Chapter - IV

Results

RESULTS

4.1 Seasonal Incidence of Insect-Pests and Their Natural Enemies of Tomato and Their Interaction with Crop-Phenology

4.1.I Population fluctuation of different insect-pests and their natural enemies

The experiment on fluctuation of population of different insect-pest species and their natural enemies was conducted in 1997-98 and 1998-99 during the tomato growing season through planting of tomato seedlings at monthly interval, starting from 24^{th} November to 24^{th} February **(P_1 crop- planted on 24^{th} November, P_2 crop- planted on 24^{th} December, P_3 crop- planted on 24^{th} January, P_4 crop- planted on 24^{th} February)**. Under present investigation aphid *(Aphis gossypii* Glover), white fly (*Bemisia tabaci* Gennadius), fruit borer *(Helicoverpa armigera* Hubner) and serpentine leaf miner *(Liriomyza trifolii* Burgess) were found predominant insect-pest species casusing damage to tomato. Among the different natural enemies, *Menochilus sexmaculata, Coccinella septempunctata* and some spider species were found to play important role in natural suppression of soft bodied pests like aphid, white fly, mite etc. The seasonal fluctuation of insect-pest and their natural enemy population as influenced by planting time as well as prevailing weather conditions are discussed below :

4.1.1.1. Aphid (*Aphis gossypii* Glover)

Aphid (*Aphis gossypii*), the small-soft bodied polyphagous insect appeared on all the four crops raised at different time in 1997-98 and 1998-99 and their relative abundance varied widely with different times of planting.

In 1997-98, aphid population was initiated on 49^{th} (0.19/leaf), 3^{rd} (0.98/leaf), 7^{th} (2.21/leaf) and 10^{th} (0.24/leaf) standard week and continued for different periods on P_1 to P_4 crop respectively (Table 4.1.1.1a). The mean aphid population was always lower in P_1 (0.18/leaf) and P_4 (0.07/leaf) crops (Table-4.1.1.11) with the highest being 0.41/leaf and 0.24/leaf on standard week 51 and 10 respectively. The mean aphid population was relatively higher on P_2 (1.92/leaf) and P_3 (1.68/leaf) crop (Table 4.1.1.11), the

Table 4.1.1.1a : Incidence and relative abundance of aphid (*Aphis gossypii* Glov.) population at different times of planting on tomato

Year	Pest Population / Planting	Standard week 49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1997-98	P_1	0.19	0.20	0.41	0.32	0.26	0.17	0.11	0.15	0.07	0.03								
	P_2							0.98	1.21	3.68	4.19	6.22	3.68	1.08	0.64	0.19	0.02		
	P_3											2.21	7.01	2.57	1.19	0.50	0.33	0.03	
	P_4														0.24	0.15	0.09	0.01	0.01
1998-99	P_1	0.67	0.78	0.57	0.39	0.50	0.25	0.19	0.11	0.03	0.01								
	P_2							0.92	1.09	2.22	7.33	3.70	1.00	0.50	0.12	0.03			
	P_3											6.21	3.31	1.21	0.67	0.20	0.05	0.01	
	P_4														0.36	0.19	0.11	0.05	0.01
Mean of two years	P_1	0.43	0.49	0.49	0.36	0.38	0.21	0.15	0.13	0.05	0.02								
	P_2							0.95	1.15	2.95	5.76	4.96	2.34	0.79	0.38	0.11	0.01		
	P_3											4.21	5.16	1.89	0.93	0.35	0.19	0.02	
	P_4														0.30	0.17	0.10	0.03	0.01

maximum being (6.22/leaf) and (7.01/leaf) on standard week 7 and 8 respectively.

With regard to the relative fluctuation of aphid population during entire crop growing season from December to May, it was observed that the builp up of aphid population was initiated (0.19/leaf) early in the season from early December on the standard week 49. A moderate level of population was maintained upto the 2nd standard week *i.e.* upto the 2nd week of January (0.17/leaf). Higher level of population was maintained from 4th-10th standard week (0.98-7.01/leaf) *i.e.* from 3rd week of January to 2nd week of March and the population reached at higher level on the standard week 8 (7.01/leaf) and the population level declined thereafter (Table 4.1.1.1b). During the period of higher incidence the average temperature, r.h., sunshine hr/day were ranged from 14.73 to 20.84°C, 61.78 to 75.93%, 3.49 to 9.21 hr/day respectively and the total rainfall was 10mm.

In 1998-99, the P_1 and P_4 crop also witnessed lower aphid population but the level was higher than the previous year 0.36/leaf and 0.10/leaf respectively (Table 4.1.1.12), but P_2 and P_3 crop witnessed less aphid population than the previous year and accounted to 1.74/leaf and 1.45/leaf respectively. The highest population level for four different crops was on 50th (0.78/leaf), 6th (7.33/leaf), 7th (6.21/leaf) and 10th (0.36/leaf) standard week during P_1 to P_4 crop respectively (Table 4.1.1.1a).

With regard to the fluctuation of aphid population during the entire crop growing season it is observed that the population increased steadily with the advancement of season and after the standard week 9 *i.e.* after the 1st week of March the population decreased gradually (Table 4.1.1.1b). The aphid was found most active from standard week 4-9 and the highest being 7.33/leaf on standard week 6. During higher period of incidence, average temperature, r.h. and sunshine hr/day were ranged from 15.93 to 22.22°C, 67.85 to 74.21%, 7.53 to 9.05 hr/day without any rainfall.

Pooled average data of two years on different plantings showed that P_2 crop recorded significantly higher mean aphid population (1.83/leaf), closely followed by P_3 (1.56/leaf). P_1 and P_4 crop witnessed lower level of population 0.27/leaf and 0.08/leaf respectively (Table 4.1.1.13). The initiation of aphid population on crops planted at different time was observed at early stage of crop growth *i.e.* only about 2 weeks after transplanting and the infestation was continued for different periods on

