Bionomics of Whitefly, *Bemisia tabaci* on soybean cultivars and its management with *Beauveria bassiana*

THESIS

Submitted to the

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

In partial fulfilment of the requirement for

The Degree of

MASTER OF SCIENCE

In

AGRICULTURE

(Entomology)

By

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2017

CERTIFICATE – I

This is to certify that the thesis entitled, **"Bionomics of Whitefly, *Bemisia tabaci* on soybean cultivars and its management with *Beauveria bassiana***" *submitted in partial fulfillment of the requirement for the degree of* ***MASTER OF SCIENCE*** *in* ***Agriculture (Entomology)*** *of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by* ***Gopaldas Sneha Latha****,* I.D. No. **150105005** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

All the assistance and help received during the course of the investigation has been acknowledged by her.

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Date: / / 2017

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LIST OF SYMBOLS

Symbol	Abbreviation	Stands for
@		At the rate of
±		Plus or minus
%		Percentage
^{0}C		Degree Centigrade / celcius
#		Numbers
( )		Parenthesis
√		Square root
	Av.	Average
	BOD	Bio oxygen demand
	CD	Critical difference
	Cv	Cultivar
	D	Doses
	Day^{-1}	Per Day
	et al	Co-workers
	Etc	et cetera
	EPF	Entomopathogenic fungi
	Fig.	Figure
	Gm or gm	Gram
	h/Hrs/hrs	Hours
	HAT	Hours after treatment
	i.e	That is
	In vitro	Under controlled conditions
	L or l	Litre
	Max.	Maximum
	Min.	Minimum
	Mm	Millimeter
	MT	Metric tones
	MMT	Million metric tones

	ml^{-1}	Per milli litre
	no.	Number
	nos.	Numbers
	NS	Non significant
	PDA	Potato dextrose agar
	Psi	Pressure per square inch
	RH	Relative humidity
	S	Strain
	SEm ±	Standard error of mean
	Spp.	Species
	Temp.	Temperature
	UV	Ultra violet
	Viz.	Namely

Plate 8 : Different immature stages of whitefly, *Bemisia tabaci*

8 a Eggs (Encircled)

8 b Crawler

8 c Second instar nymph

8 d Third instar nymphs

Plate 8 : Different immature stages of whitefly, *Bemisia tabaci*

8 a Eggs (Encircled)

8 b Crawler

8 c Second instar nymph

8 d Third instar nymphs

8 e 4th instar nymphs or Psuedo pupae

Plate 9: "T" shaped adult emergence slit

Plate 10 : Adult whiteflies

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a globally important crop. It accounts approximately 50 percent of the total production of oilseed crops in the world with many possibilities of not only improving agriculture but also supporting industries. Among the legumes, the soybean is valued for its high protein and oil content (40 and 20%, respectively). It is a rich source of amino acids, vitamins and minerals. It also improves the soil fertility by fixing atmospheric nitrogen with the symbiosis of *Rhizobium japonica* microorganism. Hence, soybean has been designated as “Wonder crop” or “Golden bean” of the 20th century and “Miracle crop” of the 21st century (Mehto, 2016).

In India, the area, production and productivity of soybean during 2015-2016 was 11.60 million (M) ha, 7.13 million metric tonnes (MMT) and 0.61 Metric tonnes (MT)/ha, respectively (www.usda.com). In Madhya Pradesh, the area, production and productivity during 2015-16 was 5.9 M ha, 4.5 MMT, 0.76 MT/ha, respectively (www.seaofindia.com).

There is a gradual reduction in the soybean yield because of various problems in the field, such as interference from plant intruder organisms (pests and diseases).The pests of soybean attack the leaves, pods and stems. Whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is one of the most serious, cosmopolitan sucking pest that causes severe yield losses in soybean. It can lead to damage either directly or indirectly (Hoodle, 2013). Direct damage occurred when the stylet of whitefly pierces the leaves and suck the liquid that causes chlorosis in plants. While, the indirect damage occurs due to the accumulation of honeydew that catalyses the growth of sooty mold on the entire surface of the leaf and disrupts the process of photosynthesis (Hilje and Morales, 2008). In addition, whiteflies act as vector of Yellow Mosaic Virus (YMV) resulting in 15-17% of yield loss (www.nmoop.gov.in).

In order to improve the ecological based management of the pest, the behaviour of the pest such as the host preference and oviposition should be known (Khan et al., 2010). It prefers the leaves having thick trichomes for egg laying and it lays stalked eggs (Ahmad and Rizvi, 2014). In resistant cultivars very few number of eggs hatch into nymphs (Vieira et al., 2011) and period of the developmental stages is also affected (Fekri et al., 2013). The number of adults developing from nymphs also decreases due to antibiosis (Sulistyo and Inayati, 2016).

Controlling insect pests in soybean by spraying insecticides is widely adopted by farmers (Song and Swinton, 2009). Excessive insecticide applications results in disturbance to the environment, pest resurgences, pest resistance to pesticides and lethal effects on non-target organisms in the agro- ecosystems in addition to direct toxicity to users (Carmo et al., 2010). The control of whiteflies by spraying chemical insecticides has not given satisfactory results. This was due to new strains of whiteflies easily formed with increased levels of resistance to pesticides (Palumbo et al., 2001). Further, the use of insecticides in the soybean does not lead to higher productivity in the field when compared with biological control (Bueno et al., 2011). Among the biocontrol agents, entomopathogenic fungi often reported to cause high levels of the epizootic in nature and are the most versatile biological control agents and are also environmentally safe. The important feature of these fungi is that the virulence is caused by contact action through penetration (Tank, 2015).

Beauveria bassiana is considered to be the most promising entomopathogenic fungi against whiteflies. The fungi also have a potentiality to infect wide host ranges of agricultural insect pests with in different orders including, Homoptera, Hymenoptera, Lepidoptera, Coleoptera (Mohammad and Deghairi, 2008).

Laboratory bioassay have revealed *B. bassiana* to be an effective pathogen against whiteflies when applied directly as concentrated conidial suspension (Wraight et al., 2000).

Unlike bacteria and viruses, this entomopathogenic fungi are able to penetrate the host integument and then develop within the host hemocoel. The process of infection begins with the attachment and germination of the conidia in the cuticle. Penetration involves both mechanical and enzymatic actions (Zimmermann, 2007).

The advantages of using myco insecticide include, no resistant, safer to non target pest. Moreover, it is cheap to mass produce, easy to store and effective over a wide range of temperatures and humidity levels and kills at economic doses (Wright, 1992)

Keeping in mind the above facts the present investigations were undertaken with the following objectives:

Objectives:

1. Biology of whitefly, *Bemisia tabaci* on soybean cultivars under laboratory conditions.
2. *In- vitro* studies on the management of whitefly with *Beauveria bassiana.*

REVIEW OF LITERATURE

The available literature relevant to the present studies had been reviewed are mentioned below:

2.1.1. Biology of whitefly, *Bemisia tabaci* on soybean cultivars under laboratory conditions

2.1 Egg

2.1.a Oviposition preference :

Byrne and Bellows (1991) reported that whitefly, *Bemisia tabaci* eggs are pyriform or ovoid and posses a pedicel or stalk that is peg like projection of the chorion, which is useful for transport of the water. Females deposit few eggs indiscriminately on the undersurface of the leaf. Oviposition rates varied depending upon the environmental conditions and host plants.

Lima and Lara (2004) reported that the number of whitefly, *B. tabaci* eggs laid on the soybean genotype with high density of trichomes is higher when compared to the soybean genotype with low density of trichomes. The trichomes favoured the attachment of the eggs to the epidermis during heavy wind.

Mansaray and Sundufu (2009) evaluated oviposition, development and survivorship of *B.tabaci* on soybean and gardenbean under laboratory conditions of 26.0±0.5ºC, 75 ± 5% RH and a photophase of 14:10 (L:D). They reported that *B.tabaci* deposited more eggs and survivorship of nymph was significantly greater on soybean compared to gardenbean. The preference for soybean over gardenbean could be possibly due to differences in physical and chemical characteristics of the leaves of the two bean species.

Khan et al. (2010) studied host plant selection, oviposition behaviour and survivorship of whitefly, *B. tabaci* on three hosts namely: brinjal (*Solanum melongena*), chilli (*Capsicum annuum*) and tomato (*Solanum lycopersicum*). Although *C. annum* and *S. lycopersicum* were also the

potential hosts of *B. tabaci* but in the presence of *S. melongena*, the attack rate remained minimum on both the host plants. The feeding and egg laying were significantly higher on *S. melongena* L. leaves as compared to other two host plants. The leaves of *S. melongena* with thick trichomes were preferred higher for egg laying as compared to other host plants. The morphological characters and plant architecture contribute to higher densities of adult whitefly compared to new leaves.

Baldin et al., (2012) reported that melon cultivar showed resistance against *B. tabaci.* The presence of glandular trichomes is considered one of the main causes of morphological resistance in plants and can affect oviposition and feeding.

Ahmad and Rizvi (2014) reported that *B. tabaci* eggs have a tube like structure called stalk, which helps the eggs to get attached with leaf surface and transports the water from the tissues to the eggs. It might also take up certain chemicals through the stalk depending upon the host plant which might result in the failure of hatching of the egg.

Kedar et al., (2014) observed that *B. tabaci* eggs are laid singly on the abaxial surface of leaves. Freshly laid eggs were yellowish white in colour, transparent and spindle shaped. The egg colour changes every day with pale brown initially and then it gets dark before hatching.

Hasanuzzaman et al. (2016) studied that leaf morphological characters can be a factor for preference of whitefly *B. tabaci* on eggplant varieties. They hypothesized that certain morphological leaf characteristics of different varieties, like leaf trichome density, trichome length, leaf lamina thickness and leaf colour, may affect whitefly landing, feeding and oviposition.

Development and survival of immatures:

Salas and Mendoza (1995) studied the development of immature stages of *B. tabaci*. They reported that under laboratory conditions at 25ºC and 65% RH, the incubation period ranges between 7.3 ± 0.5 days on

tomato and the mean duration from egg to nymphs and transitional forms was egg (7.30 ± 0.5 days), crawler (4.01 ± 1.0 days), 2nd instar (2.70 ±1.10 days), 3rd instar (2.5 ± 0.7 days) and fourth instar pupae (5.8 ± 0.3 days). The total life cycle (egg to adult) lasted for 22.30 days.

Auslane and Smith (2000) reported that whitefly, *B. tabaci* eggs hatch in six to seven days at 25^0C.Crawlers are oval in shape and measures about 0.27 mm in length and 0.14 mm in width with two yellow spots *i.e* mycetomes which are visible in the abdomen through the integument which may play important role in whitefly nutrition. Nymphs are immobile with atrophied legs and antennae while small eyes are flattened and oval in shape, greenish yellow in colour and ranges from 0.365 mm in length. Fourth instar nymphs are immobile with atrophied legs and measures about 0.662 mm in length with dark yellowish body with dark red coloured eyes and mycetomes are less visible. The duration of fourth instar nymphal period was 5-6 days. Adult *Bemisia* are soft and whitish yellow when they first emerge from their nymphal exuviae. Within a few hours, their two pairs of wings become iridescent white due to the deposition of a powdery wax. Body of the female measures 0.96 mm while male somewhat smaller and is about 0.82 mm.

Fancelli and Vendramim (2002) studied the development of *B.tabaci* on *Lycopersicon* spp. The incubation period recorded was 11.1 ± 0.1 days on variety L A1739 followed by 11.5 ± 0.1 days on L A 462. They observed that genotypes also differed in relation to the number of nymphs and nymphal viability, but not in relation to the nymphal period. Immature duration was 24.2 ± 0.9 on LA 1739 followed by 27.2±0.5 on LA 1584. Survival percentage of immatures was recorded as significantly higher on L A 1739 with 86.9 ± 2.1 followed by 42.3 ± 9.7 on L A 1609. They further reported that the number of nymphs recorded may be related to the suitability of the leaflet microclimate for egg development or epidermal characteristics that facilitated or prevented the egg desiccation. Either of these conditions may have interfered with the antixenotic and antibiotic effects.

Musa and Ren (2005) studied the development, survivorship and reproduction of *B. tabaci* on three bean cultivars. The developmental periods from egg to adult varied from 27.80 on garden bean to 18.2 days on soybean at 26±1ºC under laboratory conditions. Egg to adult survival percentage was highest on soybean (77.4%), and least survival percentage was reported on gardenbean with (64.08%). Average hatching recorded was 95.97 ± 3.58 % on soybean, followed by 91.36 ± 3.39 % on cowpea and garden bean showed the least hatching compared to other cultivars (88.85 ± 2.28%).

Fekrat and Shishehbor (2007) studied the development and reproduction of the cotton whitefly, *B. tabaci* on aubergine, tomato and potato under laboratory conditions at 30ºC and 55% RH. Average eggs per day observed was 5.8 ± 1.3, 4.2 ±1.6 and 5.13±0.97 on aubergine, tomato and potato, respectively. Immature mortality was highest (18.1%) on tomato followed by aubergine (12.9%) and least on potato (12.3%). Total life cycle from egg to adult was 14.9, 20.0 and 14.2 days on aubergine, tomato and potato, respectively. They concluded that the development from egg to adult was influenced by the host plant.

