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Comparative Effects of Some Biorational and Conventional Insecticides against Immature and Adult Stages of the Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say.) (Coleoptera: Chrysomelidae) in Russia

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ABSTRACT

Efficacy of some biorational and conventional insecticides against different stages of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say.) (Coleoptera: Chrysomelidae) was evaluated under laboratory conditions. Seven different commercial products were tested, including the biorational insecticides: Spinosad, Mectin, Fitoverm, Match, Neemix in addition to two conventional insecticides: Actara and Actellic. Data indicated that all tested insecticides showed low toxic effect to *L. decemlineata* eggs, but most hatching neonates died shortly after hatching. All tested insecticides, at their field rates showed high toxicity to larvae of *L. decemlineata*. Highest mortality was obtained in earlier instars compared to older ones and mortality increased with the time of exposure. Moreover, the lower concentrations (up to 25% of the field rate) of Actara, Mectin, Spinosad and Fitoverm showed high efficacy against *L. decemlineata* 3rd instar larvae. Also, Actara caused highest mortality in *L. decemlineata* adults, followed by Spinosad, Mectin and Fitoverm compared to Actellic, Match and Neemix. In pupal bioassay, Fitoverm caused highest reduction in *L. decemlineata* adults' emergence followed by Mectin, Actara, Actellic and Spinosad. In Translocation bioassays, Actara caused highest mortality in *L. decemlineata* 3rd instar larvae or adults followed by Spinosad and Mectin. Residual activity of the tested insecticides against 3rd instar larvae was also evaluated. Actara, Spinosad and Mectin exhibited residual effect under field conditions, as the percentages of mortality after 30 days of application were 46.67, 44.44 and 35.56%, respectively.

Key words: *Leptinotarsa decemlineata,* Biorational, Conventional Insecticides, Mortality, Bioassay, Residual effect.

INTRODUCTION

Potato, *Solanum tuberosum* L., is the world's most widely grown tuber crop and the fourth largest food crop in terms of fresh production after rice, wheat, and maize (Rutz and Janssen, 2007). This crop is subjected to severe attack with scores of insect and pathogen pests, which affect its production. The actual average worldwide losses in potato yields due to agricultural pests was estimated at 39% (Oerke and Dehne, 2004). In Russia, for instance, as much as 4 million tons of potatoes are lost annually because of the infestation with the Colorado beetle (CPB), *Leptinotarsa decemlineata* (Say.) (Coleoptera: Chrysomelidae), late blight and plant viruses (Potato World, 2008).

CPB is one of the major insect pests attacking potato in many of the potato-producing regions worldwide. In addition to potato, the preferred host plant, it devastates, by its voracious feeding, other solanaceous crops such as; eggplant, tomato, pepper, and tobacco (Hare, 1990). Moreover, CPB is widely considered as a quarantine pest in most of the world countries including Egypt (EPPO, 2006).

CPB adults over-winter below the soil surface in the potato field or in other protected sites around the field. The adults emerge in late spring, move into the field, and establish themselves on plants where they mate.

Until recently, there have been no effective biocontrol agents for the CPB. Control of this pest has relied over the past 50 years on conventional insecticides (Lipa, 2008). Shortly after insecticide applications, CPB developed resistance to the common used insecticides (Leontieva *et al.*, 2006). Biological control would be the concerted use as a major component of integrated pest management for control of CPB. Natural enemies of CPB include a variety of predatory insects, parasitoids and microbial control agents (Lacey *et al.*, 1999). Fortunately, biological control using bio-rational insecticides has become the most effective means in potato pest management programs; because their use reduces pollution and delay the development of resistance to other classical insecticides (Barčić *et al.*, 2006).

Therefore, the aim of this study is to evaluate the efficacy of some biorational insecticides for controlling CPB compared to the conventional insecticides as a contribution to introduce safer insecticides in IPM protocol for controlling several insect pests in vegetable crops.

MATERIALS AND METHODS

All experiments were conducted in the Laboratory of Plant Protection Department, Russian State Agrarian University – Moscow, Russian Federation during the period from May to August,

2007. During this period, the weather conditions were mainly hot, which provided unusual two generations of the CPB, *L. decemlineata* (Gritsenko and Osman, unpublished data).