Table 4.1.1.1b Seasonal incidence of aphid (*Aphis gossypii* Glover) on tomato

Standard Week	Aphid / leaf		
	1997-98	1998-99	Mean
49	0.19(0.83)	0.67(1.08)	0.43(0.96)
50	0.20(0.84)	0.78(1.13)	0.49(0.99)
51	0.41(0.95)	0.57(1.03)	0.49(0.99)
52	0.32(0.91)	0.39(0.94)	0.36(0.93)
1	0.26(0.87)	0.50(1.00)	0.38(0.94)
2	0.17(0.82)	0.25(0.87)	0.21(0.84)
3	0.98(1.22)	0.92(1.19)	0.95(1.20)
4	1.21(1.31)	1.09(1.26)	1.15(1.28)
5	3.68(2.04)	2.22(1.65)	2.95(1.86)
6	4.19(2.16)	7.33(2.80)	5.76(2.50)
7	6.22(2.59)	6.21(2.59)	6.22(2.59)
8	7.01(2.74)	3.11(1.90)	5.16(2.38)
9	2.57(1.75)	1.21(1.31)	1.89(1.58)
10	1.19(1.30)	0.67(1.08)	0.93(1.19)
11	0.50(1.0)	0.20(0.84)	0.35(0.92)
12	0.33(0.91)	0.11(0.81)	0.22(0.85)
13	0.03(0.73)	0.05(0.74)	0.04(0.73)
14	0.01(0.71)	0.01(0.71)	0.01(0.71)

Figure in parenthesis indicate square root transformed value.

different planted crops (Figure 4.1.1a), for 10 weeks (49th-6th and 3rd-12th standard week) in P_1 and P_2 crops respectively. In P_3 crop it was for 7 weeks (7th-13th standard week) and only 5 weeks (10th-14th standard week) for the P_4 crop.

Initial aphid population was 0.43/leaf, 0.95/leaf, 4.21/leaf and 0.30/leaf on P_1 - P_4 crop, this might be due to ecological pressure that determined the level of population. Higher initial population level on subsequently planted crops might be due to carry over of aphid population from the earlier planted crops, where aphid population had already been built up and migrated to more succulent crop. Similarly peak aphid population (Figure 4.1.1a) was also varied with different time of planting. It was only 0.49/leaf on 50th and 51st standard week to P_1 crop, 5.76/leaf on 6th standard week to P_2 crop, 5.16/leaf on 8th standard week to P_3 crop and only 0.30/leaf on 10th standard week to P_4 crop (Table 4.1.1.1a).

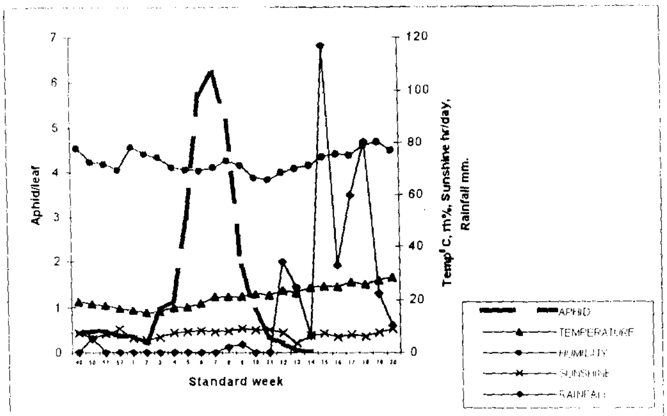


Fig 4.1.1b Seasonal incidence of aphid (*Aphis gossypii* Glov.) population (average) on tomato

It was also observed that higher level of population on tomato plant was observed only for 4-5 weeks after transplanting *i.e.* during the early establishment stage of crop growth. With the increment of age, plant became hardy, less succulent thereby less preferred by aphid, resulted in lower population.

The relative fluctuation of aphid population during the entire crop growing season of the two years studied, revealed that the aphid population was initiated on 49th standard week *i.e.* during early December and moderate population was maintained upto 2nd standard week *i.e.* upto middle of January (Figure 4.1.1b). Higher population was maintained from 3rd-10th standard week *i.e.* during

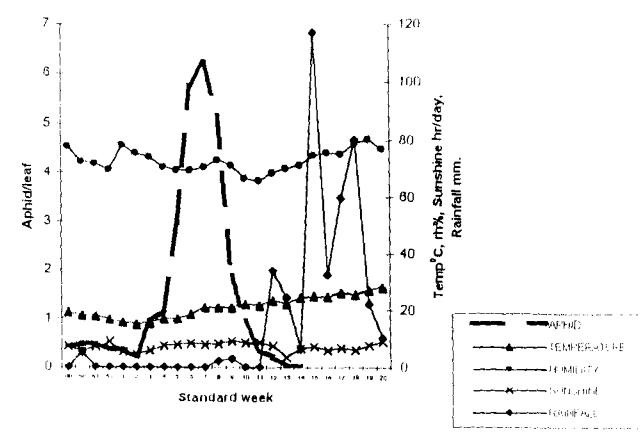


Fig 4.1.1b Seasonal incidence of aphid (*Aphis gossypii* Glov.) population (average) on tomato

middle of January to middle of March and the highest being during 7th standard week *i.e.* 3rd week of February (6.22/leaf). The population declined onward from 11th standard week (Table 4.1.1.1b). The average temperature, r.h., sunshine hr/day during the period of higher incidence were ranged 15.43 to 22.13°C, 69.11 to 73.96%, 5.70 to 8.94 hr/day respectively and the total rainfall was 5.00mm.

Correlation studies between mean aphid population and different weather parameters (Table 4.1.1.8) on crops planted at different time showed that the aphid population had significantly negative correlation with the maximum, minimum and average temperature in all plantings but temperature gradient showed positive and significant correlation in all plantings excepting the P_1. During the period of higher incidence *i.e.* on P_2 and P_3 crops, maximum and average r.h. and r.h. gradient were significantly positive and minimum r.h. had significant negative correlation to the aphid population. While the average r.h. was non-significant and positively correlated to aphid population.

Correlation between aphid population during crop growing season and prevailing weather factors revealed that the population had significant negative correlation to minimum temperature, minimum r.h. and total rainfall. But relation of aphid population with the temperature gradient, r.h. maximum and gradient and sunshine hr/day were significant and positive. The aphid population had negative and non-significant correlation with the maximum and average temperature and average r.h. (Table 4.1.1.10).

4.1.1.2 White fly (*Bemisia tabaci* Gennadius)

It is also a soft-bodied small polyphagous pest. Besides direct damage by desapping leading into devitalization of plant, it also secrete honey dew which fall on leaf and favours development of shooty mould or black fungus *(Caprodium* spp.*)* that interfere with the photosynthetic and respiratory activity of the plants. Moreover, this insect is a potential vector of tomato leaf curl viral disease, which causes huge loss to crop.

