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Use of Microbial Insecticides in Pakistan: Special Reference to Control of Chickpea pod Borer *Helicoverpa (Heliothis) Armigera* (Hübner)

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ABSTRACT

The use of microbial insecticide has been adopted in Pakistan as part of an integrated pest management approach to provide an environmentally-suitable alternative to the generally hazardous, broad-spectrum insecticides used against *Helicoverpa (Heliothis) armigera* (Hübner). Laboratory bioassays using spore-crystal preparations of *Bacillus thuringiensis* var. *kurstaki* (Berliner) indicated high mortalities of the 1st instar larvae of H. *armigera*. Potted chickpea (*Cicer arietinum* L.) plant tests revealed that Dipel® 2X and Dipel® ES at the rates of 1.6 kg/ha and 2.0 liters/ha caused 81.48 and 84.0% larval mortality, respectively. Field tests of B. thuringiensis on chickpea crops (three consecutive seasons) indicated that Dipel ® 2X and Dipel® ES at the rates of 1.6 kg/ha and 1.5 liters/ha (with and without molasses), respectively, caused significant increase in grain yield as compared to control plots. At least one Dipel® treatment was not significantly different from the best synthetic, broad-spectrum insecticide treatment in terms of yield in all field evaluations.

RESUMEN

El uso de insecticidas microbianos ha sido adoptado en Pakistán como parte de un intento de manejo integrado de plagas que brinde una alternativa adecuada al medio ambiente a los generalmente peligrosos insecticidas de amplio espectro que se usan en contra de *Helicoverpa (Heliothis) armigera(Hübner).* Los ensayos de laboratorio donde se usaron preparaciones de esporas-cristales de *Bacillus thuringiensis* var. *kurstaki* (Berliner mostraron mortalidades altas de las larvas del primer instar de *H. armigera.* Las pruebas con plantas de garbanzo *(Vicer arietinum)* en macetas revelaron que Dipel ® 2X y Dipel ® ES a dosis de 1.6 kg/ha produjeron un 81.48 y un 84.0% de mortalidad larvaria respectivamente. Las pruebas de campo de *B. thuringiensis* con cultivos de mortalidad larvaria respectivamente. Las pruebas de campo de *B. thuringiensis* con cultivos de garbanzo (en tres estaciones consecutivas) indicaron que Dipel ® 2X and Dipel ® ES en dosis de 1.6 kg/ha y 1.5 litros/ha (con o sin melazas), respectivamente, causaron un incremento significativo en el rendimiento del grano al compararse con las parcelas testigo. La aplicación de al menos un tratamiento con Dipel ® no fue significativamente diferente al mejor tratamiento de insecticida sintético de amplio espectro, en términos de los rendimientos observados en todas las evaluaciones de campo.

The use of chemical pesticides has grown in recent years despite the increase in public concern over pesticide's impact on the environment and food quality. Forget (1989) reported that pesticide imports in the third world increased more than six-fold from 1970 to 1980. Meanwhile, more than 400 arthropod species have developed resistance to various types insecticides and acaricides (Georghiou and Mellon 1983, Voss 1987). Reed & Pawar (1982) stated that the destruction of natural enemies by pesticide use and change in cropping patterns and management have promoted these insects to major pest status. Wide and indiscriminate use of chemical insecticides is believed to be the cause of a number of biological hazards (poisoning of plants, fish, birds and mammals) and is being seriously criticized by specialists throughout the world.

Bacillus thuringiensis Berliner (*Bt*) is a naturally occurring bacterium which is pathogenic to the larvae of a large number of species of Lepidoptera. The active ingredient contained in this biological insecticide is generally recognized as a spore-delta-endotoxin of *Bt*. This bacterium was first discovered in 1902 by a Japanese bacteriologist Ishiwata, who isolated an aerobic spore forming bacterium from diseased silkworm and showed it to be the cause of infection (Norris 1970). *Bt* was first recognized as a disease causing agent in silkworm in Japan and in flour moth in Germany by Berliner in 1915. It was Berliner who first used the name *Bacillus thuringiensis* to desribe these spore forming insect pathogen (Norris 1970). Since then, *Bt* has been isolated from various insect species around the world (Kreig and Langenbruch 1981).

