Results and Discussion

RESULTS AND DISCUSSION

A- LABORATORY EXPERIMENTS :

1- Infectivity of different entomopathogenic nematodes to full-grown larvae of *Ceratitis capitata* :

1.1- First method :

In this experiment, 10 individuals of *C. capitata* full-grown larvae were placed/cup.

Data presented in Table (1) show the mortality percentages among *C. capitata* larvae, one week after treatment by different nematode species at different concentrations. These data showed that *S. abbasi* and *H. bacteriophora* were, generally, more effective on the treated stages than *S. riobravis* and *H. tayserae*.

*** *S. abbasi* :**

Percentage mortality increased as the concentration of IJs increased. At a concentration of 125 IJs/cm² of soil surface, mortality in full-grown larvae of *C. capitata* was 44.0 %. As concentration of IJs was increased to 250/cm², the mortality increased to 52.0 %. At concentrations of 500, 1000 and 2000 IJs/cm² mortalities reached 70.0, 75.0 and 86.0 %, respectively. The highest mortality (96 %) was achieved when concentration of IJs was increased to the maximum of 4000/cm² of soil surface, (Table 1 and Fig. 1).

As shown in Fig. (2), the LC_{50} of *S. abbasi* to full-grown larvae of *C. capitata* was found to be 204 IJs/cm² of soil surface.

Table (1) : Mortality percentages among full-grown larvae of *C. capitata* due to infection by different nematode species at different concentrations.

Conc. IJs/cm^2 soil	Nematode species	% Mortality	
		First method (10 larvae/cup)	Second method (single larva/cup)
125	*S. abbasi*	44	60
	S. riobravis	35	40
	H. bacteriophora	42	60
	H. tayserae	39	40
250	*S. abbasi*	52	76
	S. riobravis	48	56
	H. bacteriophora	53	76
	H. tayserae	45	52
500	*S. abbasi*	70	92
	S. riobravis	57	68
	H. bacteriophora	68	88
	H. tayserae	59	60
1000	*S. abbasi*	75	100
	S. riobravis	68	78
	H. bacteriophora	76	96
	H. tayserae	69	72
2000	*S. abbasi*	86	100
	S. riobravis	79	88
	H. bacteriophora	87	100
	H. tayserae	78	84
4000	*S. abbasi*	96	100
	S. riobravis	89	96
	H. bacteriophora	97	100
	H. tayserae	88	92
LC_{50}	*S. abbasi*	204	47
	S. riobravis	308	198
	H. bacteriophora	215	82
	H. tayserae	289	240
Slope	*S. abbasi*	1.2092	1.5758
	S. riobravis	1.0413	1.2290
	H. bacteriophora	1.3145	1.5324
	H. tayserae	0.9752	1.0865
Mean	*S. abbasi*	70.5±2.6	88.0±8.2
	S. riobravis	62.7±3.2	70.7±8.2
	H. bacteriophora	70.5±3.2	86.7±7.3
	H. tayserae	63.0±2.7	66.7±9.1

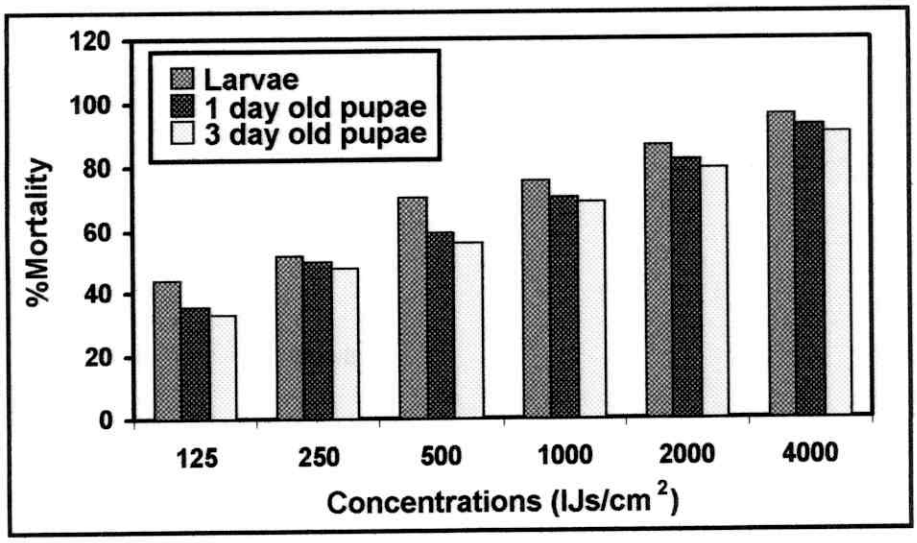

Fig. (1): Mortality percentages among *C. capitata* larvae and pupae treated with *S. abbasi.*

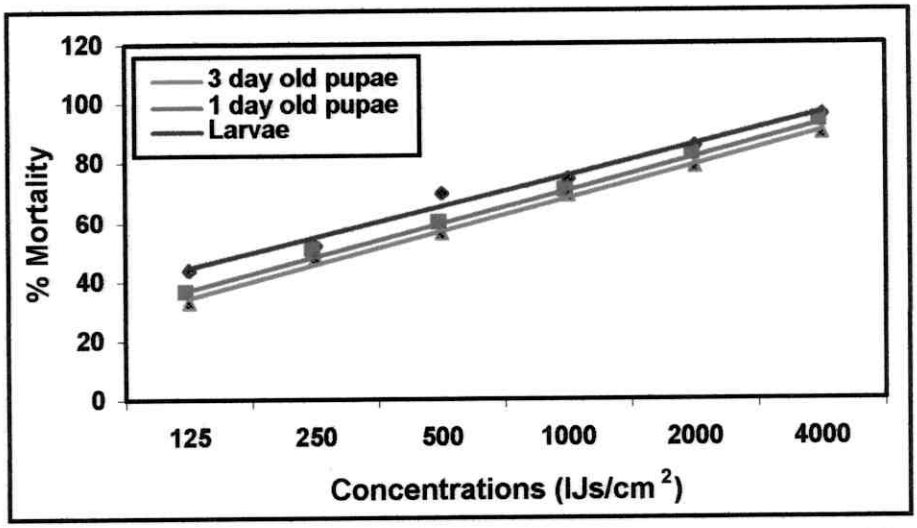

Fig. (2): Concentration – lines for different concentrations of *S. abbasi* against *C. capitata* larvae and pupae.

*** *S. riobravis* :**

Treatment of the full-grown larvae of *C. capitata* by *S. riobravis* at 125 IJs/cm² caused lower mortality percentage among the treated larvae than that recorded in case of *S. abbasi* (35 %). By increasing the concentration to 250 IJs/cm², the mortality increased to 48 %. At concentrations of 500, 1000 and 2000 IJs/cm², mortalities reached 57, 68 and 79 %, respectively. The highest mortality (89 %) occurred when the concentration of IJs was 4000/cm² of soil surface, (Table 1 and Fig. 3).

The LC_{50} of *S. riobravis* to full grown larvae of *C. capitata* reached 308 IJs/cm² of soil surface (Fig. 4).

*** *H. bacteriophora* :**

Treatment of the full-grown larvae by *H. bacteriophora* at the lowest concentration (125 IJs/cm²) caused lower mortality percentage among the treated larvae (42.0; 30-60 %), one week after treatment. By increasing the applied dose to 250 IJs/cm², the recorded mortality percentage was 53.0 (30-70 %). Percentage mortality increased to 68 % when the applied concentration was increased to 500 IJs/cm². The higher concentrations (1000, 2000 and 4000 IJs/cm² of soil surface) caused averages of 76 , 87 and 97 % mortality, respectively, (Table 1 and Fig. 5).

According to the concentration-mortality line (Fig. 6), the LC_{50} of *H. bacteriophora* to full-grown larvae of *C. capitata* was 215 IJs/cm² of soil surface.

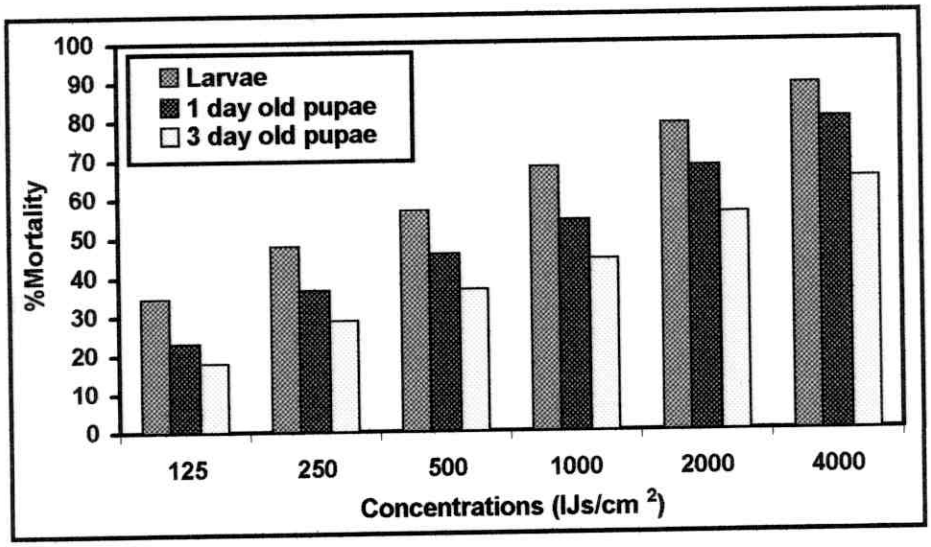

Fig. (3): Mortality percentages among *C. capitata* larvae and pupae treated with entomopathogenic nematode *S. riobravis*.

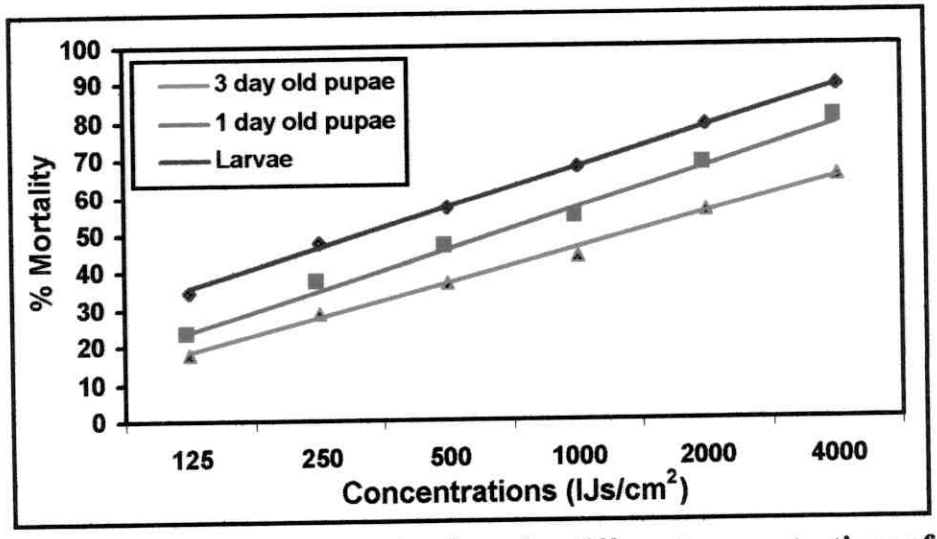

Fig. (4): Concentration – mortality lines for different concentrations of *S. riobravis* against *C. capitata* larvae and pupae.

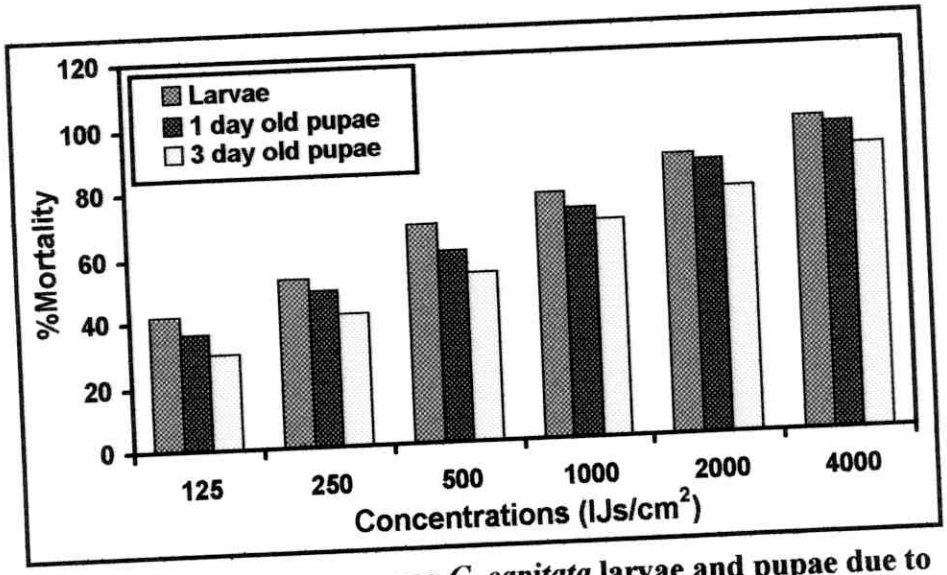

Fig. (5): Mortality percentages among *C. capitata* larvae and pupae due to treatment with entomopathogenic nematode *H.bacteriophora.*

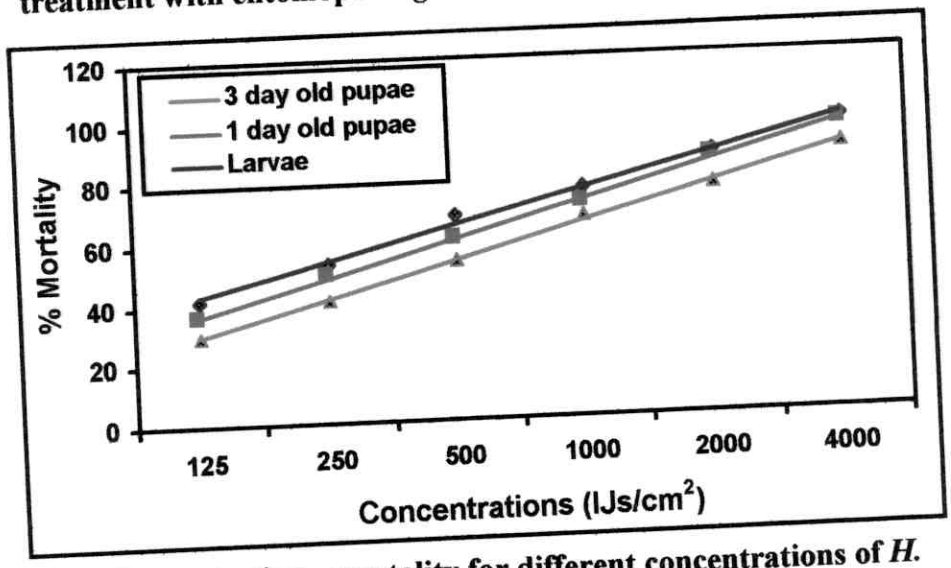

Fig. (6): Concentration - mortality for different concentrations of *H. bacteriophora* against *C. capitata* larvae and pupae.

*** *H. tayserae* :**

The lowest concentration (125 IJs/cm²) caused 39 (30-70) % mortality, one week after exposure. This percentage increased to 45, 59.0 and 68 %, when the applied concentration of IJs suspension was increased to 250, 500 and 1000 IJs/cm², respectively. By increasing the applied dose to 2000 IJs/cm² the recoded mortality was 78.0 (70-90) % mortality. The recorded mortality % increased again to reach the maximum of 88 (80-100) % when the concentration was increased to 4000 IJs/cm² of soil surface, (Table 1 and Fig. 7).

LC_{50} of *H. tayserae* to full-grown larvae of *C. capitata* was found to be 289 IJs/cm² of soil, (Fig. 8).

1.2- Second method :

In this method, only one *C. capitata* full grown larva was placed in each of a 5 cm diameter Petri-dish bottomed with sterile sand.

*** *S. abbasi* :**

Data in Table (1) indicate that, mortality percentages among the Mediterranean fruit-fly full-grown larvae increased with increasing of the inoculum level of *S. abbasi* from 125 to 4000 juveniles/cm² of soil surface. At the lower concentrations 125, 250 and 500 IJs/cm², the mortality percentages were 60.0, 76 and 92 %, respectively. Concentrations of 1000, 2000 and 4000 IJs/cm² caused 100 % mortality, (Table 1 and Fig. 9).

