

**POPULATION DYNAMICS, BIOLOGY AND MANAGEMENT OF
FRUIT FLY, *Bactrocera cucurbitae* (Coquillett) INFESTING
CUCURBITACEOUS VEGETABLE CROPS**

by

Mr. Bade Anand Sunil

(Reg. No. 2018/35)

A Thesis submitted to the
**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI – 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA.**

in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY



DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

**POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. - AHMEDNAGAR
MAHARASHTRA, INDIA.**

2023

**POPULATION DYNAMICS, BIOLOGY AND MANAGEMENT OF
FRUIT FLY, *Bactrocera cucurbitae* (Coquillett) INFESTING
CUCURBITACEOUS VEGETABLE CROPS**

by

Mr. Bade Anand Sunil

(Reg. No. 2018/35)

A Thesis submitted to the
**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI – 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA.**

in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

APPROVED BY

Dr. S. R. Kulkarni

(Chairman and Research Guide)

Dr. G.B. Kabre
(Committee Member)

Dr. A.B. Tambe
(Committee Member)

Dr. M.N. Bhalekar
(Committee Member)

Dr. V.S. Wani
(Committee Member)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

**POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. - AHMEDNAGAR
MAHARASHTRA, INDIA.**

2023

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institution
for a Degree or
Diploma

Place : MPKV, Rahuri

Date : / /2023

(Anand S. Bade)

Dr. S. R. Kulkarni
Professor,
Department of Agricultural Entomology,
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722, Dist. Ahmednagar,
Maharashtra State, INDIA

CERTIFICATE

This is to certify that the thesis entitled, “**POPULATION DYNAMICS, BIOLOGY AND MANAGEMENT OF FRUIT FLY, *Bactrocera cucurbitae* (Coquillett) INFESTING CUCURBITACEOUS VEGETABLE CROPS**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the results of a piece of *bona fide* research work carried out by **Mr. BADE ANAND SUNIL**, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

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

Place : MPKV, Rahuri

(S. R. Kulkarni)

Date : / /2023

Research Guide

Dr. C. S. Patil

Head,

Department of Agricultural Entomology,

Mahatma Phule Krishi Vidyapeeth,

Rahuri-413 722, Dist. Ahmednagar,

Maharashtra State, INDIA.

CERTIFICATE

This is to certify that the thesis entitled, “**POPULATION DYNAMICS, BIOLOGY AND MANAGEMENT OF FRUIT FLY, *Bactrocera cucurbitae* (Coquillett) INFESTING CUCURBITACEOUS VEGETABLE CROPS**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the results of a piece of *bona fide* research work carried out by **Mr. BADE ANAND SUNIL**, under the guidance and supervision of **Dr. S.R. KULKARNI**, Professor of Agricultural Entomology and that no part of the thesis has been submitted for any other degree or diploma.

Place : MPKV, Rahuri

Date : / /2023

(C. S. Patil)

Dr. B. D. Bhakare

Associate Dean,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722, Dist. Ahmednagar,
Maharashtra State, INDIA

CERTIFICATE

This is to certify that the thesis entitled, “**POPULATION DYNAMICS, BIOLOGY AND MANAGEMENT OF FRUIT FLY, *Bactrocera cucurbitae* (Coquillett) INFESTING CUCURBITACEOUS VEGETABLE CROPS**” submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY**, embodies the results of a piece of *bona fide* research work carried out by **Mr. BADE ANAND SUNIL**, under the guidance and supervision of **Dr. S.R. KULKARNI**, Professor of Agricultural Entomology and that no part of the thesis has been submitted for any other degree or diploma.

Place : MPKV, Rahuri

Date : / /2023

(B. D. Bhakare)

ACKNOWLEDGEMENT

“Native ability without education is like a tree without fruit”

To reach a goal, you don't need to know all the answers in advance. But you must have clear idea of the goal you want to reach. Success is possible only after involvement of many minds and hands to beautiful it. Emotions cannot be expressed in words because then emotions are transformed into mere formalities. Nevertheless, formalities have to be completed.

*Inspiration is the best medicine which can make it possible to run for crippled one and it is veritable gold of mine to get the talented and inspiring willful guidance of **Dr. S.R. Kulkarni**, Professor, Department of Agricultural Entomology, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri and Chairman of my Advisory Committee, who in his unique way, provided me with constant encouragement, inspiring, scholastic guidance but constructive criticism, love and affection offered to me during the course of my study and research.*

*With illimitable pleasure, I evoke on record the ineffaceable indebtedness to my advisory committee members **Dr. G.B. Kabre**, Professor, Section of Agril. Entomology, College of Agriculture, Dhule, **Dr. A.B. Tambe**, Ex. Professor of Entomology, AICRP on Forage Crops, MPKV, Rahuri, **Dr. M.N. Bhalekar**, Ex. Senior Vegetable Breeder, AICRP on Vegetables, MPKV, Rahuri, **Dr. V.S. Wani**, Professor & Head, Dept. of Statistics, MPKV, Rahuri for their suggestions and guidance at different stages of dissertation.*

*I am highly obliged to **Dr. P.G. Patil**, Hon'ble Vice-Chancellor, **Dr. S.D. Gorantiwar**, Director of Research, MPKV, Rahuri, **Dr. U.D. Chavhan**, Director of Instruction and Dean (F/A), MPKV, Rahuri, **Dr. T.K. Narute**, Director of Extension Education, MPKV, Rahuri, **Dr. B.D. Bhakare**, Associate Dean (PG), Post Graduate Institute, MPKV, Rahuri and **Dr. C.S. Patil**, Head, Department of Agricultural Entomology, MPKV, Rahuri for providing necessary educational atmosphere and financial support during the course of investigation at the campus of University.*

*I am also thankful to **Dr. S.T. Aghav**, Assistant Professor, **Dr. P.R. Palande**, Assistant Professor, **Mrs. M.G. Chemate**, **Mr. K.G. Gawade** and **Mr. S.G. Shete**, Agriculture Assistant, Department of Agricultural Entomology, Mahatma Phule Krishi Vidyapeeth, Rahuri for their suggestions and guidance at different stages of my Ph.D. Special thanks to **Dr. R.L. Naik**, Ex-Associate Professor of Entomology, College of Agriculture, Pune who advised and guided a lot during dissertation writing.*

*Everything in my life is nothing if I ignore all time encouragement, inspiration, ever green affection and latent love of my father **Mr. Sunil Jagannath Bade**, my mother **Mrs. Savita Sunil Bade**, my sisters **Miss. Shubhangi** and **Mrs. Brinda**, my beloved wife **Miss. Ashatai Kendre**, my father-in-law **Mr. Hanumantrao Kendre**,*

mother-in-law **Mrs. Kusum Kendre** and brother-in-law **Mr. Baliram Kendre** who elevated my moral during the whole educational career.

I express my deep sense of gratitude and indebtedness to **Mahatma Jyotiba Phule Research and Training Institute (MAHAJYOTI), Nagpur** for providing financial assistance for the completion of my Ph.D. degree programme.

My sincere thanks to all those who helped me in fields as well as in the laboratory during the course of investigation. I also express my thanks to **Mr. Dattu Pawar, Mr. Vaibhav Anap, Mr. Dilip Salave and Mr. Dnyaneshwar Bhusari** for his hands of co-operation.

Thanks is the worst word in friendship, yet I shall gain this opportunity to extend my sincere, heartfelt gratitude to my seniors; **Mr. Vijay Shinde, Miss. Sharayu Patil, Mr. Uday Pawar, Miss. Rasmika Kumbhar, Mr. Appala Raju Konni and Mr. Ganesh Gote** and my great batch mate friends; **Mr. Sagar Band, Mr. Sagar Patil, Mr. Narayan Ingale, Mr. Shubham Bhosale, Mr. Suraj Jadhav, Mr. Tushar Bhosale, Mr. Harshwardhan Markad** and my dear juniors **Mr. Nitin Parjane, Mr. Kiran Deshmukh, Mr. Devanand Bankar, Mr. Anand Rothe, Mr. Parmeshwar Wakade and Mr. Kiran Chaudhari** who supported me strongly and believably to carry out this research work. My sincere thanks also for extending hands of co-operation by my lovely friends; **Mr. Sumit Kharde, Mr. Gaurav Deshmukh, Mr. Pratik Phopase, Mr. Prashant Dighe, Mr. Vijay Jawane, Mr. Jairam Panchal, Mr. Ramesh Chopade, Mr. Amol Wandhekar, Mr. Shivram Dhure, Mr. Ganesh Bhandare and Mr. Rahul Gunaware** during the research work. Inadvertently I might have forgotten to mention the names of invisible hand for their help, I am thankful to them as well.

Last but not least my warm acknowledgements to **farmers, soldiers, scientists and great social workers**, who have devoted their whole life for the country.

Place : MPKV, Rahuri.

Date : / /2023

(Anand S. Bade)

CONTENTS

Chapter No.	Title	Page No.
	CANDIDATES DECLARATION	iii
	CERTIFICATE OF RESEARCH GUIDE	iv
	CERTIFICATE OF HEAD OF THE DEPARTMENT	v
	CERTIFICATE OF ASSOCIATE DEAN	vi
	ACKNOWLEDGEMENT	vii
	CONTENTS	ix
	LIST OF TABLES	xiii
	LIST OF FIGURES	xv
	LIST OF PLATES	xvi
	LIST OF ABBREVIATIONS AND SYMBOLS	xvii
	ABSTRACT	xviii
1	INTRODUCTION	1
2	REVIEW OF LITERATURE	6
	2.1 Population Dynamics of Fruit Fly, <i>B. cucurbitae</i> Infesting Cucurbitaceous Vegetable Crops	6
	2.2 Biology of Fruit Fly, <i>B. cucurbitae</i> Infesting Cucurbitaceous Vegetable Crops	18
	2.2.1 Life Stages of Fruit Fly, <i>B. cucurbitae</i> Infesting Cucurbitaceous Vegetable Crops	18
	2.2.1.1 Mating Period	18
	2.2.1.2 Pre-oviposition, Oviposition and Post-oviposition Period	18
	2.2.1.3 Fecundity	19
	2.2.1.4 Hatchability	20
	2.2.1.5 Incubation Period	20
	2.2.1.6 Maggot (Larva) Period	22
	2.2.1.7 Pre-pupal Period	24
	2.2.1.8 Pupal Period	25
	2.2.1.9 Adult Longevity	26

		2.2.1.10	Sex Ratio	28
		2.2.1.11	Total Life Cycle	29
	2.2.2	Morphometric of Fruit Fly, <i>B. cucurbitae</i> Infesting Cucurbitaceous Vegetable Crops		31
		2.2.2.1	Egg Stage	31
		2.2.2.2	Maggot (Larva) Stage	32
		2.2.2.3	Pre-pupal Stage	34
		2.2.2.4	Pupal Stage	34
		2.2.2.5	Adult Stage	35
	2.3	Management of Fruit Fly, <i>B. cucurbitae</i> Infesting Cucurbitaceous Vegetable Crops		37
		2.3.1	Bio-efficacy of Different Insecticides and Biopesticides against Fruit Fly, <i>B. cucurbitae</i>	37
		2.3.2	Evaluation of Protein Food Baits in Attracting Fruit Fly, <i>B. cucurbitae</i>	51
3.	MATERIALS AND METHODOLOGY			57
	3.1	Population Dynamics of Fruit fly, <i>B. cucurbitae</i>		57
		3.1.1	Experimental Details	57
		3.1.2	Meteorological Data	58
		3.1.3	Methodology	58
		3.1.3.1	Monitoring Fruit fly, <i>B. cucurbitae</i>	58
		3.1.3.2	Extent of Damage Caused by Fruit fly, <i>B. cucurbitae</i>	58
		3.1.3.3	Effect of Weather Parameters on Fruit fly, <i>B. cucurbitae</i>	58
	3.2	Biology of Fruit Fly, <i>B. cucurbitae</i> on Cucumber		58
		3.2.1	Experimental Site	58
		3.2.2	Experimental Material	58
		3.2.3	Methodology	59
		3.2.3.1	Rearing Technique of Fruit Fly, <i>B. cucurbitae</i>	59
		3.2.3.2	Mating Period	59
		3.2.3.3	Pre-ovipositional, Ovipositional and Post-ovipositional Period	60
		3.2.3.3	Fecundity and Hatchability	60
		3.2.3.4	Incubation Period	60

		3.2.3.5	Larval Instars and Period	60
		3.2.3.6	Pre-pupal and Pupal Period	61
		3.2.3.7	Adult Longevity	61
		3.2.3.8	Sex Ratio	61
		3.2.3.9	Total Period of Life Cycle	61
	3.2.4	Morphological and Morphometrics of Distinct Life Stages		61
	3.3	Field Management of Fruit Fly, <i>B. cucurbitae</i> on Cucumber		62
	3.3.1	Field Bio-efficacy of Test Insecticides on Cucumber		62
		3.3.1.1	Material and Equipments	62
		3.3.1.2	Experimental Details	62
		3.3.1.3	Method Adopted	63
		3.3.1.4	Fruit Infestation and Fruit Yield / Plot	63
		3.3.1.5	Economics of the Test Insecticides	64
	3.3.2	Field Evaluation of Protein Food Baits against <i>B. cucurbitae</i> on Cucumber		64
		3.3.2.1	Experimental Details	64
4.	RESULTS AND DISCUSSION			67
	4.1	Population Dynamics of Fruit fly, <i>B. cucurbitae</i>		67
		4.1.1	Monitoring of Fruit fly, <i>B. cucurbitae</i>	67
		4.1.2	Extent of Damage Caused by Fruit fly, <i>B. cucurbitae</i>	68
		4.1.3	Effect of Weather Parameters on Adult Population of <i>B. cucurbitae</i>	71
		4.1.4	Effect of Weather Parameters on Fruit Damage by <i>B. cucurbitae</i>	73
	4.2	Biology of Fruit Fly, <i>B. cucurbitae</i> on Cucumber		78
		4.2.1	Duration of Distinct Life Stages of <i>B. cucurbitae</i> Reared on Cucumber	78
		4.2.1.1	Incubation Period	78
		4.2.1.2	Larval Period	79
		4.2.1.3	Pre-pupal Stage	79
		4.2.1.4	Pupal Stage	79
		4.2.1.5	Mating Period	79
		4.2.1.6	Pre-ovipositional Period	80
		4.2.1.7	Ovipositional Period	80
		4.2.1.8	Post-ovipositional Period	80

		4.2.1.9	Fecundity	80
		4.2.1.10	Adult Longevity	82
		4.2.1.11	Sex Ratio	82
		4.2.1.12	Duration of Total Life Cycle of Single Generation	82
		4.2.2	Morphological and Morphometrics of Distinct Life Stages	82
	4.3	Field Bio-efficacy of Test Insecticides against <i>B. cucurbitae</i> on Cucumber		84
		4.3.1	Field Bio-efficacy of Test Insecticides during <i>Kharif</i> -2019	85
		4.3.2	Field Bio-efficacy of Test Insecticides during <i>Kharif</i> -2021	91
		4.3.3	Cumulative Bio-efficacy of Test Insecticides during <i>Kharif</i> -2019 and 2021	97
	4.4	Evaluation of Distinct Baits in Attracting <i>B. cucurbitae</i> Flies during <i>Kharif</i> -2019 and 2021		100
	4.5	Effect of Test Insecticides on Marketable Fruit Yield of Cucumber with per cent increase in yield over control and per cent avoidable losses		106
		4.5.1	<i>Kharif</i> -2019	106
		4.5.2	<i>Kharif</i> -2021	106
	4.6	Incremental Cost Benefit Ratio (ICBR) of Test Insecticides on Cucumber		107
5.	SUMMARY AND CONCLUSION			111
	5.1	Summary		111
		5.1.1	Population dynamics of <i>B. cucurbitae</i> during <i>Kharif</i> -2019 and 2021	111
		5.1.2	Biology of <i>B. cucurbitae</i> on Cucumber	112
		5.1.2.1	Duration of distinct life stages of <i>B. cucurbitae</i>	112
		5.1.2.2	Morphology and Morphometrics of <i>B. cucurbitae</i> on Cucumber	112
		5.1.4	Management of <i>B. cucurbitae</i> on Cucumber during <i>Kharif</i> -2019 and 2021	113
		5.1.4.1	Field Bio-efficacy of Test Insecticides against <i>B. cucurbitae</i>	113
		5.1.4.2	Field Evaluation of Protein Food Baits in Attracting Flies of <i>B. cucurbitae</i>	113
	5.2	Conclusion		114
6	LITERATURE CITED			115
7	APPENDICES			129
8	VITAE			131

LIST OF TABLES

Table No.	Description	Page
3.1	Insecticides and biopesticides used against <i>B. Cucurbitae</i>	62
3.2	Distinct baits used against <i>B. Cucurbitae</i>	65
3.3	Details of insecticides used in the bio-efficacy experiment	66
4.1	Population fluctuations and per cent fruit damage by <i>B. cucurbitae</i> in test cucurbitaceous crops during <i>Kharif-2019</i>	69
4.2	Correlation of weather parameters with adult fruit fly catches and per cent fruit damage by <i>B. cucurbitae</i> in test cucurbitaceous crops during <i>Kharif-2019</i>	70
4.3	Population fluctuations and per cent fruit damage by <i>B. cucurbitae</i> in test cucurbitaceous crops during <i>Kharif-2021</i>	74
4.4	Correlation of weather parameters with adult fruit fly catches and per cent fruit damage by <i>B. cucurbitae</i> in test cucurbitaceous crops during <i>Kharif-2021</i>	75
4.5	Data on distinct life stages of <i>B. cucurbitae</i>	81
4.6	Data on morphometrics of <i>B. cucurbitae</i>	84
4.7	Bio-efficacy of test insecticides after first spray (<i>Kharif-2019</i>)	85
4.8	Bio-efficacy of test insecticides after second spray (<i>Kharif-2019</i>)	87
4.9	Bio-efficacy of test insecticides after third spray (<i>Kharif-2019</i>)	89
4.10	Overall bio-efficacy of test insecticides during <i>Kharif-2019</i>	90
4.11	Bio-efficacy of test insecticides after first spray (<i>Kharif-2021</i>)	92
4.12	Bio-efficacy of test insecticides after second spray (<i>Kharif-2021</i>)	94
4.13	Bio-efficacy of test insecticides after third spray (<i>Kharif-2021</i>)	95
4.14	Overall bio-efficacy of test insecticides during <i>Kharif-2021</i>	97
4.15	Cumulative bio-efficacy of test insecticides during <i>Kharif-2019</i> and 2021	98
4.16	Evaluation of protein food baits in attracting adults of <i>B. cucurbitae</i> on cucumber during <i>Kharif-2019</i>	101
4.17	Percentage of adults of <i>B. cucurbitae</i> trapped by different protein food baits on cucumber during <i>Kharif-2019</i>	102

List of Table contd....

Table No.	Description	Page
4.18	Evaluation of protein food baits in attracting adults of <i>B. cucurbitae</i> on cucumber during <i>Kharif</i> -2021	103
4.19	Percentage of adults of <i>B. cucurbitae</i> trapped by different protein food baits on cucumber during <i>Kharif</i> -2021	104
4.20	Cumulative mean of trapped adults of <i>B. cucurbitae</i> by distinct baits during <i>Kharif</i> -2019 and 2021	105
4.21	Cumulative mean percentage of trapped adults of <i>B. cucurbitae</i> by distinct baits during <i>Kharif</i> -2019 and 2021	105
4.22	Yield of cucumber with per cent increase in yield over untreated check and per cent avoidable yield losses	108
4.23	Computation of cost of plant protection per hectare for cucumber	109
4.24	Incremental cost benefit ratio and net gain of insecticides and biopesticides in cucumber	110

LIST OF FIGURES

Figure No.	Description	Between pages
3.1	Layout of field experiment for evaluation of distinct protein food baits against <i>B. cucurbitae</i>	62-63
3.2	Layout of field experiment for bio-efficacy of test insecticides against <i>B. cucurbitae</i>	64-65
4.1	Population fluctuations of <i>B. cucurbitae</i> in test cucurbitaceous crops during <i>Kharif-2019</i>	70-71
4.2	Per cent fruit damage by <i>B. cucurbitae</i> in test cucurbitaceous crops during <i>Kharif-2019</i>	70-71
4.3	Population fluctuations of <i>B. cucurbitae</i> in test cucurbitaceous crops during <i>Kharif-2021</i>	74-75
4.4	Per cent fruit damage by <i>B. cucurbitae</i> in test cucurbitaceous crops during <i>Kharif-2021</i>	74-75
4.5	Bio-efficacy of test insecticides against <i>B. cucurbitae</i> on cucumber after first spray (<i>Kharif-2019</i>)	86-87
4.6	Bio-efficacy of test insecticides against <i>B. cucurbitae</i> on cucumber after second spray (<i>Kharif-2019</i>)	88-89
4.7	Bio-efficacy of test insecticides against <i>B. cucurbitae</i> on cucumber after third spray (<i>Kharif-2019</i>)	90-91
4.8	Overall bio-efficacy of test insecticides against <i>B. cucurbitae</i> on cucumber during <i>Kharif-2019</i>	90-91
4.9	Bio-efficacy of test insecticides against <i>B. cucurbitae</i> on cucumber after first spray (<i>Kharif-2021</i>)	92-93
4.10	Bio-efficacy of test insecticides against <i>B. cucurbitae</i> on cucumber after second spray (<i>Kharif-2021</i>)	94-95
4.11	Bio-efficacy of test insecticides against <i>B. cucurbitae</i> on cucumber after third spray (<i>Kharif-2021</i>)	96-97
4.12	Overall bio-efficacy of test insecticides against <i>B. cucurbitae</i> on cucumber during <i>Kharif-2021</i>	98-99
4.13	Cumulative bio-efficacy of test insecticides against <i>B. cucurbitae</i> on cucumber during <i>Kharif-2019</i> and 2021	98-99
4.14	Total number of adults of <i>B. cucurbitae</i> trapped in distinct baits on cucumber during <i>Kharif-2019</i>	102-103
4.15	Total number of adults of <i>B. cucurbitae</i> trapped in distinct baits on cucumber during <i>Kharif-2021</i>	104-105
4.16	Total number of adults of <i>B. cucurbitae</i> trapped in distinct baits on cucumber during <i>Kharif-2019</i> and 2021	106-107

LIST OF PLATES

Plate No.	Description	Between pages
3.1	Experimental plot for monitoring of <i>B. cucurbitae</i> in cucumber	58-59
3.2	Experimental plot for monitoring of <i>B. cucurbitae</i> in ridge gourd	58-59
3.3	Experimental plot for monitoring of <i>B. cucurbitae</i> in bitter gourd	58-59
3.4	Experimental plot for monitoring of <i>B. cucurbitae</i> in sponge gourd	58-59
3.5	Experimental plot for monitoring of <i>B. cucurbitae</i> in bottle gourd	58-59
4.1	Distinct life stages of <i>B. cucurbitae</i>	82-83
4.2	Fruit infestation by <i>B. cucurbitae</i>	82-83
4.3	Experimental plots for bio-efficacy of test insecticides against <i>B. cucurbitae</i> infesting cucumber	84-85
4.4	Healthy and infested fruits of cucumber	90-91
4.5	Experimental plots for evaluation of distinct protein food baits against <i>B. cucurbitae</i> infesting cucumber	100-101
4.6	Natural enemies observed at experimental field	104-105

LIST OF ABBREVIATIONS

%	:	Per cent
/	:	Per
@	:	at the rate
>	:	greater than
CD	:	Critical Difference
cm	:	Centimeter
Conc.	:	Concentration
CV	:	Coefficient of Variation
DAS	:	Days After Spraying
EC	:	Emulsifiable Concentrate
<i>et al.</i>	:	et alia (And others)
Etc	:	Etcetera
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
i.e.	:	id est. (That is)
L	:	Litre
Ltd.	:	Limited
m	:	Meter
mg	:	Milligram
ml	:	Milliliter
Mm	:	Milimeter
No.	:	Number
NS	:	Non Significant
ppm	:	Parts per million
Pvt.	:	Private
Rs.	:	Rupees
SD	:	Standard deviation
SE(m)±	:	Standard error of mean
SG	:	Soluble granules
SL	:	Soluble liquid
Sig.	:	Significant
SMW	:	Standard meteorological week
Spp.	:	Species
Sr. No.	:	Serial Number
t	:	Tonne
Tr.	:	Treatment
WG	:	Wettable Granules

ABSTRACT

“POPULATION DYNAMICS, BIOLOGY AND MANAGEMENT OF FRUIT FLY, *Bactrocera cucurbitae*, (Coquillett) INFESTING CUCURBITACEOUS VEGETABLE CROPS”

by

Mr. Anand Sunil Bade

A candidate for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

2022

Research Guide	:	Dr. S. R. Kulkarni
Discipline	:	Agricultural Entomology

Population dynamics was studied during *Kharif* 2019 and 2021 by installing cue-lure trap in five cucurbitaceous crops wherein, peak incidence was noticed during last week of August; the crop preference indicated as sponge gourd > bitter gourd > ridge gourd > cucumber > bottle gourd. Data on weather parameters correlated with adult population indicated that maximum temperature and morning relative humidity increased pest population whereas high morning relative humidity and high wind velocity reduced population during *Kharif* 2019 and 2021, respectively.

Egg incubation period was recorded as 0.73 ± 0.17 day with 90.2 ± 3.00 per cent hatching. Duration of larval period was observed as 7.2 ± 0.87 days. First, second and third instar were recorded as 1.5 ± 0.51 , 1.9 ± 0.64 and 3.75 ± 0.84 days, respectively. Pre-pupal and pupal period was found as 1.45 ± 0.51 and 8.05 ± 0.86 days, respectively. Mating period was observed as 3.35 ± 1.00 hours. Pre-ovipositional, ovipositional and post- ovipositional period recorded as 12.4 ± 1.8 , 3.45 ± 1.16 and 2.7 ± 1.05 days, respectively. Fecundity was found as 71.3 ± 9.7 eggs. Longevity of male and female fly was observed to be 13.4 ± 2.8 and 18.55 ± 2.5 days, respectively with sex ratio 1.22: 1 (female: male). Total duration of the entire life cycle completed was computed for female and male 35.93 ± 5.00 and 30.78 ± 5.29 days, respectively.

Egg was observed as glistening white, slightly curved, elongated and tapering ellipsoidal shape. Acephalous apodous maggot with three instars; first, second and third instar was found translucent-white, ellipsoidal-creamy white and yellowish-white with pointed head, respectively. Pre-pupa was sluggish and creamy-yellowish whereas, pupa was cylindrical, brownish-yellow with black dot and dark transverse line at posterior end. Adult was observed as reddish brown with yellowish vertical markings on thorax with fuscous wing margin and apical spot at apex; female possessed pointed ovipositor and was bigger in size than male.

Morphometric observations revealed that mean length of the egg, first, second, third instar, pre-pupa, pupa, adult male and female was 1.32 ± 0.15 , 1.53 ± 0.23 , 6.05 ± 0.92 , 10.02 ± 0.88 , 5.96 ± 0.16 , 5.12 ± 0.18 , 7.05 ± 0.18 , 8.71 ± 0.29 mm and breadth was 0.28 ± 0.07 , 0.29 ± 0.065 , 1.24 ± 0.13 , 2.16 ± 0.13 , 2.08 ± 0.07 , 2.34 ± 0.10 , 13.05 ± 0.37 and 15.26 ± 0.39 mm, respectively.

Field bio-efficacy of nine test insecticides along with untreated check were evaluated during both the years with three applications at ten days interval wherein, Lambda-cyhalothrin 2.5% EC, Deltamethrin 2.8% EC, Emamectin benzoate 5% SG and Spinosad 45% SC in the descending order of preference were most promising treatments followed by Azadirachtin 10000 ppm, NSE 5%, Acephate 75% SP, Lufenuron 5% EC followed by *Metarrhizium anisopliae*. ICBR was worked out in descending order as Lambda-cyhalothrin 2.5% EC (1:9.95), Deltamethrin 2.8% EC (1:9.26), Emamectin benzoate 5% SG (1:5.18), Azadirachtin 10000 ppm (1:1.78), Acephate 75% SP (1:1.75), Spinosad 45% SC (1:1.69), NSE 5% (1:1.02), Lufenuron 5% EC (1:1.68) and *Metarrhizium anisopliae* (1:1.08).

Data on field evaluation of seven protein food baits indicated in the order of preference Molasses plus Cue-lure plus Malathion > Cue-lure plus Malathion > Protein Hydrolysate plus Cue-lure plus Malathion > Jaggery plus Cue-lure plus Malathion > Yeast Autolysate plus Cue-lure plus Malathion > Soya Powder plus Cue-lure plus Malathion > Deltamethrin plus Malathion.

1. INTRODUCTION

India is a major producer of fruits and vegetables in the world due to diverse climate ensuring availability of all varieties of fresh fruits and vegetables which majorly includes cucurbitaceous crops *viz.*, cucumber, ridge gourd, bitter gourd, sponge gourd, bottle gourd, round gourd, pumpkins, gherkins *etc.* and India ranks 2nd after China for the production of fruits and vegetables in the world. Vegetables play important role in human diet as well as in economy of farmers as they are rich sources of vitamins (Vit-A, C, B and E), minerals, proteins, iron and fibers and also have some medicinal properties which are the most vital part of the balanced diet of biological value. It is suggested that an average man with vegetarian or non-vegetarian food habit needs to consume 50 g leafy vegetables, 150 g other vegetables and 100 g roots and tubers (Narsinga Rao, 2013). The Cucurbitaceae, also called cucurbits or the gourd family and are a plant family consisting of about 965 species in around 95 genera, of which are the most important to humans (Christenhusz and Byng, 2016). The members of this family of plants are grown in temperate and tropical climates, and those producing edible fruits were among the first to be cultivated in both the Old and New World. When it comes to the quantity and proportion of species used as food by humans, the Cucurbitaceae family of plants is among the top. They are a good source of dietary fibre and are low in fat, salt and sugar. Consumption of more vegetables as part of the whole healthy diet are likely to reduce the risk of certain chronic diseases. Recently, Food and Agriculture Organization celebrated the “International Year of Fruits and Vegetables-2021”.

As per Second Advance Estimates of National Horticulture Database which was published by National Horticulture Board, during 2019-20, India produced 191.77 million metric tonnes of total vegetables and area under cultivation of total vegetables was 10.35 million hectares. During 2020-21, India exported fruits and vegetables worth Rs. 9,940.95 crores/ 1,342.14 USD millions which comprised of fruits worth Rs. 4,971.22 crores/ 674.53 USD millions and vegetables worth Rs. 4,969.73 crores/ 667.61 USD millions (APEDA, 2022). While in the Maharashtra State, total area under vegetables was 0.81 million hectare and production was 14.75 million metric tonnes and ranks 5th in the area and production of total vegetables in India.

Cucumber, [*Cucumis sativus* (Linnaeus)] is one of the eldest vegetable and locally known as Kakadi (Marathi), Khira (Hindi), Kantakilata (Sanskrit), Soutekayi (Kannada), Dosakaya (Telugu), Vellari (Malayalam), Vellarikkay (Tamil), *etc.* Cucumber is a member of the Cucurbitaceae family and is primarily grown throughout the *Kharif*, *Rabi*, and *Summer* seasons. It was first cultivated between since 3,000 and 4,000 years ago in India and has spread throughout Asia, Africa, and Europe. (Patel, 1989). A raw cucumber is actually 95 per cent water and a whole cucumber is just of 16 calories. Cucumbers can cool the body and the blood, which gave rise to the phrase ‘cool as a cucumber’. Just a single cup of cucumber slices contains 14 to 19 per cent of the vitamin K which need for the day and also contains Vit B1, B2, B3, B5 and B6, folic acid, Vit C, iron, magnesium, calcium, phosphorus, potassium and zinc. India has produced 0.175 million tones cucumber and gherkins with cultivable area 0.028 million hectares with productivity 6,330 kg/ha during 2020-21 (FAOSTAT, 2022). India has exported 223,515.51 MT of Cucumber and Gherkin to the world (USA, Russia, France, Germany and Belgium) for the worth of Rs. 1,651.83 crores/ 223.05 USD Millions during the year 2020-21 (APEDA, 2022).

Cucumber and all other gourds are the popular crops of the Cucurbitaceae family grown throughout the India. Cucurbits are infested by a number of insect-pests from the germination to the harvesting of crop *viz.*, fruit fly, red pumpkin beetle, leaf miner, flea beetle, etc at different crop stages which affect the quality and quantity of produce unfavorably (Dubale *et al.*, 2018). Fruit flies are one of the world’s most destructive horticultural pests and pose risks to most commercial vegetable crops. Particularly Melon fruit fly (*Bactrocoera cucurbitae* C.) has been considered as serious pest. Quarantine laws aimed at preventing the entry and establishment of melon flies and hence reduce the export potential of crop produce (Ronald and Jayma, 2011).

Fruit flies are a very key group of pests in many countries because of their potential to cause damage in fruits which limit the admittance to international markets. One of the largest, most diverse, and fascinating acalypterate families of Diptera, the Tephritidae contains over 4200 recognised species grouped in 471 genera (Norrbom *et al.*, 1998). *Bactrocera cucurbitae* (Coquillett), a member of the Diptera family called Tephritidae, is a common pest in temperate, tropical, and subtropical climates all over the

world. It is the only tephritid species that attack a wide variety of cucurbit fruits and is most widely distributed in India. It is regarded as a quarantine pest since it has 81 or more host species, whose fruit losses might range from 30 to 100 per cent. (Dhillon *et al.*, 2005). The melon fruit fly, *Bactrocera cucurbitae* is the serious and one of the most damaging pests responsible for considerable damage that causes the direct yield loss of cucurbits vegetables and can attack about 16 different cucurbit crops (Sohrab *et al.*, 2018a). Fruit flies are one of the top ten most dangerous insect pests in India's agriculture because of the pest's polyphagous nature (maggot). Out of 207 species of fruit flies, 9 species have been identified to be the most predominant and economically important in India.

Generally, the female fruit flies pierce the delicate, soft fruits to lay their eggs under the skin of fruits using its aculeus and due to this gummy fluid ooze out. After hatching, the maggots feed on pulp of fruits by making the galleries and simultaneously secondary infection develops which results in rotting of fruits (Gupta and Verma, 1995). The full fed maggots come out of fruits by boring an exit-hole and pupate in the soil. The severity of melon fruit fly damage increases with increased humidity. Its abundance rises as daily temperatures rise, however temperatures above 31°C are bad for fruit fly growth and reproduction. (Dhillon *et al.*, 2005). Melon fruit fly occurrence and damage are largely influenced by the local agroecosystem's diversity of hosts and prevailing environmental conditions. As a result, it is crucial to research on how monitoring of pest populations in relation to weather conditions, might assist to determine the best time to take action and the most effective management strategy. (Vignesh and Viraktamath, 2015).

The melon fruit fly completes its lifespan developing through complete metamorphosis. The average time period needed for completion of life cycle by passing through the different life phases *viz.*, egg, maggot, pupa and adult, is 23.5 ± 5.94 days. The longevity of the adult male and female flies is about 13 ± 2.41 and 15.5 ± 3.49 days, respectively (Sharma *et al.*, 2017). In the environment, the pest typically has a male to female sex ratio of about 1:1. Knowledge of population dynamics and biology with regard to the different life stages of fruit flies is a crucial prerequisite for total success or for developing any other strategy for fruit fly suppression. This knowledge is also

compatible with IPM and organic pest management, which aim to manage insect pests rather than eradicate them. The biology of a species, including its nutrition and insect-pest life cycle, must be known in order to establish an effective management strategy that will minimise the negative impacts of pesticides.

The single adult form of the melon fruit fly is typically targeted for management, and numerous control strategies have been pushed globally however, three of the fly's life phases are hidden, making management difficult. There are several strategies to get rid of this pest in India, including using pesticides as a chemical control (Dashad *et al.*, 1999), combining insecticides with plant products (Saikia and Dutta, 1997) and using fungus culture filtrates (Purnima *et al.*, 1999). Without knowing the negative impact of these chemicals on the environment, pesticides with a chemical basis are employed most frequently to control them. But because fruit fly maggots are so cryptic, they are rarely affected by insecticides and this creates a rise in insecticide residues in the fruits, which not only results in high pesticide costs but also poses a multitude of risks to human health and the environment. Furthermore, the constant use of poisonous insecticides poses a risk to the ecosystem as well as the health of farmers and consumers. In order to manage fruit flies, it is vital to investigate commercially feasible and environment-friendly insecticides.

Pheromone traps offer a quick and effective way to keep track of fruit fly population activity (Alyokhin *et al.*, 2000) they may also be used for mass trapping and have been utilised effectively all over the world. The trap that consists of Cue-lure [4-(acetoxypheyl)-2-butanone], a para-pheromone (mixed with a toxicant), which attracts only the males of certain species of *Bactrocera cucurbitae* and therefore is called male annihilation technique (MAT) (Verghese *et al.*, 2006). Nowadays, plant protection strategies are moving away from the use of chemicals toward integrated pest management (IPM), as chemical pesticides are increasingly failing to control serious pests and diseases due to the growing global awareness of the unfavourable effects of deadly chemicals on human health. Some effective IPM tactics include field cleaning, removing pests from the major crops, using cue-lure traps, food baits, and hydrolyzed protein bait (Satpathy and Rai, 2002). On the other hand, the best way to prevent fruit fly infestation is to follow an integrated approach of traps (at least 30 days prior to harvest) + sanitation (removal and

destruction of all fallen fruits, 40 days prior to harvest) and soil raking below the tree (once or twice starting a month prior to harvest, if possible). Population dynamics (using lures or traps, food baits or attractants), the use of poison food baits (having an attractant plus insecticide mixture), and the use of plant extracts with insecticidal qualities are some examples of such approaches. Applying various attractive baits for females is necessary to monitor changes in the pest population and to exert direct control because female fruit flies are the main source of multiplication. These bait traps are ecologically more sound, have cheap costs, and good specificity (White and Elson-Harris, 1992; Sureshbabu and Viraktamath, 2003). In order to effectively manage this pest, it is therefore desirable to investigate other means of control. However, there is a very little information available regarding the use of safer insecticides to control melon fruit flies on cucumbers.

In the view of this, it was decided to focus our examination on cucurbitaceous vegetable crops, and the goals of the current investigations on "Population Dynamics, Biology, and Management of Fruit Fly, *Bactrocera cucurbitae* (Coquillett) infesting Cucurbitaceous Vegetable Crops" are as follows:

1. To monitor fluctuation of fruit fly, *Bactrocera cucurbitae* (Coquillett) populations in cucurbitaceous vegetable crops by employing lure traps.
2. To study on the biology of fruit fly, *Bactrocera cucurbitae* (Coquillett) infesting cucurbitaceous vegetable crops.
3. Management of fruit fly, *Bactrocera cucurbitae* (Coquillett) by chemically and organically infesting cucurbitaceous vegetable crops.
 - a. Bioefficacy of different insecticides and biopesticides against fruit fly, *Bactrocera cucurbitae* (Coquillett) infesting cucurbitaceous vegetable crops.
 - b. To evaluate protein food baits in attracting fruit fly, *Bactrocera cucurbitae* (Coquillett) infesting cucurbitaceous vegetable crops.

2. REVIEW OF LITERATURE

The investigations on “Population dynamics, biology and management of fruit fly, *Bactrocera cucurbitae* (Coquillett) infesting cucurbitaceous vegetable crops” were undertaken during *Kharif-2019* and *Kharif-2021* at Experimental farm and Laboratory of Department of Agricultural Entomology, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri. Therefore, the relevant literature available on the fruit fly, *Bactrocera cucurbitae* (C.) infesting cucurbitaceous vegetable crops has been reviewed and presented under the following heads.

2.1 Population Dynamics of Fruit Fly, *B. cucurbitae* Infesting Cucurbitaceous Vegetable Crops

Babu *et al.* (2002) showed that *B. cucurbitae* increased gradually from 32nd to 44th SMW, coinciding with 2nd week of August to last week of October ranging from 10.0 to 20.25 fruit flies/trap/week, thereafter it declined gradually up to 49th SMW and further rose during 5th SMW (19.00 fruit flies/trap/week).