Insecticidal activity of *Bt* is associated with a parasporal body proteinacious in nature formed during sporulation and often referred to as a crystal. This crystal, after ingestion by a susceptible insect species, is acted upon by various digestive enzymes and is converted into a toxic protein that destroys the cells lining the gut (Percy and Fast 1983, Heimpal and Angus 1959). If the larva ingests a lethal dose, it stops feeding and dies within a few days, but can recover and resume feeding if the dose is sublethal (Fast and Regniere 1984, Retnakaran et al. 1983, van Frankenhuyzen and Nystrom 1987).

The biologically-derived insecticides, such as *Bt*, have provided a commercial alternative to broad-spectrum chemical insecticides because of their specificity for target

pest organisms. For example, Siegal et al. (1987) tested toxicity and infectivity of *Bt* against different animals and found it highly specific showing no adverse effect on animals and other living things in the environment and ecosystem. *Bt* is currently a well-known pathogen of lepidopterous larvae and its preparations in the form of microbial insecticides such as Dipel®, Thuricide®, Bacterin®, Bactospeine®, Dendrobacillin® and others have been commercialized, and have proven very effective in control of lepidopterous pests, dipterous pests, coleopterous pests and grass hoppers (Anwarullah 1987).

With the use of new strains of *Bt* and improved commercial formulations, the insect pathogens are gaining increasing support at international level against agricultural pests. Several reports indicated use of *Bt* and its enhancement by incorporation of suitable quantity of acids, salts, oils, adjuvants, thuringiensin and chemical insecticides against lepidopterous pests including *Helicoverpa (Heliothis) armigera* (Hübner) (Salama et al. 1984, 1984 & 1986, Morris 1988, Karel and Shoonhoven 1988 and Khalique et al. 1989). Khalique et al. 1982a stated that the larval period, larval mortality and pupal mortality of H. *armigera* increased with the increase in spore-o-endotoxin of Bt (HD-1-S-1971 & Bt 145). Further, studies on H. *armigera* indicated that pre-oviposition period, fecundity and longevity of adults raised from larvae treated with spore-o-endotoxin of HD-1-S-1971 and *Bt* 145 reduced sugnificantly (Khalique et al. 1982b). However, the effectiveness of the *Bt* preparations in the field largely depends on the chemical and physical environment in which they are applied.

H. armigera is a serious pest of many crops and is commonly known as cotton bollworm, corn earworm, gram pod borer, tomato fruitworm and others. In South and South-West Asia, information on crop losses by *H. armigera* demonstrates its great economic importance (Sithanantham et al. (1983) & Hariri (1982). In Pakistan, this insect inflicts heavy yield losses (10% to 90%) under favourable environmental conditions in irrigated and rain-fed areas of the country. To combat this pest, research on the use of biorational insecticide materials was initiated in 1986-87 chickpea season to evaluate *Bt* as an environmentally suitable, alternative to hazardous chemicals, specific for this target insect pest.

MATERIALS AND METHODS

Bioassay of Bacillus thuringiensis (Bt) against H. armigera: Four commercial preparations of *Bt* var. *kurstaki*, i.e. Bactospeine®WP 16000 IU/mg, Dipel®2X 32000 IU/mg, Dipel®ES 17600 IU/mg, China *Bt* 16000 IU/mg as well as US reference standard HD-1-S-1980 16000 IU/mg potencies were evaluated in different concentrations against the 1st, 2nd, and 3rd instar larvae of chickpea pod borer, *H. armigera*, in the laboratory. Six serial dilutions of the *Bt* were prepared (2.5, 5.0, 10.0, 20.0, 40.0 and 80.0 ug of *Bt*/ml diet). The *H. armigera* diet used in the experimentation was developed by K. Ahmed and F. Khalique (Unpublished data). In each bioassay, 4 replications were maintained and in each replication 25 neonate larvae were used (Tables 1 and 2).

Bt plus Malic acid bioassays: Investigations were conducted to find out that whether the acid exudate (malic acid) of chickpea plant can cause inactivation or potentiation of the spore-o-endotoxin of *Bt* contained in the microbial preparations as an active ingredient. *Bt* droplets during the spray normally come in contact with minuscule droplets of malic acid on the plant, thereby causing dilution of the acid. Dilutions of malic acid were tested to account for the natural dilution that occurs during spray applications. A series of diet-bioassys using various concentrations of malic acid and *Bt* (US standard HD-1-S-1980) alone and in combinations against *H. armigera* were carried out (Table 3).