Takahashi et al. (2008) studied the biology of *B. tabaci i.e.* duration of egg to adult period and the percentage of hatching on collard, soybean and tomato. The number of hatched eggs was higher on collard when compared to soybean and tomato plants. Percentage of hatching on collard with 90.2±19.06, followed by soybean (72.0±10.27) and least hatching percentage was recorded on tomato with 63.9±8.22. The duration of the egg to adult period was 19.8 days on collard, followed by 21.2 days on soybean and 22.0 days on tomato. They further emphasized that collard was the most attractive among the three host species for nymphs to establish and feed with shortest duration from egg to adult period.

Aydin (2010) investigated the effects of different cotton cultivars on developmental time and mortality rates of immature stages of *B. tabaci*. The shortest and longest immature developmental stage was observed on cv DP 5111 (6.23 days) and cv DP 50 (8.16 days), respectively. Shortest pupal

period was 3.42 days on cv DP 5690, and the longest was 4.93 days on cv DP 5409. The shortest and longest growth period of *B. tabaci* immature stage was 17.64 days (cv C 1518) and 18.35 days (cv DP 90) respectively. However, no mortality was detected at pupal stage. The lowest mortality was detected at IIIrd nymphal stage while the highest mortality was in the egg stage. The highest total mortality rate of *B. tabaci* immature stage was 35.5% on cv DP 50, and no mortality was detected on cv DP 5690.

Oriani et al. (2011) studied some biological aspects of *B. tabaci* on 18 tomato genotypes, in controlled laboratory conditions. The developmental period of insects grown on L A1335, PI 365928 and LA 722 genotypes took three days longer when compared to genotype PI 134418(20.3 days). The highest mortality rate of whitefly nymphs occurred in PI365928, LA1335 and LA722 genotypes (63.8, 54.5 and 53.3%, respectively) and the lowest ones in IAC294 and IAC 68F-22-2 genotypes (4.9 and 6.2%, respectively). They concluded that LA 1335, PI 365928 and LA 722 genotypes were categorized as moderate feeding, non-preferance and antibiosis based resistance to *B. tabaci*.

Silva et al. (2012) reported that the resistant soybean genotypes extended the average duration of first nymphal instar to 1.61±0.10 in relation to the other genotypes which was due to the antibiosis nature of the resistant cultivar. The least duration was recorded in susceptible cultivars with 1.00±0.00 day. Duration of the second and third instar is longer on the resistant genotypes than on the susceptible ones. Instar duration was reported as 3.26 ± 0.35, 2.10 ± 0.10 days on resistant and susceptible cultivar, respectively. They concluded that the resistant cultivar extend the insect life cycle, indicating the occurrence of small degree of antibiosis and non preference for feeding.

Fekri et al. (2013) studied the relative resistance of 8 tomato varieties to cotton whitefly, *B. tabaci*. The egg to adult cycle varied from 26.02 days (Ergon) to 26.66 days (CAL-JN3). The total mortality varied from 20.52% (Ergon) to 33.97% (CAL-JN3). Considering all the characteristic features,

they concluded that the variety CAL-JN3 was the most resistant to *B. tabaci* among all the tomato varieties studied, while variety Ergon was susceptible.

Ahmad et al. (2014) evaluated the comparative age specific life parameters of *B. tabaci* on cotton, green gram and black gram. Hatching took minimum duration on black gram *i.e* 3.22 ± 0.38 days followed by 4.92 ± 0.18 days on green gram. Highest survival percentage of all the immature stages was observed on cotton as compared to green gram and black gram. Immature life period ranged from 14.98 ± 0.82 days on cotton to 20.51±1.00 days on green gram.

Cruz et al. (2014) investigated some biological aspects of *B. tabaci* biotype B on 14 genotypes of cowpea. They evaluated the incubation period, egg viability, duration of nymphal stages, total duration of the immature, instar mortality and total mortality of the immature stage. The genotype MNC 99-541 F21 exhibited antibiosis against the whitefly, prolonging the lifecycle of the insect. The genotypes Canapu, BRS-Urubuquara and TE97-304 G-4 also exhibited antibiosis, causing high nymphal mortality.

Kedar et al. (2014) reported that the *B. tabaci* first instar nymphs were oval in shape and yellowish white in colour which crawls over the lower surface of leaf. The duration of first instar nymphs lasted for 3-5 days on cotton. Freshly formed puparium was yellowish white in colour and oval in shape with well developed reddish brown coloured compound eyes which were distinctly visible. This instar lasted for 4 to 4.3 days on cotton cultivars. Fully developed adult emerged through a “T” shaped slit in the pupal cases. Adult female had prominent dark brown coloured compound eyes with smoky white wing and pale yellow abdomen with ovipositor. Males are comparatively smaller in size than the females.

Sulistyo and Inayati (2016) evaluated the mechanism of antixenosis, antibiosis and tolerance of 14 soybean genotypes in response to *B. tabaci*. In free choice test the resistant cultivars showed antixenosis mechanism which correlates with length and low density of leaf trichomes as well as leaf

thickness. In the no choice test antibiosis mechanism was observed from the small number of adults that developed from nymphs.

2.2. *In-vitro* studies on the management of whitefly with *Beauveria bassiana*

Ramos et al. (2000) evaluated the susceptibility of eggs and nymphs of first instar *B. tabaci* to *Beauveria bassiana* at the concentration of $1x10^8$ conidia per ml and reported 62-71 percent nymphal mortality. However, the eggs were not found susceptible to *B.bassiana.*

Nymphal stages of *B. tabaci* were highly susceptible to infection by a number of fungi including *B. bassiana* (Vincentini et al. 2001).

Sinary -El (2002) explained that the efficiency of the entomopathogenic fungi began clearly after 48 hr after inoculation and the hyphae penetrated the integument, epithelial and epidermal cells. After 72 hr, the fat tissue were damaged and mortality reached 100% after 96hr.

James et al. (2003) reported that second and third instars of the silver leaf whitely, *B. argentifolii* (Bellows & Perring), were the most susceptible nymphal stages, as conidia of *B.bassiana* readily germinated on the cuticle of these instars.

Kuang et al. (2005) isolated an isolate of *B.bassiana* from *Phaedon brassicae* which subsequently was shown to infect *Bemisia tabaci, Phyllotreta striolata*, *Plutella xylostella and Lipaphis erysimi,* in the laboratory. Immersion of *B. tabaci* in the fungal suspension of 1×10^8 conidia/ml caused the death of 84.88, 86.81, 55.94 and 38.78. 16 per cent of the first to fourth instar nymphs, respectively. The probit analysis showed that the LT_{50} values of *B. bassiana* were 4.14, 3.78, 6.24 and 7.59 days to the respective nymphal stages.

Torrado-Leon et al. (2006) studied the bioefficacy of entomopathogenic fungi *B. bassiana* on *B. tabaci*. They reported sub lethal effects on four nymphal stages of *B. tabaci* due to fungal infection which included impaired fertility, production of malformations or external variations

and reduced survival of later generations. Almost 30% of the imagos resulting from treated nymphs were unable to detach completely from the exuvia. A gradual reduction in the mortality rates between subsequent generations was observed.

Quesada et al. (2006) evaluated 25 native *B. bassiana* isolates and a commercially available *B. bassiana* based myco-insecticide for virulence to fourth instar nymphs of sweet potato white fly, *B. tabaci* at a concentration of 1×10^7 conidia/ml. All isolates were pathogenic, where as mortality rates varied from 3 to 85 per cent. A second series of bioassay was conducted on 10 selected isolates using four 10-fold concentrations ranging from 1×10^5 to 1×10^8 conidia/ml. Median lethal concentrations (LC_{50}) of the four most virulent isolates varied from 1.1×10^5 to 6.2×10^6 conidia/ml and average survival time (AST) of treated nymphs ranged from 5.9 to 7.4 days.

Vassilakos et al. (2006) reported that the optimal condition to promote *B. bassiana* infection is between 23°C and 26°C and humidity greater than 85%.

Al-Deghairi (2008) reported that differential mortality of *B. tabaci* to *B.bassiana* is based on the stage of insect and concentration of conidia. Infection level to eggs was only 4.49%, even with higher conidial concentrations 6 x 10^6 conidia ml^{-1}. Whereas, it was higher with 1st and 2nd instars (42.04%) and 3rd and 4th instars (35.93%). He concluded that nymphs were highly susceptible to fungal treatment compared with eggs.

Islam et al. (2009) reported that nymphal mortality of *B. tabaci* was highest (72.9%) 7 days after spraying of *B.bassiana* 10^8 conidia/ml suspension on egg plant.3

Ramazeame (2012) evaluated entomopathogens against *B. tabaci* adults and recorded a mortality of 98.33, 85.00, 72.33 and 95.00 per cent after 72 h after treatment with *B.bassiana, Lecanicillium lecanii, M. anisopliae* and *Paecilomyces farinosus*, respectively and concluded that among entomopathogens, *B. bassiana* was found highly effective against whitefly.

Al-alawi et al. (2014) evaluated 32 isolates of *B.bassiana* against 4th nymphal instar and adult whitefly *B. tabaci.* They reported that the four isolates along with commercial isolate were highly virulent to the whitefly causing more than 80% mortality with LC_{50} values of 3.16×10^6, 1.17×10^6, 9.33×10^5, 5.62×10^5 and 7.76×10^5, respectively. Further, greenhouse trials showed that the isolates BAU018 and BAU019 were as virulent as the commercial isolate GHA which indicated the potential of the isolates and further suggested to develop them as microbial insecticides for effective and safe *B. tabaci* management.

Zafar et al. (2016) evaluated different isolates of *B. bassiana* against different life stages of *B. tabaci* on different hosts. They reported that *B. bassiana* isolate (Bb-01) to be the most effective one with LC_{50} value of 2.4×10^7 spores/ml and 2.7×10^6 spores/ml which caused highest mortality of eggs (65.30%) and nymphs (88.82%), on *Gossypium hirsutum* in composition to other hosts.

MATERIAL AND METHODS

This chapter includes details of the material used and methodology followed during the course of present investigation. In accordance with the objectives, the studies were divided into two sections as detailed below.

1. Biology of whitefly, *Bemisia tabaci* on soybean cultivars under laboratory conditions.
2. *In- vitro* studies on the management of whitefly with *Beauveria bassiana.*

3.1 Location

The present investigation entitled, “Bionomics of whitefly, *Bemisia tabaci* on soybean cultivars and its management with *Beauveria bassiana*” were conducted in the Bio control laboratory, Department of Entomology, College of Agriculture, JNKVV, Jabalpur.

3.2 Geographical Location and Climate

Jabalpur “The Marble city” located in the central part of Madhya Pradesh lies between 22^0 49" and 28^0 8" North latitude and 78^0 21" and 80^0 58" East longitude, at an altitude of 411.78 m above the mean sea level. Jabalpur comes under the agro-climatic region of Kymore Plateau and Satpura Hills and lies in the rice-wheat crop zone of the state. The climate of the region is typically semi-humid and sub-tropical. Temperature extremes vary between minimum temperature of 2^0C in December and January months to maximum temperature of 45^0 C in May and June months. The average annual rainfall mostly received between mid June to first week of October with occasional showers in limited quantum during the winter months, ranges between 1000-1500 mm. The relative humidity remains 20 to 35% during summer and medium 40 to 60% during winter season, while it attains maximum values of 80 to 95% during rainy season.

3.3 Biology of whitefly, *Bemisia tabaci* on soybean cultivars under laboratory conditions

3.3.1 Maintenance of insect culture

The culture of *Bemisia tabaci* was multiplied and maintained on the potted plants of soybean variety JS-335. The plants were grown in screen house in disposable plastic pots having diameter and height of 10 and 20cm, respectively. The pots were filled with vermicompost, soil and sand in the ratio of 2:1:1. Watering was done manually once in every two days. Initially whitefly adults were collected from field using aspirator (Plate 1) and were released on the soybean plants which were kept inside the screen house. The whiteflies were allowed to develop and multiply on those plants (Plate 2). Second generations of the non-virulent *B.tabaci* adults were used for the study of their biology. Different immature stages and adults of whitefly were obtained from the culture for the experiment (Plate: 3).

3.3.2 Materials used

The following materials were used to conduct the studies on biology; aspirator, nylon cages, stereo zoom binocular microscope, camel hair brush, marking tags, petri dishes, ocular micrometer, 20 mega pixel camera, walk-in BOD chamber and soybean cultivars of different susceptibility groups against whitefly JS-335(susceptible)(agropedia.iitk.ac.in), JS-97-52(tolerant)(www. nrcsoya.nic.in), JS 20-98(resistant) (Pancheshwar et al., 2016).