Maintenance of *L. decemlineata*

Egg masses and different larval instars of CPB were periodically collected from the infested CPB-potato fields. Larvae were reared on potato branches (30 cm long). The lower parts of these potato branches were inserted in glass vials 2 × 10 cm, containing fresh water to maintain them fresh as long as possible (Gelman *et al.,* 2001). The vials were placed in a cage of 60×60×60 cm under the laboratory conditions of 25±2°C; 60±10% RH and photoperiod of 16: 8 (L: D) h. Upon emergence, adults of CPB were collected, fed and reared as previously mentioned larvae.

Insecticides used and soil characteristics

Formulated insecticides used in this study were: Spinosad 12% SL (spinosyns A and D, *Saccharopolyspora spinosa*), Mectin 1.8% EC (*Streptomyces avermitilis*, 80% avermectin B1a and 20% avermectin B1b), Fitoverm 0.2% EC (*Streptomyces avermitilis*, aversectin C), Match (50% EC Lufenuron), Neemix EC (4.5% Azadirachtin), Actara WG (25% Thiamethoxam) and Actellic (50% EC Pirimiphos-methyl). Solutions of all tested compounds were prepared in distilled water at the field rate concentrations (Spinosad 60 mg/l a.i., Mectin 7.2 mg/l a.i., Fitoverm 2.4 mg/l a.i, Match 200 mg/l a.i., Neemix 56.25 mg/l a.i., Actara 40 mg/l a.i. and Actellic 750 mg/l a.i.). The tested concentrations of all tested compounds in the present study were FR (field rate), FR/2, FR/4, FR/8, FR/16 and FR/32 using fresh concentrations prepared one hour prior to experiments.

The soil used was clay (10.1% Coarse Sand, 5.3% Fine Sand 25.7% Silt and 58.9% Clay; pH = 6.1; Organic mater 3.7%), which is the typical soil type in most of cultivated regions in Moscow.

Experimental bioassays

Bioassay of *L. decemlineata* eggs

CPB egg masses (<1-day old eggs) on potato leaves were used. The egg masses were treated in 9 replicates (20 eggs each) with one of the solutions of the tested insecticides through direct spray using handle sprayer. Treated eggs were then removed, kept on clean Petri dishes (10 cm diameter) and observed daily till egg hatching. Moreover, rate of mortality in 1st instar larvae was recorded 24 hours post hatching.

Bioassay of *L. decemlineata* larvae

Effect of the field rates (FR) of the tested insecticides were studied against CPB 1st, 2nd, 3rd and 4th instar larvae. Moreover, the effect of FR/2, FR/4, FR/8, RF/16 and FR/32 against CPB 3rd instar larvae was also investigated. Each treatment was replicated 9 times with 10 larvae each. The treatments were performed by dipping small potato leaves in the tested solutions for 15 seconds with gentle agitation. The treated potato leaves were then placed on a paper towel for at least 2 hours or until they dried out before being used in the experiments. The tested larvae of CPB were starved for at least 4 hours prior experiment. Larvae were removed gently by fine camel-hair brush and placed into Petri dish having small treated potato leaf. Petri dishes were closed and kept in the laboratory under the abovementioned laboratory conditions. Control treatments were also conducted with the same protocol using distilled water. One day after treatment, surviving larvae were fed on untreated leaves for the rest of the experimental period. To count mortality rate, Petri dishes were daily observed till the larvae developed into pupae. Rates of mortality in CPB larvae were recorded 3 and 7 days post feeding on the treated leaves. Larvae were considered dead if they gave no response to stimulation by touch with a hair-camel brush.

Bioassay of *L. decemlineata* pupae

To study the effect of the field rate of the tested insecticides on the pupae of CPB, each 500g of soil were mixed thoroughly with 100 ml of each insecticide solution. These treated soils were left to dry completely before being packed into small plastic pots (1 liter). Ten full grown larvae of CPB were placed on the treated soil. These pots were covered with muslin sheets and fixed in place with rubber bands. Fifteen days later, pots were checked to record rates of adult emergence. Each treatment was replicated 9 times with 10 pupae each. Control treatment was performed using the same protocol and number of replicates but with distilled water only.