Bt tests on potted chickpea plants: Potted plants at flowering stage were sprayed with different concentrations of Dipel®2X and Dipel®ES with the help of hand operated mist blower. All the plants were given complete coverage of *Bt* dilutions. Four replications were maintained in each treatment (Table 4). The sprayed plants were infested with 15 laboratory reared late 2nd stage larvae (6-7 mm size) of the test insect and after that the entire plant was covered with flexible round plastic sleeve to prevent escape of larvae feeding on contaminated plants. The data were recorded after 7 days in terms of dead and alive larvae recovered. The mortality response was assessed by using Abbott's (1925) formula in both the laboratory bioassays and the potted plant tests.

Bt field tests for control of H. armigera infesting chickpea: Field tests in 1988-89 were as follows. Chickpea variety CM 72 was sown on November 21, 1988 in a randomized complete block design with four replications, 4 meter row length, 30 centimeter row to row and 10 centimeter plant to plant distance with six rows per plot. No irrigation and no fertilizer was used. At the early podding stage of the crop (when the crop was found to be infested with 1st, 2nd and 3rd stage larvae of *H. armigera*), treatments of two commercial microbial insecticides (Dipel®2X and Dipel® ES) were applied with and without 10% molasses with the help of hand-operated knapsack sprayer. Treatments were applied four times at approximately one week intervals. The trial was harvested June 06, 1989. The data were recorded on the parameters mentioned in Table 5. Analysis of variance and Duncan's Multiple Range Test (DMRT) of the data was done with a Mstat® computer programme.

Field test in 1989-90 were as follows. Three separate chickpea trials were planted using variety CM 72 sown on November 27, 1989 in randomized complete block design with four replications, 2.0 meter row length, 30.0 centimeter row to row and 10.0 centimeter plant to plant distance with 4 rows per plot. No irrigation and no fertilizer was used. At the early podding stage of the crop (when the crop was found to be infested with 1st, 2nd and 3rd stage larvae of H. armigera), treatments of two commercial microbial insecticides (Dipel®2X and Dipel®ES), a *Bt* formulation from China and a chemical insecticide (fenvalerate 100 g AI/ha, Sumicidin® 20 EC) were applied with and without 2% molasses with a motorized Solo® back-pack sprayer. In the first trial, treatments were applied once, in second trial treatments applied twice with approximately a one-week interval and in the third trial treatments applied three times

with one-week intervals (Table 6). The trials were harvested on May 10, 1990 and recorded separately. The average total yield (kg/ha) over the three trials was calculated. The data were summarized in Table 6 including a DMRT of the data with a Mstat-C® computer programme.

Field test in 1990-91 were conducted as follows. Two separate chickpea trials were planted using a cross of chickpea varieties ICC 11514 X ILC 482 sown on November 03, 1990 in randomized complete block design with four replications, 3.0 meter row length, 30.0 centimeter row to row and 10.0 centimeter plant to plant distance with 4 rows per plot. No irrigation and no fertilizer was used. At the early podding stage of the crop (when the crop was found to be infested with 1st, 2nd and 3rd stage larvae of *H. armigera*), treatments of three commercial microbial insecticides (Dipel®2X, Dipel®ES and Bactospeine® applied with and without 7.0 percent molasses in case of *Bt* treatments only) and three chemical insecticides [fenvalerate (Sumicidin® 20 EC) 100 g AI/ha, betacyfluthrin (Bulldock® 20 EC) 100 g AI/ha, and prophenophos + cypermethrin (Polytrin-C® 440 EC) 500 + 50 g AI/ha, respectively] were with a pressurized hand-operated sprayer. On the first trial (Table 7), treatments were applied two times with one week interval, on second trial (Table 8) three times treatments applied with approx. one week interval. The trials were harvested on May 25, 1991. The data were recorded on the parameters mentioned in Tables 7 and 8. Anaylsis of variance and DMRT of the data was done with a Mstat-C® computer programme.