3.3.3 Biology of *B.tabaci*

Life history of whitefly from egg to adult stage on three soybean cultivars *viz.* JS-335, JS-97-52 and JS-20-98 were studied under laboratory conditions at 25±2^{0}C temperature, 70±10% relative humidity and with photophase period of 13 hours as per the methodology proposed by Oriani et al. (2011). Soybean cultivars were raised in small pots (50x40 cm) under caged condition (80 mesh) in walk-in BOD chamber. Each variety was maintained with 3 plants / cage and a total of 3 sets were maintained . Byrne and Bellows, (1991) has reported that adult *B.tabaci* starts mating within 1 to 8 hours after emergence. Therefore in the present study also, a pair of newly emerged adult male and female whiteflies were released in each cage

having soybean seedlings (*cv*. JS-335, JS-97-52, JS-20-98) (Plate 4) at trifoliate stage for 72 hours. The males and females of *B. tabaci* were identified on the basis of the abdominal tips and size, the females are bigger in size and have blunt abdominal tips, while the males are smaller in size and have pointed abdominal tips. Moreover, fore and hind wings and antennae of females were larger than those of males (Byrne and Houck, 1990; Baig and Ramamurthy, 2013). Further during mating, the males raise pair of wings on female (Li et al. 1989). After 72 hours of release, the adults were removed from the cages. However, the number of eggs laid on the seedlings of each cage were examined after 24, 48 and 72 hours of release. To study the incubation period of the eggs which were laid on the leaves of the seedlings were marked with marker for easy recognition. Daily observations were made to note the changes in the eggs. The length and breadth of the eggs were measured by using ocular micro meter. The incubation period, hatching (%) and survival from egg to adult, duration and measurement of various immature stages and adult emergence were recorded. Length of the immature stages was recorded by placing the ocular meter on the body in vertical position and breadth was recorded by placing it on the widest portion of the body.

3.4.1 *In- vitro* studies on the management of whitefly with *Beauveria bassiana*

3.4.2 Media preparation:

Potato dextrose agar (PDA) is the most commonly used media for the growth of entomopathogenic fungi. For this purpose, 250 g of potato was washed the skin peeled off and sliced into small pieces. To the sliced potato 500 ml water and 20g agar was added and heated for 30 minutes in an open vessel. Collected the potato extract by filtering through a muslin cloth. Added 20g dextrose to the potato extract and mixed thoroughly and made the volume to 1 litre with distilled water. Poured it in 250 ml conical flask, plugged with non- absorbent cotton wool, covered it with paper sheet and tied tightly with a rubber band. Sterilized them in an autoclave at 15 lbs pressure at 121^0C for 15 minutes (agritech.tnau.ac.in).

3.4.3 Maintenance of Insect culture mentioned in 3.3.

Table 1: Sources of entomopathogenic fungus *B.bassiana* strains

***B.bassiana* strains**	**Source**
Strain-1	NAIMCC-F-00410, (NBAIM, Mau, Uttar Pradesh)
Strain-2	NAIMCC-F-02125, (NBAIM, Mau, Uttar Pradesh)
Strain-3	Obtained from silkworm larvae

Note: NAIMCC: National Agriculturally Important Microbial Culture Collection.
NBAIM: National Bureau of Agriculturally Important Microorganisms.

3.4.4 Culturing of Entomopathogenic fungus, *Beauveria bassiana*:

Pure mother culture of fungus was maintained on PDA slants at 4^{o}C under refrigerated conditions till further use. Regular maintenance was done for further multiplication at 25±2ºC and 70±10 % RH (Plate: 5).

3.4.5 Materials used

The following materials were used to conduct the efficacy studies: stereo zoom binocular microscope, camel hair brush, marking tags, petridishes, soybean cultivar JS 335 (susceptible), atomizer, Tween-80 (0.02%), 20 mega pixel camera and walk-in BOD chamber.

3.4.6 Preparation of *Beauveria bassiana* suspension:

Aqueous conidial suspensions (10 ml) were made from conidia harvested from the slants prepared in conical flasks (250 ml) after 14 days of inoculation. Tween-80 (0.02%) was used to disperse the conidia, it was then filtered through a double layered muslin cloth. The number of conidia per ml was enumerated using plate count method (Reddy et al., 2016) Initially highest required concentration (1×10^{12} conidia ml^{-1}) of the fungal suspension was prepared. This filtrate was the stock solution and further lower concentrations (upto 1×10^{8} conidia ml^{-1}) were prepared from it by serial dilution technique (Geroh et al., 2015).

3.4.6 Bioassay against whitefly 3rd nymphal stage:

The virulence test was conducted against 3rd instar nymph of whitefly as per the methodology proposed by Wraight et al., (1998). For this purpose 3rd instar nymphs stage were obtained from soybean cultivar (JS-335) grown in plastic pots. Three strains of *B.bassiana* were tested for their efficacy against whitefly nymphs (Table 1) along with a control (untreated check). In control the nymphs were treated with distilled water + Tween-80 @ 0.02%. Each treatment was replicated thrice. A filter paper was wetted with distilled water and inserted in petridishes and infested soybean leaves having at least 10 third instar nymphs of about same age were placed in it. Soybean petiole was wrapped with cotton swap containing water in order to keep the leaves fresh. Conidial suspension was sprayed with atomizer on the leaf surface@1ml of the diluted spore suspension of different spore concentration ($1x10^{12}$, $1x10^{10}$, $1x10^{8}$ spores ml^{-1}) (Plate 6). Petridishes were placed at 25 ± 2°C, 70± 10% RH and 13h light exposure in walk-in BOD chamber under caged conditions (Plate 7). Observations on mortality of the 3rd instar *B. tabaci* nymphs were recorded at 24 hours interval and was continued upto 168 hours *i.e.* upto the adult emergence stage.

Statistical Analysis:

Statistical Analysis of data:

(I) Analysis of variance – Complete Randomized Design :

Analysis of different variables was carried out to know the degree of variation amongst all the treatments. The data was statistically analyzed and the analysis of variance of different observations has been presented in the appendix and the skeleton of ANOVA for complete randomized design (CRD) is presented below:

Skeleton of Analysis of Variance (ANOVA) :

Sources of variation	Df	SS	MSS	F cal.	F table	
					5%	1%
Treatments	t-1	SSt	MSSt= SSt / t-1	MSSt / MSSe		
Error	n-t	SSe	MSSe = SSe / n-t	-		
Total	n-1	-	-	-		

n = Total number of observations
t = Number of treatments

The 'F' test was applied to check the overall significance of various treatments in general and comparison of individual treatment was made with the help of critical difference at 5 % level of significance, which was calculated as given below : -

$$\text{SEm}\pm \text{ for treatment 't'} = \sqrt{\frac{MSS_e}{\text{No. of replications}}} \times 100$$

SEd for treatment = SEm x $\sqrt{2}$

CD for treatment = SEd x't' value at 5% error degree of freedom

Where,

SEm± = Standard Error of treatment means

SEd = Standard Error of difference between two treatments

CD = Critical difference

(II) **Analysis of variance – Factorial CRD**

Analysis of different variables was carried out to know the degree of variation amongst all the treatments. The data were statistically analyzed and the analysis of variance has been given in the appendix and the skeleton of ANOVA for Factorial CRD is presented below:

Sources of variation	Df	SS	MSS	F cal.	F tab.	
					5%	1%
Strain (s)	(a– 1)	SSs	MSs	MSs/ MSe		
Dose (d)	(b-1)	SSd	MSd	MSd/ MSe.		
Sxd	(a- 1) (b - 1)	SSxd	MS sxd	MS sxd		
Error	ab (n-1)	SSe	MSe			
Total						

Where,

a = no. of treatments / strains

b = no. of doses

SSs = Strains sum of square

SSd = Doses sum of square

Sxd = Strain x dose interaction

MSs = Mean sum of squares due to strains

MSd = Mean sum of squares due to doses

MSsxd = Interaction between strain and doses

MSe = Mean sum of squares due to error

The significance among different treatment means was judged by critical difference (CD) at 5% level of significance for comparison among the treatments, for which the marginal means of each treatment was considered. The following formula was used for various estimations:

Standard error for observation

Mean

S.Em ± for strain

$$= \sqrt{\frac{\text{MSE}}{\text{r } x \text{ No. of doses}}}$$

S.Em ± for dose

$$= \sqrt{\frac{\text{MSE}}{\text{r } x \text{ No. of strains}}}$$

S.Em± for interaction

$$= \sqrt{\frac{\text{MSE}}{r}}$$

Critical difference (CD) :

CD = SEd x 't' value at 5% error degree of freedom

Plate 1: Adult whiteflies, *Bemisia tabaci* collected from field by using aspirator

Plate 2: Mass multiplication of whiteflies on soybean plants *cv* JS-335

Plate 3: Collecting whiteflies from screen house

Plate 4: Studies on biology of whitefly under caged and controlled conditions in walk- in BOD chamber

Plate 5: *B. bassiana* mother culture

Plate 6: Leaf with 3rd instars of *B. tabaci* treated with *B. bassiana*

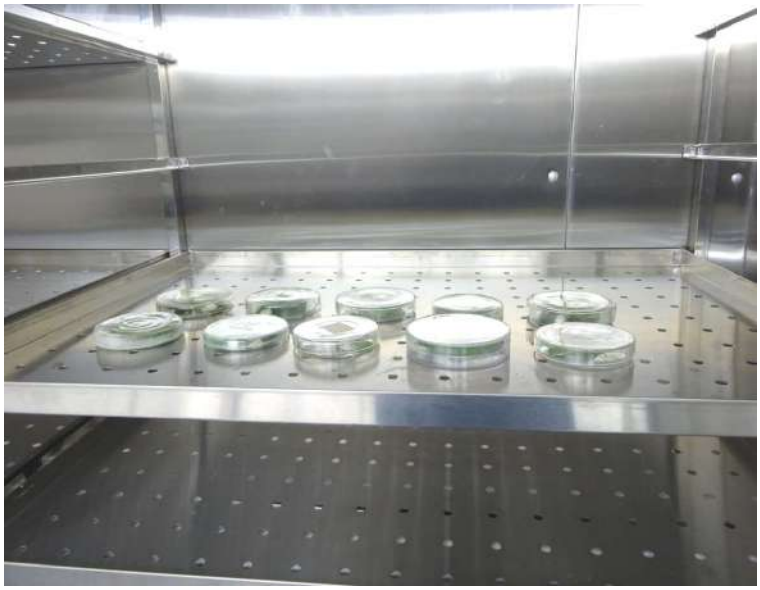

Plate 7: Treated leaves kept under controlled conditions for further bio efficacy studies

DISCUSSION

The findings of the experiment on "Bionomics of whitefly, *Bemisia tabaci* on soybean cultivars and its management with *Beauveria bassiana*" are discussed in this chapter under respective objectives.

1. Biology of whitefly, *Bemisia tabaci* on soybean cultivars under laboratory conditions:

The impact of soybean cultivars on biology of *Bemisia tabaci* were studied under laboratory conditions at 25±2^{0}C, 70±10% RH and 13 hrs photophase.

Egg:

The adult whitefly, *B. tabaci* females laid eggs singly on the lower surface of the leaves which were whitish yellow in colour, transparent and spindle shaped. The present findings are in conformity with the findings of Kedar et al. (2014), as they also reported that the eggs of *B.tabaci* are whitish yellow in colour and spindle shape. However, the present findings contradicts the findings of Byrne and Bellows (1991).They reported that the eggs of *B.tabaci* are pyriform or ovoid shape. Each egg have tube a like structure called stalk or pedicel, which helps to get attached with leaf surface and transports the water from the tissues to the eggs. The present findings confirms the findings of Byrne and Bellows (1991); Ahmad and Rizvi (2014), as they also reported that the eggs have a tube like structure.

Highest egg laying was observed on soybean cultivar JS-335 followed by JS-97-52 and lowest on JS-20-98.The preference and variation in the oviposition might be attributed to the presence of trichomes on the leaves. The present findings are in accordance with the findings of Mansaray and Sundufu (2009), Khan et al. (2010), Baldin et al, (2012), Hasanuzzaman et al. (2016) and Sulistyo and Inayati, (2016). They also reported that the presence of dense trichomes on soybean rendered it vulnerable for egg laying. The trichomes favoured the attachment of the eggs to the epidermis during heavy wind (Lima and Lara, 2004).

Average number of eggs laid on cultivar JS-335, JS-97-52 and JS-20-98 was 10.33±1.15, 9±7.81 and 7.0±6.08 per day respectively. The present findings corroborates the findings of Fekrat and Shishehbor (2007), as they also reported that average eggs laid per day by adult female whitefly was 5.8±1.3, 4.2±1.6 and 5.13± 0.97 on aubergine, tomato and potato crops, respectively. In the present study average length and breadth of eggs were 0.129±0.0046mm and 0.113±0.022mm on susceptible cultivar (JS-335), 0.126± 0.045 mm and 0.113±0.022 mm on tolerant cultivar (JS-97-52) and 0.124±0.044mm and 0.112±0.022 mm on resistant cultivar (JS-20-98), respectively. The results indicate that bigger size eggs were found to be more abundant on the susceptible cultivar, followed by tolerant and smaller size eggs on the resistant cultivar. However, no reports are available in the literature on the size of the eggs.