Like aphid, mean white fly population was also varied significantly among the different planted crops in both the years. In 1997-98, the populations of mean white fly was at a low level on the P_1 (0.23/plant) and the P_4 (0.04/plant) crop and higher population was observed on P_2 (0.72/plant) and P_3 (0.67/plant) respectively (Table 4.1.1.11). The population was initiated on 49th, 3rd, 7th and 10th standard week and continued for different time and reached the maximum level on 52nd

Table 4.1.1.2a : Incidence and relative abundance of white fly (*Bemisia tabaci* Genn.) population at different time of planting on tomato

Year	Pest Population / Planting	Standard week																					
		49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1997-98	P_1	0.09	0.24	0.35	0.58	0.38	0.27	0.21	0.15	0.17	0.20	0.12	0.01	0.01									
	P_2							0.21	0.61	1.00	1.53	1.84	1.32	0.98	0.76	0.48	0.12	0.03					
	P_3											1.07	1.32	1.20	0.98	0.76	0.33	0.16	0.05	0.02			
	P_4														0.18	0.08	0.01	0.01	0.00	0.00	0.01	0.01	
1998-99	P_1	0.23	0.38	0.33	0.28	0.50	0.27	0.17	0.05	0.09	0.28	0.12	0.05	0.01									
	P_2							0.25	0.09	0.22	1.83	0.84	1.22	1.06	0.88	0.52	0.20	0.11	0.02				
	P_3											0.33	1.06	0.72	0.84	0.50	0.11	0.02	0.01				
	P_4														0.22	0.10	0.05	0.01	0.00	0.00	0.09	0.11	0.02
Mean of two years	P_1	0.16	0.31	0.34	0.43	0.44	0.27	0.19	0.10	0.13	0.24	0.12	0.03	0.01									
	P_2							0.23	0.35	0.61	1.68	1.34	1.27	1.02	0.82	0.50	0.16	0.07	0.01				
	P_3											0.70	1.19	0.96	0.91	0.63	0.22	0.09	0.03	0.01	0.00	0.00	
	P_4														0.20	0.09	0.03	0.01	0.00	0.00	0.05	0.06	0.01

(0.58/plant), 7^{th} (1.84/plant), 8^{th} (1.32/plant) and 10^{th} (0.18/plant) standard week respectively for P_1 to P_4 crops respectively (Table 4.1.1.2a).

From the analysis of relative fluctuation of population of white fly in the entire crop-growing season from December to May, it is revealed that the activity of white fly on tomato was initiated on 49^{th} standard week *i.e.* from 1^{st} week of December and continued till 17^{th} standard week *i.e.* 1^{st} week of May. The population reached at maximum level (1.84/plant) on the 7^{th} standard week *i.e.* 3^{rd} week of February and higher population level was maintained from 5^{th}-10^{th} standard week (Table 4.1.1.2b). During the period of higher level of white fly incidence average temperature, r.h. and sunshine hr/day were ranged from 16.29 to 20.84^{0}C, 61.78 to 71.36%, 6.37 to 9.21 hr/day respectively and the total rainfall was 79.50mm.

During 1998-99, the initiation and duration of activity of white fly on different crops planted at different time followed the similar pattern as found during 1997-98. The population was also lower in P_1 (0.23/plant) and P_4 (0.06/plant) crops (Table 4.1.1.12) with the highest being on 1^{st} (0.50/plant) and 10^{th} (0.22/plant) standard week respectively, while comparatively higher level of white fly population was observed on P_2 (0.57/plant) and P_3 (0.42/plant) crop, with the highest being on 6^{th} (1.83/plant) and 8^{th} (1.06/plant) standard week respectively (Table 4.1.1.2a).

With regard to white fly population fluctuation during the entire crop growing period it is observed that the population was initiated on standard week 49 and continued its activity till 18^{th} standard week. The highest fly population (1.83/plant) was recorded on 6th standard week and a higher population (1.06-1.83/plant) was maintained from 6^{th}-9^{th} standard week *i.e.* from middle of February to 1^{st} week of March (Table 4.1.1.2b) when average temperature, r.h., sunshine hr/day were ranged from 19.95 to 22.64^{0}C, 70.50 to 74.21^{0}C, 7.33 to 9.01 hr/day respectively and no rainfall.

Analysis of pooled mean data of two years of white fly population on tomato crops raised on different time showed that the population level was significantly higher (0.65/plant) on P_2 crop, closely followed by P_3 (0.54/plant) and minimum being observed from P_4 (0.05/plant). (Table 4.1.1.13). The population of fly was initiated at very early stage of crop growth only after 2 weeks of transplanting irrespective of their time of planting, however, infestation was continued for different periods on different crops. It was for about 13 weeks (49^{th}-9^{th} standard week), 12 weeks

Table 4.1.1.2b Seasonal incidence of white fly (*Bemisia tabaci* Genn.) on tomato

Standard Week	Whitefly/plant		
	1997-98	1998-99	Mean
49	0.09(0.77)	0.23(0.85)	0.16(0.81)
50	0.24(0.86)	0.38(0.94)	0.31(0.90)
51	0.35(0.92)	0.33(0.91)	0.34(0.92)
52	0.58(1.04)	0.28(0.88)	0.43(0.96)
1	0.38(0.94)	0.50(1.00)	0.44(0.97)
2	0.27(0.88)	0.27(0.88)	0.27(0.88)
3	0.21(0.84)	0.25(0.87)	0.23(0.85)
4	0.61(1.05)	0.09(0.77)	0.35(0.92)
5	1.00(1.22)	0.22(0.85)	0.61(1.05)
6	1.53(1.42)	1.83(1.53)	1.68(1.47)
7	1.84(1.53)	0.84(1.16)	1.34(1.36)
8	1.32(1.35)	1.22(1.31)	1.27(1.33)
9	1.20(1.30)	1.06(1.25)	1.13(1.28)
10	0.98(1.22)	0.88(1.17)	0.91(1.19)
11	0.76(1.12)	0.52(1.01)	0.63(1.06)
12	0.33(0.91)	0.20(0.84)	0.26(0.87)
13	0.16(0.81)	0.11(0.78)	0.13(0.79)
14	0.05(0.74)	0.02(0.72)	0.03(0.73)
15	0.02(0.72)	0(0.71)	0.01(0.71)
16	0.01(0.71)	0.09(0.77)	0.05(0.74)
17	0.01(0.71)	0.11(0.78)	0.06(0.75)
18	0.00(0.71)	0.02(0.72)	0.01(0.71)

Figure in parenthesis indicate square root transformed value.

(3^{rd} -14^{th} standard week), 9 weeks (7^{th}-15^{th} standard week) and 9 weeks (10^{th}-18^{th} standard week) for P_1, P_2, P_3 and P_4 planted crops respectively (Figure 4.1.2a).

