

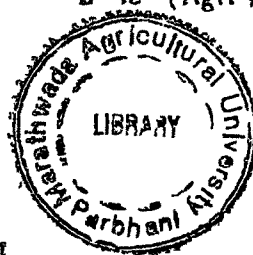
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**STUDIES ON THE EFFICACY OF Bacillus
thuringiensis BERLINER AND DIFLUBENZURON
AGAINST Achaea janata L. AND Bombyx mori L.**

BY
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B Sc (Agri)

T 1308



Dissertation

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PARBHANI
1987**

CANDIDATE'S DECLARATION

I, hereby declare that the dissertation
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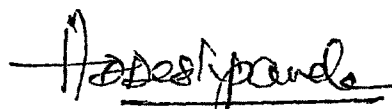

(A.D. DESHMUKH)

CERTIFICATE-I

This is to certify that the dissertation entitled "STUDIES ON THE EFFICACY OF Bacillus thuringiensis BERLINER AND DIFLUBENZURON AGAINST Achaea janata L. AND Bombyx mori L." submitted to Marathwada Agricultural University, Parbhani for the award of degree of Master of Science in Agricultural Entomology is a record of original and bonafide research work prosecuted by Shri A.D. Deshmukh under my guidance and supervision. The dissertation is of sufficiently high standard to warrant its presentation for the award of said degree. The results embodied in the dissertation have not been submitted to any other University or Institution for the award of degree or diploma. The assistance received during the course of this investigation and sources of literature have been duly acknowledged.

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(A.D. DESHPANDE)

Guide

CERTIFICATE - II

This is to certify that the dissertation entitled " STUDIES ON THE EFFICACY OF Bacillus thuringiensis BERLINER AND DIFLUBENZURON AGAINST Achaea janata L. AND Bombyx mori L" submitted by Ashok Damodharrao Deshmukh to the Marathwada Agricultural University, Parbhani in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (Agriculture) in the subject of Agricultural Entomology has been approved by the student's advisory committee after oral examination in collaboration with external examiner.

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(A.D. DESHMUKH)

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ABBREVIATIONS

@	at the rate of
a.i.	active ingredient
cm	centimetre
<u>et.al.</u>	and others
g	gram(s)
ha	hectare
kg	kilogram
lb	pounds
lit	litre
mg	milligram
%	per cent
S.Em.	Standard error mean
ppm	parts per million
µg	Microgram(s)
WP	Wettable powder

I. INTRODUCTION

1. INTRODUCTION

Microbial insecticides, because of their specificity and non toxicity or pathogenicity to non target animals are ideal biological control agents. Microbial insecticides are easier to use than the classical biological control agents i.e. parasites and predators because the grower can use them as he would ^{use} chemical insecticide, without any major change in agricultural equipment and procedure (Ignoffo, et al., 1974).

The development of insect pest resistance to certain insecticides, pest resurgence, environmental pollution and destruction of beneficial insects like parasites and predators had given new impetus to the continuing search for and development of alternate insect control methods during the past several years. Among the more promising of the biological agents, being tested for the control of various insect pests of agricultural importance, are strains of facultative spore forming bacterium, Bacillus thuringiensis Berliner (Heimpel, 1967).

About 20 varieties of B. thuringiensis cause pathogenicity in about 200 insect species of Lepidoptera (Deshpande, 1986).

The entomopathogenic activity of a variety differs in various insects and different varieties and strains of

bacterium exhibit differential susceptibility in the same host. Jaques and Fox (1960) first reported the differential toxicity of various varieties in the host, Pieris brassicae L. It is well known that the susceptibility of the host depends on the variety of B. thuringiensis (Dulmaoe, 1970b).

Castor, Ricinus communis L. is the main non edible oilseed crop of the tropic, where it is extensively cultivated. It is also a good source of foreign exchange for India. India is the second largest castor producer in the world with an area of 501.011 thousand hectares and production of 210.138 thousand tonnes. (Anonymous, 1982). Among the 61 pests damaging the crop, castor semilooper, Achaea janata L. shares the first status of major pest with castor capsule borer, Dichocrosis punctiferalis causing heavy losses by defoliation (Hai, 1976).

In field trials alongwith various chemical treatments, commercial formulation of B. thuringiensis have been successfully tried as one of the treatments for the control of castor semilooper (Kulshreshtra, et al., 1965). Similarly, Govindarajan et al. (1976) tested the efficacy of the formulated product and studied the mode of action of the bacterium in the pest.

Further, due to the pathogenicity of B. thuringiensis to silkworm, there is a controversy in the country regarding the use of this bacterium against agricultural pests. Hence, it is necessary to study the differential pathogenicity of various formulations of the bacterium against the pest as well as against the silkworm.

Insect growth regulator like diflubenzuron (Dimilin) was also successful in killing insect by inhibiting moulting. Good results of complete mortality against third instar larvae of Pieris rapae L. were given by diflubenzuron (Mo. krousova, 1977).

Hence, studies were undertaken on the comparative efficacy of different formulations of B. thuringiensis and diflubenzuron against A. janata and B. mori to find out the most effective formulation of the products against A. janata.

II. REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The emphasis of this study was centred around efficacy of endotoxin based Bacillus thuringiensis, Biobit containing B. thuringiensis variety (kurstaki) and diflubenzuron (Dimilin). Accordingly the chapter is divided into three parts.

- 2.1 The endotoxin based B. thuringiensis
 - 2.2 Biobit containing B. thuringiensis variety (kurstaki)
 - 2.3 Diflubenzuron (Dimilin 50 WP)
-
- 2.1 The endotoxin based B. thuringiensis
 - 2.1.1 Comparative toxicity of endotoxin based B. thuringiensis to insects under laboratory condition
 - 2.1.2 Comparative toxicity of endotoxin based B. thuringiensis to insects under field condition
 - 2.2 Biobit containing B. thuringiensis variety (kurstaki)
 - 2.2.1 Comparative toxicity of B. thuringiensis variety (kurstaki) to insects under laboratory condition
 - 2.2.2 Comparative toxicity of B. thuringiensis variety (kurstaki) to insects under field condition
 - 2.3 Diflubenzuron (Dimilin)

2.3.1 Toxicity of difluberzuron to insects under laboratory condition

2.3.2 Toxicity of diflubenzuron to insects under field condition

2.1.1 Comparative toxicity of endotoxin based Bacillus thuringiensis to insects under laboratory condition :

Galowalia et al. (1973) also studied the comparative potencies of the crystalline endotoxin of eight varieties of B. thuringiensis. They had selected 5th instar larvae of Pieris brassicae and were allowed to feed on the microdisc. The varieties, thuringiensis, morrisoni, entomocidus and galleriae showed similar toxicity. Variety tolworthi was one third and varieties, alesti and sotto were too weakly toxic to allow their potencies to be accurately determined. Tests with Bombyx mori indicated an entirely different order of potencies in which varieties, entomocidus, sotto, alesti and aiawai were the most toxic and variety tolworthi and thuringiensis the least.

Fast (1977) conducted experiment against sixth instar larvae of Choristoneura fumiferana (Clem.) with purified crystals, purified spores, or mixture of equal quantities of purified spores and purified crystals of B. thuringiensis and reported ^{that} spores were 200 times

less toxic than crystals for which the LD_{50} was 0.094 $\mu\text{g}/\text{larvae}$.

Schesser and Bulla (1981) studied the toxicity of B. thuringiensis parasporal crystals to larvae of Plodia interpunctella (Hb.) . The number of insects killed were in relation to crystal dry weight, mortality was determined by comparing adult emergence from larval diet treated with crystal with emergence from untreated diets. There was only 30 per cent survival at an application of 0.414 $\mu\text{g}/\text{cm}^2$ and the mean LC_{50} was found to be 0.299 $\mu\text{g}/\text{cm}^2$.

Salama et al. (1981) studied potercy of spore delta endotoxin complex in laboratory in Egypt against the cotton pest Spodoptera littoralis (Boisd), H. armigera (Hb.) and S. exigua (Hb.). LC_{50} s of the endotoxin produced by B. thuringiensis (entomocidus) were 30.5 $\mu\text{g}/\text{ml}$ diet for S. littoralis and 110.5 $\mu\text{g}/\text{ml}$ diet for S. exigua and LC_{50} for (aizwai) for H. armigera was 79.8 $\mu\text{g}/\text{ml}$ diet.

Deshpande and Hamakrishnan (1982) did comparative bioassay of spore + endotoxin and predissolved endotoxin against 5th instar larvae of A. janata and reported that variety kurstaki was more pathogenic followed by variety galleriae and berliner. Varieties sotto, entomocidus and aizwai or their endotoxin alone did not show pathogenicity to 5th instar larvae of A. janata.

Ignoffo et al. (1982) carried out an experiment in laboratory in USA and reported that larvae of the potato pest Leptinotassa decemlineata (Say) were susceptible to the delta endotoxin of B. thuringiensis (kurstaki). Percentage mortality increased with the application rate.

Salama and Foda (1984) studied susceptibility of some cotton pest to B. thuringiensis. The spores and endotoxin preparations were tested in laboratory in Egypt for effectiveness against Pectinophora gossypiella (Saunders), Earias insulana (Boisduval)

and Aerotis ipsilon (Hfn.). The most effective sub sp. were B. thuringiensis finitimus against P. gossypiella, B. thuringiensis entomocrius against E. insulana and B. thuringiensis tolworthi against A. ipsilon.

Sai et al. (1984) tested three preparations of delta endotoxin purified from one strain (thuringiensis) and two from (Kurstaki) in the laboratory in Belgium against third instar larvae of Spodoptera littoralis (Boisduval). The LD_{50} s were 454.6, 1.184 and 594.1 ppm for three strains respectively.

2.1.2 Comparative toxicity of endotoxin based

B. thuringiensis to insects under field condition:

Chilingaryan et al. (1977) tried Bitoxibacillin (BTP) a crystalline form of B. thuringiensis against

Tetranychus urticae Koch on cucumber in the glass house. Mortality was 91 per cent, 84 per cent and 70 per cent after 10, 15 and 20 days in 1975 and 96 and 86 per cent after 15 and 20 days in 1976. Most effective concentration appeared to be 1 per cent.

An outbreak of Satin moth, Stilbonotia salicis on poplar in western Switzerland was successfully controlled by applying endotoxin, resulting in heavy mortality of larvae 92-94 per cent a week after treatment (Maksymov, 1980).

Baranovskii et al. (1986) tested 'Lepidocide' produced from crystals of (kurstaki) in fields of Siberia and reported that 'Lepidocide' was highly effective against Dendrolimus sibiricus on larch (Larix sibirica) and superior to 'Dendro bacillin'.

2.2.1 Comparative toxicity of Bacillus thuringiensis variety (kurstaki) to insects under laboratory condition :

Varma et al. (1974 b) 'Thricide HPSC' @ 1.5 g/lit and 'Dipel' @ 1.0 and 1.5 g/lit (both 'kurstaki') preparations proved equally effective, giving more than 80 per cent mortality of Pieris brassicae L. six days after treatment.

Dobrivojevic and Injac (1975) tried 'Dipel' (kurstaki) and 'Bactospene' (thurinogensis) @ 0.5, 0.125 and 0.031 per cent 'Dipel' proved to be most effective with LD₅₀ of 11 ppm as compared with LD₅₀ of 18 ppm in 'Bactospeine'.

Govindarajan et al. (1976) stated 'Thuricide 90 TS' flowable at concentration of 1 ml in 40-600 ml water produced 100 per cent mortality in averaged 1.1^c, 2.03, 6.11 and 6.16 days of A. janata first, second, third and fourth instar respectively.

Zivanovic and Stamenkovic (1976) evaluated 'Dipel' (kurstaki) containing 16000 IU/mg in laboratory in Yugoslavia against Hyphantria cunea (Dru) second to seventh instar and reported that 0.1 per cent 'Dipel' afforded complete mortality of larvae in second to fifth instar in seven days. In a field test 0.1 per cent 'Dipel' gave 100 per cent mortality of larvae of H.cunea in third, fourth and fifth instars, but had no effect on the other orchard pests.