Incubation period:

The mean incubation period on the three cultivars *viz*., JS-335**,** J S - 97-52 and JS-20-98 varied and it was 5.5±0.5, 7.0±1.0 and 8.0±1.0 days, respectively. The present findings are in accordance with the findings of Salas and Mendoza (1995); Auslane and Smith (2000); Fancelli and Vendramim (2002). They also reported that incubation period of *B.tabaci* was 7.3 ± 0.5 days and 6-7 days on tomato, while it was 11.1±0.1 and 11.5 ± 0.1 days on *Lycopersicon* spp. cv. LA-1739 and LA-492, respectively.

Hatching percentage:

The hatching percentage was maximum (93.55%) on susceptible cultivar (JS-335) followed by 85.19% on tolerant cultivar (JS-97-52) and minimum (76.19%) on the resistant cultivar (JS-20-98).The present findings confirms the findings of Musa and Ren (2005); Takahashi et al., (2008) and Ahmad et al., (2014). They also reported that the egg hatching percentage on soybean was 95.97± 3.58, 91.36±3.39 and 88.85±2.28%, respectively.

Highest egg mortality (23.81%) was recorded on JS-20-98, followed by JS-97-52(14.81%) and lowest on JS-335(6.45%), respectively.

The duration required for hatching was minimum (5.5±0.5 days) on susceptible cultivar (JS-335), followed by tolerant cultivar (JS-97-52)

(7.0±1.0 days) and maximum (8±1 days) on resistant cultivar (JS-20-98), respectively. No reports are available in the literature on the duration of egg hatching.

Development and survival of immature stages:

Newly emerged first instar nymphs are known as crawlers. They are oval in shape, yellowish white in colour. The present findings are in conformity with the findings of Kedar et al., (2014), as they also reported that the first instar nymphs or crawlers are oval in shape and whitish in colour.

Mean developmental period of the first instar nymphs or crawlers on the three soybean cultivars varied, and it was highest (3.5±0.4 days) on the resistant cultivar (JS-20-98), followed by tolerant cultivar (JS-97-52) (3.5 ± 0.5 days) and lowest (2.5 ± 0.5 days) on susceptible cultivar (JS-335), respectively. Thus the developmental period of crawlers was minimum on the susceptible cultivar followed by tolerant and resistant cultivar, respectively. The present findings are in conformity with the findings of Salas and Mendoza (1995); Kedar et al., (2014) and Silva et al., (2012). They also reported that mean developmental period of the first instar nymphs was 4.01±1.0 days on tomato and 3 to 5 days on cotton while on resistant soybean genotype it was1.61±0.10 days and lowest(1.00±0.00 days) in susceptible cultivar, respectively. This indicates that resistant cultivar extends the developmental period of the crawlers, which may be attributed to the presence of some degree of antibiosis factor (Silva et al., 2012).

In the present study the average length and breadth of crawlers were 0.231±0.047mm and 0.224±0.049mm on susceptible cultivar (JS-335), 0.235±0.049mm and 0.297±0.003mm on tolerant cultivar (JS-97-52) and 0.238±0.050mm and 0.213±0.034mm on resistant (JS-20-98), respectively. The results indicates that the breadth of the crawlers was maximum which developed on susceptible cultivar followed by tolerant and resistant cultivars, respectively.The present findings are in accordance with the findings of Auslane and Smith (2000), as they also reported that the length and width of crawlers were 0.27mm and 0.14mm, respectively.

Maximum mortality of crawlers were recorded on cultivar JS-20-98(12.50%), followed by JS-97-52(4.35%), minimum on JS-335 (3.45%), respectively.

The freshly moulted second instar nymphs were whitish yellow in colour, oval and flat and became yellowish and dome shaped after feeding. The present findings contradicts the findings of Auslane and Smith (2000), as they reported that on tomato, the second instar nymphs are greenish yellow in colour and oval in shape. The variation in the colour of the nymphs might be due to the influence of the host crops on which it feeds and develops. The second instar nymphs are immobile with atrophied legs and mycetomes are visible in the abdomen.

The mean developmental period of the second instar nymphs on the three soybean cultivars varied, and it was highest (3.5±0.5 days) on cultivar JS-20-98, followed by cultivars JS-97-52 and JS-335 (2.5 ±0.5 days), respectively. The present findings are in conformity with the findings of Salas and Mendoza (1995) and Silva et al., (2012). They also reported that on tomato the duration of the second instar nymphs were 2.70 ±1.10 and 2.5 ± 0.7 days, 3.26 ± 0.35 and 2.10 ± 0.10 days, respectively.

Highest mortality of second instar nymphs was recorded on cultivar JS-20-98(7.15%), followed by JS-97-52 (4.55%) and lowest on JS-335(3.58%), respectively.

The average length and breadth of the of second instar nymphs which developed on susceptible cultivar (JS-335) were 0.332±0.048 mm and 0.246±0.051 mm, while it was 0.323±0.043 mm and 0.218±0.039 mm on tolerant cultivar (JS-97-52) and 0.321±0.043mm and 0.229±0.048mm on resistant cultivar (JS-20-98), respectively. No reports are available in the literature on the size of second instar nymphs.

The results indicate that bigger size second instar nymphs were found to be more abundant on the susceptible cultivar followed by tolerant and resistant cultivar, respectively. However, no reports are available in the literature on the size of the second instar nymphs.

The freshly moulted third instar nymphs were also oval and flat. Initially it appeared pale yellow and gradually turned dark yellow after feeding and mycetomes continued to be visible. No reports are available in the literature on the colour and shape of the third instar nymphs.

Highest mortality of third instar nymphs (15.39%) was recorded on resistant cultivar (JS-20-98), followed by tolerant cultivar (JS-97-52) (4.77%) and lowest on susceptible cultivar (JS-335) (3.75%), respectively.

The mean developmental period of the third instar nymphs on the three soybean cultivars varied, and it was lowest on JS-335 and JS-97-52 (2.5±0.5 days) while it was highest (3.5±0.5 days) on JS-20-98, respectively. Thus the mean duration of developmental period of third instar nymphs were found to be highest on the resistant cultivar (JS-20-98) and lowest both in the susceptible (JS-335) and tolerant cultivars (JS-97-52), respectively.The present findings are in conformity with the findings of Salas and Mendoza (1995) and Silva et al., 2012. They also reported that the mean developmental period of third instar nymphs on tomato was 2.5±0.7 days while it was 3.26±0.35 and 2.10±0.10 days on resistant and susceptible tomato cultivars, respectively.

Observations on measurement of third instar nymphs revealed that the average length and breadth of the nymphs which developed on susceptible cultivar (JS-335) were 0.430±0.047 mm and 0.333±0.048 mm, while it was 0.424±0.049 mm and 0.333±0.048 mm on tolerant cultivar (JS-97-52) and 0.415±0.038 mm and 0.324±0.044 mm on resistant cultivar (JS-20-98), respectively. The results indicate that the breadth of the third instar nymphs was maximum, which developed on susceptible cultivar followed by tolerant and resistant cultivars, respectively. No reports are available in the literature on the size of the third instar nymphs.

The freshly moulted fourth instar nymphs or pseudo pupa were oval shape and yellowish in colour. Well developed reddish brown coloured compound eyes were distinctly visible. The present findings corroborates the findings of Auslane and Smith (2010) and Kedar et al., (2014), as they also reported similar shape and colour of the pseudo pupa.

The mean developmental period of the fourth instar nymphs on the three soybean cultivars varied, and it was on lowest (3.5±0.5 days) both on susceptible and tolerant cultivars (JS-335 and JS-97-52 respectively) and highest (4.5±0.5 days) on resistant cultivar (JS-20-98), respectively. Thus the mean duration of developmental period of fourth instar nymphs were found to be highest on the resistant cultivar and lowest, both on susceptible and tolerant cultivars, respectively. The present findings are in accordance with the findings of Salas and Mendoza (1995); Auslane and Smith (2000); Aydin (2010) and Kedar et al., (2014). They also reported that the duration of fourth instar nymphs or pseudo pupae on tomato was 5.8±0.3 days and 5-6 days, while it was 3.42 and 4.93 days on susceptible and resistant cotton cultivars and 4 to 4.3 days on cotton cultivars, respectively.

Maximum mortality of fourth instar nymphs or pseudo pupa were recorded on cultivar JS-20-98 (18.19%), followed by JS-97-52(10.00%) and minimum on JS-335 (7.70%), respectively. On the contrary Aydin (2010) reported that there was no pupal mortality.

Observations on measurement of fourth instar nymphs revealed that the average length and breadth the nymphs which developed on cultivar JS-335 were 0.531±0.047 mm and 0.450±0.051 mm, while it was 0.530±0.047 mm and 0.435±0.049 mm on JS-97-52 and 0.527±0.047 mm and 0.427±0.040 mm on JS-20-98, respectively.The present findings are in accordance with the findings of Auslane and Smith (2000) as they also reported that the average length of fourth instar nymphs on tomato cultivars was 0.662mm.The results indicates that bigger size fourth instar nymphs were found to be more abundant on the susceptible cultivar followed by tolerant and resistant cultivar, respectively.

The fully developed adult emerged through “T” shaped slit on the dorsal surface of the pupal case. Adult female had prominent dark brown compound eyes with smoky white wings and pale yellow broader abdomen. The abdomen of adult male was narrow and comparatively smaller in size than the adult female. The present findings are in accordance with the findings of Auslane and Smith, (2000) and Kedar et al. (2014). They also

reported that fully developed adults emerge from “T” shaped slits, body whitish yellow in colour and adult males are smaller in size than the females.

The mean total developmental period (from egg to adult) on the three soybean cultivars varied, and it was highest (23.0±3 days) on resistant cultivar (JS-20-98), followed by tolerant cultivar (JS-97-52) (19.0±3.0 days) and lowest (16.5 ±2.5 days) on susceptible cultivar (JS-335), respectively. The results indicates that luxuriant growth with very short developmental period of whitefly was observed on susceptible cultivar (JS-335), and it was prolonged in tolerant (JS-97-52) and resistant cultivar (JS-20-98), respectively. The present findings are in conformity with the findings of Salas and Mendoza (1995); Takahashi et al., (2008); Oriani (2011) and Cruz et al. (2014). They also reported that the developmental period was 22.30, 19.8, 21.2 and 22.0 days on collard, soybean and tomato respectively. The variation in the developmental period may be attributed to the presence of some antibiotic factors which influenced the duration of the development of the pest. The present findings are in contradiction with the findings of Musa and Ren (2005); Fekrat and Shishehbor (2007) and Fekri et al., (2013). They also reported that the developmental period varied in different host crops and was 18.2, 14.9, 20.0 to 26.66 and 14.2 days on soybean, aubergine, tomato and potato, respectively.

The survival percentage of various immature stages on the soybean cultivars varied. It was maximum in susceptible cultivar, JS-335(93.55% crawler, 96.55% second instar nymph, 96.42% third instar nymph and 96.29% pseudo pupa, respectively) followed by tolerant cultivar, JS-97-52(85.19% crawler, 95.65% second instar nymphs, 95.45% third instar nymphs and 95.23% pseudo pupa, respectively) and minimum in resistant cultivar, JS-20-98 (76.19% crawler, 87.5% second instar nymphs, 92.85% third instar nymphs and 84.61% pseudo pupa, respectively).

The present findings are in conformity with the findings of Fancelli and Vendramim (2002), they reported that the total survival percentage of immature stages was 86.9%±2.1% and 42.3±9.7% on *Lycopersicon* spp.cv. LA1739 and LA1609, respectively. Similarly Musa and Ren (2005) reported

that the survival percentage was 77.4% and 64.08% on soybean and gardenbean, respectively.

2. *In vitro* studies on the management of whitefly with *Beauveria bassiana*

The present studies revealed that the third instar nymphal stage of *B.tabaci* was highly susceptible to infection by *Beauveria bassiana*. The present findings confirms the findings of Vincentini et al., (2001), James et al., (2003) and Al-Deghairi (2008). They also reported *B.tabaci* and *B. argentifolii* nymphs to be highly vulnerable to *B. bassiana* infection, respectively. The effects of the fungal infection included impaired fertility, production of malformation or external variations and reduced survival of later generations (Torrado-leon et al 2006).

In the present study, out of the three strains and doses of *B. bassiana*, strain S-3 was found to be most virulent at highest dose (10^{12} spores/ml). At 24 hours after spray at the highest dose ($1x10^{12}$ spores/ml), differences in the nymphal mortality among different *B. bassiana* strains were not significant. Among the strains, strain S-3 recorded highest nymphal mortality (6.67%), followed by strain S-1(3.33%), while no mortality was recorded in strain S-2 and control. At 48 hours after spray the differences in the nymphal mortality among different strains were significant, but the trend was same as in 24 hrs after spray.