Banerji *et al.* (2005) reported that the highest incidence of *B. cucurbitae* on bitter gourd during *kharif* followed by *summer* and it was lowest in *Rabi*. The per cent fruit infestation was positively correlated with minimum temperature during *Rabi* and *summer* seasons.

Shivayya and Kumar (2008) observed the peak incidence of *B. cucurbitae* on bitter gourd during September and lowest incidence during November at Bangalore. The incidence and population fluctuation were significantly correlated with maximum temperature, rainfall, evening relative humidity and average relative humidity.

Kate *et al.* (2009) revealed that infestation of fruit fly on cucumber commenced during 5th week after germination and increased during next four weeks (6th, 7th, 8th and 9th week after germination) and formed the peak with an infestation of 22.4 per cent. Then, the infestation declined gradually up to 12.00 per cent during last week of April i.e. 12th week after germination. The correlation studies revealed that the maximum and minimum temperature had positive correlation with infestation to fruits ($r = 0.6667$ and 0.3798 , respectively). While, morning relative humidity had positive correlation ($r = 0.2160$) and evening relative humidity had negative correlation ($r = -0.1738$) with fruit infestation.

Laskar and Chatterjee (2010) investigated the incidence pattern of *B. cucurbitae* by trapping melon fly by using attractant cue lure in the pumpkin field around the year at the instructional farm Cooch Behar, West Bengal. The results revealed that during warm rainy month viz., June, July, August at 25-37⁰C, the flies were more as compared to dry and winter months (December, January, February) at 8-23⁰C. Significant positive correlation of fly incidence was noticed with minimum ($r = +0.7596$) and maximum temperature ($r = +0.7376$) whereas, temperature gradient correlated negatively ($r = -0.4789$) with fly incidence. Negative correlation of fly incidence was recorded with maximum humidity ($r = -0.4249$) and humidity gradient ($r = -0.5481$) and positive ($r = +0.4366$) with minimum humidity. The rainfall and sunshine hours per day showed positive and negative correlation with fly incidence, respectively.

Thakur *et al.* (2010) monitored population of fruit flies, *Bactrocera* spp., with the help of attractant-insecticide traps (viz., suspension traps and wooden block traps) in cucumber field. The catch consisted of males of mixed populations of *B. tau*, *B. cucurbitae* and *B. scutellaris*, the latter dominating over the other two species. The mean catch was higher (23.7 adults/trap/week) ranging from (7.8 - 43.4 adults/trap) in wooden block traps than suspension traps (16.6 adults/trap/week) (ranging from 4.6 - 28.4 adults/trap). The maximum catch (43.4 adults/trap) was recorded during 32nd standard week in wooden block traps. A significant positive correlation was evident between trap catch data and minimum temperature ($r = 0.57$) and relative humidity ($r = 0.71$) in suspension traps, as well as in wooden block traps ($r = 0.64$ and 0.65 , respectively).

Mwatawala *et al.* (2010) studied the incidence and host range of the melon fruit fly, *B. cucurbitae*, in the Morogoro Region of Central Tanzania between October 2004 and October 2006. Population reached a peak in the dry season, between July and September. Highly preferred cucurbit hosts were cucumber (*Cucumis sativus*), melon (*Cucumis melo*) and watermelon (*Citrullus lanatus*), while *Momordica trifoliata* was the most important wild host. *B. cucurbitae* appeared to dominate most indigenous cucurbit infesters, with the exception of *Dacus ciliatus* which was still dominant in some cucurbitaceous spp.

Sharma *et al.* (2010) studied the influence of weather parameters on mixed population of *B. cucurbitae* and *B. tau* infesting cucumber during 2006-2007 at Nauri,

Solan, indicated that in the cropping season of 2006, the minimum infestation was observed in 24th SMW, while maximum in 30th SMW. Whereas, during 2007, the minimum infestation was recorded during 25th SMW and maximum in 32nd SMW. Correlation studies revealed that fruit fly infestation had non-significant negative correlation with maximum temperature and significance with minimum temperature. As regarding relative humidity, significant positive correlation was noticed; however, rainfall had non-significant positive correlation.

Alim *et al.* (2012) monitored seasonal variations of melon fly, *B. cucurbitae* in three different agricultural habitats of Bangladesh from January 2007 to December 2008 using cue-lure baited McPhail traps in three different study areas *viz.*, Pubail, Goloar char and Ganakbari. The population of melon fly was prevalent at high level during the two-year surveillance period except in October and November. In both the years, the highest capture was recorded in April to June while the lowest was in October to November. The variations of the melon fly population in two consecutive years (2007 and 2008) showed almost mirror images.

Raghuvanshi *et al.* (2012) studied that, there was an abundance of fruit flies in Cue-lure baited traps throughout the year. Two peaks; in *summer* and *Kharif* (*Autumn*) coincided with the 14th SMW and 43rd SMW respectively. In *Kharif*, maximum bitter melon fruit damage (62.70%) occurred in the 45th SMW. A second peak, with 49.70 per cent fruit damage was observed during the 15th SMW period. The temperature (maximum and minimum) showed a significant positive correlation with adult abundance, fruit damage and pupal population. Other abiotic factors had a non-significant effect on fruit fly adult activity, fruit damage and pupal population.

Ganie *et al.* (2013) carried out experiment at six different locations in Jammu and Kashmir, India. With regard to locations, mean fruit fly population was highest (6.09, 4.55, 3.87 and 3.60 flies/trap/week) at Batamaloo and Chadoora (4.73, 3.93, 2.73 and 2.73 flies/trap/week) on cucumber, bottle gourd, ridge gourd and bitter melon, respectively. The population of fruit flies was significantly correlated with the minimum and maximum temperature. The maximum species diversity of fruit flies was 0.511, recorded in Chadoora. *B. cucurbitae* was the most predominant species in both

Srinagar and Budgam, followed by *B. dorsalis* and *B. tau*, while *B. scutellaris* was found only in Chadoora.

Lanjar *et al.* (2013) observed three population peaks of melon fruit flies during 1st and 3rd week of April and 1st week of May (91.4 ± 3.56 , 77.4 ± 2.48 , 56.2 ± 2.67 fruit flies/trap) on musk melon and two population peaks during first and third week of April (81.8 ± 3.44 and 66.4 ± 3.50 fruit flies/trap) on Indian squash respectively.

Ghule *et al.* (2014) reported the incidence pattern of *Bactrocera cucurbitae* (Coq.), *Henosepilachna septima* (Dieke), *Aulacophora foveicollis* (Lucas) on cucumber. Peak fruit fly larval incidence was recorded during third week of February, 2011 (20.57 maggots/fruit) and second week of February, 2012 (20.70 maggots/fruit). Highest per cent fruit damage observed during third week of February, 2011 (86%) and last week of February, 2012 (44.17%). Fruit fly incidence had positive significant association with maximum ($r = +0.870$) and minimum ($r = +0.730$) temperature, whereas negatively significant with minimum relative humidity ($r = -0.738$).

Ghule *et al.* (2015) conducted the experiment from December second week to March second week in 2011 and March first week to June first week in 2012. The peak fruit fly larval incidence (11.1 maggots/fruit) was recorded during first week of March during 2011 whereas, (14.4 maggots/fruit) on fourth week of May during 2012. Highest per cent fruit damage by fruit fly, 62.5 per cent was recorded during fourth week of February, 2011 and 71.6 per cent recorded during third week of May, 2012. Peak incidence of initiated from last week of February up to third week of March during 2011 whereas; during 2012, incidence was high in end of April.

Maharjan *et al.* (2015) monitored and observed population dynamics of cucurbit fruit fly by using four different types of traps was conducted in Sipadole VDC of Bhaktapur district during 2012. Three different types of fruit flies were recorded, in which the number of *B. cucurbitae* dominated to other species. Only *B. cucurbitae* damaged the cucumber, which was trapped 92.68, 87.05, 90.61 and 69.38 per cent in cue-lure, banana pulp bait, sticky traps and fly catcher, respectively. The highest number of fruit flies (167.5 male fruit flies/3 traps) was recorded in cue-lure trap during the first week of September, which coincided with 85.45 per cent RH and 21.67°C and 25.04°C

minimum and maximum temperature, respectively. Positive relation of temperature, relative humidity and fruit fly catches was observed.

Vignesh and Viraktamath (2015) studied population dynamics of melon fruit fly, *B. cucurbitae* during *Kharif* and *Rabi* season of 2014-2015 at Dharwad and Navalur by using cue-lure traps on cucumber (*Cucumis sativus* L.). Incidence of fruit fly was high (55.67 fruit flies/trap/week) on the crop planted during *Kharif* and low (19.67 fruit flies/trap/week) on the crop planted in *Rabi*. The level of fruit infestation by *B. cucurbitae* was 70.90 per cent during *Kharif*-2014. Pooled incidence data of melon fruit fly showed significant positive correlation with minimum temperature ($r = 0.388$), morning ($r = 0.372$) and evening relative humidity ($r = 0.427$).

Abhilash *et al.* (2017) conducted experiment on monitoring of melon fruit fly in relation to weather parameters in the farmers field at three locations *viz.*, Bommankatte, Basavnagangur and Abbalgere using Barrix cue-lure trap during *Rabi* 2016-17. The results revealed that the highest trap catches of 28.40 fruit flies/trap/ week were recorded in mid-March (11th standard week of 2017) at Abbalgere. However at Bommankatte and Basavanagangur peak trap catches of 21.40 and 22.20 fruit flies/trap/week were recorded, respectively from ninth standard week of 2017 during peak fruiting period. The incidence of melon fruit fly from three locations showed significant positive correlation with maximum and minimum temperature. Whereas, afternoon relative humidity and rainfall had significant negative correlation with melon fruit fly incidence from all three locations.

Abro *et al.* (2017) carried out studies on population magnitude of melon fruit fly, *B. cucurbitae* during 2015 on cucurbit crops in district Hyderabad at two discrete localities, Jeay Shah and Dehli Farm, in three different crops *i.e.*, bottle gourd (*Lagenaria siceraria*), bitter melon (*Momordica charantia*) and ridge gourd (*Luffa acutangula*) using cue-lure baited traps. The results revealed that significantly highest (124.86) population was recorded on *L. acutangula* and lowest (104.725) on *L. siceraria* at both experimental sites throughout the course of experiment. Moreover, significantly higher population densities of *B. cucurbitae* were observed during the 4th week of May on *L. acutangula* (339.4 ± 22.59) and lowest (11.0 ± 0.45) during 1st week of January. Similarly, in case of *M. charantia* and *L. siceraria* statistically higher densities ($334.6 \pm$

22.76, 333.2 ± 20.13) of *B. cucurbitae* was observed on 4th week of May and lowest (9.4 ± 1.60 , 7.6 ± 1.72) on the 1st week of January. The trapping of *B. cucurbitae* were positively correlated with the temperature while negatively correlated with relative humidity.

Das *et al.* (2017) observed maximum population of melon fruit fly in the months of May 2014 (17th and 24th may) and showed a higher positive correlation with seasonal average maximum temperature (0.823**) and positive correlation with minimum temperature (0.123) and morning humidity (0.40) and negative correlation with afternoon humidity (-0.726*) and rainfall (-0.54).

Sunil and Jayram (2017) observed the peak fruit fly infestation during first week of September (52%) and in last week of February (33%). The incidence of fruit fly in *Kharif* recorded significant positive correlation with rainfall ($r = 0.71$) and positively correlated with maximum temperature ($r = 0.35$) and maximum RH ($r = 0.59$). During *Rabi*, significant positive correlation with maximum temperature ($r = 0.76$). Multiple linear regression suggests that incidence of fruit fly on bitter gourd was influenced by 51 per cent by rainfall during *Kharif* and 59 per cent by maximum temperature during *Rabi*.

Dubale *et al.* (2018) carried out experiment on studies on incidence of fruit flies in relation to weather parameters on ridge gourd and results revealed that there were marked differences in infestation of fruit flies. The infestation of fruit flies was started after fruit setting in the third week of August (33th SMW). Minimum (16.67 ± 18.25) per cent infestation of fruit flies was recorded in 36th SMW, while maximum (50.00 ± 18.25) per cent infestation was observed during 40th SMW. The data on correlation between per cent infestation of fruit flies with different meteorological parameters showed that the significant negative correlation ($r = -0.720$) with morning relative humidity, while remaining various meteorological parameters were found to be non-significant.

Saha *et al.* (2018) were studied the population dynamics of prevailing six insect-pests of cucumber and its natural enemies in relation to weather parameters. The correlation studies between insect pests and weather parameters revealed that the melon fruit fly (*Bactrocera cucurbitae* Coquillett), epilachna beetle (*Epilachna vigintioctopunctata* Fabricius), red pumpkin beetle (*Aulacophora foveicollis* Lucas),

whitefly (*Bemisia tabaci* Gennadius), pumpkin caterpillar (*Diaphania indica* Saunders) and leaf miner (*Liriomyza trifolii* Burgess) showed significant positive correlation with maximum and minimum temperature, whereas negative and non-significant correlation with relative humidity and rainfall. The natural enemies such as coccinellids and spiders showed significant positive correlation with maximum and minimum temperature and non-significant negative correlation with relative humidity and rainfall. Sunshine hour showed positive correlation with all the insect pests and natural enemies except epilachna beetle.

Shinde *et al.* (2018a) carried out study on influence of abiotic factors on relative abundance of fruit flies infesting cucumber during *Kharif*-2017. The initiation of fruit flies infestation was started after fruit setting in the last week of July (30th SMW). Minimum per cent fruit flies infestation (35.71 ± 36.91) was recorded in 34th SMW, while maximum (100.00 ± 36.91) per cent infestation was recorded during 30th SMW and 31st SMW. The data on correlation between fruit flies with different meteorological parameters showed that the various meteorological parameters were found to be non-significant.

Sohrab *et al.* (2018a) recorded population of cucurbit fruit flies, *B. cucurbitae* of bitter gourd and which was observed vary much changeability at Block Daurala, District Meerut. Decreasing temperature negative effect was observed in cucurbits fruit flies population at District Meerut but positive effect of temperature was observed in cucurbit fruit population at District Saharanpur. Fruit flies population of cucurbits fruit increased with the increase of relative humidity, rainfall and decreased temperature while negative relationship was observed with maximum correlation in cucurbits in *Zaid* and *Kharif*. Moderate to high negative correlation coefficients were observed between maximum temperature and population fluctuation of cucurbit fruit flies in cucurbits at both places.

Anant *et al.* (2019) conducted experiment on seasonal incidence and extent of damage by cucurbit fruit fly, *B. cucurbitae* on spine gourd (*Momordica dioica* roxb.) The population of 0.2 adult/plant was first observed during first week of August and then increased gradually afterwards to reach highest number with 3.0 adult/plant in second week of September, However, after attaining peak, the population reduced and

minimum level of none adult/plant was recorded in last week of October (43th SMW). The per cent fruit infestation of spine gourd was first observed on fruit number and weight basis at 19.61 and 19.28 per cent respectively, whereas the larval density of 2.57 maggot/fruit was observed during the first picking of fruits (July, 31). Thereafter, the per cent fruit infestation showed a gradual increasing trend and reach peak infestation with 43.23 and 43.31 per cent respectively, when the maggot density of 6.85 maggot/fruit was observed during fifth picking of fruits (September, 30). The infestation percentage was decreased by 32.58 and 35.99 per cent respectively, when the maggot density was also decreased in the ranges 4.58 maggot/plant in last picking of fruits (October, 15). Hence, the maximum plant protection measures should be applied in the month of September for the reduction of pest population and damage.

Afroz *et al.* (2019) investigated the effect of weather parameters on the abundance of the insects. Red pumpkin beetle, epilachna beetle and fruit fly showed the highest level of infestation during 3rd week of December, 3rd week of January and 4th week of February, respectively. All the insects revealed the lowest level of infestation on BD274 and BD277 germplasm. Relative humidity had insignificant positive correlation with all the insects. Red pumpkin beetle showed significant positive correlation with temperature. Temperature, relative humidity and rainfall showed 43.2 per cent contribution on fruit fly abundance and the individual effect of relative humidity was the highest (27.0 %).

Hossain *et al.* (2019) conducted an experiment on fruit fly monitoring. The traps baited with male lures (cue lure, methyl eugenol, zingerone) were maintained for two years (November 2016 to October 2018) at ten sites in village-style subsistence agriculture environments, at the Atomic Energy Research Establishment Campus, Dhaka, Bangladesh. A total of 15 species and 135,034 flies were collected, dominated by polyphagous fruit pest *Bactrocera dorsalis* (58.0% of all trapped flies), cucurbit pests *Zeugodacus cucurbitae* (23.6%) and *Z. tau* (13.5%), and non-pest *B. rubigina* (3.6%). Three other pest species, collected in much smaller numbers, were polyphagous fruit pests *B. zonata* and *B. correcta* and cucurbit pest *Dacus longicornis*. Seasonal abundance of *Z. cucurbitae* peaked in March 2017, early in the rainy season, and May 2018, in the

middle of the rainy summer season, with no clear correlation with rainfall, humidity, or host availability.

Jakhrani *et al.* (2019) performed research work assessed the persistency and durability of cue-lure sex pheromone and of three different insecticides including Limda, Amida and Route. Results revealed that significant higher *Bactrocera cucurbitae* were captured in the fifteen days of replenished which ($41.89 \pm 1.83a$). However, significantly lower ($19.44 \pm 1.46e$) after sixty days of replenished. It was observed that lure might be replenished after every fortnight in the month of May, June and July-2016. Moreover, results also depicted that considerably higher (49.62 ± 1.95) killing of *B. cucurbitae* were observed in route and lower (38.30 ± 1.92) in Amida.

Meena *et al.* (2019) conducted experiment on seasonal incidence of *B. cucurbitae* on bottle gourd and their correlation with abiotic factors *summer*, 2017 and 2018. The incidence of fruit fly observed in terms of per cent fruit infestation on number and weight basis it caused to bottle guard fruits at three days interval during the crop period. The infestation of fruit fly observed on bottle gourd from third week of May. The peak infestation was recorded in first week of June while maximum and minimum temperature had significant positive correlation with fruit fly infestation. The morning and evening relative humidity had non-significant correlation with the infestation of fruits due to fruit fly however; rainfall had non-significant negative correlation.

Nehra *et al.* (2019a) carried out investigations on the seasonal incidence *B. cucurbitae* on round gourd in relation to abiotic factors *Summer*, 2016. The initial infestation of fruit fly with 8.52 per cent was observed in mid-March *i.e.*, 30-35 DAS of the crop which increased gradually and reached to its peak, 36.42 per cent in the first week of April and there after it started declining. However, the infestation was observed till last picking of the fruits of the season. During peak period infestation the maximum and minimum temperatures 36.40°C and 20°C , respectively and relative humidity 38.5 per cent. There was no rainfall observed during the study period. The correlation studies revealed that the infestation of fruit fly on round gourd showed significantly positive correlation with maximum and minimum temperature ($r = 0.6072$ and 0.6119 , respectively), while significant negative with relative humidity ($r = -0.5678$).

Sawai *et al.* (2019) recorded population of adult flies of *B. cucurbitae* and noticed the peak activity and was recorded from third week of September to the last week of October with a distinct peak in the last week of September, coinciding with the fruiting season of cucurbits. The activity of *B. tau* was noticed from 30th to 36th SMW. The maximum catch of flies was 196.33 flies/trap in 38th SMW and no incidence of the flies was noticed from 1st SMW to 18th SMW. The correlation of *B. cucurbitae* population with weather parameters indicated that the fly catch in the cue lure baited trap had a significantly positive correlation with average temperature and negative correlation with bright sunshine hours. *B. tau* had significant positive correlation with maximum relative humidity and negative correlation with bright sunshine hour.

Wazir *et al.* (2019) studied the effect of weather parameters on population dynamics of fruit fly *B. cucurbitae* using Green victory Methyl Eugenol fruit fly traps to determine the seasonal incidence of fruit fly for 2017-2018. The studies revealed that, seasonal incidence of fruit fly was found damaging and remained active on summer squash attaining peak value in the 26th Standard week (317 fruit flies/trap). The correlation studies showed that the fruit fly population was highly significant and positively correlated with mean relative morning humidity, relative evening humidity and rainfall but highly negatively correlated with maximum temperature.

Nahid *et al.* (2020) monitored population dynamics and infestation of fruit fly, *B. cucurbitae* on cucumber using methyl eugenol trap during summer and autumn in 2017 at Gazipur, Bangladesh and studied relationship between the abundance of fruit fly and meteorological factors. The fruit fly showed significantly higher abundance in summer compared to autumn. The larval population per fruit was found higher in summer (24.9 fruit⁻¹) than that in autumn (1.5 fruit⁻¹). The daily mean temperature had significant positive, light intensity had insignificant positive, relative humidity had insignificant negative and rainfall had insignificant negative correlation with fruit fly abundance. The temperature, light intensity, relative humidity and rainfall individually contributed to fruit fly abundance of 14.1, 24.0, 0.8 and 1.8 per cent, respectively. The combined effect of the weather parameters on fruit fly abundance was 40.7 per cent and the equations were insignificant. The fruit fly showed significantly lower level of infestation in methyl eugenol treated plots as compared to controls in both *summer* and *autumn*.

Nair and Pal (2020) carried out study of two years duration in cucurbit ecosystem in Tripura to investigate the seasonal incidence of *Z. cucurbitae* in relation to abiotic factors using parapheromone lure (cue-lure) baited traps. The population of male fruit flies showed almost similar pattern of population fluctuation throughout the study period. Moderate to high population was recorded from February to October and during the cooler months *i.e.* from November to January the adult activity was low (5-16 flies/trap/week). The numbers of fruit flies captured in cue lure baited traps correlated positively with temperature, relative humidity and rainfall. Maximum temperature, minimum temperature and rainfall have significant influence on *Z. cucurbitae* population.

Sowmiya *et al.* (2020) assessed the seasonal occurrence, fluctuation and species diversity of *Z. cucurbitae* by conducting field experiment at farmer's field at Kumaravadi village, Tiruchirappalli during *kharif* and *rabi* season 2019-20. The fruit fly species of *Z. cucurbitae*, *Z. gavisus* and *B. vishnu* were trapped in cue lure baited traps and the species *viz.*, *B. dorsalis*, *B. zonata* and *B. correcta* species were trapped in methyl eugenol traps and the species were taxonomically categorized. The maximum population was noticed and trapped in 35th SMW *i.e.*, 25.80 fruit flies/trap in *kharif* and 10th SMW (12.3 fruit flies/trap) in *rabi*. On comparing the weather parameters relative humidity and rainfall shows negative correlation and other factors are positively correlated with the trap catches in both the seasons.

Patel and Das (2021) carried out studies on population dynamics of fruit fly *Bactrocera cucurbitae* (Coq.) and observed the significant variation in its incidence during 2016-2018. It was not present during 48th to 52nd SMW in 2017 and 49th, 52nd and 1st to 3rd SMW in 2018. There were peaks during 33rd (2016), 33rd and 36th (2017) and 8th SMW (2018). The incidence was less during 42nd to 12th SMW and was moderate to high during other SMWs with few exceptions. Significant positive correlation was observed with maximum ($r = 0.63$) and minimum temperature ($r = 0.82$) and rainfall ($r = 0.69$). The maximum temperature led to 39.4% variations and it was 67.1% with minimum temperature and 47.3% with rainfall.

Shinde *et al.* (2021a) conducted experiment on influence of abiotic factors on relative abundance and infestation rates of the fruit flies in ridge gourd during *Kharif*-2018 and 2019. During *Kharif*-2018, the adult fruit flies catch ranged from 31.77 to 98.33

per trap per week. The activity of fruit flies reaching the peak of 98.33 fruit flies/trap/week during 1st week of September (36th SMW). During cropping season, the infestation varied from 15.18 to 56.98 per cent on number basis. Minimum per cent fruit damage (15.18%) was recorded in 2nd week of October (41st SMW), while maximum (56.98%) during 1st week September (36th SMW). While during *Kharif*-2019, number of fruit fly adults ranged from 18.67 to 83.33 per trap per week. Minimum per cent fruit damage (7.33%) was recorded in 1st week of August (31st SMW), while maximum (56.12%) during 1st week of September (35th SMW). The data on correlation between fruit flies with different meteorological parameters showed that the various meteorological parameters were found to be non-significant except minimum temperature.

Sen *et al.* (2022) observed that trap catches of *Bactrocera cucurbitae* was found maximum which varied in different weeks during February to June at Sekhampur and Kalyani locations in *Summer* 2016 and 2017. Temperature (maximum and minimum) and rainfall had significant positive relationship with fruit flies at Sekhampur, whereas correlation with minimum temperature, rainfall and evening relative humidity was recorded positively significant at Kalyani.

Kumar *et al.* (2022) conducted experiment on population dynamics of fruit fly (*Bactrocera* spp.) in cucurbits at different locations Department of Entomology, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, during 2020-21. Trapping of fruit fly was started from the 9th SMW and continued up to 25th SMW by using sex attractant, Cuelure and methyl eugenol. The incidence of *B. cucurbitae* and *B. tau*, was observed high (33.41 fruit flies/trap/week) and (18.00 fruit flies/trap/week), respectively on 20th SMW caught through cue lure. Mean population of *B. cucurbitae*, *B. tau* showed non-significantly positive correlation with minimum temperature and significantly positive correlation with maximum temperature however it was significantly negatively correlated with relative humidity and non-significantly negative correlated with rainfall, respectively in Zaid season of 2020.

2.2 **Biology of Fruit Fly, *B. cucurbitae* Infesting Cucurbitaceous Vegetable Crops**

2.2.1 **Life stages of fruit fly, *B. cucurbitae***

2.2.1.1 **Mating period**

Mir *et al.* (2014) recorded a mating period of *B. cucurbitae* of 2 - 4 hrs and found to be sufficiently for sperm transfer to occur.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that mating time generally extends 10.25 to 11.40 hrs.

2.2.1.2 **Pre-oviposition, oviposition and post-oviposition period**

Mukherjee *et al.* (2007) studied pre-oviposition period and oviposition period of melon fruit fly and revealed that the pre-oviposition period varied from 8 to 15 days with an average of 11.25 ± 1.29 days. In this study, the oviposition period was found to vary from 5 to 14 days with an average of 9.75 ± 1.63 days.

Ullah *et al.* (2008) studied comparative biology of *B. cucurbitae* on five different cucurbit species and was found highest oviposition period in the flies reared on squash (35.33 ± 2.08 days) which was followed by sweet gourd (35.00 ± 1.00 days) and the differences between these were insignificant. The lowest oviposition period (21.31 ± 0.58 days) was found in case of the flies reared on bitter gourd. Bottle gourd and snake gourd had the oviposition period of 26.67 ± 1.53 days and 24.62 ± 1.53 days, respectively.

Mir *et al.* (2014) observed the pre-oviposition period of *B. cucurbitae* was of 12.4 ± 2.36 days and varied from 10 to 15 days, whereas the oviposition period was 18.2 ± 5.61 days and ranged from 12 to 28 days.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that pre-oviposition period extends 10.31 to 12.64 days.

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and found that the females had a pre-oviposition period of 9 to 13 days. However, the mean pre-oviposition period was recorded to be 11.00 ± 0.667 (10 to 12 days), 11.67 ± 0.500 (11 to 12 days) and 11.57 ± 1.272 days (9 to 13 days) for bitter gourd, bottle gourd and

watermelon, respectively. The oviposition period ranged from 2 to 5 days with the mean oviposition period of 2.80 ± 0.632 (2 to 4 days), 3.67 ± 0.707 (3 to 5 days) and 3.29 ± 1.254 days (2 to 5 days) for bitter gourd, bottle gourd and watermelon, respectively. The mean post-oviposition period of 1.60 ± 0.699 , 1.89 ± 0.782 and 2.00 ± 0.577 days was recorded for bitter gourd, bottle gourd and watermelon, respectively.

Gaddanakeri and Rolania (2020) observed that the oviposition period of female melon fruit fly was ranged from 10 to 24 days with a mean of 16.3 ± 4.85 days.

2.2.1.3 Fecundity

Mukherjee *et al.* (2007) reported that the numbers of eggs were laid by the female fruit fly varied from 36 to 74 with an average of 52.75 ± 6.83 . A female melon fly can lay a total of 800-900 eggs during her life span (Vargas *et al.*, 1984). The fecundity of a female may varied widely due to seasonal parameters; like quality of food, feeding, environment etc.

Ullah *et al.* (2008) studied comparative biology of *B. cucurbitae* on five different cucurbit species and squash showed the most suitable host for egg laying (237.53 ± 17.87) among five different hosts. The flies reared on sweet gourd had the second highest fecundity (201.35 ± 9.72) which was followed by bottle gourd (167.24 ± 10.34). The lowest numbers of eggs were laid by the flies reared on bitter gourd (126.59 ± 2.37) which was closely followed by the snake gourd (143.70 ± 7.40).

Laskar (2013) recorded fecundity, *i.e.* the egg laying capacity of a sexually mature adult female of melon fruit fly and it was 138.40 ± 44.05 (mean \pm SD) when reared on bitter gourd that ranged from 90.00 to 197.00. In pumpkin, the fecundity varied from 98.00 to 175.00 (mean \pm SD = 135.60 ± 33.04).

Mir *et al.* (2014) observed the fecundity of *B. cucurbitae*, *i.e.*, the egg laying capacity of a sexually mature adult female, was 75.8 ± 12.49 and varied from 58 to 92. However the flies did not lay eggs regularly during their life span but at an intervals of 1 to 4 days.

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and reported that the fecundity of females ranged from 32 to 35 eggs (5 - 15 in cluster) with a mean of 33.40 ± 1.342 eggs per five females on bitter gourd, 42 to 46 eggs with a mean of 44.40 ± 1.517 eggs per five females under study in case of bottle gourd and 50 to 55

eggs with a mean of 53.00 ± 2.000 eggs per 5 female in case of watermelon, however the fly did not lay eggs regularly during her life span, but at intervals of 1-5 days.

Gaddanakeri and Rolania (2020) reported that female of *B. cucurbitae* on an average laid 87.8 ± 8.61 eggs (5 to 15 in cluster) with a range of 80-108 eggs under laboratory conditions.

2.2.1.4 Hatchability

Laskar (2013) observed that the highest percentage of eggs hatched when the fruit fly was reared on pumpkin (mean \pm SD = 89.60 ± 6.07) that ranged from 82.00 to 98.00 per cent. On the other hand, in bitter gourd hatchability varied from 80.00 to 97.00 (86.40 ± 7.09) per cent.

Mir *et al.* (2014) found that the mean hatching percentage of *B. cucurbitae* was 86.1 ± 0.54 .

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and observed the hatching percentage differed on different hosts and ranged from 80.00 to 92.00 per cent. It is evident that maximum egg hatching percentage of 92.00 was recorded when reared on bitter gourd while, minimum egg hatching i.e. 80.00 per cent was recorded in watermelon and 88.00 per cent on bottle gourd.

2.2.1.5 Incubation period

Mukherjee *et al.* (2007) recorded the incubation period of melon fruit fly varied from 18 to 21 hours with an average of 19.5 ± 0.56 hours.

Ullah *et al.* (2008) studied comparative biology of *B. cucurbitae* on five different cucurbit species and the incubation period of the eggs found highest *i.e.*, 28.00 ± 1.26 days on bitter gourd which was followed by snake gourd (27.25 ± 0.82 days). The lowest incubation period of 24.25 ± 0.82 days was observed on squash followed by sweet gourd (25.50 ± 0.50 days) and bottle gourd (25.25 ± 0.82 days).

Manzar and Srivastava (2009) found that the mean incubation period of melon fruit fly on bitter gourd varied from 1.7 ± 0.12 day in 2002 and 1.4 ± 0.16 days in 2003.

Barma and Jha (2011) studied the incubation period of fruit fly, *B. cucurbitae* which was varied from 2 to 5 days in June-July and 4 to 6 days in August-October.

Laskar (2013) studied the duration of developmental days between laying and hatching *i.e.* the incubation period of *B. cucurbitae* which was varied in the specimen reared on different hosts. Incubation period was recorded higher in pumpkin than the bitter gourd. It varied from 1.50 to 2.00 (mean \pm SD = 1.85 ± 0.22) days and 1.50 to 2.25 (mean \pm SD = 1.90 ± 0.29) days when reared on bitter gourd and pumpkin respectively.

Bhowmik *et al.* (2014a) studied that the incubation period of melon fruit fly was 1.2 ± 0.42 days in June-July and 1.7 ± 0.82 days in November-December during 2011. But in 2012, the incubation period was 1.5 ± 0.71 days, 1.2 ± 0.42 days, 1.5 ± 0.53 days and 1.6 ± 0.52 days in February-March, May-June, July-August and November-December, respectively.

Mir *et al.* (2014) reported the duration of development between laying and hatching, *i.e.*, the incubation period of *B. cucurbitae* and it was 12 to 24 hr with a mean of 16.8 ± 6.19 hr.

Rahman *et al.* (2015) studied biology of cucurbit fruit fly, *B. cucurbitae* and reported that the mean incubation period of the fruit fly was 6.98 days.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that the egg incubation period ranges from 1.12 to 1.38 days, different cultivars of *C. indica* did not exhibit any significant difference towards the egg incubation period.

Das *et al.* (2017) recorded that the incubation period of melon fruit fly was varied from 1.5 to 3 (mean \pm SD = 1.9 ± 0.65) days.

Sharma *et al.* (2017) reported the incubation period of *B. cucurbitae* ranged from 1 to 3 days with an average 2 ± 0.79 days.

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and observed that the incubation period varied from 1 to 3 days on different hosts. Results showed that the incubation period of *B. cucurbitae* eggs ranged from 1 to 2 days for bitter gourd and bottle gourd while, it was 1 to 3 days for watermelon. The incubation period was 1.28 ± 0.458 , 1.32 ± 0.476 and 1.36 ± 0.700 days for bitter gourd, bottle gourd and watermelon, respectively. The egg period on bitter gourd was lower than the bottle gourd and watermelon.

Akter and Sohel (2020) reported that the egg hatching period of *B. cucurbitae* was 1.69 ± 0.28 and the data range was 1.0-2.0 on bottle gourd.

Gaddanakeri and Rolania (2020) observed that the incubation period of *B. cucurbitae* was ranged from 12 to 24 hours with a mean of 18.0 ± 6.32 hours.

2.2.1.6 Larval (maggot) period

Mukherjee *et al.* (2007) reported that the larval period of melon fruit fly ranged from 11 to 13 days and the mean larval period was 12.25 ± 0.41 days.

Ullah *et al.* (2008) studied comparative biology of *B. cucurbitae* on five different cucurbit species and the highest duration was recorded on bitter gourd (8.67 ± 0.58 days) which was closely followed by snake gourd (8.33 ± 0.66 days) and sweet gourd (7.67 ± 0.58 days) and showed the significant difference among the hosts. Moreover, larval duration was the lowest on squash (7.00 ± 0.58 days) and then on bottle gourd (7.33 ± 0.12 days).

Manzar and Srivastava (2009) observed the average duration of the 1st instar maggot was 1.3 ± 0.016 days during 2002, while in 2003 it was 1.2 ± 0.063 days. The average duration of 2nd instar maggots were 1.35 ± 0.018 days during 2002, while in 2003 it was 1.30 ± 0.011 days. The average duration of 3rd instar maggots in days was 3.20 ± 0.213 in 2002 and 2.6 ± 0.15 days in 2003. The total larval period was 5.9 ± 0.979 days and 5.19 ± 0.745 days during 2002 and 2003, respectively.

Barma and Jha (2011) studied the total larval period of fruit fly, *B. cucurbitae* and were found to be 5 to 7 days in June-July and 16 to 19 days in August-October.

Laskar (2013) recorded the maggot developmental period of *B. cucurbitae* which was varied from 5.00 to 6.75 days with a mean of 5.75 ± 0.75 days on bitter gourd and 5.50 to 7.00 days with a mean of 6.10 ± 0.55 days on pumpkin.

Bhowmik *et al.* (2014a) reported that the duration of 1st instar was 1.3 ± 0.48 days in June-July and 2.3 ± 0.48 days in November-December during 2011. But in 2012, the duration was found to be 1.5 ± 0.53 , 1.2 ± 0.42 , 1.1 ± 0.32 and 1.9 ± 0.74 days in February-March, May-June, July-August and November-December, respectively. The 2nd instar maggots were broad tapering at both ends and the duration were 2.3 ± 0.48 and 4.7 ± 0.82 days in June-July and November-December, respectively in 2011 and $3.4 \pm$

0.52, 2.3 ± 0.48 , 1.4 ± 0.52 and 3.5 ± 0.53 days in February-March, May-June, July-August and November-December in 2012, respectively. The duration of 3rd instar were 3.4 ± 0.52 and 10.9 ± 2.28 days in June-July and November-December during 2011. The duration was 8.9 ± 1.66 , 2.6 ± 0.52 , 1.6 ± 0.52 and 5.3 ± 1.16 days in February-March, May-June, July-August and November-December in 2012, respectively. Total maggot period was 7 ± 1.05 and 17.8 ± 3.26 days in respective months in 2011 and 13.4 ± 2.37 , 6.2 ± 1.03 , 4 ± 1.05 and 11.2 ± 2.04 days during respective months during 2012.

Mir *et al.* (2014) studied the developmental period of the 1st, 2nd and 3rd instar maggots of *B. cucurbitae* and periods were 0.7 ± 0.26 , 1.5 ± 0.40 and 2.3 ± 0.47 days, respectively; and their total developmental periods were 4.5 ± 1.13 and 6.45 ± 1.38 days, respectively.

Rahman *et al.* (2015) studied biology of cucurbit fruit fly, *B. cucurbitae* and reported that the average larval developmental period was 18.66 days.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that larval period ranges from 3.21 to 4.90 days. Larval development was earlier in wild round (3.20 days) and Naadu (3.21 days) cultivars. Larval development was extended in Kattai (4.78 days) and wild elliptical (4.90 days) cultivars.

Das *et al.* (2017) reported the duration of 1st instar maggot of melon fruit fly was varied from 1 to 2 (mean \pm SD= 2.4 ± 0.55) days. Duration of 2nd instar varied from 1 to 2 (mean \pm SD= 1.4 ± 0.55) days. Duration of 3rd instar varied from 3 to 4 (mean \pm SD= 3.6 ± 0.55) days.

Sharma *et al.* (2017) observed that the larval stage of *B. cucurbitae* lasts for 5 to 15 days with the mean 10 ± 3.96 days.

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and found that the period of 1st instar development ranged from 1 to 2 days for all the three hosts. However, average minimum period of 1st instar maggot was 1.08 ± 0.277 days for bitter gourd, 1.16 ± 0.374 days for bottle gourd and 1.08 ± 0.277 days for watermelon. The period of 2nd instar development ranged from 1 to 2 days for all the three hosts. However, the average mean development of 2nd instar maggot were 1.64 ± 0.490 days, 1.72 ± 0.458 days and 1.68 ± 0.476 days for bitter gourd, bottle gourd and watermelon,

respectively. The 3rd instar maggot period ranged from 2 to 7 days on different hosts. However, the average mean development of 3rd instar maggot were 3.32 ± 0.627 (2 to 5 days), 5.24 ± 0.523 (4 to 6 days) and 5.32 ± 0.802 days (4 to 7 days) for bitter gourd, bottle gourd and watermelon, respectively. The total maggot period ranged from 6.08 to 8.12 days on different hosts. It is evident that the mean maggot period were 6.08 ± 0.493 (5 to 7 days), 8.12 ± 0.332 (8 to 9 days) and 8.08 ± 0.812 days (7 to 10 days) for bitter gourd, bottle gourd and watermelon, respectively. Bitter gourd recorded shorter maggot period than rest of the hosts.

Akter and Sohel (2020) reported that the period required for first, second and third instar larvae of *B. cucurbitae* was 1.72 ± 0.33 , 1.41 ± 0.31 and 2.31 ± 0.51 days, respectively.