Berti Filho and Gallo (1977) studied effect of 'Dipel' (kurstaki) containing 16000 IU/mg against palmworm Brassolis astyra astyra Godt. and found that 0.1 per cent concentration by feeding has resulted in heavy mortality of test insects.

Srivastava and Nayak (1978) tested the comparative efficacy of 'Dipel' (kurstaki) WP containing 25×10^9 viable spores, 'Bactospeine' containing 1.6×10^8 spores of B. thuringiensis per g and 'Thuricide HP' containing 30×10^6 spores of (kurstaki) per mg against Cnaphalocrosis medinalis (Gn.). All product at 0.0625 per cent to 1 per cent gave significant control. 'Thuricide' and 'Dipel' were superior to 'Bactospeine' and 'Cajarab'. 'Bactospeine' and 'Thuricide' were equally effective at 0.5 and 1 per cent while 'Dipel' had similar mortality effect at 0.125 and 0.5 per cent.

Nayak et al. (1978) studied effect of 'Thuricide HP' (kurstaki) and reported that 1 per cent 'Thuricide HP' spraying reduced damage by Scirpophaga incertulas and reduced the number of dead hearts by 76.36 per cent, white heads by 67.45 per cent and number of living larvae in tillers by 76.87 per cent in rice.

Dabi et al. (1980) evaluated six concentrations of 'Dipel' (kurstaki) against third and fifth instar larvae of Euproctis lunata Wlk. on pearl millet in laboratory in Rajasthan, India. Most effective treatment after 96 hrs of application was 'Dipel' 1120 g/ha (17.92×10^9 IU/ha).

Dabi et al. (1980) studied effectiveness of 'Dipel' (kurstaki) against final instar larvae of Spilosoma obliqua Wlk. infesting sesame in laboratory in India. Maximum mortality of 96 per cent after 72 hrs was observed by treated leaves with a dose of 16000 IU/ml of solution .

Gangwar et al. (1981) studied formulation against third instar larvae of Aganais ficus (F.) Hymenia recurvalis F. and Euproctis fraterna (Moore) in laboratory in India and reported that 'Dipel' (kurstaki) was found to be most effective against A. ficus and least effective against F. fraterna. The high mortalities observed after treatment with a low concentration of 'Dipel' was 0.05 per cent.

McLeod et al. (1982) studied efficacy of 'Dipel' (kurstaki) against Dioryctria amatella (Hulst.) in laboratory in Arkansas. First instar larvae were more susceptible with a LC_{50} of 0.64 IU/ml diet and for second instar 42.3 IU/ml.

Deshpande and Ramakrishnan (1982) tested six varieties of B. thuringiensis against A. janata. They claimed the superiority of variety kurstaki as compared to other varieties tested against A. janata.

Cohen et al. (1983) in laboratory studies of formulation 'Bactospeine' (thuringiensis) and 'Dipel' (kurstaki) against Boarmia selenaria (Denis and Schiff)

in Israel observed that both were highly effective against second and third instar larvae at a concentration 3×10^8 units/ml and against fourth instar at a concentration 3×10^9 units/ml .

Jensens et al. (1986) tested four preparation of B. thuringiensis in Belgium against first to fifth instar larvae of Spodoptera littoralis. Formulations of 'Thuricide' WP, 'Dipel' WP and 'ABG 6105' contained (kurstaki) while 'Bactospeine' contained (thuringiensis) 'ABG 6105' caused highest mortality followed by 'Dipel' WP and 'Bactospeine'. 'Thuricide' WP was not effective . Larval susceptibility to all active formulation decreased with increasing larval age.

2.2.2 Comparative toxicity of Bacillus thuringiensis variety (kurstaki) to insects under field condition:

Yunusov (1974) controlled Adelphocoris lineolatus to 40 per cent by 0.3 per cent 'Dendrobacillin' (dendrolimus), 56 per cent by 0.3 per cent 'Entobakterin' (galleriae), 71.2 per cent by 0.3 per cent 'endotoxin' (thuringiensis) and 79.2 per cent by 0.3 per cent 'Dipel' (kurstaki).

Wysoki et al. (1975) reported 'Dipel' containing 3.2 per cent B. thuringiensis variety (kurstaki) at 0.25 - 1.5 per cent gave complete mortality of Cryptoblabes gnidiella (Mill) in all stages.

Creighton and McFadden (1975) proved that 'Dipel' (kurstaki) 3.2 per cent WP was more effective in reducing plant damage than was flowable powder or WP formulation of 'Bactospeine' (thuringiensis) . Pests controlled were Trichoplusia ni, Pieris rapae and Plutella xylostella.

Niemezyk et al. (1976) carried out field tests with 'Dipel' (kurstaki) . Three applications of 0.3 per cent or two applications of 0.4 per cent 'Dipel' reported to reduce the number of apples damaged by Cydia pomonella by more than 70 per cent.

Cavalcaselle (1976) tried 'Bactospeine Pm 600' and 'Dipel' (kurstaki) against Thaumetopoea pityocampa (Schiff) in field. They reported that 2 and 3 kg/ha were effective , giving highly significant larval mortality.

Dronka et al. (1976) tested 'Dipel' (kurstaki) against Eutromula pariana (CL) and found excellent control of larvae with a single application of 'Dipel' at 0.1 , 0.2 and 0.3 per cent which was as effective as sprays of malathion and dichlorovos.

McNeil et al. (1977) conducted field tests in Quebec and concluded that Thymelicus lineola (Ochs) on timothy grass can be controlled by 'Dipel' (kurstaki) $5 - 10 \times 10^9$ IU/ha.

Cruz (1977) conducted field test in Brazil with 'Makapel 320' B. thuringiensis a dust containing 320 IU/mg applied at 26 kg/ha and 'Dipel' WP containing 16000 IU/mg applied at 0.4 per cent spray against Erinnyis ello (L.) on rubber and reported 98 and 96 per cent mortality by 'Makapel' and 'Dipel' respectively.

Pascovici et al. (1978) conducted trial in forest of Oaks (Quercus) against Lymantria dispar L. and tried 'Dipel' and 'Thuringin' in Romania, Maximum mortality of 90-98 per cent was recorded on 9th to 12th day.

Saxena (1979) tried 'Dipel' (kurstaki) against third instar larvae of Athalia-lugens proxima (Klug.) in India. Three concentrations 0.2, 0.1 and 0.05 per cent were tested and resulted in more than 50 per cent larval mortality after three days and 100 per cent after four days. Toxicity was lost after seven days.

Awate and Naik (1979) conducted field plot test for the control of Phthorimaea operculella (Zell) on potato in India and reported foliar sprays of 'Thuricide' (kurstaki) at 2.5 kg/ha is equally effective with spray of quinalphos at 500 g a.i./ha.

Manchev (1980) tried 'Dipel' (kurstaki) against silkworm in Bulgaria and found that 0.003 per cent 'Dipel' caused 77.3, 66.2, 38.0 and 13.8 per cent mortality in the

first, second, third and fourth instar of mulberry silkworm after varying number of days.

Krishnaiah et al. (1981) conducted field studies in Karnataka, India for effectiveness of 'Dipel' (kurstaki) against Earias vitella (F.) on okra, H. armigera (Hub.) on tomato, Plutella xylostella (L.) on cabbage and reported that weekly spraying of 'Dipel' at 0.5 kg/ha controlled E. vitella 'Dipel' spraying at 10 days at 0.5 kg/ha controlled H. armigera (Hub.) effectively.

Sarmiento and Pazuri (1982) conducted field test on maize in Peru and compared effectiveness of 'Dipel' (kurstaki) with insecticides for the control of Spodoptera frugiperda and Diatraea saccharalis F. It was concluded that 'Dipel' was superior to carbaryl against S. frugiperda.

Krishnaiah and Mohan (1983) concluded that 'Dipel' (kurstaki) was capable in suppressing the population of Plutella xylostella (L) and Myzus persicae (Sulz) on cabbage for one week.

Smirnoff (1985) tested the new formulation 'Futura' of (kurstaki) in aerial spraying against Choristoneura fumiferana in Quebec. 'Futura' with 20×10^9 IU/ha in final volume of 2.5 litre/ha spraying

by two aircraft gave 91 and 88.7 per cent larval mortality and resulted in 86.6 and 75.1 per cent foliage protection. These results are better than those obtained with formulation used earlier at 4.7 litres/ha.

2.3.1 Toxicity of diflubenzuron (Dimilin) to insects under laboratory condition :

Zabel and Ostojic (1973) tried diflubenzuron (PH 60-40), and found that complete mortality of second instar larvae of Malcosoma neustria resulted from a dose of 12.5 - 37.5 ppm, and third instar with 50-300 ppm. In Lymantria dispar L. third, fourth and fifth instar suffered 100 per cent mortality with 200 ppm. Total mortality of third instar of Hyphantria cunea (L.) was obtained with 25-100 ppm.

Hartinger (1976) evaluated diflubenzuron (Dimilin) near Munich against larvae of Yponomeuta euonymellus (L.) and reported 100 per cent mortality of fourth and fifth instar at 0.6 and 60 ppm.

Lipa (1976) evaluated diflubenzuron (Dimilin) 25 per cent WP in laboratory of Poland against Agrotis segetum (Schiff) and Mamestra brassicae (L.). They reported heavy mortality of both insects at a concentration of 0.00025-25 ppm through diet.

Sundaramurthy (1977) reported 0.1 per cent diflubenzuron fed to final instar larvae of Spodoptera litura (F.) with castor leaves has resulted in 46-96 per cent inhibition of moulting and various degrees of morphological deformity in the pupae.

Ascher et al. (1978) studied effect of diflubenzuron on larvae of Earias insulana (Boisd) a pest of cotton, in Israel and reported 99.2-100 per cent and 76.00 to 94.5 per cent mortality for small and large larvae respectively with diflubenzuron WP incorporated in artificial diet at 0.005-0.1 per cent.

Coudriet and Seay (1979) tested diflubenzuron against Trichoplusia ni (Hub.), Spodoptera exigua (Hub.) and Heliothis virescens (F.) in laboratory in USA and reported that larvae of three insects in first three instar were more susceptible than those in later instar. Fifth instar of T. ni were more susceptible to a concentration of 100 ppm than other two species.

Diflubenzuron was tested in the laboratory in Cairo, Egypt, against the eggs and larvae of Spodoptera littoralis (Boisd) . It was effective at low doses against the larvae. LC_{50} after 96 hrs was 0.0005-0.0013 per cent (EL Sayeed, 1980).

Rabindra and Balasubramanian (1981) determined the effect of diflubenzuron against larvae of A. janata in laboratory in India. The lowest concentration tested 0.05 g/lit inhibited moulting and cause 96 per cent mortality while 1.0 g/lit caused 100 per cent mortality.

Elliott and Iyer (1982) in British Columbia laboratory carried out test and showed that nymphs of Melanoplus sanguinipes (F.) were sensitive to diflubenzuron. At concentration 10 ppm and above diflubenzuron completely inhibited moulting of second instar nymphs.

Rajendran and Shivaramaiah (1983) studied effect of diflubenzuron on the larvae of Trogoderma granarium Everts and reported that 12.8 mg/a.i./kg diet caused 94, 80 and 76 per cent mortality in larvae of 3, 7 and 14 days old respectively.

Velcheva (1983) studied the effectiveness of diflubenzuron (Dimilin) against Mamestra brassicae L in Bulgaria at concentration 25, 37.5, 75, 250, 375 and 750 ppm. In the laboratory 100 per cent larval mortality occurred on fourth day with 750 ppm, on the eighth day with 250 ppm and on the tenth day with 37.5 or 25 ppm. In the field, 100 per cent mortality of third instar larvae was obtained seven days after

treatment with 250 ppm.

Chokalingam and Noorjahan (1984) tried difluberzuron (Dimilin) against Dysdercus cingulatus and Chrysocoris purpureus in laboratory in India. LC_{50} and LC_{100} was 100 and 1000 ppm respectively. Egg hatch was reduced in eggs upto 48 hrs old at exposure.

2.3.2 Toxicity of diflubenzuron (Dimilin) to insects under field condition :

Audemard et al. (1975) reported that larvae of Cydia pomonella (L.) was completely eradicated with a dose of 30 g/hl diflubenzuron.