At 72 hours after spray the strain, S-3@$1x10^{12}$ spores/ml was found to be most effective as it recorded highest nymphal mortality (23.33%) followed by strain S-1(13.33%), but both were at par with each other. The least effective strain was S-2(10.00%) and was significantly superior than control.

However, Ramazeame (2012) reported that at 72 hrs after spray the mortality ranged from 72 to 98.33%. The differences in the mortality in the present studies might be due to the variation in the virulency of the tested *B. bassiana* strains and doses.

At 96 hours after spray at $1x10^{12}$ spores/ml, the differences in the mean nymphal mortality among different strains were significant. Among the

strains, S-3 was found to be most effective as it recorded highest nymphal mortality (36.67%), followed by strain S-1(26.67%), but both were statistically at par with each other. The least effective strain was S-2(16.67%), but significantly superior than control (3.33%).Similar trend was observed at 120, 144 and 168 hrs after spray at $1x10^{12}$ spores/ml but with increased nymphal mortality *i.e* highest (76.67%) recorded in strain S-3, followed by S-1 (56.67%) and S-2 (46.67%) and lowest in control (10%), respectively.

At 24 hours after spray at $1X10^{10}$spores/ml, differences in the nymphal mortality among different *B. bassiana* strains were not significant. Among the strains, strain S-3 recorded highest nymphal mortality (3.33%), while no nymphal mortality was recorded in the strains S-1, S-2 and untreated control. At 168 hrs after spray there was an increase in the nymphal mortality with higher mortality registered by S-3 (53.33%), followed by S-1(46.66%) and S-2(40.00%) and lowest in control (10.00%), respectively.

At 24 hours after spray at the lowest dose of $1x10^{8}$spores/ml, no mortality was recorded in any of the strains. At 48 hours after spray at $1x10^{8}$ spores/ml, the differences in the mean nymphal mortality among different treatments were non significant. Among the strains, S-3 recorded highest mortality (10.00%), followed by strain S-1(6.67%) and S-2(3.33%) respectively, whereas no mortality was observed in control.

At 168 hrs after spray there was a slight increase in the nymphal mortality, highest (50%) was recorded in strain S-3, followed by S-1 (36.67%), S-2 (30%) and lowest in control (10%), respectively. On the contrary Sinary EI (2002) reported 100% nymphal mortality after 96 hours of spray of *B.bassiana* @$1x10^{8}$ conidia/ml. Similarly Ramos et al., (2000), Kuang (2005) and Islam (2009) reported nymphal mortality 62-71%, 84.88% to 86.81%, and 38.78% to 72.9% after 7 days of spray of *B.bassiana* @$1x10^{8}$ conidia/ml, respectively. The differences in the mortality in the present studies might be due to the variations in the virulency of the *B. bassiana* strains and doses (Quesada et al 2006).

Toxicity of three strains of *B.bassiana* was determined against *B. tabaci* using probit analysis and the LC_{50} values were recorded. The results of the analysis indicated good fit as indicated by χ^2 for all the strains .The LC_{50} value at 24 hours after treatment for strain S-3 was $8.67x10^{17}$spores/ml with very high lower and very low upper fiducial limits ($3.57x10^{6}$ and 2.11×10^{29}, respectively). The present findings are in accordance with the findings of Al alawi et al., (2014) and Zafar et al., (2016). They also reported LC_{50} values $3.16x10^{6}$, $1.17x10^{6}$, $9.33x10^{5}$, $5.62x10^{5}$ and $7.76x10^{5}$ against the test strains of *B. bassiana.*

SUMMARY AND CONCLUSIONS

6.1. Summary

The present investigation entitled, “Bionomics of whitefly, *Bemisia tabaci* on soybean cultivars and its management with *Beauveria* bassiana” was carried in the Biocontrol Laboratory, Department of Entomology, JNKVV, Jabalpur (M.P.), during 2016-2017.

The experiment was conducted with the following two objectives:

1. Biology of whitefly, *Bemisia tabaci* on soybean cultivars under laboratory conditions.
2. *In- vitro* studies on the management of whitefly with *Beauveria bassiana.*

1. Biology of whitefly, *Bemisia tabaci* on soybean cultivars under laboratory conditions:

Study on biology of *B. tabaci* was carried on three soybean cultivars under controlled conditions 25±2^{o}C, 70±10% RH with 13 hrs photophase period.

Eggs

Site, colour and pattern of egg laying:

The *B*. *tabaci* females laid eggs singly on the lower surface of the leaves. The eggs are very small with a tube like structure called stalk or pedicel, which helps the eggs to get attached with the leaf surface and transports the water from the tissues to the eggs.

After 72 hrs of exposure of soybean cultivars to the adult whitefly pairs, cultivar JS-335 was found to be the most preferred host as maximum total oviposition (39.24%) was recorded on it which was followed by JS-97-52 (34.17%) and minimum on JS- 20-98 (26.58%).

The average length and breadth of eggs laid on JS-335 was maximum (0.129 ± 0.460 mm and 0.113 ± 0.022 mm, respectively) followed by JS-97-52 (0.126± 0.045 mm and 0.113± 0.022mm, respectively) and

minimum on JS-20-98 (0.124± 0.044 mm and 0.112± 0.022 mm, respectively).

The bigger size eggs were found to be more abundant on the susceptible cultivar (JS-335) followed by tolerant (JS-97-52) and smallest in resistant cultivar (JS-20-98).

Incubation period

Incubation period was lowest on JS-335 (5.5±0.5 days) followed by JS-97-52 (7.0±1.0 days) and highest on JS-20-98 (8.0±1.0 days).

Hatching percentage

The hatching percentage of eggs was highest (93.55%) on cultivar JS 335 followed by JS- 97-52 (85.19%) and lowest on JS -20-98 (76.19%)

Nymphs:

Crawler

Newly emerged first instar nymphs are known as crawlers. At the time of hatching, the emerging nymphs bends toward the leaf surface until its front legs can clasp it, and the egg shell is pushed away by other four legs, assisted by alternate contraction and expansion of the abdomen. These nymphs crawl actively in search of suitable sites hence named as “crawler”. They are oval in shape, yellowish white in colour which crawls over the lower surface of leaf for 1-2 hours to establish on the feeding site.

The mean duration of developmental period of crawlers was found to be highest on the resistant and tolerant cultivars (JS-20-98 and JS-97-52) and lowest in susceptible cultivar (JS-335).

The average length and breadth of crawlers which developed on cultivar JS-335 was 0.231±0.047 mm and 0.224±0.044 mm, while it was 0.235±0.049 mm and 0.217±0.003 mm on JS-97-52 and 0.238±0.050 mm and 0.213±0.034 mm on JS-20-98, respectively.

The breadth of the crawlers was found to be maximum which were developing on the susceptible cultivar (JS-335) followed by tolerant cultivar (JS-97-52) and minimum in resistant cultivar (JS-20-98).

Second instar nymphs:

The freshly moulted second instar nymphs were oval, flat and whitish yellow in colour. They became yellowish and dome shaped after feeding, Second instar nymphs are immobile with atrophied legs and mycetomes are also visible *i.e.* two yellowish dot like structures present in the abdomen which play an important role in nutrition. Highest emergence of second instar nymph (96.55%) was recorded on JS-335 followed by JS-97-52 (95.65%) and lowest on JS-20-98(87.50%).

The mean duration of developmental period of second instar nymphs were found to be highest on the resistant cultivar (JS-20-98) and lowest in tolerant and susceptible cultivars (JS-97-52 and JS-335, respectively).

The average length and breadth of the nymphs which developed on cultivar JS-335 was 0.332±0.048 mm and 0.246±0.051 mm, while it was 0.323±0.043 mm and 0.218±0.039 on JS-97-52 and 0.321±0.043 and 0.229±0.048 on JS-20-98, respectively.

The bigger size second instar nymphs were more abundant on the susceptible cultivar (JS-335) followed by tolerant cultivar (JS-97-52) and smallest in resistant cultivar (JS-20-98).

Third instar nymphs

The freshly moulted third instar nymphs were also oval and flat. Initially it appeared pale yellow and gradually turned dark yellow after feeding and mycetomes continued to be visible.

Highest emergence of third instar nymphs (96.42%) was recorded on JS-335 followed by JS-97-52 (95.45%) and lowest on JS- 20-98 (92.85%).

The mean duration of developmental period of third instar nymphs were found to be highest on the resistant cultivar (JS-20-98) and lowest in susceptible and tolerant cultivars (JS-335 and JS-97-52, respectively).

Average length and breadth of the nymphs which developed on cultivar JS-335 was 0.430±0.047 mm and 0.333±0.048 mm, while it was

0.424±0.049 mm and 0.333±0.048 mm on JS-97-52 and 0.415±0.038 mm and 0.324±0.044 mm on JS-20-98, respectively.

Bigger size third instar nymphs were more abundant in the susceptible cultivar (JS-335) followed by tolerant cultivar (JS-97-52) and smallest on resistant cultivar (JS-20-98).

Fourth instar nymphs / Pseudo pupa

The freshly moulted fourth instar nymphs or pseudo pupa were oval shape and yellowish in colour. Well developed reddish brown coloured compound eyes were distinctly visible.

Highest emergence of fourth instar nymphs/ pseudo pupa (96.29%) was recorded on JS-335 followed by JS-97-52 (95.23%) and lowest on JS-20-98 (84.61%).

Mean duration of developmental period of fourth instar nymphs resulting in the emergence of the adult were found to be highest on the resistant cultivar (JS-20-98) and lowest on susceptible and tolerant cultivars (JS-335 and JS-97-52, respectively).

Average length and breadth the nymphs which developed on cultivar JS-335 was 0.531±0.047 mm and 0.450±0.051 mm, while it was 0.530±0.047 mm and 0.435±0.049 mm on JS-97-52 and 0.527±0.047 mm and 0.427±0.040 mm on JS-20-98, respectively.

Bigger size fourth instar nymphs were more abundant on the susceptible cultivar (JS-335) followed by tolerant cultivar (JS-97-52) and smallest on resistant cultivar (JS- 20-98).

Adult:

The fully developed adult emerged through “T” shaped slit on the dorsal surface of the pupal case. Adult female had prominent dark brown compound eyes with smoky white wings and pale yellow broader abdomen. The abdomen of adult male was narrow and comparatively smaller in size than the adult female. Fore and hind wings and antennae of females were larger than the males.

Highest emergence of adults (92.30%) was recorded on cultivar JS-335 followed by JS-97-52 (90.00%) and lowest on JS-20-98 (81.80%).

Total developmental period:

The mean total developmental period (from egg to adult) on the three soybean cultivars varied and it was lowest (16.5 ±2.5 days) on JS-335, followed by JS-97-52 (19.0±3.0 days) and highest (23.0±3 days) on JS-20-98.

Mortality:

Highest egg mortality (23.81%) was recorded on JS-20-98, followed by JS-97-52(14.81%) and lowest on JS-335(6.45%). Maximum mortality of crawlers were recorded on JS-20-98(12.50%), followed by JS-97-52(4.35%) and minimum on JS-335 (3.45%), respectively.

Highest mortality of second and third instar nymphs were recorded on JS-20-98(7.15 and 15.39%, respectively), followed by JS-97-52 (4.55 and 4.77%, respectively) and lowest on JS-335(3.58 and 3.71%, respectively).

Maximum mortality of 4^{th} instar nymphs or pseudo pupa were recorded on JS-20-98 (18.19%), followed by JS-97-52(10.00%) and lowest on JS-335 (7.70%).

2. *In- vitro* studies on the management of whitefly with *Beauveria bassiana*

The third instar nymphal stage of *B.tabaci* was highly susceptible to infection by *Beauveria bassiana*. Out of the three strains and doses of *B. bassiana*, strain S-3 was found to be most virulent at highest dose (10^{12} spores /ml).

At 24 hours after spray with $1x10^{12}$ spores/ ml among the strains, strain S-3 recorded highest nymphal mortality (6.67%), followed by strain S-1(3.33%), while no mortality was recorded in strain S-2 and control.

At 48 hours after spray with $1x10^{12}$ spores/ ml among the strains, S-3 recorded highest mortality (20.00%) this was followed by strains S-1(6.67%).

Least mortality was recorded in S-2(3.33%) Whereas no mortality was observed in control.

At 72 hours after treatment with $1x10^{12}$ spores/ ml among the strains, S-3 was found to be most effective as it recorded highest nymphal mortality (23.33%) followed by strain S-1(13.33.The least effective strain was S-2(10.00%) and was significantly superior than control .

At 96 hours after spray with $1x10^{12}$ spores/ ml among the strains, S-3 was found to be most effective as it recorded highest nymphal mortality (36.67%) followed by strain S-1(26.67%), but both were statistically at par with each other. The least effective strain was S-2(16.67%) but significantly superior than control (3.33%).

At 120 hours after spray with $1x10^{12}$ spores/ ml highest nymphal mortality (50.00%) was recorded in strain S-3 followed by strain S-1(43.33.The least effective strain was S-2(26.67%), but it differed significantly from control (3.33%)

At 144 hours after spray with $1x10^{12}$ spores/ ml highest nymphal mortality (53.33%) was recorded in S-1 and S-3 followed by strain S-2 (46.67%), While in control the mortality recorded was 10.00% .