Monitoring H. armigera populations: The pheromone trap used in present study consisted of 2.5 meter long angle iron rod fixed in the ground (0.5 meter under, and 2.0 meter above the ground). The upper bent-side of the angle iron held a white plastic funnel with an aluminium plate which

Table 1. Toxicity of *Bt* preparations against chickpea pod borer *H. armigera* (diet bioassays) as reported by K. Ahmed and F. Khalique, NARC, Islamabad, Pakistan.

Bt preparation	Larval instar	Mean LC50 (ug/ml)	95% Confidence interval (ug/ml)	
			Lower limit	Upper limit
Dipel®2X	2nd	8.6	6.2	11.0
Dipel® ES	1st	37.5	27.6	56.9
Bt-China	1st	47.9	33.4	91.3

The USDA's reference standard strain (HD-1-S-1980, Khalique et al 1989) was more toxic than Bactospein® preparation for both the larval stages tested. The differences were more pronounced for third instar larvae. Trottier et al. (1988) did eleven bioassays of US reference standard (HD-1-S-1980) against 3rd instar larvae of bertha armyworm, *Mamestra configurata* and reported average LC50 964 ug primary powder/ml diet. Van Frankenhunzen and Fast (1989) also reported LC50 of HD-1-S-1980 to be 2.62 ug protien/ ml diet against 3rd instar larvae of western spruce budworm, *Choristoneura fumiferana* (Clemens) and Kulkarni and Amonkar (1988a) studied the comparative pathogenicity of three isolates of *Bt* subspecie *kenyae* (ISPA-1, ISPC-4 and ISPC-7) against 2nd instar larvae of *H.* armigera and reported that LC50s of ISPC-1, ISPC-4 and ISPC-7 were 2.57 X 10^7, 2.85 X 10^7 and 7.04 X 10^8 spores/ml, respectively. Thus, in these and other reported tests, *H. armigera* and other lepidopterous species were found to be highly susceptible to *Bt*.

Table 2. Mortality response of *H. armigera* larvae to *Bt* (HD-1-S-1980), malic acid and combinations in diet after 7 days at 25±4 (S) °C, as recorded in the Annual Report 1988-89, Food Legumes Improvement Programme, NARC, Islamabad, Pakistan.

Bt ug per ml diet	Mortality [a] (%) ± S by malic acid (MA) concentrations [%(pH)]				
	0%(6.3)	1%(3.8)	2%(3.3)	4%(2.8)	8%(2.4)
2.5	12±3	18±2	7±1	30±2	86±1
5	9±3	3v±2	24±1	55±3	85±3
10	12±1	27±4	29±4	77±1	97±1
20	24±3	30±1	44±4	98±1	99±1
40	36±3	52±3	81±3	100±0	100±0
80	64±3	92±1	98±1	100±0	99±1
MA control		0±0	1±1	8±1	60±3

a Corrected for natural mortality by Abbott's (1925) formula.

Bt plus Malic acid bioassays: Based on bioassay results, significant synergistic interaction was observed in most of the combinations of *Bt* with malic acid (from 1.0 to 4.0%). For Bt concentrations of 10 ug/ml or greater, 1% malic acid increased mortality by an average of 1.6-fold and 4% malic acid increased mortality by 3.7-fold. The larval mortalities caused by the combination of *Bt*+1.0% MA was higher as compared to the mortalities caused by *Bt* and MA alone at most concentrations. The overall dosage-mortality response of the noctuid *H. armigera* to combination treatments of *Bt* with MA enhanced the effectiveness of the bacteria (Table 2). However, the effectiveness of these preparations in the field would largely depend on the type of environment in which these are applied. Salama et al. (1986) reported the potentiation of HD-1-S-1980 with 0.5% picric acid and 1% tannic acid concentration in diet against *S. littoralis* (Boisd.) and Charles and Robert (1964) also stated that 1% boric acid with *Bt* significantly increased larval mortality of gypsy moth (*Lymantria dispar* L.).

Table 3. Mortality[a] response of H. armigera larvae to *Bt* (Dipel®2X and Dipel®ES) on treated chickpea plants at flowering stage, as reported by K. Ahmed & F. Khalique, NARC, Ialamabad, Pakistan.