The LC_{50} of *S. abbasi* to full-grown larvae of *C. capitata* was found to be 47 IJs/cm² of soil (Fig. 10).

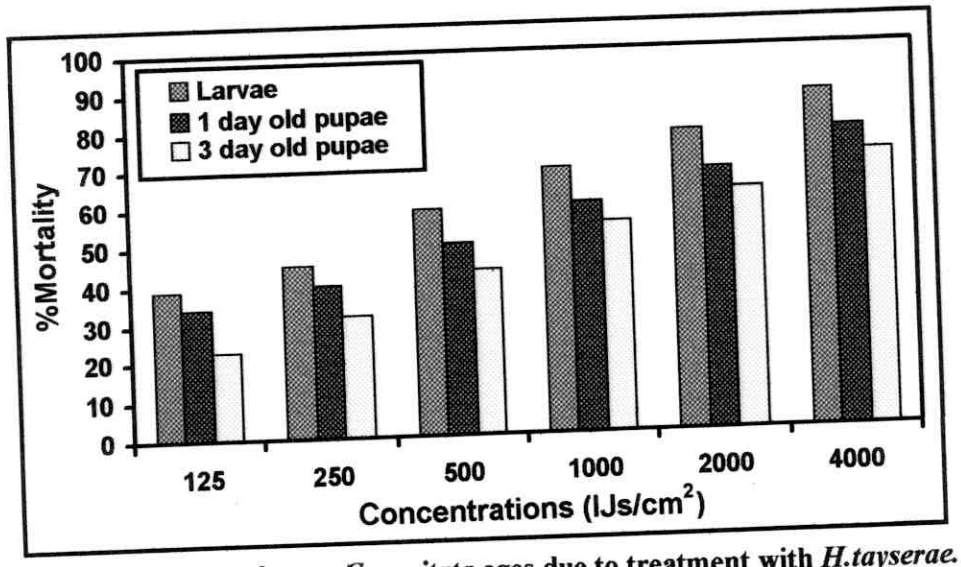

Fig. (7): Mortality of some *C. capitata* ages due to treatment with *H.tayserae.*

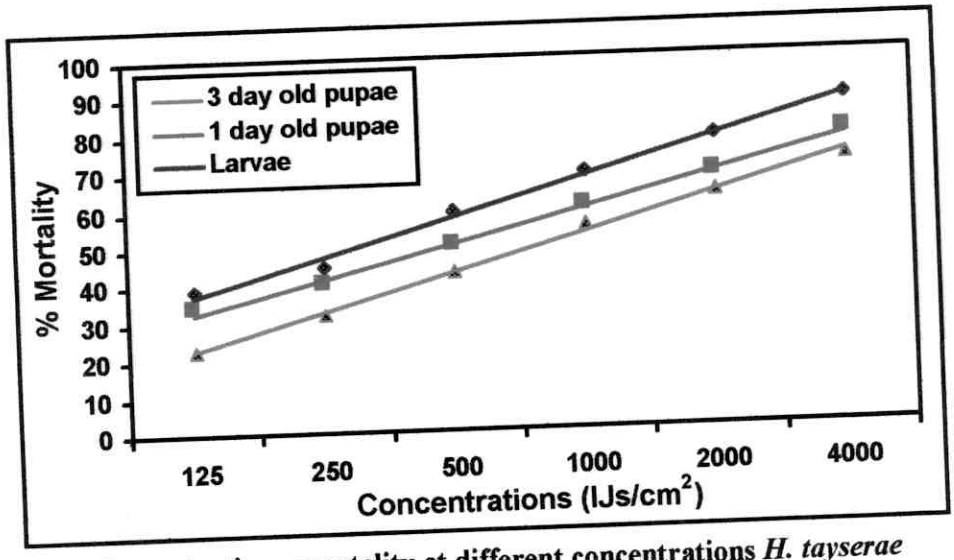

Fig. (8): Concentration - mortality at different concentrations *H. tayserae* against *C. capitata* ages.

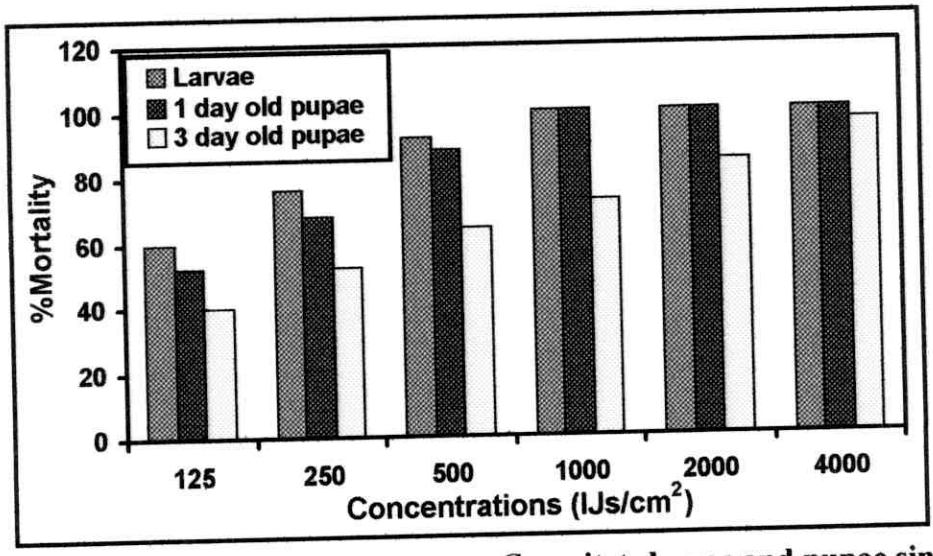

Fig. (9): Mortality percentages among *C. capitata* larvae and pupae singly treated with *S. abbasi*.

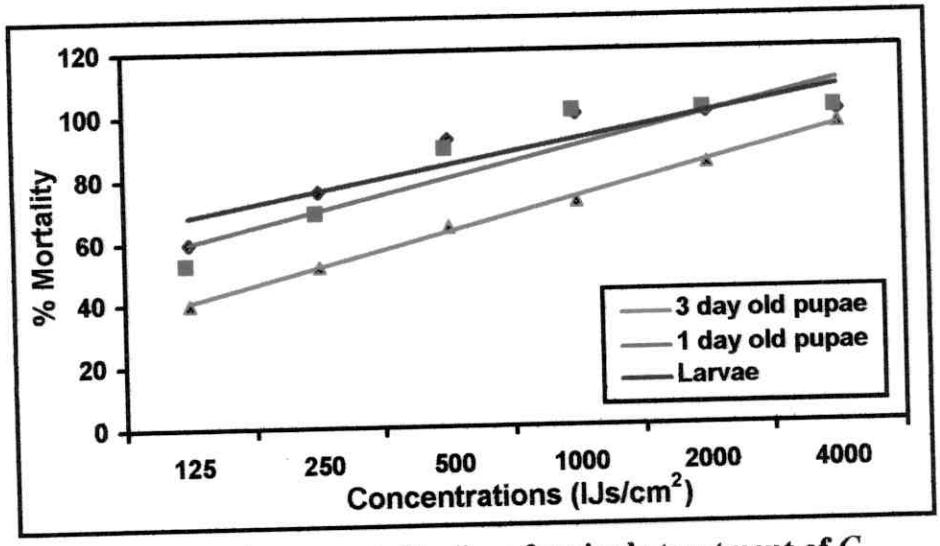

Fig. (10): Concentration – mortality lines for single treatment of *C. capitata* larvae and pupae with *S. abbasi*.

*** *S. riobravis* :**

The lowest concentration (125 IJs/cm² of soil surface) caused 40 % mortality among the treated full-grown *C. capitata* larvae. By increasing the concentration of IJs to 250/cm², the mortality increased to 56.0 %. At concentrations of 500, 1000 and 2000 IJs/cm², mortalities reached 68, 76 and 88 %, respectively. The highest mortality rate (96 %) was achieved when the concentration of IJs was 4000/cm² of soil surface, (Table 1 and Fig. 11).

The LC_{50} of *S. riobravis* to full-grown larvae of *C. capitata* was found to be 198 IJs/cm² of soil surface (Fig. 12).

*** *H. bacteriophora* :**

Treatment of the full-grown larvae with *H. bacteriophora* at 125 IJs/cm² of soil surface (the lowest concentration used) caused lowest mortality percentages among the treated larvae (60 %), one week after exposure. When the applied concentration was increased to 250 IJs/cm², the mortality percentage increased consequently to 76 %. By increasing the dose to 500 IJs/cm² the recorded mortality reached to 88 %. mortality. As the applied concentration was increased again to 1000, 2000 and 4000 IJs/cm², the averages in *C. capitata* larval mortality were 96, 100 and 100 %, respectively, (Table 1 and Fig. 13). The LC_{50} value of *H. bacteriophora* to full-grown larvae of *C. capitata* was found to be 82 IJs/cm² of soil surface, (Fig. 14).

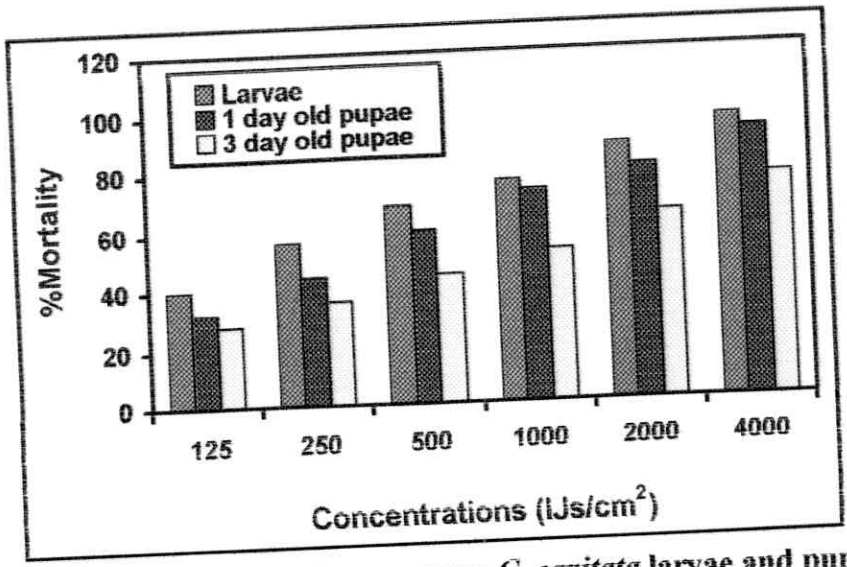

Fig. (11): Mortality percentages among *C. capitata* larvae and pupae of single treatment with *S. riobravis*.

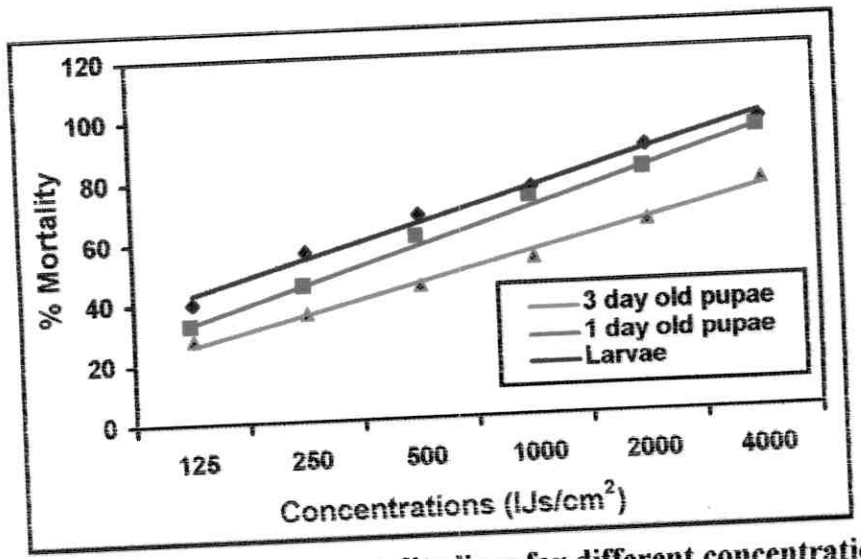

Fig. (12): Concentration – mortality lines for different concentrations of *S. riobravis* against singly treated *C. capitata* larvae and pupae.

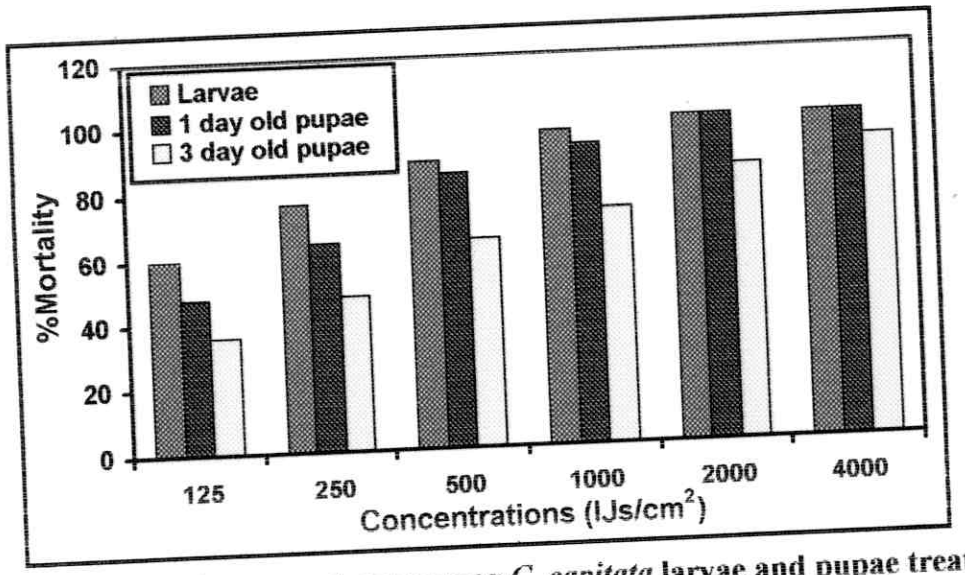

Fig. (13): Mortality percentages among *C. capitata* larvae and pupae treated with *H. bacteriophora*.

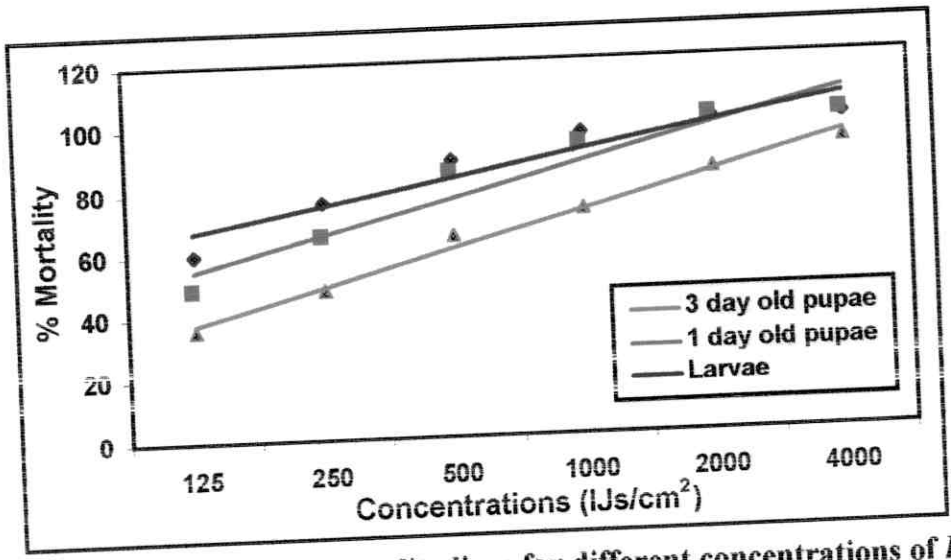

Fig. (14): Concentration - mortality lines for different concentrations of *H. bacteriophora* against singly treated *C. capitata* larvae and pupae.