Bioassay of *L. decemlineata* adults

Three concentrations (FR, FR/2 and FR/4) of each insecticide were tested. Potato leaves were treated as previously mentioned in larval bioassay. Each treatment was replicated 9 times. The tested adults were starved for at least 4 hours prior experiment. Ten CPB adults were confined in clean Petri dish with treated potato leaves. Petri dishes were then closed and kept under the aforementioned laboratory conditions. One day later, adults were checked and fed on untreated potato leaves until the end of experimental period. Control treatments were also conducted using the same protocol with distilled water. Treatments were checked at daily basis and rate of adult mortality was recorded 3 and 7 days post feeding on the treated leaves.

Persistence of insecticides on foliage treated potato plants

To study the persistency/ residual activity of the tested insecticides against CPB larvae under filed conditions, 3 plants (5 week-old) were carefully sprayed with the FR of each of the tested insecticides. Another 3 potato plants were also spayed with water as untreated control. Exactly 0, 5, 10, 20, 30 and 40 days after application, leaves of the treated and non-treated were picked up and transferred to the laboratory. The bioassay was conducted only for starving 3rd instar larvae of CPB. Nine replicates with 10 3rd instar larvae were used for each treatment. Larvae were gently moved into the Petri dish and allowed to feed on the treated leaves for 24 hours only then they were fed on untreated leaves till the end of the experiment. CPB larvae were daily observed and the mortality percentages were recorded 3 and 7 days post feeding on treated leaves.

Translocation of the tested insecticides into plants

This study was carried out to record the translocation activity of the tested insecticides through potato plants and their residual activity against CPB larvae and adults. Potato was planted in untreated soil in plastic pots. Pots were irrigated for the first time with tested solutions of insecticides at field rate, and then with fresh water when needed. After 25 days of planting, each pot was covered thoroughly with transparent muslin and provided with ten 3rd instar larvae or adults of CPB. Nine replicates were used for each treatment including control. Insects were observed at 3-day interval after exposure and the rates of mortality in CPB larvae or adults were recorded.

Statistical analysis

Mortality data in CPB eggs, larvae, pupae and adults were analyzed using one-way ANOVA (SAS Institute. 2003). In case of significant F-values, means were separated by Tukey' HSD at a 0.05 level of significance.

RESULTS AND DISCUSSION

Biological activity of tested insecticides on different stages of *L. decemlineata*

a. Egg stage

Data in Fig. (1) showed that the tested insecticides were not effective against CPB eggs and no significant differences were observed in hatchability ($F= 2.748$; $P \leq 0.015$). However, significant differences occurred among the tested insecticides in rates of mortality in surviving first instar larvae one day after hatching ($F= 129.748$; $P \leq 0.000$). Mortality rates could be arranged as Fitoverm > Mectin > Spinosad > Actara > Actellic > Neemix > Match.

The tested insecticides showed also low toxicity to CPB eggs; however, most hatching neonates died shortly after hatching. These results agree with those reported by Koopmanschap *et al.* (1989) who found that the larvae of CPB failed to emerge from treated eggs with the juvenile hormone analogue, S-71639 and emerging larvae died soon after hatching.

b. Larval stage

All tested insecticides at their field rates showed high toxicity to larvae of CPB (Table 1). Mortality rates decreased as CPB larvae aged, but increased with the increase of time post treatment. There were significant differences among tested insecticides in their mortality rates in 1st instar cohorts 3 days post treatment ($F= 25.844$; $P \leq 0.000$) and 7 days ($F= 137.617$; $P \leq 0.000$) post treatment; and in 2nd instar cohorts 3 days ($F= 26.975$; $P \leq 0.000$) and 7 days post treatment ($F= 108.333$; $P \leq 0.000$). The same trend of significance was observed in 3rd instar larvae ($F= 16.75$; $P \leq 0.000$ for 3 days; $F= 43.19$; $P \leq 0.000$ for 7 days) and in 4th instar bioassays ($F= 31.65$; $P \leq 0.000$ for 3 days; $F= 72.50$; $P \leq 0.000$ for 7 days). Generally, Actra and Mectin achieved highest mortalities in all tested larval instars; being 100% after 7 days of treatment, whereas Neemix was the least effective insecticide (Table 1).