Frye et al. (1976) has observed that the highest mortality of Paleacrita vernata (Peck) in forest by the application of diflubenzuron (Dimilin) at 0.113 kg/acre at North Dakota.

Granett et al. (1976) conducted field tests and reported that difluberzuron (Dimilin) at a rate of 0.0078 lb toxicant/1045 gal water to apple trees infested with Lymantria dispar L. has effected mortality 100, 99.6 and 78.3 per cent first, second and third instar larvae respectively.

Mokrousova (1977) studied effect of diflubenzuron against Pieris rapae (L.), Spodoptera exigua (Hub.) .

and Leptinotarsa decemlineata (Say). Complete mortality of third or fourth instar larvae of above insects was given by diflubenzuron at 0.1 or 0.01 per cent.

Godais et al. (1978) sprayed diflubenzuron by aircraft against Thaumetopoea pityocampa (Schiff) on pine and reported that a single application in August 76 resulted in about 98 per cent mortality in November, 1976.

Natesan and Balasubramanian (1979) conducted field trial in Tamil Nadu, India, against Spodoptera litura (F.) on groundnut and reported, 0.02 per cent diflubenzuron caused 77.14 per cent mortality 144 hrs after treatment.

Field plot test carried out in Tamil Nadu, India, against S. litura (F.) on tobacco with 0.01 per cent diflubenzuron and it gave 27.59 and 90.66 per cent reduction of larval population in two and seven days respectively (Santharam and Balasubramanian, 1980).

Dulic and Injac (1981) studied effect of diflubenzuron (Dimilin) in apple orchard in Yugoslavia against the pest Leucoptera scitella Zell, Lithocolletis blancardella F. and L. corylifoliella. Spray of 0.05 diflubenzuron (Dimilin) were effective against L. scitella causing 95.81 and 78 per cent mortality.

Retnakaran and Tomkin (1982) applied diflubenzuron (Dimilin) and triflumuron in sprays as 1 per cent suspension in sunspray oil to Red Oak trees (Quercus rubra) in the

field in Ontario and reported a reduction in populations of Croesia semipurpurana (Kearfott) by 99.4 and 100 per cent respectively.

Guzeev and Mansurov (1983) reported control of Neoris huttoni Moore infesting pistachio in USSR, trichorfon, parathion methyl and phosalone at 0.6 kg a.i./ha and diflubenzuron (Dimilir) at 0.05 kg a.i./ha and were highly effective against second and third instar larvae, causing 99.4, 95.5, 90.4 and 95.3 per cent mortality respectively.

Jaipal (1985) carried field plot test in India and showed that spraying diflubenzuron at the rate of 200 mg a.i./litre and gave effective control of larvae of Diacrisia obliqua on pigeonpea Cajanus cajan and susceptibility to the insecticide decreased with larval instar.

III. MATERIALS AND METHODS

III. MATERIALS AND METHODS

The investigations were carried out to study the efficacy of endotoxin based Bacillus thuringiensis Berliner, Biobit B. thuringiensis variety kurstaki and diflubenzuron (Dimilin) against castor semilooper, Achaea janata L. and silkworm, Bombyx mori L. under laboratory conditions.

The materials used and methods adopted during the present investigation are presented in this chapter.

3.1 Test insects :

Castor semilooper (Achaea janata L.)

Family : Noctuidae, Order : Lepidoptera

Silkworm (Bombyx mori L.)

Family : Bombycidae, Order : Lepidoptera

3.1.1 Rearing of test insect A. janata :

A healthy laboratory culture of A. janata was maintained exclusively on castor leaves, Ricinus communis L. at $28^{\circ} \pm 2^{\circ}$ C throughout the experimental period. The first instar larvae collected from castor plants in the field were used as an initial source of culture. The larvae were reared in groups of 15 to 20 in sterilized plastic boxes of 10 x 25 cm size with clean castor leaves as food. The boxes were covered with muslin cloth held in position by rubber bands. The larvae were allowed to pupate on castor leaves inside the boxes. The moths

emerged after about 9-10 days. They were transferred by breeding cages. Cotton swab soaked in five per cent honey solution was kept in the cage as food for the moths. Castor leaves with petioles dipped in water in a conical flask served as a site for oviposition. The pre oviposition period was 5-6 days. The eggs were collected every day and reared separately in order to maintain uniform conditions for test insect. The eggs, larval and pupal periods were 3-4, 14-16 and 9-10 days, respectively. The adult longevity was 8-9 days. Experiment was conducted against 3rd instar larvae of A. Janata.

3.1.2 Rearing of test insect Bombyx mori L. :

Disease free eggs of mulberry silkworm were procured from the Sericulture Laboratory, M.A.U., Parbhani. Eggs were kept for hatching in the laboratory at room temperature. Egg sheets were kept in trays in cool place. Care was taken for protecting the eggs against rats, cockroaches and ants etc. After hatching of the eggs tender mulberry leaves were finely chopped and sprinkled over the young worms, which crawl on to the leaves and started eating from cut edges. Food was provided for four times a day. During moulting they were not provided with any food and were not disturbed. They eat voraciously during the fifth or last stage. In the last stage body of silkworm larvae became shiny and translucent with golden

colour. Such type of worms were mounted on the spinning trays called 'mountage' or Chandrika". Larvae spin the cocoon within 3 days. The pupae remain inside the cocoon till emergence. Adult moth do not require any food during their life span. Immediately after the emergence of adult, mating takes place. Females start laying eggs after mating for 3 hours. Experiment was conducted against 3rd instar larvae of B. mori .

3.2 Test material:

The details of the material and their doses used in the present investigation are given in Table 1.

3.3 Comparative bioassay of various formulations of B. thuringiensis and difluberzuron (Dimilin) against A. janata and B. mori:

3.3.1 Bioassay with endotoxin based B. thuringiensis :

The material was available as wettable powder as well as in liquid form. In the bioassay study with, above toxin, serial dilutions of 1.00, 0.75, 0.5, 0.25, 0.125, 0.062 and 0.031 per cent concentrations were prepared from the wettable powder and liquid formulations with distilled water including sandovit as a sticker. Discs of 2.5 cm diameter were cut out from castor leaves for A. janata and mulberry leaves for B. mori, and were applied with 50 µl of each of the dilution, starting with lowest concentration with the help of camel hair brush, and were

Table 1 : Details of material used in experimentation

Sr. No.	Technical name/ chemical name	Trade name	Formulation	Conc./ spore count	Source of supply
1.	Endotoxin based				
	<u>Bacillus thuringiensis</u> Berliner	-	Wettable powder and liquid without spore	-	Hindustan Lever Ltd., Bombay
2.	<u>Bacillus thuringiensis</u> variety (kurstaki)	Biobit	Wettable powder and liquid	16000 IU/g	Microbial Resources Limited, Theale Technology Centre, Theale, Berkshire
3.	Diflubenzuron	Dimilin	Wettable powder	50 % a.i.	Coromandel Indag Product, India(P) Ltd.

allowed to dry under fan. These treated leaf discs were placed in specimen tube (one discs per tube) and 3rd instar larvae which were previously starved for 2 hrs were released (one larva per tube). These specimen tubes were closed with muslin cloth held in position by rubber band. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration. Adequate number of larvae were kept as control. Mortality data were recorded at an interval of 12 hrs upto 96 hrs. Separate experiments were laid out for different formulations i.e. wettable powder and liquid as well as for different test insects i.e. A. janata and B. mori.

3.3.2 Bioassay with Biobit containing B. thuringiensis :

The material (B. thuringiensis variety kurstaki) was available in wettable powder as well as liquid formulation. In the bioassay study, with above micro organism, serial dilutions of 1.00, 0.75, 0.5, 0.25, 0.125, 0.062 and 0.031 per cent concentrations were prepared with distilled water including sardovit as a sticker. Discs of 2.5 cm diameter were cut out from castor leaves for A. janata and mulberry leaves for B. mori and were applied with 50 µl of each of the dilution, starting with lowest concentration with the help of camel hair brush, and were allowed to dry under fan. These treated leaf discs were placed in specimen tube (one disc per tube) and third instar larvae which were previously starved for

2 hrs were released (one larvae per tube). These specimen tubes were closed with muslin cloth held in position by rubber band. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration. Adequate number of larvae were kept as control. Mortality data were recorded at an interval of 12 hrs upto 96 hrs. Separate experiments were laidout for different formulations i.e. wettable powder and liquid as well as for different test insects i.e. A. janata and B. mori.

3.3.3 Bioassay with diflubenzuron (Dimilin) :

In the bioassay study, with above material serial dilution of 1.00, 0.75, 0.50, 0.25, 0.125 and 2.00, 1.00, 0.75, 0.50, 0.25, 0.125, 0.062, 0.035 per cent concentrations were prepared with distilled water including sandovit as a sticker for A. janata and B. mori, respectively. Discs of 2.5 cm were cut out from castor leaves for A. janata and mulberry leaves for B. mori and were applied 50 μ l of each of the dilution, starting with the lowest concentration with the help of camel hair brush and were allowed to dry under fan. These treated leaf discs were placed in specimen tube (one disc per tube) and 3 rd instar larvae which were previously starved for 2 hrs were released (one larvae per tube). These specimen tubes were closed with muslin cloth held in position by rubber band. Treated leaf discs

were again offered after 24 and 48 hrs as a second and third dose of the chemical. Fresh food was offered at 24 hrs interval after completion of feeding by treated leaves. A total of 10 larvae were treated for each concentration. Adequate number of larvae were kept as control. Mortality data were recorded at an interval of 12 hrs upto 216 hrs. Separate experiment was laid out for different test insects i.e. A. janata and B. mori .

3.4 Statistical analysis :

In the bioassay studies, the mortality data were subjected to Abbot's formula for corrected mortality. The LC_{50} values were calculated by probit analysis (Finney, 1977). In case of paired samples in the experiment on studies 't' test was applied for the comparison of the data (Sukhatme and Amble, 1978).

IV. RESULTS

IV. RESULTS

In the present investigation, different formulations of Bacillus thuringiensis Berliner and Diflubenzuron (Dimilin) were tested for their efficacy against third instar larvae of castor semilooper, Achaea janata L. and silkworm Bombyx mori L. Different concentrations were tested against third instar larvae by feeding and mortality data were recorded. The data thus collected were subjected to the probit analysis. The results obtained in the present investigation are described under the following subheads.

- 4.1 Results on the efficacy of B. thuringiensis against A. janata
 - 4.1.1 Efficacy of endotoxin based B. thuringiensis WP against A. janata
 - 4.1.2 Efficacy of endotoxin based B. thuringiensis liquid against A. janata
 - 4.1.3 Efficacy of Biobit WP containing B. thuringiensis against A. janata
 - 4.1.4 Efficacy of Biobit liquid containing B. thuringiensis against A. janata
- 4.2 Results on the efficacy of B. thuringiensis against B. mori

- 4.2.1 Efficacy of endotoxin based B. thuringiensis WP against B. mori
- 4.2.2 Efficacy of endotoxin based B. thuringiensis liquid against B. mori
- 4.2.3 Efficacy of Biobit WP containing B. thuringiensis against B. mori
- 4.2.4 Efficacy of Biobit liquid containing B. thuringiensis against B. mori
- 4.3 Results on the efficacy of Diflubenzuron WP (Dimilin) against A. janata and B. mori
 - 4.3.1 Efficacy of Diflubenzuron WP (Dimilin) against A. janata
 - 4.3.2 Efficacy of Diflubenzuron WP (Dimilin) against B. mori
- 4.1.1 Efficacy of endotoxin based B. thuringiensis WP against A. janata

The different concentrations of endotoxin based B. thuringiensis WP were prepared and applied to discs of castor leaves and dried under fan. These treated leaf discs were fed to 3rd instar larvae of A. janata in specimen tube. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration and mortality data at an interval of 12 hrs upto 96 hrs were recorded which is given in Table 2.