* ***H. tayserae*** **:**

At the concentration of 125 IJs/cm² of soil surface, mortality among full-grown larvae of *C. capitata* was 40 %. This percentage increased to 52 % when the applied concentration of IJs was increased to 250/cm² of soil surface. At concentrations of 500, 1000 and 2000 IJs/cm², mortalities were, consequently, increased to 60 , 72 and 84 %, respectively. The highest mortality percentage (92 %) was achieved when the applied concentration was 4000 IJs/ cm² of soil, (Table 1 and Fig. 15). Also, the LC_{50} of *H. tayserae* to full-grown larvae of *C. capitata* was found to be 240 IJs/cm² of soil surface, (Fig. 16).

These results concerning the efficacy of 4 species of insect parasitic nemtodes against the full-grown larvae of *C. capitata* look similar to those reported by **Lindegren (1990).** The auther tested *S. carpocapsae* under laboratory conditions against the full-grown larvae of Mediterranean fruit fly *C. capitata*; melon fly *Dacus cucurbitae*, and the oriental fruit fly *D. dorsalis*. At concentrations ranging from 500,000 to 5,000 IJs/cup, mean corrected mortalities, 6 days after exposure, ranged from 92 to 9 % for *C. capitata*, 86 to 0 % for *D. cucurbitae*, and 85 to 9 % for *D. dorsalis*.

El-Hakim and El-Kilfl (1987) evaluated the efficacy of two insect parasitic nematodes, *H. heliothidis* and *S. carpocapsae*, as biocontrol agents against *C. capitata*. They found that a level of 10,000 IJs of *H. heliothidis*/10 gm sandy soil caused 69.8 % mortality among the full-grown larvae, while 40,000 IJs/100 gm caused 100 % mortality.

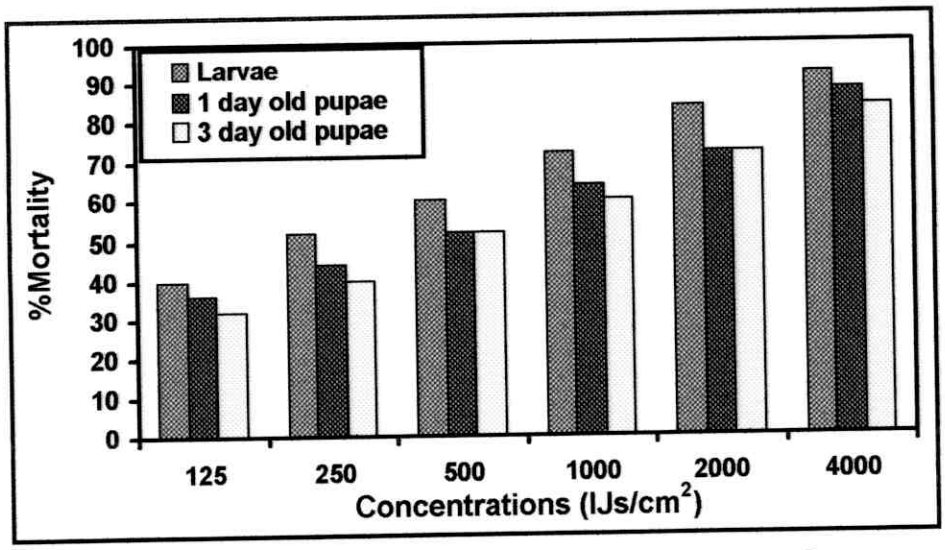

Fig. (15): Mortality percentages among *C. capitata* larvae and pupae treated with *H. tayserae.*

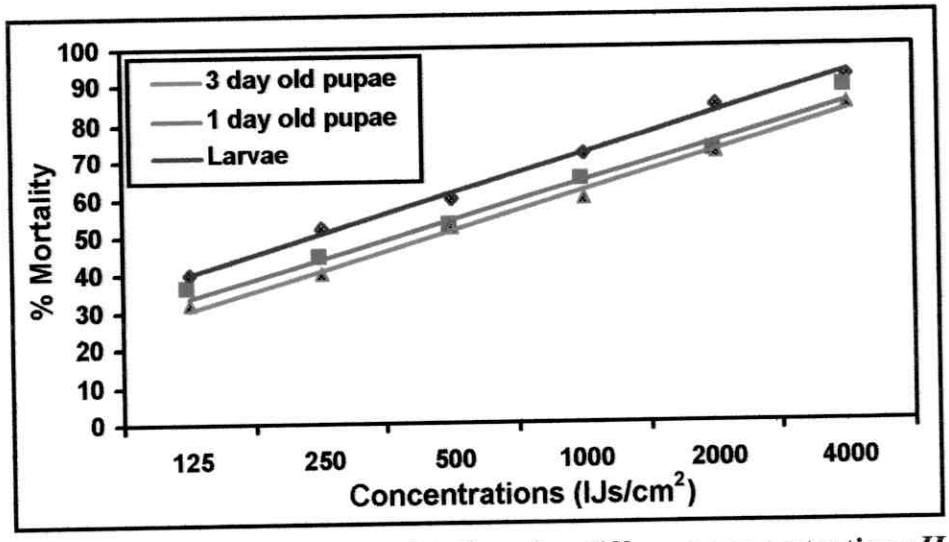

Fig. (16): Concentration - mortality lines for different concentrations *H. tayserae* against singly treated *C. capitata* larvae and pupae.

S. carpocapsae was more efficient as 2,500 and 15,000 IJs/100 gm sandy soil caused 69.4 and 100 % mortality, respectively. LC_{50} for *S. carpocapsae* and *H. heliothidis* to full-grown larvae of *C. capitata* were 100 and 5940 IJs/100 cm^2 of sandy soil, respectively.

Other dipterous larvae, however, are much more sensitive to entomopathogenic nematodes. For example, **Choo *et al.* (1996)** reported that *S. glaseri, S. carpocapsae* and *H. bacteriophora* caused mortalities of 96, 90 and 86 %, respectively, in larvae of *Muscina stabulans* at a concentration of 20 IJs/larva.

2- Infectivity of Different Entomopathogenic Nematodes to One Day Old Pupae of *C. capitata* :

2.1- First method :

Data presented In Table (2) show the mortality percentages among *C. capitata* pupae of one day old, after one week of treatment by each of the mentioned 4 nematode species. These data indicated that, as occurred in case of full-grown larval treatment, *S. abbasi, H. bacteriophora* were superior in their efficacy on one day old pupae of *C. capitata* than *H. tayserae* and *S. riobravis*.

**** S. abbasi* :**

The percentage mortality increased as the applied concentration of *S. abbasi* IJs increased. At a concentration of 125 IJs/cm^2 of soil surface, mortality among one day old pupae of *C. capitata* was 36 %. Increasing the concentration of IJs to 250 IJs/cm^2, the mortality increased to 50 %.

Table (2) : Mortality percentages among one day old pupae of *C. capitata* due to infection by different nematode species at different concentrations.

Conc. IJs/cm^2 soil	Nematode species	% Mortality	
		First method (10 pupae/cup)	Second method (single pupa/cup)
125	*S. abbasi*	36	52
	S. riobravis	23	32
	H. bacteriophora	36	48
	H. tayserae	34	36
250	*S. abbasi*	50	68
	S. riobravis	37	44
	H. bacteriophora	49	64
	H. tayserae	40	44
500	*S. abbasi*	59	88
	S. riobravis	46	60
	H. bacteriophora	60	84
	H. tayserae	50	52
1000	*S. abbasi*	70	100
	S. riobravis	54	72
	H. bacteriophora	71	92
	H. tayserae	60	64
2000	*S. abbasi*	82	100
	S. riobravis	68	80
	H. bacteriophora	85	100
	H. tayserae	68	72
4000	*S. abbasi*	93	100
	S. riobravis	80	92
	H. bacteriophora	95	100
	H. tayserae	78	88±6.6
LC_{50}	*S. abbasi*	282	103
	S. riobravis	645	323
	H. bacteriophora	281	140
	H. tayserae	462	365
Slope	*S. abbasi*	1.1626	1.7544
	S. riobravis	0.9960	1.2051
	H. bacteriophora	1.28199	1.7602
	H. tayserae	0.7507	0.9679
Mean	*S. abbasi*	65.0±2.4	84.0±8.8
	S. riobravis	51.3±2.6	63.4±8.8
	H. bacteriophora	66.0±2.5	81.4±8.3
	H. tayserae	55.0±2.4	59.0±9.3

As the concentrations were increased to 500, 1000 and 2000 IJs/cm², mortalities reached 59, 70.0 and 82 %, respectively. The highest mortality rate (93 %) was achieved when the applied concentration of IJs was increased to a maximum of 4000/cm² of soil surface, (Table 2 and Fig. 1).

The LC_{50} value of *S. abbasi* to one day old pupae of *C. capitata* was found to be 282 IJs/cm² of soil, (Table 2 and Fig. 2).

*** *S. riobravis* :**

Treatment of *C. capitata* pupae, one day old, by this species at 125 IJs/cm² of soil surface caused lower mortality percentage among the treated pupae (23 %). When the appplied concentration was increased to 250 IJs/cm², the rate of mortality was also increased to 37 %. At concentrations of 500, 1000 and 2000 IJs/cm², mortalities reached 46, 54 and 68 %, respectively. Highest rate of mortality due to treatment by *S. riobravis* (80 %) was achieved when the applied concentration was increased to 4000 IJs/cm² of soil surface, (Table 2 and Fig. 3). The LC_{50} value of *S. riobravis* to one day old pupae of *C. capitata* was found to be 645 IJs/cm² of soil, (Table 2 and Fig. 4).

*** *H. bacteriophora* :**

As shown in Table (2) and Fig. (5), the lower concentrations; 125, 250 and 500 IJs/cm² caused lower mortality rates; 36, 49 and 60 %, respectively, one week after treatment. By increasing the applied concentration to 1000 IJs/cm², the mortality increased to 71 % and this

percentage increased again to 85 % when the applied concentration was increased to 2000 IJs/cm². At the highest concentration (4000 IJs/cm² of the soil surface), the mean percentage mortality reached a maximum of 95 %. The LC_{50} value of *H. bacteriophora* to one day old pupae of *C. capitata* was found to be 281 IJs/cm² of soil surface, (Table 2 and Fig. 6).

*** *H. tayserae* :**

One week after treatment of one day old pupae of *C. capitata,* the lower concentration (125 IJs/cm²), the recorded mortality reached 34 % among the treated pupae. This percentage increased to 40 % when the applied concentration increased to 250 IJs/cm². At concentrations of 500, 1000 and 2000 IJs/cm,² mortalities reached 50, 60 and 68 %, respectively. The highest concentration (4000 IJs/cm²) caused the highest mortality rate (78 %), (Table 2 and Fig. 7). The LC_{50} value of *H. tayserae* to one day old pupae of *C. capitata* was found to be 462 IJs/cm² of soil, (Table 2 and Fig. 8).

2.2- Second method :

*** *S. abbasi* :**

Data presented in Table (2) show the mortality percentages among the single treated one day old pupae of the Mediterranean fruit-fly. At the concentrations of 125, 250 and 500 IJs/cm² of soil surface, mortalities reached 52, 68 and 88 %, respectively. The higher concentrations of 1000, 2000 and 4000 IJs/cm² soil surface gave 100 % mortality, (Table 2 and Fig. 9).

The LC_{50} value of *S. abbasi* to one day old pupae of *C. capitata* was found to be 103 IJs/cm² of soil, (Table 2 and Fig. 10).

*** *S. riobravis* :**

The concentration of 125 IJs/cm² of soil surface caused the lowest mortality rate among treated one day old pupae (32.0). Increasing the concentration to 250 IJs/cm², caused an increase in the mortality percentage which reached 44 %. Concentrations of 500, 1000 and 2000 IJs/cm² caused mortalities reached 60, 72 and 80 %, respectively. The highest mortality rate (92 %) was achieved when the concentration of IJs was 4000 IJs/cm² of soil, (Table 2 and Fig. 11). The LC_{50} value of *S. riobravis* to one day old pupae of *C. capitata* was found to be 323 IJs/cm² of soil (Table 2 and Fig. 12).

*** *H. bacteriophora* :**

One week after treatment by different concentrations of *H. bacteriophora*, the lowest mortality rate (48 %) was achieved due to application of the lowest concentration (125 IJs/cm²). By increasing the applied dose to 250, 500 and 1000 IJs/cm², the mortality increased to 64, 84 and 92 %, respectively. The highest mortality rate (100 %) was achieved at the concentrations of 2000 and 4000 IJs/cm² of soil surface, (Table 2 and Fig. 13). The LC_{50} value of *H. bacteriophora* to one day old pupae of *C. capitata* was found to be 140 IJs/cm² of soil, (Table 2 and Fig. 14).

* ***H. tayserae*** **:**

At the lowest concentration (125 IJs/cm²), the mortality was 36 % one week after exposure. The mortality increased to 44 % when the concentration was increased to 250 IJs/cm². By increasing the applied dose to 500, 1000 and 2000 IJs/cm², the average mortalities were 52, 64 and 72 %, respectively. The highest concentration (4000 IJs/cm²) led to the highest mortality rate (88 %) among the treated pupae (Table 2 and Fig. 15). The LC_{50} value of *H. tayserae* to one day old pupae of *C. capitata* was found to be 325 IJs/cm² of soil, (Table 2 and Fig. 16).

3- Infectivity of Different Entomopathogenic Nematodes to three day old Pupae of *C. capitata* :

3.1- First method :

Data presented in Table (3) show the mortality percentages among *C. capitata* three day old pupae after one week of treatment by each of the six concentrations of either of the 4 entomoparasitic nematode species. Treatment in this method was achieved by applying the nematode suspension, at the desired concentration, on sandy soil containing 10 pupae placed in each cup.

* ***S. abbasi*** **:**

Percentage mortality increased as the concentration of IJs in water increased. At lower concentrations of 125, 250 and 500 IJs/cm² of soil surface, mortalities among pupae were 33, 48 and 56 %, respectively.

Table (3) : Mortality percentages among three day old pupae of *C. capitata* due to infection by different nematode species at different concentrations.

Conc. IJs/cm^2 soil surface	Nematode species	% Mortality	
		First method (10 pupae/cup)	Second method (single pupa/cup)
125	*S. abbasi*	33	40
	S. riobravis	18	28
	H. bacteriophora	30	36
	H. tayserae	23	32
250	*S. abbasi*	48	52
	S. riobravis	29	36
	H. bacteriophora	41	48
	H. tayserae	32	40
500	*S. abbasi*	56	64
	S. riobravis	37	44
	H. bacteriophora	53	64
	H. tayserae	43	52
1000	*S. abbasi*	69	72
	S. riobravis	44	52
	H. bacteriophora	67	72
	H. tayserae	55	60
2000	*S. abbasi*	79	84
	S. riobravis	56	64
	H. bacteriophora	76	84
	H. tayserae	63	72
4000	*S. abbasi*	90	96
	S. riobravis	65	76
	H. bacteriophora	88	92
	H. tayserae	72	84
LC_{50}	*S. abbasi*	321	241
	S. riobravis	1350	698
	H. bacteriophora	402	267
	H. tayserae	880	446
Slope	*S. abbasi*	1.0944	1.2374
	S. riobravis	0.8379	0.83602
	H. bacteriophora	1.1108	1.1567
	H. tayserae	0.8834	0.94799
Mean	*S. abbasi*	62.5±2.6	68.0±8.5
	S. riobravis	41.5±2.6	50.0±9.6
	H. bacteriophora	59.2±2.5	66.0±8.7
	H. tayserae	48.0±1.8	56.7±9.4

At higher concentrations of 1000 and 2000 IJs/cm² of soil surface, mortality reached 69 and 79 %, respectively. The highest mortality rate (90.0 %) was achieved when the concentration was 4000 IJs/cm² of soil, (Table 3 and Fig. 1).

LC_{50} of *S. abbasi* for the three day old pupae of *C. capitata* was found to be 321 IJs/cm² of soil, (Table 3 and Fig. 2).

*** *S. riobravis* :**

The lowest concentration of *S. riobravis* (125 IJs/cm² of soil surface) caused 18 % among the treated 3 day old pupae of *C. capitata*. Increasing the concentration of IJs to 250 IJs/cm² increased the morality to 29 %. At concentrations of 500, 1000 and 2000 IJs/cm², mortalities reached 37, 44 and 56 %, respectively. The highest mortality rate (65 %) was achieved when the concentration of IJs was increased to 4000/cm² of soil surface, (Table 3 and Fig. 3). The LC_{50} of *S. riobravis* for the three day old pupae of *C. capitata* was found to be 1350 IJs/cm² of soil, (Table 3 and Fig. 4).