In foliar bioassays, the tested insecticides differed in their toxicity to CPB larval instars. High mortality was obtained in earlier instars as compared to older ones and mortality increased with the time after exposure. The most effective insecticides were; Actara, Mectin and Spinosad. These findings are in agreement with those reported for Thiamethoxam (Actara), which is regularly used by potato growers in the US as systemic insecticides to control CPB, and *Empoasca fabae* (Kuhar *et al.*, 2007).

As for CPB 3rd instar larvae bioassays, data indicated that the mortality rate increased significantly with the increase of insecticide concentration (Table 2). While Mectin was the most toxic insecticide to CPB 3rd instar larvae, Neemix was the least effective one. Three and seven days post treatments, mortality rates differed significantly among tested insecticides.

As shown in Table (2), the low concentration of the tested insecticides such as; Actara, Mectin, Spinosad and Fitoverm showed high efficacy when used up to 25% of the field rate. This, undoubtedly, has two advantages; first, it might reduce the amount of insecticides in the environment and encourage the natural enemies of CPB, and second, it might increase the profit by reducing the cost of control. Fortunately, Spinosad, Mectin and Fitoverm are worldwide recognized as benign compounds towards biocontrol agents and are widely used in IPM

Table (1): Mortality (%± SE) of *L. decemlineata* larvae fed on potato leaves treated with the recommended concentrations of certain insecticides three and seven days post treatment.

Treatment	Concentration mg/l a.i.	% Mortality							
		First instar		Second instar		Third instar		Fourth instar	
		Post 3 days	Post 7 days	Post 3 days	Post 7 days	Post 3 days	Post 7 days	Post 3 days	Post 7 days
Control	0	4.44 ± 2.94b	8.89±3.51^{b}	6.67±3.33^{c}	8.89±3.51c	2.22±2.22^{c}	8.89±3.51^{c}	0^{d}	6.67±3.33^{c}
Spinosad	60	86.67 ± 5.77^{a}	100^{a}	84.44±6.48^{a}	100^{a}	73.33±8.82^{ab}	100^{a}	57.78±9.69 ^{ab}	95.56 ± 4.44^{a}
Mectin	7.2	88.89 ± 6.76 ^{a}	100^{a}	73.33±4.71^{a}	100^{a}	71.11±5.88^{ab}	100^{a}	48.89 ± 5.88 ^{b}	100^{a}
Fitoverm	2.4	77.78 ± 5.21^{a}	100^{a}	75.56±6.48^{a}	100^{a}	64.44± 4.44^{abc}	95.56 ± 4.44 ^{a}	46.67± 3.33b^{c}	66.67±3.33^{b}
Match	200	60.00±10.54 ^{a}	100^{a}	42.22±9.10 b	97.78±2.22^{a}	37.78 ±10.24^{cd}	82.22±10.24^{ab}	0 ^{d}	46.67±9.43^{b}
Neemix	56.25	15.56±7.29b	88.89±5.88^{a}	11.11±3.51^{c}	71.11±6.76^{b}	15.56 ± 4.44^{de}	24.44±5.56 ^{c}	0 ^{d}	6.67±4.71^{c}
Actara	40	88.89±5.88^{a}	100^{a}	84.44 ± 6.48^{a}	100^{a}	82.22 ± 7.78 ^{a}	100 ^{a}	75.56±7.29^{a}	100^{a}
Actellic	750	80.00±6.67^{a}	93.33±3.33^{a}	66.67±6.67^{ab}	86.67 ± 3.33^{a}	46.67±8.82^{bcd}	66.67 ± 8.82 ^{b}	24.44±5.56^{c}	53.33±3.33^{b}
F. value		25.844	137.617	26.975	108.333	16.746	43.187	31.659	72.507
P. value		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Means followed with the same letters (column wise) are not significantly different (Tukey' HSD; P≤ 0.05)

Table (2): Effect of different concentrations of certain insecticides on the mortality of *L. decemlineata* 3rd instar larvae, three and seven days post treatment.