Like aphid, initial white fly population level was 0.16/plant, 0.23/plant, 0.70/plant and 0.20/plant for P_1 to P_4 crops respectively. Difference in higher initial population level with deferred plantings might be due to carry over through local migration of fly from earlier planted crop because of preference of fly population to the more succulent plants. Similarly population reached at highest level at different time on different crops planted at different time (Figure 4.1.2a). It was only 0.44/plant on 1^{st} standard week, 1.68/plant on 6^{th} standard week, 1.19/plant on 8^{th} standard week and 0.20/plant on 10^{th} standard week for P_1, P_2, P_3 and P_4 crops respectively (Table 4.1.1.2a).

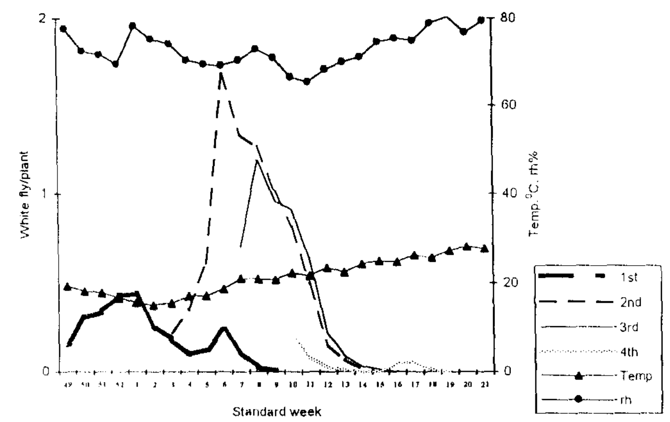


Fig : 4.1.2a Incidence and fluctuation of white fly (*Bemisia tabaci* Genn.) population (average)at different time of planting on tomato

With regard to relative fluctuation of mean white fly population during entire crop growing season for two years studied it was revealed that the white fly population was initiated on the 49^{th} standard week *i.e.* from early December. The population was maintained at a moderate level upto 5^{th} standard week *i.e.* upto first week of February (Figure 4.1.2b). The population reached at the highest level (1.68/plant) on the 6^{th} standard week *i.e.* middle of February and higher level of population was maintained from 6^{th}-10^{th} standard week *i.e.* from middle of February to middle of March and declined gradually thereafter (Table 4.1.1.2b). During the period of higher incidence of this pest the average temperature, r.h. and sunshine hr/day were recorded 17.07-22.13^{0}C, 65.29-72.78%, 7.79-8.94 hr/day respectively and the total rainfall was 5mm.

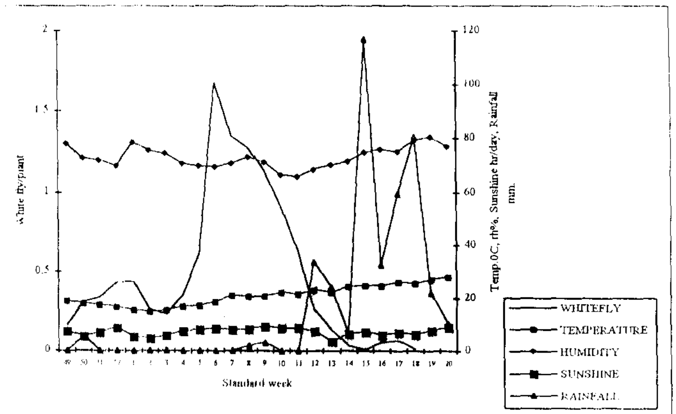


Fig 4.1.2b Seasonal incidence of white fly (*Bemisia tabaci* Genn.) population (average) on tomato

Table 4.1.1.8 Correlation between insect-pests population on tomato crops at different times of planting and prevailing weather conditions

Weather Parameters \ Planting	Aphid				White fly				Leaf miner				Fruit borer				Tingid bug		Hadda beetle	
	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4	P_3	P_4	P_1	P_4
Max. temp. °C	-0.561*	-0.350	-0.681*	-0.521*	-0.723*	-0.152	-0.759*	-0.452	0.776*	0.797*	0.824*	0.724*	0.793*	0.686*	0.792*	0.867*	0.407	0.140	-0.274	0.621*
Min. temp. °C	-0.528*	-0.613*	-0.665*	-0.731*	-0.698*	-0.387	-0.862*	-0.656*	0.762*	0.922*	0.904*	0.918*	0.782*	0.757*	0.811*	0.917*	0.449	-0.123	0.014	0.574*
Temp. grad °C	-0.724*	0.593	0.559*	0.765*	-0.364	0.728*	0.802*	0.695*	0.369	-0.753*	-0.824*	-0.920*	0.046	-0.658*	-0.732*	-0.815*	-0.410	0.234	-0.484	0.466
Ave.. temp °C	-0.527*	-0.439	-0.691*	-0.699*	-0.470	-0.286	-0.857*	-0.615*	0.684*	0.879*	0.908*	0.887*	0.734*	0.745*	0.812	0.933*	0.450	0.023	0.141	0.613*
Max. r.h.%	-0.321	0.666*	0.888*	-0.575*	0.967*	0.586*	0.676*	-0.459	-0.813*	-0.804*	-0.375	0.773*	-0.811*	-0.580*	0.712*	0.898*	-0.711*	-0.145	0.216	0.747*
Min. r.h.%	0.424	-0.570*	-0.440	-0.831*	0.439	-0.329	-0.815*	-0.750*	-0.399	0.837*	0.920*	0.945*	-0.161	0.691*	0.772*	0.811*	0.474	-0.027	0.601*	0.550*
r.h. grad %	-0.586*	0.674*	0.707*	0.856*	-0.561*	0.692*	0.891*	0.794*	-0.038	-0.913*	-0.866*	-0.884*	-0.345	-0.796*	-0.745*	-0.683*	-0.674*	-0.028	-0.474	-0.562*
Ave. r.h.%	0.135	0.021	0.018	-0.769*	0.474	-0.157	-0.412	-0.681*	-0.626*	-0.047	0.434	0.951*	-0.609*	0.355	0.798*	0.859*	-0.031	-0.059	0.493	0.629*

* Significant

Studies on correlation between level of white fly population on crops of different time and important weather parameters (Table 4.1.1.8) revealed that the population was significant and negatively correlated with the maximum and minimum temperature and r.h. gradient but significant and positively correlated with maximum r.h., however, average temperature and temperature gradient was non significant and negatively correlated while non-significant and positive correlation was found with the minimum and average r.h. on P_1 crop. In P_2 crop, temperature and r.h. gradient and maximum r.h. were significant and positively correlated with white fly population but maximum, minimum and average temperature and average r.h. had non-significant negative correlation. On P_3 crop, the population had significantly negative correlation with maximum, minimum and average temperature and minimum r.h. but had a significant positive correlation with temperature and r.h. gradient and maximum r.h.. Average r.h. had non-significant and negative correlation. While in P_4 crop, the population remained significant and negatively correlated with minimum and average temperature and r.h. respectively, but had a positive correlation with temperature and r.h. gradient. But maximum temperature and r.h. respectively had non-significant and negative correlation with white fly population.