At 168 hours after spray with $1x10^{12}$ spores/ ml, highest nymphal mortality (76.67%) was recorded in strain S-3 .This was followed by strain S-1(56.67%) and S-2 (46.67%), while least mortality was recorded in control (10.00%).

However, the two strains of *B.bassiana* S-1 and S-2 and the lower doses *i.e.* $1x10^{10}$ spores/ml and $1x10^{8}$ spores/ml were not so effective as was evident by the nymphal mortality even after 168 hrs of spray. Thus S-3 was found to be most virulent and at higher dose of $1x10^{12}$ spores /ml it recorded more than 75% nymphal mortality after 168 hrs of treatment.

The results of the probit analysis also showed good fit as indicated by χ^2 for all the strains .The LC_{50} value at 168 hours after treatment for strain S-3 was $1.72x10^{9}$ spores/ml with very high lower and very low upper fiducial limits ($5.64x10^{7}$ and 5.24x10, respectively).

The strain S-3 with least LC_{50} value showed the highest mortality at 168 hours after sprays.

CONCLUSIONS

The adult whitefly, *B.tabaci* females laid eggs singly on the lower surface of the leaves which were whitish yellow in colour, transparent and spindle shaped. Among the three soybean cultivars, JS-335 was found to be highly susceptible to whitefly and is evident by maximum oviposition and hatching coupled with short developmental period of the various immature stages, least mortality and high survival percentage. However, cultivars JS-97-52 and JS-20-98 were found to have detrimental effect on the biology of the whitefly *i.e.* less oviposition and hatching, with prolonged developmental period, high mortality coupled with less survival percentage.

All the three *B. bassiana* strains were significantly superior over control. However, strain S-3 was the most virulent strain against *B. tabaci* third instar nymphs and recorded highest mortality @ $1x10^{12}$ spores /ml dose.

Suggestions for further work:

In view of the changing climatic conditions, the studies on the biology of the whitefly, *Bemisia tabaci* should be continued on all the major host crops and more precisely on the legumes so as to identify tolerant or resistant genotypes.

Further the present work sufficiently gives an indication that the entomopathogenic fungus, *Beauveria bassiana* have been found to be promising against whitefly, hence this work should be continued to identify virulent strains and doses, so that they can be incorporated in the integrated pest management modules. Detailed characterization (morphological and molecular) of most effective strain of *Beauveria bassiana*.

2. *In vitro* studies on the management of whitefly with *Beauveria bassiana*

2.1. Dose: 1x 10^{12} spores /ml

2.1. i. At 24 hours after spraying

Data presented in Table 16 showed that at 24 hours after spray, differences in the nymphal mortality among different *B. bassiana* strains tested were not significant. Among the strains, strain S-3 recorded highest nymphal mortality (6.67%), followed by strain S-1(3.33%), while no mortality was recorded in strain S-2 and control.

Corrected mortality is expressed as increase or decrease in nymphal mortality over control. Computation of corrected nymphal mortality at 24 hours after spray revealed that there was no significant difference among the strains. However, highest nymphal corrected mortality was recorded in strain S-3(6.67%), followed by strain S-1(3.33%), whereas no nymphal mortality was observed in strain S-2 (Table 17).

2.1. ii At 48 hours after spraying

Perusal of the data in Table 16 revealed that at 48 hours after spray, the differences in the mean nymphal mortality among different treatments were significant. Among the strains, S-3 recorded highest mortality (20.00%) and was significantly superior than all the strains. This was followed by strains S-1(6.67%) but both were at par with each other. Least mortality was recorded in S-2(3.33%) Whereas no mortality was observed in control.

Computation of corrected nymphal mortality at 48 hours after spray revealed that there was no significant difference among the strains. However, highest nymphal corrected mortality was recorded in strain S-3 (20.00%) followed by strain S-1 (6.67%) and lowest in strain S-2 (3.33%) (Table 17).

2.1.iii At 72 hours after spraying

At 72 hours after treatment, the differences in the nymphal mortality among different strains were significant. All the *B. bassiana* strains significantly reduced the nymphal population as compared to control (3.33%). Among the strains, S-3 was found to be most effective as it recorded highest nymphal mortality (23.33%)

followed by strain S-1(13.33%), but both were at par with each other. The least effective strain was S-2(10.00%) and was significantly superior than control (Table 16).

Corrected nymphal mortality at 72 hrs after spray revealed that there was no significant difference among the strains. However, highest nymphal corrected mortality was recorded in strain S-3 (20.37%), followed by S-1(10.00%) and lowest mortality in strain S-2(6.67%) (Table 17).

2.1.iv. At 96 hours after spraying

Perusal of the data in Table 16 revealed that at 96 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Among the strains, S-3 was found to be most effective as it recorded highest nymphal mortality (36.67%) followed by strain S-1(26.67%), but both were statistically at par with each other. The least effective strain was S-2(16.67%) but significantly superior than control (3.33%).

Perusal of the data in Table 17 revealed that at 96 hours after spray there was significant increase in the corrected nymphal mortality.Strain, S-3 was found to be most effective as it recorded highest nymphal corrected mortality (34.44%) and was significantly superior than all other strains. This was followed by strain S-1(24.07%) and S-2 (13.70), but both were at par with each other.

2.1.v. At 120 hours after spraying

At 120 hours after spray, the differences in the mean nymphal mortality among the strains were significant. Highest nymphal mortality (50.00%) was recorded in strain S-3 followed by strain S-1(43.33%), but both were at par with each other. The least effective strain was S-2(26.67%), but it differed significantly from control (3.33%) (Table 16).

Perusal of the data in Table 17 revealed that at 120 hours after spray there was significant increase in the corrected nymphal mortality. Strain, S-3 was found to be highly effective as it recorded highest nymphal corrected mortality (48.52%) followed by strain S-1 (41.11%), but they did not differ significantly from each other. The least effective strain was S-2(24.07%).

2.1.vi. At 144 hours after spraying

At 144 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Highest nymphal mortality (53.33%) was recorded in S-1 and S-3 followed by strain S-2 (46.67%), but they were statistically at par with each other. While in control the mortality recorded was 10.00% (Table 16).

Corrected nymphal mortality at 144 hours after spray revealed that there was no significant difference among the strains. However, highest nymphal corrected mortality (48.15%) was recorded in strains S-1and S-3 and lowest mortality in strain S-2 (40.74%) (Table 17).

2.1. vii. At 168 hours after spraying

Perusal of the data in Table 16 revealed that at 168 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Highest nymphal mortality (76.67%) was recorded in strain S-3 and was significantly superior than all the strains. This was followed by strain S-1(56.67%) and S-2 (46.67%), but they did not differ significantly with each other, while least mortality was recorded in control (10.00%).

Perusal of the data in Table 17 revealed that at 168 hours after spray there was significant increase in the corrected nymphal mortality. Strain, S-3 was found to be highly effective as it recorded highest nymphal corrected mortality (74.07%) and was significantly superior than all the strains. This was followed by strain S-1(48.15%) and S-2(40.74%), but both were at par with each other.

2.2. Dose: 1x 10^{10} spores /ml

2.2. i. At 24 hours after spraying

Data presented in Table 18 showed that at 24 hours after spray, differences in the nymphal mortality among different *B. bassiana* strains tested were not significant. Among the strains, strain S-3 recorded highest nymphal mortality (3.33%), while no nymphal mortality was recorded in the strains S-1, S-2 and untreated control.

Computation of the corrected nymphal mortality at 24 hours after spray revealed that there was no significant difference among the strains. However, highest

nymphal corrected mortality was recorded in strain S-3(3.33%), whereas no nymphal mortality was observed in strainS-1 and S-2 (Table 19).

2.2. ii At 48 hours after spraying

Perusal of the data in Table 18 revealed that at 48 hours after spray, the differences in the mean nymphal mortality among different treatments were not significant. However, among the strains, S-3 recorded highest mortality (13.33%) followed by strains S-1 and S-2 (3.33%), while no nymphal mortality was recorded in control.

Computation of the corrected nymphal mortality at 48 hours after spray revealed that there was no significant difference among the strains. However, highest nymphal corrected mortality was recorded in strain S-3(13.33%), followed by strains S-1 and S-2 (3.33%) (Table 19).

2.2.iii At 72 hours after spraying

At 72 hours after treatment, the differences in the nymphal mortality among different strains were not significant. Among the strains, S-3 recorded highest nymphal mortality (16.67%), followed by strain S-1(10.00%) and strain S-2 (6.67%). The least mortality was recorded in control (3.33%) (Table 18).

Computation of corrected nymphal mortality at 72 hrs after spray revealed that there was no significant difference among the strains. However, highest nymphal corrected mortality was recorded in strain S-3 (16.67%), followed by S-1(10.00%) and lowest mortality in strain S-2(6.67%) (Table 19)

2.2.iv. At 96 hours after spraying

Perusal of the data in Table 18 revealed that at 96 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Among the strains, S-3 was found to be most effective as it recorded highest nymphal mortality (26.67%), followed by strain S-1(16.67%), but both were statistically at par with each other. The least effective strain was S-2(10.00%), but significantly superior than control (3.33%).

Perusal of the data in Table 19 revealed that at 96 hours after spray there was no significant difference in the corrected nymphal mortality. However, highest

nymphal corrected mortality was recorded in strain S-3 (26.66%) followed by strain S-1(16.66%) and S-2 (10.00%).

2.2.v. At 120 hours after spraying

At 120 hours after spray, the differences in the mean nymphal mortality among the strains were significant. Highest nymphal mortality (33.33%) was recorded in strains S-1 and S-3, but both were at par with each other. The least effective strain was S-2(20.00%), but it differed significantly from control (3.33%). (Table 18).

Perusal of the data in Table 19 revealed that at 120 hours after spray there was significant increase in the corrected nymphal mortality. Strain, S-3 was found to be highly effective as it recorded highest nymphal corrected mortality (31.11%) followed by strain S-1 (30.74%), but they did not differ significantly from each other. The least effective strain was S-2(17.04%).

2.2.vi. At 144 hours after spraying

At 144 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Highest nymphal mortality (50.00%) was recorded in S-3 followed by strain S-1 (43.33%) and S-2 (30.00%) and they differed significantly from each other. The least mortality was recorded in control (10.00%) (Table 18).

Perusal of the data in Table 19, revealed that at 144 hours after spray there was significant increase in the corrected nymphal mortality. Strain S-3 was found to be highly effective as it recorded highest nymphal corrected mortality (44.44%). The next effective strain was S-1(33.33%) followed by strain S-2 (22.22%) but were at par with each other.

2.2. vii. At 168 hours after spraying

Perusal of the data in Table 18 revealed that at 168 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Highest nymphal mortality (53.33%) was recorded in strain S-3 followed by strain S-1(46.66%) and S-2 (40.00%), but were at par with each other. Least mortality was recorded in control (10.00%).

Perusal of the data in Table 19 revealed that at 168 hours after spray there was significant increase in the corrected nymphal mortality. Strain, S-3 was found to be highly effective as it recorded highest nymphal corrected mortality (48.15%) followed by strain S-1(37.04%) and S-2(33.33%), but were at par with each other.

2.3. Dose: 1x 10^8 spores /ml

2.3. i. At 24 hours after spraying

Data presented in Table 20 showed that at 24 hours after spray, no mortality was recorded in any of the strains. Similar trend was observed with corrected nymphal mortality (Table 21).

2.3. ii At 48 hours after spraying

Perusal of the data in Table 20 revealed that at 48 hours after spray, the differences in the mean nymphal mortality among different treatments were non significant. Among the strains, S-3 recorded highest mortality (10.00%), followed by strain S-1(6.67%) and S-2(3.33%), whereas no mortality was observed in control.

Computation of corrected nymphal mortality at 48 hours after spray revealed that there was no significant difference among the strains. However, highest nymphal corrected mortality was recorded in strain S-3(10.00%) followed by strains S-1 and S-2 (3.33%) (Table 21).

2.3.iii At 72 hours after spraying

At 72 hours after treatment, the differences in the nymphal mortality among different strains were non significant. Among the strains, S-3 recorded highest nymphal mortality (13.33%), followed by strain S-1(10.00%) and S-2(6.67%), while it was lowest in control (3.33%) (Table 20).

Corrected nymphal mortality at 72 hrs after spray revealed that there was no significant difference among the strains. However, highest nymphal corrected mortality was recorded in strain S-3 (10.37%), followed by S-1(6.67%) and lowest in strain S-2(3.33%) (Table 21).

2.3.iv. At 96 hours after spraying

Perusal of the data in Table 20 revealed that at 96 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Among the strains, S-3 was found to be most effective as it recorded highest nymphal mortality (20.00%) followed by strain S-1 and S-2(10.00%), but were at par with each other. However, all the strains were significantly superior than control (3.33%).