*** *H. bacteriophora* :**

Treatment of the three day old pupae by the lowest concentration (125 IJs/cm²) caused lowest mortality percentages among the treated pupae (30 %) one week after treatment. By increasing the applied concentration to 250 and IJs/cm², the recorded mortality increased to 41 % and 53 %, respectively. At higher concentrations; 1000, 2000 and 4000 IJs/cm², the mortalities averaged 67, 76 and 88 %, respectively,

(Table 3 and Fig. 5). The LC_{50} of *H. bacteriophora* for the three day old pupae of *C. capitata* was found to be 402 IJs/cm² of soil surface, (Table 3 and Fig. 6).

*** *H. tayserae* :**

One week after exposure of the 3 day old *C. capitata* pupae to *H. tayserae,* the lower concentration of 125 IJs/cm² caused 23 % mortality. The mortality percentages increased to 32, 43 and 55 % when the applied concentrations increased to 250, 500 and 1000 IJs/cm², respectively. By increasing the applied dose to 2000 and 4000 IJs/cm², respective mortalities were 63 and 72 %, (Table 3 and Fig. 7).

The LC_{50} of *H. tayserae* for the three day old *C. capitata* pupae was 880 IJs/cm² of soil surface, (Table 3 and Fig. 8).

3.2- Second method :

Three day old *C. capitata* pupae were placed, singly, in sandy soil to be treated with the different concentrations of each of the bioassayed entomopathogenic nematode species.

*** *S. abbasi* :**

At the lower concentration (125, 250 and 500 IJs/cm² of soil surface), mortality percentages among treated pupae were 40, 52.0 and 64.0 %, respectively. At higher concentrations (1000, 2000 and 4000 IJs/cm²), the respective mortalities were 72, 84 and 96 %, (Table 3 and Fig. 9).

The *S. abbasi* needed a concentration of 241 IJs/cm² of soil, to kill 50 % of the three day old pupae of *C. capitata* (Table 3 and Fig. 10).

*** *S. riobravis* :**

The percentages of mortality among the single treated 3 day old *C. capitata* pupae, increased as the concentration of IJs increased. At a concentration of 125 IJs/cm² of soil surface, mortality was 28 %. Increasing the concentration of IJs to 250/cm² gave 36 % mortality. At concentrations of 500, 1000 and 2000 IJs/cm², mortalities reached 44, 52 and 64 %, respectively. The highest mortality percentage obtained among *C. capitata* pupae (76 %) was achieved after one week of exposure to the highest *S. riobravis* concentration (4000 IJs/cm² of soil surface), (Table 3 and Fig. 11).

LC_{50} of *S. riobravis* for the three day old pupae of *C. capitata* was 698 IJs/cm² of soil, (Fig. 12).

*** *H. bacteriophora* :**

At a concentration of 125 *H. bacteriophora* IJs/cm² of soil surface, mortality among three day old pupae was 36 %. Increasing the concentration of IJs to 250/cm² caused 48 % mortality among the treated pupae. At concentrations of 500, 1000 and 2000 IJs/cm², mortalities reached 64, 72 and 84 %, respectively. The highest mortality (92 %) was achieved when the applied concentration reached a maximum of 4000/cm² of soil surface, (Table 3 and Fig. 13). The LC_{50} of *H. bacteriophora* for the three day old pupae of *C. capitata* was found to be 267 IJs/cm² of soil, (Table 3 and Fig. 14).

*** *H. tayserae* :**

Treatment of 3 day old pupae by this species at 125 IJs/cm² caused lowest mortality percentage among the treated pupae (32 %). By increasing the applied concentration to 250 IJs/cm², the mortality increased to 40 %. At concentrations of 500, 1000 and 2000 IJs/cm² of soil surface, the mortalities reached 52, 60 and 72.0 9.2 %, respectively. At the highest concentration (4000 IJs/cm² of soil surface), the percentage mortality reached 84 %, (Table 3 and Fig. 15). The LC_{50} of *H. tayserae* for the three day old pupae of *C. capitata* was found to be 446 IJs/cm² of soil, (Table 3 and Fig. 16).

El-Hakim and El-Kifl (1987) studied the efficacy of *H. heliothidis* and *S. carpocapsae* on 2- and 5-day old pupae of *C. capitata* in laboratory. They found that the levels of 500 to 15000 IJs of *S. carpocapsae*/100 gm sandy soil caused 42.0 to 100 % and 1.2 to 37.8 % mortality in 2-day and 5-day old pupae, respectively. In case of *H. heliothidis*, levels of 5000 to 50,000 IJs/100 gm sandy soil caused respective mortalities of 12.0 to 91.6 and 15.0 to 81.2 %. Calculated LC_{50} values for *S. carpocapsae* were 1340 and 2780 IJs/100 gm soil for 2- and 5-day old pupae, respectively. The respective figures for *H. heliothidis* were 18030 and 21230 IJs/100 gm soil.

4- Host Finding :

As presented in Table (4), it was found that all tested nematode species could reach their host pupae of *C. capitata* when placed at 5 cm height from the point of release (bottom of the cup). At 10 cm height,

Table (4) : **Mortality percentages among *C. capitata* pupae caused by four entomopathogenic nematode species when placed at different depths (5 and 10 cm) from sand surface (soil treatment at 4000 IJs/cm^2 of soil surface).**

Height (cm)	Nematode species	% Mortality (10 pupae/cup)
5	*S. abbasi*	80
	S. riobravis	58
	H. bacteriophora	84
	H. tayserae	60
10	*S. abbasi*	0
	S. riobravis	0
	H. bacteriophora	0
	H. tayserae	0

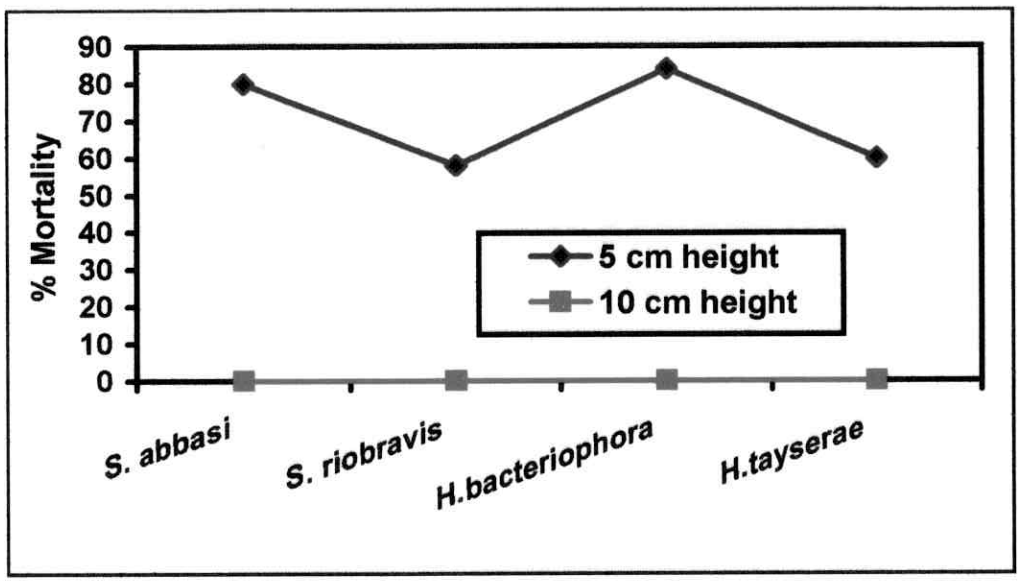

Fig.(17): Mortality percentages among *C. capitata* pupae placed at 5 and 10 cm height in sandy soil and treated by four nematode species at concentration of 4000 IJs/cm^2 of soil surface.

however, none of the infective juveniles could reach the host and no mortality occurred to the one day old *C. capitata* pupae.

H. bacteriophora was superior among the four tested nematodes in reaching and killing the desired host (*C. capitata* pupae), causing 84 (80-90) % mortality. *S. abbasi* ranked the second as it caused 80 (70-90) % mortality. *H. tayserae* and *S. riobravis* were less effective and caused 60 (50-70) and 58 (50-60) % mortalities, respectively, (Table 4 and Fig. 17).

Schroeder and Beavers (1987) studied the movement of infective juveniles of *H. heliothidis, H. bacteriophora, S. carpocapsae* and *S. glaseri* in sandy soil in the laboratory. They found that vertical and lateral dispersal of IJs was limited to mostly 0-30 cm. All species dispersed more readily upwards than downwards. On the other hand, **Georgis and Poinar (1983)**. reported that when IJs of *H. heliothidis* were placed on the soil surface, most of them remained at the 0-2 cm depth, while, *H. bacteriophora* IJs showed a tendency to move down at 8-10 cm depth.

5- Production of Infective Juveniles (IJs) from *C. capitata* Pupae by Four Species of Entomopathogenic Nematodes :

As presented in Table (5), *S. abbasi* proved to be the most effective and reproductive species among the four tested nematodes followed by *H. bacteriophora* at the two tested concentrations; 2000 and 4000 IJs/cm^2 of soil surface. Production of IJs by *S. riobravis* and *H. tayserae* was very poor compared to the two former species.

Table (5) : Production of infective juveniles by four entomopathogenic nematode species from pupae of *C. capitata* exposed to nematodes appiied at 2000 and 4000 IJs/cm^2 of soil surface.

No. of pupa	Produced IJs/pupa			
	S. abbasi	*S. riobravis*	*H. bacteriophora*	*H. tayserae*
	2000 IJs/cm^2			
1	7200	450	4700	200
2	8000	560	6050	530
3	6900	480	6200	420
4	7100	620	5800	550
5	6500	610	6100	530
6	7200	580	5300	360
7	6700	680	5200	200
8	6850	480	6100	380
9	7900	450	4800	290
10	7200	630	5250	450
Average	7155	554	5550	391
	4000 IJs/cm^2			
1	13600	990	14300	770
2	12000	1500	13500	830
3	13000	3800	15950	860
4	14400	2600	12600	950
5	15700	2200	13200	1000
6	16800	1800	10050	680
7	17600	950	10200	690
8	17200	1200	14300	870
9	12900	3300	10800	620
10	13500	980	12200	980
Average	14670	1932	12710	825

A single one day old pupa of *C. capitata* infected with *S. abbasi* produced an average of 7155 (6500-8000) IJs by infection at a concentration of 2000 IJs/cm² of soil surface and 14670 (1200-17600) by infection at 4000 IJs/cm² of soil surface.

H. bacteriophora produced an average of 5550 (4700-6200) IJs/pupa by infection at a concentration of 2000 IJs/cm2 of soil surface and an average of 12700 (10050- 15950) IJs/pupa at a concentration of 4000 IJs/cm² of soil surface.

In contrast to the former two species, the infected one day old pupae with *S. riobravis* or *H. tayserae* produced much lower numbers of IJs/pupa. The nematode species produced 554 (450-680) and 391 (200-550) IJs/pupa, respectively, at a concentration of 2000 IJs/cm² of soil surface. Their respective average productions were 1932 (950-3800) and 825 (620-1000) IJs/pupa when *C. capitata* pupae received 4000 IJs of *S. riobravis* and *H. tayserae*/cm² of soil surface, (Table 5 and Fig. 18).

Table (6) : % Mortality in one day old pupae of *C. capitata* caused by different nematode species at different water contents of soil by nematodes at different conc.

Conc. IJs/ cm^2 soil	Nematode species	Percentage mortality at humidities levels :			
		20 %		15 %	
500	*S. abbasi*	57.8	(50-64)	53.0	(48-60)
	S. riobravis	35.8	(30-42)	28.6	(24-34)
	H. bacteriophora	57.4	(50-64)	55.2	(48-60)
	H. tayserae	43.6	(36-54)	36.2	(34-38)
1000	*S. abbasi*	68.0	(62-76)	62.2	(56-74)
	S. riobravis	45.0	(40-52)	39.4	(34-46)
	H. bacteriophora	66.2	(60-76)	61.6	(56-72)
	H. tayserae	50.8	(42-60)	46.0	(40-52)
2000	*S. abbasi*	81.6	(78-86)	71.0	64-78)
	S. riobravis	52.6	(46-60)	47.6	(40-56)
	H. bacteriophora	72.6	(66-78)	70.0	(56-76)
	H. tayserae	62.2	(50-76)	58.0	(50-66)
4000	*S. abbasi*	90.8	(80-96)	80.0	(70-90)
	S. riobravis	63.6	(50-70)	55.2	(50-60)
	H. bacteriophora	83.4	(76-88)	77.8	(74-80)
	H. tayserae	71.6	(52-80)	68.4	(64-76)
8000	*S. abbasi*	94.4	(92-98)	88.2	(82-96)
	S. riobravis	72.4	(66-78)	65.0	(58-72)
	H. bacteriophora	92.8	(88-98)	85.6	(80-92)
	H. taysèrae	76.8	(56-84)	72.0	(60-78)
Mean	*S. abbasi*	78.5	(50-98)	70.8	(48-92)
	S. riobravis	53.9	(30-78)	47.2	(24-72)
	H. bacteriophora	74.5	(50-98)	70.04	(48-92)
	H. tayserae	61.0	(36-84)	56.1	(34-78)
LC_{50}	*S. abbasi*	365		513	
	S. riobravis	1484		2527	
	H. bacteriophora	396		384	
	H. tayserae	812		1276	
Slope	*S. abbasi*	1.1796		0.9967	
	S. riobravis	0.7875		0.7605	
	H. bacteriophora	1.0430		0.7572	
	H. tayserae	0.7726		0.8135	

Table (6) : Continued.

Conc. IJs/ cm^2 soil	Nematode species	Percentage mortality at humidities levels :			
		10 %		5 %	
500	*S. abbasi*	30.4	(24-40)	13.8	(8-20)
	S. riobravis	19.6	(16-24)	12.8	(10-16)
	H. bacteriophora	35.0	(30-40)	20.4	(16-30)
	H. tayserae	27.0	(24-30)	18.0	(16-20)
1000	*S. abbasi*	42.2	(36-52)	25.0	(20-32)
	S. riobravis	27.2	(22-32)	17.6	(16-20)
	H. bacteriophora	45.2	(38-56)	31.2	(24-40)
	H. tayserae	38.4	(34-44)	31.0	(28-36)
2000	*S. abbasi*	54.0	(48-60)	38.2	(32-58)
	S. riobravis	34.4	(30-38)	29.2	(24-36)
	H. bacteriophora	53.4	(48-60)	41.2	(34-50)
	H. tayserae	49.8	(42-60)	40.0	(34-44)
4000	*S. abbasi*	67.0	(60-78)	50.0	(40-64)
	S. riobravis	49.4	(40-52)	37.0	(30-44)
	H. bacteriophora	63.0	(56-72)	51.2	(42-66)
	H. tayserae	59.0	(52-72)	49.2	(40-58)
8000	*S. abbasi*	79.6	(70-86)	63.0	(56-72)
	S. riobravis	52.8	(48-58)	40.6	(34-48)
	H. bacteriophora	72.2	(64-80)	61.2	(54-70)
	H. tayserae	66.0	(60-76)	57.4	(52-70)
Mean	*S. abbasi*	54.6	(24-86)	38.0	(8-72)
	S. riobravis	36.7	(16.58)	27.4	(10-48)
	H. bacteriophora	53.8	(30-80)	41.04	(16-70)
	H. tayserae	48.04	(24-76)	39.12	(16-70)
LC_{50}	*S. abbasi*	1531		3969	
	S. riobravis	5802		12362	
	H. bacteriophora	1538		3748	
	H. tayserae	2354		4386	
Slope	*S. abbasi*	1.09602		0.8232	
	S. riobravis	0.8104		0.8223	
	H. bacteriophora	0.7970		0.92031	
	H. tayserae	0.8565		0.8874	

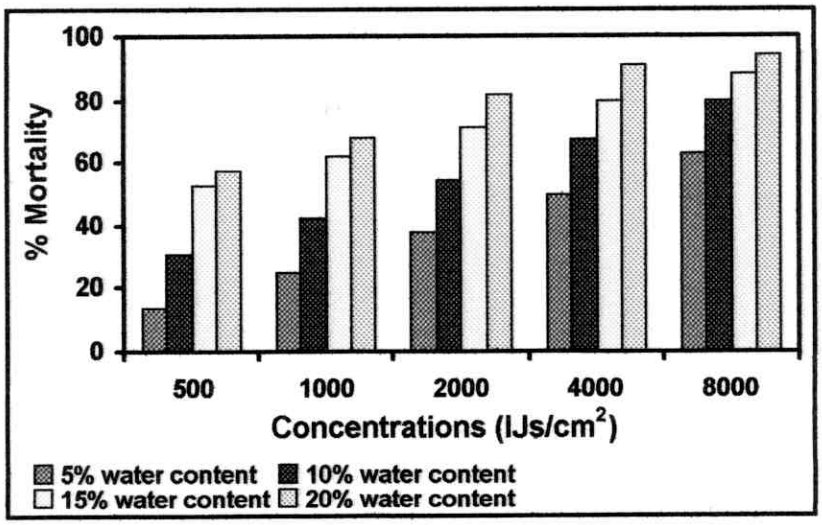

Fig. (19): Mortality percentages of *C. capitata* larvae and pupae treated in sandy soil at different rates of water content by different concentrations of *S. abbasi*.