Gaddanakeri and Rolania (2020) concluded that the total maggot period of *B. cucurbitae* was ranged from 5 to 7 (mean \pm SD = 5.80 ± 0.78) days with the average duration of first, second and third instars ranging from 0.5 to 1 (mean \pm SD = 0.8 ± 0.26), 1.5 to 3 (mean \pm SD = 2.0 ± 0.53) and 2 to 3 (mean \pm SD = 2.55 ± 0.44) days, respectively.

2.2.1.7 Pre-pupal period

Laskar (2013) observed that the pre-pupal stage is a very short duration stage that lasted not even a day. Duration of the stage was same on bitter gourd and pumpkin varying from 0.50 to 1.00 with a mean of 0.60 ± 0.22 days and 0.70 ± 0.27 days, respectively.

Mir *et al.* (2014) found the average duration of pre-pupal stage of *B. cucurbitae* and it was 0.8 ± 0.25 days.

Sharma *et al.* (2017) reported the non-feeding pre-pupal stage of *B. cucurbitae* lasts for 1 to 2 days with an average 1.5 ± 0.25 days.

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and pre-pupal periods on different hosts were ranged from 1.08 to 1.12 days on different host. There was no impact of host on pre-pupal period of *B. cucurbitae*. The pre-pupal period of *B. cucurbitae* varied from 1 to 2 days and the mean pre-pupal period was 1.08 ± 0.277 days for both bitter gourd and watermelon whereas it was 1.12 ± 0.332 days for bottle gourd.

Akter and Sohel (2020) reported that the 0.74 ± 0.17 days was required to pass pre-pupal period.

Gaddanakeri and Rolania (2020) studied the duration of pre-pupal period and was ranged from 0.5 - 1.0 day with average duration of 0.7 ± 0.20 days.

2.2.1.8 Pupal period

Mukherjee *et al.* (2007) found that the duration of pupal period of melon fruit fly varied from 7 to 9 days with an average of 7.75 ± 0.41 days.

Ullah *et al.* (2008) studied comparative biology of *B. cucurbitae* on five different cucurbit species and the mean pupal period was the shortest on bitter gourd (5.33 ± 0.12 days) and appeared to be the highest on squash (8.33 ± 2.50), compared to others. The bottle gourd, sweet gourd and snake gourd showed the almost same mean pupal duration.

Barma and Jha (2011) studied the pupal period of fruit fly, *B. cucurbitae* varied from 6 to 9 days and 17 to 21 days in June-July and in August-October respectively.

Laskar (2013) recorded the duration of pupal stage varied from 6.00 to 8.00 days on both bitter gourd and pumpkin. The fly took more time to complete pupal stage on pumpkin as compared to that of bitter gourd. The mean \pm SD value of pupal duration was derived as 6.80 ± 0.83 and 7.40 ± 0.89 days on bitter gourd and pumpkin, respectively.

Bhowmik *et al.* (2014a) observed that pupal period was 5 ± 1.41 and 13.3 ± 0.48 days in June-July and November-December during 2011, respectively. During 2012, it was 9.9 ± 0.99 , 7 ± 1.05 , 5.3 ± 0.48 and 10.2 ± 2.1 days in February-March, May-June, July-August and November-December in 2012, respectively.

Mir *et al.* (2014) reported the duration of pupal stage of *B. cucurbitae* and it was varied from 8 to 9 days with a mean of 8.4 ± 0.51 days, respectively.

Rahman *et al.* (2015) studied biology of cucurbit fruit fly, *B. cucurbitae* and reported that the average pupal period was 21.3 days.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that pupal period ranges from 5.29 to 7.81 days. In case of Naadu and wild round fruits

pupal development of fruit fly was earlier, recorded 5.35 and 5.29 days respectively. Regards Kattai and wild elliptical cultivars, pupal development was extended and noticed 7.81 and 7.10 days respectively.

Das *et al.* (2017) recorded that the duration of pupal stage varied from 6 to 7 days. The mean \pm SD value of pupal duration was derived as 6.2 ± 0.45 days.

Sharma *et al.* (2017) studied biology of *B. cucurbitae* under laboratory conditions and found that pupal stage lasts for 9 to 11 days with an average 10 ± 0.79 days.

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and periods of pupae on different hosts differed significantly from each other and it varied from 5 to 11 days. Results on pupal period showed that the average means pupal period of 5.88 ± 0.600 (5 to 7 days), 7.16 ± 0.374 (7 to 8 days) and 9.40 ± 0.645 days (9 to 11 days) for bitter gourd, bottle gourd and watermelon, respectively. Thus, different hosts serving as food for maggots were found to have significant influence on the pupal period of *B. cucurbitae*.

Akter and Sohel (2020) reported that the 9.2 ± 0.78 days were required to complete the pupal period and the data range was 8.0 - 10.0 days.

Gaddanakeri and Rolania (2020) observed the duration of pupal period ranged from 6.0 - 8.0 days with average duration of 6.9 ± 0.87 days.

2.2.1.9 Adult longevity

Mukherjee *et al.* (2007) recorded the longevity of male and female adult fruit fly varied from 16 to 20 days and 20 to 27 days with an average of 18.25 ± 0.74 and 23.50 ± 1.35 days, respectively.

Ullah *et al.* (2008) studied comparative biology of *B. cucurbitae* on five different cucurbit species and the highest longevity of male was found on squash (45.62 ± 1.51 days) followed by sweet gourd (45.00 ± 2.52 days) and they differed significantly from the rests of the hosts. Bitter gourd was the most unsuitable host for the survival of male *B. cucurbitae* (25.33 ± 2.00 days) which was closely followed by snake gourd (28.62 ± 1.00 days) and they differed insignificantly from each other. Like as male, female also showed the highest longevity on squash followed by sweet gourd and bottle

gourd. The lowest female longevity was recorded on bitter gourd (26.00 ± 1.53 days) and then on snake gourd (29.33 ± 0.58 days) and they showed insignificant differences.

Manzar and Srivastava (2009) found the average longevity of male was 12.74 ± 2.83 days and 13.09 ± 2.37 days whereas; female longevity was 15.03 ± 3.14 days and 15.56 ± 2.67 days during 2002 and 2003, respectively.

Barma and Jha (2011) studied the adult longevity of fruit fly, *B. cucurbitae* varied from 37 to 41 days with the mean 38.5 ± 1.35 and 23 to 32 days with the mean 28.2 ± 2.65 during June-July and during August-October respectively.

Laskar (2013) observed the longevity of melon fruit fly and adult male duration was longer (mean \pm SD = 31.60 ± 9.14 days) that ranged from 18.00 to 41.00 days on bitter gourd. On the contrary, when reared on pumpkin the male adults were short lived (mean \pm SD = 27.20 ± 7.40 days) and the longevity varied from 16.00 to 34.00 days. As a whole, the female adult lived longer than that of the male. Duration of female adult was ranged from 25.00 to 41.00 days when reared on bitter gourd, the average being 33.20 ± 6.34 days (mean \pm SD). But the fly when reared on pumpkin the longevity of female adult varied from 19.00 to 41.00 days (mean \pm SD = 30.60 ± 8.20).

Bhowmik *et al.* (2014a) observed that the longevity of adult male was 6 ± 1.05 and 21.2 ± 7.8 days during June-July and November-December, respectively in 2011. It was 11.5 ± 2.64 , 8.2 ± 1.4 , 6.6 ± 1.43 and 20.8 ± 5.87 days in February-March, May-June, July-August and November-December in 2012, respectively. The longevity of adult female were 9.8 ± 1.03 and 23.2 ± 9.65 days during June-July and November-December in 2011 and 16.2 ± 1.23 , 11.5 ± 1.51 , 8.3 ± 2 and 21.9 ± 7.80 days during February-March, May-June, July-August and November-December in 2012, respectively.

Mir *et al.* (2014) conducted experiment on adult longevity of *B. cucurbitae* and found that when adults were provided neither food nor water immediately after their emergence, they died after 1.4 ± 0.54 days, range of 1.0 to 2 days. The longevity of adults was extended up to 2 to 3 and 3 to 4 days by access to water only. When provided with water and honey (1:1), flies lived 12 to 35 days. When supplied with water, molasses and proteinex, males lived 40.4 ± 2.95 ranging from 30 to 52 days and females lived 48.6 ± 3.51 days ranging from 32 to 60 days.

Rahman *et al.* (2015) studied biology of cucurbit fruit fly, *B. cucurbitae* and reported that the mean duration of adult stage was 27.67 days.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that adult period ranges from 7.24 to 10.89 days.

Das *et al.* (2017) recorded the longevity of male adult was ranged from 15 to 32 days (mean \pm SD = 25 ± 8.72 days). Duration of female adult was ranged from 18 to 38 days with an average of 30 ± 10.07 days (mean \pm SD).

Sharma *et al.* (2017) studied biology of *B. cucurbitae* under laboratory conditions and reported that adult longevity of male and female feeding on cucumber juice has been recorded to vary between 10 to 16 days, with an average of 13 ± 2.37 days and 11 to 20 days with an average of 15.5 ± 3.49 days respectively.

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and results showed that female lived for longer time than the male when reared on all the three hosts. The female longevity varied from 12 to 20 days with an average of 15.10 ± 0.738 (14 to 16 days), 17.22 ± 0.833 (16 to 19 days) and 16.86 ± 2.734 days (12 to 20 days) for bitter gourd, bottle gourd and watermelon, respectively. Likewise, the males lived with a range of 9 to 16 days and mean longevity was 10.33 ± 0.617 (9 to 11 days), 12.81 ± 0.655 (11 to 12 days) and 13.11 ± 2.111 days (10 to 16 days) for bitter gourd, bottle gourd and watermelon, respectively.

Gaddanakeri and Rolania (2020) stated that the female adult longevity varied from 20.00 to 33.00 days, the average being 25.9 ± 4.15 days. Longevity of male adult ranged from 18 to 31 days, the average being 23.7 ± 3.77 days.

2.2.1.10 Sex ratio

Laskar (2013) observed that the sex ratio, male: female was also found to be varied from host to host. It was noted 1.102 ± 0.136 (mean \pm SD) in bitter gourd that ranged from 0.95 to 1.26. When reared on pumpkin the sex ratio was recorded as 0.976 ± 0.104 (mean \pm SD) which varied from 0.91 to 1.12.

Bhowmik *et al.* (2014a) observed that the sex ratio (Male: Female) of adult and was found to be 1.063: 1 and 1: 1.03 during June-July and November-December in 2011. But in 2012, the ratio was found to be 1: 2.096, 1.063: 1, 1: 1 and 1:

1.09 during February-March, May-June, July-August and November-December in 2012, respectively.

Mir *et al.* (2014) found the sex ratio of *B. cucurbitae* was 1.10 ± 0.14 (mean \pm SD), which varied from 0.95 to 1.25 (male: female).

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and found sex ratio of male and female was 1: 0.67, 1: 0.56 and 1: 0.39 when *B. cucurbitae* maggots reared on bitter gourd, bottle gourd and watermelon crop, respectively.

Gaddanakeri and Rolania (2020) observed the sex ratio of melon fruit fly (male oriented in the study) and it was 1:0.84 (male: female).

2.2.1.11 Total life cycle

Manzar and Srivastava (2009) found that the average life cycle was 13.5 ± 1.952 days and 13.66 ± 2.483 days during 2002 and 2003, respectively.

Ullah *et al.* (2008) studied comparative biology of *B. cucurbitae* on five different cucurbit species and showed that the duration of life span of female was the highest on sweet gourd (62.13 days) which was almost identical to the squash (58.03 days) and the lowest on bitter gourd (28.43 days) which was statistically identical to the snake gourd (31.33 days). The bottle gourd showed an intermediate duration (53.13 days) compared to rest of the four. The female flies lived longer than the males. Life span of male was the highest on sweet gourd (60.13 days) which was statistically identical to squash (58.7 days). Total life span of cucurbit fruit fly was much shorter on bitter gourd which was identical to the snake gourd.

Barma and Jha (2011) studied the total duration from egg to adult stage of fruit fly, *Bactrocera cucurbitae* and were found to vary from 16 to 22 days in June-July and 51 to 59 days in August-October.

Laskar (2013) reported total life period, right from egg to death of the adult of melon fly varied from male to female and also on the host on which the insect was reared. In case of male it varied from 31.50 to 57.00 days with mean of 46.00 ± 10.34 days on bitter gourd and 30.25 to 50.75 (mean \pm SD = 43.30 ± 8.62) days on pumpkin. In female fly, it was slightly longer where it varied from 38.50 to 56.50 and 33.25 to 55.75 days in bitter gourd and pumpkin, respectively. The average duration was

derived as 48.20 ± 6.93 days on bitter gourd and 46.70 ± 9.27 days on pumpkin (mean \pm SD).

Bhowmik *et al.* (2014a) recorded the total life span of male was 20 ± 3.4 and 56.9 ± 11.12 days during June-July and November-December in 2011 and 36.5 ± 7.12 , 24.6 ± 3.6 , 18.8 ± 2.78 and 42.5 ± 12.2 days during February-March, May-June, July-August and November-December in 2012, respectively. The total life period of adult female was found to be 25.2 ± 3.82 and 54.1 ± 13.65 days during June-July and November-December in 2011 and 41.2 ± 4.57 , 26.7 ± 3.4 , 19.6 ± 3.63 and 41.4 ± 10.05 days during February-March, May-June, July-August and November-December in 2012, respectively.

Rahman *et al.* (2015) studied biology of cucurbit fruit fly, *B. cucurbitae* and reported that the mean duration of egg to adult was 40.34 days.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that total life cycle of fruit fly ranges from 27.60 to 36.76 days.

Das *et al.* (2017) studied the total life period, right from egg to death of the adult of melon fly varied from male to female and also on the host on which the insect was reared. In case of male it varied from 29.5 to 48 day with mean of 39.5 ± 8.82 days. In female fly, it was slightly longer where it varied from 31.5 to 53 days. The average duration was derived as days 44.5 ± 10.56 .

Patel and Patel (2018) studied comparative biology of *B. cucurbitae* and the adult periods for female differed significantly on various hosts. The period from egg to the death of adult occupied by females was 29.20 ± 1.033 (28 to 31 days), 35.80 ± 1.814 (34 to 38 days) and 38.00 ± 3.512 days (32 to 42 days) on bitter gourd, bottle gourd and watermelon crop, respectively.

Akter and Sohel (2020) reported that the total development period (Egg to adult mortality) was 36 ± 1.69 days and the data range was 33.0 - 37.7 days.

Gaddanakeri and Rolania (2020) reported that the total life period of male fruit fly ranged from 30 to 46 days with a mean of 36.2 ± 5.77 days. In case of female fruit fly it was slightly longer where it ranged from 32 to 50 days with a mean of 40.4 ± 6.24 days.

2.2.2 Morphometric of Fruit Fly, *B. cucurbitae*

2.2.2.1 Egg stage

Mukherjee *et al.* (2007) conducted morphometric measurements of *B. cucurbitae* and found that eggs were 1.40 to 1.60 mm long with an average of 1.48 ± 0.04 mm and breadth ranged from 0.40 to 0.55 mm with an average of 0.48 ± 0.03 mm.

Barma and Jha (2011) found that freshly laid eggs of *B. cucurbitae* was measured from 0.76 mm to 0.84 mm in length and 0.20 mm to 0.26 mm in width.

Laskar (2013) studied morphometric observations of melon fruit fly and revealed that the length of egg varied from 1.22 to 1.36 mm. on bitter gourd and the mean \pm SD value derived as 1.28 ± 0.059 mm. The eggs reared on pumpkin recorded slightly shorter ranging from 1.20 to 1.35 mm with mean of 1.26 ± 0.060 mm. Breadth of egg varied from 0.18 to 0.32 mm when reared in bitter gourd and 0.17 to 0.31 mm in pumpkin. The average value of breadth was derived as 0.26 ± 0.057 mm and 0.25 ± 0.053 mm in bitter gourd and pumpkin, respectively that were very close to each other.

Bhowmik *et al.* (2014a) revealed that the freshly laid eggs measured from 0.75 mm to 1.5 mm in length with an average of 1.06 ± 0.25 mm and 0.1 mm to 0.3 mm in width with an average of 0.21 ± 0.08 mm.

Mir *et al.* (2014) conducted the morphometric observations of *B. cucurbitae* and revealed that the length of egg varied from 0.98 to 1.28 mm with a mean of 1.13 ± 0.14 mm and the breadth varied from 0.21 to 0.34 mm with a mean of 0.28 ± 0.05 mm, respectively.

Rahman *et al.* (2015) studied biology of cucurbit fruit fly, *B. cucurbitae* and reported that the freshly laid eggs measured on an average 0.78 mm in length and 0.16 mm in width.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that the melon fruit fly egg length varies from 1.20 to 1.24 mm, egg breadth ranges 0.21 to 0.25 mm.

Das *et al.* (2017) recorded the morphometric observations and revealed that the length of egg varied from 1.2 to 1.4 mm on pumpkin with mean of 1.30 ± 0.08

mm. Breadth of egg varied from 0.19 to 0.32 mm with an average value of 0.25 ± 0.05 mm in pumpkin.

Gaddanakeri and Rolania (2020) studied morphometric of melon fruit fly and revealed that the length and breadth of egg varied from 1.12 to 1.34 mm (mean \pm SD = 1.22 ± 0.07 mm) and 0.16 to 0.28 mm (mean \pm SD = 0.23 ± 0.04 mm), respectively.

2.2.2.2 Larval (maggot) stage

Mukherjee *et al.* (2007) found that the length of full grown larvae of *B. cucurbitae* varied from 9.50 to 11.00 mm with an average of 10.13 ± 0.27 mm and breadth ranged from 3.00 to 4.00 mm with an average of 3.18 ± 0.21 mm. A full grown maggot is 9 to 10 mm long and 2 mm broad in the middle.

Barma and Jha (2011) observed that the length and width of 1st instar maggots varied 1.20 to 1.62 mm and 0.22 to 0.38 mm respectively. The length and width of 2nd instar maggots varied from 4 to 4.70 mm and 1.08 to 1.44 mm respectively. The length and width of 3rd instar maggots at the stage varied from 7.50 was to 9.20 mm and 1.88 to 2.48 mm respectively.

Laskar (2013) reported the length of mature maggots when reared in bitter gourd ranged from 8.90 to 11.50 mm with the mean value being 10.28 ± 0.99 mm. (mean \pm SD). When pumpkin was used as host of the melon fly the length of mature maggots varied from 8.50 to 11.25 mm and the mean value recorded 10.29 ± 1.11 mm. (Mean \pm SD). Breadth of mature maggots ranged from 1.59 to 2.25 mm in bitter gourd and 1.55 to 2.20 mm in pumpkin. The mean values were 1.95 ± 0.26 and 1.90 ± 0.24 mm in bitter gourd and pumpkin respectively. Weight of maggots found to be slightly higher in bitter gourd reared specimen (23.40 ± 2.70 mg) than the pumpkin reared specimen (22.00 ± 2.55 mg). Weight ranged from 20.00 to 27.00 mg and 19.00 to 25.00 mg bitter gourd and pumpkin, respectively.

Bhowmik *et al.* (2014a) observed that the length 1st instar maggots were varied from 1.1 mm to 1.92 mm with an average of 1.6 ± 0.25 mm and the width ranged between 0.2 mm to 0.39 mm with an average of 0.27 ± 0.05 mm. The length of the 2nd instar larvae varied from 4 mm to 4.52 mm with an average of 4.23 ± 0.16 mm and the width ranged between 1.05 mm to 1.4 mm with an average of 1.22 ± 0.12 mm. While the

length and width of 3rd instar maggots varied from 7 mm to 11 mm with an average of 9.5 ± 0.9 mm and 0.67 mm to 1.33 mm with an average of 1.31 ± 0.12 mm respectively.

Mir *et al.* (2014) measured the 1st, 2nd and 3rd instars maggots of *B. cucurbitae* and found 1.49 ± 0.28 , 6.40 ± 0.86 and 9.62 ± 0.87 mm in length, respectively and 0.31 ± 0.07 , 1.21 ± 0.09 and 2.05 ± 0.32 mm in breadth, respectively.

Rahman *et al.* (2015) studied biology of cucurbit fruit fly, *B. cucurbitae* and reported that the average length of 1st instar maggot was 1.48 mm and width was 0.26 mm. The average length of full grown 2nd instar maggot was 5.2 mm and width was 0.84 mm. The average length of 3rd instar maggot was 8.8 mm and width was 1.52 mm.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that matured maggots length varied from 10.05 to 10.28 mm; regarding the breadth varied from 1.84 to 2.03 mm. The matured maggot weights ranged from 20.23 to 26.20 mg.

Das *et al.* (2017) concluded that the length of 1st instar varied from 1.1 mm to 1.9 mm with an average of 1.57 ± 0.26 mm and the width ranged between 0.1 to 0.3 mm with an average of 0.25 ± 0.07 mm. The length of the 2nd instar larvae varied from 4 to 5.1 mm with an average of 4.71 ± 0.34 mm and the width ranged between 1.9 to 1.3 mm with an average of 0.93 ± 0.31 mm. The length and width of 3rd instar maggots varied from 7 mm to 9.2 mm with an average of 8.44 ± 0.88 mm and 1.2 to 2 mm with an average of 1.57 ± 0.29 mm respectively.

Akter and Sohel (2020) reported that the lengths of all three larval instars of *B. cucurbitae* were 1.1 ± 0.9 , 3.03 ± 0.95 and 6.42 ± 0.90 mm and the widths were 0.22 ± 0.11 , 1.12 ± 0.01 and 2.13 ± 0.20 mm, respectively.

Gaddanakeri and Rolania (2020) conducted morphometric observations of melon fruit fly and revealed that the length and breadth of first instar maggot ranged from 1.16 to 1.84 mm (mean \pm SD = 1.54 ± 0.28 mm) and 0.20 to 0.36 mm (mean \pm SD = 0.29 ± 0.07 mm), respectively. The length and breadth of second instar maggots ranged from 4.90 to 7.15 mm (mean \pm SD = 6.10 ± 0.82 mm) and 1.06 to 1.32 mm (mean \pm SD = 1.19 ± 0.11 mm), respectively. The length and breadth of third instar maggot ranged from 8.25

to 10.75 mm (mean \pm SD = 9.29 ± 0.80 mm) and 1.75 to 2.35 mm (mean \pm SD = 2.04 ± 0.23 mm), respectively.

2.2.2.3 Pre-pupal stage

Laskar (2013) recorded the length of the pre-pupa varied from 6.20 to 7.50 mm (mean \pm SD = 6.89 ± 0.46) in bitter melon and 6.00 to 7.50 mm (mean \pm SD = 6.70 ± 0.60) in pumpkin. Breadth varied from 1.75 to 2.30 mm in both the cases of hosts but the mean \pm SD value was noted as 2.04 ± 0.23 mm and 1.99 ± 0.22 mm in bitter melon and pumpkin respectively. Weight of the pre-pupa ranged from 16.60 to 18.80 (mean \pm SD = 17.73 ± 1.09) mg in bitter melon and 16.50 to 19.00 (mean \pm SD = 17.71 ± 1.13) mg in pumpkin.

Mir *et al.* (2014) observed the length and breadth of pre-pupa *B. cucurbitae* and it was 6.46 ± 0.14 mm and 2 ± 0.02 mm, respectively.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and measured pre-pupal length, breadth and weight ranged from 5.87 to 6.82 mm, 1.74 to 2.04 mm and 16.28 to 17.53 mg, respectively.

Akter and Sohel (2020) reported that the length and width of the pre-pupa of *B. cucurbitae* were 5.86 ± 0.48 mm and 1.94 ± 0.23 mm, respectively.

Gaddanakeri and Rolania (2020) studied the length and breadth of pre-pupa and was varied from 6.25 to 6.54 mm (mean \pm SD = 6.41 ± 0.15 mm) and 1.98 to 2.08 mm (mean \pm SD = 2.03 ± 0.04 mm), respectively.

2.2.2.4 Pupal stage

Mukherjee *et al.* (2007) found that the length and breadth of pupae of *B. cucurbitae* varied from 5.0 to 7.0 and 2.0 to 2.3 mm with an average of 6.00 ± 0.31 and 2.18 ± 0.05 mm, respectively. The pupae were barrel shaped, light brown or pale in colour.

Barma and Jha (2011) were showed that the length and width of pupal stage of fruit fly, *B. cucurbitae* varied from 5.25 to 5.88 mm and 2.09 to 2.59 mm respectively.

Laskar (2013) observed that the length and breadth of pupa varied from 5.30 to 6.50 (mean \pm SD = 5.85 ± 0.46) mm and 2.10 to 2.60 (mean \pm SD = 2.29 ± 0.19)

mm in bitter gourd respectively. When pumpkin was used as host of the fly length varied from 5.20 to 6.10 (mean \pm SD = 5.56 ± 0.48) mm and breadth from 2.00 to 2.60 (mean \pm SD = 2.26 ± 0.22) mm. When weight of the pupa considered it varied from 15.75 to 17.00 (mean \pm SD = 16.16 ± 0.58 mg) in bitter gourd and in pumpkin it ranged from 15.40 to 16.65 (mean \pm SD = 15.96 ± 0.58).

Bhowmik *et al.* (2014a) reported that the length and width of pupae varied from 4.25 mm to 6.1 mm (average 5.22 ± 0.52 mm) and 1.9 mm to 2.5 mm (average 2.1 ± 0.12 mm), respectively.

Mir *et al.* (2014) found the average length and breadth of pupae of *B. cucurbitae* were 5.72 ± 0.13 mm and 2.46 ± 0.11 mm, respectively.

Rahman *et al.* (2015) studied biology of cucurbit fruit fly, *B. cucurbitae* and reported that the average length of pupa was 4.22 mm and width was 1.76 mm.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and the pupal length, breadth and weight assessed 4.86 to 5.83 mm, 1.90 to 2.20 mm and 15.04 to 15.50 mg, respectively.

Das *et al.* (2017) observed that the length and breadth of pupa of *B. cucurbitae* varied from 5 to 6 (mean \pm SD = 5.65 ± 0.42) mm and breadth from 2.00 to 2.5 (mean \pm SD = 2.3 ± 0.18) mm.

Akter and Sohel (2020) reported that the length and width of the pupa of *B. cucurbitae* were 5.68 ± 0.26 mm and 2.39 ± 0.20 mm, respectively.

Gaddanakeri and Rolania (2020) found the length and breadth of pupa ranged from 5.30 to 6.45 mm (mean \pm SD = 5.98 ± 0.38 mm) and 2.35 to 2.72 mm (mean \pm SD = 2.54 ± 0.14 mm), respectively.

2.2.2.5 Adult stage

Mukherjee *et al.* (2007) reported that the length of male and female *B. cucurbitae* varied from 7.0 to 8.0 and 8.0 to 9.0 mm with an average of 7.5 ± 0.25 and 8.75 ± 0.22 mm, respectively. The breadth of male and female varied from 3.0 to 4.0 and 5.0 to 6.0 mm with an average of 3.25 ± 0.22 and 5.50 ± 0.25 mm, respectively.

Barma and Jha (2011) found that the length and width of adult males of fruit fly, *Bactrocera cucurbitae* ranged from 6.48 to 7.54 mm (mean \pm SD = 7.19 ± 0.32)

and 2.21 to 2.38 mm (mean \pm SD = 2.30 ± 0.07), respectively. Whereas length and width of adult females ranged from 8.04 to 9.18 mm (mean \pm SD = 8.50 ± 0.38) and 2.30 to 2.54 (mean \pm SD = 2.43 ± 0.09).

Laskar (2013) recorded length of melon fruit fly when reared on bitter gourd varied from 5.55 to 7.20 (mean \pm SD = 6.31 ± 0.60) mm while in case of pumpkin it was found to varied from 5.50 to 7.00 (mean \pm SD = 6.20 ± 0.55) mm. Breadth of the fly, *i.e.* the wing expanse varied from 10.10 to 12.65 (mean \pm SD = 11.50 ± 1.01) mm and 10.10 to 12.60 (mean \pm SD = 11.44 ± 0.99) mm in bitter gourd and pumpkin respectively. Weight of adult male was noted slightly higher when reared on bitter gourd 12.82 ± 0.79 mg (that ranged from 11.80 to 14.00 mg) than the pumpkin reared specimen (12.40 ± 1.23) mg that varied from 11.60 to 14.00 mg. Length and breadth (wing expanse) of the female adult were found to varied from 7.45 to 9.50 (mean \pm SD = 8.61 ± 0.79) mm and 12.20 to 16.50 (mean \pm SD = 14.00 ± 1.69) mm respectively when reared on bitter gourd. Weight of a single female adult was ranged from 12.90 to 15.00 (mean \pm SD = 13.44 ± 1.04) mg. In case of pumpkin the length and breadth (wing expanse) varied from 7.40 to 9.45 (mean \pm SD = 8.53 ± 0.80) mm and 12.00 to 16.00 (mean \pm SD = 13.80 ± 1.60) mm respectively. Weight of the female found slightly lower (mean \pm SD = 13.20 ± 1.68 mg) when reared on pumpkin that ranged from 10.50 to 15.00 mg.

Bhowmik *et al.* (2014a) reported that the male length varied from 5.5 mm to 9 mm with an average of 7.28 ± 0.9 mm and width varied from 7 mm to 14 mm with an average of 9.97 ± 1.62 mm. The length of female melon fruit fly ranged between 7 mm to 10 mm with an average of 8.83 ± 1.02 mm and width varied from 8 mm to 16 mm with an average of 10.75 ± 1.88 mm.

Mir *et al.* (2014) measured length and breadth of *B. cucurbitae* and found that the length and breadth of the male with expanded wings was 8.74 ± 0.32 mm and 11.46 ± 1.16 mm, respectively, whereas, the female with expanded wings measured 9.94 ± 0.20 mm in length and 15.92 ± 0.74 mm in breadth.

Rahman *et al.* (2015) studied biology of cucurbit fruit fly, *B. cucurbitae* and reported that the average length of the adult male was 13.78 mm and width was 7.06 mm, where the average length of the adult female was 15.62 mm and width was 8.86 mm.

Vigneswaran *et al.* (2016) carried out experiment on biology and morphometric study of *B. cucurbitae* on different *Coccinia indica* cultivars and reported that the adult female length, breadth and weight ranged from 5.82 to 6.11 mm, 10.88 to 11.50 mm and 11.35 to 12.76 mg respectively. The adult male length, breadth and weight ranged 8.00 to 8.4 mm, 13.03 to 13.80 mm and 12.75 to 13.14 mg, respectively.

Das *et al.* (2017) recorded the length of males was varied from 6 to 7.1 (mean \pm SD = 6.79 \pm 0.40) mm. Breadth of the fly, *i.e.* the wing expanse varied from 12.1 to 15.3 (mean \pm SD = 13.14 \pm 1.05) mm. Length and breadth (wing expanse) of the female adult were found varied from 7.5 to 9.3 (mean \pm SD = 8.55 \pm 0.71) mm and 12 to 17.5 (mean \pm SD = 14.95 \pm 1.48) mm.

Akter and Sohel (2020) reported that the length of male and female of *B. cucurbitae* were 6.61 \pm 0.59 and 8.28 \pm 0.52 mm. The widths of males and females with wingspan were 10.97 \pm 0.43 and 13.02 \pm 1.28 mm, respectively.

Gaddanakeri and Rolania (2020) stated that the average length and breadth (with expanded wings) of male fruit fly was 8.41 \pm 0.24 mm (8.05 to 8.74 mm) and 11.35 \pm 0.90 mm (10.04 to 12.05 mm), respectively, whereas, the average length and breadth (with expanded wings) of female was 9.74 \pm 0.22 mm (9.44 to 10.15 mm) and 15.61 \pm 0.75 mm (14.50 to 16.90 mm), respectively.

2.3 Management of Fruit Fly, *B. cucurbitae* Infesting Cucurbitaceous Vegetable Crops

2.3.1 Bio-efficacy of insecticides and biopesticides against *B. cucurbitae*

Mehta *et al.* (2000) observed that the deltamethrin (0.0028%) and acephate (0.05%) are the most effective in reducing fruit infestation by *B. cucurbitae* and recorded lowest number of maggots per cucumber fruit. However, highest fruit infestation and maggot population was observed in malathion treatment.

Koyama *et al.* (2004) successfully applied the sterile insect technique (SIT) from 1972 to 1993 to eradicate the melon fly, *B. cucurbitae*, which was invaded in South Western Islands of Japan and conducted technical research into SIT functions, such as suppression of density, mass-rearing, sterilization, shipment, release, evaluation of efficacy and quality control of mass-reared insects for this eradication project. Fundamental research into the dispersion, mating and oviposition behaviour, population

dynamics and estimation of density, eradication models, spatial distribution, genetics and evolution of the melon fly was also undertaken and supported the success of the eradication project.

Dhillon *et al.* (2005) reported that melon fruit fly can successfully be managed over a local area by bagging fruits, field sanitation, protein baits, cue-lure traps, growing fruit fly-resistant genotypes, augmentation of biocontrol agents and soft insecticides. The wide area management program involves the coordination of different characteristics of an insect eradication program (including local area options) over an entire area within a defensible perimeter and subsequently protected against reinvasion by quarantine controls. Although, the sterile insect technique has been successfully used in wide area approaches, this approach needs to use more sophisticated and powerful technologies in eradication programs such as insect transgenesis and geographical information systems, which could be deployed over a wide area.

Khan *et al.* (2007) tested neem leaf dust and a commercial formulation of neem on adult *B. cucurbitae* (Coquillett) and *B. dorsalis* (Hendel) to determine their effects on the longevity, fecundity and ovarian development. Experimental results confirmed that neem can be effectively used as a safe alternative insecticide for the control of *Bactrocera* species.

Nath *et al.* (2007) reported that the NSKE @ 5%, bait spray (Malathion 50 ml + molasses 500 g + water 50 L) and cypermethrin applied one after another as per schedule resulted in minimum fruit damage by the fruit fly whereas the control plots exhibited maximum damage in bottle gourd fruits.

Mukherjee *et al.* (2007) evaluated different management practices and revealed that the bagging of fruits showed the lowest level of infestation and the highest yield was obtained in the bagging treatment. So, the study indicated that bagging of fruits might be considered as a suitable method in suppressing fruit fly on sweet gourd.

Amin *et al.* (2008) conducted experiment to know the economic effect of different management practices *viz.*, application of Nimbicidine @ 5 ml/L, Secufon 80 SP @ 1 ml/L, Decis 2.5 EC @ 1 ml/L water and bagging of fruits at two days after anthesis on *B. cucurbitae* in sweet gourd (*Cucurbita moschata*). The evaluation of different management practices revealed that the bagging of fruits in scaffold showed the lowest

level of infestation and demanded the highest cost (356.45 US \$) per hectare. The highest yield (19.51 t/ha) was obtained in the bagging treatment and resulted lowest benefit: cost ratio (06.89). It was concluded that bagging of fruits was found to be as a superior method in controlling the damage by fruit fly in sweet gourd.

Oke (2008) assessed two insecticides *viz.*, deltamethrin and lambda-cyhalothrin for the control of *B. cucurbitae* on cucumber and observed both the insecticides effective against this pest. However, lambda-cyhalothrin was found to be better in respect of reducing the oviposition marks and number of pupae than that of deltamethrin.

Sharma and Sinha (2009) evaluated six insecticides, *viz.*, alphamethrin, cypermethrin, endosulfan, spinosad, emamectin benzoate and neem baan against *B. cucurbitae* on bitter gourd during *kharif*, 2007 revealed that alphamethrin @ 20 g a.i./ha was the most effective and resulted in 5.52 per cent damage as compared to 15.14 per cent in control. Emamectin benzoate @ 15 g a.i./ha and neem baan @ 1ml/L too were found effective.

Waseem *et al.* (2009) estimated efficacy of different chemicals against *B. cucurbitae* in cucumber variety 'Dharwad green'. The treatments i.e. spinosad 45% SC and imidacloprid 17.8% SL recorded 4.00 per cent and 5.67 per cent damage respectively and were on par with Nimbex (0.15%). The highest per cent fruit damage was recorded in untreated check (43.67%). While in the treatments *viz.*, indoxacarb 14.5% SC, emamectin benzoate 5% SG and diafenthuron 50% WP, the damage was 17.67, 19.67 and 32.67 per cent, respectively and all the treatments were at par.

Kate *et al.* (2010) tested the nine insecticides among which, malathion (0.1%) proved to be the most effective against fruit fly on cucumber under the field conditions which was at par with fenthion (0.1%). The fenitrothion (0.03%) and alfamethrin (0.005%) stood second in order in their effectiveness. The highest yield of cucumber fruits (8299 kg/ha) was recorded in the treatment of malathion (0.1%) which was at par with fenthion (0.1%) (7982 kg/ha). While fenitrothion (0.03%) and alfamethrin (0.005%) gave 7648 kg/ha and 7255 kg/ha yield, respectively. The application of malathion (0.1%) gave the highest and net realization of Rs.19934/ha with cost benefit ratio of 1:13.75 followed by endosulfan (0.05%) with net realization of

Rs.8609/ha and CBR 1:10.44, fenthion (0.1%) with net realization of Rs.18035/ha and CBR 1:9.49 and fenitrothion (0.03%) with net realization of Rs. 16034/ha and CBR 1:8.57.

Sapkota *et al.* (2010) conducted experiment under farmer field conditions to assess losses and to measure the efficacy of different local and recommended management options to address the problem of it in squash *var.* Bulam House (F1). Cucurbit fruit fly preferred young and immature fruits and resulted in a loss of 9.7 per cent female flowers. Out of total fruits set, more than one-fourth (26%) fruits were dropped or damaged just after set and 14.04 per cent fruits were damaged during harvesting stage, giving only 38.8 per cent fruits of marketable quality. Application of locally made botanical pesticide ‘Jholmal’ was found superior in terms of fruit size (895 g), quality and yield (62.8 t/ha) and reduced fruit fly infestation in squash as compared to other treatments. Although, ‘Jholmal’ preparation is easy and its application is effective for the management of cucurbit fruit fly, it involves more labor cost and frequent application is a tedious process.

Ali *et al.* (2011) carried out experiment during the year 2009 to find the bio-efficacy of different plant extracts against melon fruit fly, *B. cucurbitae* in bitter gourd (*Momordica charantia* L.). The experiment consisted of three varieties Ambika, Rama Krishna and Phauja and five different treatments (including check) i.e. Methomyl, Neem seed extract, *Parthenium hysterophorus* L. extract and Eucalyptus leaves extract. All the botanicals showed significant results and minimized the percent damage as compared to the check. The minimum population of melon fruit fly adults m^{-2} were found in Methomyl and Neem seed extract treatments, followed by *Parthenium* plant extract and Eucalyptus leaves extract. The maximum adults m^{-2} were found in the control plots. The minimum per cent damage (41.94%) was found in Neem seed extract treated plots. The results of the experiment revealed that botanicals can be replaced for the management of melon fruit flies instead of using the synthetic pesticides in order to save the environment from their hazards.

Sheikh and Desh (2012) conducted field experiments to evaluate seven insecticides and biopesticides against fruit flies, *Bactrocera* spp. in cucumber and bitter gourd. Abamectin (0.0015%) was the most effective treatment in terms of reducing the

fruit infestation as well as number of maggots in both the crops. Lambda-cyhalothrin (0.004%) was the next best treatment followed by azadiractin (0.0045%) and carbaryl 50 WP (0.20%). However, chlorpyrifos 20 EC (0.05%) and Malathion 50 EC (0.05%) were found to be inferior resulting in comparatively less reduction in fruit infestation and number of maggots per infested fruit. From the economic point of view, lambda-cyhalothrin was found a better option resulting in returns of 31.4 and 26.5 at Palampur and 62.9 and 40.6 at Bara (Hamirpur) for cucumber and bitter gourd, respectively per rupee invested.

Oke and Sinon (2013) conducted field experiment from October to December in the 2009 and 2010 planting seasons at Vegetable Evaluation and Research Sub-Station farm at Praslin, Seychelles and evaluated the effectiveness of three insecticides namely lambda-cyhalothrin, deltamethrin and mercaptothion, to control the melon fruit fly (*B. cucurbitae*) in cucumber crop. The results obtained showed that the use of deltamethrin insecticide recorded the lowest number of ovipositor marks, number of pupae and number of emerged melon fruit flies. This study showed that deltamethrin insecticide was the most effective and could be recommended for the control of melon fruit fly in cucumber under field conditions.