Treatment	FR* (Concentration, mg/l a.i.)	% Mortality											
		FR		FR/2		FR/4		FR/8		FR/16		FR/32	
		Post 3 days	Post 7 days	Post 3 days	Post 7 days	Post 3 days	Post 7 days	Post 3 days	Post 7 days	Post 3 days	Post 7 days	Post 3 days	Post 7 days
Control	0	2.22 ±2.22^{e}	8.89 ±3.51^{c}	2.22 ±2.22^{c}	8.89 ±3.51^{c}	2.22 ±2.22^{d}	8.89 ±3.51^{c}	2.22 ±2.22^{d}	8.89 ±3.51^{d}	2.22 ±2.22^{d}	8.89 ±3.51^{c}	2.22 ±2.22^{c}	8.89 ±3.51^{d}
Spinosad	60	73.33 ±8.82^{ab}	100^{a}	71.11 ±6.76^{ab}	100^{a}	62.22 ±5.21^{ab}	97.78 ±2.22^{a}	64.44 ±9.87^{a}	97.78 ±2.22 ^{a}	46.67 ±10.54^{ab}	88.89 ±4.84^{a}	24.44 ±4.44^{bc}	44.44 ±2.94^{c}
Mectin	7.2	71.11 ±5.88^{ab}	100^{a}	68.89 ±5.88^{ab}	100^{a}	68.89 ±7.54^{a}	100^{a}	62.22 ±5.21^{a}	100^{a}	62.22 ±4.01^{a}	97.78 ±2.22^{a}	55.56 ±4.44^{a}	91.11 ±3.51^{a}
Fitoverm	2.4	64.44 ±4.44^{abc}	95.56 ±4.44^{a}	60.00 ±3.33^{ab}	93.33 ±3.33^{a}	53.33 ±4.71^{ab}	93.33 ±4.71^{a}	44.44 ±4.44^{abc}	86.67 ±5.774^{a}	35.56 ±8.68^{abc}	77.78 ±5.21^{ab}	35.56 ±6.48^{ab}	68.89 ±7.54^{b}
Match	200	37.78 ±10.24^{cd}	82.22 ±10.24^{ab}	57.78 ±7.02^{ab}	88.89 ±5.88^{a}	37.78 ±11.76^{bc}	71.11 ±8.24^{b}	26.67 ±4.71bcd	60.00 ±4.71^{b}	20.00 ±8.17^{bcd}	57.78 ±10.24^{b}	20.00 ±6.67^{bc}	37.78 ±5.21^{c}
Neemix	56.25	15.56 ±4.44^{de}	24.44 ±5.56^{c}	11.11 ± 4.84^{c}	17.78 ±4.01^{c}	6.67 ±3.33^{d}	15.56 ±5.56^{c}	4.44 ±2.94^{d}	13.33 ±4.71^{d}	2.22 ±2.22^{d}	11.11 ±3.51^{c}	2.22 ±2.22^{c}	11.11 ±3.51^{d}
Actara	40	82.22 ± 7.78^{a}	100^{a}	82.22 ±6.19^{a}	100a	77.78 ±7.78^{a}	100^{a}	53.33 ±9.43^{ab}	95.56 ±2.94^{a}	22.22 ±5.21^{bcd}	64.44 ±7.29^{b}	22.22 ±7.78^{bc}	40.00 ±5.77^{c}
Actellic	750	46.67 ±8.82^{bcd}	66.67 ±8.82^{b}	46.67 ±9.43^{b}	60.00 ±11.55^{b}	17.78 ±6.19^{cd}	26.67 ±3.33^{c}	22.22 ±5.21^{cd}	33.33 ±3.33^{c}	13.33 ±4.71^{cd}	22.22 ±2.22^{c}	20.00 ±5.77^{bc}	35.56 ±4.44^{c}
F. value		16.746	43.187	22.400	55.946	18.975	87.381	16.486	104.252	11.033	40.908	10.468	32.865
P. value		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Means followed with the same letters (column wise) are not significantly different (Tukey' HSD; P≤ 0.05)
* = Field Rate

Table (3): Effect of different concentrations of certain insecticides on the mortality of *L. decemlineata* adults three and seven days post treatment.