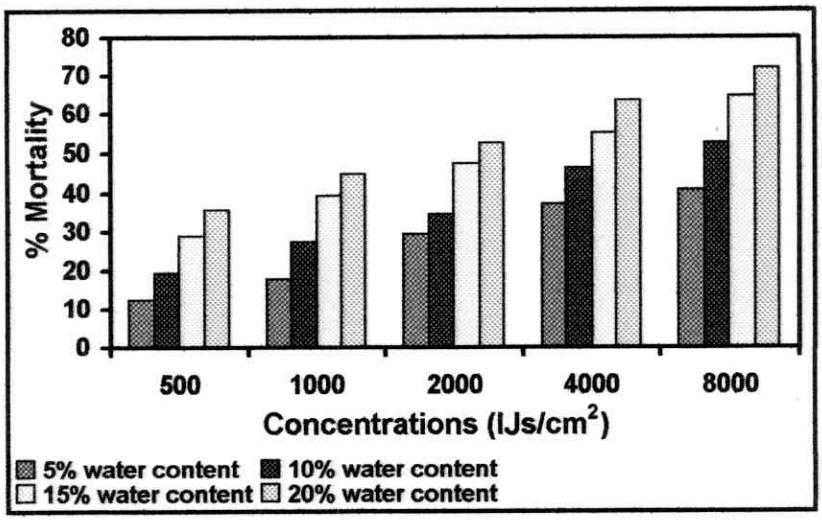

Fig. (20): Mortality percentages of *C. capitata* larvae and pupae treated in sandy soil at different rates of water content by different concentrations of *S. riobravis*.

*** *S. riobravis* :**

Mortality percentages increased as the soil water-content increased. At 20, 15, 10 and 5 % water contents, the highest concentration of nematode suspension (8000 IJs/cm² of soil surface) gave 72.4 (66-78), 65 (58-72), 52.8 (48-58) and 40.6 (34-48) % mortality, respectively. At the lowest concentration (500 IJs/cm² of soil), however, the respective mortalities were 35.8 (30-42), 28.6 (24-34), 19.6 (16-24) and 12.8 (10-16) %, (Table 6 and Fig. 20). As shown in Table (6), the LC_{50} values of *S. riobravis* to *C. capitata* at the water contents of 20, 15, 10 and 5 were found to be 1484, 2527, 5802 and 12362 IJs/cm² of soil, respectively.

*** *H. bacteriophora* :**

Mortality percentages increased as the soil water-content increased. At the mentioned percentages of water contents, the highest concentration of nematode suspension (8000 IJs/cm² of soil surface) gave 92.8 (88-09), 85.6 (80-92), 72.2 (64-80) and 61.2 (54-70) % mortalities, respectively. While, by applying the lowest (500 IJs/cm²), the respective mortalities were 57.4 (50-64), 55.2 (48-60), 35.0 (30-40) and 20.4 (16.30) %, (Table 6 and Fig. 21).

LC_{50}'s of *H. bacteriophora* for *C. capitata* pupae were found to be 398, 384, 1538 and 3748 IJs/cm² of soil surface, respectively.

*** *H. tayserae* :**

As occurred with the 3 remaining species, the mortality percentages increased as the soil water-content increased. At 20, 15, 10 and 5 %

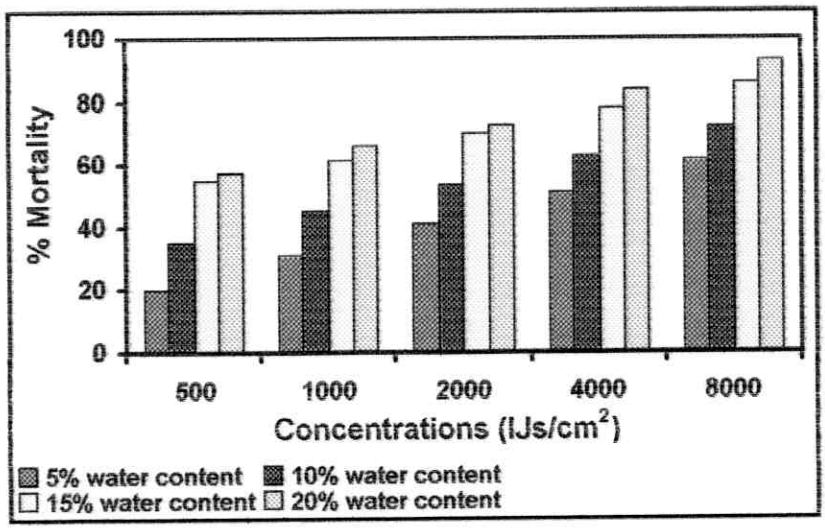

Fig. (21): Mortality percentages of *C. capitata* larvae and pupae treated in sandy soil at different rates of water content by different concentrations of *H. bacteriophora*.

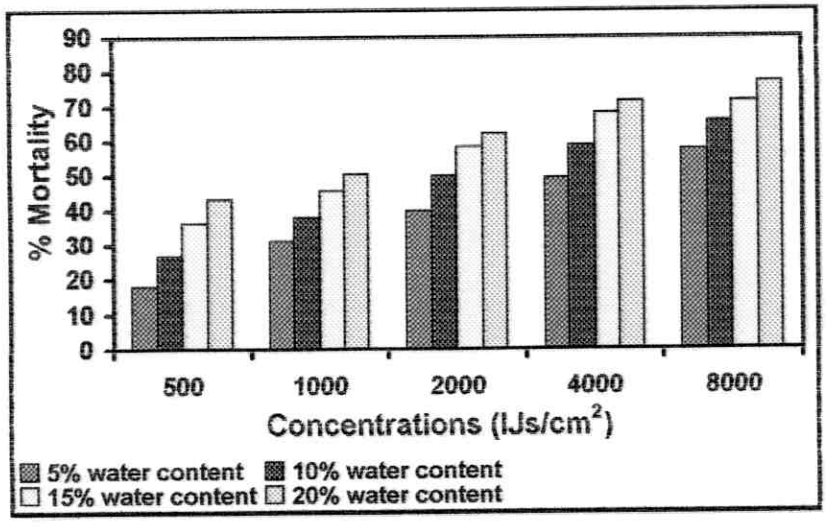

Fig. (22): Mortality percentages of *C. capitata* larvae and pupae treated in sandy soil at different rates of water content by different concentrations of *H. tayserae*.

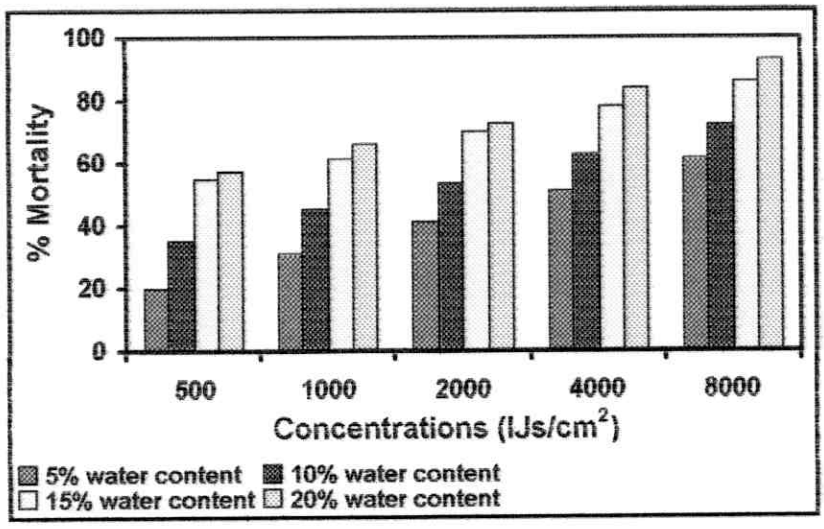

Fig. (21): Mortality percentages of *C. capitata* larvae and pupae treated in sandy soil at different rates of water content by different concentrations of *H. bacteriophora*.

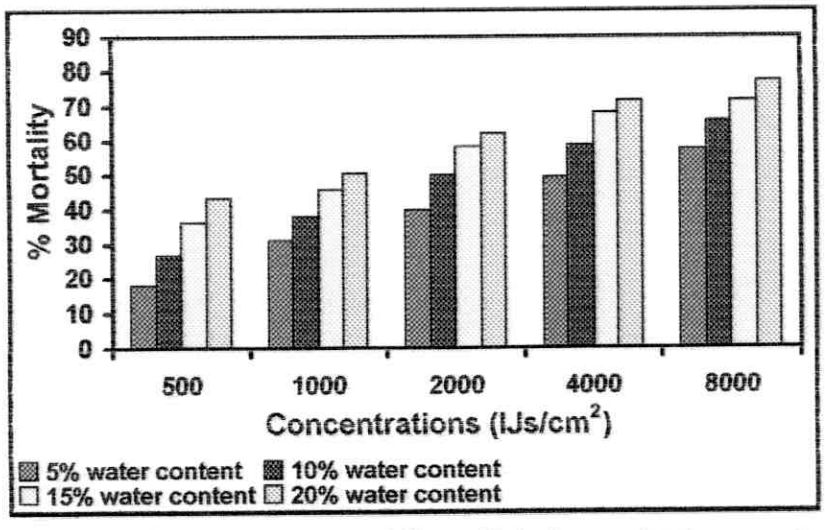

Fig. (22): Mortality percentages of *C. capitata* larvae and pupae treated in sandy soil at different rates of water content by different concentrations of *H. tayserae*.

water contents, the highest concentration of nematode suspension (8000 IJs/cm² of soil surface) caused 76.8 (56-84), 72.0 (60-78), 66.0 (60-76) and 57.4 (52- 70) % mortality, respectively among the treated pupae. At the lowest concentration, however, the respective mortalities were 43.6 (36-54), 36.2 (34-38), 27.0 (24-30), 18.0 (16-20), (Table 6 and Fig. 22).

The LC_{50} values for *H. tayserae* to one day old pupae of *C. capitata* at the water-contents of 20, 15, 10 and 5 % were found to be 812, 1276, 2354 and 4386 IJs/cm² of soil surface, respectively.

2- Infectivity of entomopathogenic nematodes to full-grown larvae of *C. capitata* in sandy and sandy-clay soils :

2.1- Sandy soil :

Data presented in Table (7) show the mortality percentages among *C. capitata* full-grown larvae after one week of treatment by either of the 4 nematode species under study. These data show that, generally, *S. abbasi* and *H. bacteriophora* to be more effective than the two other species.

*** *S. abbasi* :**

Mortality percentage increased as the concentration of IJs increased. At a lowest concentration (500 IJs/cm² soil surface), mortality among treated full-grown larvae of *C. capitata* was 64 (56-72) %. By increasing the concentrations of IJs to 1000, 2000 and 4000/cm², the mortalities increased to 71.6 (66-78), 83.8 (78-88) and 91.2 (86-96) %,

Table (7) : % Mortality of full grown larvae of *C. capitata* caused by different nematode species at different concentrations in sand and sand-clay soil at semi-field experiments.

Conc. IJs/ cm^2 soil	Nematode species	Percentage mortality at soil types :			
		Sandy soil		Sandy/clay soil	
500	*S. abbasi*	64.0	(56-72)	69.8	(64-76)
	S. riobravis	47.6	(40-52)	54.4	(48-62)
	H. bacteriophora	60.0	(54-68)	67.0	(60-76)
	H. tayserae	46.2	(38-58)	58.8	(52-70)
1000	*S. abbasi*	71.06	(66-78)	75.0	(66-80)
	S. riobravis	56.4	(48-72)	60.8	(58-70)
	H. bacteriophora	68.8	(62-76)	75.3	(66-80)
	H. tayserae	53.2	(42-66)	66.2	(54-80)
2000	*S. abbasi*	83.8	(78-88)	85.6	(80-90)
	S. riobravis	65.2	(50-78)	71.0	(64-78)
	H. bacteriophora	77.0	(66-86)	80.0	(72-90)
	H. tayserae	65.8	(52-80)	71.0	(60-76)
4000	*S. abbasi*	91.2	(86-96)	96.0	(92-98)
	S. riobravis	70.2	(62-78)	79.0	(74-86)
	H. bacteriophora	84.4	(80-90)	86.6	(80-92)
	H. tayserae	73.2	(50-84)	77.6	(72-84)
8000	*S. abbasi*	95.8	(92-98)	98.0	(94-100)
	S. riobravis	81.8	(72-94)	87.0	(78-92)
	H. bacteriophora	93.0	(80-98)	96.6	(94-100)
	H. tayserae	80.2	(72-90)	83.0	(80-90)
Mean	*S. abbasi*	81.3	(75.6-86.4)	84.9	(79.2-88.8)
	S. riobravis	64.2	(54.4-74.8)	70.4	(64.4-77.6)
	H. bacteriophora	76.7	(68.4-83.6)	81.1	(74.4-87.0)
	H. tayserae	63.7	(50.8-75.6)	71.3	(63.6-80)
LC_{50}	*S. abbasi*	284		268	
	S. riobravis	626		433	
	H. bacteriophora	310		255	
	H. tayserae	705		230	
Slope	*S. abbasi*	1.1755		1.3874	
	S. riobravis	0.7671		0.8598	
	H. bacteriophora	0.97903		1.1219	
	H. tayserae	0.8068		0.6181	

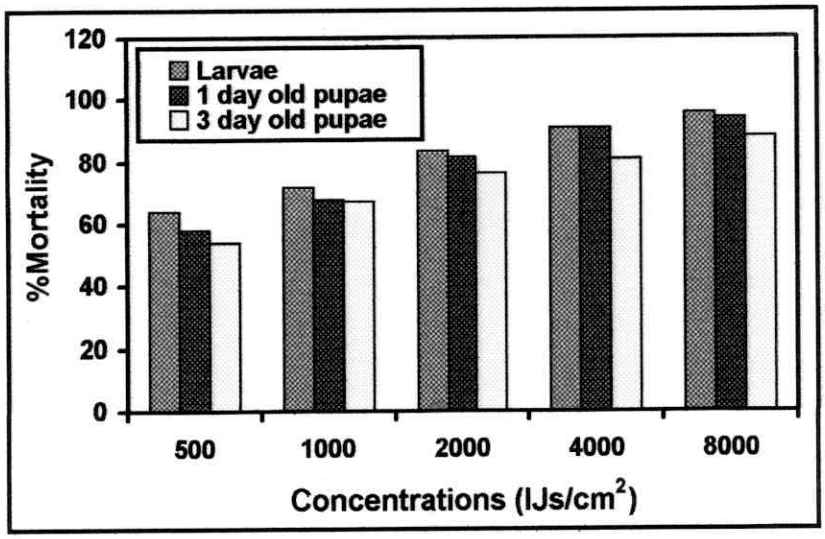

Fig. (23): Mortality percentages among *C. capitata* larvae and pupae treated with *S. abbasi* in sandy soil. (semi - field experiment).