Bhowmik *et al.* (2014c) conducted two field trials to determine the bioefficacy of few biorational insecticides against melon fruit fly (*B. cucurbitae*) on pointed gourd, during pre-*Kharif* and *Kharif* seasons in the year 2012 at Bhabanipur village of Nadia district, West Bengal. Insecticides of different groups (conventional, botanicals and microbials) were sprayed thrice at an interval of 15 days. The most effective treatment in reducing the fruit infestation was chlorfenapyr in both seasons followed by deltamethrin in pre-*Kharif* season and spinosad in *Kharif* season. Neemazal and karanja oil were the least effective insecticide in reducing the fruit infestation by melon fruit fly on pointed gourd during the respective seasons. The highest yield of pointed gourd was observed in chlorfenapyr treated plots during both the seasons.

Sawai *et al.* (2014) evaluated relative efficacy of different insecticides under field conditions. The cumulative pooled data of the year 2011 and 2012 pertaining to the fruit damage by fruit fly revealed that treatment deltamethrin (0.0016%) recorded significantly the lowest (20.15%) fruit damage, however it was statistically at par with

DDVP (0.05%), emamectin benzoate (0.0016%) and azadirachtin (0.0025%) with 22.83, 24.05 and 24.79 per cent fruit damage, respectively.

Khatun *et al.* (2016) evaluated efficacy of two bacterial fermented bio-pesticides (abamectin and emamectin benzoate), one insect growth regulator (lufenuron) and one newer pyrethroid (lambda-cyhalothrin) against cucurbit fruit fly, *B. cucurbitae* on bitter melon. The results revealed that abamectin (Ambush 1.8% EC) was found as the most effective one followed by emamectin benzoate (Suspend 5% SG) while the insect growth regulator, lufenuron (Haron 5% EC) was found as less effective against the *B. cucurbitae* based on the parameters studied.

Sharma *et al.* (2016) conducted experiment on comparative evaluation of 10 organic formulations and synthetic insecticide against fruit fly on cucumber during the years 2011 and 2012 at certified Model Organic Farm, Palampur. The lowest fruit infestation of 7.69 and 9.09 per cent was registered in treatment with cypermethrin 25% EC @ 0.5 ml/L followed by treatment with neem oil (Nimbecidene) 5ml/L as 12.50 and 13.58 per cent during both respective years of study. Similar trend of fruit yield was observed using cypermethrin 25% EC gave highest fruit yield 191.48 and 183.33 q/ha followed by neem oil (Nimbecidene) as 189.01 and 181.48 q/ha during both years of study. However, both these formulations were significantly at par but under organic conditions four sprays of neem oil formulation coinciding with infestation at 10-day interval can be effectively used to manage this pest.

Shafiullah *et al.* (2016) evaluated aqueous extracts of leaves of neem (*Azadirachta indica*), eucalyptus (*Eucalyptus globules*), telakucha (*Coccinia indica*), mahogany (*Swietenia macrophylla*) and joba (*Hibiscus rosa-sinensis*) for their repellence, abundance and infestation on fruit fly (*B. cucurbitae*). The repellent effect on the insect was observed in laboratory and the abundance and infestation activities were studied in ash gourd (*Benincasa hispida*) in the field. The results indicated that the repellent effect of the extracts on fruit fly varied from 4.0 ± 2.4 to 60.0 ± 3.2 per cent, where the maximum effect was obtained with 4% neem leaf extract at 1 hour after treatment. The minimum effect was achieved with 1% joba leaf extract at 5 hour after treatment. The plant extract also affected the abundance and infestation of the insect, where 4% neem leaf extract caused the lowest abundance (3.7/30 sweeps) and fruit infestation (8.7%).

Sunil *et al.* (2016) conducted field experiments and evaluated the efficacy of selected insecticides against melon fruit fly, *B. cucurbitae* in bitter gourd and results revealed that Deltamethrin 2.8 EC + jaggery bait (0.0028 + 0.015%) was the most effective treatment resulting in minimum fruit infestation (13.15, 8.61%), as well as lowest number of maggots per fruit (12.58, 9.58). The next superior treatment was deltamethrin 2.8 EC (0.0028%), azadirachtin 1 EC (0.005%) and malathion 50 EC (0.1%) which were on par in terms of reduction of fruit infestation. However, spinosad 45 SC (0.014%) and dichlorovos 76 SC (0.152%) were found to be inferior with comparatively lesser reduction in fruit infestation as well as number of maggots per infested fruit as compared to the other treatments, except untreated control.

Amin *et al.* (2017) evaluated toxicity and physiological effects of aqueous extracts of neem (*Azadirachta indica*), eucalyptus (*Eucalyptus globulus*), telakucha (*Coccinia indica*), mahogany (*Swietenia macrophylla*) and joba (*Hibiscus rosa-sinensis*) leaves were used to on fruit fly, *B. cucurbitae* reared on ash gourd (*Benincasa hispida*). Among the treatments, neem revealed the most toxic effect as it showed the lowest LC₅₀ and LC₉₅ values as well as steepest slope of the concentration curve. The order of toxicity of the plants was neem > eucalyptus > telakucha > mehagony > joba. All the extracts reduced pupation, adult emergence, protein content in larval body and body weight of male and female flies. The highest reduction of protein, body weight of male and female flies, pupation and adult emergence were found with 4 % neem extract. Among the tested extracts, 4% neem extract was found as the most effective botanical insecticide against *B. Cucurbitae*.

Bharadiya and Bhut (2017) carried out field experiment on effect of five different insecticides against fruit fly, *B. cucurbitae* infesting sponge gourd during 2014 and 2015 at Agronomy Farm, Junagadh Agricultural University, Junagadh. The insecticides abamectin 0.0025 per cent and emamectin benzoate 0.002 per cent were found most effective and economic and were statistically at par with each other. The significantly minimum fruit infestation 19.35 per cent with 32.01 per cent yield increased in the treatment of abamectin. While in emamectin benzoate 20.62 per cent fruit infestation with 29.10 per cent yield increased. However, the treatment of dichlorovos

0.07 per cent (22.65% fruit infestation with 26.32% increased yield) was proved next best insecticide.

Sarkar *et al.* (2017) carried out field and laboratory studies to find out the extent of fruit fly infestation at different fruiting stages of bitter gourd as well as to determine the efficacy of some pesticidal and other control approaches applied either separately or in combination. The pesticidal efficacy of three commonly used insecticides such as secufon, malathion, karate and karanja oil as botanicals with the concentrations of 0.25, 0.50, 0.75 and 1.00 per cent, respectively was determined against the larvae of cucurbit fruit fly, *B. cucurbitae* in the laboratory based on mortality at different time intervals. All the pesticides caused maximum mortality at 72 h with 1.00 per cent concentration. The level of fruit fly infestation at different fruiting stages of bitter gourd ranged from 8.91 to 88.19 per cent, 9.24 to 94.89 per cent and 5.01 to 89.27 per cent at early, mid and late fruiting stage, respectively. Soil treatment with furadan @ 10 kg ha⁻¹ + bagging of fruits showed significantly lowest infestation (9.46%) which was ten times lower than that of untreated control (91.43%). The other control approaches *viz.*, sex pheromone, bait trap with secufon + cucurbit chop, bait trap consisted of secufon + banana chop reduced fruit fly infestation to a significant level. The highest number (83.67) of flies trapped at mid fruiting stage of bitter gourd was recorded in sex pheromone trap while the ratio of male and female flies ranged from 1.13 to 1.24 in the trapped individuals.

Shivangi *et al.* (2017) investigated the bio-efficacy of different bio-intensive treatment modules against cucurbit fruit fly, *B. cucurbitae* in cucumber during *kharif*, 2016. The results revealed that among eight spray combinations of biopesticides *viz.*, Spinosad (200 ml/ha), Azadirachtin (0.03%) and NSKE (5%), three sprays of Spinosad (200 ml/ha), first spray applied as soon as the ovipositor marks were seen on the fruits and subsequent sprays at an interval of twelve days proved to be the most effective treatment module in controlling the fruit fly with least mean number of fruits with ovipositor marks (1.50), mean number of pupae of fruit fly formed from damaged fruits (5.92) and mean per cent fruit infestation (8.28 per cent). The treatment module comprising two spray applications of Spinosad (200 ml/ha) followed by a spray of Azadirachtin (0.03%) was the next effective treatment.

Abhilash *et al.* (2018) assessed six different botanicals against melon fruit fly in ridge gourd at farmer field at Basavangalur, Shivamogga during *Rabi* 2016-17. During the investigation, among the botanicals, the lowest fruit infestation of 26.53 per cent was registered from Azadirachtin 1% EC @ 2 ml/L treatment followed by NSKE 5% treatment with 29.06 per cent fruit infestation. Among various botanical treated fruits of ridge gourd, Azadirachtin 1% EC and NSKE 5% treated fruits recorded higher per cent ovipositional deterrence over control of 74.26 and 68.26 per cent, respectively and lower egg hatchability of 60.50 and 62.25 per cent, respectively.

Abrol *et al.* (2018) were conducted field trials to evaluate some insecticides, biopesticides and clay for the management of fruit fly, *Bactrocera* spp. infesting bottle gourd. Among insecticides, λ -cyhalothrin with least fruit infestation (14.62%) and maximum avoidable loss value (47.93%) proved effective in managing fruit flies. Among biopesticides, spinosad (17.38% infestation) and azadirachtin though inferior over the synthetic pyrethroid, were found effective over neem and pongamia oil, *Beauveria bassiana*, clay and also over the recommended insecticide i.e malathion. Neem oil, *B. bassiana*, pongamia oil, clay and neemastra treatments were not found much effective though these were superior over control. The highest benefit cost ratio (BCR) was recorded in deltamethrin (20.54:1) and was followed by λ - cyhalothrin (15.39:1) treatment. The botanicals and microbials were not economically viable as the BCR computed was <1 except for *B. bassiana*, with a quite low BCR value (1.21:1).

Balas *et al.* (2018) investigated comparative efficacy of different insecticides against fruit fly, *B. cucurbitae* on cucumber variety Dharwad green at Instructional farm, College of Agriculture, Junagadh Agricultural University, Junagadh during *Kharif*-2015. The results of the two spraying of Fipronil, Dichlorvos, Polytrin C, Profenophos, Spinosad, Lambda-cyhalothrin, Malathion, Clorantraniliprole and Bifenthrin insecticides against the cucumber fruit fly revealed that Dichlorvos @ 0.05%, Lambda-cyhalothrin @ 0.005% and Malathion @ 0.1% were found more effective treatments against the pest as compared to other insecticides.

Hirekurubar *et al.* (2018) revealed that the minimum per cent fruit damage of 14.27 was recorded in spinosad 45 SC @ 0.3 ml/l treated plot, making it most effective treatment followed by chlorantraniliprole 18.5 SC @ 0.2 ml/l (16.97%) which was at par

with deltamethrin 2.8 EC @ 0.5 ml/l (20.35%). Spinosad 45 SC @ 0.3 ml/l treated plot registered highest fruit yield (22.08 t/ha) which was at par with chlorantraniliprole 18.5 SC @ 0.2 ml/l (20.16 t/ha) and significantly superior than deltamethrin 2.8 EC @ 0.5 ml/l (18.86 t/ha). The yield obtained from NSKE 5% (16.86 t/ha) and azadirachtin 1500 ppm @ 5 ml/l (16.95 t/ha) were also found at par with deltamethrin 2.8 EC @ 0.5 ml/l and significantly higher than the untreated control (13.51 t/ha). The highest cost benefit ratio of 1: 2.64 was obtained in spinosad 45 SC treated plot.

Srinivas *et al.* (2018) carried out field experiment on effect of different insecticides against fruit fly, *B. cucurbitae* infesting cucumber during *Kharif*-2017 and *Summer*-2018 at Chikkamagaluru. The results revealed that significantly lowest number of ovipositional punctures (0.72 and 0.98/fruit), lowest number of maggots (8.0 and 8.93/fruit), lowest percent fruit infestation (14.92 and 17.90%), highest marketable fruit yield (15.63 and 16.49 t/ha.) and more cost-benefit ratio (1:2.30 and 1:2.43) was recorded in the treatment with spinosad 45 SC (0.15 ml/L) during both *kharif* and summer season, respectively and it was on par with the treatment dichlorvos 76 EC (1.0 ml/L). However, highest number of ovipositional punctures (2.72 and 3.01/fruit), highest number of maggots (19.13 and 19.80/fruit), highest per cent of fruit infestation (46.91 and 56.79%) and lowest marketable fruit yield (10.75 and 9.01 t/ha.) was obtained in the jaggery treatment (10 g/L) which was followed by control in both *kharif* and *summer* season, respectively.

Shinde *et al.* (2018b) carried out field experiment to evaluate of bio-efficacy of insecticides against fruit flies infesting cucumber during *Kharif*-2017 at Central Experimental Station, Wakawali, Dist- Ratnagiri. The results on efficacy of insecticides against fruit flies infesting cucumber indicated that spinosad 45 SC @ 0.014 per cent was the best treatment which recorded minimum (15.38%) mean fruit infestation and was at par with emamectin benzoate 5 SG @ 0.002 per cent (20.49%). The next best treatments were azadirachtin (1%) @ 0.003 per cent (27.99%) and malathion 50 EC @ 0.05 per cent (32.89%) which were at par with each other. Similarly, malathion 50 EC @ 0.05 per cent (32.89%) which was at par with deltamethrin 2.8 EC @ 0.0024 per cent and dichlorvos 76 EC @ 0.05 per cent recorded 37.32 and 38.99 per cent fruit infestation, respectively.

Nehra *et al.* (2019b) carried out investigations on the bio-efficacy of newer insecticides and biopesticides against fruit fly, *B. cucurbitae* on round gourd at Horticultural farm of SKN College of agriculture, Jobner, Jaipur during *Summer*, 2016. Among the insecticides evaluated against fruit fly on round gourd, spinosad was found most effective. The next effective treatments were acephate + molasses followed by acephate and fipronil. The treatments Neem Gold and NSE were found least effective.

Pawar *et al.* (2019) conducted experiment during *Kharif* 2018 for evaluation of different modules against major pests of cucumber (*Cucumis sativus* L.). During the course of study, three pest management modules *viz.*, Chemical, Bio-intensive and IPM module consisting spraying of different pesticides as well as biopesticides were evaluated with untreated control in Randomized Block Design (RBD) with five replications. The studies on evaluation of pest management modules for major pests of cucumber revealed that in for control of thrips, whitefly and aphids IPM module observed 4.31 thrips, 3.80 whitefly and 3.90 aphids/3 leaves/plant, respectively. Whereas, in case of leaf miner and fruit fly, the IPM module was significantly superior module and observed 21.15 per cent damaged leaves and 10.84 per cent damaged fruits, respectively. Effect of different strategies on predatory coccinellids showed that the Bio-intensive module recorded the highest grub population per plant (3.85 grubs/plant) and was at par with the IPM module which recorded 3.36 grubs/plant indicating their relative safety to the grubs of lady bird beetles. The highest yield of cucumber fruits 230 q/ha was registered from the IPM module with highest ICBR 1:13.86 as against 160 q/ha in untreated control.

Rahman *et al.* (2019) were tested efficacies of three biopesticides *viz.*, Spinosad, Abamectin and *Lecanicillium muscarium* either by an individual or their combined application were evaluated against the insect attack and yield of bitter gourd (*Momordica charantia* L.). The individual application of Spinosad had provided moderate efficacy. The combination of Spinosad and *L. muscarium* was the most effective approach to produce the highest per cent of healthy fruits (83.32) and the lowest fruit infestation (16.68) protecting the most top per cent (54.21) of fruits from infestation. The maximum number of marketable fruits per m² were (13.67), the highest marketable yield (5.15 ton/ha) and the lowest infested yield (0.17 ton/ha) also were obtained from this

combined treatment. The fruit yield increased almost twice over control. These suggest that there might be an additive or synergistic action between Spinosad and *L. muscarium* admixture. However, the Abamectin with *L. muscarium* treatment did not increase yield, and other parameters significantly suggesting the incompatibility or an antagonistic effect between them.

Sharma and Gupta (2019) laid experiment to study the efficacy and monetary returns of different new insecticides against fruit flies in cucumber during cropping season 2018 in the mid-hill region of Himachal Pradesh State of India. The results of the bioefficacy study revealed lambda-cyhalothrin @ 0.004% with least fruit infestation (17.13%) as the most effective insecticide in checking the fruit fly population which was followed by emamectin benzoate @ 0.002% (24.64% infestation). Also, the maximum avoidable loss (65.57%) was recorded in lambda-cyhalothrin followed by emamectin benzoate (61.11%) treated plots which proved their efficiency in managing fruit flies. The highest benefit cost ratio (BCR) was recorded in lambda-cyhalothrin (28.74:1) and was followed by malathion (5.67:1) treatment. In rynaxypyr and diflubendiamide treatments the negative BCR ratios were obtained due to very high cost of the test treatment.

Lad *et al.* (2020) carried out investigations on efficacy of some insecticides against melon fruit fly, *Bactrocera* spp. on bitter gourd during *rabi-summer* season of 2017-18 at College of Agriculture, Dapoli, Ratnagiri (M.S). The results indicated that the efficacy of treatment spinosad 45 SC @ 0.014 per cent was found effective against fruit flies which recorded minimum (16.69%) mean fruit infestation and was at par with emamectin benzoate 5 SG @ 0.002 per cent (20.26%). The next effective treatment was chlorantraniliprole 18.5 SC @ 0.005 per cent with 26.84 per cent fruit infestation. Whereas, the maximum (71.37%) mean fruit infestation was noticed in untreated control plot.

Abhishek *et al.* (2021) exploited newer insecticides for the management of *Bactrocera cucurbitae* (Coquillett) under field condition during *kharif*, 2019. Observation on per cent fruit infestation and larval population per fruit were recorded by picking marketable size fruits at 60 days after sowing. Spinosad 45 SC @ 0.3 ml L⁻¹ was the most effective insecticide against *B. cucurbitae* with significantly lowest fruit infestation

(28.62%), larval population (6.53/fruit) with higher marketable yield of 12.86 tons ha⁻¹. Thiodicarb 75 WP @ 1.0 g L⁻¹ was the next best treatment in the order of efficacy against melon fly with 31.72 per cent of fruit infestation, 7.84 of larvae per fruit followed by emamectin benzoate @ 0.4 g L⁻¹ (34.32% and 8.82/fruit), flubendiamide @ 0.75 ml L⁻¹ (36.39% and 8.54/fruit) and lambda cyhalothrin @ 1.0 ml L⁻¹ (36.39% and 8.92/fruit). Per cent reduction of fruit infestation over the control was high in Spinosad 45 SC @ 0.3 ml L⁻¹ (55.49%) followed by thiodicarb 75 WP @ 1.0 g L⁻¹ (50.67%). It is concluded that 2 foliar spray of either spinosad 45 EC @ 0.3 ml L⁻¹ or thiodicarb 75 WP @ 1.0 g L⁻¹ at flowering and fruiting stage of the crop offer better protection against melon fly.

Alam and Khan (2021) carried out an experiment to evaluate the efficiency of different biopesticides against the fruit fly infestation on bottle gourd. Among the treatments, Spinosad (Tracer 45 SC) performed the best based on minimum per cent fruit infestation on both number and weight basis (30.71% and 32.64%) and highest per cent protection of fruit over control (60.86% and 58.94%). Again, the highest marketable fruit yield (60.43 ton/ha) and per cent yield increase of marketable fruit (70.46%) were also observed on Spinosad treated plot. Based on the same parameters, Neem oil was inferior to Spinosad, which was followed by the treatment of Abamectin (Ambush 1.8 EC), Allamanda leaf extract and Mahogany oil.

Gautum *et al.* (2021) conducted investigation on evaluation of comparative efficacy of different insecticides against cucurbit fruit fly, *B. cucurbitae* in bottle gourd at farmer's field in Sarlahi. The maximum number of fruit fly per plant was 8.40 (10 DAS-III) during the experiment. Cucurbit fruit flies preferred young fruits and flowers for oviposition and the results obtained high pre-set damage of 43.85 per cent (10 DAS-I) and post-set damage of 68.14 per cent (10 DAS-II). The highest fruit infestation was 52.41 and 53.71 per cent based on number and weight respectively under control treatment. Under spinosad treatment, the lowest insect population (1.33 at 3 DAS-III) was obtained with least pre-set damage, post-set damage and minimum fruit infestation of the insect by number (27.29%) and weight (25.90%) followed by dichlorovos and lambda-cyhalothrin for similar traits. While, jholmal and Azadirachtin were inferior in controlling the fruit fly population and reducing the infestation at pre-set, post-set and harvest stage. However, azadirachtin and lambda-cyhalothrin were on par in terms of

post-set damage (46.32 and 47.50%), respectively. Results revealed that spinosad is the best bio-pesticide against cucurbit fruit fly in bottle gourd with dichlorvos and lambda-cyhalothrin next in order while jholmal and azadirachtin offered a better quality of fruits and higher yield in bottle gourd. While chemical insecticides may seem effective for short term, we must opt to use eco-friendly pesticides/botanicals such as spinosad, jholmal and azadirachtin for pest management.

Kubar *et al.* (2021) carried out field experiments in bottle gourd, sponge gourd, Indian squash and bitter gourd and revealed that among the solo treatments, the plots sprayed with chemical (T2 = Tracer) had least number of infested fruits (29.75 ± 2.69) while in combine treatments, the most effective treatment was T16 (Tracer + Protein hydrolysate + cuelure + *T. daci*) with 2.00 ± 0.41 infested fruits. Moreover, the highest punctures fruit⁻¹ were recorded in control plot (23.25 ± 2.21) cultivated with Bottle gourd whereas, the least punctures were found in bitter ground (1.05 ± 0.38) cultivated plot. On the basis of results obtained from the current study, it can be concluded that the combination of different treatments can significantly reduce the infestation caused by melon fruit fly.

Parkash *et al.* (2021) reported that, among different treatments, Malathion 50 EC (1 ml/l) in addition with jaggery (3 g/l) was highly efficient with highest fruit yield (233.42 q) and minimum fruit infestation after two sprays (19.53%). Nimbecidine and NSKE (10%) were statistically at par and observed best effective treatments with fruit infestation of 27.41 and 27.79%, respectively. NSKE (5%), *Beauveria bassiana* and *Metarhizum anisopliae* were also effective to certain extent with 50.59, 47.31 and 41.85% reduction in fruit infestation over control, respectively. Cow urine treatment was least effective treatment but had significantly lower per cent of fruit infestation (39.86%) as compared to control (54.29%).

Shinde *et al.* (2021b) reported that Spinosad 45 SC was the most effective treatment which recorded minimum (19.38%) mean fruit infestation and was at par with Deltamethrin 2.8 EC (20.34%) continued its superiority over rest of the treatments under study. The next best treatments were Azadirachtin 10000 ppm (25.21%), Emamectin Benzoate 5 SG (27.48%), Dichlorvos 76 EC (26.14%), Dashparni ark (31.67%) and Lantana extract (34.03%) were statistically at par with each other.

Meena *et al.* (2022) evaluated five insecticides and four botanicals for their bio efficacy against fruit fly, *B. cucurbitae*, revealed that spinosad 45 SC (0.013%) was most effective followed by indoxacarb 14.5 SC (0.010%) and acephate 75 SP (0.075%). The next effective treatments were dimethoate 30 EC (0.030%) and quinalphos 25 EC (0.025%). The treatments khimp and tumba extract were found least effective against fruit fly infestation.

2.3.2 Evaluation of different protein food baits in attracting *B. cucurbitae*

Sookar *et al.* (2002) testified the attractancy to the melon fly, *B. cucurbitae* and phytotoxicity of four prepared with waste brewer's yeast, were assessed in a plantation of calabash, *Lagenaria siceraria* Mol., in Mauritius with cloth ground-sheet catchers mounted below bait spots. Protein hydrolysate was used as the standard bait. No bait exhibited any phytotoxicity. As spot sprays, protein hydrolysate attracted significantly more melon flies than the prepared baits, brewer's yeast autolysate with fresh green pawpaw juice than with papain and brewer's yeast with papain more than with fresh or boiled pineapple juice. The efficacy of the same baits to control the melon fly was then assessed as weekly bait sprays in ridge gourd, *Luffa acutangulata* (L.) Roxb. Fruit fly infestation levels were initially high (40-80%) in all plots, but after 12 weeks, infestation was 100 per cent in an untreated control, 2 per cent with protein hydrolysate protection, 1 per cent with yeast autolysed with papain, 2 per cent with yeast autolysate with pawpaw, 6 per cent with yeast autolysate with pineapple and 7 per cent with the boiled yeast preparation.

Chinajariyawong *et al.* (2003) tested the efficacy of Australian Pinnacle protein bait and Thai yeast bait to control *B. cucurbitae* and *B. tau* infestations in angled luffa and bitter gourd. The angled luffa plot treated with Pinnacle and bitter gourd plots treated with either Pinnacle or Thai bait had considerably lower percent infested fruits when compared with the untreated plots. Yields obtained in the angled luffa plot treated with Pinnacle were 81.57 per cent higher than in the untreated plot and in the bitter gourd plots treated with either Pinnacle or Thai bait, increased yields were 67.22 and 59.98 per cent higher, respectively, than in the untreated plot. *B. cucurbitae* and *B. tau* were the only two species that infested fruits of both crops. Among dead fruit flies feeding on the

poison baits, collected from funnel traps, *B. cucurbitae* and *B. tau* were the most common species.

Nasiruddin *et al.* (2003) explored the bait traps of cue-lure pheromone and mashed sweet gourd (MSG) in bitter gourd crop attracted large numbers of fruit flies effecting 40 to 65 per cent reduction in fruit fly infestation and damage to the fruits and producing 2-4 times higher yields as compared to the non-baited fields. The technique was highly effective for the control of fruit fly and production of cucurbit crops free of pesticides. Continuous mass-trapping tended to diminish fruit fly population in the area.

Barry *et al.* (2006) determined attraction and feeding responses of oriental fruit fly, *B. dorsalis* and melon fruit fly, *B. cucurbitae*, for different protein baits. In separate choice attraction assays for each species, significantly more flies arrived at stations with bait than water, but no differences existed among baits of GF-120 Fruit Fly Bait, GF-120 NF Naturalyte Fruit Fly Bait, Provesta 621 autolyzed yeast extract and Mazoferm E 802. In comparison with *B. dorsalis*, *B. cucurbitae* had 2.8 times more responders and a 4.8 times better discrimination between baits and water. In a second attraction assay with only *B. dorsalis*, volume of bait was negatively correlated to numbers of flies alighting on the bait. Feeding assays for both species demonstrated that time spent feeding and duration on a leaf was both significantly affected by bait type. *B. dorsalis* fed the longest on Provesta 621, with significantly less feeding on the other baits and with all baits resulting in more feeding than water. The longest feeding times for *B. cucurbitae* resulted with Mazoferm E 802 and Provesta 621 and all baits except GF-120 NF resulted in eliciting a significantly longer feeding duration than water. In separate toxicology assays for each species, significantly higher mortality resulted from bait formulations containing spinosad compared with blank baits, but no differences existed between GF-120 and GF-120 NF formulations.

Verma and Nath (2006) conducted research work on different aspects of the management of fruit flies through trapping. Various trapping strategies *viz.*, bait sprays, traps and lures has been discussed along with the bait composition used by different workers.

Vargas *et al.* (2010) deployed the Methyl eugenol (ME) and Cue-lure (C-L) traps with solid lure dispensers in the areas with low and high populations of oriental

fruit fly, *B. dorsalis* and melon fly, *B. cucurbitae*, respectively. In low-density areas, standard Jackson traps or Hawaii Fruit Fly Area wide Pest Management (AWPM) traps with FT Mallet ME wafers impregnated with dimethyl dichloro-vinyl phosphate (DDVP) or AWPM traps with Scentry ME cones and vapor tape performed equally as well as standard Jackson traps with liquid ME/C-L and naled. Standard Jackson traps or AWPM traps with FT Mallet C-L wafers impregnated with DDVP or AWPM traps with Scentry C-L plugs with vapor tape performed equally as well as standard Jackson traps with a lure-naled solution. In high density areas, captures with traps containing FT Mallet wafers (ME and C-L) out performed AWPM traps with Scentry cones and plugs (ME and C-L) with DDVP insecticidal strips over a 6-mo period. Captures of *B. dorsalis* and *B. cucurbitae* with wafers containing both ME and raspberry ketones (FT Mallet MC) were equivalent to those containing separate lures.

Praveen *et al.* (2012) undertaken an area-wide control (AWC) programme for management of melon fly, *B. cucurbitae*, in 3 km² area in Kashapura village of Karnataka State from 52nd week of 2007 to 30th week of 2010. Implementation of the AWC programme included field sanitation, male annihilation technique (MAT) through para-pheromone, Cue lure and bait application technique (BAT). This AWC programme resulted in steady decline of melon fly population in the grid area and corresponding reduction in per cent fruit fly infested gherkin fruits. In the AWC (grid) area, flies trapped per day (FTD) led to attaining suppression (1 to 0.1 FTD) and eradication levels (1 FTD) during majority of weeks under observation.

Thakur and Gupta (2013) carried out laboratory experiments to find out the efficacy of food substances namely protein hydrolysate, yeast hydrolysate, sugar, bitter gourd and cucumber, against fruit fly, *B. tau* and *B. cucurbitae* adults. Protein hydrolysate proved most attractive for both *B. tau* (6.1 adult/30 min) and *B. cucurbitae* (6.3 adults/30 min) followed by yeast hydrolysate (4.9 and 5.1 adults/30 min, respectively). Although both the species showed similar trend of preference for the test food material, but *B. tau* adults preferred bitter gourd (3.7/30 min) in comparison to cucumber (2.6/30 min). Female fruit flies were more active visitors in case of both *B. tau* and *B. cucurbitae* with an average of 4.6 and 4.8 females/30 min, respectively as compared to males (3.8 and 3.9 males/30 min, respectively).

Kotikal and Math (2017) conducted review work on different aspects of management of fruit flies with the particular reference to trapping. Various trapping strategies *viz.*, bait sprays, traps and lures have been discussed along with the bait composition used by different workers. Because of the fruit flies are pests of international importance that are difficult to manage as they are polyphagous, multivoltine and have high mobility and fecundity. Only adults are exposed, while eggs and maggots remain protected in the host tissues and pupae are in the soil. Thus, most insecticidal treatments are ineffective. The stage of the pest that can be targeted is the adult insect.

Pinero *et al.* (2017) reported that adult tephritid fruit fly females require protein sources for adequate egg production and ammonia and its derivatives serve as volatile cues to locate protein-rich food. The attractiveness of beer waste and the commercially available baits Nu-Lure® Insect Bait, Buminal® and Bugs for Bugs® Fruit Fly Bait with and without ammonium acetate or ammonium carbonate to males and females of *B. dorsalis* and *B. cucurbitae* was quantified in semi-field cage studies in Hawaii. Evaluations also compared the relative attractiveness of the baits to that of the standard bait GF-120® NF Naturalyte® Fruit Fly Bait. Our findings indicate that ammonium carbonate did not exert any effect on the response of *B. cucurbitae* or *B. dorsalis* to the protein baits evaluated and that the addition of ammonium acetate to beer waste and to the commercially available bait Bugs for Bugs® can improve bait attractiveness in particular to females of *B. cucurbitae*. Beer waste laced with ammonium acetate performed as well as the standard fruit fly bait GF-120®. There were variations in the level and type of response between *B. cucurbitae* and *B. dorsalis* and such variability was dependent upon the type of bait being evaluated. For example, there were several instances where baits lacking ammonium acetate (e.g., beer waste and Nu-Lure® for *B. cucurbitae*; Buminal® for *B. dorsalis*) were as attractive as GF-120®. Results are discussed in light of potential applications associated with the use of beer waste as a low-cost, readily available material for fruit fly monitoring and suppression.

Sohrab *et al.* (2018b) reported for management of cucurbit fruit flies among four cucurbits crops *viz.*, bitter melon, ridge melon and pumpkin and bottle melon crops Methyl eugenol and cue lure traps were found the most effective methods for monitoring the population of fruit fly and one of the best tools for taking decision for its

management. Cue lure traps were gave the most effective result against cucurbit fruit fly than methyl eugenol traps. Large numbers of cucurbit fruit flies were caught by using cue lure traps among four cucurbits crops fields than methyl eugenol traps at Meerut and Saharanpur.

Divya *et al.* (2019) carried out experiment in pumpkin and bottle gourd field in Tamil Nadu Agricultural University, Coimbatore. The trap was placed at the distance of 10 m for each replication. All the traps used in this study were checked for number of melon fruit flies collected was observed every week for ten weeks. The mean of overall captured of *B. cucurbitae* in Jar trap + Cue lure + ME (Disc) combination were significantly greater than all other treatments (208.5 numbers) and less in treatments Jar trap + AA (Disc) combination (5.75 numbers) respectively.

Abinaya *et al.* (2020) evaluated the attraction of the female melon fly, *Z. cucurbitae* (Coq.) (Diptera: Tephritidae) to three food baits were in snake gourd (*Trichosanthes anguina* L.) and ridge gourd (*Luffa acutangula* L.) ecosystems at both Coimbatore and Tiruppur districts during January to march 2020. Food bait admixtures were prepared by combining base baits (guava-B1, muskmelon-B2 and guava+ muskmelon-B3) and bait additives (yeast, food grade alcohol, cane sugar and ProtineX®). The result indicated that both ridge gourd and snake gourd at Coimbatore (23 fruit flies/trap/day) attracted more adult flies than at Tiruppur. Greater number of *Z. cucurbitae* were attracted to food bait traps in snake gourd field (24 fruit flies/trap/day) at both Coimbatore and Tiruppur. In common, the performance of guava bait admixture (21 fruit flies/trap/day) was relatively greater than other two baits by trapping more adult flies. At individual sites, the three food baits attracted equivalently higher number of females than males (about 70% females). The number of adult flies trapped at first week (42 fruit flies/trap/day) was high and gradually decreased in successive weeks and found low at 11th (2 fruit fly/trap/day) and 12th (1 fruit fly/trap/day) weeks. This management practice for *Z. cucurbitae* effectively reduced the pest population by attracting most females.

Sowmiya *et al.* (2021) investigated that the male fruit flies were captured maximum (17.67 fruit flies/ trap) in the natural extracts of banana with yeast, black jaggery and 5% acetic acid followed by grapes (15.33 fruit flies/trap). The snake gourd

red pumpkin are next in performance. The ocimum and cruciferous leaf extracts to be least in attraction of male fruit flies. The female fruit flies are highly attracted to the ammonium acetate combination of banana and grapes with the fruit fly catches of 11.00 and 6.00 fruit flies/trap. The fruit extracts of red pumpkin and snake gourd was found be next. The synthetic attractants of methyl eugenol and cue lure was found to be least performance of female fruit flies (1.67 and 1.00 fruit flies/ trap). On comparing the overall natural attractant sources, banana and grapes was found to be effective in trapping of fruit flies with the highest cost benefit ratio of 1.82 and 1.74.

Manikantha *et al.* (2022) were carried out field tests in snake gourd and bitter gourd fields at Peraiyur, Madurai, Tamil Nadu to determine the effectiveness of protein baits i.e., protineX® and soybean bait and natural food baits i.e., tomato and banana bait in capturing melon fruit fly, *Zeugodcaus cucurbitae*. The results indicated that protineX® bait attracted more adult flies than all other baits. Soybean bait ranked next to protineX® which was followed by tomato and banana pulp bait. The majority of the fruit flies collected in the traps were females, revealing that females were drawn to protein sources more than males for their relative higher protein requirements for female growth and sexual maturation.

Sruthi *et al.* (2022) was conducted a field experiment against cucurbit fruit fly (*Zeugodacus cucurbitae*) (Coquillet) in bitter gourd fields to evaluate the attractiveness of various protein and food baits *viz.*, protein baits were soybean, yeast, casein and Proteinex baits and food baits were banana, guava, tomato, pineapple and bitter gourd juice baits. Among the evaluated protein baits, Proteinex bait trapped more i.e., 8.05/trap/week (female-4.94 and male-3.11) and showing 44.45 per cent reduction incidence. Of the food baits assessed, tomato juice bait was the best, trapping 3.35 fruit flies/ trap/ week (female-2.09 and male-1.26) with 37.16 per cent damage reduction. From the present investigation it can be concluded that among protein and food baits evaluated, Proteinex and tomato respectively with attractant materials @ 12 nos/ ha with weekly replenishment may effectively attract both sexes of adult fruit flies and thereby act as reliable management strategy against fruit flies in horticultural crops.

3. MATERIAL AND METHODS

The present investigations were undertaken with three objectives *viz.*, population dynamics, biology and management of fruit fly, *B. cucurbitae* on five cucurbitaceous vegetable crops during *Kharif*, 2019 and 2021 at the Experimental Farm and Ecofriendly Laboratory of Department of Agricultural Entomology, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri. The material and methods adopted during the entire course of investigations are described under the following heads. Considering the persistent need for an effective management strategy for fruit fly as a major pest of cucurbitaceous vegetables it becomes imperative to undertake the present investigations on basic aspects with the following objectives.

3.1 Population Dynamics of Fruit fly, *B. cucurbitae*

3.1.1 Experimental Details

Five cucurbitaceous vegetable crops *viz.*, cucumber, ridge gourd, bitter gourd, sponge gourd and bottle gourd were planted in *Kharif* season of 2019 and 2021 at the lonely field with 1.5 m x 0.5 m spacing keeping away each of the test crop by 5 m isolated space. All the package of practices recommended by MPKV, Rahuri were adopted, except the plant protection measures.

The studies on population dynamics were carried out by installing cue-lure pheromone traps in each of the five cucurbitaceous crops *viz.*, cucumber, ridge gourd, bitter gourd, sponge gourd and bottle gourd during all the crop growth phases as advocated by Messing (1999).

1. Location : Experimental Farm of Department of Agricultural Entomology, MPKV, Rahuri
2. Crops : Cucumber, Ridge Gourd, Bitter Gourd, Sponge Gourd and Bottle Gourd
3. Spacing : 1.5 m x 0.5 m
4. Cultivation practices : All the package of practices of the plant recommended by MPKV, Rahuri were adopted, except the plant protection measures

3.1.2 Meteorological Data

The meteorological data from July, 2019 to November, 2019 and July, 2021 to November, 2021 have been obtained from the Interfaculty Department of Water Management, MPKV, Rahuri.

3.1.3 Methodology

3.1.3.1 Monitoring fruit fly, *B. cucurbitae*

Observations were recorded at weekly intervals initiating from 30th to 44th and 29th to 43th SMW of *Kharif*, 2019 and 2021. The adult fruit flies were counted and examined in each of the lure traps. In order to ensure the test species, the methodology was adopted on more or less in the similar lines as suggested Drew (1989).

3.1.3.2 Extent of damage caused by fruit fly, *B. cucurbitae*

Observations were recorded on the basis of infested, healthy and total fruits on number basis at each of the pickings to compute per cent infestation of the test species in five crops. The data were subjected to analyze by the following formula,

$$\text{Per cent fruit infestation} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

3.1.3.3 Effect of weather parameters on fruit fly, *B. cucurbitae*

Adult populations recorded at weekly intervals were statistically correlated with nine weather parameters *viz.*, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall, wind velocity, number of rainy days and sunshine hours to ascertain the effect on population of test species.

3.2 Biology of Fruit Fly, *B. cucurbitae* on Cucumber

3.2.1 Experimental site

The studies on biology of fruit fly, *B. cucurbitae* were carried out on the single host crop, Cucumber, at Ecofriendly Laboratory, Post Graduate Institute during both *Kharif*, 2019 and 2021.

3.2.2 Experimental material

Rearing cage, beakers, glass vial, plastics jars, petri plates, compound / binocular microscope, muslin cloth, cotton swab, thread, rubber bands, honey, water,

fresh cucumber fruits, magnifying glass, stage and ocular micrometer, vanier caliper, chloroform, divider, scale, brush, scissor etc.