Table 2 : Efficacy of endotoxin based B. thuringiensis
WP against A. janata

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Concentration in percentage	Percentage mortality up to 96 hrs	Corrected percentage mortality
0.031	50.00	44.44
0.062	60.00	55.55
0.125	80.00	77.77
0.250	80.00	77.77
0.500	90.00	88.88
0.750	90.00	88.88
1.000	100.00	100.00
Control	10.00	-

The above data were subjected to probit analysis and the regression equation for the mortality has been worked out to be $Y = 3.3369 + 1.0278 x$ and LC_{50} value was 0.041.

4.1.2 Efficacy of endotoxin based B. thuringiensis
liquid against A. janata :

The different concentrations of endotoxin based B. thuringiensis liquid were prepared and applied to discs of castor leaves and dried under fan. The treated leaf discs were fed to 3rd instar larvae of A. janata in specimen tube. Fresh food was offered at 24 hrs interval.

A total of 10 larvae were treated for each concentration and mortality data at an interval of 12 hrs upto 96 hrs were recorded which is given in Table 3 .

Table 3 : Efficacy of endotoxin based B. thuringiensis liquid against A. janata

Concentration in percentage	Percentage mortality upto 96 hrs	Corrected percentage mortality
0.031	20.00	11.11
0.062	60.00	55.55
0.125	70.00	66.66
0.250	80.00	77.77
0.500	90.00	88.88
0.750	100.00	100.00
1.000	100.00	100.00
Control	10.00	-

The above data were subjected to probit analysis and the regression equation for the toxicity has been worked out to be $Y = 3.1217 + 1.1376 x$ and LC_{50} value was 0.044.

Perusal of the data presented in Table 2 and 3 in Fig. 1 revealed that the LC_{50} values for endotoxin based B. thuringiensis WP was 0.041 per cent and for liquid formulation was 0.044 per cent against third instar larvae of A. janata.

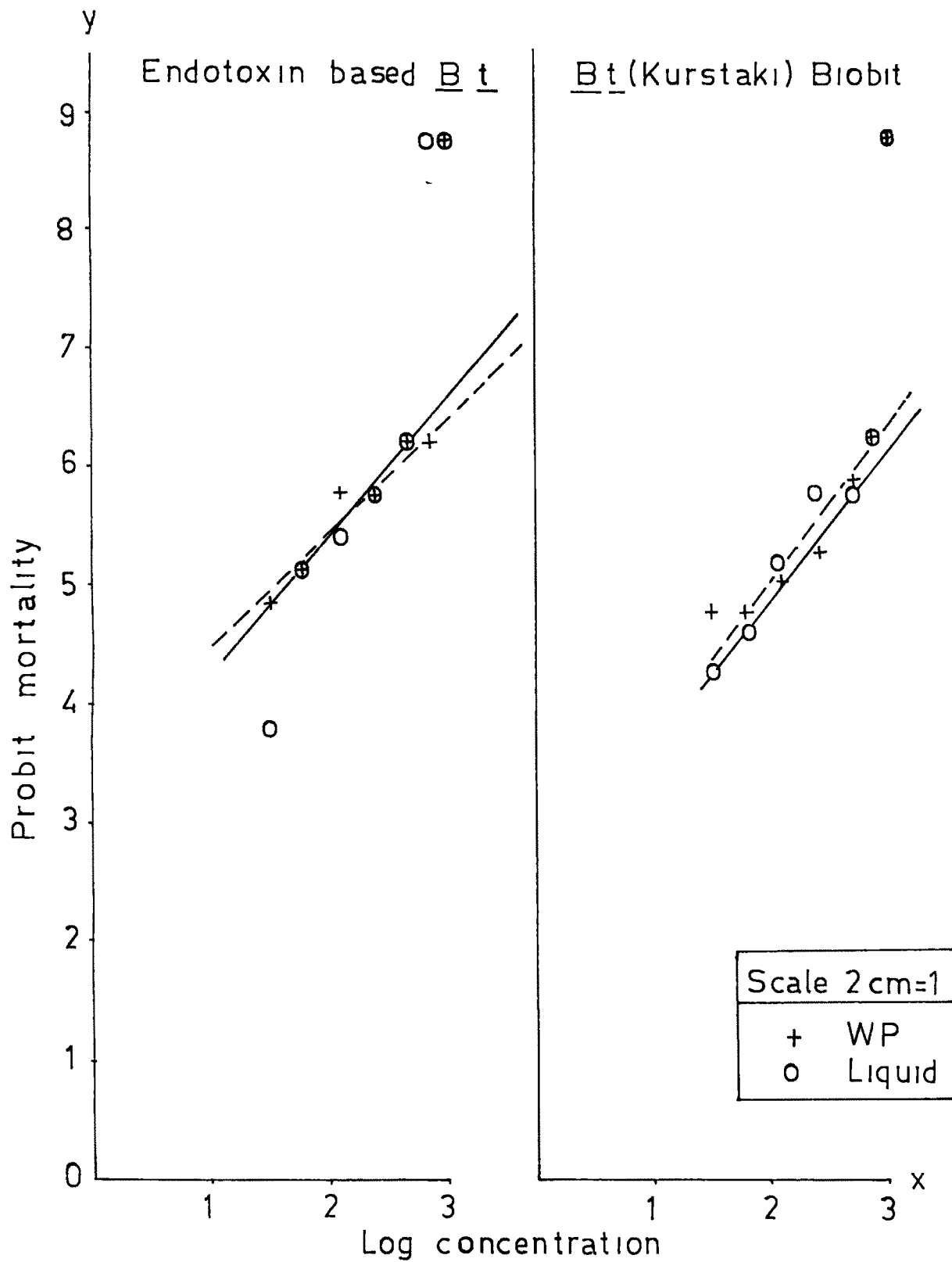


Fig 1 LOG CONCENTRATION-PROBIT KILL REGRESSION LINES OF ENDOTOXIN BASED B thuringiensis AND BIOBIT AGAINST THIRD INSTAR LARVAE OF A janata

The data on the comparison of LC_{50} values of the two formulations of endotoxin based B. thuringiensis are presented in Table 4.

Table 4 : Comparison of Log LC_{50} of endotoxin based B. thuringiensis against A. janata

Formulation of endotoxin	Log LC_{50}	S.E. _m	t value in comparison to
Wettable powder	1.6128	0.2555	
Liquid	1.6435	0.2451	0.0416

There is no significant difference between Log LC_{50} value of wettable powder and liquid formulation of endotoxin based B. thuringiensis against A. janata.

4.1.3 Efficacy of Biobit WP containing B. thuringiensis against A. janata :

The different concentrations of WP containing B. thuringiensis variety (kurstaki) were prepared and applied to discs of castor leaves and dried under fan. These treated leaf discs of castor leaves were fed to 3rd instar larvae of A. janata in specimen tube. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration and mortality data at an interval of 12 hrs upto 96 hrs were recorded which is given in Table 5.

Table 5 : Efficacy of Biobit WP containing B.thuringiensis against A. janata

Concentration in percentage	Percentage mortality up to 96 hrs	Corrected percentage mortality
0.031	40.00	40.00
0.062	40.00	40.00
0.125	50.00	50.00
0.250	60.00	60.00
0.500	80.00	80.00
0.750	90.00	90.00
1.000	100.00	100.00
Control	-	-

The above data were subjected to probit analysis and the regression equation for the toxicity has been worked out to be $Y = 2.1844 + 1.41 x$ and LC_{50} value was 0.0990.

4.1.4 Efficacy of Biobit liquid containing B.thuringiensis against A. janata :

The different concentrations of Biobit liquid containing B. thuringiensis variety (kurstaki) were prepared and applied to discs of castor leaves and dried under fan.

The treated leaf discs were fed to 3rd instar larvae of A. janata in specimen tube. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration and mortality data at an interval of 12 hrs upto 96 hrs were recorded which is given in Table 6.

Table 6 : Efficacy of Biobit liquid containing B. thuringiensis against A. janata :

Concentration in percentage	Percentage mortality upto 96 hrs	Corrected percentage mortality
0.031	30.00	22.22
0.062	40.00	33.33
0.125	60.00	55.55
0.250	80.00	77.77
0.500	80.00	77.77
0.750	90.00	88.88
1.000	100.00	100.00
Control	10.00	-

The above data were subjected to probit analysis and the regression equation for the toxicity has been worked out to be $Y = 1.3384 + 1.7895 x$ and LC_{50} value was 0.111.

Perusal of the data presented in Table 5 and 6 and Fig.1. revealed that the LC_{50} values for Biobit WP containing B. thuringiensis variety (kurstaki) was 0.099 and for Biobit liquid formulation was 0.111 per cent against third instar larvae of A. janata.

The data on the comparison of LC_{50} values of the two formulations of Biobit containing B. thuringiensis are presented in Table 7.

Table 7 : Comparison of Log LC_{50} of Biobit containing B. thuringiensis against A. janata

Formulation of Biobit	Log LC_{50}	S.Em.	t value in comparison to
Wettable powder	1.9956	0.128	
Liquid	2.0453	0.0103	0.0287

There is no significant differences between log LC_{50} values of wettable powder and liquid formulations of Biobit containing B. thuringiensis against A. janata.

From the efficacy of these four formulations of B. thuringiensis against A. janata it will be observed that the endotoxin based B. thuringiensis WP was better followed by endotoxin based B. thuringiensis liquid, Biobit WP containing B. thuringiensis variety (kurstaki) and Biobit liquid containing B. thuringiensis variety (kurstaki) as the values of LC_{50} were 0.041, 0.044, 0.099 and 0.111 per cent respectively.

4.2.1 Efficacy of endotoxin based B. thuringiensis WP against E. mori :

The different concentration of endotoxin based B. thuringiensis WP were prepared and applied to discs of

mulberry leaves and dried under fan. These treated leaf discs were fed to 3 rd instar larvae of B. mori in specimen tube. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration and mortality data at an interval of 12 hrs upto 96 hrs were recorded which are given in Table 8.

Table 8 : Efficacy of endotoxin based B. thuringiensis WP against B. mori

Concentration in percentage	Percentage mortality upto 96 hrs	Corrected percentage mortality
0.031	00.00	00.00
0.062	00.00	00.00
0.125	20.00	20.00
0.250	30.00	30.00
0.500	60.00	60.00
0.750	70.00	70.00
1.000	80.00	80.00
Control	-	-

The above data were subjected to probit analysis and the regression equation for the mortality has been worked out to be $Y = - 0.0348 + 1.9305 x$ and LC_{50} value was 0.398.

4.2.2 Efficacy of endotoxin based B. thuringiensis liquid against B. mori :

The different concentrations of endotoxin based B. thuringiensis liquid were prepared and applied to discs of mulberry leaves and dried under fan. The treated leaf discs were fed to 3rd instar larvae of B. mori in specimen tube. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration and mortality data at an interval of 12 hrs upto 96 hrs were recorded which is given in Table 9.

Table 9 : Efficacy of endotoxin based B. thuringiensis liquid against B. mori

Concentration in percentage	Percentage mortality up to 96 hrs	Corrected percentage mortality
0.031	00.00	00.00
0.062	00.00	00.00
0.125	20.00	11.11
0.250	30.00	22.22
0.500	60.00	55.55
0.750	70.00	66.66
1.000	80.00	77.77
Control	10.00	-

The above data were subjected to probit analysis and the regression equation for the toxicity has been worked out to be $Y = -0.3082 + 1.978 x$ and LC_{50} value was 0.481 per cent.

Perusal of data presented in Table 8 and 9 and Fig. 2 revealed that the LC_{50} value for endotoxin based B. thuringiensis WP was 0.398 per cent while LC_{50} value for endotoxin based B. thuringiensis liquid was 0.481 per cent against third instar larvae of B. mori.

The data on the comparison of LC_{50} values of two formulations of endotoxin based B. thuringiensis are presented in Table 10.

Table 10: Comparison of Log LC_{50} of endotoxin based B. thuringiensis against B. mori

Formulation of endotoxin	Log LC_{50}	S.E.m	t value in comparison to
Wettable powder	2.5988	0.0979	
Liquid	2.6821	0.0987	0.5992

There is no significant difference between log LC_{50} values of wettable powder and liquid, formulations of endotoxin based B. thuringiensis against B. mori.