Perusal of the data in Table 21 revealed that at 96 hours after spray there was an increase in the corrected nymphal mortality, but statistically found to be non significant. Strain, S-3 was found to be most effective as it recorded highest nymphal corrected mortality (17.04%), followed by strains S-1 and S-2 (6.67%).

2.3.v. At 120 hours after spraying

At 120 hours after spray, the differences in the mean nymphal mortality among the strains were significant. Highest nymphal mortality (30.00%) was recorded in strain S-3 followed by strain S-1(23.33%), but both were at par with each other. The least effective strain was S-2(13.33%), but it differed significantly from control (3.33%) (Table 20).

Perusal of the data in Table 21 revealed that at 120 hours after spray there was significant increase in the corrected nymphal mortality. Strain, S-3 recorded highest nymphal corrected mortality (27.78%), followed by strain S-1 (20.74%) and S-2(10.37%).

2.3.vi. At 144 hours after spraying

At 144 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Highest nymphal mortality (40.00%) was recorded in S-3, followed by strain S-1(26.67%) and S-2 (16.67%) and they differed significantly from each other. The least mortality was recorded in control (10.00%) (Table 20).

Perusal of the data in Table 21 revealed that at 144 hours after spray there was no significant increase in the corrected nymphal mortality. Strain S-3 recorded

highest nymphal corrected mortality (33.33%), followed by strain S-1(29.63%) and S-2(7.41%).

2.3. vii. At 168 hours after spraying

Perusal of the data in Table 20 revealed that at 168 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Highest nymphal mortality (50.00%) was recorded in strain S-3 and was significantly superior than all the strains. This was followed by strain S-1(36.67%) and S-2 (30.00%), but they did not differ significantly with each other, while least mortality was recorded in control (10.00%).

Perusal of the data in Table 21 revealed that at 168 hours after spray there was significant increase in the corrected nymphal mortality. Strain S-3 recorded highest nymphal corrected mortality (44.44%), followed by strain S-1(22.22%) and S-2(18.52%) but both were at par with each other.

2.4 Effect of *Beauveria bassiana* strains and doses and their interaction on *Bemisia tabaci* (3^{rd} instar nymphs):

2.4.a. At 24 hours after spraying (Table 22)

Factor A: Strains

Perusal of the data in Table 22 revealed that at 24 hours after spray, the differences in the mean nymphal mortality among different strains were not significant. Among the strains, S-3 was found to be most effective as it recorded highest mortality (3.33%), followed by S-1 (1.11%). However, no mortality was recorded in strain S-2 and control.

Factor B: Doses

Different doses of *B. bassiana* evaluated for nymphal mortality at 24 hours after spray were found to be non significant. However, highest nymphal mortality (3.33%) was recorded with dose D_1 ($1x\ 10^{12}$ spores / ml), followed by D_2 ($1x10^{10}$ spores / ml) (1.11%), while no mortality was recorded with the lowest dose D_3 ($1x10^{8}$ spores / ml).

Interaction: Strains x Doses

The interaction of *B. bassiana* strains and doses had no significant impact on the nymphal mortality.

2.4.b At 48 hours after spraying (Table 23)

Factor A: Strains

Perusal of the data in Table 23 revealed that at 48 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Among the strains, S-3 was found to be most effective as it recorded highest mortality (14.44%), this was followed by S-1(4.44%) and S-2 (3.33%), but both were at par with each other.

Factor B: Doses

Different doses of *B. bassiana* evaluated for nymphal mortality at 48 hours after spray were found to be non-significant. However, highest mortality (10.00%) was registered with dose D_1 ($1x10^{12}$spores / ml), followed by dose D_2 ($1x10^{10}$ spores / ml) and dose D_3 ($1x10^{8}$ spores / ml) (6.67 and 5.56% nymphal mortality, respectively).

Interactions: Strains x Doses

The interaction of *B.bassiana* strains and doses had no significant impact on the nymphal mortality.

2.4.c At 72 hours after spraying

Factor A: Strains

Perusal of the data in Table 24 revealed that at 72 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Among the strains, S-3 was found to be most effective as it recorded highest mortality (17.78%) followed by S-1(11.11%), but were at par with each other. Least mortality was recorded in S-2 (7.77%).

Factor B: Doses

Different doses of *B. bassiana* evaluated for nymphal mortality at 72 hours after spray were found to be non significant. However, highest mortality (15.56%)

was registered with dose D_1($1x10^{12}$spores / ml), followed by D_2 ($1x10^{10}$ spores / ml) and D_3 ($1x10^8$ spores / ml) (11.11%and 10.00%, respectively).

Interaction: Strains x Doses

The interaction of *B. bassiana* strains and doses had no significant impact on the nymphal mortality.

2.4.d. At 96 hours after spraying

Factor A: Strains

Perusals of the data in Table 25 revealed that at 96 hours after spray, the difference in the mean nymphal mortality among different strains were significant. Among the strains, S-3 was found to be most effective as it recorded highest mortality (27.78%) and was significantly superior than the other strains. This was followed by S-1(17.78%) and S-2 (12.22%), but they differed significantly from each other.

Factor B: Doses

Different doses of *B. bassiana* evaluated for nymphal mortality at 96 hours after spray were found to be significant. Highest nymphal mortality (26.66%) was registered with dose D_1 ($1x10^{12}$spores / ml) and was superior than all other doses. This was followed by dose D_2 ($1x10^{10}$ spores / ml) and D3 ($1x10^8$ spores / ml) (17.77%and 13.33%, respectively), but at par with each other.The results indicate that the nymphal mortality was dose dependent.

Interaction: Strains x Doses

The interaction of *B. bassiana* strains and doses had no significant impact on the nymphal mortality.

2.4.e At 120 hours after spraying

Factor A: Strains

Perusal of the data in Table 26 revealed that at 120 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Among the strains, S-1 was found to be most effective as it recorded highest mortality (33.33%), followed by strain, S-3 (27.78%) but both were at par with each

other. However, strain S-2 was found to be least effective as it recorded lowest nymphal mortality (20.00%).

Factor B: Doses

Evauation of *B.*bassiana at varied doses after 120 hours of spray was found to be significant. The data revealed that highest mortality was recorded with dose D_1 ($1x10^{12}$ spores/ml) (35.56%) followed by dose D_2 ($1x10^{10}$ spores/ml) (26.67%) and D_3 ($1x10^{8}$ spores/ml) (18.89%) and they differed significantly from each other.

The results indicated that the nymphal mortality was dose dependent .

Interaction: Strains x Doses

The interaction of strains and doses had no significant impact on the nymphal mortality.

2.4.f At 144 hours after spraying

Factor A: Strains

Perusal of the data in Table 27 revealed that at 144 hours after spray, the differences in the mean nymphal mortality among different strains were significant. Among the strains, S-1 was found to be most effective as it recorded highest mortality (41.11%), followed by S-3(37.78%), but both were at par with each other. However, strain S-2 was found to be least effective as it recorded lowest nymphal mortality (31.11%).

Factor B: Doses

Evaluation of *B.*bassiana at varied doses after 144 hours of spray was found to be significant. The data revealed that highest mortality (50.00%) was recorded with dose D_1 ($1x10^{12}$ spores/ml) followed by dose D_2 ($1x10^{10}$ spores/ml) (35.55%) and D_3 ($1x10^{8}$ spores/ml) (24.44%), but they differed significantly from each other.

The results indicated that the nymphal mortality was dose dependent.

Interaction: Strains x Doses

The interaction of strains and doses had significant impact on the nymphal mortality.

2.4.g At 168 hours after spraying

Factor A: Strains

Perusal of the data in Table 28 revealed that at 168 hours after spray, the differences in the mean nymphal mortality among different strains were significant.

Among the strains, S-3 was found to be most effective as it recorded highest mortality (60.00%) followed by S-1(46.67%) and S-2 (38.89%) but they differed significantly from each other.

Factor B: Doses

Evaluation of *B.*bassiana at varied doses after 168 hours of spray were found to be significant. The data revealed that highest mortality was recorded with dose D_1 (60.00%) followed by dose D_2 (46.67%) and D_3 (38.89%) and they differed significantly from each other.

The results indicated that the nymphal mortality was dose dependent.

Interaction: Strains x Doses

The interaction of strains and doses had significant impact on the nymphal mortality.

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APPENDICES

APPENDIX-I

ANOVA 1: Efficacy of different strains of *Beauveria bassiana* ($1x10^{12}$ spores ml^{-1}) on *Bemisia tabaci* (3^{rd} instar nymphs) at different intervals after treatment

i. 24 hours after treatment

Sources	df	SS	MSS	Fcal	Ftab
Treatment	3	202.418	67.47	1.833	4.07
Error	8	294.426	36.08	-	-
Total	11	496.844	-	-	-

SEm ± = 3.50 CD at 5% = NS

ii. 48 hours after treatment

Sources	df	SS	MSS	Fcal	Ftab
Treatment	3	832.082	277.36	5.52	4.07
Error	8	401.483	50.18	-	-
Total	11	1233.566	-	-	-

SEm ± = 4.09 CD at 5% = 13.33

iii. 72 hours after treatment

Sources	df	SS	MSS	Fcal	Ftab
Treatment	3	621.914	207.30	7.57	4.07
Error	8	219.020	27.37	-	-
Total	11	840.940	-	-	-

SEm± = 3.02 CD at 5% = 9.85

iv. 96 hours after treatment

Sources	df	SS	MSS	Fcal	Ftab
Treatment	3	1356.159	452.05	14.88	4.07
Error	8	243.026	30.37	-	-
Total	11	1599.186	-	-	-

SEm± = 3.18 CD at 5% = 10.37

v. 120 hours after treatment

Sources	df	SS	MSS	Fcal	Ftab
Treatment	3	2384.662	794.88	23.99	4.07
Error	8	265.0341	33.129	-	-
Total	11	2649.696	-	-	-

SEm± = 3.32 CD at 5% = 10.83

vi. 144 hours after treatment

Sources	df	SS	MSS	Fcal	Ftab
Treatment	3	1694.37	564.78	67.85	4.07
Error	8	66.580	8.323	-	-
Total	11	1760.955	-	-	-

SEm ± = 1.66 CD at 5% = 5.43

vii. 168 hours after treatment

Sources	df	SS	MSS	Fcal	Ftab
Treatment	3	2908.29	969.43	104.98	4.07
Error	8	73.870	9.2340	-	-
Total	11	2982.163	-	-	-

SEm ± = 1.75 CD at 5% = 5.72

ANOVA 2: Efficacy of different strains of *Beauveria bassiana* ($1x10^{12}$spores ml^{-1}) on *B. tabaci* (3^{rd} instar nymphs) at different intervals after treatment (Corrected mortality)

i. 24 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	147.0633	73.53163	1.5	5.14
Error	6	294.1265	49.02109	-	-
Total	8	441.1898	-	-	-

SEm ± = 4.04 CD at 5% = NS

ii. 48 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	462.4422	231.221	3.436309	4.46
Error	6	403.7257	67.287	-	-
Total	8	866.1679	-	-	-

SEm ± = 4.73 CD at 5% = NS

iii. 72 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	258.2149	129.10	1.516744	4.46
Error	6	510.7285	85.121	-	-
Total	8	768.9434	-	-	-

SEm± = 5.32 CD at 5% =NS

iv. 96 hours after treatment

Sources	Df	SS	MSS	F CAL	F TAB
Treatment	2	294.341	147.170	10.950	5.14
Error	6	80.637	13.439	-	-
Total	8	374.970	-	-	-

SEm ± = 2.11 CD at 5% = 7.32

v. 120 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	349.513	174.756	9.2517	5.14
Error	6	113.333	18.888	-	-
Total	8	462.847	-	-	-

SEm ± = 2.50 CD at 5% = 8.68

vi. 144 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	32.230	16.115	1.169	5.14
Error	6	82.680	13.7810	-	-
Total	8	114.910	-	-	-

SEm ±= 2.14 CD= NS

vii. 168 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	655.270	327.6352	21.9327	5.14
Error	6	89.629	14.9382	-	-
Total	8	744.899	-	-	-

SEm ± = 2.23 CD at 5% = 7.72

ANOVA 3: Efficacy of different strains of *Beauveria bassiana* ($1x10^{10}$ spores ml^{-1}) on *Bemisia tabaci* (3^{rd} instar nymphs) at different intervals after treatment

i. 24 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	3	55.2049	18.40163	1	4.07
Error	8	147.2131	18.40163	-	-
Total	11	202.418	-	-	-

SEm± =2.47 CD at 5% = NS

ii. 48 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	3	504.5378	168.1793	3.990023	4.07
Error	8	337.1995	42.14994	-	-
Total	11	841.7373	-	-	-

SEm ± = 3.74 CD at 5% = NS

iii. 72 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	**3**	385.6067	128.5356	3.049484	4.07
Error	**8**	337.1995	42.14994	-	-
Total	**11**	722.8062	-	-	-

SEm ± = 3.74 CD at 5% = NS

iv. 96 hours after treatment

Sources	df	SS	MSS	F cal	F tab
Treatment	3	795.858	265.2863	9.689652	4.07
Error	8	219.026	27.37831	-	-
Total	11	1014.88	-	-	-