3.2.3 Methodology

3.2.3.1 Rearing technique of fruit fly, *B. cucurbitae*

Infested cucumber fruits were collected and the nucleus culture of the test species was maintained under laboratory conditions. Infested fruits were kept in plastic tray containing 5 cm thick layer of sieved medium black soil which were kept in insect rearing cage of 35 x 30 x 35 cm dimension. After 6-7 days the rotten fruits were removed and the soil was sieved to collect pupa. Thereafter, pupae were individually transferred in glass vials admeasuring 2.5 cm diameter and 18 cm height. Freshly emerged pair of sexed flies were collected from in each of the vials and then transferred within plastic jars with 15 cm diameter and 20 cm height for mating. Mouth of glass jars were covered with white muslin cloth, tightly fitted with rubber band to prevent adult escape. Jars were then kept in wooden cages admeasuring 68 cm x 53 cm x 37 cm dimension to prevent from predators. Cotton swab soaked in 10 per cent honey solution was suspended inside the jar as food source for the flies and then fresh and tender healthy cucumber fruit was kept within the jar for about a week to the facilitate oviposition. Thereafter fresh fruit was replaced for further oviposition, if any. The fruit was subjected to record the observations on pre and post oviposition. After incubation of eggs, neonate maggots were gently transferred on fresh cucumber fruit slice (2 cm x 2 cm x 1 cm size) in petri dish separately for further larval rearing. Slice along with petri dish was replaced every day to avoid microbial development on fruit slice. Maggots were reared on fruit slices till were full grown. Thereafter, they were transferred in plastic jar admeasuring 15 cm diameter and 20 cm height dimension filled with thin (5 cm) layer of soil and these jars were covered with muslin cloth tightened with rubber band for preventing escaping of the maggots.

3.2.3.2 Mating period

Ten adult pairs were carefully examined in the separate set of experiment for recording observations on mating time within the glass jar wherein the time taken in between the initiation and the cessation of mating was considered as mating period.

3.2.3.3 Pre-ovipositional, ovipositional and post-ovipositional period

Ten adult mated females were carefully examined in the separate set of experiment for recording observations on pre-oviposition period wherein, the time period from mating to initiation of the egg laying was considered. Egg laying of each of the mated females was observed daily and the duration from initiation of egg laying till its termination was recorded as ovipositional period. The post-ovipositional period was considered from the date of ceasing of egg laying till the death of female.

3.2.3.3 Fecundity and hatchability

Ten adult mated females were carefully examined in the separate set of experiment for recording observations on fecundity and hatchability. Number of eggs laid within the fruits by each of the female was examined with magnifying 10 X lens. After cessation of egg laying, mean fecundity and per cent hatching was computed thereafter infested fruits were removed and examined to mark freshly deposited egg (s).

3.2.3.4 Incubation period

In a separate set of experiment, ten freshly laid eggs were kept individually in fruit slice by making a small hole with sharp pointer. The eggs were carefully examined under compound microscope till hatching. Eggs were considered as hatched eggs after the emergence of tiny maggot. The period from fresh deposition till hatching was considered as the incubation period.

3.2.3.5 Larval instars and larval period

In a separate set of experiment, newly hatched larvae (maggots) were transferred individually onto fruit slice. Larvae were reared in plastic jar (15 cm diameter and 20 cm height) having bottom layer of 5 cm soil. Jars were covered with muslin cloth tightened with rubber band. Larvae were reared till become full grown and about to pupate within the jar. Food was changed daily to maintain sanitation within petri dish. Larval instars were considered as described by Mir *et al.* (2014) wherein, first, second and third instar acephalous maggots are reported as translucent-white, ellipsoidal-creamy white and yellowish-white with pointed head, respectively.

Duration from the incubation to pre-pupal formation was considered as larval period.

3.2.3.6 Pre-pupal and pupal period

In a separate set of experiment, ten individual full grown last instar maggots were kept in separate glass vial which were later on transferred into plastic jar (15 cm diameter and 20 cm height) containing with 5 cm layer of sieved soil at its bottom for pupation. The soil was frequently moistened with water to avoid desiccation of pupae. Full grown third instar maggot becomes sluggish, ceases feeding and stop movements before ecdysis to pupation, this phase is ascertained to be pre-pupal stage as described by Mir *et al.* (2014) and Patel and Patel (2018). The pre-pupa undergoes the ecdysis and forms coarctate, barrel shaped pupa having brownish yellow tinge covering which is ascertained to be pupal phase as described by Mir *et al.* (2014) and Patel and Patel (2018). Besides, to determine pupae were watched daily, till adult emergence. Period required for both pre-pupal and pupal stage were computed separately.

3.2.3.7 Adult longevity

In a separate set of experiment, freshly emerged male and female (10:10) were kept in glass jar (15 cm diameter and 20 cm height) during their entire life span. Longevity in respect of both the sexes were recorded as period of survival.

3.2.3.8 Sex ratio

In a separate set of experiment, hundred pupae were kept in plastic jar containing 5 cm sieved soil at its bottom and the jar was covered with muslin cloth tightened with rubber band to avoid their escape. The newly emerged flies from pupae were counted separately for the sex wherein, female possesses ovipositor which lacks in male and sex ratio was computed thereafter.

3.2.3.9 Total period of life cycle

Duration contributed by single generation was computed separately assuming observational period recorded in earlier data in the present studies. Thus, the duration from oviposition, till death of adult was considered as completion of life cycle.

3.2.4 Morphological and morphometrics of distinct life stages

Morphometric studies of distinct life stages were recorded under the compound microscope by using calibrated ocular micrometer and/or vernier caliper. Measurement of ten individuals of each of the life stages were recorded. Besides, the

morphological observations *viz.*, colour and shape for each of the life stage were noted separately.

3.3 Field Management of Fruit Fly, *B. cucurbitae* on Cucumber

Field experiment was conducted at Experimental Farm of Department of Agricultural Entomology, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri during the *Kharif*, 2019 and 2021.

3.3.1 Field bio-efficacy of test insecticides on cucumber

Bio-efficacy of six synthetic, two biorational and one biological insecticides along with untreated check was evaluated under field conditions.

3.3.1.1 Material and equipments

Laminated labels, knapsack sprayer, tags, electronic weighing balance, digital camera, magnifying lens etc. were procured from the parent department.

3.3.1.2 Experimental Details

Place of research work : Experimental Farm of Department of Agril. Entomology,
PGI, MPKV, Rahuri

Treatments : 10

Replications : 03

Experimental design : Randomized Block Design

Crop : Cucumber

Spacing : 1 m x 0.5 m

Table 3.1 Insecticides and Biopesticides Used against *B. cucurbitae*

No.	Treatment	Dose (g or ml/L of water)	Concentration (%)
T ₁	Deltamethrin 2.8% EC	1.00	0.0042
T ₂	Spinosad 45% SC	3.12	0.210
T ₃	Lambda-Cyhalothrin 5% EC	2.00	0.007
T ₄	Emamectin benzoate 5% SG	1.5	0.011
T ₅	Lufenuron 5% EC	2.00	0.015
T ₆	Acephate 75% SP	0.5	0.056
T ₇	NSE 5%	50	0.375
T ₈	Azadirachtin 10000 ppm	3	0.0045
T ₉	<i>Metarrhizium anisopliae</i> (SA)	20 g/vine	0.069
T ₁₀	Untreated check	Water spray	

3.3.1.3 Method adopted

Content, concentration used, trade name and source of the insecticides under the studies are briefed in Table 3.3. Five plants from each of the plot were randomly selected and sprayed with test insecticides and water spray (untreated check). The spray suspension of respective treatment made as per required concentration (Table 3.1). The application of spray liquid @ 5 litres/3 plots was done with the help of the knapsack sprayer. For recording observations, healthy, infested and total number of fruits recorded from randomly selected 5 plants from each of the plot before spray application and 3, 7 and 10 days after each application. Data, thus obtained were subjected to ANOVA for arcsine transformation to analyze the variance.

3.3.1.4 Fruit infestation and fruit yield/plot

To evaluate efficacy of nine test insecticides, total fruit count was taken in treated as well as control plots. From the total fruits, infested and healthy fruits / plot were counted and computed to work out the per cent fruit damage. Observations on fruit yield also have been recorded to work out yield of cucumber with increase in yield over control and avoidable yield loss.

The per cent fruit damage on number was calculated by using following formula :

$$\text{Per cent infestation by number} = \frac{\text{Number of fruits infested per plot}}{\text{Total number of fruits per plot}} \times 100$$

The per cent increase in yield over control was calculated by using following formula:

$$\text{Yield increased over control (\%)} = \frac{T - C}{T} \times 100$$

The per cent avoidable yield loss was calculated by using following formula:

$$\text{Yield increased over control (\%)} = \frac{T - C}{T} \times 100$$

Where,

T = Yield of respective treatment (t/ha)

C = Yield of control (t/ha)

3.3.1.5 Economics of the test insecticides

In order to assess the economics of test insecticides evaluated against *B. cucurbitae* infesting cucumber, the Incremental Cost Benefit Ratio (ICBR) was worked out. For this purpose, additional income and additional cost of treatment per hectare including labour expenditure along with cost of plant protection were calculated for each treatment based on prevailing market price of pesticides.

$$\text{Increased cost : benefit ratio (ICBR)} = \frac{\text{Net income (Rs/ha)}}{\text{Total cost of protection (Rs/ha)}}$$

3.3.2 Field evaluation of protein food baits against *B. cucurbitae* on cucumber

3.3.2.1 Experimental details

Place of research work : Experimental Farm of Department of Agril. Entomology,
PGI, MPKV, Rahuri

Treatments : 8

Replications : 3

Experimental design : Randomized Block Design

Crop : Cucumber

Spacing : 1 m x 0.5 m

The field experiment was conducted at fruiting phase of crop. The bio-efficacy of different combinations of baits, attractant and insecticide was determined during the *Kharif*, 2019 and 2021. Comparative efficacy and attractability of these bait combinations were evaluated in terms of male annihilation technique (MAT) of adult male flies from the location. Bait treatments consists of female food-lures, mixed with 1 ml of attractant (cue-lure) and 1 ml of toxicant (Malathion 50 EC). Cotton wicks were soaked in bait combinations and were suspended in the traps. The baited traps were installed in each of the plot of cucumber field at height of 1.5 metre above the ground level. Each treatment was replicated thrice. The impregnated cotton wicks were changed

at weekly intervals and the number of flies trapped or annihilated was checked at weekly intervals. The data pertaining to the efficacy of different treatments were analysed statistically. The bait combinations were used during entire course of investigations are given below.

Table 3.2. Distinct Baits Used against *B. cucurbitae*

No.	Treatment
T ₁	Soya Powder (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)
T ₂	Yeast Autolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)
T ₃	Jaggery (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)
T ₄	Protein Hydrolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)
T ₅	Molasses (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)
T ₆	Cue-lure (1 ml) + Malathion 50 EC (1 ml)
T ₇	Deltamethrin 2.8% EC (1 ml) + Jaggery Bait (15 g)
T ₈	Untreated check

Table 3.3 Details of Insecticides Used in the Bio-efficacy Experiment

Tr. No.	Common name	Formulation	Trade name	Chemical formula	Source
T ₁	Deltamethrin	2.8% EC	Decis	(S)- α -Cyano-3-phenoxybenzyl (1R)-cis-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropanecarboxylate	Bayer Crop Science Ltd.
T ₂	Spinosad	45% SC	Tracer	5-[(dimethylamino)-6-methyloxan-2-yl]oxy-19-ethyl-14-methyl-7-[(2R,3R,4R,5S,6S)-3,4,5-trimethoxy-6-methyloxan-2-yl]oxy-20-oxatetracyclo[10.10.0.0.02,10.05,9]docosa-3,11-diene-13,21-dione	Dow Agro Sciences Pvt. Ltd.
T ₃	Lambda-Cyhalothrin	5% EC	Karate	[R-cyano-(3-phenoxyphenyl)methyl] (1S,3S)-3-[(Z)-2-chloro-3,3,3-trifluoroprop-1-enyl]-2,2-dimethylcyclopropane-1-carboxylate	Syngenta India Pvt. Ltd.
T ₄	Emamectin benzoate	5% SG	Proclaim	Benzoic acid 65-85-0 Dracylic acid benzenecarboxylic acid Carboxybenzene	Syngenta India Pvt. Ltd.
T ₅	Lufenuron	5% EC	Lunox	1-[2,5-Dichloro-4-(1,1,2,3,3,3-hexafluoropropoxy)phenyl]-3-(2,6-difluorobenzoyl)urea	Crystal Crop Protection Ltd.
T ₆	Acephate	75% SP	Asataf	O,S-Dimethyl acetylphosphoramidothioate ₂	Rallis India Ltd.
T ₇	NSE	5%	-	-	Manually prepared
T ₈	Azadirachtin	10000 ppm	Econeem	-	M/s. Margo Bio Controls Pvt. Ltd., Bangalore
T ₉	<i>Metarrhizium anisopliae</i>	1 × 10 ⁸ CFU/gm	Phule <i>Metarhizium</i>	-	Biological Control Laboratory, MPKV, Rahuri

4. RESULTS AND DISCUSSION

The current research was carried out over the *Kharif*, 2019 and *Kharif*, 2021 seasons at the Experimental Farm and Ecofriendly Laboratory of the Department of Agricultural Entomology, PGI, MPKV, Rahuri (Maharashtra) on the “Population Dynamics, Biology, and Management of Fruit Fly, *Bactrocera cucurbitae* (Coquillett) infesting Cucurbitaceous Vegetable Crops”. The following headings are used to present the findings that were discovered throughout the entire investigation process.

4.1 Population Dynamics of Fruit fly, *B. cucurbitae*

Studies on population dynamics of *B. cucurbitae* were carried out by installing cue-lure pheromone traps in five crops *viz.*, cucumber, ridge gourd, bitter gourd, sponge gourd and bottle gourd. Population of the trapped flies were recorded at weekly interval initiating from 30th to 44th and 29th to 43th SMW of *Kharif*, 2019 and 2021, respectively. Layout of experiment is depicted separately.

4.1.1 Monitoring of Fruit fly, *B. cucurbitae*

The data on adult fruit flies captured with the cue-lure trap in all the five cucurbitaceous crops are depicted in Table 4.1 and 4.3 and illustrated in Fig 4.1.

The data revealed that during the entire course of investigations none of the species other than the test species were trapped therein in all the test crops. Messing (1999) pointed out that the cue-lure predominantly attracts *B. cucurbitae*, however the lure may also attracts other species however with lesser extent. Vargas *et al.* (2010), Thakur *et al.* (2010), Ganie *et al.* (2013), Maharjan *et al.* (2015) and Sawai *et al.* (2019) reported the extent of the test species trapped was principally more than other one or two species. The indications of numerical count on adults trapped per week in five crops under the investigations have been briefed as under.

In cucumber, the numerical population count recorded during *Kharif*-2019 was initiated (19 flies/trap) at 2nd week of August (32nd SMW) and was gradually increased (78 flies/trap) thereafter till 3rd week of September (38th SMW); the peak count (87 flies/trap) was observed during last week of August (35th SMW). During *Kharif*-2021, adult population was initiated at 31st SMW (3 flies/trap) and was at peak (96 flies/trap) at 35th SMW.

In ridge gourd, the numerical population count recorded during *Kharif*-2019 was initiated (39 flies/trap) at 2nd week of August (32nd SMW) and was gradually increased (73 flies/trap) till 3rd week of September (38th SMW); the peak count (91 flies/trap) was observed during last week of August (35th SMW). During *Kharif*-2021, adult population was initiated (9 flies/trap) at 31st SMW and was at peak (119 flies/trap) at 35th SMW.

In bitter gourd, the numerical population count recorded during *Kharif*-2019 was initiated (3 flies/trap) at 1st week of August (31st SMW) and was gradually increased (82 flies/trap) till 3rd week of September (38th SMW); the peak count (94 flies/trap) was observed during last week of August (35th SMW). During *Kharif*-2021, adult population was initiated (12 flies/trap) at 31st SMW and was at peak (145 flies/trap) at 35th SMW.

In sponge gourd, the numerical population count recorded during *Kharif*-2019 was initiated (2 flies/trap) at 1st week of August (31st SMW) and was gradually increased (62 flies/trap) till 3rd week of September (38th SMW); the peak count (98 flies/trap) was observed during last week of August (35th SMW). During *Kharif*-2021, adult population was initiated (10 flies/trap) at 31st SMW and was at peak (171 flies/trap) at 35th SMW.

In bottle gourd, the numerical population count recorded during *Kharif*-2019 was initiated (16 flies/trap) at 2nd week of August (32nd SMW) and was gradually increased (72 flies/trap) till 3rd week of September (38th SMW); the peak count (79 flies/trap) was observed during last week of August (35th SMW). During *Kharif*-2021, adult population was initiated (7 flies/trap) at 31st SMW and was at peak (139 flies/trap) at 1st week of October (40th SMW).

In all the five cucurbitaceous crops, the population was found to be active since initiation of flowering and prevailed till the fruiting phase. Amongst these crops, the numerical data pointed out that the preference of the flies was indicated as sponge gourd > bitter gourd > ridge gourd > cucumber > bottle gourd.

4.1.2 Extent of Damage Caused by Fruit fly, *B. cucurbitae*

Numerical count on fruit damage occurred in all the five cucurbitaceous crops were gathered during *Kharif*, 2019 and 2021 and are depicted in Table 4.1 and 4.3

Table 4.1 Population Fluctuations and Per cent Fruit Damage by *B. cucurbitae* in Cucurbitaceous Crops during *Kharif-2019*

SMW/Date	Cucumber		Ridge Gourd		Bitter Gourd		Sponge Gourd		Bottle Gourd	
	Adults / trap/week	Fruit damage	Adults / trap/week	Fruit damage	Adults / trap/week	Fruit damage	Adults / trap/week	Fruit damage	Adults / trap/week	Fruit damage
	Number	%	Number	%	Number	%	Number	%	Number	%
30 (23 Jul - 29 Jul)	0	0	0	0	0	0	0	0	0	0
31 (30 Jul - 05 Aug)	0	0	0	0	3	0	2	0	0	0
32 (06 Aug - 12 Aug)	19	0	39	0	32	0	42	0	16	0
33 (13 Aug - 19 Aug)	37	19.04	53	22.72	43	18.42	48	17.85	27	0
34 (20 Aug - 26 Aug)	62	28.12	84	32.50	75	29.26	76	31.70	64	15.00
35 (27 Aug - 02 Sept)	87	42.86	91	47.82	94	48.97	98	49.12	79	36.84
36 (03 Sept - 09 Sept)	71	31.91	68	32.69	71	33.96	62	35.48	56	31.81
37 (10 Sept - 16 Sept)	63	25.45	62	27.41	59	28.33	41	30.90	49	27.27
38 (17 Sept - 23 Sept)	78	35.41	73	36.84	82	35.08	62	34.42	72	35.08
39 (24 Sept - 30 Sept)	69	30.35	68	30.35	57	29.03	55	30.61	67	30.76
40 (01 Oct - 07 Oct)	62	27.86	37	24.59	49	25.00	41	27.77	56	26.31
41 (08 Oct - 14 Oct)	50	23.07	43	25.53	41	23.07	32	22.91	49	23.91
42 (15 Oct - 21 Oct)	31	18.18	36	21.42	34	17.50	28	20.00	38	19.51
43 (22 Oct - 28 Oct)	23	15.38	22	14.81	18	11.76	23	12.12	21	14.70
44 (29 Oct - 04 Nov)	17	12.50	17	6.66	12	9.09	13	8.69	16	11.53

Table 4.2 Correlation of Weather Parameters with Adult Fruit Fly Catches and Per cent Fruit Damage by *B. cucurbitae* in Cucurbitaceous Crops during *Kharif*-2019

Weather Parameters	Correlation Coefficient Value									
	Cucumber		Ridge Gourd		Bitter Gourd		Sponge Gourd		Bottle Gourd	
	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)
Maximum temperature (°C)	0.518*	0.517*	0.518*	0.520*	0.515*	0.533*	0.523*	0.524*	0.535*	0.303
Minimum temperature (°C)	-0.007	-0.141	0.060	-0.118	0.067	-0.047	0.127	-0.076	-0.139	-0.184
Morning relative humidity (%)	-0.452	-0.400	-0.595*	-0.482	-0.547*	-0.468	-0.591*	-0.474	-0.430	-0.144
Evening relative humidity (%)	-0.345	-0.356	-0.411	-0.373	-0.362	-0.362	-0.415	-0.361	-0.398	-0.129
Bright sunshine hours (Hrs)	0.341	0.430	0.394	0.436	0.335	0.378	0.400	0.368	0.414	0.139
Wind velocity (Km/hr)	-0.233	-0.369	0.039	-0.271	-0.026	-0.266	0.107	-0.276	-0.325	-0.550*
Rainfall (mm)	0.065	0.176	0.008	0.184	0.058	0.157	0.067	0.137	0.098	0.263
Number of rainy days	-0.099	0.003	-0.192	0.001	-0.130	-0.006	-0.150	-0.018	-0.062	0.146
Evapotranspiration (mm)	0.450	0.446	0.521*	0.448	0.491	0.448	0.518*	0.449	0.456	0.180

*5% level of significance df 13 = 0.514

**1% level of significance df 13 = 0.641

and illustrated in Fig 4.2. The extent of minimum and maximum fruit damage during *Kharif* season of 2019 for cucumber, ridge gourd, bitter gourd, sponge gourd and bottle gourd was found in the range of 12.50-42.86, 6.66-47.82, 9.09-48.97, 8.96-49.12 and 11.53-36.84 per cent, respectively. Extent of minimum and maximum fruit damage during *Kharif*, 2021 for cucumber, ridge gourd, bitter gourd, sponge gourd and bottle gourd was found in the range of 11.11-34.88, 9.52-37.20, 10.71-39.62, 13.63-40.38 and 19.23-37.77, respectively. The peak infestation was especially noticed at 35th SMW of both the years in all the test crops.

4.1.3 Effect of Weather Parameters on Adult Population of *B. cucurbitae*

Adult populations recorded at weekly intervals were correlated statistically with weather parameters and data are depicted in Table 4.2 and Table 4.4.

In cucumber, during *kharif*, 2019, correlation studies on adult population with maximum temperature ($r = 0.518$) showed significantly positive correlation; bright sunshine hours ($r = 0.341$), rainfall ($r = 0.065$) and evapotranspiration ($r = 0.450$) exhibited non-significant positive correlation and minimum temperature ($r = -0.007$), morning ($r = -0.452$) and evening ($r = -0.345$) relative humidity, wind velocity ($r = -0.233$) and number of rainy days ($r = -0.099$) indicated non-significant negative correlation. Whereas, during *kharif*, 2021, morning relative humidity ($r = 0.535$) had showed significantly positive correlation; evening relative humidity ($r = 0.253$), bright sunshine hours ($r = 0.123$), rainfall ($r = 0.460$) and number of rainy days ($r = 0.241$) showed non-significant positive correlation while, wind velocity ($r = -0.516$) showed significantly negative correlation and maximum ($r = -0.205$) and minimum temperature ($r = -0.094$) and evapotranspiration ($r = -0.077$) showed non-significant negative correlation.

In ridge gourd, during *kharif*, 2019, correlation studies on adult population with maximum temperature ($r = 0.518$) and evapotranspiration ($r = 0.521$) showed significantly positive correlation; minimum temperature ($r = 0.060$), bright sunshine hours ($r = 0.394$), wind velocity ($r = 0.039$) and rainfall ($r = 0.008$) showed non-significant positive correlation and morning relative humidity ($r = -0.595$) shows significant negative correlation while, evening relative humidity ($r = -0.411$) and number of rainy days ($r = -0.192$) showed non-significant negative correlation. Whereas during

kharif, 2021, morning relative humidity ($r = 0.693$) had showed significantly positive correlation; maximum temperature ($r = 0.045$), evening relative humidity ($r = 0.065$), bright sunshine hours ($r = 0.334$), rainfall ($r = 0.449$) and number of rainy days ($r = 0.168$) showed non-significant positive correlation and wind velocity ($r = -0.738$) showed significantly negative correlation while, minimum temperature ($r = -0.297$) and evapotranspiration ($r = -0.012$) showed non-significant negative correlation.

In bitter gourd, during *kharif*, 2019, correlation studies on adult population with maximum temperature ($r = 0.515$) showed significantly positive correlation; minimum temperature ($r = 0.067$), bright sunshine hours ($r = 0.335$), rainfall ($r = 0.058$) and evapotranspiration ($r = 0.491$) showed non-significant positive correlation and morning relative humidity ($r = -0.547$) showed significant negative correlation while, evening relative humidity ($r = -0.362$), wind velocity ($r = -0.026$) and number of rainy days ($r = -0.130$) showed non-significant negative correlation. Whereas, during *kharif*, 2021, morning relative humidity ($r = 0.521$) had showed significantly positive correlation; evening relative humidity ($r = 0.112$), bright sunshine hours ($r = 0.227$), rainfall ($r = 0.442$) and number of rainy days ($r = 0.137$) showed non-significant positive correlation and wind velocity ($r = -0.619$) showed significantly negative correlation while, maximum temperature ($r = -0.062$), minimum temperature ($r = -0.219$) and evapotranspiration ($r = 0.0002$) showed non-significant negative correlation.

In sponge gourd, during *kharif*, 2019, correlation studies on adult population with maximum temperature ($r = 0.523$) and evapotranspiration ($r = 0.518$) showed significantly positive correlation; minimum temperature ($r = 0.127$), bright sunshine hours ($r = 0.400$), wind velocity ($r = 0.107$) and rainfall ($r = 0.067$) showed non-significant positive correlation and morning relative humidity ($r = -0.591$) showed significant negative correlation while, evening relative humidity ($r = -0.415$) and number of rainy days ($r = -0.150$) showed non-significant negative correlation. Whereas, during *kharif*, 2021, morning relative humidity ($r = 0.524$) had showed significantly positive correlation; evening relative humidity ($r = 0.171$), bright sunshine hours ($r = 0.138$), rainfall ($r = 0.512$) and number of rainy days ($r = 0.176$) showed non-significant positive correlation and wind velocity ($r = -0.585$) showed significantly negative correlation

while, maximum temperature ($r = -0.159$), minimum temperature ($r = -0.179$) and evapotranspiration ($r = -0.118$) showed non-significant negative correlation.

In bottle gourd, during *kharif*, 2019, correlation studies on adult population with maximum temperature ($r = 0.535$) showed significantly positive correlation; bright sunshine hours ($r = 0.414$), rainfall ($r = 0.098$) and evapotranspiration ($r = 0.456$) showed non-significant positive correlation and minimum temperature ($r = -0.139$), morning ($r = -0.430$) and evening relative humidity ($r = -0.398$), wind velocity ($r = -0.325$) and number of rainy days ($r = -0.062$) showed non-significant negative correlation. Whereas, during *Kharif*, 2021, morning relative humidity ($r = 0.724$) had showed significantly positive correlation; maximum temperature ($r = 0.115$), evening relative humidity ($r = 0.145$), bright sunshine hours ($r = 0.282$), rainfall ($r = 0.392$) and number of rainy days ($r = 0.256$) showed non-significant positive correlation and wind velocity ($r = -0.662$) showed significantly negative correlation while, minimum temperature ($r = -0.175$) and evapotranspiration ($r = -0.019$) showed non-significant negative correlation.

4.1.4 Effect of Weather Parameters on Fruit Damage by *B. cucurbitae*

Per cent fruit damage recorded at weekly intervals were correlated statistically with weather parameters and data are depicted in Table 4.2 and Table 4.4.

In cucumber, during *Kharif*, 2019, correlation studies on per cent fruit damage with maximum temperature ($r = 0.517$) showed significantly positive correlation; bright sunshine hours ($r = 0.430$), rainfall ($r = 0.176$), number of rainy days ($r = 0.003$) and evapotranspiration ($r = 0.446$) exhibited non-significant positive correlation and minimum temperature ($r = -0.141$), morning ($r = -0.400$) and evening ($r = -0.356$) relative humidity and wind velocity ($r = -0.369$) indicated non-significant negative correlation. Whereas, during *Kharif*, 2021, morning relative humidity ($r = 0.664$) and rainfall ($r = 0.652$) had showed significantly positive correlation with; evening relative humidity ($r = 0.228$), bright sunshine hours ($r = 0.161$) and number of rainy days ($r = 0.337$) showed non-significant positive correlation while, wind velocity ($r = -0.569$) showed significantly negative correlation and maximum ($r = -0.053$) and minimum temperature ($r = -0.157$) and evapotranspiration ($r = -0.276$) showed non-significant negative correlation.

Table 4.3. Population Fluctuations and per cent Fruit Damage by *B. cucurbitae* in Cucurbitaceous Crops during *Kharif-2021*

SMW/Date	Cucumber		Ridge Gourd		Bitter Gourd		Sponge Gourd		Bottle Gourd	
	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)
29 (16 Jul - 22 Jul)	0	0	0	0	0	0	0	0	0	0
30 (23 Jul - 29 Jul)	0	0	0	0	0	0	0	0	0	0
31 (30 Jul - 05 Aug)	3	0	9	0	12	0	10	0	7	0
32 (06 Aug - 12 Aug)	14	11.11	27	0	29	0	23	0	13	0
33 (13 Aug - 19 Aug)	34	15.62	38	9.52	43	16.27	47	15.00	27	0
34 (20 Aug - 26 Aug)	67	20.75	92	18.75	78	22.44	109	27.65	59	21.42
35 (27 Aug - 02 Sept)	96	34.88	119	37.20	145	39.62	171	40.38	87	32.20
36 (03 Sept - 09 Sept)	11	27.77	38	27.41	26	31.91	44	32.75	21	28.57
37 (10 Sept - 16 Sept)	8	24.13	9	21.81	12	23.63	10	24.59	11	22.72
38 (17 Sept - 23 Sept)	14	17.74	49	17.64	37	18.96	32	21.42	68	18.75
39 (24 Sept - 30 Sept)	17	23.07	53	22.80	42	24.07	37	27.41	71	27.45
40 (01 Oct - 07 Oct)	59	26.56	102	29.50	78	29.16	69	35.84	139	37.77
41 (08 Oct - 14 Oct)	27	20.40	87	25.53	62	24.39	57	28.26	98	30.61
42 (15 Oct - 21 Oct)	15	13.33	66	18.91	47	19.44	46	20.51	63	23.68
43 (22 Oct - 28 Oct)	8	11.76	31	14.28	29	10.71	24	13.63	10	19.23

Table 4.4. Correlation of Weather Parameters with Adult Fruit Fly Catches and Per cent Fruit Damage by *B. cucurbitae* in Cucurbitaceous Crops during *Kharif*-2021

Weather Parameters	Correlation Coefficient Value									
	Cucumber		Ridge Gourd		Bitter Gourd		Sponge Gourd		Bottle Gourd	
	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)	Fruit fly catches/trap/week	Fruit damage (%)
Maximum temperature (°C)	-0.205	-0.053	0.045	0.086	-0.062	-0.068	-0.159	-0.024	0.115	0.284
Minimum temperature (°C)	-0.094	-0.157	-0.297	-0.295	-0.219	-0.221	-0.179	-0.259	-0.175	-0.372
Morning relative humidity (%)	0.535*	0.664**	0.693**	0.713**	0.521*	0.739**	0.524*	0.790**	0.724**	0.720**
Evening relative humidity (%)	0.253	0.228	0.065	0.085	0.112	0.197	0.171	0.178	0.145	-0.040
Bright sunshine hours (Hrs)	0.123	0.161	0.334	0.282	0.227	0.164	0.138	0.213	0.282	0.410
Wind velocity (Km/hr)	-0.516*	-0.569*	-0.738**	-0.613*	-0.619*	-0.585*	-0.564*	-0.626*	-0.662**	-0.627*
Rainfall (mm)	0.460	0.652**	0.449	0.617*	0.442	0.682**	0.512	0.664**	0.392	0.515*
Number of rainy days	0.241	0.337	0.168	0.261	0.137	0.355	0.176	0.358	0.256	0.189
Evapotranspiration (mm)	-0.077	-0.276	-0.012	-0.197	0.0002	-0.293	-0.118	-0.285	-0.019	-0.137

*5% level of significance df 13 = 0.514

**1% level of significance df 13 = 0.641

In ridge gourd, during *kharif*, 2019, correlation studies on per cent fruit damage with maximum temperature ($r = 0.520$) showed significantly positive correlation; bright sunshine hours ($r = 0.436$), rainfall ($r = 0.184$), number of rainy days ($r = 0.001$) and evapotranspiration ($r = 0.448$) showed non-significant positive correlation and minimum temperature ($r = -0.118$), morning and ($r = -0.482$) evening relative humidity ($r = -0.373$) and wind velocity ($r = -0.271$), showed non-significant negative correlation. Whereas during *kharif*, 2021, morning relative humidity ($r = 0.713$) and rainfall ($r = 0.617$) had showed significantly positive correlation; maximum temperature ($r = 0.086$), evening relative humidity ($r = 0.085$), bright sunshine hours ($r = 0.282$) and number of rainy days ($r = 0.261$) showed non-significant positive correlation and wind velocity ($r = -0.613$) showed significantly negative correlation with while, minimum temperature ($r = -0.295$) and evapotranspiration ($r = -0.197$) showed non-significant negative correlation.

In bitter gourd, during *kharif*, 2019, correlation studies on per cent fruit damage with maximum temperature ($r = 0.533$) showed significantly positive correlation; bright sunshine hours ($r = 0.378$), rainfall ($r = 0.157$) and evapotranspiration ($r = 0.448$) showed non-significant positive correlation and minimum temperature ($r = -0.047$), morning ($r = -0.468$) and evening ($r = -0.362$) relative humidity, wind velocity ($r = -0.266$) and number of rainy days ($r = -0.006$) showed non-significant negative correlation. Whereas, during *kharif*, 2021, morning relative humidity ($r = 0.739$) and rainfall ($r = 0.682$) had showed significantly positive correlation; evening relative humidity ($r = 0.197$), bright sunshine hours ($r = 0.164$) and number of rainy days ($r = 0.355$) showed non-significant positive correlation and wind velocity ($r = -0.585$) showed significantly negative correlation while, maximum ($r = -0.068$) and minimum temperature ($r = -0.221$) and evapotranspiration ($r = -0.293$) showed non-significant negative correlation.

In sponge gourd, during *kharif*, 2019, correlation studies on per cent fruit damage with maximum temperature ($r = 0.524$) showed significantly positive correlation; bright sunshine hours ($r = 0.368$), rainfall ($r = 0.137$) and evapotranspiration ($r = 0.449$) showed non-significant positive correlation and minimum temperature ($r = -0.076$), morning ($r = -0.474$) and evening ($r = -0.361$) relative humidity, wind velocity ($r = -0.276$) and number of rainy days ($r = -0.018$) showed non-significant negative

correlation. Whereas, during *kharif*, 2021, morning relative humidity ($r = 0.790$) and rainfall ($r = 0.664$) had showed significantly positive correlation; evening relative humidity ($r = 0.178$), bright sunshine hours ($r = 0.213$) and number of rainy days ($r = 0.358$) showed non-significant positive correlation and wind velocity ($r = -0.626$) showed significantly negative correlation while, maximum ($r = -0.024$) and minimum ($r = -0.259$) temperature and evapotranspiration ($r = -0.285$) showed non-significant negative correlation.

In bottle gourd, during *kharif*, 2019, correlation studies on per cent fruit damage with wind velocity ($r = -0.550$) showed significantly negative correlation; maximum temperature ($r = 0.303$), bright sunshine hours ($r = 0.139$), rainfall ($r = 0.263$), number of rainy days ($r = 0.146$) and evapotranspiration ($r = 0.180$) showed non-significant positive correlation and minimum temperature ($r = -0.184$), morning ($r = -0.144$) and evening ($r = -0.129$) relative humidity showed non-significant negative correlation. Whereas, during *kharif*, 2021, morning relative humidity ($r = 0.720$) and rainfall ($r = 0.515$) had showed significantly positive correlation; maximum temperature ($r = 0.284$), bright sunshine hours ($r = 0.410$) and number of rainy days ($r = 0.189$) showed non-significant positive correlation and wind velocity ($r = -0.627$) showed significantly negative correlation while, minimum temperature ($r = -0.372$), evening relative humidity ($r = -0.040$) and evapotranspiration ($r = -0.137$) showed non-significant negative correlation.

Under the present studies carried out during *kharif*, 2019 indicated that maximum temperature increased the pest population in all the five crops. High morning relative humidity comparatively reduced the activity of the pest in ridge gourd, bitter gourd and sponge gourd. These findings are in agreement with that reported by Laskar and Chatterjee (2010), Ghule *et al.* (2014), Dubale *et al.* (2018) and Nair and Pal (2020). More or less similar findings have been reported by Nehra *et al.* (2019a) and Barma and Jha (2011) in round gourd and pointed gourd, respectively.

The studies undertaken during *kharif*, 2021 indicated that morning relative humidity increased the pest activity while high wind velocity reduced the pest population in all the five crops. The present findings in respect of all the five cucurbitaceous crops are in confirmation with that reported by Nair and Pal (2020). Similar observations have

been reported by Maharjan *et al.* (2015) in cucurbit. Wazir *et al.* (2019) observed similar observations for morning relative humidity and rainfall in summer squash.

In all the five crops considering the overall impact of both the *kharif* seasons, the data in turn pointed out that maximum temperature and morning relative humidity favours more built-up of pest population and on the contrary high wind velocity reduces the pest population during August-October wherein the fruits are in ripening phase. Remaining six weather parameters did not exhibited any influential effect on pest population. More or less similar findings have been reported by Mwatawala *et al.* (2010), Sawai *et al.* (2019) and Nair and Pal (2020) in cucurbitaceous ecosystem.

4.2 Biology of Fruit Fly, *B. cucurbitae* on Cucumber

Present studies were carried out under laboratory conditions at Ecofriendly Laboratory, Post Graduate Institute, Rahuri during *kharif*, 2019 and 2021.

4.2.1 Duration of Distinct Life Stages of *B. cucurbitae* Reared on Cucumber

Distinct life stages of *B. cucurbitae* were studied during *kharif*, 2019 and 2021 wherein, in each of the experimental sets ten individuals of the concerned life stages were considered for the periodic observations. Data on distinct life stages are depicted in Table 4.5.

4.2.1.1 Incubation period

Incubation period was recorded in the range of 0.5 to 1 days for both the years and the cumulative mean was depicted to be 0.73 ± 0.17 day. The findings are in confirmation with that of Mukharjee *et al.* (2007), Mir *et al.* (2014), Gaddanakeri and Rolania (2020) and Pradhan *et al.* (2020) whereas, the period has been reported in the range of 1 to 3 days by Laskar (2013), Bhowmik *et al.* (2014a) and Patel and Patel (2018).

Hatching percentage was found in the range of 85.36 to 96.77 and 85.71 to 94.44 per cent during *Kharif*, 2019 and 2021, respectively with the cumulative mean 90.2 ± 3.00 per cent. The findings in respect of cumulative mean are in similar with that reported by Mir *et al.* (2014). Similar observations have also been recorded on pumpkin and bitter gourd as 89 and 86 per cent by Laskar (2013), respectively.

4.2.1.2 Larval (Maggot) period

The mean duration of first, second and third instar maggots was recorded as 1.4 ± 0.51 , 1.8 ± 0.63 and 3.6 ± 0.96 days for *kharif*-2019 and 1.6 ± 0.51 , 2.0 ± 0.66 and 3.9 ± 0.73 days during *Kharif*-2021, respectively; the cumulative mean for the consequent instars was depicted to be 1.5 ± 0.51 , 1.9 ± 0.64 and 3.75 ± 0.84 days, respectively. The average total larval period was observed as 6.8 ± 0.91 days (*kharif*-2019) and 7.6 ± 0.84 days (*kharif*-2021) with cumulative mean 7.2 ± 0.87 days.