Concentration of Dipel 2X	Mortality (%±SE)	Concentration of Dipel ES	Mortality (%+SE)
200 g/ha	48±0.9	1.0 l/ha	88+1.3
400 g/ha	62±0.8	2.0 l/ha	84+0.9
800 g/ha	67±0.8	4.0 l/ha	79+1.7
1600 g/ha	81±0.8		

[a]Corrected for natural mortality by Abbot's (1925) formula, for SE values n=4.

was fixed with a nut bolt. A polyethylene bag was mounted around the rim of the funnel. The cut opened corner was tied with a wire. A pheromone impregnated septum supplied by International Crop Research Institute for the Semi-Arid Tropics (Hyderabad, India) was suspended in middle of the aluminium plate. Adult male *H. armigera* attracted to the trap septum were captured in the polyethylene bag as adults slipped through the funnel. Four to six pheromone traps were maintained at National Agricultural Research Center (NARC), with a trap spacing of a 100 m trap to trap distance. The trapped moths were checked daily, counted and removed. The data recorded with traps and summarized at the average number of adults for specific dates for each of the four years surveyed (Figure 1).

RESULTS AND DISCUSSION

Bioassay of Bt against H. armigera: The results obtained from the bioassays indicated that Dipel®2X was found to be the most potent preparation against 2nd instar larvae showing an LC50 of 8.53 ug/ml. Dipel®ES and the China formulation of *Bt* had Lc50's of 37.54 and 47.86 ug/ml diet when tested against 1st instar larvae, and were ranked as the second and third most potent preparations, respectively (Table 1).

Bt tests on potted chickpea plants: The results in Table 3 showed that application of Bt, Dipel®2X, (32,000,000 IU/g) at the rate of 800 g (25.6 BIU) and 1600 g (51.2 BIU)/ha caused 67% and 81% larval mortality respectively while Dipel®ES (17,600,000 IU/mL) at the reate of 2 l/ha (35.2 BIU)/ha caused 84% larval mortality of *H. armigera.* In comparison, Dabi et al, (1980) reported more than

Table 4. Effect of microbial insecticides alone and with adjuants on the pod damage yield of chickpea as presented in the Annual Report 1988-89, Food Legumes Improvement Programme, NARC, Islamabad, Pakistan.

Treatment[a] (kg or l/ha)	No. pods/10 plants	No. damaged pods/10 plants	Yield (g)/plot	Ca. yield (kg/ha)
Dipel 2X+M (0.8)	438	43 bc	1453 a	3460
Dipel ES+M (1.5)	444	34 bcd	1260 a	3000
Dipel 2X+M (2.4)	390	20 de	1101 a	2621
Dipel 2X (0.8)	428	39 bcd	1079 a	2570
Dipel 2X (1.6)	514	27 cde	1057 a	2518
Dipel ES (2.5)	404	31 bcde	1008 a	2400
Dipel ES (1.0)	418	49 b	979 a	2330
Dipel 2X (2.4)	450	32 bcde	824 a	1939
Dipel 2X+M(1.6)	469	21 de	817 a	1945
Dipel ES (1.5)	296	47 bc	793 a	1887
Dipel ES+M(2.5)	283	13 e	661 a	1580
Dipel ES+M(1.0)	297	28 bcde	660 a	1570
Control	322	83 a	452 a	1075

[a]Mean followed by common letters are not significantly different using DMRT, $p<0.05$, M = 10% Molasses.

Kulkarni and Amonkar (1988b) reported larval population of *H. armigera* infesting chickpea following treatment with *Bt* but they observed no effect on chickpea yield. As far as yield of chickpea is concerned, our finding did not correspond with the findings of Kulkarni and Amonkar (1988b) for the reason that we observed significant increase in the yield of chickpea as compared to controls during three years of field trials. In these experiments, several of the *Bt* treatments increased yields compared to the control and compared favorably with synthetic chemical insecticides in terms of reduced crop damage and increased yields. Thus, the results in Pulses Programme on the use of microbial insecticides, indicates that *Bt* materials can be used to control *H. armigera* infesting chickpea and should provide an Integrated Pest Management control tactic which is biologically and environmentally safe.

Table 5. Means and ancova for 16 treatments of biological and chemical insecticides for control of chickpea pod borer as presented in the Annual Report 1989-90, Pulses Programme, NARC, Islamabad, Pakistan.