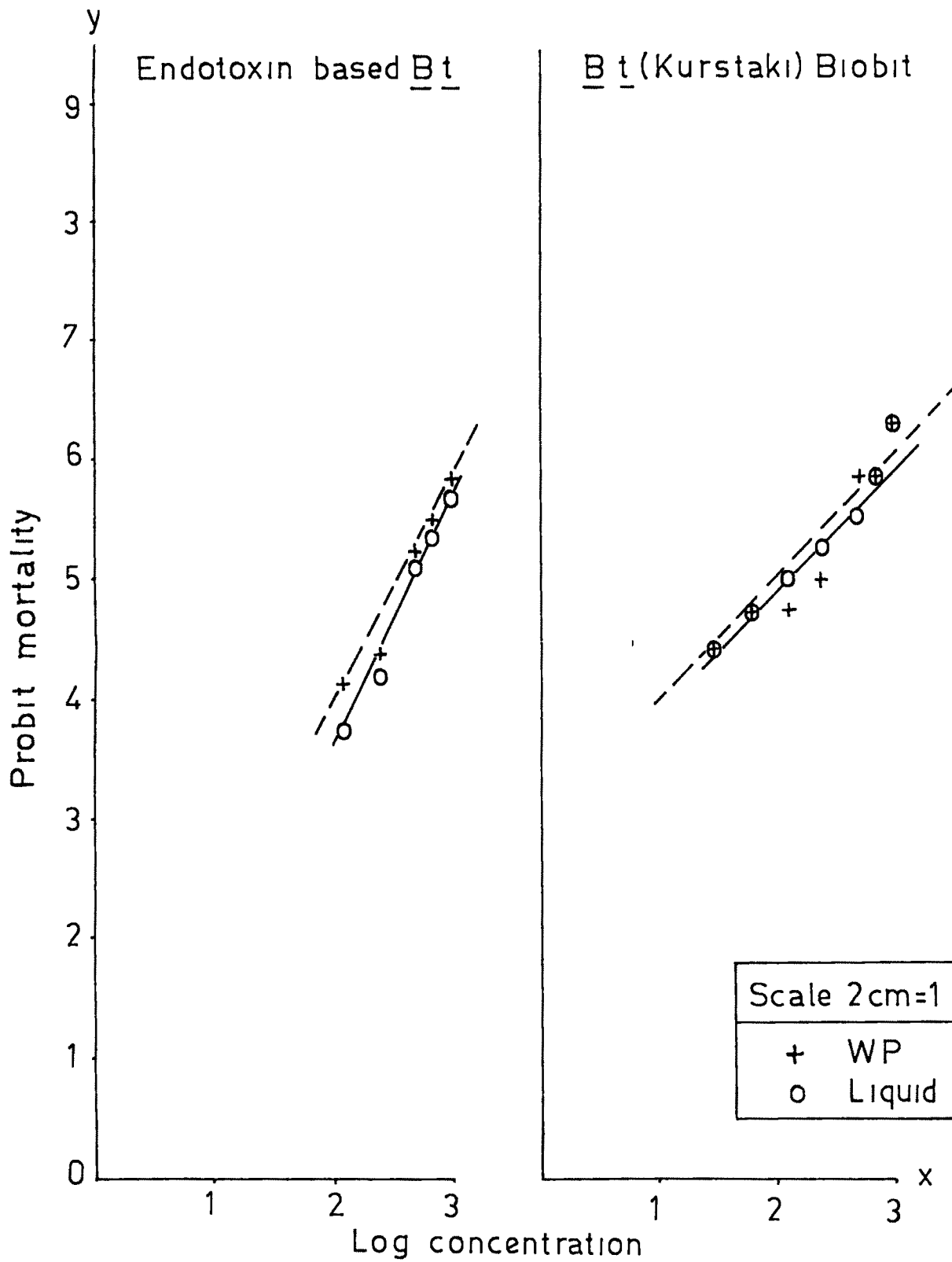


Fig 2 LOG CONCENTRATION-PROBIT KILL REGRESSION LINES OF ENDOTOXIN BASED B thuringiensis AND BIOBIT AGAINST THIRD INSTAR LARVAE OF B mori

4.2.3 Efficacy of Biobit WP containing B. thuringiensis against B. mori :

The different concentrations of Biobit WP containing B. thuringiensis variety (kurstaki) were prepared and applied to discs of treated leaves and dried under fan. These treated leaf discs of mulberry leaves were fed to 3rd instar larvae of B. mori in specimen tube. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration and mortality data at an interval of 12 hrs upto 96 hrs were recorded which are given in Table 11.

Table 11 : Efficacy of Biobit WP containing B. thuringiensis against B. mori

Concentration in percentage	Percentage mortality upto 96 hrs	Correct percentage mortality
0.031	30.00	30.00
0.062	40.00	40.00
0.125	40.00	40.00
0.250	50.00	50.00
0.500	80.00	80.00
0.750	80.00	80.00
1.000	90.00	90.00
Control	-	-

The above data were subjected to probit analysis and the regression equation for the toxicity has been worked out to be $Y = 2.6483 + 1.0844 x$ and LC_{50} value was 0.1476.

4.2.4 Efficacy of Biobit liquid containing B.thuringiensis against B. mori :

The different concentrations of Biobit liquid containing B. thuringiensis variety (kurstaki) were prepared and applied to discs of mulberry leaves and dried under fan. These treated leaf discs of mulberry leaves were fed to 3 rd instar larvae of B. mori in specimen tube. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration and mortality data at an interval of 12 hrs upto 96 hrs were recorded which are given in Table 12.

Table 12 : Efficacy of Biobit liquid containing B. thuringiensis against B. mori

Concentration in percentage	Percentage mortality up to 96 hrs	Corrected percentage mortality
0.031	30.00	30.00
0.062	40.00	40.00
0.125	50.00	50.00
0.250	60.00	60.00
0.500	70.00	70.00
0.750	80.00	80.00
1.000	90.00	90.00
Control	-	-

The above data were subjected to probit analysis and the regression equation for the toxicity has been worked out to be $Y = 2.7825 + 1.0825 x$ and LC_{50} value was 0.11.

Perusal of data presented in Table 11 and 12 and Fig. 2. revealed that the LC_{50} value for Biobit WP containing B. thuringiensis variety (kurstaki) was 0.1476 per cent while LC_{50} value for Biobit liquid containing B.thuringiensis variety (kurstaki) was 0.11 per cent against third instar larvae. of Bombyx mori .

The data on the comparison of the LC_{50} values of the two formulations of Biobit containing B.thuringiensis are presented in Table 13.

Table 13 : Comparison of Log LC_{50} of Biobit containing B. thuringiensis against B. mori

Formulation of Biobit	Log LC_{50}	S.Em	t value in comparison to
Wettable powder	2.1673	0.1526	
Liquid	2.0414	0.1620	0.1663

There is no significant difference between Log LC_{50} values of wettable powder and liquid, formulations of Biobit containing B. thuringiensis against B. mori.

From the efficacy of these four formulations of B. thuringiensis against B. mori, it was observed that the Biobit liquid containing B. thuringiensis was more toxic followed by Biobit WP containing B. thuringiensis variety (kurstaki), endotoxin based B. thuringiensis WP and liquid containing endotoxin based B. thuringiensis. The values of LC_{50} were 0.11, 0.147, 0.398 and 0.481 per cent respectively.

4.3.1 Efficacy of diflubenzuron (Dimilin) against

A. janata :

Different concentrations of Diflubenzuron (Dimilin) 50 % WP were prepared and applied to discs of castor leaves and dried under fan. These treated leaf discs were fed to 3rd instar larvae of A. janata in specimen tube 3 times at an interval of 24 hrs. Fresh food was offered at 24 hrs interval after treatment. A total of 10 larvae were treated for each concentration. Mortality data at an interval of 12 hrs upto 120 hrs, 168 hrs and 216 hrs were recorded which are given in Table 14.

The data presented in Table 14 were subjected to probit analysis and the regression equations for the toxicity has been worked out to be $Y = 2.6681 + 0.7886 x$, $Y = 4.3215 + 0.5195 x$ and $Y = 4.1728 + 0.6418x$ for 120, 168 and 216 hrs respectively. The values of LC_{50} were 0.9057, 0.02 and 0.0199 per cent for 120, 168 and 216 hrs respectively.

Table 14 : Efficacy of diflubenzuron (Dimilin) against *A. janata* .

Concentration in percentage	Percentage mortality upto 120 hrs	Corrected percentage mortality	Percentage mortality upto 168 hrs	Corrected percentage mortality	Percentage mortality upto 216 hrs	Corrected percentage mortality
0.125	50.00	44.44	70.00	66.66	70.00	66.66
0.250	40.00	33.33	80.00	77.77	80.00	77.77
0.500	40.00	33.33	70.00	66.66	70.00	66.66
0.750	50.00	44.44	80.00	77.77	90.00	88.88.
1.000	60.00	55.55	80.00	77.77	90.00	88.88
Control	10.00	-	10.00	-	10.00	-

4.3.2 Efficacy of diflubenzuron (Dimilin) against silkworm B. mori:

Different concentrations of diflubenzuron (Dimilin) 50% WP were prepared and applied to discs of mulberry leaves and dried under fan. These treated leaf discs were fed to 3rd instar larvae of B. mori in specimen tube 3 times at an interval of 24 hrs. Fresh food was offered at 24 hrs interval. A total of 10 larvae were treated for each concentration and mortality data at an interval of 12 hrs upto 266 hrs were recorded which are given in Table 15.

Data presented in Table 15 were subjected to probit analysis and the regression equation for the toxicity has been worked out to be $Y = 1.6903 + 0.9601 x$, $Y = 0.7911 + 1.533 x$ and $Y = 3.4148 + 0.724 x$ for 120, 168 and 216 hrs respectively. The values of LC_{50} were 2.799, 0.5082 and 0.1543 per cent for 120, 168 and 216 hrs respectively.

From the efficacy of diflubenzuron (Dimilin) Table 14 and 15 and Fig.3 it will be observed that the powder was three times more toxic to A. janata than to B. mori in 120 hrs as the LC_{50} values were 0.9057 and 2.799 per cent respectively, twenty five times more toxic to A. janata than to B. mori as the LC_{50} values were 0.02 and 0.5082 per cent respectively for 168 hrs and eight times more toxic to A. janata than to B. mori as the LC_{50} values were 0.0199 and 1.1543 per cent respectively for 216 hrs. Overall, diflubenzuron (Dimilin) 50% WP was more toxic to A. janata than B. mori.