In the present studies, total larval period was observed to be in the range of 5 to 9 days in respect of cucumber and the findings are in the similar lines with the results obtained by Mir *et al.* (2014). Larval period has been reported Laskar (2013), Patel and Patel (2018) and Gaddanakeri and Rolania (2020) to be 5 to 7 days reared on bitter gourd. Bhowmik *et al.* (2014a) and Patel and Patel (2018) reported the period as 5 to 6 days and 8 to 9 days reared on bottle gourd, respectively.

4.2.1.3 Pre-pupal stage

The pre-pupal period was observed in the range of 1 to 2 days on cucumber for both the years and the cumulative mean was depicted to be 1.45 ± 0.51 days. The finding on are in close agreement with that reported by Sharma *et al.* (2017). Similar observations have also been observed by Patel and Patel (2018) on bitter gourd, bottle gourd and watermelon.

4.2.1.4 Pupal stage

The pupal period was found in the range of 7 to 10 days on cucumber for both the years and the cumulative mean was depicted to be 8.05 ± 0.86 days. The findings are in more or less similar range that reported by Mir *et al.* (2014) and Sharma *et al.* (2017). Laskar (2013), Patel and Patel (2018) and Gaddanakeri and Rolania (2020) observed the pupal period as 6 to 8, 5 to 7 and 6 to 8 days, respectively on bitter gourd; Mukharjee *et al.* (2007) reported to be 7 to 9 days on sweet gourd.

4.2.1.5 Mating period

In the present laboratory studies, it was observed that mating generally occurs at evening (dusk). It was further noted that prior to mating as a copulatory behavior, female shakes its abdomen and signals the male to copulate. Simultaneously, male vibrates its wings and then climbs on back of female to copulate wherein, male uses

pro and meso-thoracic legs for holding on the female during the entire process. Similar observations have been recorded by Mir *et al.* (2014) and Sharma *et al.* (2017). Mating period was found to be in the range of 2 to 5 hours for both years with the cumulative mean 3.35 ± 1.00 hours. The period has been reported to be 4 hours whereas, contradictory observation (10.25 to 11.40 hours) has been reported by Vigneswaran *et al.* (2016).

4.2.1.6 Pre-ovipositional period

The pre-ovipositional period was found in the range of 9 to 15 days and 10 to 14 days in *kharif*, 2019 and 2021, respectively on cucumber with the cumulative mean of 12.4 ± 1.8 days. The findings are in close agreement with that of reported by Mukharjee *et al.* (2007), Mir *et al.* (2014), Vigneswaran *et al.* (2016) and Patel and Patel (2018) whereas, in contradiction with that reported by Dhillon *et al.* (2005) and Waseem *et al.* (2012) wherein the period was found to be >10 to 20 days especially during winter season.

4.2.1.7 Ovipositional period

The period was found in the range of 2 to 5 days for both the years and the cumulative mean was depicted as 3.45 ± 1.16 days. The observations recorded herein are in close agreement with that reported by Mir *et al.* (2014) and Patel and Patel (2018). The period was reported in sweet gourd and bitter gourd in the range of 5 to 14 and 10 to 14 days by Mukharjee *et al.* (2007) and Gaddanakeri and Rolania (2020), respectively.

4.2.1.8 Post-ovipositional period

The period was found in the range of 1 to 4 days for both the years with the cumulative mean as 2.7 ± 1.05 days. The findings are more or less in similar with that reported by Patel and Patel (2018) on bitter gourd, bottle gourd and watermelon.

4.2.1.9 Fecundity

The single female deposits its eggs in cluster under the rind of fruit with a slender pseudo ovipositor. The number of eggs deposited was found in the range of 54 to 83 and 57 to 88 eggs/female during *kharif*, 2019 and 2021, respectively with the cumulative mean 71.3 ± 9.7 eggs/female. The mean number of eggs deposited by a single female/cucumber fruit reported to be 75.8 and 57.08 by Mir *et al.* (2014) and Pradhan *et al.* (2020), respectively. Variation in the fecundity may be attributed to the environmental

factors such as temperature, relative humidity and diet. Mukharjee *et al.* (2007) and Gaddanakeri and Rolania (2020) found fecundity in the range of 36 to 74 and 80 to 108 eggs/female in sweet gourd and bitter gourd, respectively.

Table 4.5 Data on Distinct Life Stages of *B. cucurbitae*

Life stages	<i>Kharif-2019</i>		<i>Kharif-2021</i>		Cumulative Mean \pm SD
	Range	Mean \pm SD	Range	Mean \pm SD	
Incubation period (Days)					
	0.5 - 1	0.71 \pm 0.15	0.5 - 1	0.76 \pm 0.19	0.73 \pm 0.17
Hatching percentage (%)					
	85.36 - 96.77	90.80 \pm 3.24	85.71 - 94.44	89.60 \pm 2.76	90.2 \pm 3.00
Larval period (Days)					
First	1 - 2	1.4 \pm 0.51	1 - 2	1.6 \pm 0.51	1.5 \pm 0.51
Second	1 - 3	1.8 \pm 0.63	1 - 3	2.0 \pm 0.66	1.9 \pm 0.64
Third	2 - 5	3.6 \pm 0.96	3 - 5	3.9 \pm 0.73	3.75 \pm 0.84
Total	5 - 8	6.8 \pm 0.91	7 - 9	7.6 \pm 0.84	7.2 \pm 0.87
Pre-pupal period (Days)					
	1 - 2	1.4 \pm 0.51	1 - 2	1.5 \pm 0.52	1.45 \pm 0.51
Pupal period (Days)					
	7 - 9	7.8 \pm 0.78	7 - 10	8.3 \pm 0.94	8.05 \pm 0.86
Mating period (Hours)					
	2 - 5	3.4 \pm 0.96	2 - 5	3.3 \pm 1.05	3.35 \pm 1.00
Pre-ovipositional period (Days)					
	9 - 15	12.6 \pm 2.06	10 - 14	12.2 \pm 1.54	12.4 \pm 1.8
Ovipositional period (Days)					
	2 - 5	3.3 \pm 1.15	2 - 5	3.6 \pm 1.17	3.45 \pm 1.16
Post-ovipositional period (Days)					
	1 - 4	2.6 \pm 1.07	1 - 4	2.8 \pm 1.03	2.7 \pm 1.05
Fecundity / female					
	54 - 83	69.4 \pm 9.09	57 - 88	73.2 \pm 10.31	71.3 \pm 9.7
Adult longevity (Days)					
Male	9 - 16	12.6 \pm 2.63	12 - 20	14.2 \pm 2.97	13.4 \pm 2.8
Female	13 - 22	18.5 \pm 2.67	16 - 23	18.6 \pm 2.36	18.55 \pm 2.5
Sex ratio					
	<i>Kharif-2019</i>		<i>Kharif-2021</i>		Cumulative
	1.27 : 1		1.17 : 1		1.22:1
Total life cycle (Days)					
Male	22.5 - 36	29.21 \pm 5.12	27.5 - 42	32.36 \pm 5.46	30.78 \pm 5.29
Female	26.5 - 42	35.11 \pm 5.16	31.5 - 45	36.76 \pm 4.85	35.93 \pm 5.00

4.2.1.10 Adult longevity

Longevity of male and female fly was observed in the range of 9-16 and 12-20 and 13-22 and 16-23 days during *kharif*, 2019 and 2021, respectively. Cumulative mean for male and female fly was worked out to be 13.4 ± 2.8 and 18.55 ± 2.5 days, respectively. The findings in respect of both the sexes are in conformity with that reported by Mir *et al.* (2014) and Sharma *et al.* (2017). The longevity reported by the earlier workers Mukharjee *et al.* (2007), Manzar and Srivastava (2009) and Patel and Patel (2018) reported with little variation, may be attributed to environmental factors such as temperature, relative humidity and diet.

4.2.1.11 Sex ratio

Sex ratio (female: male) was found to be 1.27: 1 and 1.17: 1 during *kharif*, 2019 and 2021, respectively with cumulative mean 1.22:1. The findings are in agreement with that reported by Mir *et al.* (2014) and Pradhan *et al.* (2020). Similar observations have been reported by Laskar (2013), Bhowmik *et al.* (2014a) and Gaddanakeri and Rolania (2020) in other cucurbit hosts.

4.2.1.12 Duration of total life cycle of single generation

Duration contributed by single generation (period from oviposition to death of adult) was considered as completion of life cycle. Mean total period for completing the life cycle in male was found to be 29.21 ± 5.12 and 32.36 ± 5.46 days during *kharif*, 2019 and 2021, respectively with the cumulative mean 30.78 ± 5.29 days whereas, in female, it was observed to be 35.11 ± 5.16 and 36.76 ± 4.85 days during *kharif*, 2019 and 2021, respectively with the cumulative mean 35.93 ± 5.00 days. The literature reveals that there is paucity of information in respect of cucumber as host and hence not discussed herein apart from distinct host.

4.2.2 Morphological and Morphometrics of Distinct Life Stages

Data on distinct life stages are depicted in Table 4.6.

Morphological observations recorded in present studies reveals that;

- Freshly deposited egg was glistening white, slightly curved, elongated and tapering at one end while rounded at the other end.
- Larva (maggot) was acephalous apodous with three distinct instars; first, second and third instar was translucent-white, ellipsoidal-creamy white and yellowish-

white with pointed head, respectively. Prior to entering into pre-pupal / pupal stage, ceases feeding, tucks into air, by curving and tightly seizing posterior body end with the help of special oral hooks and their sudden release

- Pre-pupa was sluggish and creamy-yellowish. Pupa was cylindrical, brownish-yellow with 11 segments at posterior end with black dot and dark transverse line.
- The adult's coloration was reddish brown with lemon yellow curved vertical lines on the thorax and fuscous shadings on the outer wing border; the wing margin had a circular brownish marking at the apex and the posterior cross vein had grown apically to produce a sizable apical patch. The female fly was larger than the male and had a pointed ovipositor.

Morphometric observations recorded in the present studies revealed that;

- Cumulative mean length and breadth of the egg was 1.32 ± 0.15 and 0.28 ± 0.07 mm, respectively.
- Cumulative mean length and breadth of first instar maggot was 1.53 ± 0.23 and 0.29 ± 0.065 mm, respectively.
- Cumulative mean length and breadth of second instar maggot was 6.05 ± 0.92 and 1.24 ± 0.13 mm, respectively.
- Cumulative mean length and breadth of third instar maggot was 10.02 ± 0.88 and 2.16 ± 0.13 mm, respectively.
- Cumulative mean length and breadth of pre-pupa was 5.96 ± 0.16 and 2.08 ± 0.07 mm, respectively.
- Cumulative mean length and breadth of pupa was 5.12 ± 0.18 and 2.34 ± 0.10 mm, respectively.
- Cumulative mean length and breadth of male was 7.05 ± 0.18 and 13.05 ± 0.37 mm, respectively.
- Cumulative mean length and breadth of female was 8.71 ± 0.29 and 15.26 ± 0.39 mm, respectively.

Size, shape and colour of eggs, maggot, pre-pupa, pupa and adult recorded during the present studies are in conformity with that reported by Mukharjee *et al.* (2007), Laskar (2013), Mir *et al.* (2014), Bhowmik *et al.* (2014a), Das *et al.* (2017), Gaddanakeri and Rolania (2020) and Pradhan *et al.* (2020).

Table 4.6. Data on Morphometrics of *B. cucurbitae*

Stage	<i>Kharif-2019</i>		<i>Kharif-2021</i>		Cumulative Mean \pm SD
	Range	Mean \pm SD	Range	Mean \pm SD	
Egg stage					
Length (mm)	1.14 - 1.72	1.30 \pm 0.15	1.13 - 1.66	1.35 \pm 0.15	1.32 \pm 0.15
Breadth (mm)	0.21 - 0.44	0.27 \pm 0.06	0.18 - 0.43	0.30 \pm 0.08	0.28 \pm 0.07
Larval stage					
I instar					
Length (mm)	1.21 - 1.91	1.52 \pm 0.25	1.24 - 1.89	1.54 \pm 0.22	1.53 \pm 0.23
Breadth (mm)	0.21 - 0.42	0.29 \pm 0.07	0.20 - 0.35	0.29 \pm 0.06	0.29 \pm 0.065
II instar					
Length (mm)	4.62 - 7.13	6.10 \pm 0.86	4.53 - 7.18	6.00 \pm 0.98	6.05 \pm 0.92
Breadth (mm)	1.02 - 1.41	1.24 \pm 0.13	1.08 - 1.44	1.24 \pm 0.13	1.24 \pm 0.13
III instar					
Length (mm)	8.52 - 11.03	10.01 \pm 0.92	8.64 - 11.08	10.03 \pm 0.85	10.02 \pm 0.88
Breadth (mm)	1.95 - 2.37	2.14 \pm 0.15	1.98 - 2.34	2.18 \pm 0.12	2.16 \pm 0.13
Pre-pupal stage					
Length (mm)	5.71 - 6.17	5.96 \pm 0.13	5.68 - 6.21	5.94 \pm 0.19	5.96 \pm 0.16
Breadth (mm)	1.96 - 2.16	2.06 \pm 0.07	1.98 - 2.21	2.10 \pm 0.07	2.08 \pm 0.07
Pupal stage					
Length (mm)	4.79 - 5.36	5.11 \pm 0.18	4.84 - 5.42	5.14 \pm 0.18	5.12 \pm 0.18
Breadth (mm)	2.18 - 2.48	2.31 \pm 0.10	2.21 - 2.54	2.38 \pm 0.11	2.34 \pm 0.10
Adult stage					
Male (with expanded wings)					
Length (mm)	6.68 - 7.26	7.03 \pm 0.20	6.86 - 7.31	7.08 \pm 0.16	7.05 \pm 0.18
Breadth (mm)	12.33 - 13.61	13.03 \pm 0.37	12.52 - 13.64	13.07 \pm 0.38	13.05 \pm 0.37
Female (with expanded wings)					
Length (mm)	8.26 - 9.09	8.69 \pm 0.28	8.28 - 9.12	8.73 \pm 0.31	8.71 \pm 0.29
Breadth (mm)	14.67 - 15.96	15.26 \pm 0.38	14.65 - 15.84	15.27 \pm 0.40	15.26 \pm 0.39

4.3 Field Bio-efficacy of Test Insecticides against *B. cucurbitae* on Cucumber

Bio-efficacy of six synthetic, two biorational and one biological insecticides were evaluated under field conditions at experimental farm during *Kharif*, 2019 and 2021. In all three subsequent rounds of foliar applications at an interval of 10 days were given in each year, except in biological insecticide which was applied by ring method as soil application. The experimental set was also comprising of untreated check wherein only foliar water application was given. Besides, rest of the recommended package of the crop practices was followed. Pre-count and post-count observations on per

cent infested fruits were recorded with initiation of fruiting at an interval of 3, 7 and 10 days after spray (DAS) application. Data on per cent fruit infestation was subjected to arcsine transformation and thereafter statistically analyzed.

4.3.1 Field Bio-efficacy of Test Insecticides during *Kharif-2019*

In all three foliar applications were given. Observations on per cent fruit infestation was recorded in each of the replicate at 0, 3, 7 and 10 DAS under the studies and the data are presented in Table 4.7 and illustrated in Fig. 4.3.

Table 4.7 Bio-efficacy of Test Insecticides after First Spray (*Kharif-2019*)

Tr. No.	Treatments	Pre-count 0 DAS	Fruit Infestation (%)		
			3 DAS	7 DAS	10 DAS
T ₁	Deltamethrin 2.8% EC	49.77 (44.87)*	33.97 (35.65)	28.61 (32.34)	30.55 (33.55)
T ₂	Spinosad 45% SC	51.75 (46.00)	38.42 (38.30)	31.56 (34.18)	32.62 (34.83)
T ₃	Lambda-Cyhalothrin 2.5% EC	50.40 (45.23)	32.78 (34.93)	27.42 (31.58)	28.97 (32.56)
T ₄	Emamectin benzoate 5% SG	50.86 (45.49)	35.73 (36.71)	29.72 (33.04)	31.74 (34.29)
T ₅	Lufenuron 5% EC	51.49 (45.85)	46.63 (43.07)	40.65 (39.61)	42.06 (40.43)
T ₆	Acephate 75% SP	51.28 (45.73)	43.98 (41.54)	36.26 (37.02)	37.90 (38.00)
T ₇	NSE 5%	49.47 (44.70)	40.98 (39.80)	34.62 (36.04)	36.94 (37.43)
T ₈	Azadirachtin 10000 ppm	50.73 (45.42)	39.59 (38.99)	33.13 (35.14)	35.40 (36.51)
T ₉	<i>Metarrhizium anisopliae</i>	51.01 (45.58)	48.48 (44.13)	42.93 (40.94)	45.77 (42.57)
T ₁₀	Untreated check	51.43 (45.82)	53.86 (47.21)	54.85 (47.78)	57.57 (49.35)
	S.Em. ±	3.15	1.99	1.67	1.91
	CD at 5 %	9.37	5.93	4.97	5.69
	F test	NS	Sig.	Sig.	Sig.
	CV	12.01	8.64	7.88	8.75

*Figures in parenthesis are arcsine transformed values

DAS – Days After Spray

First foliar application

The first foliar application was given at fruit initiation phase of crop.

At 0 DAS

Statistical analysis of the data reveals that per cent fruit infestation was found to be non-significant in all the treatments, inclusive of the untreated check exhibiting the pre-treatment observations were found to be relatively homogenous and ranged from 49.47 to 51.75 per cent.

At 3 DAS

Highest per cent infestation was noticed in the untreated check (53.86%). Test insecticides were found to be statistically superior over the untreated check. Lowest infestation was noticed in Lambda-cyhalothrin (32.78%) which was on par with Deltamethrin (33.97%), Emamectin benzoate (34.92%) and Spinosad (38.42%). Next best treatments in the order of preference were Azadirachtin (39.59%), NSE (40.98%), Acephate (43.98%), Lufenuron (46.63%) and *M. anisopliae* (48.48%).

At 7 DAS

The Lambda-cyhalothrin (27.42%) was found to be most effective treatment and was found to be at par with Deltamethrin (28.61%), Emamectin benzoate (29.72%), Spinosad (31.56%), Azadirachtin (33.13%) and NSE (34.62%) in the order of preference. Acephate (36.26%), Lufenuron (40.65%) and *M. anisopliae* (42.93%) were the next best treatments which however were statistically on par.

At 10 DAS

Lambda-cyhalothrin (28.97%) was observed to be the most prominent which was found at par with Deltamethrin (30.55%), Emamectin benzoate (31.74%), Spinosad (32.62%), Azadirachtin (35.40%), NSE (36.94%) and Acephate (37.90%) in the order of preference. Next best treatments were Lufenuron (42.06%) and *M. anisopliae* (45.77%) which were at par with each other.

Second foliar application

The second foliar application was given at 12 days after first spray application.

Table 4.8 Bio-efficacy of Test Insecticides after Second Spray (Kharif-2019)

Tr. No.	Treatments	Fruit Infestation (%)		
		3 DAS	7 DAS	10 DAS
T ₁	Deltamethrin 2.8% EC	24.09 (29.39)*	21.26 (27.46)	21.80 (27.83)
T ₂	Spinosad 45% SC	26.67 (31.09)	22.41 (28.25)	24.07 (29.38)
T ₃	Lambda-Cyhalothrin 2.5% EC	22.56 (28.36)	18.84 (25.72)	19.44 (26.16)
T ₄	Emamectin benzoate 5% SG	25.12 (30.08)	21.43 (27.58)	21.67 (27.74)
T ₅	Lufenuron 5% EC	33.89 (35.60)	31.48 (34.13)	32.75 (34.91)
T ₆	Acephate 75% SP	32.22 (34.58)	30.55 (33.55)	32.62 (34.83)
T ₇	NSE 5%	30.46 (33.50)	27.61 (31.70)	28.53 (32.29)
T ₈	Azadirachtin 10000 ppm	28.80 (32.46)	26.67 (31.09)	26.95 (31.27)
T ₉	<i>Metarrhizium anisopliae</i>	36.31 (37.05)	34.34 (35.87)	36.94 (37.43)
T ₁₀	Untreated check	57.07 (49.06)	58.40 (49.84)	60.57 (51.10)
	S.Em. ±	1.81	1.93	1.77
	CD at 5 %	5.38	5.76	5.25
	F test	Sig.	Sig.	Sig.
	CV	9.21	10.36	9.22

*Figures in parenthesis are arcsine transformed values

DAS – Days After Spray

At 3 DAS

Highest per cent infestation was noticed in the untreated check (57.07%) which was statistically inferior to the remaining test insecticides. The lowest infestation was noticed in lambda-cyhalothrin (22.56%) which was on par with Deltamethrin (24.09%), Emamectin benzoate (25.12%), Spinosad (26.67%), Azadirachtin (28.80%) and NSE (30.46%). Next best treatments in the order of preference were Acephate (32.22%), Lufenuron (33.89%) and *M. anisopliae* (36.31%).

At 7 DAS

Lambda-cyhalothrin (18.84%) was found to be most promising treatment which was found on par with Deltamethrin (21.26%), Emamectin benzoate (21.43%), Spinosad (22.41%) and Azadirachtin (26.67%) in the order of preference. NSE (27.61%), Acephate (30.55%), Lufenuron (31.48%) and *M. anisopliae* (34.34%) were the next best treatments which however were statistically on par.

At 10 DAS

Lambda-cyhalothrin (19.44%) was observed to be the most efficient treatment which was found at par with Deltamethrin (21.80%), Emamectin benzoate (21.67%), Spinosad (24.07%) and Azadirachtin (26.95%). Next best treatments in the order of preference were NSE (28.53%), Acephate (32.62%), Lufenuron (32.75%) and *M. anisopliae* (36.94%) which were on par.

Third foliar application

Third foliar application was given at 12 days after second spray application.

At 3 DAS

Maximum per cent infestation was recorded in the untreated check (60.90%). The remaining test insecticides were statistically superior to untreated check. Lowest infestation was recorded in lambda-cyhalothrin (15.50%) which was on par with Deltamethrin (16.89%), Emamectin benzoate (17.92%), Spinosad (19.63%) and Azadirachtin (22.69%). In the order of preference, next best treatments were NSE (23.72%), Acephate (26.67%), Lufenuron (28.61%) and *M. anisopliae* (33.23%) which were on par with each other except the *M. anisopliae*.

At 7 DAS

Lambda-cyhalothrin (14.99%) was observed to be the best treatment which was found on par with Deltamethrin (16.80%), Emamectin benzoate (18.59%) and Spinosad (20.56%) in the order of preference. Azadirachtin (23.43%), NSE (24.19%), Acephate (27.78%), Lufenuron (29.44%) and *M. anisopliae* (34.62%) were found statistically on par.

At 10 DAS

Lambda-cyhalothrin (16.34%) was found to be the most effective treatment which was found at par with Deltamethrin (17.73%), Emamectin benzoate (19.91%), Spinosad (21.43%). Next best treatments in the order of preference were Azadirachtin (24.07%), NSE (26.85%), Acephate (30.16%), Lufenuron (32.78%) and *M. anisopliae* (36.84%) which were at par with each other.

Table 4.9 Bio-efficacy of Test Insecticides after Third Spray (Kharif-2019)

Tr. No.	Treatments	Fruit Infestation (%)		
		3 DAS	7 DAS	10 DAS
T ₁	Deltamethrin 2.8% EC	16.89 (24.27)*	16.80 (24.20)	17.73 (24.90)
T ₂	Spinosad 45% SC	19.63 (26.30)	20.56 (26.96)	21.43 (27.58)
T ₃	Lambda-Cyhalothrin 2.5% EC	15.60 (23.26)	14.99 (22.78)	16.34 (23.84)
T ₄	Emamectin benzoate 5% SG	17.92 (25.04)	18.59 (25.54)	19.91 (26.50)
T ₅	Lufenuron 5% EC	28.61 (32.34)	29.44 (32.86)	32.78 (34.93)
T ₆	Acephate 75% SP	26.67 (31.09)	27.78 (31.81)	30.16 (33.31)
T ₇	NSE 5%	23.72 (29.15)	24.19 (29.46)	26.85 (31.21)
T ₈	Azadirachtin 10000 ppm	22.69 (28.45)	23.43 (28.95)	24.07 (30.00)
T ₉	<i>Metarrhizium anisopliae</i>	33.23 (35.20)	34.62 (36.04)	36.84 (37.37)
T ₁₀	Untreated check	60.90 (51.30)	62.48 (52.23)	65.28 (53.90)
	S.Em. ±	1.79	1.68	1.95
	CD at 5 %	5.31	5.00	5.79
	F test	Sig.	Sig.	Sig.
	CV	10.13	9.40	10.49

*Figures in parenthesis are arcsine transformed values

DAS – Days After Spray

4.3.1.1 Overall bio-efficacy of test insecticides during *Kharif-2019*

The data have been presented in Table 4.10 and Fig. 4.6 wherein, the trend of the results projected for each of the observational dates is given below.

At 3 DAS

Lambda-cyhalothrin (23.65%) was found to be the most promising which was on par with Deltamethrin (24.98%), Emamectin benzoate (26.26%) and Spinosad (28.24%) followed by Azadirachtin (30.36%), NSE (31.72%), Acephate (34.29%), Lufenuron (36.38%) and *M. anisopliae* (39.34%) in descending order of efficacy.

Table 4.10 Overall Bio-efficacy of Test Insecticides during *Kharif-2019*

Tr. No.	Treatments	Fruit Infestation (%)		
		3 DAS	7 DAS	10 DAS
T ₁	Deltamethrin 2.8% EC	24.98 (29.99)	22.22 (28.12)	23.36 (28.9)
T ₂	Spinosad 45% SC	28.24 (32.1)	24.84 (29.89)	26.04 (30.68)
T ₃	Lambda-Cyhalothrin 2.5% EC	23.65 (29.1)	20.42 (26.86)	21.58 (27.68)
T ₄	Emamectin benzoate 5% SG	26.26 (30.83)	23.25 (28.83)	24.44 (29.63)
T ₅	Lufenuron 5% EC	36.38 (37.1)	33.86 (35.58)	35.86 (36.79)
T ₆	Acephate 75% SP	34.29 (35.84)	31.53 (34.16)	33.56 (35.4)
T ₇	NSE 5%	31.72 (34.28)	28.81 (32.46)	30.77 (33.69)
T ₈	Azadirachtin 10000 ppm	30.36 (33.44)	27.74 (31.78)	28.81 (32.46)
T ₉	<i>Metarrhizium anisopliae</i>	39.34 (38.85)	37.30 (37.64)	39.85 (39.14)
T ₁₀	Untreated check	57.28 (49.19)	58.58 (49.94)	61.14 (51.44)
	S.Em. ±	1.41	1.11	1.13
	CD at 5 %	4.19	3.31	3.38
	F test	Sig.	Sig.	Sig.
	CV	7.00	5.77	5.71

*Figures in parenthesis are arcsine transformed values

DAS – Days After Spray

At 7 DAS

Lambda-cyhalothrin (20.42%) continued to be most promising and was on par with Deltamethrin (22.22%), Emamectin benzoate (23.25%) and Spinosad (24.84%) followed by Azadirachtin (27.74%), NSE (28.81%) and Acephate (31.53%) which were on par followed by Lufenuron (33.86%) and *M. anisopliae* (37.30%) which were at par with each other.

At 10 DAS

Lambda-cyhalothrin (21.58%) continued to be most prominent which was on par with Deltamethrin (23.36%), Emamectin benzoate (24.44%) and Spinosad (26.04%) followed by Azadirachtin (28.81%), NSE (30.77%) and Acephate (33.56%) which were at par with each other followed by Lufenuron (35.86%) followed by *M. anisopliae* (39.85%).

On the basis of observations recorded at 3, 7 and 10 DAS, the overall field bio-efficacy exhibited during *Kharif-2019* reflects in descending order as Lambda-cyhalothrin, Deltamethrin, Emamectin benzoate and Spinosad followed by Azadirachtin, NSE and Acephate followed by Lufenuron followed by *M. anisopliae*.

4.3.2 Field Bio-efficacy of Test Insecticides during *Kharif-2021*

In all three foliar applications were given. Observations on per cent fruit infestation was recorded in each of the replicate at 0, 3, 7 and 10 DAS under the studies and the data are presented in Table 4.11 and illustrated in Fig. 4.7.

First foliar application

The first foliar application was given at fruit initiation phase of crop.

At 0 DAS

Data reveals that infestation in fruits was found to be non-significant in all test treatments, inclusive untreated check and ranged from 43.39 to 47.62 per cent indicating pre-treatment observations were statistically homogenous.

At 3 DAS

Highest infestation of fruits was recorded in the untreated check (48.15%). Test insecticides were found to be significantly effective over untreated check. Lowest infestation was observed in Lambda-cyhalothrin (29.43%) which was on par with Deltamethrin (31.74%), Emamectin benzoate (33.13%) and Spinosad (33.73%),

Azadirachtin (35.45%), NSE (36.83%), Acephate (37.90%) and Lufenuron (38.33%) followed by *M. anisopliae* (40.28%).

Table 4.11 Bio-efficacy of Test Insecticides after First Spray (Kharif-2021)

Tr. No.	Treatments	Pre-count 0 DAS	Fruit Infestation (%)		
			3 DAS	7 DAS	10 DAS
T ₁	Deltamethrin 2.8% EC	43.98 (41.54)*	31.74 (34.29)	24.83 (29.89)	25.26 (30.17)
T ₂	Spinosad 45% SC	45.77 (42.57)	33.73 (35.51)	26.11 (30.73)	26.85 (31.21)
T ₃	Lambda-Cyhalothrin 2.5% EC	43.45 (41.24)	29.43 (32.85)	23.60 (29.06)	24.07 (29.38)
T ₄	Emamectin benzoate 5% SG	46.82 (43.18)	33.13 (35.14)	25.74 (30.49)	26.19 (30.78)
T ₅	Lufenuron 5% EC	47.62 (43.64)	38.33 (38.25)	33.61 (35.43)	33.97 (35.65)
T ₆	Acephate 75% SP	44.29 (41.72)	37.90 (38.00)	32.22 (34.58)	32.80 (34.94)
T ₇	NSE 5%	43.39 (41.20)	36.83 (37.36)	29.72 (33.04)	30.55 (33.55)
T ₈	Azadirachtin 10000 ppm	45.31 (42.31)	35.45 (36.54)	28.97 (32.56)	29.44 (32.86)
T ₉	<i>Metarrhizium anisopliae</i>	46.36 (42.91)	40.28 (39.40)	35.73 (36.71)	34.92 (36.22)
T ₁₀	Untreated check	45.77 (42.57)	48.15 (43.94)	50.34 (45.19)	53.70 (47.12)
	S.Em. ±	2.11	1.92	1.52	1.76
	CD at 5 %	6.28	5.72	4.54	5.23
	F test	NS	Sig.	Sig.	Sig.
	CV	8.66	9.00	7.85	8.94

*Figures in parenthesis are arcsine transformed values

DAS – Days After Spray

At 7 DAS

In the order of preference, Lambda-cyhalothrin (23.60%) was found to be most efficient treatment and was on par with Deltamethrin (24.83%), Emamectin benzoate (25.74%), Spinosad (26.11%), Azadirachtin (28.97%) and NSE (29.72%). Acephate (32.22%), Lufenuron (33.61%) and *M. anisopliae* (35.73%) were the next best treatments which however were statistically at par with each other.

At 10 DAS

Lambda-cyhalothrin (24.07%) was found to be the most effective which was found on par with Deltamethrin (25.26%), Emamectin benzoate (26.19%), Spinosad (26.85%), Azadirachtin (29.44%) and NSE (30.55%). Next best treatments were Acephate (32.80%), Lufenuron (33.97%) and *M. anisopliae* (34.92%) which were on par with each other.

Second foliar application

The second foliar application was given at 12 days after first spray application.

At 3 DAS

Maximum per cent infestation was observed in untreated check (53.37%) which was significantly lower in comparison with the remaining test insecticides. Minimum infestation was recorded in lambda-cyhalothrin (20.13%) and was on par with Deltamethrin (21.06%), Emamectin benzoate (22.41%), Spinosad (24.83%) and Azadirachtin (26.50%). In the descending order of efficacy, next best treatments were NSE (27.86%), Acephate (29.53%), Lufenuron (29.91%) and *M. anisopliae* (33.23%).

At 7 DAS

Lambda-cyhalothrin (16.34%) was found to be more efficient which however was on par with Deltamethrin (21.26%), Emamectin benzoate (19.58%), Spinosad (20.56%), Azadirachtin (22.41%) and NSE (23.10%) were found at par with each other followed by Acephate (24.07%), Lufenuron (25.74%) and *M. anisopliae* (28.53%) and were on par.

At 10 DAS

Lambda-cyhalothrin (16.99%) continued to be the most promising treatment which was on par with Deltamethrin (19.91%), Emamectin benzoate (21.30%), Spinosad (22.41%) and Azadirachtin (23.61%). Next best treatments in the descending order of effectiveness were NSE (23.93%), Acephate (24.67%), Lufenuron (26.85%) and *M. anisopliae* (28.97%) and were at par with each other.

Table 4.12. Bio-efficacy of Test Insecticides after Second Spray (Kharif-2021)

Tr. No.	Treatments	Fruit Infestation (%)		
		3 DAS	7 DAS	10 DAS
T ₁	Deltamethrin 2.8% EC	21.06 (27.32)*	18.24 (25.28)	19.91 (26.50)
T ₂	Spinosad 45% SC	24.83 (29.89)	20.56 (26.96)	22.41 (28.25)
T ₃	Lambda-Cyhalothrin 2.5% EC	20.13 (26.66)	16.34 (23.84)	16.99 (24.34)
T ₄	Emamectin benzoate 5% SG	22.41 (28.25)	19.58 (26.26)	21.30 (27.49)
T ₅	Lufenuron 5% EC	29.91 (33.15)	25.74 (30.49)	26.85 (31.21)
T ₆	Acephate 75% SP	29.53 (32.92)	24.07 (29.38)	24.67 (29.78)
T ₇	NSE 5%	27.86 (31.86)	23.10 (28.73)	23.93 (29.29)
T ₈	Azadirachtin 10000 ppm	26.50 (30.98)	22.41 (28.25)	23.61 (29.07)
T ₉	<i>Metarrhizium anisopliae</i>	33.23 (35.20)	28.53 (32.29)	28.97 (32.56)
T ₁₀	Untreated check	53.37 (46.93)	56.70 (48.85)	59.35 (50.39)
	S.Em. ±	1.63	1.85	1.66
	CD at 5 %	4.86	5.50	4.96
	F test	Sig.	Sig.	Sig.
	CV	8.79	10.72	9.41

*Figures in parenthesis are arcsine transformed values

DAS – Days After Spray

Third foliar application

Third foliar application was given at 12 days after second spray application.

At 3 DAS

Highest per cent infestation was recorded in the untreated check (60.57%). The remaining test insecticides were significantly superior over untreated check. Lowest infestation was found in Lambda-cyhalothrin (15.13%) and was on par with Deltamethrin (16.96%), Emamectin benzoate (18.24%), Spinosad (20.66%), Azadirachtin (21.26%)

and NSE (22.41%). Statistically next best treatments were, Acephate (24.07%), Lufenuron (24.83%) and *M. anisopliae* (26.11%) which were at par with each other.

Table 4.13 Bio-efficacy of Test Insecticides after Third Spray (Kharif-2021)

Tr. No.	Treatments	Fruit Infestation (%)		
		3 DAS	7 DAS	10 DAS
T ₁	Deltamethrin 2.8% EC	16.96 (24.32)*	12.63 (20.82)	14.02 (21.99)
T ₂	Spinosad 45% SC	20.66 (27.03)	17.63 (24.83)	18.52 (25.49)
T ₃	Lambda-Cyhalothrin 2.5% EC	15.13 (22.89)	12.04 (20.30)	13.43 (21.50)
T ₄	Emamectin benzoate 5% SG	18.24 (25.28)	14.54 (22.42)	16.93 (24.30)
T ₅	Lufenuron 5% EC	24.83 (29.89)	25.74 (30.49)	26.85 (31.21)
T ₆	Acephate 75% SP	24.07 (29.38)	25.26 (30.17)	26.11 (30.73)
T ₇	NSE 5%	22.41 (28.25)	23.48 (28.98)	24.07 (29.38)
T ₈	Azadirachtin 10000 ppm	21.26 (27.46)	21.80 (27.83)	22.68 (28.44)
T ₉	<i>Metarrhizium anisopliae</i>	26.11 (30.73)	28.53 (32.29)	30.55 (33.55)
T ₁₀	Untreated check	60.57 (51.10)	62.05 (51.97)	66.39 (54.57)
	S.Em. ±	1.86	1.56	2.05
	CD at 5 %	5.55	4.65	6.09
	F test	Sig.	Sig.	Sig.
	CV	10.97	9.37	11.83

*Figures in parenthesis are arcsine transformed values

DAS – Days After Spray

At 7 DAS

Lambda-cyhalothrin (12.04%) continued to be the best treatment which was found on par with Deltamethrin (12.63%), Emamectin benzoate (14.54%) and Spinosad (17.63%) followed by Azadirachtin (21.80%) and NSE (23.48%) followed by Acephate (25.26%), Lufenuron (25.74%) and *M. anisopliae* (24.83%) which were at par with each other.

At 10 DAS

Lambda-cyhalothrin (13.43%) was found to be the most promising and was recorded on par with Deltamethrin (14.02%), Emamectin benzoate (16.93%) and Spinosad (18.52%) followed by Azadirachtin (22.68%), NSE (24.07%), Acephate (26.11%), Lufenuron (26.85%) and *M. anisopliae* (27.78%) which were at par with each other.

4.3.2.1 Overall bio-efficacy of test insecticides during *Kharif-2021*

The data have been presented in Table 4.14 and Fig. 4.10 wherein, the trend of the results projected for each of the observational dates is given below.

At 3 DAS

Lambda-cyhalothrin (21.56%) was found to be prominent treatment and was on par with Deltamethrin (23.25%), Emamectin benzoate (24.59%), Spinosad (26.41%) and Azadirachtin (27.74%) followed by NSE (29.03%), Acephate (30.50%), Lufenuron (31.02%) and *M. anisopliae* (33.21%) in the descending order.

At 7 DAS

Lambda-cyhalothrin (17.33%) continued to be most promising which was on par with Deltamethrin (18.57%), Emamectin benzoate (19.95%) and Spinosad (21.43%) followed by Azadirachtin (24.39%), NSE (25.43%) and Acephate (27.18%) which were at par with each other followed by Lufenuron (28.36%) and *M. anisopliae* (30.93%) which were statistically in similar range.

At 10 DAS

Lambda-cyhalothrin (18.16%) continued to be most prominent which was on par with Deltamethrin (19.73%), Emamectin benzoate (21.47%) and Spinosad (22.59%) followed by Azadirachtin (25.24%), NSE (26.18%), Acephate (27.86%), Lufenuron (29.22%) and *M. anisopliae* (31.48%) which were at par with each other.

On the basis of observations recorded at 3, 7 and 10 DAS, the overall field bio-efficacy exhibited during *Kharif-2021* reflects in descending order as Lambda-cyhalothrin, Deltamethrin, Emamectin benzoate and Spinosad followed by Azadirachtin, NSE, Acephate and Lufenuron followed by *M. anisopliae*.