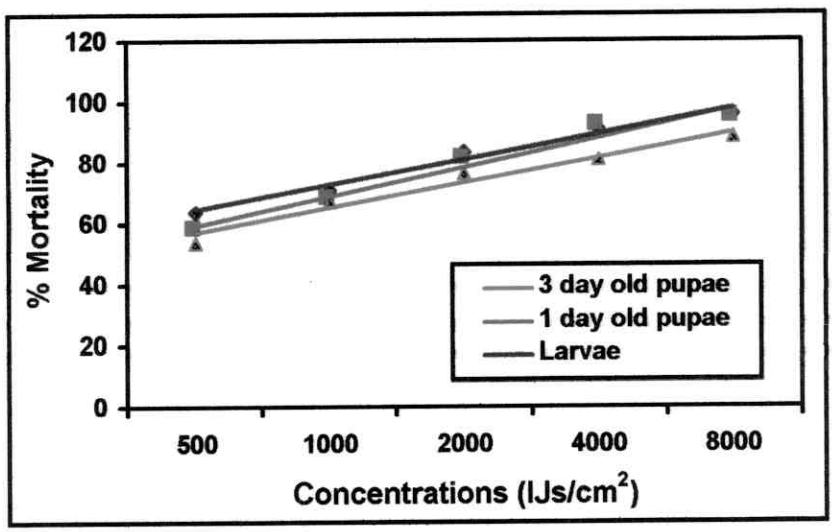

Fig.(24): Concentration – mortality lines for different concentrations of *S. abbasi* against *C. capitata* larvae and pupae treated in sandy soil. (semi - field experiment).

respectively. At the highest concentration (8000 IJs/cm²), the mortality reached a maximum of 95.8 (92-98) %, (Table 7 and Fig. 23). The LC_{50} of *S. abbasi* for full-grown larvae of *C. capitata* was found to be 284 IJs/cm² of sandy soil surface, (Table 7 and Fig. 24).

*** *S. riobravis* :**

Percent mortality increased as the concentration of IJs increased. At the lowest concentration (500 IJs/cm² of soil surface), mortality in full-grown larvae of *C. capitata* was 47.6 (40-52) %. Increasing the concentrations of IJs to 1000, 2000 and 4000/cm², the mortalities increased to 56.4 (48-72), 65.2 (50-78) and 70.2 (62-78) %, respectively. At the highest concentration (8000 IJs/cm² of soil surface) the mortality was 81.8 (72-94) %, (Table 7 and Fig. 25).

LC_{50} of *S. riobravis* for full grown larvae of *C. capitata* was found to be 626 IJs/cm² of sand soil surface, (Table 7 and Fig. 26).

*** *H. bacteriophora* :**

Percent mortality increased as the concentration of IJs increased. At the lowest concentration (500 IJs/cm² of soil), mortality in full-grown larvae of *C. capitata* was 60.0 (54-68) %. Increasing the concentrations of IJs to 1000, 2000 and 4000/cm², the mortalities increased to 68.8 (62.76), 77 (66-86) and 84.4 (80-90) %, respectively. At the highest concentration (8000 IJs/cm²), mortality was 93 (80-98) %, (Table 7 and Fig. 27).

LC_{50} of *H. bacteriophora* for full grown larvae of *C. capitata* was found to be 310 IJs/cm² of sandy soil surface, (Table 7 and Fig. 28).

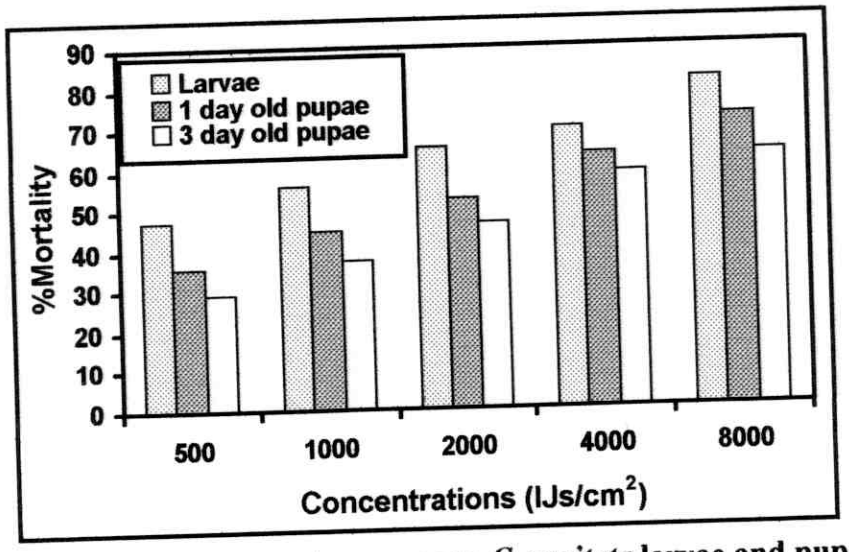

Fig. (25): Mortality percentages among *C. capitata* larvae and pupae treated with *S. riobravis* in sandy soil. (semi - field experiment).

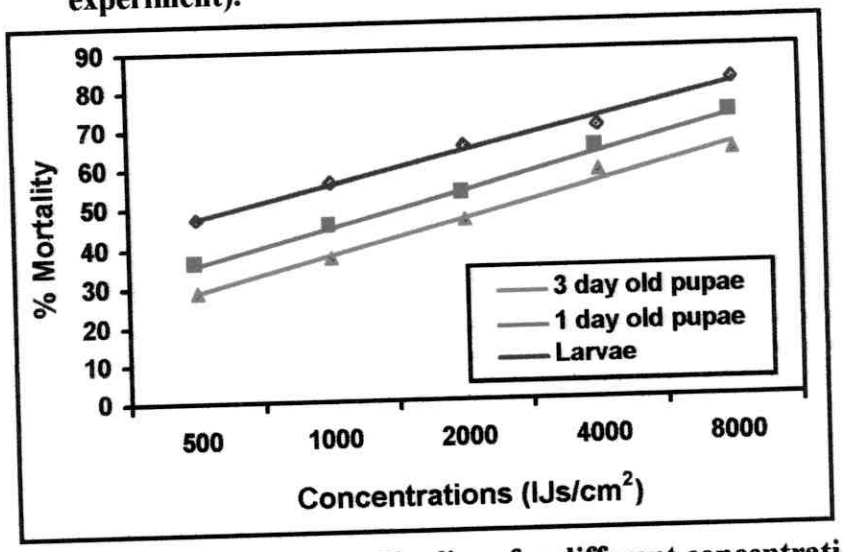

Fig.(26): Concentration – mortality lines for different concentrations of *S. riobravis* against *C. capitata* larvae and pupae treated in sandy soil. (semi - field experiment).

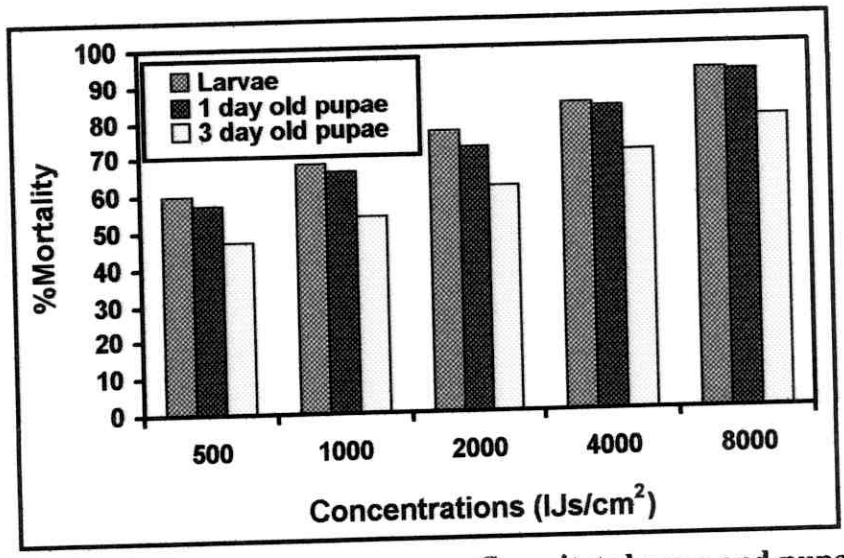

Fig. (27): Mortality percentages among *C. capitata* larvae and pupae treated with *H. bacteriophora* in sandy soil. (semi - field experiment).

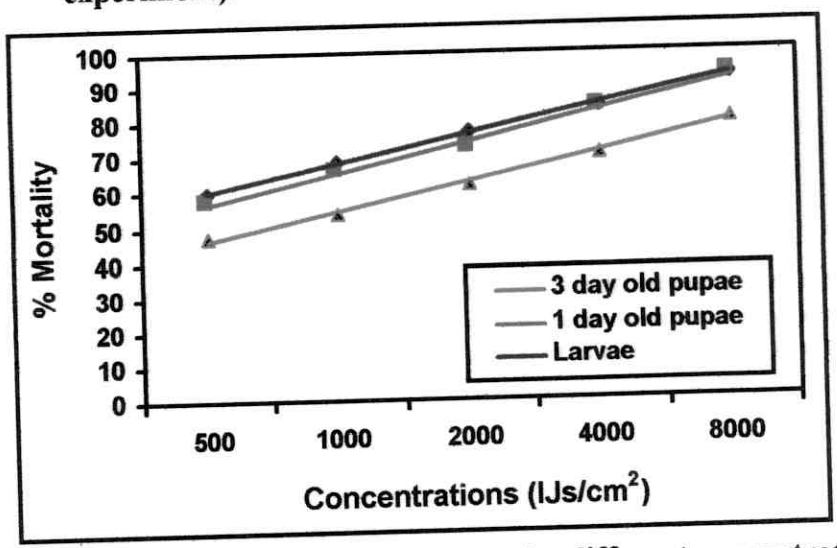

Fig.(28): Concentration – mortality lines for different concentrations of *H. bacteriophora* against *C. capitata* larvae and pupae treated in sandy soil. (semi - field experiment).

*** *H. tayserae* :**

Percent mortality increased as the concentration of IJs increased. At the lowest concentration (500 IJs/cm² of soil), mortality in full-grown larvae of *C. capitata* was 46.2 (38-58) %. Increasing the concentrations of IJs to 1000, 2000 and 4000/cm², the mortalities increased to 53.2 (42-66), 65.8 (52-80) and 73.2 (50-84) %, respectively. At the highest concentration (8000 IJs/cm²), mortality was 80.2 (72-92) %, (Table 7 and Fig. 29).

LC_{50} of *H. tayserae* for full-grown larvae of *C. capitata* was found to be 705 IJs/cm² of sand-soil surface, (Table 7 and Fig. 30).

2.2- Sandy-clay soil :

*** *S. abbasi* :**

At the lowest concentration (500 IJs/cm² of soil surface), mortality in full-grown larvae of *C. capitata* was 69.8 (64.76) %. By increasing the applied dose to 1000 IJs/cm², the recorded mortality increased to 75 (66-8) %. At concentrations of 2000 and 4000 IJs/cm² of soil surface, % mortalities increased to 85.6 (80-90) and 96.0 (92- 98) %, respectively. At the highest concentration (8000 IJs/cm² of soil surface), mortality was 98 (94-100) %, (Table 7 and Fig. 31).

LC_{50} of *S. abbasi* for full-grown larvae of *C. capitata* was found to be 268 IJs/cm² of sand-clay soil surface, (Table 7 and Fig. 32).

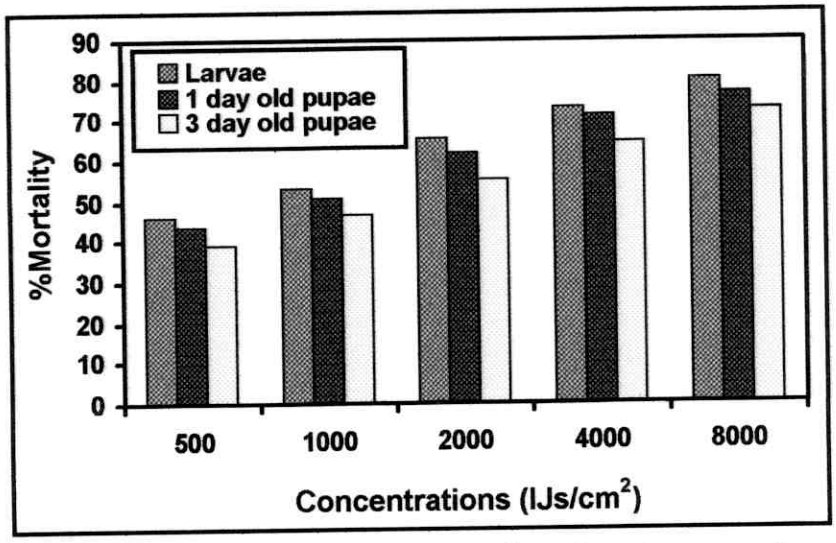

Fig. (29): Mortality percentages among *C. capitata* larvae and pupae treated with *H. tayserae* in sandy soil. (semi - field experiment).

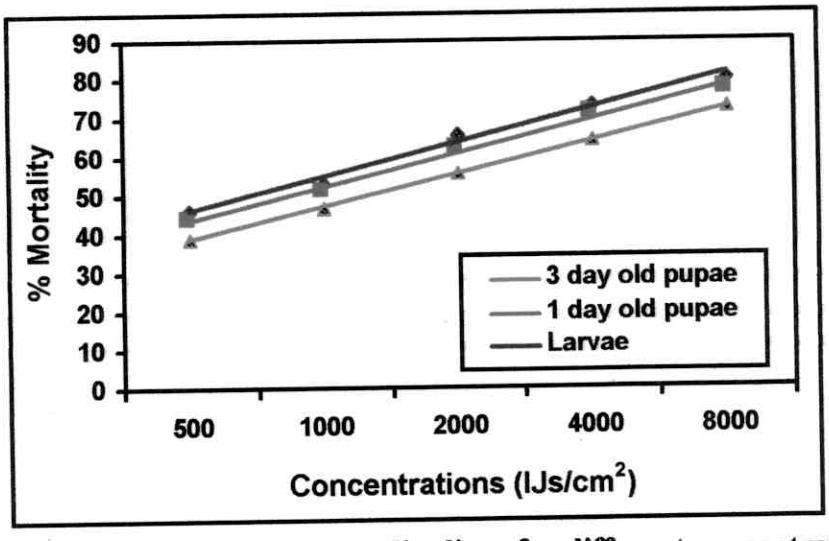

Fig.(30): Concentration – mortality lines for different concentrations of *H. tayserae* against *C. capitata* larvae and pupae treated in sandy soil. (semi - field experiment).

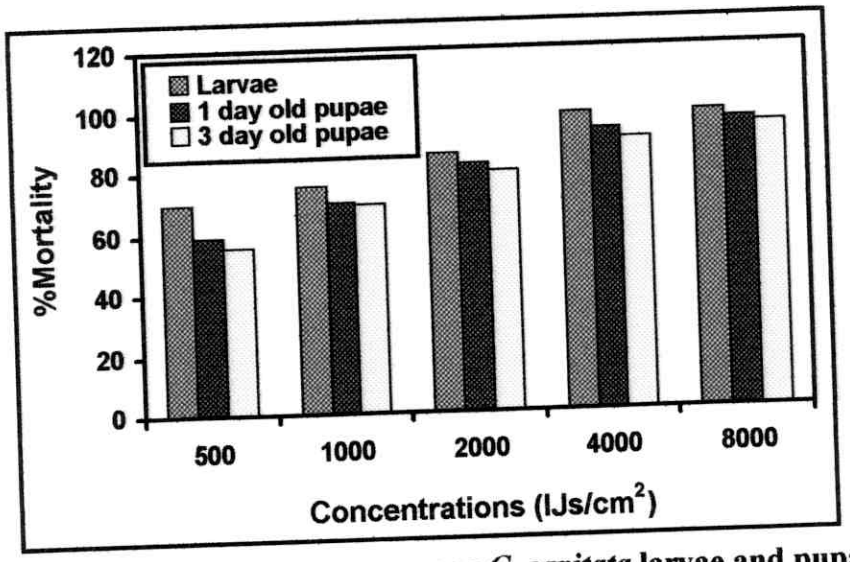

Fig. (31): Mortality percentages among *C. capitata* larvae and pupae treated with *S. abbasi* in sand clay soil. (semi - field experiment).