Treatment	FR* (Concentration, mg/l a.i.)	% Mortality					
		FR		FR/2		FR/4	
		Post 3 days	Post 7 days	Post 3 days	Post 7 days	Post 3 days	Post 7 days
Control	0	0 c	2.22 ± 2.22 c	0 c	2.22 ± 2.22 d	0 c	2.22 ± 2.22 c
Spinosad	60	86.67 ± 6.67 a	93.33 ± 3.33 a	73.33 ± 5.77 a	86.67 ± 3.33 a	62.22 ± 5.21 a	77.78 ± 2.22 a
Mectin	7.2	71.11 ± 4.84 ab	95.56 ± 2.94 a	62.22 ± 5.21 a	82.22 ± 4.01 a	51.11 ± 4.84 a	75.56 ± 5.56 a
Fitoverm	2.4	80.00 ± 5.77 ab	93.33 ± 3.33 a	60.00 ± 3.33 a	84.44 ± 4.44 a	51.11 ± 4.84 a	75.56 ± 4.44 a
Match	200	2.22 ± 2.22 c	11.11 ± 3.51 c	0 c	6.67 ± 3.33 d	0 c	6.67 ± 3.33 c
Neemix	56.25	24.44 ± 5.56 c	35.56 ± 6.48 b	15.56 ± 4.44 bc	26.67 ± 3.33 c	13.33 ± 3.33 bc	17.78 ± 2.22 c
Actara	40	91.11 ± 3.51 a	100 a	73.33 ± 3.33 a	93.33 ± 3.33 a	60.00 ± 4.71 a	86.67 ± 3.33 a
Actellic	750	57.78 ± 11.28 b	86.67 ± 6.67 a	31.11 ± 7.54 b	62.22 ± 4.01 b	24.44 ± 8.01 b	48.89 ± 7.54 b
F. value		40.724	101.447	50.162	113.505	32.477	68.142
P. value		0.000	0.000	0.000	0.000	0.000	0.000

Means followed with the same letters (column wise) are not significantly different (Tukey' HSD; P≤ 0.05)
* = Field Rate

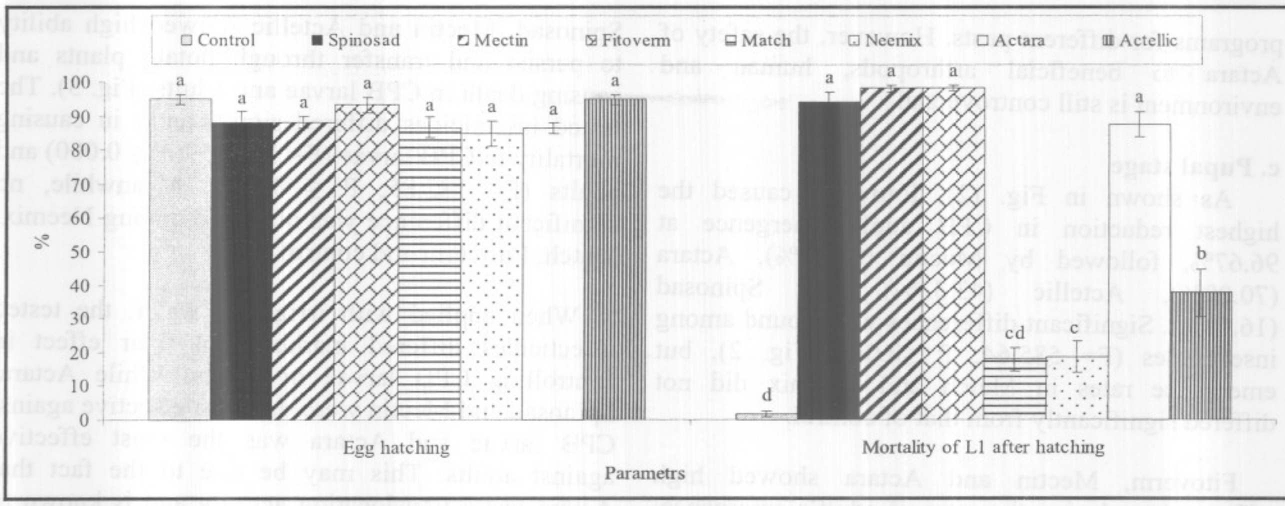

Fig. (1): Effect of tested insecticides on the percentages of egg hatching and mortality of 1st instar larvae of *L. decemlineata*. (Bars with the same letters are not significantly different (Tukey' HSD; P≤ 0.05).