Table 4.14. Overall Bio-efficacy of Test Insecticides during *Kharif-2021*

Tr. No.	Treatments	Fruit Infestation (%)		
		3 DAS	7 DAS	10 DAS
T ₁	Deltamethrin 2.8% EC	23.25 (28.83)*	18.57 (25.53)	19.73 (26.37)
T ₂	Spinosad 45% SC	26.41 (30.92)	21.43 (27.58)	22.59 (28.38)
T ₃	Lambda-Cyhalothrin 2.5% EC	21.56 (27.67)	17.33 (24.60)	18.16 (25.22)
T ₄	Emamectin benzoate 5% SG	24.59 (29.73)	19.95 (26.53)	21.47 (27.60)
T ₅	Lufenuron 5% EC	31.02 (33.85)	28.36 (32.18)	29.22 (32.72)
T ₆	Acephate 75% SP	30.50 (33.52)	27.18 (31.42)	27.86 (31.86)
T ₇	NSE 5%	29.03 (32.60)	25.43 (30.28)	26.18 (30.77)
T ₈	Azadirachtin 10000 ppm	27.74 (31.78)	24.39 (29.59)	25.24 (30.16)
T ₉	<i>Metarrhizium anisopliae</i>	33.21 (35.19)	30.93 (33.79)	31.48 (34.13)
T ₁₀	Untreated check	54.03 (47.31)	56.36 (48.65)	59.81 (50.66)
	S.Em. ±	1.51	1.35	1.33
	CD at 5 %	4.49	4.01	3.96
	F test	Sig.	Sig.	Sig.
	CV	7.92	7.55	7.27

*Figures in parenthesis are arcsine transformed values

DAS – Days After Spray

4.3.3 Cumulative Bio-efficacy of Test Insecticides during *Kharif-2019* and **2021**

Data on cumulative performance of test insecticides are presented in Table 4.15 and illustrated in Fig. 4.1.

At 3 DAS

Lambda-cyhalothrin (22.61%) was observed to be predominant treatment and was on par with Deltamethrin (24.12%), Emamectin benzoate (25.43%), Spinosad

(27.33%) and Azadirachtin (29.05%) followed by NSE (30.38%), Acephate (32.40%), Lufenuron (33.70%) and *M. anisopliae* (36.27%).

Table 4.15. Cumulative Bio-efficacy of Test Insecticides during *Kharif*-2019 and 2021

Tr. No.	Treatments	Pooled Mean on Fruit Infestation (%)		
		3 DAS	7 DAS	10 DAS
T ₁	Deltamethrin 2.8% EC	24.12 (29.41)*	20.40 (26.85)	21.55 (27.66)
T ₂	Spinosad 45% SC	27.33 (31.52)	23.14 (28.75)	24.32 (29.55)
T ₃	Lambda-Cyhalothrin 2.5% EC	22.61 (28.39)	18.87 (25.75)	19.88 (26.48)
T ₄	Emamectin benzoate 5% SG	25.43 (30.28)	21.60 (27.69)	22.96 (28.63)
T ₅	Lufenuron 5% EC	33.70 (35.49)	31.11 (33.9)	32.55 (34.79)
T ₆	Acephate 75% SP	32.40 (34.7)	29.36 (32.81)	30.71 (33.65)
T ₇	NSE 5%	30.38 (33.45)	27.12 (31.38)	28.48 (32.25)
T ₈	Azadirachtin 10000 ppm	29.05 (32.61)	26.07 (30.70)	27.03 (31.33)
T ₉	<i>Metarrhizium anisopliae</i>	36.27 (37.03)	34.11 (35.74)	35.67 (36.67)
T ₁₀	Untreated check	55.56 (48.19)	57.47 (49.30)	60.40 (51.00)
	S.Em. ±	1.44	1.20	1.21
	CD at 5 %	4.28	3.58	3.59
	F test	Sig.	Sig.	Sig.
	CV	7.35	6.49	6.32

*Figures in parenthesis are arcsine transformed values

DAS – Days After Spray

At 7 DAS

Lambda-cyhalothrin (18.87%) continued to be most promising which was on par with Deltamethrin (20.40%), Emamectin benzoate (21.60%) and Spinosad (23.14%) followed by Azadirachtin (26.07%), NSE (27.12%) and Acephate (29.36%)

followed by Lufenuron (31.11%) and *Metarrhizium anisopliae* (33.50%) which were at par with each other except *M. anisopliae*.

At 10 DAS

Supremacy of Lambda-cyhalothrin (19.88%) was continued which was on par with Deltamethrin (21.55%), Emamectin benzoate (22.96%) and Spinosad (24.32%) followed by Azadirachtin (27.03%), NSE (28.48%), Acephate (30.71%), Lufenuron (32.55%) and *M. anisopliae* (35.22%).

The statistical analysis pointed out that amongst test insecticides, the field bio-efficacy in the descending order was as Lambda-cyhalothrin, Deltamethrin, Emamectin benzoate and Spinosad > Azadirachtin, NSE, Acephate, Lufenuron > *Metarrhizium anisopliae*.

In the present studies carried out on cucumber, Lambda-cyhalothrin, Deltamethrin, Emamectin benzoate and Spinosad in the order of preference were found promising treatments. The findings in respect of Lambda-cyhalothrin are in agreement with that reported by Oke (2008), Balas *et al.* (2018) and Sharma and Gupta (2019). In respect of Deltamethrin, the findings are in confirmation with that reported by Oke and Sinon (2013). In respect of Emamectin benzoate, the findings are in corroboration with that reported by Shinde *et al.* (2018b) and Sharma and Gupta (2019). In respect of Spinosad, the findings are in confirmation with that reported by Shivangi *et al.* (2017) and Shinde *et al.* (2018b). Findings in respect of Azadirachtin and NSE are in confirmation with that reported by Shivangi *et al.* (2017). Sawai *et al.* (2014) advocated deltamethrin, emamectin benzoate and azadirachtin on ridge gourd. Bharadiya and Bhut (2017) recommended emamectin benzoate on the sponge gourd. Bhowmik *et al.* (2014b) and Bhowmik *et al.* (2014c) advocated Deltamethrin and Spinosad on bitter gourd and pointed gourd, respectively. Nehra *et al.* (2019) recommended Spinosad on round gourd. Gautam *et al.* (2021) advocated Spinosad and Lambda-cyhalothrin on bottle gourd. Spinosad recommended by Meena *et al.* (2022) on bottle gourd.

4.4 Evaluation of Distinct Baits in Attracting *B. cucurbitae* Flies during *Kharif-2019* and 2021

Field experiments were undertaken in cucumber during *Kharif-2019* and 2021 to evaluate seven combinations of protein food baits along with the untreated check. Observations on weekly catches of number of flies trapped were recorded initiating from 34th to 41st SMW and the data were statistically analyzed and data are presented in Table 4.20.

Total number of flies trapped in between 34th to 41st SMW during both the years were considered to judge the efficacy of test treatments. Data reveals that lowest number of flies were caught in the trap with in the untreated check (24.00) and rest of the test treatments were found significantly superior over it. Efficacy was indicated as Molasses plus Cue-lure plus Malathion (460.00) followed by Cue-lure plus Malathion (391.00) followed by Protein Hydrolysate plus Cue-lure plus Malathion (322.67) followed by Jaggery plus Cue-lure plus Malathion (234.00) followed by Yeast Autolysate plus Cue-lure plus Malathion (195.33) followed by Soya Powder plus Cue-lure plus Malathion (152.00) followed by Deltamethrin plus Malathion (78.67).

Data presented in Table 4.21 on mean percentage flies trapped during both the years from 34th to 41st SMW in distinct combination of protein food baits numerically indicated that higher percentage of flies were trapped in Molasses plus Cue-lure plus Malathion (24.85%), Cue-lure plus Malathion (20.94%) and Protein Hydrolysate plus Cue-lure plus Malathion (17.18%). Moderately lower per cent was observed in descending order as Jaggery plus Cue-lure plus Malathion (12.63%), Yeast Autolysate plus Cue-lure plus Malathion (10.60%), Soya Powder plus Cue-lure plus Malathion (8.19%), Deltamethrin plus Jaggery bait (4.33%) and the untreated check (1.22%). The perusal of literature reveals that protein diet with carbohydrates and moisture are essential for female flies to attain sexual maturity (Christenson and Foote, 1960) and especially during the pre-oviposition (Verma and Nath, 2006). In present studies, treatment with Molasses plus Cue-lure plus Malathion and Cue-lure plus Malathion were found to be effective, the results however could not be compared due to paucity of literature. Next best treatment was found with Protein Hydrolysate plus Cue-lure plus Malathion and the findings are in confirmation with that of reported by Bateman and Arretz (1973), Thakur and Gupta (2013), Nasiruddin *et al.*, (2003) and Kotikal and Math (2017).

Table 4.16. Evaluation of Protein Food Baits in Attracting Adults of *B. cucurbitae* on Cucumber during *Kharif*-2019

Tr. No.	Treatments	Mean number of fruit flies trapped/week during SMW no.									
		34	35	36	37	38	39	40	41	Total	Mean
T ₁	Soya powder (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	4.67 (2.27)*	6.33 (2.61)	8.67 (3.03)	11.67 (3.49)	13.33 (3.72)	13.00 (3.67)	9.33 (3.14)	7.33 (2.80)	74.33	9.29
T ₂	Yeast Autolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	5.33 (2.41)	8.33 (2.97)	10.33 (3.29)	14.67 (3.89)	18.00 (4.30)	16.67 (4.14)	15.33 (3.98)	10.67 (3.34)	99.33	12.41
T ₃	Jaggery (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	6.67 (2.68)	10.33 (3.29)	12.00 (3.54)	18.33 (4.34)	21.00 (4.64)	19.67 (4.49)	16.00 (4.06)	11.67 (3.49)	115.67	14.45
T ₄	Protein Hydrolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	7.67 (2.86)	13.67 (3.76)	19.33 (4.45)	24.67 (5.02)	30.00 (5.52)	27.33 (5.28)	17.00 (4.18)	13.33 (3.72)	153	19.12
T ₅	Molasses (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	12.33 (3.58)	18.00 (4.30)	28.67 (5.40)	32.00 (5.70)	38.67 (6.26)	35.67 (6.01)	26.67 (5.21)	20.33 (4.56)	212.34	26.54
T ₆	Cue-lure (1 ml) + Malathion 50 EC (1 ml)	10.67 (3.34)	15.33 (3.98)	25.00 (5.05)	27.67 (5.31)	32.67 (5.76)	31.67 (5.67)	24.33 (4.98)	16.00 (4.06)	183.34	23.04
T ₇	Deltamethrin 2.8% EC (1 ml) + Jaggery Bait (15 g)	2.67 (1.78)	5.33 (2.41)	5.67 (2.48)	7.00 (2.74)	7.33 (2.80)	5.33 (2.41)	4.67 (2.27)	3.00 (1.87)	41	5.12
T ₈	Untreated check	0.33 (0.91)	1.33 (1.35)	1.67 (1.47)	2.00 (1.58)	2.67 (1.78)	2.00 (1.58)	1.67 (1.47)	0.67 (1.08)	12.34	1.54
	Total	50.34	78.65	111.34	138.01	163.67	151.67	115	83	-	-
	S.Em. ±	-	-	-	-	-	-	-	-	-	2.28
	CD at 5 %	-	-	-	-	-	-	-	-	-	6.92
	F test	-	-	-	-	-	-	-	-	-	Sig.
	CV	-	-	-	-	-	-	-	-	-	3.55

*Figures in parenthesis are square root transformed values

Table 4.17. Percentage of Adults of *B. cucurbitae* Trapped by Different Protein Food Baits on Cucumber during *Kharif*-2019

Tr. No.	Treatments	Per cent of fruit flies trapped during SMW no.								
		34	35	36	37	38	39	40	41	Mean
T ₁	Soya powder (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	9.27 (17.73)*	8.04 (16.47)	7.78 (16.20)	8.45 (16.90)	8.14 (16.58)	8.57 (17.02)	8.11 (16.55)	8.83 (17.29)	8.39
T ₂	Yeast Autolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	10.58 (18.98)	10.59 (18.99)	9.27 (17.73)	10.62 (19.02)	10.99 (19.36)	10.99 (19.36)	13.33 (21.41)	12.85 (21.01)	11.15
T ₃	Jaggery (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	13.24 (21.34)	13.13 (21.24)	10.77 (19.16)	13.28 (21.37)	12.83 (20.99)	12.96 (21.10)	13.91 (21.90)	14.06 (22.02)	13.02
T ₄	Protein Hydrolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	15.23 (22.97)	17.38 (24.64)	17.36 (24.62)	17.87 (25.01)	18.32 (25.34)	18.01 (25.11)	14.78 (22.61)	16.06 (23.63)	16.87
T ₅	Molasses (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	24.49 (29.66)	22.88 (28.58)	25.74 (30.49)	23.18 (28.78)	23.62 (29.08)	23.51 (29.00)	23.19 (28.79)	24.49 (29.66)	23.88
T ₆	Cue-lure (1 ml) + Malathion 50 EC (1 ml)	21.19 (27.41)	19.49 (26.20)	22.45 (28.28)	20.04 (26.59)	19.96 (26.54)	20.88 (27.19)	21.15 (27.38)	19.27 (26.04)	20.55
T ₇	Deltamethrin 2.8 % EC (1 ml) + Jaggery Bait (15 g)	5.30 (13.31)	6.77 (15.08)	5.09 (13.04)	5.07 (13.01)	4.47 (12.21)	3.51 (10.80)	4.06 (11.62)	3.61 (10.95)	4.73
T ₈	Untreated check	0.65 (4.62)	1.69 (7.47)	1.49 (7.01)	1.44 (6.89)	1.63 (7.34)	1.31 (6.57)	1.45 (6.92)	0.80 (5.13)	1.31

*Figures in parenthesis are arcsine transformed values

Table 4.18 Evaluation of Protein Food Baits in Attracting Adults of *B. cucurbitae* on Cucumber during *Kharif*-2021

Tr. No.	Treatments	Mean number of fruit flies trapped/week during SMW no.									
		34	35	36	37	38	39	40	41	Total	Mean
T ₁	Soya powder (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	4.00 (2.12)*	6.00 (2.55)	9.33 (3.14)	13.33 (3.72)	16.33 (4.10)	14.33 (3.85)	10.00 (3.24)	6.33 (2.61)	79.65	9.95
T ₂	Yeast Autolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	6.67 (2.68)	7.33 (2.80)	10.67 (3.34)	14.67 (3.89)	18.33 (4.34)	15.00 (3.94)	13.67 (3.76)	9.67 (3.19)	96.01	12.00
T ₃	Jaggery (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	7.00 (2.74)	9.67 (3.19)	14.33 (3.85)	20.33 (4.56)	21.00 (4.64)	19.33 (4.45)	15.67 (4.02)	11.00 (3.39)	118.33	14.79
T ₄	Protein Hydrolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	9.67 (3.19)	14.00 (3.81)	20.33 (4.56)	26.67 (5.21)	32.33 (5.73)	28.67 (5.40)	21.33 (4.67)	16.67 (4.14)	169.67	21.20
T ₅	Molasses (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	14.67 (3.89)	20.33 (4.56)	31.67 (5.67)	38.00 (6.20)	45.67 (6.79)	40.33 (6.39)	32.00 (5.70)	25.67 (5.12)	248.34	31.04
T ₆	Cue-lure (1 ml) + Malathion 50 EC (1 ml)	12.00 (3.54)	16.33 (4.10)	27.67 (5.31)	32.33 (5.73)	40.00 (6.36)	34.33 (5.90)	26.67 (5.21)	18.33 (4.34)	207.66	25.95
T ₇	Deltamethrin 2.8% EC (1 ml) + Jaggery Bait (15 g)	2.33 (1.68)	4.33 (2.20)	4.67 (2.27)	6.00 (2.55)	7.67 (2.86)	5.67 (2.48)	4.33 (2.20)	2.67 (1.78)	37.67	4.70
T ₈	Untreated check	0.33 (0.91)	1.00 (1.22)	1.33 (1.35)	2.33 (1.68)	3.00 (1.87)	2.33 (1.68)	1.00 (1.22)	0.67 (1.08)	11.99	1.49
	Total	56.67	78.99	120	153.66	184.33	159.99	124.67	91.01	-	-
	S.Em. ±	-	-	-	-	-	-	-	-	-	3.50
	CD at 5 %	-	-	-	-	-	-	-	-	-	10.64
	F test	-	-	-	-	-	-	-	-	-	Sig.
	CV	-	-	-	-	-	-	-	-	-	5.03

*Figures in parenthesis are square root transformed values

Table 4.19 Percentage of Adults of *B. cucurbitae* Trapped by Different Protein Food Baits on Cucumber during *Kharif*-2021

Tr. No.	Treatments	Per cent of fruit flies trapped during SMW no.								
		34	35	36	37	38	39	40	41	Mean
T ₁	Soya powder (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	7.05 (15.40)*	7.59 (15.99)	7.77 (16.19)	8.67 (17.12)	8.85 (17.31)	8.95 (17.41)	8.02 (16.45)	6.95 (15.29)	7.98
T ₂	Yeast Autolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	11.76 (20.06)	9.27 (17.73)	8.89 (17.35)	9.54 (17.99)	9.94 (18.38)	9.37 (17.82)	10.96 (19.33)	10.62 (19.02)	10.04
T ₃	Jaggery (10 g) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	12.35 (20.57)	12.24 (20.48)	11.94 (20.21)	13.23 (21.33)	11.39 (19.72)	12.08 (20.34)	12.56 (20.76)	12.08 (20.34)	12.23
T ₄	Protein Hydrolysate (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	17.06 (24.40)	17.72 (24.89)	16.94 (24.30)	17.35 (24.62)	17.53 (24.75)	17.91 (25.04)	17.10 (24.43)	18.31 (25.33)	17.49
T ₅	Molasses (10 ml) + Cue-lure (1 ml) + Malathion 50 EC (1 ml)	25.88 (30.58)	25.73 (30.48)	26.39 (30.91)	24.72 (29.81)	24.77 (29.85)	25.20 (30.13)	25.66 (30.43)	28.20 (32.08)	25.81
T ₆	Cue-lure (1 ml) + Malathion 50 EC (1 ml)	21.17 (27.39)	20.67 (27.04)	23.05 (28.69)	21.03 (27.30)	21.70 (27.76)	21.45 (27.59)	21.39 (27.55)	20.14 (26.67)	21.32
T ₇	Deltamethrin 2.8 % EC (1 ml) + Jaggery Bait (15 g)	4.11 (11.70)	5.48 (13.54)	3.89 (11.38)	3.90 (11.39)	4.16 (11.77)	3.54 (10.84)	3.47 (10.74)	2.93 (9.86)	3.93
T ₈	Untreated check	0.58 (4.37)	1.26 (6.45)	1.10 (6.02)	1.51 (7.06)	1.62 (7.31)	1.45 (6.92)	0.80 (5.13)	0.73 (4.90)	1.13

*Figures in parenthesis are arcsine transformed values

Table 4.20. Cumulative Mean of Trapped Adults of *B. cucurbitae* by Distinct Baits during *Kharif-2019* and *2021*

Treatments	<i>Kharif-2019</i>	<i>Kharif-2021</i>	Cumulative Mean
T ₁	74.33 (8.65)*	77.67 (8.84)	152.00 (12.35)
T ₂	99.33 (9.99)	96.00 (9.82)	195.33 (13.99)
T ₃	115.67 (10.78)	118.33 (10.90)	234.00 (15.31)
T ₄	153.00 (12.39)	169.67 (13.04)	322.67 (17.98)
T ₅	212.33 (14.59)	247.67 (15.75)	460.00 (21.46)
T ₆	183.33 (13.56)	207.67 (14.43)	391.00 (19.79)
T ₇	41.00 (6.44)	37.67 (6.18)	78.67 (8.90)
T ₈	12.33 (3.58)	11.67 (3.49)	24.00 (4.95)
S.Em. ±	2.28	3.50	5.27
CD at 5 %	6.92	10.64	15.99
F test	Sig.	Sig.	Sig.
CV	3.55	5.03	3.93

*Figures in parenthesis are square root transformed values

Table 4.21 Cumulative Mean Percentage of Trapped Adults of *B. cucurbitae* by Distinct Baits during *Kharif-2019* and *2021*

Treatments	<i>Kharif-2019</i>	<i>Kharif-2021</i>	Cumulative Mean Percentage
T ₁	8.39 (16.84)*	7.98 (16.41)	8.19 (16.63)
T ₂	11.15 (19.51)	10.04 (18.47)	10.60 (19)
T ₃	13.02 (21.15)	12.23 (20.47)	12.63 (20.82)
T ₄	16.87 (24.25)	17.49 (24.72)	17.18 (24.49)
T ₅	23.88 (29.25)	25.81 (30.53)	24.85 (29.9)
T ₆	20.55 (26.96)	21.32 (27.5)	20.94 (27.23)
T ₇	4.73 (12.56)	3.93 (11.43)	4.33 (12.01)
T ₈	1.31 (6.57)	1.13 (6.1)	1.22 (6.34)

*Figures in parenthesis are arcsine transformed values

4.5 Effect of Test Insecticides on Marketable Fruit Yield of Cucumber with Per cent Increase in Yield over Control and Per cent Avoidable Yield Losses

Data on marketable fruit yield of cucumber, per cent increase in yield over untreated check and avoidable yield loss in respect of *Kharif*, 2019 and 2021 have been presented in Table 4.23.

4.5.1 *Kharif-2019*

Marketable yield of cucumber fruits in all the treatments varied from 3.81 to 7.08 t ha⁻¹; the lowest in untreated check (3.81 t ha⁻¹) and highest in Lambda-cyhalothrin (7.08 t ha⁻¹). All the test insecticides were found to be significantly effective in comparison with untreated check; amongst Lambda-cyhalothrin was found to be the most prominent treatment. In order of preference, next best treatments were Deltamethrin (6.81 t ha⁻¹), Emamectin benzoate (6.45 t ha⁻¹) and Spinosad (6.31 t ha⁻¹) which were at par with each other followed by Azadirachtin (6.00 t ha⁻¹), NSE (5.81 t ha⁻¹), Acephate (4.98 t ha⁻¹), Lufenuron (4.60 t ha⁻¹) and *Metarrhizium anisopliae* (4.51 t ha⁻¹). The per cent increase in yield over untreated check computed to be Lambda-cyhalothrin (85.82), Deltamethrin (78.74), Emamectin benzoate (69.29) and Spinosad (65.61) followed by Azadirachtin (57.48), NSE (52.49), Acephate (30.70), Lufenuron (20.73) and *Metarrhizium anisopliae* (18.37) per cent; avoidable yield loss in these test treatments were 46.18, 44.05, 40.93, 39.61, 36.50, 34.42, 23.49, 17.17 and 15.52 per cent, respectively.

4.5.2 *Kharif-2021*

Marketable yield of cucumber fruits in all the treatments varied from 3.95 to 7.35 t ha⁻¹; the lowest in untreated check (3.95 t ha⁻¹) and highest in Lambda-cyhalothrin (7.35 t ha⁻¹). All the test insecticides were found to be significantly effective in comparison with untreated check; amongst Lambda-cyhalothrin was found to be the most prominent treatment. In order of preference, next best treatments were Deltamethrin (7.16 t ha⁻¹), Emamectin benzoate (6.65 t ha⁻¹), Spinosad (6.51 t ha⁻¹), Azadirachtin (6.10 t ha⁻¹) and NSE (5.96 t ha⁻¹) which were at par with each other followed by Acephate (5.21 t ha⁻¹), Lufenuron (4.91 t ha⁻¹) and *Metarrhizium anisopliae* (4.68 t ha⁻¹). The per cent increase in yield over untreated check computed to be Lambda-cyhalothrin (86.07),

Deltamethrin (81.26), Emamectin benzoate (68.35) and Spinosad (64.81) followed by Azadirachtin (54.43), NSE (50.88), Acephate (31.89), Lufenuron (24.30) and *Metarrhizium anisopliae* (20.61) per cent; avoidable yield loss in these test treatments were 46.25, 44.83, 40.60, 39.32, 35.24, 33.72, 24.18, 19.55 and 15.59 per cent, respectively.

Data on cumulative mean of cucumber yield of both the years under the studies reveals that higher yield was obtained in Lambda-cyhalothrin (7.21 t ha⁻¹) which was on par with Deltamethrin (6.98 t ha⁻¹), Emamectin benzoate (6.55 t ha⁻¹), Spinosad (6.41 t ha⁻¹), Azadirachtin (6.05 t ha⁻¹) and NSE (5.89 t ha⁻¹) followed by Acephate (5.09 t ha⁻¹), Lufenuron (4.75 t ha⁻¹) and *Metarrhizium anisopliae* (4.59 t ha⁻¹). In comparison, lower yield was found in the untreated check (3.88 t ha⁻¹).

Data on cumulative mean of per cent increase in yield over untreated check reveals that highest increase was obtained in Lambda-cyhalothrin (85.82), Deltamethrin (79.89), Emamectin benzoate (68.81) and Spinosad (65.20) followed by Azadirachtin (55.92), NSE (51.80), Acephate (31.18), Lufenuron (22.42) and *Metarrhizium anisopliae* (18.29) per cent; the avoidable yield loss in these test treatments were 46.18, 44.41, 40.76, 39.46, 35.86, 34.12, 23.77, 18.31 and 15.46 per cent, respectively.

4.6 Incremental Cost Benefit Ratio (ICBR) of Test Insecticides on Cucumber

The economics of test insecticides were computed on the basis of fruit yield during *Kharif*, 2019 and 2021 and presented in Table 4.24.

Highest increase in yield over untreated check was depicted as 3.33, 3.10, 2.67 and 2.53 t ha⁻¹ by Lambda-cyhalothrin, Deltamethrin, Emamectin benzoate and Spinosad, respectively. Considering the expenditure incurred towards the foliar applications, the ICBR was worked out in descending order as Lambda-cyhalothrin (1:9.95), Deltamethrin (1:9.26), Emamectin benzoate (1:5.18), Azadirachtin (1:1.78), Acephate (1:1.75), Spinosad (1:1.69), NSE (1:1.02), Lufenuron (1:1.68) and *Metarrhizium anisopliae* (1:1.08).

Table 4.22 Yield of Cucumber with Per cent Increase in Yield over Untreated check and Per cent Avoidable Yield Losses

Sr. No.	Treatments	Yield (t ha ⁻¹)			Yield increased over control (%)			Avoidable yield loss (%)		
		<i>Kharif, 2019</i>	<i>Kharif, 2021</i>	Pooled data	<i>Kharif, 2019</i>	<i>Kharif, 2021</i>	Pooled data	<i>Kharif, 2019</i>	<i>Kharif, 2021</i>	Pooled data
1.	Deltamethrin 2.8% EC	6.81	7.16	6.98	78.74	81.26	79.89	44.05	44.83	44.41
2.	Spinosad 45% SC	6.31	6.51	6.41	65.61	64.81	65.20	39.61	39.32	39.46
3.	Lambda-Cyhalothrin 2.5% EC	7.08	7.35	7.21	85.82	86.07	85.82	46.18	46.25	46.18
4.	Emamectin benzoate 5% SG	6.45	6.65	6.55	69.29	68.35	68.81	40.93	40.60	40.76
5.	Lufenuron 5% EC	4.60	4.91	4.75	20.73	24.30	22.42	17.17	19.55	18.31
6.	Acephate 75% SP	4.98	5.21	5.09	30.70	31.89	31.18	23.49	24.18	23.77
7.	NSE 5 %	5.81	5.96	5.89	52.49	50.88	51.80	34.42	33.72	34.12
8.	Azadirachtin 10000 ppm	6.00	6.10	6.05	57.48	54.43	55.92	36.50	35.24	35.86
9.	<i>Metarrhizium anisopliae</i> (SA)	4.51	4.68	4.59	18.37	20.61	18.29	15.52	15.59	15.46
10.	Control	3.81	3.95	3.88	0	0	0	0	0	0
	S.Em. ±	0.34	0.52	0.47	-	-	-	-	-	-
	CD at 5 %	1.02	1.55	1.40	-	-	-	-	-	-
	F test	Sig.	Sig.	Sig.	-	-	-	-	-	-
	CV	4.36	6.51	5.92	-	-	-	-	-	-

Table 4.23. Computation of cost of plant protection per hectare for cucumber

Sr. No.	Treatments	Formulation (ml or g/ha)	Price of insecticide (Rs./kg or L)	Qty. req. for 1 ha. for 3 spray (ml or g/ha)	Cost (Rs./ha)	Labour charges (Rs./ha)	Total cost (Rs./ha)
1.	Deltamethrin 2.8% EC	450	690	1350	931.5	3600	4531.5
2.	Spinosad 45% SC	175	20000	525	10500	3600	14100
3.	Lambda-Cyhalothrin 2.5% EC	500	640	1500	960	3600	4560
4.	Emamectin benzoate 5% SG	200	4800	600	2880	3600	6480
5.	Lufenuron 5% EC	600	700	1800	1260	3600	4860
6.	Acephate 75% SP	833	1200	2499	2998.8	3600	6598.8
7.	NSE 5 %	25000	150	75000	11250	3600	14850
8.	Azadirachtin 10000 ppm	1250	2160	3750	8100	3600	11700
9.	<i>Metarrhizium anisopliae</i> (SA)	2500	200	7500	1500	3600	5100
10.	Control	-	-	-	-	-	-

Labour charges: Rs. 300/labour/day (four labours required per hectare for one spray)

Table 4.24. Incremental Cost Benefit Ratio and Net Gain of Insecticides and Biopesticides in Cucumber

Sr. No.	Treatments	Conc. %	Total cost (Rs./ha) (A)	Yield (t ha ⁻¹)	Gross realization (Rs./ha)	Increased yield over control (t ha ⁻¹)	Net realization over control (Rs./ha) (B)	Net gain (Rs./ha) (C) = (B-A)	Net ICBR (C/A)
1.	Deltamethrin 2.8% EC	0.0042	4531.5	6.98	104700	3.10	46500	41968.5	1 : 9.26
2.	Spinosad 45% SC	0.210	14100	6.41	96150	2.53	37950	23850	1 : 1.69
3.	Lambda-Cyhalothrin 2.5% EC	0.007	4560	7.21	108150	3.33	49950	45390	1 : 9.95
4.	Emamectin benzoate 5% SG	0.011	6480	6.55	98250	2.67	40050	33568	1 : 5.18
5.	Lufenuron 5% EC	0.015	4860	4.75	71250	0.87	13050	8190	1 : 1.68
6.	Acephate 75% SP	0.056	6598.8	5.09	76350	1.21	18150	11551.2	1 : 1.75
7.	NSE 5 %	0.375	14850	5.89	88350	2.01	30000	15100	1 : 1.02
8.	Azadirachtin 10000 ppm	0.0045	11700	6.05	90750	2.17	32550	20850	1 : 1.78
9.	<i>Metarrhizium anisopliae</i> (SA)	0.069	5100	4.59	68850	0.71	10650	5550	1 : 1.08
10.	Control	-	-	3.88	58200	0	0	0	0
Here, Labour charges: Rs. 300/labour/day (4 labour/ha/spray), Market price of cucumber: Rs. 15,000/tonne									
Chemical name:									
Deltamethrin 2.8 % EC - Rs.690/lit.					Lufenuron 5 % EC - Rs.700/lit.				
Spinosad 45 % SC - Rs.20000/lit.					Acephate 75 % SP - Rs.1200/kg				
Lambda-Cyhalothrin 2.5 % EC - Rs.640/lit.					NSE 5 % - Rs.150/ kg				
Emamectin benzoate 5 % SG - Rs.4800/kg					Azadirachtin 10000 ppm - Rs.2160/lit.				
					<i>Metarrhizium anisopliae</i> - Rs.200/kg				

5. SUMMARY AND CONCLUSION

The present investigations were carried out for studying the population dynamics, biology and management of fruit fly, *Bactrocera cucurbitae* (Coquillett) at MPKV, Rahuri during *Kharif*, 2019 and 2021. Summary of research findings and the conclusions drawn are presented below.

5.1 Summary

5.1.1 Population Dynamics of *B. cucurbitae* during *Kharif*-2019 and 2021

Studies were carried out by installing cue-lure pheromone traps in five crops *viz.*, cucumber, ridge gourd, bitter gourd, sponge gourd and bottle gourd. Population of the trapped flies were recorded at weekly interval initiating from 30th to 44th and 29th to 43th SMW of both *Kharif*, 2019 and 2021, respectively.

Indications of numerical count on adults trapped per week in five crops under the investigations have been briefed as under.

In cucumber and ridge gourd, numerical population count recorded was initiated at 2nd week (32nd SMW) and 1st week (31st SMW) of August *Kharif*, 2019 and 2021, respectively which however gradually increased thereafter and was observed at its peak during last week of August (35th SMW) during both the years. In bitter gourd and sponge gourd, numerical population count recorded was initiated at 1st week (31st SMW) of August which however gradually increased thereafter and was observed at its peak during last week of August (35th SMW) during both the years. In bottle gourd, numerical population count recorded was initiated at 2nd week (32nd SMW) and 1st week (31st SMW) of August which however gradually increased thereafter and was observed at its peak during last week of August (35th SMW) and 1st week of October (40th SMW) during *Kharif*, 2019 and 2021, respectively. In all the five cucurbitaceous crops, the population was found to be active since initiation of flowering and prevailed till the fruiting phase. Amongst these crops, the data pointed out that preference of the flies was in the order of sponge gourd > bitter gourd > ridge gourd > cucumber > bottle gourd.

The extent of minimum and maximum fruit damage during *Kharif*, 2019 for cucumber, ridge gourd, bitter gourd, sponge gourd and bottle gourd was in the order of range of 12.50-52.38, 6.66-47.82, 9.09-48.97, 8.96-49.12 and 11.53-36.84 per cent and

during *Kharif*, 2021 for cucumber, ridge gourd, bitter gourd, sponge gourd and bottle gourd was in the range of 11-32.35, 9.52-37.20, 10.71-39.62, 13.63-40.38 and 19.23-37.77, respectively. The peak infestation was especially noticed at 35th SMW of both the years in all the test crops.

Adult population and fruit damage were statistically correlated with weather parameters. The data reveals that maximum temperature increased the population in all the five crops whereas, high morning relative humidity comparatively reduced the pest activity in ridge gourd, bitter gourd and sponge gourd during *Kharif*-2019. However, high wind velocity reduced the population in all the five crops whereas, morning relative humidity increased the pest activity during *Kharif*-2021.

5.1.2 Biology of *B. cucurbitae* on Cucumber

5.1.2.1 Duration of Distinct Life Stages of *B. cucurbitae*

Mean incubation period was recorded as 0.73 ± 0.17 day with 90.2 ± 3.00 per cent hatching. Duration of larval period was observed as 7.2 ± 0.87 days wherein, first, second and third instar contributed 1.5 ± 0.51 , 1.9 ± 0.64 and 3.75 ± 0.84 days, respectively. Pre-pupal and pupal period was found as 1.45 ± 0.51 and 8.05 ± 0.86 days, respectively. Mating period was observed as 3.35 ± 1.00 hours. Pre-ovipositional, ovipositional and post- ovipositional period recorded as 12.4 ± 1.8 , 3.45 ± 1.16 and 2.7 ± 1.05 days, respectively. Single female deposits its eggs in clusters under rind of fruit and exhibited fecundity as 71.3 ± 9.7 eggs. Longevity of male and female fly was observed as 13.4 ± 2.8 and 18.55 ± 2.5 days, respectively with sex ratio 1.22: 1 (female: male). Thus, the duration of the entire life cycle completed under the studies was computed for female and male 35.93 ± 5.00 and 30.78 ± 5.29 days, respectively.

5.1.2.2 Morphology and Morphometric of *B. cucurbitae*

Morphological observations revealed that the egg was observed glistening white, slightly curved, elongated and ellipsoidal shape. Acephalous apodous maggot with three instars; first, second and third instar was found translucent-white, ellipsoidal-creamy white and yellowish-white with pointed head, respectively. Pre-pupa was sluggish and creamy-yellowish whereas, pupa was cylindrical, brownish-yellow with black dot and dark transverse line at posterior end. Adult was observed as reddish brown

with yellowish vertical markings on thorax with fuscous wing margin and apical spot at apex; female possessed pointed ovipositor and was bigger in size than male.

Morphometric observations revealed that mean length of the egg, first, second, third instar, pre-pupa, pupa, adult male and female was 1.32 ± 0.15 , 1.53 ± 0.23 , 6.05 ± 0.92 , 10.02 ± 0.88 , 5.96 ± 0.16 , 5.12 ± 0.18 , 7.05 ± 0.18 , 8.71 ± 0.29 mm and breadth was 0.28 ± 0.07 , 0.29 ± 0.065 , 1.24 ± 0.13 , 2.16 ± 0.13 , 2.08 ± 0.07 , 2.34 ± 0.10 , 13.05 ± 0.37 and 15.26 ± 0.39 mm, respectively.

5.1.4 Management of *B. cucurbitae* on Cucumber during *Kharif-2019* and *2021*

5.1.4.1 Field Bio-efficacy of Test Insecticides against *B. cucurbitae*

Data on field bio-efficacy of test insecticides revealed that Lambda-cyhalothrin 2.5% EC, Deltamethrin 2.8% EC, Emamectin benzoate 5% SG and Spinosad 45% SC in the descending order of preference were most promising treatments followed by Azadirachtin 10000 ppm, NSE 5%, Acephate 75% SP, Lufenuron 5% EC followed by *Metarrhizium anisopliae*. ICBR was worked out in descending order as Lambda-cyhalothrin 2.5% EC (1:9.95), Deltamethrin 2.8% EC (1:9.26), Emamectin benzoate 5% SG (1:5.18), Azadirachtin 10000 ppm (1:1.78), Acephate 75% SP (1:1.75), Spinosad 45% SC (1:1.69), NSE 5% (1:1.02), Lufenuron 5% EC (1:1.68) and *Metarrhizium anisopliae* (1:1.08).

5.1.4.2 Field Evaluation of Protein Food Baits in Attracting Flies of *B. cucurbitae*

In both the years, mean per cent flies trapped in between 34th to 41st SMW in distinct test treatments was considered on numerical basis which indicated that higher percentage of flies were trapped in Molasses plus Cue-lure plus Malathion (24.85 %), Cue-lure plus Malathion and Protein Hydrolysate plus Cue-lure plus Malathion whereas lower in the untreated check and the rest of the treatments exhibited moderate population.

In both the years, total number of flies trapped in distinct test treatments pointed out that lowest count was recorded in the untreated check and rest of the test treatments were found significantly superior over it. Efficacy was in the descending order of Molasses plus Cue-lure plus Malathion > Cue-lure plus Malathion > Protein Hydrolysate plus Cue-lure plus Malathion > Jaggery plus Cue-lure plus Malathion >

Yeast Autolysate plus Cue-lure plus Malathion > Soya Powder plus Cue-lure plus Malathion > Deltamethrin plus Malathion.

5.2 Conclusion

From the present investigations following conclusions have been drawn:

1. It can be observed that, melon fly populations fluctuated much and recorded higher population density during the period August to October. High temperature, morning relative humidity or rainfall enhances the pest activity and high wind speed reduced the activity of pest in the field. Whereas, preference of the flies was in the order of sponge gourd > bitter gourd > ridge gourd > cucumber > bottle gourd.
2. Studies on biology of *B. cucurbitae* under laboratory conditions, suggested that cucumber was observed to be relatively suitable host for its growth and development.
3. Lambda-cyhalothrin 2.5% EC, Deltamethrin 2.8% EC, Emamectin benzoate 5% SG and Spinosad 45% SC were found promising treatments in the order of preference followed by Azadirachtin 10000 ppm, NSE 5%, Acephate 75% SP, Lufenuron 5% EC and *Metarrhizium anisopliae*, amongst which ICBR was depicted higher especially in former three treatments. Thus, Lambda-cyhalothrin showed best effect among the tested chemicals and hence can be recommend for the effective management of the *B. cucurbitae*.
4. Molasses plus Cue-lure plus Malathion, Cue-lure plus Malathion and Protein Hydrolysate plus Cue-lure plus Malathion could be comparatively effective which showed an overall strong response to protein baits in attracting flies of *B. cucurbitae*.
5. To conclude, the pest activity starts during August and continued upto October during *Kharif* season. It is recommended that, control meausres should be done during August to October by first application of Azadirachtin 10000 ppm spray followed by the spray of Lambda-cyhalothrin 2.5% EC or Deltamethrin 2.8% EC or Emamectin benzoate 5% SG. Use of protein baits is at nascent stage therefore more forward-looking study should be required for developing long lasting, economically viable and ecofriendly baits which gives best results.