Correlation studies between white fly population during entire crop growing season and important weather parameters showed that the population had non significant and negative correlation with maximum and average temperature, but minimum temperature, minimum and average r.h. and total rainfall showed negative and significant correlation with white fly population. The population was found significant and positively correlated with temperature and r.h. gradient and sunshine hr/day, while maximum r.h. had non significant and positive correlation (Table 4.1.1.10).

4.1.1.3 Leaf miner *(Liriomyza trifolii* Burgess)

Adult leaf miner fly damages the leaves to feed or to lay the eggs and the larvae tunnel within the leaf, make characteristic serpentine mine and reduces photosynthetic activity of the plants. Leaf miner infestation varied significantly over four different planted crops in both the years.

During 1997-98 leaf miner appeared at the early stage of crop growth on P_1 crop (50^{th} standard week) and remained active only for a period of three weeks with a very low level of infestation (0.01-1.25% mined leaves). But after a lapse of five weeks (1-5^{th} standard week) it reappeared with

Table 4.1.1.3a : Incidence and relative abundance of leaf miner (*Liriomyza trifolii* Burgess) infestation at different times of planting on tomato

Year	Pest Population / Planting	Standard week																								
		49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1997-98	P_1	0.00	0.01	1.25	0.76	0.00	0.00	0.00	0.00	0.00	2.21	5.23	7.67	10.37	15.22	20.67										
	P_2									1.34	7.34	6.67	18.94	33.67	30.25	48.60	60.92	72.01	82.30	88.51						
	P_3											2.22	15.23	45.68	46.51	48.37	50.36	71.68	75.21	81.67	85.24	88.23				
	P_4														15.33	28.82	47.33	58.67	68.20	71.98	76.37	84.23	89.67	93.98		
1998-99	P_1	0.00	0.61	0.27	0.00	0.00	0.00	0.00	0.00	0.00	1.33	4.55	9.49	15.49	16.19	28.00										
	P_2									0.00	1.00	7.19	10.86	30.39	38.85	66.70	88.22	89.67	90.00	95.33						
	P_3											0.00	1.11	11.92	39.89	41.23	35.00	45.00	68.11	78.75	82.00	86.33				
	P_4														12.91	25.00	10.92	25.00	60.29	57.23	68.25	70.00	77.09	80.00	82.50	86.00
Mean of two years	P_1	0.00	0.31	0.76	0.38	0.00	0.00	0.00	0.00	0.00	1.77	4.89	8.58	12.93	15.71	24.34										
	P_2									0.67	4.17	6.93	14.90	32.05	34.55	57.65	74.57	80.84	86.15	91.92						
	P_3											1.11	8.17	28.80	43.20	44.80	42.68	58.34	71.66	80.21	83.62	87.28				
	P_4														14.12	26.19	23.13	46.84	62.74	66.11	72.31	77.12	83.38	86.99		

Table 4.1.1.3a : Incidence and relative abundance of leaf miner (*Liriomyza trifolii* Burgess) infestation at different times of planting on tomato

Year	Pest Population / Planting	Standard week																								
		49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1997-98	P1	0.00	0.01	1.25	0.76	0.00	0.00	0.00	0.00	0.00	2.21	5.23	7.67	10.37	15.22	20.67										
	P2									1.34	7.34	6.67	[illegible]	[illegible]	[illegible]	48.60	60.92	72.01	82.30	88.51						
	P3											2.22	15.23	45.68	46.51	48.37	50.36	71.68	75.21	81.67	85.24	88.23				
	P4														15.33	28.82	47.33	58.67	68.20	71.98	76.37	84.23	89.67	93.98		
1998-99	P1	0.00	0.61	0.27	0.00	0.00	0.00	0.00	0.00	0.00	1.33	4.55	9.49	15.49	16.19	28.00										
	P2									0.00	1.00	7.19	10.86	30.39	38.85	66.70	88.22	89.67	90.00	95.33						
	P3											0.00	1.11	11.92	39.89	41.23	35.00	45.00	68.11	78.75	82.00	86.33				
	P4														12.91	25.00	10.92	25.00	60.29	57.23	68.25	70.00	77.09	80.00	82.50	86.00
Mean of two years	P1	0.00	0.31	0.76	0.38	0.00	0.00	0.00	0.00	0.00	1.77	4.89	8.58	12.93	15.71	24.34										
	P2									0.67	4.17	6.93	14.90	32.05	34.55	57.65	74.57	80.84	86.15	91.92						
	P3											1.11	8.17	28.80	43.20	44.80	42.68	58.34	71.66	80.21	83.62	87.28				
	P4														14.12	26.19	23.13	46.84	62.74	66.11	72.31	77.12	83.38	86.99		

Table 4.1.1.3b Seasonal incidence of leaf miner (*Liriomyza trifolii* Burgess) infestation on tomato (in %)

Standard Week	Mined leaf %		
	1997-98	1998-99	Mean
49	0.00(0.71)	0.00(0.71)	0.00(0.71)
50	0.01(0.71)	0.61(1.05)	0.31(0.90)
51	1.25(1.32)	0.27(0.88)	0.76(1.12)
52	0.76(1.12)	0.00(0.71)	0.38(0.94)
1	0.00(0.71)	0.00(0.71)	0.00(0.71)
2	0.00(0.71)	0.00(0.71)	0.00(0.71)
3	0.00(0.71)	0.00(0.71)	0.00(0.71)
4	0.00(0.71)	0.00(0.71)	0.00(0.71)
5	1.34(1.36)	0.00(0.71)	0.67(1.08)
6	7.34(2.80)	1.33(1.35)	4.35(2.20)
7	6.67(2.68)	7.19(2.77)	6.93(2.72)
8	18.94(4.41)	10.68(3.34)	14.90(3.92)
9	45.68(6.80)	30.39(5.56)	38.04(6.21)
10	46.51(6.86)	38.89(6.27)	42.68(6.57)
11	48.37(6.99)	66.70(8.20)	57.54(7.62)
12	60.92(7.84)	88.22(9.42)	74.57(8.66)
13	72.01(8.52)	89.67(9.50)	80.84(9.02)
14	82.30(9.10)	90.00(9.51)	86.15(9.31)
15	88.51(9.43)	95.33(9.79)	91.92(9.61)
16	85.24(9.26)	82.00(9.08)	83.62(9.17)
17	88.23(9.42)	86.33(9.32)	87.28(9.37)
18	89.67(9.50)	77.09(8.81)	83.38(9.16)
19	93.98(9.72)	80.00(8.97)	86.99(9.35)
20		82.50(9.11)	
21		86.00(9.30)	

Figure in parenthesis indicate square root transformed value.