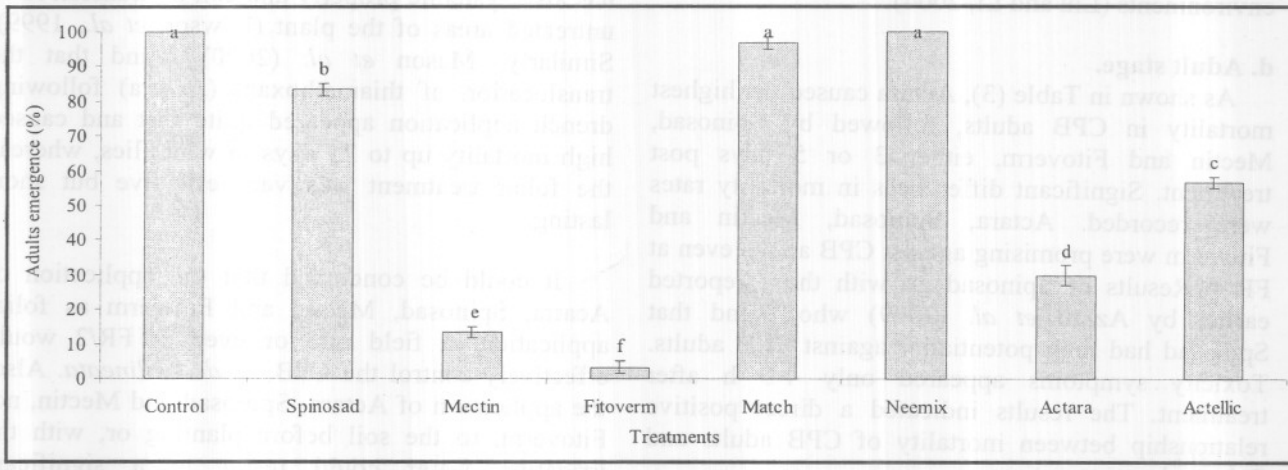

Fig. (2): Adult emergence (%±SE) of *L. decemlineata* placed as full grown larvae on treated soil with the recommended dose of certain insecticides (Bars with the same letters are not significantly different (Tukey' HSD; P≤ 0.05).

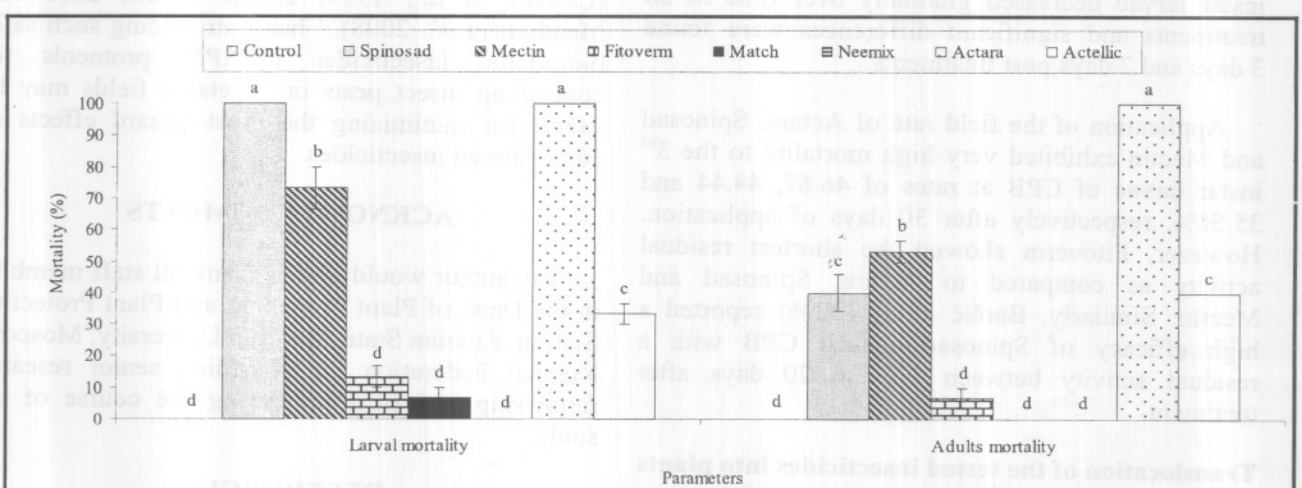

Fig. (3): Mortality (%±SE) of third instar larvae and adults of *L. decemlineata* fed on leaves of potato plants irrigated for the first time with insecticide solutions. Bars with the same letters are not significantly different (Tukey' HSD; P≤ 0.05).