6. LITERATURE CITED

- Abhilash, J., Naveen, N.E., Patil, S.U. and Sharanabasappa. (2018). Assessment of efficacy of botanicals against melon fruit fly (*Bactrocera cucurbitae*) Col. (Diptera: Tephritidae) in ridge gourd. *J. Entomol. and Zool. Stud.*, 6(3) : 1795-1800.
- Abhilash, J., Naveen, N.E., Patil, S.U., Sharanabasappa and Mohankumar, K.S. (2017). Monitoring of melon fruit fly (*Bactrocera cucurbitae*) Col. (Diptera: Tephritidae) in relation to weather parameters. *J. Entomol. and Zool. Stud.*, 5(5) : 1930-1935.
- Abhishek, B.M., Panduranga, G.S., Venkateswarlu, N.C., Srilatha, V. and Ramanamurthy, B. (2021). Management of melon fly, *Bactrocera cucurbitae* (Coquillett) on bitter gourd (*Momordica charantia* L.) With newer insecticides. *J. Exp. Zool. India.*, 24(2): 1119-1123.
- Abinaya, S., Elaiyabharathi, T., Srinivasan, T. and Paramasivam, M. (2020). Field evaluation of food baits against female melon fruit fly, *Zeugodacus cucurbitae* (Coquillett) (Diptera: Tephritidae). *J. Entomol. and Zool. Stud.*, 8 (6): 895-899.
- Abro, Z.A., Baloch, N., Khuhro, N.H., Qazi, W.A. and Saeed, N.A. (2017). Population densities of melon fruit fly *Bactrocera cucurbitae* (Coquillett) in vegetables agro-ecosystem in District Hyderabad, Sindh, Pakistan. *Sarhad J. Agril.*, 33(2): 331-337.
- Abrol, D., Gupta, D. and Sharma, I. (2019). Evaluation of insecticides, biopesticides and clay for the management of fruit fly, *Bactrocera* spp. infesting bottle gourd. *J. Entomol. and Zool. Stud.*, 7(1): 311-314.
- Afroz, M., Amin, Md.R., Miah, Md.R.U. and Hossain, M.M. (2019). Effects of weather on the abundance and infestation of major insect pests of sweet gourd in Gazipur. *Bangladesh J. Zool.*, 47(2): 285-291.
- Akter, T. and Sohel, M.H. (2020). Biology of the cucurbit fruit fly, *Bactrocera cucurbitae* (Coq) on host bottle gourd, *Lagenaria siceraria*. *J. Biosci. Agric. Res.*, 25(02): 2098-2106.

- Alam, R. and Khan, M.R. (2021). Efficacy of some biopesticides for the management of cucurbit fruit fly (*Bactrocera cucurbitae* Coquillett) infesting bottle gourd (*Lagenaria siceraria*) in Barind tract of Bangladesh. *J. Entomol. and Zool. Stud.*, 9(6): 203-207.
- Ali, H., Ahmad, S., Hassan, G., Amin, A., Hussain, Z. and Naeem, M. (2011). Bioefficacy of different plant extracts against melon fruit fly in bitter gourd. *Pak. J. Weed Sci. Res.*, 17(2): 143-149.
- Alim, M.A., Hossain, M.A., Khan, M., Khan, S.A., Islam, M.S. and Khalequzzaman, M. (2012). Seasonal variations of melon fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) in different agricultural habitats of Bangladesh ARP. *J. Agric. and Biol. Sci.*, 7(11): 905-911.
- Alyokhin, A.V., Messing, R.H. and Duan, J.J. (2000). Visual and olfactory stimuli and fruit maturity affect trap capture of oriental fruit flies (Diptera: Tephritidae). *J. Econ. Entomol.*, 93 : 644-649.
- Amin, M.R., Ara, R., Mukherjee, S., Bhuyain, M.M.H. and Uddin, M.N. (2008). Economic evaluation of different management practices of cucurbit fruit fly (*Bactrocera cucurbitae*) in sweet gourd. *J. Sci. Technol.*, 6 : 1091-111.
- Amin, M.R., Shafiullah, S.M.A., Monda, E. and Ahmed, T. (2017). Toxicity and physiological effects of some plant extracts on fruit fly infesting ash gourd. *SAARC J. Agri.*, 15(2): 125-135.
- Anant, P., Painkra, K.L., Painkra, G.P., Tiwari, J.K. and Bhagat, P.K. (2019). Seasonal incidence and extent of damage by cucurbit fruit fly, *Bactrocera cucurbitae* (Coq.) on spine gourd (*Momordica dioica* Roxb.). *J. Plant Develop. Sci.*, 11(9): 543-546.
- APEDA, (2022). (<https://apeda.gov.in/apedawebsite/SubHeadProducts/CucumberandGherkins>).
- Babu, P.G., Reddy, D.J., Jadhav, D.R., Chranjeevi, C. and Khan, M.A.M. (2002). Comparative efficacy of selected insecticides against pest of water melon. *Pestic. Res. J.*, pp. 1457-1462.

- Balas, T.K., Virani, V.R. and Parekh, K.M. (2018). Comparative efficacy of different insecticides against fruit fly, *Bactrocera cucurbitae* (Coquillett) on cucumber. *J. Entomol. and Zool. Stud.*, 6(4): 1434-1443.
- Banerji, R., Sahoo, S.K., Das, S.K. and Jha, S. (2005). Studies on incidence of melon fly, *Bactrocera cucurbitae* (Coquillett) in relation to weather parameters on bitter melon in new alluvial zone of West Bengal. *J. Entomol. Res.*, 29(3): 179-182.
- Barma, P. and Jha, S. (2011). Biology, seasonal activity of fruit fly (*Bactrocera cucurbitae* Coq.) on pointed gourd (*Trichosanthes dioica* Roxb.) and weather relations. *The J. Plant Protect. Sci.*, 3(1): 48-53.
- Barry, J.D., Miller, N.W., Pin-Ero, J.C., Tuttle, A., Ronald, Mau, F.L. and Vargas, R.I. (2006). Effectiveness of Protein Baits on Melon Fly and Oriental Fruit Fly (Diptera: Tephritidae): Attraction and Feeding. *J. Econ. Entomol.*, 99(4) : 1161-1167.
- Bateman, M.A. and Arretz, P. (1973). The eradication of Queensland fruit fly from Easter Island. *FAO Pl. Prot. Bull.*, 21 : 114.
- Bharadiya, A.M. and Bhut, J.B. (2017). Effect of different insecticides against fruit fly, *Bactrocera cucurbitae* Coquillett infesting sponge melon. *Int. J. Chem. Stud.*, 5(5): 1866-1868.
- Bhowmik, P., Laishana Devi, L., Chatterjee, M. and Mandal, D. (2014a). Seasonal bionomics of melon fruit fly, *Bactrocera cucurbitae* Coquillett on bottle melon in laboratory condition. *The Ecoscan*, 8 (1&2): 157-162.
- Bhowmik, P., Mandal, D. and Chatterjee, M.L. (2014b). Chemical management of melon fruit fly, *Bactrocera cucurbitae* Coquillett (Diptera: Tephritidae) on bitter melon (*Momordica charantia* Linn.). *Pesticide Res. J.*, 26 (1): 68-73.
- Bhowmik, P., Mandal, D. and Chatterjee, M.L. (2014c). Biorational Management of Melon Fruit Fly, *Bactrocera cucurbitae* on Pointed Melon. *Indian J. Plant Protect.*, 42(1) : 34-37.
- Chinajariyawong, A., Kritsaneepaiboon, S. and Drew, R.A.I. (2003). Efficacy of protein bait sprays in controlling fruit flies (Diptera: Tephritidae) infesting angled

- luffa and bitter gourd in Thailand. *The Raffles Bulletin of Zool.*, 51 (1): 7-15.
- Christenhusz, M.J.M. and Byng, J.W. (2016). The number of known plants species in the world and its annual increase. *Phytotaxa.*, 261(3) : 201-217.
- Christenson, L.D. and Foote, R.H. (1960). Biology of fruit flies. *Ann. Rev. Entomol.*, 5 : 171-192.
- Das, U.K., Kashar, N., Okram, S., Jha, S. and Karmakar, S. (2017). Seasonal activity, weather relations and biology of melon fly (*Bactrocera cucurbita* Coq.) on Pumpkin. *Environment and Ecology*, 35 (3): 1634-1638.
- Dashad, S.S., Chaudhary, O.P. and Rakesh. 1999. Chemical control of ber fruit fly. *Crop Research Hisar*, 17: 333-335.
- Dhillon, M.K., Singh, R., Naresh, J.S. and Sharma, H.C. (2005). The melon fruit fly, *Bactrocera cucurbitae*: A review of its biology and management. *J. Insect Sci.*, 5(40): 1-16.
- Divya, S., Kalyanasundaram, M. and Sidhanandham, S. (2019). Studies on combination of different traps and lures in cucurbit fruit flies attraction. *J. Entomol. and Zool. Stud.*, 7(3) : 996-998.
- Drew, R.A.I. (1989). The tropical fruit flies (Diptera: Tephritidae) of the Australian and Oceanian regions. *Memoirs of the Queensland Museum*, 26 : 1-521.
- Dubale, M.M., Jalgaonkar, V.N., Naik, K.V., Munj, A.Y. and Golvankar, G.M. (2018). Studies on incidence of fruit flies in relation to weather parameters on ridge gourd in Konkan region. *J. Entomol. and Zool. Stud.*, 6(5) : 2012-2014.
- FAOSTAT, (2022). (<https://www.fao.org/faostat/en/#data/QCL>).
- Gaddanakeri, S. and Rolania, K. (2020). Biology and morphometrics of melon fruit fly, *Bactrocera cucurbitae* Coquillett on bitter gourd (*Momordica charantia* L.). *J. Entomol. and Zool. Stud.*, 8(5) : 994-998.
- Ganie, S.A., Khan, Z.H., Ahangar, R.A., Bhat, H.A. and Hussain, B. (2013). Population dynamics, distribution and species diversity of fruit flies on cucurbits in Kashmir Valley, India. *J. Insect Sci.*, 13(3): 1-6.

- Gautam, M., Poude, S., Dhungana, N. and Bhusal, N. (2021). Comparative Efficacy of Different Insecticides against Cucurbit Fruit Fly (*Bactrocera cucurbitae*) on Bottle Gourd (*Lagenaria siceraria*) in Sarlahi District, Nepal. *Int. J. Nat. Res. Ecol. and Manag.*, 6(2): 27-37.
- Ghule, T.M., Laishana Devi, L., Uikey, B. and Jha, S. (2015). Incidence studies on some important insect pests of ridge gourd (*Luffa acutangula*). *Environment and Ecology*, 33(1A): 351-355.
- Ghule, T.M., Uikey, B., Barma P. and Jha, S. (2014). Incidence studies on some important insect pests of cucumber (*Cucumis sativus* L.). *The Ecoscan*, 8(1&2): 177-180.
- Gupta, D. and Verma, A.K. (1995). Host specific demographic studies of the melon fruit fly, *Dacus cucurbitae* Coquillett (Diptera: Tephritidae). *J. Insect Sci.*, 8 : 87-89.
- Hirekurubar, R.B., Hanchinamani, C.N., Patil, S. and Tatagar, M.H. (2018). Management of fruit fly, *Bactrocera cucurbitae* (Coquillett) in Ridge Gourd through botanicals and newer insecticides. *International J. Bot. and Res.*, 8(2): 21-26.
- Hossain, M.A., Leblanc, L., Momen, M., Bari, M.A. and Khan, S.A. (2019). Seasonal abundance of economically important fruit flies (diptera: tephritidae: dacinae) in Bangladesh, in relation to abiotic factors and host plants. *Proc. Hawaii Entomol. Soc.*, 51(2): 25-37.
- Jakhrani, N.A., Baloch, N., Khuhro, N.H., Khan, T., Ali, S. and Zain-ul-Aabdin, A. (2019). Evaluation of cue-lure pheromone for the attraction of Melon fruit fly *Bactrocera cucurbitae* in Bitter gourd vegetable crop. *J. Entomol. and Zool. Stud.*, 7(5): 1224-1229.
- Kate, A.O., Bharodia, R.K., Joshi, M.D., Pardeshi, A.M. and Makadia, R.R. (2010). Efficacy of various insecticides against fruit fly, *Bactrocera cucurbitae* (Coquillett) infesting cucumber. *Int. J. Plant Protec.*, 3(1): 80-82.
- Kate, A.O., Bharodia, R.K., Joshi, M.D., Pardeshi, A.M. and Makadia, R.R. (2009). Seasonal incidence of fruit fly, *Bactrocera cucurbitae* (Coquillett) on cucumber. *Asian Sciences*, 4(1&2): 83-84.

- Khan, M., Hossain, M.A. and Islam, M.S. (2007). Effects of neem leaf dust and a commercial formulation of a neem compound on the longevity, fecundity and ovarian development of the melon fly, *Bactrocera cucurbitae* (Coquillett) and the oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). *Pak. J. Biol. Sci.*, 10(20): 3656-3661.
- Khatun, N., Howlader, M.T.H., Islam, T. and Das, G. (2016). Comparative efficacy of some biopesticides and a pyrethroid against cucurbit fruit fly, *Bactrocera cucurbitae* (Coquillett) on Bitter gourd. *Int. J. Entomol. Res.*, 1(2): 23-28.
- Kotikal, Y.K. and Math, M. (2017). Management of fruit flies through traps and attractants-A review. *J. Farm Sci.*, 30(1): 1-11.
- Koyama, J., Kakinohana, H. and Miyatake, T. (2004). Eradication of the melon fly, *Bactrocera cucurbitae*, in Japan: Importance of Behavior, Ecology, Genetics and Evolution. *Annu. Rev. Entomol.*, 49 : 331-349.
- Kubar, M.I., Khoso, F.N., Khatri, I., Khuhro, N.H. and Gilal, A.A. (2021). Effect of different management strategies on melon fruit fly, *Bactrocera cucurbitae* (Coquillett), infestation in cucurbit vegetables. *Sarhad J. Agric.*, 37(3): 915-920.
- Kumar, P., Chandra, U., Mishra, R., Kumar, D., Ramkumar and Gawande, K. (2022). Impact of weather parameters on population dynamics of fruit fly (*Bactrocera* spp.) in cucurbits at different locations. *The Pharma Innovation J.*, 11(9): 704-707.
- Lad, S.S., Naik, K.V. and Golvankar, G.M. (2020). Efficacy of some insecticides against melon fruit fly, *Bactrocera* spp. on Bitter Gourd. *J. Exp. Zool. India.*, 23(1): 635-64.
- Lanjar, A.G., Sahito, H.A., Talpur, M.A. and Channa, M.S. (2013). Biology and population of melon fruit fly on musk melon and Indian squash. *Int. J. Farm Alli. Sci.*, 2(2): 42-47.
- Laskar, N. (2013). Biology and biometrics of melon fruit fly, *Bactrocera cucurbitae* (Coq.) on bitter gourd, *Momordica charantia* L. and pumpkin, *Cucurbita pepo* L. *Current Biotica*, 7(1&2): 51-59.

- Laskar, N. and Chatterjee, H. (2010). The effect of meteorological factors on the population dynamics of melon fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) in the foot hills of Himalaya. *J. Appl. Sci. Environ. Mgt.*, 14 (3): 53 -58.
- Maharjan, R., Regmi, R. and Poudel, K. (2015). Monitoring and varietal screening cucurbit of fruit fly, *Bactrocera cucurbitae* Coquillett (Diptera: Tephritidae) on cucumber in Bhaktapur and Kathmandu, Nepal. *Int. J. Appl. Sci. Biotechnol.*, 3 (4): 714-720.
- Manikantha, J., Kavitha, Z., Shanthi, M. and Subaharan, K. (2022). Field evaluation of attractiveness of protein and food baits to the cucurbit fruit fly, *Zeugodacus cucurbitae* Coquillett. *The Pharma Innovation J.*, 11(7): 4481-4486.
- Manzar, A. and Srivastava, J.P. (2009). Biology of Melon Fruit Fly, *Bactrocera cucurbitae* (Coq.) on Bitter Gourd (*Momordica charantia* L.). *Trends in Biosciences*, 2(1): 42-43.
- Meena, D.S., Acharya, V.S. and Kumar, D. (2019). Seasonal incidence of fruit fly, *Bactrocera cucurbitae* on bottle gourd and their correlation with abiotic factors. *Int. J. Curr. Microbiol. App. Sci.*, 8(12): 381-388.
- Meena, D.S., Acharya, V.S., Singh, V., Mehra, K. and Rajput, V.S. (2022). Bio-efficacy of different insecticides/botanicals against fruit fly, *B. cucurbitae* on bottle gourd. *The Pharm Innov. J.*, 11 (3): 824-828.
- Mehta, P.K., Chandel, R.S. and Kashyap, N.P. (2000). Control of fruit fly, *Bactrocera cucurbitae* (Coq.) on cucumber in Himachal Pradesh. *Pestology*, xxiv (10): 53-55.
- Messing, R. (1999). Managing fruit flies on farm in Hawaii. CTAHR-Sept. 1999, IP-4. [Online], Available at: <http://www.ctahr.hawaii.edu/oc/>>.
- Mir, S.H., Dar, S.A., Mir, G.M. and Ahmad, S.B. (2014). Biology of *Bactrocera cucurbitae* (Diptera: Tephritidae) on Cucumber. *Florida Entomologist*, 97(2): 753-758.

- Mukherjee, S., Tithi, D.A., Bachchu, A.A., Ara, R. and Amin, M.R. (2007). Life history and management of cucurbit fruit fly *Bactrocera cucurbitae* on sweet gourd. *J. Sci. Technol.* 5: 17-27.
- Mwatawalaa, M., Maererea, A.P., Makundib, R. and De Meyerc, M. (2010). Incidence and host range of the melon fruit fly *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) in Central Tanzania. *Int. J. Pest Manag.*, 56(3): 265-273.
- Nahid, S., Amin, M.R., Haque, M.M. and Suh, S.J. (2020). Seasonal abundance and infestation of fruit fly on cucumber. *SAARC J. Agric.*, 18(2): 233-241.
- Nair, N. and Pal, P. (2020). Seasonal incidence of fruit fly (*Zeugodacus cucurbitae*) in cucurbit ecosystem in Tripura, N.E. India. *J. Entomol. and Zool. Stud.*, 8(6): 1253-1256.
- Narsinga Rao, B.S. (2013). Fruits, vegetables, milk and animal foods in balanced Indian diets-a critical appraisal. Bulletin of the Nutrition Foundation of India. Vol. 34, No. 1.
- Nasiruddin, M., Alam, S.N., Khorsheduzzaman, M., Jasmine, H.S., Karim, A.N.M.R. and Rajotte, E. (2003). Management of cucurbit fruit fly, *Bactrocera cucurbitae*, in bitter gourd by using pheromone and indigenous bait traps and its effect on year-round incidence of fruit fly. <https://www.researchgate.net/publication/265542679>.
- Nath, P., Bhushan, S. and Kumar, A. (2007). Efficacy of certain eco-friendly insecticides and bait spray against fruit fly (*B. cucurbitae*) infesting fruits of bottle gourd. *Vegetable Sci.*, 34 : 150-152.
- Nehra, S., Singh, S., Choudhary, S.K., Samota, R.G. and Choudhary, A.L. (2019a). Seasonal incidence of fruit fly, *Bactrocera cucurbitae* (Coquillett) on round gourd in relation to abiotic factors. *J. Entomol. and Zool. Stud.*, 7 (4): 324-327.
- Nehra, S., Singh, S., Samota, R.G. and Choudhary, A.L. (2019b). Bio-efficacy of newer insecticides and biopesticides against fruit fly, *Bactrocera cucurbitae* (Coquillett) on round gourd. *J. Entomol. and Zool. Stud.*, 7(4): 97-101.

- Norrbom, A.L., Corroll, L.E. and Friedberg, A. (1998). Status of Knowledge. *Myia*, 9 : 9-48.
- Oke, O.A. (2008). Effectiveness of two insecticides to control melon fruit fly (*Bactrocera cucurbitae* Coq.) in cucumber (*Cucumis sativus* L.) crop at Anse Boileau Seychelles. *European J. Scientific Res.*, 22(1): 84-86.
- Oke, O.A. and Sinon, S.G. (2013). Effectiveness of three insecticides to control *Bactrocera cucurbitae* (Diptera: Tephritidae) on the cucumber crop at Praslin, Seychelles. *Florida Entomologist*, 96(1): 120-123.
- Parkash, J., Singh, B., Yadav, S.S. and Paras. (2021). Bio-ecological management of melon fruit fly, *Bactrocera cucurbitae* Coquillett on bottle gourd. *J. Entomol. Res.*, 45: 937-939.
- Patel, L.C. and Das, S. (2021). Population dynamics of fruit fly *Bactrocera cucurbitae* (Coquillett) of cucurbits. *Indian J. Entomol.*, 83: Online published Ref. No. e20255. DoI No.: [10.5958/0974-8172.2021.00053.5](https://doi.org/10.5958/0974-8172.2021.00053.5).
- Patel, N.M. and Patel, K.A. (2018). Comparative biology of melon fruit fly, *Bactrocera cucurbitae* in different cucurbitaceous crops. *J. Entomol. and Zool. Stud.*, 6(6): 694-698.
- Patel, N.V. (1989). Biology of fruit fly, *Bactrocera cucurbitae* (Coquillett) on cucurbits and chemical control on bitter gourd. M.Sc. (Agri.) thesis submitted to G.A.U, Navsari.
- Pawar, S.A., Boraste, A.A., Bhalekar, M.N. and Datkhile, R.V. (2019). Evaluation of different modules against major pests of cucumber (*Cucumis sativus* L.). *J. Entomol. and Zool. Stud.*, 7(6): 1032-1036.
- Pinero, J.C., Souder, S.K., Smith, T.R. and Vargas, R.I. (2017). Attraction of *Bactrocera cucurbitae* and *Bactrocera dorsalis* (Diptera: Tephritidae) to beer waste and other protein sources laced with ammonium acetate. *Florida Entomologist*, 100(1): 70-76.
- Pradhan, Y., Gupta, M.K., Kumar, C.N. and Longkumer, I.Y. (2020). Biology and biometrics of melon fly, *Bactrocera cucurbitae* Coquillett (Diptera: Tephritidae) on some cucurbitaceous crops. *J. Entomol. and Zool. Stud.*, 8(5): 2263-2267.

- Praveen, H.M., Nandeesh, M., Chandra Mouli, M.R., Rao, G.V.G. and Vijaysegaran, S. (2012). Management of melon fly, *Bactrocera cucurbitae* (Coquillett) infesting gherkin: An areawide control programme adopted in Peninsular India. *J. Hortl. Sci.*, 7(1): 68-74.
- Purnima, S., Saxena, S.K. and Sinha, P. (1999). Effect of culture filtrates of three fungi, in different combinations, on the development of the fruit fly, *Dacus cucurbitae* (C.) *Ann. Pl. Protec. Sci.*, 7 : 96-99.
- Raghuvanshi, A.K., Satpathy, S. and Mishra, D.S. (2012). Role of abiotic factors on seasonal abundance and infestation of fruit fly, *Bactrocera cucurbitae* (Coquillett) on bitter gourd. *J. Plant Protec. Res.*, 52(10): B264-267.
- Rahaman, M.A., Jahan, M., Islam, K.S. and Alam, S.N. (2015). Study on the biology of cucurbit fruit fly, *Bactrocera cucurbitae* (Coquillett). *J. Sylhet Agril. Univ.*, 2(2): 203-208.
- Rahman, M.M., Howlader, M.T.H., Islam, K.S., Morshed, M.N. (2019). Efficacy of three biopesticides against cucurbit fruit fly, *Bactrocera cucurbitae* Coquillett (Diptera: Tephritidae) and yield of bitter gourd. *J. Bangladesh Agril. Univ.*, 17(4): 483-489.
- Ronald, F.L.M. and Jayma, L.M.K. (2011). Distribution and host range of *Bactrocera cucurbitae* (Coquillett). (<http://extento.hawaii.edu/kbase/crop/type/bactroc.htm>).
- Saha, T., Chandran, N., Kumar, S. and Kumari, K. (2018). Effect of weather parameters on incidence of insect pests of cucumber in eastern Bihar. *Agrometeo.*, 20(1): 57-61.
- Saikia, D.K. and Dutta, S.K. (1997). Efficacy of some insecticides and plant products against fruit fly, *Bactrocera tau* on ridge gourd, *Luffa acutangula*. *J. Agril. Sci. Soc., of North East India*, 10 : 132-135.
- Sapkota, R., Dahal, K.C. and Thapa, R.B. (2010). Damage assessment and management of cucurbit fruit flies in spring-summer squash. *J. Entomol. and Nematol.*, 2(1): 007-012.

- Sarkar, R., Das, S., Kamal, M.M., Islam, K.S. and Jahan, M. (2017). Efficacy of management approaches against cucurbit fruit fly (*Bactrocera cucurbitae* Coquillett) of bitter gourd Bangladesh. *J. Agril. Res.*, 42(4): 757-766.
- Satpathy, S. and Rai, S. (2002). Luring ability of indigenous food baits for fruit fly *B. cucurbitae* (Coq.). *Ind. J. Entomol. Res.*, 26(3): 249-252.
- Sawai, H.R., Godase, S.K., Narangalkar, A.L. and Navik, O. (2019). Population fluctuation of fruit flies in cucurbit ecosystem. *J. Ent. Res.*, 43(2): 149-152.
- Sawai, H.R., Godse, S.K., Narangalkar, A.L., Haldankar, P.M. and Sanas, A.P. (2014). Bio efficacy of some insecticides against fruit flies infesting ridge gourd. *J. Soils and Crops*, 24(1): 174-180.
- Sen, K., Dhar, P.P. and Samanta, A. (2022). Seasonal abundance of different insect pests and predatory coccinellids in association with weather factors on bitter gourd, *Momordica charantia* L. *J. Crop and Weed.*, 18(1): 136-143.
- Shafiullah, S.M.A., Amin, M.R., Miah, M.R.U., Rahman, M.A. and Ahmed, T. (2016). Insecticidal effect of plant extracts on the activity of fruit fly. *Ann. Bangladesh Agric.*, 20(1&2): 87-93.
- Sharma S.K., Punam and Kumar, R. (2016). Management of fruit fly (*Bactrocera* spp.) in cucumber (*Cucumis sativus* Linn.) grown organically. *J. Biopest.*, 9(1): 73-79.
- Sharma, M., Sharma, I.D. and Singh, R. (2010). Effect of cucumber genotypes and weather factor on the incidence of fruit flies *Bactrocera cucurbitae* (Coquillett) and *Bactrocera tau* Walker. *J. Insect Sci.*, 23(3): 263-268.
- Sharma, N. and Gupta, D. (2019). Evaluation of some new insecticides molecules for the management of fruit fly, *Bactrocera* spp. infesting cucumber. *J. Entomol. and Zool. Stud.*, 7(6): 1172-1175.
- Sharma, R. K. and Sinha, S. R. (2009). Evaluation of some novel and eco-friendly insecticides against fruit fly of bitter gourd. *J. Insect Sci.*, 22 (2): 202-203.
- Sharma, S., Shrikhandia, P. and Tara, J.S. (2017). Biology and life cycle of *Bactrocera cucurbitae* Coquillett, a serious pest of cucurbits in Jammu region (Jammu and Kashmir) India. *International J. Recent Scientific Res.*, 8(11): 22047-22050.

- Sheikh, K. and Desh, R. (2012). Bio-efficacy of certain insecticides and biopesticides against melon fruit flies, *Bactrocera* spp. *Pest Management in Horticultural Ecosystems*, 18(2): 143-148.
- Shinde, P.B., Naik, K.V., Golvankar, G.M., Jalgaonkar, V.N. and Shinde, B.D. (2018a). Influence of abiotic factors on relative abundance of fruit flies (Diptera: Tephritidae) infesting cucumber. *J. Entomol. and Zool. Stud.*, 6(5): 16-18.
- Shinde, P.B., Naik, K.V., Golvankar, G.M., Shinde, B.D. and Jalgaonkar, V.N. (2018b). Bio-efficacy of insecticides against fruit flies infesting cucumber. *International J. Chemical Stud.*, 6(5): 1681-1684.
- Shinde, V.M., Kabre, G.B. and Aghav, S.T. (2021b). Evaluation of insecticides and botanicals in the management of fruit flies infesting ridge gourd. *The Pharma Innovation J.*, 10(7): 226-229.
- Shinde, V.M., Kabre, G.B. and Pawar, S.A. (2021a). Surveillance of fruit fly, *Bactrocera cucurbitae* (Coquillett) on ridge gourd in relation to abiotic factors. *The Pharma Innovation J.*, 10(7): 861-864.
- Shivangi, Lekha and Swami, H. (2017). Bio-intensive management of fruit fly, *Bactrocera cucurbitae* (Coquillett.) in cucumber. *J. Entomol. and Zool. Stud.*, 5(3): 1823-1826.
- Shivayya, V. and Kumar, C.T.A. (2008). Seasonal incidence and population fluctuation of melon fly, *Bactrocera cucurbitae* (Coquillett) on bitter gourd, *Momardica charantia* L. *Environ. Ecol.*, 26(1A): 282-328.
- Sohrab, Hasan, W. and Prasad, C.S. (2018b). Investigation on level of infestation and management of cucurbit fruit fly, *Bactrocera cucurbitae* (Coquillett) in different cucurbit crops. *Int. J. Pure App. Biosci.*, 6(5): 1276-1288.
- Sohrab, Prasad, C.S. and Hasan, W. (2018a). Investigation on population fluctuation of cucurbit fruit flies, *Bactrocera cucurbitae* associated with cucurbit crops. *International J. Bioassays.*, 7(6): 5652-5658.
- Sookar, P., Facknath, S., Permalloo, S. and Seewooruthun, S.I. (2002). Evaluation of modified waste brewer's yeast as a protein source for the control of melon fruit fly, *Bactrocera cucurbitae* (Coquillett). Proceedings of 6th International Fruit Fly Symposium, Stellenbosch, South Africa. 295-299 pp.

- Sowmiya, L., Chandrasekaran, M. and Soundararajan, R.P. (2021). Evaluation of cost effective natural attractants for fruit fly in snake gourd ecosystem. *J. Pharmacognosy and Phytochem.*, 10(2): 151-156.
- Sowmiya, L., Chandrasekaran, M., Soundararajan, R.P. and Ramesh, D. (2020). Influence of weather factors on the occurrence, population fluctuation and species diversity of fruit flies in Snake Gourd ecosystem. *Int. J. Curr. Microbiol. App. Sci.*, 9(9): 165-173.
- Srinivas, M.P., Suchithra Kumari, M.H., Hanumantharaya, L., Thippeshappa, G.N. and Yalleshkumar, H.S. (2018). Bio-efficacy of insecticides against fruit fly, *Bactrocera cucurbitae* (Coquillett) in cucumber. *J. Entomol. and Zool. Stud.*, 6(6): 449-452.
- Sruthi, A.B., Kavitha, Z., Shanthi, M. and Beulah, A. (2022). Role of protein and food baits in attraction of melon fruit fly *Zeugodacus cucurbitae* in bitter gourd. *Indian Journal of Entomology*, Online published. Ref. No. e21224. DoI.: [10.55446/IJE.2022.432](https://doi.org/10.55446/IJE.2022.432).
- Sunil, T.M. and Jayaram, C.S. (2017). Seasonal incidence of fruit borers with special reference to melon fruit fly, *Bactrocera cucurbitae* (Coquillett) on bitter gourd (*Momordica charantia* L.). *Int. J. Pure App. Biosci.*, 4 (3): 87-92.
- Sunil, Thippaiah, M., Jagadish, K.S. and Chakravarthy, A.K. (2016). Efficacy of insecticides against melon fruit fly *Bactrocera cucurbitae* (Coquillett) in bitter gourd. *Entomon.*, 41(3): 233-238.
- Sureshbabu, K. and Viraktamath, S. (2003). Species diversity and population dynamics of fruit flies (Diptera: Tephritidae) on mango in Northern Karnataka. *Pest Manage.and Econ. Zool.*, 11(2): 103-110.
- Thakur, M. and Gupta, D. (2013). Efficacy of different food attractants for control of fruit flies [*Bactrocera tau* and *B. cucurbitae* (Diptera: Tephritidae)]. *Int. J. Agricult. Stat. Sci.*, 9(2): 575-580.
- Thakur, M., Gupta, D. and Singh, M. (2010). Population fluctuations of fruit flies, *Bactrocera* spp., infesting cucumber monitored by attractant-insecticide bait traps. *Pest Manag. and Econ. Zool.*, 18(1/2): 327-333.

- Ullah, M.S., Das, G. and Islam, K.S. (2008). Biology and host suitability of cucurbit fruit fly, *Bactrocera cucurbitae* (Coq.): a comparative study on five different cucurbit species. *J. Agrofor. Environ.* 2(1): 1-6.
- Vargas, R.I., Mau, R.F.L., Stark, J.D., Ero, J.C.P., Leblanc, L. and Souder, S.K. (2010). Evaluation of methyl eugenol and cue-lure traps with solid lure and insecticide dispensers for fruit fly monitoring and male annihilation in the Hawaii area wide pest management program. *J. Econ. Entomol.*, 103(2): 409-415.
- Vergheese A., Sreedevi, K., Nagaraju, D.K. and Jayanthi Mala, B.R. (2006). Short note on a farmer-friendly trap for the management of the fruit fly *Bactrocera* spp. (Tephritidae: Diptera). *Pest Management in Horticultural Ecosystems*, 12(2): 164-167.
- Verma, J.S. and Nath, A. (2006). Management of fruit flies through trapping - A review. *Agric. Rev.*, 27(1): 44-52.
- Vignesh, R. and Viraktamath, S. (2015). Population dynamics of melon fruit fly *Bactrocera cucurbitae* (Coquillett) on cucumber (*Cucumis sativus* L.) *Karnataka J. Agric. Sci.*, 28(4): 528-530.
- Vigneswaran, S., Rani, W.B., Kalyanasundaram, M. and Shanthi, M. (2016). Biology and morphometric studies of *Bactrocera cucurbitae* Coquillett (Diptera: Tephritidae) on different *Coccinia indica* Wight and Arn. Cultivars. *Int. J. Agric. Sci.*, 8(1): 938-941.
- Waseem, M.A., Nagangoud, A., Patil, B.V., Prabhuraj, A. and Hussain, A. (2009). Efficacy of some insecticides against melon fly, *Bactrocera cucurbitae* Coquillett on cucumber. *Karnataka J. Agril. Sci.*, 22 : 701-702.
- Wazir, Z.A., Singh, A.K. and Ramana, N. (2019). Seasonal incidence of fruit fly on Summer squash (*Cucurbita pepo* L.) and effect of weather parameters on population dynamics of fruit fly *Bactrocera cucurbitae* (Coquillett). *J. Entomol. and Zool. Stud.*, 7(5): 167-170.
- White, I. and Elson-Harris, M.M. (1992). Fruit flies of economic significance: Their identification and bionomics. Commonwealth Agriculture Bureau International, Oxon, UK, pp. 601.

7. APPENDICES

Appendix-I: Weekly mean weather data during *Kharif-2019*

SMW	Month and Date	Temperature ($^{\circ}\text{C}$)		Humidity (%)		Bright Sunshine Hours	Wind Velocity (Km/Hr)	Daily Rain (mm)	No. of Rainy Days	Open Pan Evaporation (mm)
		Max	Min	RH I	RH II					
30	23 Jul – 29 Jul	30.5	23.6	78	68	2.3	4.1	18.4	2	3.3
31	30 Jul – 05 Aug	27	22.8	88	77	0.2	4.8	47.8	5	1.9
32	06 Aug – 12 Aug	28	23.3	80	68	2	8.2	3.6	0	3.6
33	13 Aug – 19 Aug	31	22.5	75	59	8.4	6.9	1.4	0	5.4
34	20 Aug – 26 Aug	32.5	21.3	72	47	7.9	4.1	0	0	6.2
35	27 Aug – 02 Sep	32	23	75	56	5.9	4.1	87.2	4	4.8
36	03 Sep – 09 Sep	30	23.3	77	71	1.8	3.6	3	0	4.3
37	10 Sep – 16 Sep	28.8	22.5	78	68	1.3	4.6	21.6	2	3.7
38	17 Sep – 23 Sep	29.8	21.7	83	71	4.2	1.6	84.2	4	3.7
39	24 Sep – 30 Sep	30.2	21.9	83	67	4.9	0.8	36.6	3	3.3
40	01 Oct – 07 Oct	31.1	21.1	80	59	6.1	1.1	7.8	1	5
41	08 Oct – 14 Oct	31.7	21.1	77	50	7.1	0.7	2.8	0	4.9
42	15 Oct – 21 Oct	28.2	18.6	81	68	5	1.4	52.4	3	3.6
43	22 Oct – 28 Oct	25.7	20.8	87	79	2.4	1.3	141.8	6	1.6
44	29 Oct – 04 Nov	30.4	21	84	58	6.1	1.1	4	1	5

Appendix-II: Weekly mean weather data during *Kharif*-2021

SMW	Month and Date	Temperature ($^{\circ}\text{C}$)		Humidity (%)		Bright Sunshine Hours	Wind Velocity (Km/Hr)	Daily Rain (mm)	No. of Rainy Days	Open Pan Evaporation (mm)
		Max	Min	RH I	RH II					
29	16 Jul – 22 Jul	30.1	23.9	85	66	3	2.3	43.6	4	4.2
30	23 Jul – 29 Jul	30.1	24.6	82	59	3.6	6.9	2.8	0	4.8
31	30 Jul – 05 Aug	28	23.6	83	67	2.1	6.7	4.8	1	4.4
32	06 Aug – 12 Aug	31.3	24.2	80	58	5.5	3.2	1.2	0	5.3
33	13 Aug – 19 Aug	25.8	22.7	88	68	2.9	2.4	34.6	4	4.7
34	20 Aug – 26 Aug	27.8	22.2	93	68	4.2	0.9	48.8	3	3.4
35	27 Aug – 02 Sep	29.3	22.9	88	66	4.7	1.1	81.2	2	4.5
36	03 Sep – 09 Sep	29.6	23	92	67	4.3	2.6	117.4	4	3.5
37	10 Sep – 16 Sep	29.8	23.9	84	64	4.3	5	7.6	1	4.2
38	17 Sep – 23 Sep	28.9	23.1	87	69	3.6	1.8	51.6	3	3.7
39	24 Sep – 30 Sep	28.6	22.4	92	69	1.7	1.3	58.8	5	3.2
40	01 Oct – 07 Oct	31.2	22.7	94	65	7.7	1	63.2	4	5.1
41	08 Oct – 14 Oct	30.8	22.7	92	59	6.1	0.7	25.4	0	4.9
42	15 Oct – 21 Oct	32.3	20.7	85	39	8.3	0.9	0	0	5.5
43	22 Oct – 28 Oct	32.1	18.5	84	32	9.8	1.3	0	0	5.8

8. VITAE

Mr. BADE ANAND SUNIL
DOCTOR OF PHILOSOHY (AGRICULTURE)
IN
DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
2023

Title of thesis	:	Population Dynamics, Biology and Management of Fruit Fly, <i>Bactrocera cucurbitae</i> (Coquillett) Infesting Cucurbitaceous Vegetable Crops
Major field	:	Agricultural Entomology
Biographical Information	:	
Personal	Date of birth	: 19 January, 1994
	Place of birth	: A/P-Bhilwade, Tal- Pathardi, Dist- Ahmednagar
	Father's name	: Mr. Sunil Jagannath Bade
	Mother's name	: Mrs. Savita Sunil Bade
Educational	Bachelor Degree Obtained	: College of Agriculture, Kolhapur
	Class	: Second Class
	Name of University	: Mahatma Phule Krishi Vidyapeeth, Rahuri
	Master Degree Obtained	: College of Agriculture, Latur
	Class	: First Division with Distinction
	Name of University	: Vasantrya Naik Marathwada Krishi Vidyapeeth, Parbhani
	Address	: Flat No. 4, Omkareshwar Apartment, Phase II, Near Savedi Bus Stop, Savedi, Ahmednagar, Tal and Dist- Ahmednagar, Pin- 414 003
	Email-id	: anandbade11@gmail.com
	Contact number	: 9420009118