With regard to infestation level althrough the season the infestation pattern was similar to that of previous year but the total period of incidence was longer in 1998-99 and continued till 21st standard week (Table 4.1.1.3b). The average temperature, r.h. and sunshine hr/ were ranged from 22.45 to 28.86°C, 63.57 to 81.64%, 4.14 to 8.48 hr/days respectively and the total rainfall was 594.70mm during the higher period of leaf miner incidence (11th – 21st standard week).

Analysis of pooled data for two years of leaf miner infestation revealed that P_1 crop always recorded lower leaf damage, the maximum being 24.34% on the 11th standard ssweek (Figure 4.1.3a). Among the four plantings the highest level of infestation (91.92%) was recorded in P_2 crop on 15th standard week but the percentage of leaf miner infestation was consistently in higher proportion in P_3 and P_4 crops, where the maximum value was 87.28% in the 17th standard week and 86.99% in the 19th standard week respectively (Table 4.1.1.3a). The mean leaf miner incidence was found significantly lower on P_1 crop (3.28%) and the highest being on P_4 crop (51.27%), closely followed by 43.63% on P_3 crop. The P_2 crop witnessed 27.24% leaf miner infestation (Table 4.1.1.13).

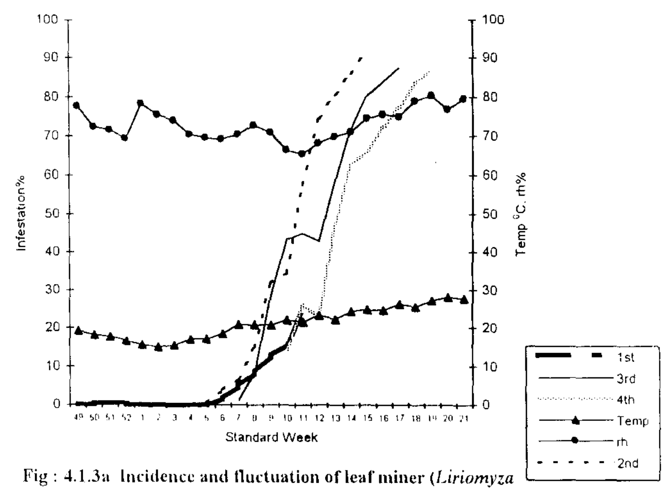


Fig : 4.1.3a Incidence and fluctuation of leaf miner (*Liriomyza trifolii* Burgess) infestation (average) at different time of planting on tomato

The overall observation revealed that the infestation of leaf miner was initiated during mid December for a short spell of three weeks and after a gap of 5 weeks, the activity was continued from 5th-19th standard week. With the advancement of season the intensity of infestation also increased and recorded the highest level of 91.92% on 15th standard week (Figure 4.1.3b). High level of infestation persisted from 11th to 19th standard week (Table

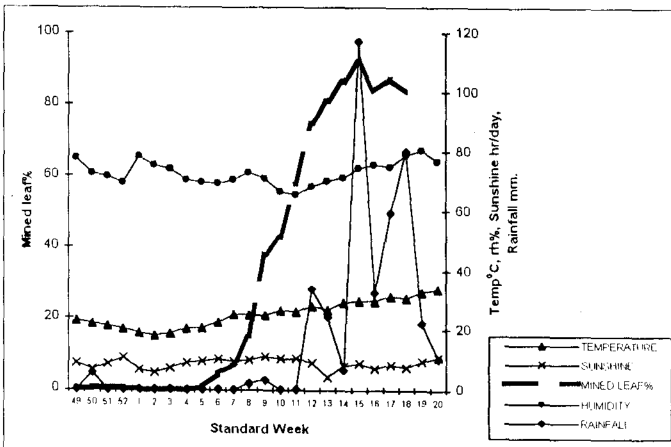
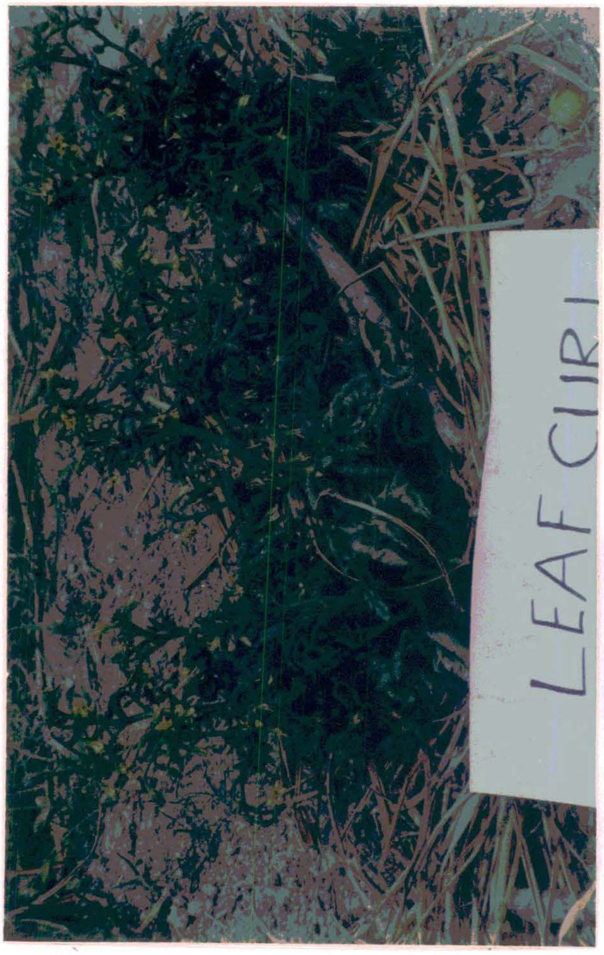


Fig 4.1.3b Seasonal Incidence of Leaf miner (*Liriomyza trifolii* Burgess) in respect of mined leaf% (average) on tomato

Photograph showing fruit borer feed on fruit

Photograph showing mined leaf in tomato plant



Photograph showing leaf curl diseased plant

Photograph showing group of hadda beetle and its damage symptoms on tomato leaf

4.1.1.3b) *i.e.* from late March to late May at the average temperature 21.60-27.23°C, average r.h. 65.39-80.25%, average sunshine hr/day, 3.39-8.49 hr/day and total rainfall of 375.30mm.