Treatment	Adjusted mean yield (g)/30 plants			Average yield
(kg or l/ha)	One Spray	Two Sprays	Three Sprays	(kg/ha)
Sumicidin (0.50)	61 a	168 ab	170 a	1475
Sumicidin (0.75)	48 a	145 abc	187 a	1404
Dipel 2X (1.6)	36 a	181 a	137 a	1311
Dipel 2X+M(1.6)	43 a	134 bcd	112 bc	1067
Dipel ES(1.5)	34 a	115 cde	109 bcd	955
Dipel ES(1.0)	32 a	100 def	106 bcd	879
China Bt(2.0)	37 a	99 def	99 cde	842
Dipel ES+M(1.5)	37 a	110 cdef	113 bc	838
Dipel 2X(0.8)	43 a	84 ef	96 cdef	825
Dipel ES+M(0.8)	27 a	88 ef	107 bcd	823
Dipel 2X+M(0.8)	29 a	99 def	80 cdef	750
China Bt(1.0)	37 a	68 f	94 cdef	736
China Bt+M(1.0)	14 a	79 ef	82 cdef	649
China Bt+M(2.0)	15 a	78 ef	65 f	533
control-water	15 a	92 def	76 def	678
control-unsprayed	23 a	94 def	69 ef	688

Mean followed by common letters are not significantly different at p<0.01, Sumicidin 20 EC=fenvalerate, +M=addition of 2% Molasses (Black molasses 80% dry matter).

Table 6. Means and anova for 16 treatments (two applications) of biological and chemical insecticides for control of chickpea pod borer as presented in the Annual Report 1990-91, Pulses Programme, NARC, Islamabad, Pakistan.

Treatment (kg or l/ha)	Undamaged pods/15 plants	Damaged pods /15 plants	Yield/15 plants	Yield /ha (kg)
Bulldock 20 EC(0.5)	430 a	95 abc	142 a	3155
Sumicidin 20 EC(0.5)	442 a	103 abc	139 a	3075
Polytrin-C 440 EC(1.25)	295 ab	73 bc	105 ab	2327
Dipel ES+M(2.0)	204 bc	95 abc	98 abc	2184
Dipel 2X+M(1.6)	209 bc	96 abc	83 abcd	1840
Dipel 2X+M(0.8)	159 bcd	128 abc	56 bcde	1252
Bactospeine+M(2.0)	152 bcd	117 abc	56 bcde	1244
Dipel ES+M(1.0)	106 cd	151 a	41 cde	908
Dipel 2X(1.6)	91 cd	162 a	37 cde	830
Bactospeine (2.0)	98 cd	95 abc	35 de	770
Bactospeine(1.0)	76 cd	143 ab	34 de	750
Dipel ES(2.0)	86 cd	154 a	33 de	730
Dipel 2X(0.8)	74 cd	115 abc	32 e	706
Dipel ES (1.0)	40 cd	104 abc	16 e	355
Bactospeine+M(1.0)	27 d	97 abc	11 e	236
Control	13 d	55 c	5 e	102

Mean followed by common letters are not significantly different (DMRT) at p<0.01, +M=addition of 7.0% molasses. Bulldock=betacyfluthrin, Sumicidin=fenvalerate, and Polytrin C=prophenophos‘cypermethrin.

85.0% mortality of third and fifth instar larvae of *Euproctis lunata* (Walker) after 96 h of feeding of contaminated leaves of pearlmillet plants sprayed with Dipel®(16000 IU/mg potency) @ 17.92 BIU/ha.

Bt field tests for control of H. armigera infesting chickpea: During 1988-89 chickpea season, field evaluation of Dipel®2X at the rate of 0.8 kg/ha and Dipel®ES at the rate of 1.5 liter/ha without molasses resulted in 2570 kg/ha and 1887 kg/ha chickpea grain yield, respectively, as compared to 1075 kg/ha yield in the control plot (Table 4). The addition of molasses to these treatments increased yield 26% and 37%, respectively. Dipel®2X at 1.6 kg/ha was not significantly different from fenvalerate in any of the three tests (Table 6). During 1989-90 chickpea season (2nd year test), application of Dipel®2X at the rate of 1.6 kg/ha and Dipel®ES at the rate 1.5 liter/ha resulted in 1311 kg/ha and 955 kg/ha chickpea grain yield as compared to 688 kg/ha yield in the control plot (Table 5). During 1990-91, application of Dipel® 2X and Dipel®ES at the rate of 1.6 kg/ha and 2.0 liters/ha with 7.0% molasses gave 1840 and 2184 kg/ha yield, respectively, as compared to 102 kg/ha yield in the control (Table 6). In the last field evaluation four *Bt* treatments resulted in greater yields than the control (Table 7).