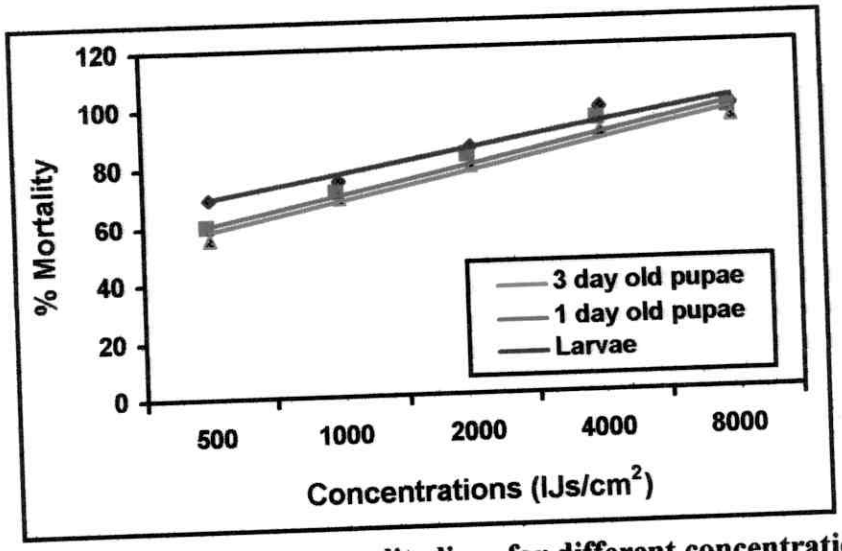

Fig.(32): Concentration – mortality lines for different concentrations of *S. abbasi* against *C. capitata* larvae and pupae treated in sand clay soil. (semi - field experiment).

*** *S. riobravis* :**

At the lowest concentration (500 IJs/cm² of soil surface), mortality in full-grown larvae of *C. capitata* was 54.4 (48-62) %. By increasing the applied dose to 1000/cm², the recorded mortality increased to 60.8 (58-70) %. At concentrations of 2000 and 4000 IJs/cm² of soil, % mortalities increased to 71.0 (64-78) and 79.0 (74-86) %, respectively. At the highest concentration (8000 IJs/cm² of soil surface), mortality was 87 (78-92) %, (Table 7 and Fig. 33). LC_{50} of *S. riobravis* for full-grown larvae was found to be 433 IJs/cm² of sand-clay soil surface, (Table 7 and Fig. 34).

*** *H. bacteriophora* :**

At the lowest concentration (500 IJs/cm² of soil surface), mortality in full-grown larvae of *C. capitata* was 67 (60-76) %. By increasing the applied dose to 1000/cm², the recorded mortality increased to 75.4 (66-80) %. At concentrations of 2000 and 4000 IJs/cm² of soil surface, % mortalities increased to 80.0 (72-90) and 86.6 (80-92) %, respectively. At the highest concentration (8000 IJs/cm² of soil surface), mortality was 96.6 (94-100) %, (Table 7 and Fig. 35). LC_{50} of *H. bacteriophora* for full-grown larvae of *C. capitata* was found to be 255 IJs/cm² of sand-clay soil surface, (Table 7 and Fig. 36).

*** *T. tayserae* :**

At the lowest concentration (500 IJs/cm² of soil surface), mortality in full-grown larvae of *C. capitata* was 58.8 (52-70) %. By increasing the applied dose to 1000/cm², the recorded mortality increased 66.2

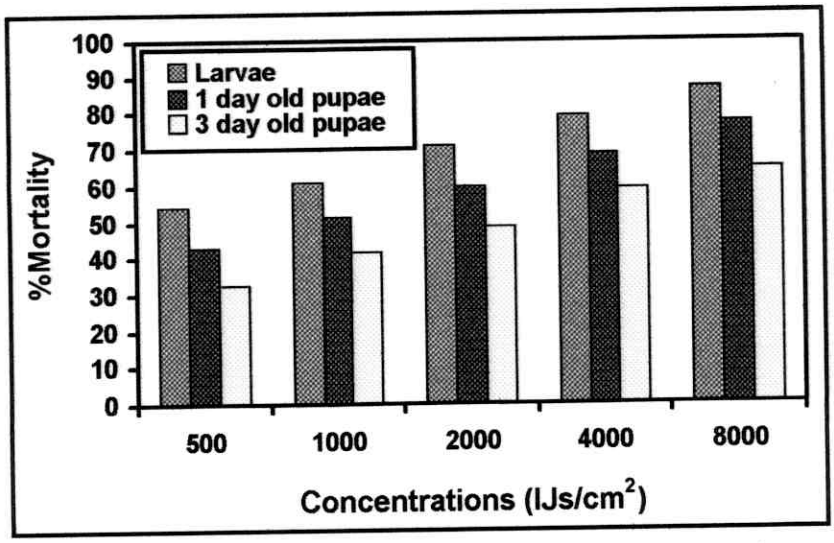

Fig. (33): Mortality percentages among *C. capitata* larvae and pupae treated with *S. riobravis* in sand clay soil. (semi - field experiment).

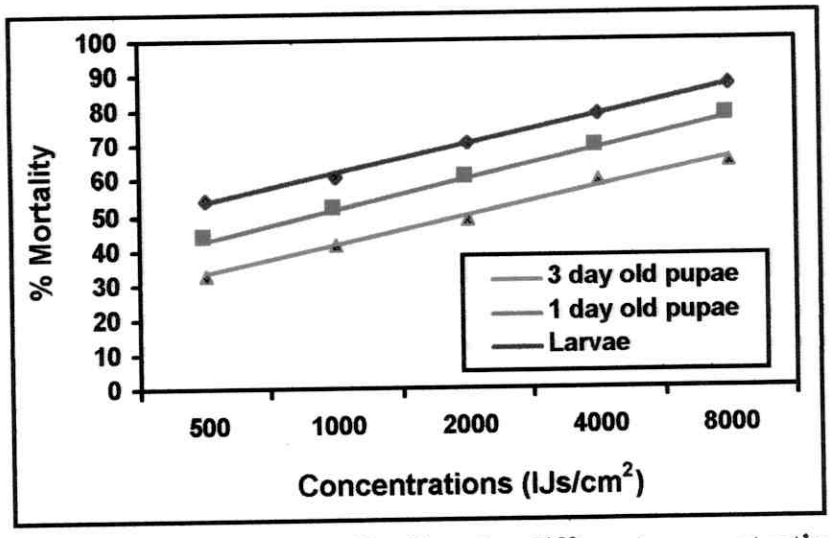

Fig.(34): Concentration – mortality lines for different concentrations of *S. riobravis* against *C. capitata* larvae and pupae treated in sand clay soil. (semi - field experiment).

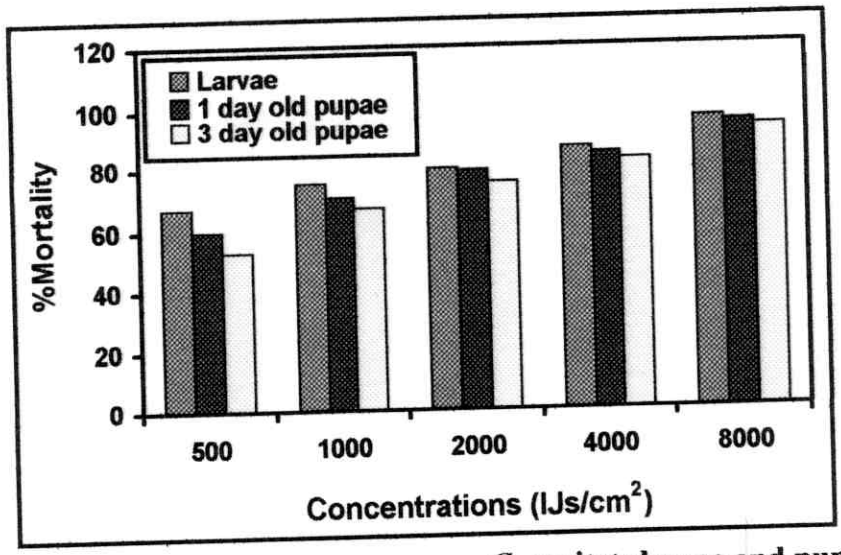

Fig. (35): Mortality percentages among *C. capitata* larvae and pupae treated with *H. bacteriophora* in sand clay soil. (semi - field experiment).

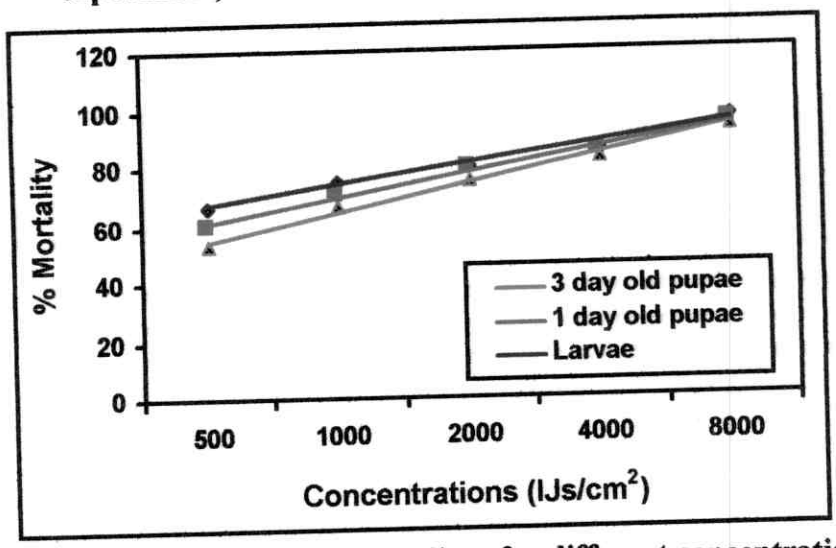

Fig.(36): Concentration – mortality lines for different concentrations of *H. bacteriophora* against *C. capitata* larvae and pupae treated in sand clay soil. (semi - field experiment).

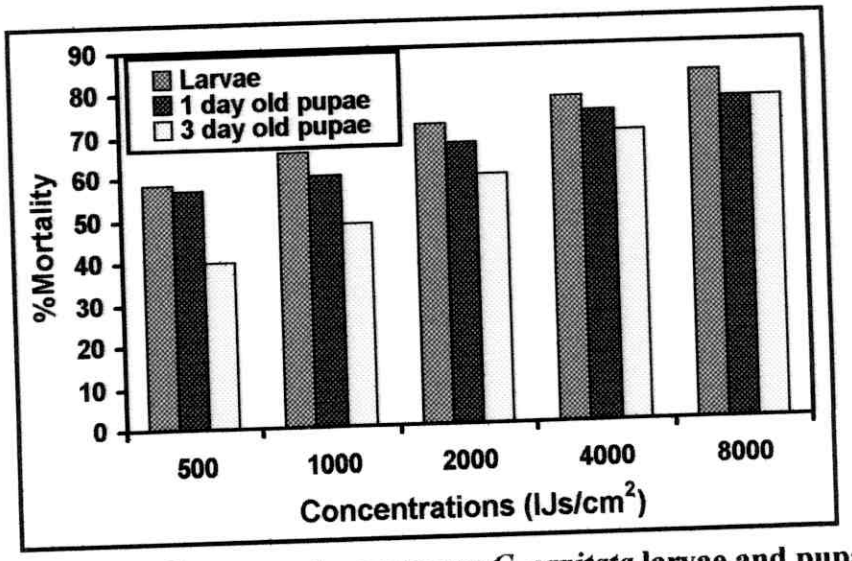

Fig. (37): Mortality percentages among *C. capitata* larvae and pupae treated with *H. tayserae* in sand clay soil. (semi – field experiment).

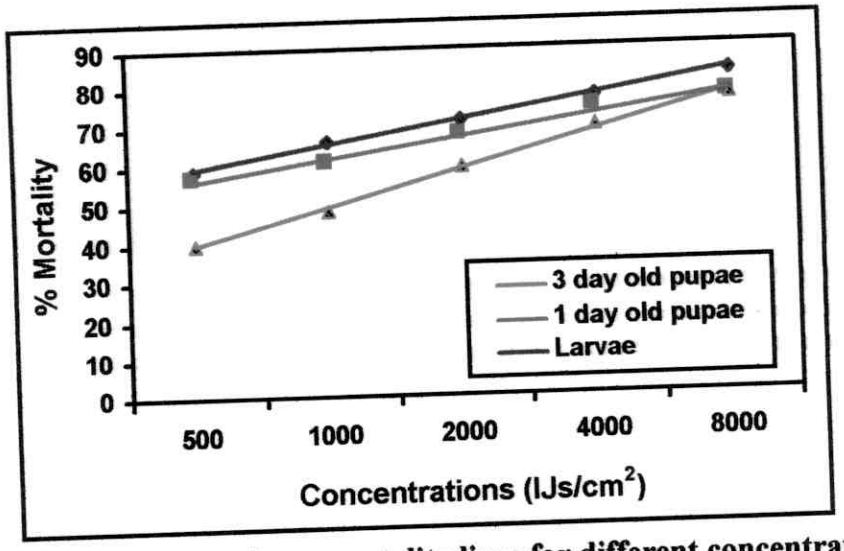

Fig.(38): Concentration – mortality lines for different concentrations of *H. tayserae* against *C. capitata* larvae and pupae treated in sand clay soil. (semi - field experiment).

(54-80) %. At concentrations of 2000 and 4000 IJs/cm² of soil surface, % mortalities increased to 71 (60-76) and 77.6 (72-84) %, respectively. At the highest concentration (8000 IJs/cm² of soil surface), mortality was 83 (80-90) %, (Table 7 and Fig. 37).

LC_{50} of *H. tayserae* for full-grown larvae of *C. capitata* was found to be 230 IJs/cm² of soil surface, (Table 7 and Fig. 38).

3- Infectivity of the different entomopathogenic nematodes to one day old pupae of *C. capitata* in sandy and sandy- clay soils :

3.1- Sand soil :

Data presented in Table (8) show the mortality percentages among *C. capitata* pupae (one day old) after one week treatment. These data showed that, generally, *S. abbasi* and *H. bacteriophora* were more effective on the treated stages than *H. tayserae* and *S. riobravis*.

*** *S. abbasi* :**

At concentrations of 500, 1000 and 2000 IJs/cm² of soil surface, mortality percentages among the treated pupae were 57.8 (50-64), 68 (62-76) and 81.6 (78-86) %, respectively. At higher concentrations (4000 and 8000 IJs/cm² of soil surface), the respective mortalities were 90.8 (80-96) % and 94.4 (92-98) %, (Table 8 and Fig. 23).

LC_{50} of *S. abbasi* for one day old pupae of *C. capitata* was found to be 365 IJs/cm² of sandy soil surface, (Table 8 and Fig. 24).

Table (8) : % Mortality in one day old pupae of *C. capitata* caused by different nematode species at different concentrations in sand and sand-clay soil at semi-field experiment.

Conc. IJs/ cm^2 soil	Nematode species	Percentage mortality at soil types :			
		Sandy soil		Sandy/clay soil	
500	*S. abbasi*	57.8	(50-64)	59.0	(56-66)
	S. riobravis	35.8	(30-42)	43.2	(36-52)
	H. bacteriophora	57.4	(50-64)	59.4	(52-70)
	H. tayserae	43.6	(36-54)	57.0	(50-66)
1000	*S. abbasi*	68.0	(62-76)	70.0	(64-72)
	S. riobravis	45.0	(40-52)	51.4	(46-58)
	H. bacteriophora	66.2	(60-76)	70.8	(64-80)
	H. tayserae	50.8	(42-60)	60.4	(50-70)
2000	*S. abbasi*	81.6	(78-86)	82.0	(78-88)
	S. riobravis	52.6	(48-60)	60.0	(52-68)
	H. bacteriophora	72.6	(66-78)	79.4	(74-84)
	H. tayserae	62.2	(50-76)	67.4	(60-78)
4000	*S. abbasi*	90.8	(80-96)	93.0	(84-96)
	S. riobravis	63.6	(50-70)	69.2	(66-74)
	H. bacteriophora	83.4	(76-88)	84.8	(80-90)
	H. tayserae	71.6	(52-80)	74.4	(60-84)
8000	*S. abbasi*	94.4	(92-98)	95.8	(94-98)
	S. riobravis	72.4	(66-78)	77.6	(70-84)
	H. bacteriophora	92.8	(88-98)	94.6	(90-98)
	H. tayserae	76.8	(56-84)	79.6	(74-86)
Mean	*S. abbasi*	78.5	(50-90)	79.8	(75.2-84)
	S. riobravis	53.9	(30-78)	60.3	(54-67.2)
	H. bacteriophora	74.5	(50-98)	77.8	(72-84.4)
	H. tayserae	61.0	(36-84)	67.8	(58.8-76.8)
LC_{50}	*S. abbasi*	365		334	
	S. riobravis	1484		893	
	H. bacteriophora	398		362	
	H. tayserae	812		684	
Slope	*S. abbasi*	1.1796		1.3284	
	S. riobravis	0.7875		0.7859	
	H. bacteriophora	1.0430		1.0994	
	H. tayserae	0.7726		0.5475	

*** *S. riobravis* :**

At concentrations of 500, 1000 and 2000 IJs/cm² of soil surface, mortality percentages among the treated pupae were 35.8 (30- 42), 45 (40-52) and 52.6 (48-60) %, respectively. At the higher concentrations (4000 and 8000 IJs/cm² of soil surface), the respective mortalities were 63.6 (50-70) and 72.4 (6-78) %, (Table 8 and Fig. 25).