programs for different pests. However, the safety of Actara to beneficial arthropods, human and environment is still controversial.

c. Pupal stage

As shown in Fig. (2), Fitoverm caused the highest reduction in CPB adult emergence at 96.67%, followed by Mectin (86.67%), Actara (70.00%), Actellic (43.33%) and Spinosad (16.67%). Significant differences were found among insecticides (F= 585.64; P $\leq$0.000; Fig. 2), but emergence rates in Match and Neemix did not differed significantly from that of control.

Fitoverm, Mectin and Actara showed high efficacy in reducing the rates of adult's emergence; however, the action of Spinosad was less pronounced. The lower mortality may be attributable to the rapid degradation of Spinosad in wet environments (Liu and Li, 2004).

d. Adult stage.

As shown in Table (3), Actara caused the highest mortality in CPB adults, followed by Spinosad, Mectin and Fitoverm, either 3 or 5 days post treatment. Significant differences in mortality rates were recorded. Actara, Spinosad, Mectin and Fitoverm were promising against CPB adults even at FR/4. Results of Spinosad go with those reported earlier by Azimi *et al.* (2009) who found that Spinosad had high potentiality against CPB adults. Toxicity symptoms appeared only 4-5 h after treatment. The results indicated a direct positive relationship between mortality of CPB adults and Spinosad exposure time.

Residual activities of tested insecticides to third instar larvae of *L. decemlineata*

As shown it table (4), mortality rate of CPB 3rd instar larvae decreased gradually over time in all treatments and significant differences were found 3 days and 7 days post treatments.

Application of the field rate of Actara, Spinosad and Mectin exhibited very high mortality to the 3rd instar larvae of CPB at rates of 46.67, 44.44 and 35.56%, respectively after 30 days of application. However, Fitoverm showed the shortest residual activity as compared to Actara, Spinosad and Mectin. Similarly, Barčić *et al.* (2006) reported a high efficacy of Spinosad against CPB with a residual activity between 10 and 20 days after treatment.

Translocation of the tested insecticides into plants

L. decemlineata 3rd instar larvae and adults were allowed to feed on potato leaves taken from plants cultivated in treated clay soil after 25 days of planting and insecticide application. Actara, Spinosad, Mectin and Actellic showed high ability to persist and transfer through potato plants and causing death in CPB larvae and adults (Fig. 3). The tested insecticides differed significantly in causing mortality in CPB larvae (F= 141.859; P $\leq$ 0.000) and adults (F= 182.85; P $\leq$ 0.000). Meanwhile, no significant difference was observed among Neemix, Match, Fitoverm and control.

When applied with irrigation water, the tested insecticides differed markedly in their effect in controlling CPB larvae or adults. While Actara, Spinosad and Mectin were the most effective against CPB larvae and Actara was the most effective against adults. This may be due to the fact that Actara has a translocation activity and is known to be translocated via the xylem (Senn *et al.*, 1998), and this property has been confirmed by its prompt activity following drench application. In addition, it has also systemic property and can be transferred to untreated areas of the plant (Lawson *et al.*, 1999). Similarly, Mason *et al.* (2000) found that the translocation of thiamethoxam (Actara) following drench application appeared quite fast and caused high mortality up to 25 days in whiteflies, whereas the foliar treatment was very effective but short lasting.

It could be concluded that the application of Acatra, Spinosad, Mectin and Fitoverm as foliar application at field rate or even at FR/2 would effectively control the CPB, *L. decemlineata*. Also, the application of Actara, Spinosad and Mectin, not Fitoverm, to the soil before planting or, with the irrigation water could result in a significant reduction in CPB population for at least one month (with approximate 50% mortality). The applications of these three insecticides had minimal effects on beneficial insects, mammals and environment (Lawson *et al.*, 1999; Barčić *et al.*, 2006 and Mandour *et al.*, 2008). Thus, introducing such safer biorational insecticides in IPM protocols for controlling insect pests in vegetable fields may be useful for minimizing the most hazard effects of conventional insecticides.

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