Table 7. Means and anova for 16 treatments (three applications) of biological and chemical insecticides for control of chick-pea pod borer as presented in the Annual Report 1990-91, Pulses Programme, NARC, Islamabad, Pakistan.

Treatment kg or l/ha	Undamaged pods/15 plants	Damaged pods/15 plants	Yield/15 plants	Yield/ha (kg)
Sumicidin 20 EC (0.5)	449 a	82 abcd	151 a	3221
Polytrin-C 440 EC (1.25)	415 a	81 bcd	132 ab	2838
Bulldock 20 EC (0.5)	449 a	52 cd	132 ab	2906
Dipel 2X+M (1.6)	270 b	130 abc	106 abc	2345
Dipel ES+M (2.0)	230 bc	117 abcd	85 bcd	1881
Dipel 2X+M (0.8)	218 bcd	146 ab	80 cd	1782
Dipel 2X (0.8)	138 cde	113 abcd	59 cde	1314
Bactospeine+M (2.0)	79 de	158 a	38 def	854
Bactospeine+M (1.0)	92 cde	132 ab	37 def	828
Dipel 2X (0.8)	72 e	123 abcd	28 ef	622
Dipel ES+M (1.0)	60 e	122 abcd	25 ef	548
Dipel ES (2.0)	37 e	121 abcd	16 ef	356
Bactospeine (1.0)	25 e	89 abcd	10 ef	217
Bactospeine (2.0)	22 e	97 abcd	7 ef	147
Dipel ES (1.0)	16 e	90 abcd	6 ef	131
Control	7 e	45 d	3 f	112

Mean followed by common letters are not significantly different (DMRT) at p<0.0, +M= addition of 7.0% molasses. Bulldock=betacyfluthrin, Sumicidin=fenvalerate, and Polytrin C=cypermethrin.

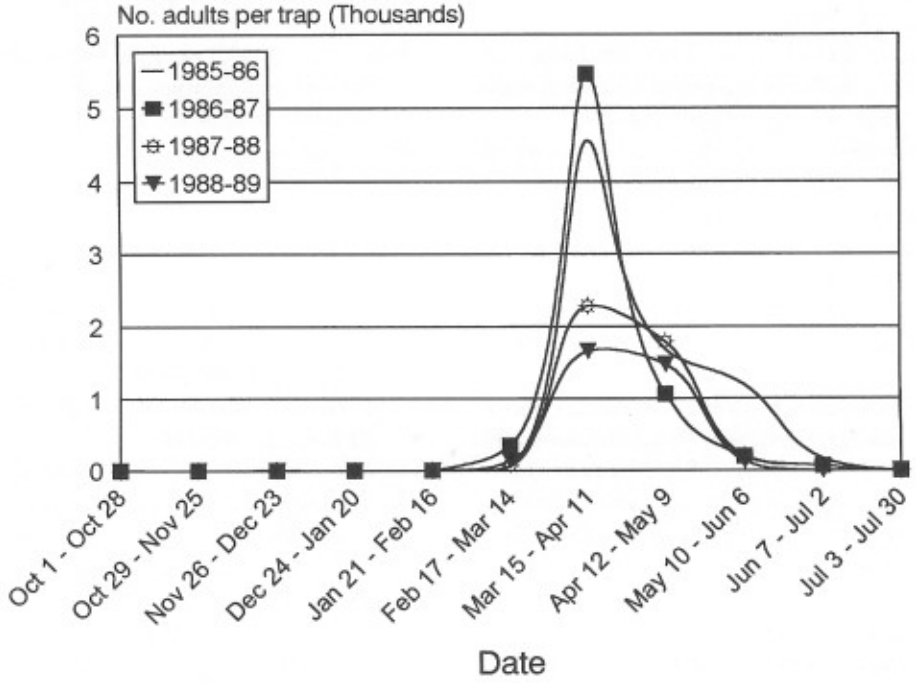

Fig 1. Studies on population dynamics of *H. armigera* using pheromone traps, NARC 1985-89

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