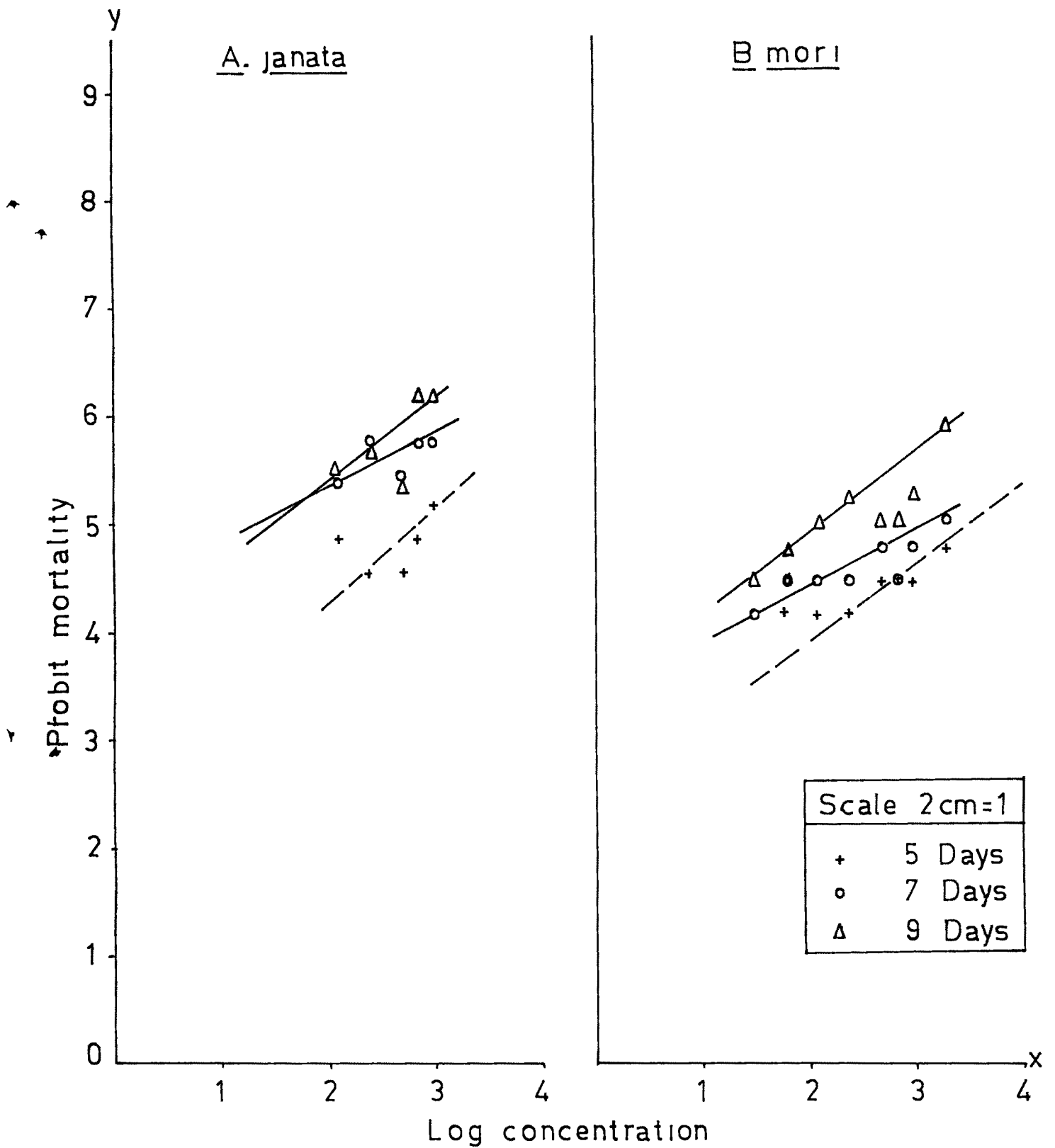


Fig 3 LOG CONCENTRATION-PROBIT KILL REGRESSION LINES OF DIFLUBENZURON (DIMILIN) AGAINST THIRD INSTAR LARVAE OF A. janata AND B. mori

Table 15 : Efficacy of diflubenzuron (Dimilin) against E. mori

Concentration in percentage	Percentage mortality upto 120 hrs	Corrected percentage mortality	Percentage mortality upto 168 hrs	Corrected percentage mortality	Percentage mortality up to 216 hrs	Corrected percentage mortality
0.031	00.00	00.00	20.00	20.00	30.00	30.00
0.062	20.00	20.00	30.00	30.00	40.00	40.00
0.125	20.00	20.00	30.00	30.00	50.00	50.00
0.250	20.00	20.00	30.00	30.00	60.00	60.00
0.500	30.00	30.00	40.00	40.00	50.00	50.00
0.750	30.00	30.00	30.00	30.00	50.00	50.00
1.000	30.00	30.00	40.00	40.00	60.00	60.00
2.000	40.00	40.00	50.00	50.00	80.00	80.00
Control	-	-	-	-	-	-

V. DISCUSSION

V. DISCUSSION

The present investigation was undertaken for the detail study of the toxicity of some formulations of microbial insecticides and insect growth regulator, against castor semilooper, Achaea janata which causes heavy losses by defoliation in castor plant and with a view to find out the most effective microbial insecticide for the pest. At the same time detail study of the toxicity of concerned material against mulberry silkworm, Bombyx mori was also undertaken to find out the pathogenicity of B. thuringiensis and toxicity of difluberzuron (Dimilin) to silkworm.

For this purpose different formulations of endotoxin based B. thuringiensis WP and liquid, Biohit (kurstaki) WP and liquid and diflubenzuron (Dimilin) WP were tested for their toxicity against both the insects. Different concentrations were prepared and each of them applied to discs of castor leaves and mulberry leaves and fed to third instar larvae of castor semilooper and silkworm. The control was also maintained for each insecticide, to know the effect of natural mortality. The observations on the mortality were recorded at the interval of 12 hrs, however, for final analysis the observation recorded after 96 hrs were considered. The results of efficacy of different formulations against

A. janata are discussed below.

5.1 Results on the efficacy of B. thuringiensis against A. janata :

5.1.1 Efficacy of endotoxin based B. thuringiensis WP against A. janata :

Observations on the mortality of castor semilooper upto 96 hrs after feeding endotoxin based B. thuringiensis WP, are presented in Table 2.

The data presented in Table 2 were subjected to probit analysis and value of LC_{50} was worked out which was 0.041 per cent.

Bai et al. (1984) reported that three preparations of delta endotoxin were found toxic to the third instar larvae of Spodoptera littoralis Boisd. The LD_{50} s were 454.6, 1.84 and 594.1 ppm for 3 strains respectively.

Baranovskii et al. (1986) concluded that crystals of (kurstaki) in 'Lepidocide' were highly toxic to Dendrolimus sibiricus .

In the present study the results of this treatment are in agreement with the findings of Bai et al. (1984)

5.1.2 Efficacy of endotoxin based B. thuringiensis liquid against A. janata :

Observations on the mortality of castor semilooper

up to 96 hrs after feeding endotoxin based B.t. thuringiensis liquid are presented in Table 3.

Perusal of data presented in Table 3 were subjected to probit analysis and value of LC_{50} was worked out which was 0.044 per cent.

Deshpande and Ramakrishnan (1982) stated that pre dissolved endotoxin of variety kurstaki was more pathogenic to fifth instar larvae of A. janata.

In the present finding the results of endotoxin based B. thuringiensis liquid are in agreement with the findings of Bai et al. (1984) .

The data presented in Table 4 would reveal that there were no significant differences between LC_{50} values of wettable powder and liquid formulation of endotoxin based B. thuringiensis against A. janata.

5.1.3 Efficacy of Biobit WP containing B. thuringiensis against A. janata :

Observation on the mortality of castor semilooper upto 96 hrs after feeding Biobit WP containing B.thuringiensis WP are presented in Table 5.

The data presented in Table 5 were subjected to probit analysis and value of LC_{50} was worked out which was 0.0990 per cent.

Varma et al. (1974)reported that 'Dipel' @ 1.0 and 1.5 g i.e. 0.1 and 0.15 per cent to be effective

against Pieris brassicae giving more than 80 per cent mortality.

Zivanovic and Stamenkovic (1976) stated that 0.1 per cent 'Dipel' (kurstaki) caused 100 per cent mortality of second to fifth instar of Hyphantria cunea (Dru) in laboratory and field condition.

Berti-Filho and Gallo (1977) obtained heavy mortality of Brassolis astyra astyra by 0.1 per cent 'Dipel' containing 16000 IU/mg.

Shrivastava and Ramakrishnan (1980) tested 'Dipel' (kurstaki) against three day old larvae of A. janata and reported LD₅₀ value of 0.0111 µg/mg body weight.

In the present studies the results of Biobit WP are in agreement with the findings of Varma et al. (1974b), Zivanovic and Stamenkovic (1976) and Berti-Filho and Gallo (1977).

5.1.4 Efficacy of Biobit liquid containing B. thuringiensis against A. janata :

Observations on the mortality of castor semilooper upto 96 hrs after feeding Biobit liquid containing B. thuringiensis (kurstaki) are presented in Table 6.

The data presented in Table 6 were subjected to probit analysis and value of LC₅₀ was worked out which

was 0.111 per cent.

Earlier workers like Govindarajan et al. (1976) reported 100 per cent mortality of A. janata to first, second, third and fourth instar larvae in 1.19, 2.03, 6.11 and 6.16 days with 'Thuricide 90 TS' flowable at concentration 1 ml in 400-600 ml water.

Dabi et al. (1980) reported 96 per cent mortality of Spilosoma obliqua Wlk. in 72 hrs by treated leaves with a dose of 16000 IU/ml of 'Dipel' (kurstaki).

McLeod et al. (1982) stated 42.3 IU/ml LC₅₀ value for 'Dipel' (kurstaki) against second instar larvae of Diorcyctria amatella (Hulst.)

The data presented in Table 7 would reveal that there were no significant differences between LC₅₀ values of Biobit WP and liquid against A. janata. However Biobit WP formulation performed better than Biobit liquid.

Creighton and McFadden (1975) proved 'Dipel' (kurstaki) WP as more effective than flowable in reducing pest population of Trichoplusia ni, Pieris brassicae and Plutella xylostella on cabbage.

In the present findings, Biobit WP was more effective than Biobit liquid, are in agreement with the findings of Creighton and McFadden (1975).

5.2 Results or the efficacy of *B. thuringiensis* against *B. mori* :

5.2.1 Efficacy of endotoxin based *B. thuringiensis* WP against *B. mori* :

Observations on the mortality of silkworm upto 96 hrs after feeding endotoxin based *B. thuringiensis* WP are presented in Table 8.

The data presented in Table 8 were subjected to probit analysis and value of LC_{50} was worked out which was 0.398 per cent.

Ramakrishnan and Kumar (1979) stated that crystal of dendrolimus and entomocidus are toxic to *B. mori* and LD_{50} 2.08 and 0.082 ug.

Nishitsutsuji and Endo (1980) stated delta endotoxin caused complete paralysis in *B. mori* larvae when fed through diet.

Li and Chen (1981) square crystals of endotoxin exhibited highest toxicity to *B. mori*.

In the present studies the results of this treatment are in agreement with Ramakrishnan and Kumar (1979) confirming that endotoxin is toxic to *B. mori*.

5.2.2 Efficacy of endotoxin based B. thuringiensis liquid against B. mori :

Observation on the mortality of silkworm up to 96 hrs after feeding endotoxin based B. thuringiensis liquid are presented in Table 9.

The data presented in Table 9 were subjected to probit analysis and value of LC_{50} was worked out which was 0.481 per cent.

Earlier worker like Angus (1967) reported toxicity of parasporal crystal of B. thuringiensis variety thuringiensis, sotto, and entomocidus (26,0.02 and 0.03 microgram per larva respectively).

Galowalia et al. (1973) reported crystalline endotoxin of varieties entomocidus, sotto, alesti, galleriae and aizwai to be most toxic and variety tolworthy and thuringiensis to be the least to L. mori.

The data presented in Table 10 would reveal that there were no significant differences between IC_{50} values of endotoxin based B. thuringiensis WP and liquid. However, WP formulation performed better than liquid formulation.

5.2.3 Efficacy of Biobit WP containing B. thuringiensis against B. mori :

Observations on the mortality of silkworm upto 96 hrs after feeding Biobit WP (kurstaki) are presented in Table 11.

The data presented in Table 11 were subjected to probit analysis and value of LC_{50} was worked out which was 0.1476 per cent.

Manchev (1980) tried 'Dipel' (kurstaki) against silkworm and found that 0.003 per cent 'Dipel' caused 77.3, 66.2, 38.0 and 13.8 per cent mortality in first, second, third and fourth instar after varying number of days.

In the present study the results are not in agreement with Manchev (1980) and the LC_{50} of Biobit (kurstaki) is higher in the present investigation.

5.2.4 Efficacy of Biobit liquid containing B.thuringiensis against B. mori:

Observations on the mortality of silkworm upto 96 hrs, after feeding Biobit liquid (kurstaki) are presented in Table 12.

The data presented in Table 12 were subjected to probit analysis and value of LC_{50} was worked out which was 0.11 per cent.

Dronka et al. (1976) obtained good control of larvae of Eutromula pariana (Cl.) with 0.1, 0.2 and 0.3 per cent 'Dipel' .

In the present studies the results of this treatment are in agreement with Dronka et al. (1976).

The data presented in Table 13 showed that there were no significant differences between LC_{50} values of Biobit WP and liquid formulation against B. mori.