SEm ± = 3.02 CD at 5% = 9.85

v. 120 hours after treatment

Sources	df	SS	MSS	F cal	F tab
Treatment	3	1406.39	468.7985	19.21177	4.07
Error	8	195.213	24.40163	-	-
Total	11	1601.609	-	-	-

SE m ± = 2.85 CD at 5% = 9.30

vi. 144 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	3	1242.285	414.0949	149.2552	4.07
Error	8	22.196	2.774408	-	-
Total	11	1264.48	-	-	-

SEm ± = 0.96 CD at 5% = 3.13

vii. 168 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	3	1454.453	484.8177	87.37317	4.07
Error	8	44.39053	5.548817	-	-
Total	11	1498.844	-	-	-

SEm± = 1.36 CD at 5% = 4.43

ANOVA 4: Efficacy of different strains of *Beauveria bassiana* ($1x10^{10}$spores ml^{-1}) on *B. tabaci* (3^{rd} instar nymphs) at different intervals after treatment (Corrected mortality)

i. 24 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	49.01	24.502	0.999353	5.14
Error	6	147.11	24.518	-	-
Total	8	196.12	-	-	-

SEm± = 2.85 CD at 5% = NS

ii. 48 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	294.65	147.3241	2.612905	5.14
Error	6	338.30	56.38326	-	-
Total	8	632.95	-	-	-

SEm± = 4.33 CD at 5% = NS

iii. 72 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	237.12	118.562	2.133846	5.14
Error	6	333.38	55.562	-	-
Total	8	570.50	-	-	-

SEm± = 4.30 CD at 5% = NS

iv. 96 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	323.749	161.874	3.122952	5.14
Error	6	311.0029	51.833	-	-
Total	8	634.7518	-	-	-

SEm ± = 4.15 CD at 5% = NS

v. 120 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	180.8954	90.4477	5.528554	5.14
Error	6	98.1606	16.3601	-	-
Total	8	279.056	-	-	-

SEm ± = 2.33 CD at 5%= 8.08

vi. 144 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	266.997	133.499	8.555095	5.14
Error	6	93.628	15.6046	-	-
Total	8	360.624	-	-	-

SEm± = 2.28 CD at 5% = 7.89

vii. 168 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	122.2149	61.108	6.578009	5.14
Error	6	55.73794	9.2897	-	-
Total	8	177.9528	-	-	-

SEm ± = 1.75 CD at 5% = 6.08

ANOVA 5: Efficacy of different strains of *Beauveria bassiana* ($1x10^8$ spores ml^{-1}) on *Bemisia tabaci* (3^{rd} instar nymphs) at different intervals after treatment

i. 24 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	3	0.00	0.00	0.00	4.07
Error	8	0.00	0.00	-	-
Total	11	0.00	-	-	-

SEm± = 0.00 CD at 5% = NS

ii. 48 hours after treatment

Sources	Df	SS	MSS	F CAL	F TAB
Treatment	3	368.0327	122.6776	3.3334	4.07
Error	8	294.4261	36.80327	-	-
Total	11	662.4588	-	-	-

SEm ±=3.50 CD at 5% = NS

iii. 72 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	3	277.9723	92.65743	2.198281	4.07
Error	8	337.1995	42.14994	-	-
Total	11	615.1718	-	-	-

SEm± = 3.74 CD at 5% = NS

iv. 96 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	3	460.7801	153.5934	4.8325	4.07
Error	8	254.2705	31.78381	-	-
Total	11	715.0506	-	-	-

SEm ± = 3.25 CD at 5% = 10.61

v. 120 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	3	1024.854	341.6181	9.156622	4.07
Error	8	298.4665	37.30831	-	-
Total	11	1323.321	-	-	-

SEm± = 3.52 CD at 5% = 11.50

Vi. 144 hours after treatment

Sources	Df	SS	MSS	F CAL	F TAB
Treatment	3	730.784	243.5947	26.537	4.07
Error	8	73.439	9.179742	-	-
Total	11	804.23	-	-	-

SEm ± = 1.74 CD at 5% = 5.70

vii. 168 hours after treatment

Sources	Df	SS	MSS	F CAL	F TAB
Treatment	3	1118.991	372.9969	123.5075	4.07
Error	8	24.16027	3.020033	-	-
Total	11	1143.151	-	-	-

SEm± = 1.00 CD at 5% = 3.27

ANOVA 6 : Efficacy of different strains of *Beauveria bassiana* ($1x10^8$ spores ml^{-1}) on *B. tabaci* (3^{rd} instar nymphs) at different intervals after treatment (Corrected mortality)

i. **24 hours after treatment**

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	0.00	0.00	0.00	5.14
Error	6	0.00	0.00	-	-
Total	8	0.00	-	-	-

SEm ± = 0.00 CD at 5% = NS

ii. 48 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	177.64	88.819	1.811852	5.14
Error	6	294.127	49.022	-	-
Total	8	471.778	-	-	-

SEm ± = 4.04 CD at 5% = NS

iii. 72 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	143.219	71.609	1.457213	5.14
Error	6	294.848	49.1415	-	-
Total	8	438.067	-	-	-

SEm ± = 4.87 CD at 5% = NS

iv. 96 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	189.987	94.9934	1.324686	5.14
Error	6	430.259	71.7099	-	-
Total	8	620.246	-	-	-

SEm± =4.04 CD at 5% =NS

v. **120 hours after treatment**

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	256.68	254.6757	6.7709	5.14
Error	6	43.6129	37.6129	-	-
Total	8	300.289	-	-	-

SEm± = 3.54 CD at 5% = 12.25

vi. 144 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	764.4296	762.4297	3.894003	5.14
Error	6	201.7959	195.7959	-	-
Total	8	966.2255	-	-	-

SEm± = 8.07 CD at 5% =NS

vii. 168 hours after treatment

Sources	df	SS	MSS	F CAL	F TAB
Treatment	2	469.929	467.929	10.63547	5.14
Error	6	49.99707	43.997	-	-
Total	8	519.9268	-	-	-

SEm± = 3.82 CD at 5% =13.25

ANOVA 7: Effect of *Beauveria bassiana* strains and doses on *Bemisia tabaci* (3rd instar nymphs) at different hours after treatment

i. 24 hours after treatment

Sources	D.F	S.S	M.S	Fcal	Ftab	SEm±	CD@5%
Strain	2	114.49	57.245	2.334	3.55	1.65	NS
Dose	2	114.49	57.245	2.334	3.55	1.65	NS
Sxd	4	81.78	20.445	0.834	2.93	2.85	NS
Error	18	441.63	24.535	-	-	-	-
Total	26	752.39	-	-	-	-	-

-

ii. 48 hours after treatment

Sources	D.F	S.S	M.S	Fcal	Ftab	SEm±	CD@5%
Strain	2	947.43	473.715	8.2537	3.55	2.52	7.49
Dose	2	86.57	43.285	0.755	3.55	2.52	NS
Sxd	4	50.19	12.548	0.2187	2.93	4.37	NS
Error	18	1033.1	57.395	-	-	-	-
Total	26	2117.29	-	-	-	-	-

iii. 72 hours after treatment

Sources	D.F	S.S	M.S	Fcal	Ftab	SEm±	CD@5%
Strain	2	329.32	164.66	5.993	3.55	1.74	5.18
Dose	2	185.02	92.51	3.367	3.55	1.74	NS
Sxd	4	33.15	8.2875	0.302	2.93	3.02	NS
Error	18	494.55	27.475	-	-	-	-
Total	26	1042.04	-	-	-	-	-

IV. 96 hours after treatment

Sources	D.F	S.S	M.S	Fcal	Ftab	SEm±	CD@5%
Strain	2	563.54	281.77	18.465	3.55	1.30	3.87
Dose	2	427.05	213.525	13.992	3.55	1.30	3.87
Sxd	4	47.18	11.795	0.773	2.93	2.26	NS
Error	18	274.68	15.26	-	-	-	-
Total	26	1312.45	-	-	-	-	-

v. 120 hours after treatment

Sources	D.F	S.S	M.S	Fcal	Ftab	SEm±	CD@5%
Strain	2	643.89	321.945	18.277	3.55	1.39	4.15
Dose	2	585.44	292.72	16.618	3.55	1.39	4.15
Sxd	4	28.78	7.195	0.408	2.93	2.42	NS
Error	18	317.07	17.615	-	-	-	-
Total	26	1575.18	-	-	-	-	-

vi. 144 hours after treatment

Sources	D.F	S.S	M.S	Fcal	Ftab	SEm±	CD@ 5%
Strain	2	488.72	244.36	27.116	3.55	1.00	2.97
Dose	2	927.86	463.93	51.481	3.55	1.00	2.97
s*d	4	113.02	28.255	3.135	2.93	1.73	5.14
Error	18	162.21	9.011667	-	-	-	-
Total	26	1691.81	-	-	-	-	-

vii. 168 hours after treatment

Sources	D.F	S.S	M.S	Fcal	Ftab	SEm±	CD@5%
Strain	2	725.93	362.965	45.874	3.55	0.94	2.78
Dose	2	728.21	364.105	46.018	3.55	0.94	2.78
s*d	4	94	23.5	2.970	2.93	1.62	4.82
Error	18	142.42	7.912222	-	-	-	-
Total	26	1690.56	-	-	-	-	-

ABSTRACT

Title of the thesis	:	"Bionomics of Whitefly, *Bemisia tabaci* on soybean cultivars and its management with *Beauveria bassiana*"
Student's Name	:	**Gopaldas Sneha Latha**
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Name and address of major advisor	:	**Dr. S. B. Das professor** **Department of Entomology, JNKVV, Jabalpur (M.P.)**
Degree to be awarded	:	Master of Science in Agriculture
Year of award of degree	:	2017
Major subject	:	Entomology
Total no. of pages in the thesis	:	84
Number of words in the abstract	:	302

Signature of Advisor	Signature of Head of Department	Signature of Student
(Dr. S. B. Das)	**(Dr. A. K. Bhoumick)**	**(Gopaldas Sneha latha)**

Abstract

"**Bionomics of *Bemisia tabaci* on soybean cultivars and its management with *Beauveria bassiana*"**

Name of the student	**:**	Gopaldas Sneha Latha
Name and designation of the advisor	**:**	Dr. S.B.Das Professor, Department of Entomology
College	**:**	Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

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Madhya Pradesh is one of the main soybean producers in the country. But a considerable part of the production is lost due to *Bemisia tabaci* (Genn.) attacks. Resistant plants can be an important method for controlling this pest in an integrated pest management. Tests for evaluating some biological aspects of *B. tabaci* were carried out on three soybean cultivars, in controlled laboratory conditions (25± 2^0 C, 70±10% RH, 13 photophase). Trifoliate plants placed in plastic cages were infested with a pair of whitefly, for 72 hrs. The development was observed until adult emergence. The development period of insects grown on JS-20-98 cultivar (23.0±3.0 days) took 4-7 days longer when compared to the grown in JS-97-52 (19.0±3.0 days) and JS-335 (16.5±2.5 days). Adult emergence percentage highest on JS-335(92.30%), 85.19 on (JS- 97-52) 76.19% on (JS-20-98).The highest mortality rate of whitefly egg to whitefly occurred in JS-20-98(77.04%) and followed by JS-97-52 (38.48%) the lowest on JS-335 (24.89%, respectively).

Bemisia tabaci management by using *Beauveria bassiana*. The LC_{50} value at 168 hours after treatment for strain S-3 was$1.72x10^9$ spores/ml with very high lower and very low upper fiducial limits of ($5.64x10^7$ and 5.24x 10, respectively) followed by S-2 and S-1 there is a difference among the strains at highest period of spraying. Among the doses at 168 hours after spray $1x10^{12}$ spores/ml is showing highest mean mortality (51.05%) followed by $1x10^{10}$ spores/ml with mean mortality (43.08%), least mortality was recorded in $1x10^8$ spores/ml (38.48%,respectively).

Key words : *Bemisia tabaci*, *Beauveria bassiana*, strain, Doses.

CURRICULUM VITAE

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She passed her High School (10th) with (83.33%) in the year 2008 from Saidaiah Concept school, Kodad (Dist.). Nalgonda (A.P) and passed Higher Secondary School (12th) with (84.1%) in the year 2010 from Narayana Jr., College, Hyderabad (A.P).

She took admission for B.SC. (Ag.) in the Professor Jayashankar Telangana State Agricultural University (Telangana) in the year 2011. She has successfully completed her graduation with 8.03 OGPA in the year 2015.

After graduation, for further study, she got admission in M.Sc.(Ag.) for specialization in Entomology at the College of Agriculture, JNKVV, Jabalpur(M.P), where she successfully completed all the course requirement for master's degree with OGPA 7.74 out of 10 points scale in the year 2015.

For the partial fulfillment of the master's degree she has successfully conducted this piece of research work entitled "Bionomics of whitefly, *Bemisia tabaci* on soybean cultivars and its management with *Beauveria bassiana*" which is being submitted in the form of this thesis.