LC_{50} of *S. riobravis* for one day old pupae of *C. capitata* was found to be 148 IJs/cm² of sandy soil surface, (Table 8 and Fig. 26).

*** *H. bacteriophora* :**

At concentrations of 500, 1000 and 2000 IJs/cm² of soil surface, mortality percentages among the treated pupae were 57.4 (50-64), 66.2 (60-76) and 72.6 (66-78) %, respectively. At the higher concentrations (4000 and 8000 IJs/cm² of soil surface), the respective mortalities were 83.4 (76-88) and 92.8 (88-98) %, (Table 8 and Fig. 27).

LC_{50} of *H. bacteriophora* for one day old pupae of *C. capitata* was found to be 398 IJs/cm² of sand soil surface, (Table 8 and Fig. 28).

*** *H. tayserae* :**

At concentrations of 500, 1000 and 2000 IJs/cm² of soil surface, mortality percentages among the treated pupae were 43.6 (36-54), 50.8 (42-60) and 62.2 (50-76) %, respectively. At the higher concentrations (4000 and 8000 IJs/cm² of soil surface), the respective mortalities were 71.6 (52-80) and 76.8 (56-84) %, (Table 8 and Fig. 29).

LC_{50} of *H. tayserae* for one day old pupae of *C. capitata* was found to be 812 IJs/cm² of sand soil surface, (Table 8 and Fig. 30).

3.2- Sandy-clay soil :

Data presented in Table (8) show the mortality percentages among *C. capitata* pupae (one day old) after one week of treatment.

**** S. abbasi* :**

Treatment of the pupae at the lowest concentration (500 IJs/cm²) led to 59 (56-66) % mortality. Successive increase in mortality percentage occurred among the treated pupae by increasing the applied doses. At concentrations of 1000, 2000, 4000 and 8000 IJs/cm² of soil surface, percentage mortalities were 70 (64-72), 82 (78-88), 93 (84-96) and 95.8 (94-98) %, respectively, (Table 8 and Fig. 31).

LC_{50} of *S. abbasi* for one day old pupae of *C. capitata* was found to be 362 IJs/cm² of sand-clay soil surface, (Table 8 and Fig. 32).

**** S. riobravis* :**

Treatment of the pupae at the lowest concentration (500 IJs/cm²) led to 43.2 (36-52) % mortality. Successive increase in mortality percentage occurred among the treated pupae by increasing the applied doses. At concentrations of 1000, 2000, 4000 and 8000 IJs/cm² of soil surface, percentage mortalities were 51.4 (46-58), 60 (52-68), 69.2 (66-74) and 77.6 (70-84) %, respectively, (Table 8 and Fig. 33).

*** *S. riobravis* :**

At concentrations of 500, 1000 and 2000 IJs/cm² of soil surface, mortality percentages among the treated pupae were 35.8 (30- 42), 45 (40-52) and 52.6 (48-60) %, respectively. At the higher concentrations (4000 and 8000 IJs/cm² of soil surface), the respective mortalities were 63.6 (50-70) and 72.4 (6-78) %, (Table 8 and Fig. 25).

LC_{50} of *S. riobravis* for one day old pupae of *C. capitata* was found to be 148 IJs/cm² of sandy soil surface, (Table 8 and Fig. 26).

*** *H. bacteriophora* :**

At concentrations of 500, 1000 and 2000 IJs/cm² of soil surface, mortality percentages among the treated pupae were 57.4 (50-64), 66.2 (60-76) and 72.6 (66-78) %, respectively. At the higher concentrations (4000 and 8000 IJs/cm² of soil surface), the respective mortalities were 83.4 (76-88) and 92.8 (88-98) %, (Table 8 and Fig. 27).

LC_{50} of *H. bacteriophora* for one day old pupae of *C. capitata* was found to be 398 IJs/cm² of sand soil surface, (Table 8 and Fig. 28).

*** *H. tayserae* :**

At concentrations of 500, 1000 and 2000 IJs/cm² of soil surface, mortality percentages among the treated pupae were 43.6 (36-54), 50.8 (42-60) and 62.2 (50-76) %, respectively. At the higher concentrations (4000 and 8000 IJs/cm² of soil surface), the respective mortalities were 71.6 (52-80) and 76.8 (56-84) %, (Table 8 and Fig. 29).

LC_{50} of *H. tayserae* for one day old pupae of *C. capitata* was found to be 812 IJs/cm² of sand soil surface, (Table 8 and Fig. 30).

3.2- Sandy-clay soil :

Data presented in Table (8) show the mortality percentages among *C. capitata* pupae (one day old) after one week of treatment.

**** S. abbasi* :**

Treatment of the pupae at the lowest concentration (500 IJs/cm²) led to 59 (56-66) % mortality. Successive increase in mortality percentage occurred among the treated pupae by increasing the applied doses. At concentrations of 1000, 2000, 4000 and 8000 IJs/cm² of soil surface, percentage mortalities were 70 (64-72), 82 (78-88), 93 (84-96) and 95.8 (94-98) %, respectively, (Table 8 and Fig. 31).

LC_{50} of *S. abbasi* for one day old pupae of *C. capitata* was found to be 362 IJs/cm² of sand-clay soil surface, (Table 8 and Fig. 32).

**** S. riobravis* :**

Treatment of the pupae at the lowest concentration (500 IJs/cm²) led to 43.2 (36-52) % mortality. Successive increase in mortality percentage occurred among the treated pupae by increasing the applied doses. At concentrations of 1000, 2000, 4000 and 8000 IJs/cm² of soil surface, percentage mortalities were 51.4 (46-58), 60 (52-68), 69.2 (66-74) and 77.6 (70-84) %, respectively, (Table 8 and Fig. 33).

LC_{50} of *S. riobravis* for one day old pupae of *C. capitata* was found to be 893 IJs/cm² of sandy-clay soil surface, (Table 8 and Fig. 34).

*** *H. bacteriophora* :**

Treatment of the pupae at the lowest concentration (500 IJs/cm²) led to 59.4 (52-70) % mortality. Successive increase in mortality percentage occurred among the treated pupae by increasing the applied doses. At concentrations of 1000, 2000, 4000 and 8000 IJs/cm² of soil surface, percentage mortalities were 70.8 (64-80), 79.4 (74-84), 84.8 (80-90) and 94.6 (90-98) %, respectively, (Table 8 and Fig. 35).

LC_{50} of *H. bacteriophora* for one day old pupae of *C. capitata* was found to be 362 IJs/cm² of sandy-clay soil surface, (Table 8 and Fig. 36).

*** *H. tayserae* :**

Treatment of the pupae at the lowest concentration (500 IJs/cm²) led to 57 (50-66) % mortality. Successive increase in mortality percentage occurred among the treated pupae by increasing the applied doses. At concentrations of 1000, 2000, 4000 and 8000 IJs/cm² of soil surface, percentage mortalities were 60.4 (50-70), 67.4 (60-78), 74.4 (60-84) and 79.6 (74-86) %, respectively, (Table 8 and Fig. 37).

LC_{50} of *H. tayserae* for one day old pupae of *C. capitata* was found to be 684 IJs/cm² of sand-clay soil surface, (Table 8 and Fig. 38).

4- Infectivity of the different entomopathogenic nematodes to three day old pupae of *C. capitata* in sandy and sand- clay soils :

4.1- Sandy soil :

Data presented in Table (9) show the mortality percentages among *C. capitata* pupae (three day old) after one week of treatment. These data show that, generally, *S. abbasi* and *H. bacteriophora* were more effective on the treated stage than *H. tayserae* and *S. riobravis*.

*** *S. abbasi* :**

The three day old pupae of *C. capitata* were found to be more tolerant to infection than the one day old pupae. At a concentration of 500 IJs/cm² of soil surface, mortality in pupae was 54.2 (48-62) %. By increasing the concentrations of IJs to 1000, 2000 and 4000/cm² of soil surface, the mortalities increased to 67.2 (60-76), 76.8 (66-86) and 81.2 (76-88) %, respectively. The highest concentration (8000 IJs/cm²) caused the highest mortality 88.4 (82-96) %, (Table 9 and Fig. 23).

Claculated LC_{50} of *S. abbasi* for three day old pupae of *C. capitata* was found to be 336 IJs/cm² of sandy soil surface, (Table 9 and Fig. 24).

*** *S. riobravis* :**

The three day old pupae of *C. capitata* were found to be more tolerant to infection than the one day old pupae. At a concentration of 500 IJs/cm² of soil surface, mortality in pupae was 29 (22-38) %. By

Table (9) : % Mortality in three day old pupae of *C. capitata* caused by different nematode species at different concentrations in sandy and sandy-clay soil at semi-field experiment.

Conc. IJs/ cm^2 soil	Nematode species	Percentage mortality at soil types :			
		Sandy soil		Sandy/clay soil	
500	*S. abbasi*	54.2	(48-62)	55.6	(48-06)
	S. riobravis	29.0	(22-38)	33.8	(30-38)
	H. bacteriophora	47.2	(44-50)	53.0	(48-60)
	H. tayserae	39.2	(34-44)	40.2	(36-44)
1000	*S. abbasi*	67.2	(60-76)	69.0	(62-76)
	S. riobravis	37.4	(30-44)	41.6	(36-46)
	H. bacteriophora	54.0	(48-62)	67.0	(60-76)
	H. tayserae	46.8	(38-56)	48.6	(46-52)
2000	*S. abbasi*	76.8	(66-86)	79.0	(76-86)
	S. riobravis	46.4	(40-52)	48.8	(40-52)
	H. bacteriophora	62.0	(56-68)	78.2	(70-78)
	H. tayserae	55.6	(40-66)	59.6	(52-64)
4000	*S. abbasi*	81.2	(76-88)	89.8	(80-96)
	S. riobravis	58.6	(50-72)	59.6	(54-66)
	H. bacteriophora	71.0	(64-78)	83.0	(76-88)
	H. tayserae	64.4	(46-84)	69.4	(60-84)
8000	*S. abbasi*	88.4	(82-96)	94.2	(92-96)
	S. riobravis	63.4	(58-76)	64.8	(58-76)
	H. bacteriophora	80.0	(72-88)	93.6	(92-96)
	H. tayserae	72.8	(52-86)	76.8	(70-86)
Mean	*S. abbasi*	73.6	(66.4-81.6)	77.5	(71.6-84)
	S. riobravis	46.96	(40-56.4)	49.5	(43.6-55.6)
	H. bacteriophora	62.8	(56.8-69.2)	74.96	(69.2-79.6)
	H. tayserae	55.8	(42-67.2)	58.9	(52.8-66)
LC_{50}	*S. abbasi*	336		351	
	S. riobravis	2563		2744	
	H. bacteriophora	701		491	
	H. tayserae	1257		1348	
Slope	*S. abbasi*	0.8631		0.9360	
	S. riobravis	0.7704		0.6071	
	H. bacteriophora	0.7583		1.2318	
	H. tayserae	0.7373		0.8333	

increasing the concentrations of IJs to 1000, 2000 and 4000/cm² of soil surface, the mortalities increased to 37.4 (30-44), 46.4 (40-52) and 58.6 (50-72) %, respectively. The highest concentration (8000 IJs/cm²) caused the highest mortality 63.4 (58-76) %, (Table 9 and Fig. 25).

Calculated LC_{50} of *S. riobravis* for three day old pupae of *C. capitata* was found to be 2562 IJs/cm² of sandy soil surface, (Table 9 and Fig. 26).

*** *H. bacteriophora* :**

The three day old pupae of *C. capitata* were found to be more tolerant to infection than the one day old pupae. At a concentration of 500 IJs/cm² of soil surface, mortality in pupae was 47.2 (44-50) %. By increasing the concentrations of IJs to 1000, 2000 and 4000/cm² of soil surface, the mortalities increased to 54 (48-62), 62 (56-68), and 71 (64-78) %, respectively. The highest concentration (8000 IJs/cm²) caused the highest mortality 80 (72-88) %, (Table 9 and Fig. 27).

Calculated LC_{50} of *H. bacteriophora* for three day old pupae of *C. capitata* was found to be 701 IJs/cm2 of sandy soil surface, (Table 9 and Fig. 28).

*** *H. tayserae* :**

The three day old pupae of *C. capitata* were found to be more tolerant to infection than the one day old pupae. At a concentration of 500 IJs/cm² of soil surface, mortality in pupae was 39.2 (34- 44) %. By

increasing the concentrations of IJs to 1000, 2000 and 4000/cm² of soil surface, the mortalities increased to 46.8 (38-56), 5.6 (40-66) and 64.4 (46.84) %, respectively. The highest concentration (8000 IJs/cm²) caused the highest mortality 72.8 (52-86) %, (Table 9 and Fig. 29).

Calculated LC_{50} of *H. iayserae* for three day old pupae of *C. capitata* was found to be 1257 IJs/cm² of sandy soil surface, (Table 9 and Fig. 30).

4.2- Sand-clay soil :

Data in Table (9) show the percent mortality among *C. capitata* pupae (three day old). These data show that, generally, *S. abbasi* and *H. bacteriophora* were more effective on the treated stage than *H. tayserae* and *S. riobravis*.

**** S. abbasi* :**

At a concentration of 500 IJs/cm² of soil surface, mortality in pupae was 55.6 (48-66) %. By increasing the concentrations of IJs to 1000, 2000 and 4000/cm² of soil surface, the mortalities increased to 69 (62-76), 79 (76-86) and 89.8 (80-96) %, respectively. The highest concentration (8000 IJs/cm²) caused the highest mortality 94.2 (92-96) %, (Table 9 and Fig. 31).

LC_{50} of *S. abbasi* for three-day old pupae of *C. capitata* found to be 351 IJs/cm² of sand-clay soil surface, (Table 9 and Fig. 32).

*** *S. riobravis* :**

At a concentration of 500 IJs/cm² of soil surface, mortality in pupae was 32.8 (30-38) %. By increasing the concentrations of IJs to 1000, 2000 and 4000/cm² of soil surface, the mortalities increased to 41.6 (36-46), 48.8 (40-52) and 59.6 (54-66) %, respectively. The highest concentration (8000 IJs/cm²) caused the highest mortality 64.8 (58-76) %, (Table 9 and Fig. 33).

LC_{50} of *S. riobravis* for three day old pupae of *C. capitata* found to be 2744 IJs/cm² of sand-clay soil surface, (Table 9 and Fig. 34).

*** *H. bacteriophora* :**

At a concentration of 500 IJs/cm² of soil surface, mortality in pupae was 53 (48-60) %. By increasing the concentrations of IJs to 1000, 2000 and 4000/cm² of soil surface, the mortalities increased to 67 (60-76), 78.2 (70-78) and 83 (76-88) %, respectively. The highest concentration (8000 IJs/cm²) caused the highest mortality 93.6 (92-96) %, (Table 9 and Fig. 35).

LC_{50} of *H. bacteriophora* for three day old pupae of *C. capitata* was found to be 491 IJs/cm² of sand-clay soil surface, (Table 9 and Fig. 36).

*** *H. tayserae* :**

At a concentration of 500 IJs/cm² of soil surface, mortality in pupae was 40.2 (36- 44) %. By increasing the concentrations of IJs to 1000, 2000 and 4000/cm² of soil surface, the mortalities increased to 48.6

(46-52), 59.6 (52-64) and 69.4 (60-84) %, respectively. The highest concentration (8000 IJs/cm²) caused the highest mortality 76.8 (70-86) %, (Table 9 and Fig. 37).

LC_{50} of *H. tayserae* for three day old pupae of *C. capitata* was found to be 1348 IJs/cm² of sand-clay soil surface, (Table 9 and Fig. 38).