5.3 Efficacy of diflubenzuron against A. janata and B. mori :

5.3.1 Efficacy of diflubenzuron WP (Dimilin) against A. janata :

Observation on the mortality of A. janata up to 120, 168 and 216 hrs, after feeding diflubenzuron (Dimilin) are presented in Table 14.

The data presented in Table 14 were subjected to probit analysis and value of LC_{50} s were 0.9057, 0.02 and 0.0199 per cent for 120, 168 and 216 hrs, respectively.

Previous workers like Zabel and Ostojic (1973) observed complete mortality of third instar larvae of Malcosoma neustria L. with 50-300 ppm diflubenzuron, while in Lymantria dispar complete mortality was observed with 200 ppm.

Natesan and Balasubramanian (1979) reported that 0.02 per cent diflubenzuron caused 77.14 per cent mortality in Spodoptera litura (F.)

Rabindra and Balasubramanian (1981) reported that diflubenzuron (Dimilin) 0.5 g/lit inhibited molting and caused 96 per cent mortality while a dose of 1.0 g/lit caused 100 per cent mortality in A. janata .

In the present studies the result obtained in this treatment are in agreement with result of Rabindra and Balasubramanian (1981).

5.3.2 Efficacy of diflubenzuron WP (Dimilin) against B. mori :

Observation on the mortality of B. mori upto 120, 168 and 216 hrs after feeding diflubenzuron (Dimilin) are presented in Table 15.

The data presented in Table 15 were subjected to probit analysis and values of LC_{50} s were 2.799, 0.5082 and 0.1543 per cent for 120, 168 and 216 hrs respectively.

Hartinger (1976) reported that 0.6 to 60 ppm diflubenzuron (Dimilin) caused 100 per cent mortality in fourth and fifth instar larvae of Yponomeuta euonymellus (L.)

Coudriet and Seay (1979) stated that first three instar larvae of Trichoplusia ni (Hub.), Spodoptera exigua (Hub.) and Heliothis virescens (F.) were more susceptible to diflubenzuron.

Chockalingam and Noorjahan (1984) stated that, LC_{100} for difluberzuron (Dimilin) against Dysdercus cingulatus and Chrysocoris purpureus, were 100 and 1000 ppm.

In the present studies the results obtained in this treatment are in agreement with the result of Coudriet and Seay (1979) i.e. first three instar larvae were more susceptible to diflubenzuron.

Considering the efficacy of different formulations of B. thuringiensis; endotoxin based B. thuringiensis WP was more toxic to A. janata, followed by endotoxin based B. thuringiensis liquid, Biobit WP containing B. thuringiensis (kurstaki) and Biobit liquid containing B. thuringiensis (kurstaki). Deshpande and Ramakrishnan (1982) observed that predissolved endotoxin of B. thuringiensis was more pathogenic to 5th instar larvae of A. janata.

While in case of B. mori efficacy of different formulations tested, Biobit liquid containing B. thuringiensis (kurstaki) was more toxic followed by Biobit WP containing B. thuringiensis (kurstaki), endotoxin based B. thuringiensis WP and endotoxin based B. thuringiensis liquid. Manchev (1980) reported 0.003 per cent 'Dipel' (kurstaki) against silkworm, caused 77.3, 66.2, 38.0 and 13.8 per cent mortality in first, second, third and fourth instar larvae after varying number of days.

In case of insect growth regulator, diflubenzuron (Dimilin), the toxicity of the product was more in A. janata than B. mori. Rabindra and Balasubramanian (1981) reported 100 per cent mortality caused by 1.0 μ g/lit diflubenzuron (Dimilin) in A. janata.

In case of B. mori, Biobit liquid containing B. thuringiensis (kurstaki) was more toxic and hence may be judiciously used in the pest control programme, in the silk producing areas.

Based on the percentage mortality and ultimate LC_{50} values, endotoxin based B. thuringiensis WP may be considered better against castor semilooper, A. janata. Diflubenzuron (Dimilin) WP was more toxic to the larvae of A. janata than B. mori. Hence possibilities may be explored for using these products for the control of A. janata after elaborate field trials.

SUMMARY

VI. SUMMARY

Investigations on the efficacy of some microbial insecticide formulations and insect growth regulator, were carried out against the castor semilooper, Achaea janata L. and Bombyx mori L. under laboratory conditions in the Marathwada Agricultural University, Parbhani, during the year 1986-87. Different formulations containing endotoxin based B. thuringiensis. Biobit B. thuringiensis variety (kurstaki) and diflubenzuron (Dimilin) were tested for their efficacy against these insects.

Efficacy of these products were assessed on the basis of total mortality after 96 hrs. Different concentrations of the microbial insecticides and diflubenzuron were prepared and applied to the leaf discs of castor and mulberry leaves and fed to third instar larvae of A. janata and B. mori, respectively. Mortality count at an interval of 12 hrs upto 96 hrs were recorded. Total of 10 larvae were treated for each concentration and total mortality at 96 hrs were considered for analysis. In case of insect growth regulator, diflubenzuron (Dimilin), mortality data at 120, 168 and 216 hrs were recorded. The data were subjected to probit analysis and LC_{50} values calculated were compared.

The results revealed that the endotoxin WP was more toxic to A. janata (LC_{50} 0.041), followed by endotoxin based B. thuringiensis liquid (LC_{50} 0.044), Biobit WP containing B. thuringiensis (kurstaki) (LC_{50} 0.099) and Biobit liquid containing B. thuringiensis (kurstaki) (LC_{50} 0.111).

While in case of B. mori among the different formulations tested, biobit liquid containing B. thuringiensis (kurstaki) was more toxic (LC_{50} 0.111), followed by Biobit WP containing B. thuringiensis (kurstaki) (LC_{50} 0.147), endotoxin based B. thuringiensis WP (LC_{50} 0.398) and endotoxin based B. thuringiensis liquid (LC_{50} 0.481).

In case of insect growth regulator, diflubenzuron (Dimilin) the toxicity of the product was more to A. janata than B. mori as the LC_{50} values were 0.9057, 0.02, 0.0199 and 2.799, 0.5082, 0.1543 in 120, 168 and 216 hrs respectively.

Based on the percentage mortality and ultimate LC_{50} values endotoxin based B. thuringiensis WP may be considered better against castor semilooper, A. janata.

In case of B. mori Biobit liquid containing B. thuringiensis (kurstaki) was more toxic and hence may be judiciously used in the pest control programme in the silk producing areas.

Diflubenzuron (Dimilin) WP was toxic to A. janata and larvae of B. mori were comparatively less susceptible. Hence possibilities may be explored for using these products for the control of A. janata after elaborate field trials.

REFERENCES

REFERENCES

- * Angus, T.A. 1967. Comparative toxicity of parasporal inclusions of three entomogenous bacteria. J. Invertebr. Pathol., 9 : 256-260.
- *Anonymous.1982. Agricultural Situation in India. 36: 914-916.
- Ascher, K.R.S., Wysoki, M., Nemny, N.E. and Gur-Telzak, L. 1978. The effect of diflubenzuron upon larvae of the geometrid Boarmia (Ascotis) scleparia on avocado leaves. Pesticide Sci., 9 (3): 219-224.
- Audemard, H., Guennelon, G., Baudouin, J.M., Dolbeau, C. and Schutz, D. 1975. Preliminary tests on the codling moth (Laspeyresia pomonella) of an insecticide presenting a new mode of action: diflubenzuron. Phytiatrie - Phytopharmacie., 24 (3): 179-192.
- Awate, B.G. and Naik, L.M. 1979. Efficacies of insecticidal dusts applied to soil surface for controlling potato tuber moth Phthorimaea operculella Zeller in field. J. Maharashtra Agri. Univ., 4 (1): 100.
- Bai, C., Vanhaecke, M., and Dehuelle, D. 1984. Cytopathology of Spodoptera littoralis Boisdu midgut epithelium following treatment with delta endotoxin of Bacillus thuringiensis Berliner. J. Mede delingen van de facultetis Landbouwwetensch appen Rijksuniversity Gent., 49(39) : 875-884.

- Baranovskii, V.I., Zurabova, E.R., Larionov, G.V., Omelenchuk, S.V. and Bakhvalov, S.A. 1966. 'Lepidocide' for control of Dendrolimus sibiricus J. Lesnoe Khozvaistvo., 1 : 62-64.
- BertiFilho, E. and Gallo, D. 1977. The use of Bacillus thuringiensis Berliner for the control of the palmworms Brassalis astyra astyra Godort (1765) (Lepidoptera - Erassolidae). J. Anais da Sociedade Entomologica do Brasil, 6(1):85-91.
- Cavalcaselle, B. 1976. Evaluation of the effectiveness of two commercial preparations of Bacillus thuringiensis in control of Thaumetopoea pityocampa . J. Cellulosa e Carta, 27(2):21-26 .
- Chilirgaryan, Y.A., Kazaryan, B.K., Ormanyar Zh, Kh and Pogosyar A.G. 1977. Acaricidal effectiveness of Bitoxibacillin J. Zashchita Rasten, 5 : 24.
- Chokalingam, S., and Noorjahan, A. 1984. The ovicidal effect of diflubenzuron on Hemipterian bugs, Dysdercus cingulatus and Chrysocoris purpureus. Curr. Sci., 53(20):1112-1113.
- Cohen, M., Wysoki, M. and Sneh, B. 1983. The effect of different strains of Bacillus thuringiensis Berliner on larvae of the giant looper Boarmia (Ascotis) selenaria Schiffermuller (Lepidoptera - Geometridae). Zeitschrift fur Angewandte Entomologie, 96(1): 68-74.
- Coudriet, D.L. and Seay, R.S. 1979. Diflubenzuron : laboratory evaluation against three lepidopteran pests of vegetables. Georgia Entomological Society , 14 (4): 325-329.

- Creighton, C.S. and McFadden, T.L. 1975. Cabbage caterpillar : efficacy of chlordimeform and Bacillus thuringiensis in spray mixture and comparative efficacy of several chemical and B. thuringiensis formulations. J. Econ. Ent., 68(1):57-60.
- Cruz, P.F.N. 1977. Preliminary results on the effectiveness of Bacillus thuringiensis Berliner for the control of rubber hawk moth, Erinnyis ello L. (Lepidoptera)- in Bahia. Revista Theobroma, 7(3):93-98.
- Dabi, R.K.; Gupta, H.C. and Sharma, S.K. 1980. Bioefficacy of Bacillus thuringiensis Berliner against Euproctis lunata Walker on pearl millet . Indian J. Agril. Sci., 50(4): 356-358.
- Dabi, R.K., Mehrotra, P. and Shinde, V.K.R. 1980. Bioefficacy of different levels of Bacillus thuringiensis Berliner against Diacrisia obliqua Walker. J. Entomol. Res., 4(2):231-233.
- Deshpande, A.D. 1986. Use of bioinsecticides of bacterial origin. Paper presented in Summer Institute on Pesticide Management held at Marathwada Agricultural University, Parbhani (unpublished).
- Deshpande, A.D. Ramakrishnan, N. 1982. Pathogenicity of certain serotypes of Bacillus thuringiensis Berliner against Achaea janata L. Entomon., 7(2):239-245.
- Dobrivojevic, K. and Injac, M. 1975. Laboratory investigation of the effectiveness of the microbial insecticides 'Dipel' T M. and 'Bactosceine' for the control of the wooly moth. Hypogymna morio L. Zastita Bilja., 26(134)365-369.

