laid on same genotype with maximum hatching percentage, adult emergence whereas the least adult longevity and total life cycle were observed respectively. The per cent seed weight loss was also more in the same genotype.

The highest mortality of *C. maculatus* was recorded in the treatment T_6 (eucalyptus oil @ 10ml/kg seeds) at both the intervals (3 and 5 DAT) and also has no adverse effect on germination of seeds.

The results obtained in this investigation are based on one season and one location data. Therefore, in order to arrive at definite conclusion, it is necessary to continue the studies with long duration trial.

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LITERATURE CITED

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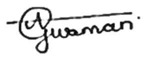
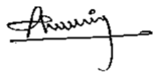
THESIS ABSTRACT

a)	Title of the thesis	: "Management of pulse beetle, *Callosobruchus maculatus* (fab.) (Coleoptera: Chrysomelidae) infesting cowpea, *Vigna unguiculata* (L.)"
b)	Full name of the student	: Waman Abhijit Gokul
c)	Name and address of the major advisor	: Dr. A. Y. Munj Junior Entomologist, Regional Fruit Research Station, Vengurle
d)	Degree to be awarded	: M.Sc. (Agri.)
e)	Year of award of degree	: 2022
f)	Major subject	: Agricultural Entomology
g)	Total pages in the thesis	: 53+v
h)	No. of words in the abstract	: 242
i)	Signature of student	
j)	Signature, Name and address of forwarding authority	 Dr. A. Y. Munj Junior Entomologist, Regional Fruit Research Station, Vengurle.

The laboratory experiment was carried out at laboratory of Department of Agricultural Entomology, College of Agricultural Dapoli, Ratnagiri Maharashtra during the year 2021-22 to study the 'Management of pulse beetle, *Callosobruchus maculatus* (fab.) (Coleoptera: Chrysomelidae) infesting cowpea, *Vigna unguiculata* (L.)'. Eight different genotypes of cowpea *viz.*, CP-06, CP-08, CP-13, SNJ-11, SNJ-22, SNJ-27, SNJ-32 and PP were examined for the orientation, oviposition and developmental period of *C. maculatus*. The cowpea variety Konkan safed was used for the management of *C. maculatus* and to work out the germination percentage using different ITK based plant products and the inert materials such as neem leaf powder, karanj leaf powder, vekhand powder, turmeric powder, wood ash, eucalyptus oil and fine sand. The overall study resulted that, the genotype SNJ-11 was observed to be the least preferred by *C. maculatus* for oviposition. Also, the minimum number of eggs (113.67 eggs) were laid on the same genotype with minimum hatching percentage (50%) and adult emergence (27.00 adults). For management, of *C. maculatus* the seed treatment of cowpea seeds with eucalyptus oil @10ml/kg was proved to be the most effective with cent per cent mortality of *C. maculatus* at 5 DAT. The seed treatment with vekhand powder was observed to be the next best treatment. The maximum germination percentage was observed in seeds treated with wood ash (88%); However, there was no any adverse effect on germination in the seeds treated with other ITKs.

Key words: *Callosobruchus maculatus,* cowpea, management.

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This letter confirms that manuscript titled **"To study the ovipositional preference and developmental stages of pulse beetle, *Callosobruchus maculatus* (fab.) (Coleoptera: Chrysomelidae) infesting different genotype of cowpea, *Vigna unguiculata* (L.)"** authored by **Abhijit Waman, Ajay Munj, Tushar Thorat and Arshad Shaikh** has been accepted for publication.

Corresponding author: Abhijit Waman

Yours Sincerely,

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