In case of all the plantings, the leaf miner infestation showed significantly positive correlation with the maximum, minimum and average temperature but temperature gradient showed a negative significant correlation (Table 4.1.1.8). In P_1 crop the maximum and average r.h. had a significant negative correlation but r.h. minimum and gradient was non-significant and negatively correlated with leaf miner infestation. In case of P_2 crop r.h. maximum and gradient showed negative and significant correlation, while r.h. minimum had a significant positive correlation with leaf miner incidence. The P_4 crop showed significant positive and negative leaf miner infestation with r.h. minimum and its gradient respectively but had non-significant positive and negative correlation with r.h. maximum and average respectively. But in P_4 crop, maximum, minimum and average r.h. was significant and positively correlated, while r.h. gradient had negative and significant correlation with leaf miner infestation.

With regard to leaf miner infestation in the entire crop growing season *i.e.* December-May, significant and positive correlation was obtained with maximum, minimum and average temperature, minimum r.h. and total rainfall while temperature gradient, r.h. maximum and gradient had significant and negative correlation with leaf miner infestation. The infestation was found non-significant and positive to average r.h. but was non-significantly negative to average sunshine hr/day (Table 4.1.1.10).

4.1.1.4 Fruit borer *(Helicoverpa armigera* Hubner)

Fruit borer (*Helicoverpa armigera*) is a cosmopolitan, polyphagous pest. It is a key pest of tomato causing huge quantity of fruit damage that can not be replenished by any means, since it attacks the cashable part of tomato.

In terai region, infestation by fruit borer causes much loss to tomato. The magnitude of damage varied with the time of planting as well as with the years of investigation. However, damage was restricted to about 8 to 9 weeks and only during the fruiting stage of the crop. During 1997-98, the infestation was initiated on the 7th standard week on P_1 crop and continued upto 13th standard week with a maximum damage of 12.33% on the 12th standard week. In case of P_2 crop the initiation of infestation occurred on 11th standard week and continued till 19th standard week with the highest population of 23.90% on 15th standard week. In P_3 crop the population was

Table 4.1.1.4a : Incidence and relative abundance of fruit borer (*Helicoverpa armigera* Hubner) as per cent bored fruit at different time of planting on tomato (% in number)

Year	Planting \ Pest population	Standard week																
		6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1997-98	P_1		5.50	7.23	8.22	9.87	10.67	12.33	11.50									
	P_2						10.68	9.86	11.13	9.51	23.9[illegible]	16.36	10.11	10.21	7.13			
	P_3								6.25	12.00	20.00	12.68	16.33	10.34	9.51	8.21		
	P_4										14.26	9.48	8.77	9.29	15.40	25.01		
1998-99	P_1	1.21	3.86	7.71	4.33	9.93	15.98	14.22	10.84	8.53								
	P_2						7.98	10.54	8.39	13.77	12.00	20.00	15.89	10.65	6.67			
	P_3								8.33	14.28	20.00	12.00	10.63	9.50	7.77	6.23		
	P_4										5.00	7.14	11.11	9.99	14.50	13.83	13.50	26.09
Mean of two years	P_1	0.61	4.68	7.47	6.28	9.89	13.32	13.28	11.17	4.27								
	P_2						9.33	10.20	9.76	11.64	17.95	18.18	13.00	10.43	6.90			
	P_3								7.29	13.14	20.00	12.34	13.48	9.92	8.64	7.22		
	P_4										9.68	8.31	9.94	9.64	14.95	19.42		

noticed on 13th standard week and reached at the maximum level 20.00% on 15th standard week and continued upto 20th standard week, whereas, in P_4 crop fruit boring started from 15th standard week and with gradual increase infestation level reached at a maximum of 25.01% on the 20th standard week (Table 4.1.1.4a). The mean infestation level was significantly highest in P_4 crop (13.70%) and significantly lowest on P_1 crop (8.16%). The P_2 and P_3 crop witnessed 10.74% and 11.91% attack respectively (Table 4.1.1.11).

Considering the entire season, fruit borer incidence was initiated on 7th standard week and continues upto 20th standard week. Highest level of infestation was recorded on 20th standard week (25.01%) (Table 4.1.1.4b). In general the fluctuation of borer infestation followed no definite pattern rather it was inconsistent. However, high level of infestation was recorded from 15th to 20th standard week, when average temperature was 22.10 to 29.87°C, average r.h. was 74.93 to 83.43%, sunshine hr/day was 3.13 to 9.98 hr/day and total rainfall was 258.50mm.

During 1998-99, the pattern of fruit borer infestation followed the trend similar to that of 1997-98. However, the duration of infestation was longer and degree of infestation was also lower (Table 4.1.1.4a). Mean infestation level was also significantly higher on P_4 crop (12.68%) followed by P_3 (12.09%) and P_2 (11.27%) crops respectively. The P_1 crop had recorded 8.51% bored fruit in number (Table 4.1.1.12).

With regard to the pattern of incidence during the entire crop growing season, the total duration of fruit borer infestation was recorded longer than previous year, started from 6th and persisted till 22nd standard week and the highest infestation (26.09%) was observed on the 22nd standard week (Table 4.1.1.4b). In this year too fluctuation of fruit borer infestation followed no definite pattern, rather it was inconsistent. From the over all observation, it can be said that higher level of fruit borer incidence was maintained from 11th to 22nd standard week when average temperature, r.h. and sunshine hr/day were 22.45 to 27.58°C, 63.57 to 81.64%, 2.71 to 8.48 hr/day and the total rainfall was 660.10mm respectively.

The pooled mean data of two years on fruit borer incidence revealed that the borer infestation was initiated on 6th, 11th, 13th and 15th standard week in P_1 to P_4 crops respectively. The percentage of fruit damaged (in number) was found significantly lowest (8.34%) on P_1 crop. With gradual increase fruit damages reached at the highest level (13.19%) in

Table 4.1.1.4b Seasonal incidence of fruit borer (*Helicoverpa armigera* Hb.) on tomato (% in number)

Standard Week	Bored fruit %		
	1997-98	1998-99	Mean
6		1.21(1.31)	0.61(1.05)
7	5.50(2.45)	3.86(2.09)	4.68(2.27)
8	7.23(2.78)	7.71(2.86)	7.47(2.82)
9	8.22(2.96)	4.33(2.20)	6.28(2.60)
10	9.85(3.21)	9.93(3.23)	9.89(3.22)
11	10.67(3.34)	15.98(4.06)	13.32(3.72)
12	12.33(3.58)	14.22(3.84)	13.28(3.71)
13	11.50(3.46)	10.84(3.37)	11.17(3.42)
14	12.00(3.54)	14.28(3.84)	13.14(3.69)
15	23.90(4.40)	20.00(4.53)	21.95(4.74)
16	16.36(4.11)	20.00(4.53)	18.18(4.32)
17	16.33(4.10)	15.89(4.05)	16.11(4.08)
18	10.34(3.29)	10.65(3.34)	10.49(3.31)
19	15.40(3.99)	14.50(3.87)	14.95(3.93)
20	25.01(5.05)	13.83(3.78)	19.42(4.46)
21		13.50(3.74)	
22		26.09(5.16)	

Figure in parenthesis indicate square root transformed value.