- Dronka, K., Niemczyk, E. and Dadaaj, J. 1976. The effectiveness of the bacterial preparation 'Dipel' and certain chemical insecticides in controlling the apple leaf skeletoniser (*Simethis pariana* Clek) in apple orchards. Roczniki Nauk Rolniczych.E., 6(1): 159-164.
- Dulic, K. and Injac, M. 1981. Control of the leaf miners *Leucoptera scitella* Zell, *Lithocolletis blancardella* F. and *Lithocolletis corlifoliella* (Hw.) under condition of apple production. Zastita Bilja, 32(4): 409-429.
- *Dulmage, H.T. 1970 b. Production of the spore delta endotoxin complex by variants of *Bacillus thuringiensis* in two fermentation media. J. Invertebr. Pathol., 16:385-389.
- Elliott, R.H. and Iyer, R. 1982. Toxicity of diflubenzuron to nymphs of the migratory grasshopper *Melanoplus sanguinipes* (Orthoptera - Acrididae). Canadian Entomologist., 114(6): 479-484.
- El-Sayeed, E.I. 1980. Larvicidal and Ovicidal effects of Dimilin, PH 66-13 and PH- 66-14 on the Egyptian cotton leafworm. Laboratory of plant Protection, NRC, Cairo, Egypt, 381-391.
- Fast, P.C. 1977. *Bacillus thuringiensis* delta endotoxin on the relative roles of spores and crystals in toxicity of spruce budworm. (Lepidoptera- Tortricidae). Canadian Entomologist., 109(11):2515-2518.
- Finney, D.J. 1977. Probit analysis. Cambridge University Press, London, New York, Melbourne.
- Frye, R.D., Elichuk, T.L. and Stein, T.D. 1976. Dispersing of *Bacillus thuringiensis* for control of canker worm in shelter belt. Res. Note Forest Service, U.S.D.A. 315-7.

- Gadais, M., Mahieu, N. and Gilbert, R. 1978. Control of the pine processionary in the Loire-Atlantique and Vendee. Phytoma., 30(303):19-21.
- *Galowalia, M.M.S., Gibson, N.H.E. and Wolf, J. 1973. The comparative potencies of the crystalline endotoxin of eight varieties of Bacillus thuringiensis to larvae of Pieris brassicae L. J. Invertebr. Pathol., 21(3):301-308.
- Gangwar, S.K., Yadava, C.P.S., Mishra, R.K., Dadheech, L.N. and Saxena, R.C. 1981. Efficacy of Bacillus thuringiensis against Lepidopterous pests. Indian J. of Plant Protection, 8(2): 154-156.
- Govindarajan, R.; Jayaraj, S. and Narayanan, K. 1976. Studies on the effect of Bacillus thuringiensis Berliner on the castor semilooper, Achaea janata L. (Noctuidae - Lepidoptera). Zeitschrift fur Angewandte Entomologie, 80(2):191-200.
- Granett, J., Dunbar, D.M. and Weselon, R.M. 1976. Gypsy moth control with Dimilin sprays timed to minimised effects on the parasite Apanteles melanoscelus. J. Econ. Entomol., 69(3): 403-404.
- Guzeev, G.F. and Mansurov, O.A. 1983. The Turkestan saturniid. Zashchita Rastenii., 11:42.
- Hartinger, C. 1976. On the effect of development inhibitor Dimilin on ermine moths Yponomeuta spp and their parasites. Anzeiger fur schadlingskunde Pflanzenschutz Umweltschutz., 49(10):156-158.
- *Heimpel, A.M. 1967. A critical review of Bacillus thuringiensis Berliner and other crystalliferous bacteria. Ann. Rev. Entomol., 12:287-322.

- Ignoffo, C.M., Garcia, C. and Kroha, M. 1982.
Susceptibility of the colorado potato beetle
Leptinotarsa decemlineata to Bacillus thuringiensis .
J. Invertebr. Pathol., 39(2):244-246.
- *Ignoffo, C.M.; Hostetter, D.L. and Pinnell, R.E. 1974.
Stability of Bacillus thuringiensis and
Baculovirus heliothis on soybean foliage.
Environ. Entomol., 3: 117-119.
- *Jaques, R.P. and Fox, J.S. 1960. The influence of
stickers on the effectiveness of spray of
Bacillus thuringiensis var. thuringiensis Berliner
and Bacillus entomocidus Heimpel and Angus.
J. Insect Pathol., 2:17-23.
- Jaipal, S. 1985. Evaluation of diflubenzuron for the
control of Bihar hairy caterpillar. Ann. Appl.
Biol., 106.
- Jensens, S.; Vanhaecke, M. and Degheele, D. 1986. Effect
of Bacillus thuringiensis Berliner formulation
against larval instars of Spodoptera littoralis
Boisduval. Parasitica., 40(1):41-50.
- Krishnaiah, K. and Mohan, N.J. 1983. Control of cabbage
pests by new insecticides. Ind. J. Ent.,
45 (3):222-228.
- Krishnaiah, K., Mohan, N.J. and Prasad, V.G. 1981.
Efficacy of Bacillus thuringiensis Berliner
for the control of Lepidopterous pests of
vegetable crops. Entomon., 6(2):87-93.
- *Kulshreshtra, J.P., Sanghi, P.K. and Ravindranath, V. 1965.
Microbial control of castor semilooper Achaea jarata
L. Ind. J. Ent., 27:353-354.

- Li, R. and Chen, T. 1981. The toxicity and morphology of the crystal from several strains of Bacillus thuringiensis. Acta Microbiologica Sinica, 21(3):311-317.
- Lipa, J.J. 1976. Laboratory experiments with Dimilin WP 25 against larvae of Agrotis segetum Schiff and Mamestra brassicae L. (Lepidoptera-Noctuidae). Bulletin de Academie Polonoise des Sciences Sciences Biologiques, 24(9):509-515.
- Maksymov, J.K. 1980. Biological control of the sâtin moth Stilpnotie salicis L. (Lepidoptera-Lymantriadae) with Bacillus thuringiensis Berliner. Anzeiger fur Schadlingskunde. Pflanzenschutz Umweltschutz, 65(4):52-56.
- Manchev, M. 1980. Induction of spontaneous nuclear p6lyhedrosis in the silkworm. Rastitelna Zashchita, 28(2):13-14.
- McLeod, P.J., Yearian, W.C. and Young, S.Y. 1982. Effectiveness of Bacillus thuringiensis against the southern pine coneworm, Diorcyctria amatella (Lepidoptera - Puralidae). Environ Entomol., 4(6): 1305-1306.
- McNeil, J.N., Smirnoff, W.A. and Letendre, M. 1977. Bacillus thuringiensis as a mean of control for the European skipper, Thymelicus lincola (Lepidoptera-Hesperidae) . Canadian Entomologist, 109(1):37-38.
- Mokrousova, E.P. 1977. Diflubenzuron for the control of harmful insects. Zashchita Rastenii, 4:27.

- Natesar, R. and Balasubramanian, M . 1979. Efficacy of diflubenzuron (inhibitor of chitin depositor) in the control of tobacco caterpillar, Spodoptera litura on Groundnut. Ind . J. Plant. Protect., 7(2):141-144.
- Nayak, P., Rao, P.S. and Padmarabhan, S.Y. 1978. Effect of thuricide on rice stem berrers. Proceedings Indian Academy of Sciences. B. 87(3):59-62 .
- Niemczyk, E.; Olszak, F. and Miszczak, M. 1976. The effectiveness of the bacterial preparation ('Dipel' in controlling the codling moth. (Laspeyresia pomonella L.) and leaf rollers (Tortricides) during the summer period . Roczniki Nauk Rolniczych E., 6(1):151-157.
- Nishitsutsuji U.J. and Endo, Y. 1980. Mode of action of Bacillus thuringiensis of endotoxin general characteristics of intoxicated Bombyx mori larvae. J. Invertebr. Pathol., 35(3):219-228.
- Pascovici, V.; Mihalacheş G. Pirvescu, D. and Simionescu, D. 1978. Experiment on the control of pest Lymantria dispar (L.) and other defoliators by means of bacterial preparations. Zastita Bilja, 29(1/2):69-76.
- Rabindra, R.J. and Balasubramanian, M. 1981. The effect of diflubenzuron on the castor semilooper Acraea janata Linn Lepidoptera-Noc'tuidae . Entomon., 6(1):15-18.
- * Rai, B.K. 1976. Pests of Oilseed Crops in India and their Control. Indian Council of Agricultural Research, New Delhi. pp. 47.

- Rajendran, S., Shivaramaiah, H.M. 1983. Effect of diflubenzuron on the productivity of khapra beetle, Trogoderma granarium. Entomologia Experimentalis et Applicata. 33(1):15-19.
- Ramakrishnan, N. and Kumar, S. 1979. Status of Bacillus thuringiensis with reference to the silk worm Bombyx mori. Pesticide, 13(6):28-30.
- Retnakaran, A. and Tomkins, W. 1982. Effectiveness of moult-inhibiting insect growth regulators in controlling the oak leaf shredder. Canadian Forestry Service Research Note. 2(1):5-6.
- Salama, H.S. and Foda, M.S. 1984. Studies on the susceptibility of some cotton pests to various strains of Bacillus thuringiensis, Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz., 91(1):65-70.
- Salama, H.S., Foda, M.S. and El-Sharaby, A.M. 1981. Potency of spore delta endotoxin complexes of Bacillus thuringiensis against some cotton pests. Zeitschrift fur Angewandte Entomologie, 91(4):388-398.
- Santharam, G. and Balasubramanian, M. 1980. Note on the control of Spodoptera litura Fabricius (Lepidoptera - Noctuidae) on tobacco with nuclear polyhedrosis virus and diflubenzuron. Ind. J. Agril. Sci., 50(9):726-727.
- Sarmiento, M.J.A. and Fazuri, R.V. 1982. Bacillus thuringiensis for the control of Spodoptera frugiperda and of Diatraea saccharalis on maize. Revista Peruana de Entomologia, 21(1): 121-124.

- Saxena, R.C. 1979. Efficacy of Bacillus thuringiensis Berliner for the control of Athalia proxima Klug. Ind. J. of Plant Protect., 6 (1): 33-35.
- Schesser, N.H. and Bulla, L.A.J. 1981. Toxicity of parasporal crustals of Bacillus thuringiensis to the Indian meal moth Plodia interpunctella App. and Environ Microb., 37(5):1012-1015.
- Smirnoff, W.A. 1985. Field tests of a highly concentrated formulation of Bacillus thuringiensis against spruce budworm (Choristoneura fumiferana, Lepidoptera-Tortricidae) . Canadian Entomologists., 117 (7) : 877-881.
- Shrivastava, K.L. and Ramakrishnan, N.1980. Potency of 'Bactospeine' and 'Dipel' two commercial formulation of B. thuringiensis against castor semilooper, Achaea janata. Ind. J. of Entomol., 42(4):769-772.
- Srivastava, R.P. and Nayak, P.1978. Laboratory evaluation of four formulations of Bacillus thuringiensis against Cnaphalocrocis medinalis Gn. (Pyralidae-Lepidoptera) the rice leaf roller. Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz., 85(11): 641-644.
- Sukhatme, P.V. and Amble, V.N. 1978. Statistical methods for Agricultural workers (Panse, V.G. and Sukhatme P.V.P 3 rd Edn. pp.57. Indian Council of Agril. Research, New Delhi. pp .347.
- Sundaramurthy,V.T. 1977. Effect of an inhibitor of chitin deposition on the growth and differentiation of tobacco caterpillar, Spodoptera litura (Fb.) (Lepidoptera Noctuidae). Zeitschrift fur Pflanzenkrankheiten und Pflanzenschutz , 84(11):597-501.

- Varma, G.C., Bindra, O.S. and Darshan Singh. 1974 .
Comparative efficacy of Bacillus thuringiensis
Berliner formulations against Pieris brassicae
L. Curr. Sci. 43 (22):734-735.
- Velcheva, N. 1983. Insecticidal activity of diflubenzuron
against larvae of the cabbage moth. Rastitelna
zashchita ., 31(10): 35-37.
- Wysoki, M., Izhar, Y., Gurvitz, E., Swirski, E. and
Greenbery, S. 1975 . Control of the honeydew
moth , Cryptoblabes gnidiella Mill (Lepidoptera-
phyticidae) with Bacillus thuringiensis Berliner
in avocada plantations. Phytoparasttica.,
3 (2): 103-111.
- Yunusov, I. 1974. Biopreparations destroy the lucerne
bug. Zashchita Rastenii. 8 :32.
- Zabel, A. and Ostojic, N. 1973. Insecticidal action
of the experimental chemical PH-60-40 on the
larval stage of some Lepidoptera. Zastita Bilja. 24
(123) : 97-102.
- Zivanovic, V., and Stamenkovic, S. 1976. The insecticide
'Dipel' for control of the larvae of some
lepidoptera. Zastita Bilja., 27(3/4) : 381-327.

* Original not seen.