P_4 crop. While in P_2 and P_3 crop 11.00% and 12.00% damaged fruit in number was recorded. (Table 4.1.1.13). Period of borer infestation was longer in P_1 and P_2 crops than in the P_3 and the least being in P_4 crop (Figure 4.1.4a). The duration of borer infestation was related to fruiting stage of the crop. The crop duration vis-à-vis fruiting stage was longer in earlier planting resulted maximum period of incidence. With the advancement of seasons, temperature was raised and fruiting period was shortened, which ultimately resulted shorter period of fruit borer infestation *i.e.* only for 6 weeks in P_4 crop. Fruit borer incidence was consistently higher on P_2 crop (6.90-18.18%). The incidence of fruit borer infestation was highest on 11th standard week (13.32%), 16th standard week (18.18%), 15th standard week (20.00%) and 20th standard week (19.42%) respectively from P_1 to P_4 crops (Table 4.1.1.4a).

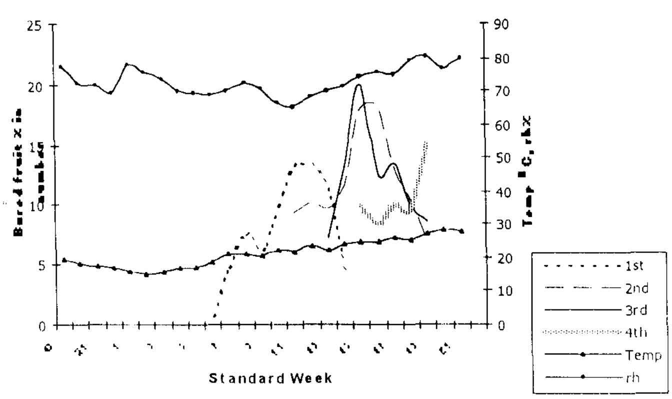


Fig : 4.1.4a Incidence and fluctuation of fruit borer (*Helicoverpa armigera* Hb.)(average) at different time of planting on tomato

Similar trend was also observed as in case of damaged fruit in respect of weight. Here also that P_1 crop had significantly lowest attack (8.04%) over other crops and the minimum being 12.50% in P_4 crop followed by 11.49% and 10.28% in P_3 and P_2 crops respectively. (Table 4.1.1.11-4.1.1.13).

With regard to mean fruit borer infestation during the entire crop growing season it is observed that fruit borer infestation was initiated on 6th standard week and continued upto 20th standard week. The fluctuation of fruit borer infestation followed no definite pattern. It was comparatively lower (below 10%) at the early part of the season but with the advancement of season infestation increased (Figure 4.1.4b). Higher level of infestation was observed from 11th to 20th standard week (11.17-19.42%) *i.e.* during March to May (Table 4.1.1.4b). During this period average temperature, r.h. and sunshine hr/day

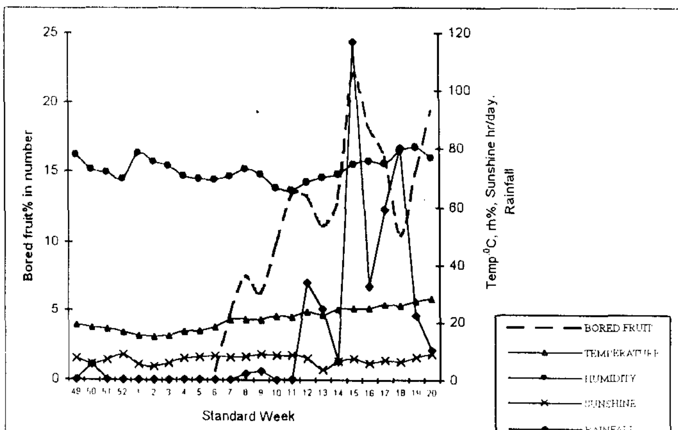


Fig-4.1.4b Seasonal incidence of fruit borer(*Helicoverpa armigera* Hubner) (average) of tomato were ranged from 21.60 to 28.13^{0}C, 65.39 to 80.25%, 3.39 to 8.77 hr/day respectively and the total rainfall was 385.45mm.

Studies of correlation between important weather parameters and borer infestation on crops planted at different time (Table 4.1.1.8), it is observed that temperature maximum, minimum, and average were significant and positively correlated with borer attack but temperature gradient showed a significant negative correlation with borer infestation in all the plantings. In P_1 crop r.h. maximum and average was significantly negative but r.h. minimum and gradient was non-significant and negatively correlated with fruit borer infestation. In P_2 crop r.h. maximum and gradient had significant and negative correlation but maximum and average r.h. had positive correlation. During higher infestation period *i.e.* P_3 and P_4 crops, r.h. maximum, minimum and average showed a significant positive correlation but r.h. gradient was significant and negatively correlated with borer infestation.

Correlation of overall borer infestation with climatic parameters althrough the crop growing season, showed that the population had a significant positive correlation with maximum, minimum and average temperature, minimum r.h. and total rainfall, while temperature gradient, r.h. maximum and gradient showed negative and significant correlation. Average r.h. and sunshine hr/day were found to be non-significant and positively correlated with borer infestation (Table 4.1.1.10).

4.1.1.5. Tingid bug *(Urentius hystricellus* Richter)

Although, tingid bug is a major pest of brinjal but it attacked tomato plants too only on late-planted crops, however population was always recorded low.

During 1997-98 P_3 and P_4 crop, the bug population was initiated on 11th and 10th standard week respectively. The mean tingid bug population was found significantly higher 1.14/leaf in P_4 crop than the P_3 crop one with 1.01 bug/leaf (Table 4.1.1.11). The highest bug population was recorded on 13th standard week (2.67/leaf) in P_3 crop but on P_4 crop on 15th standard week (2.78/leaf) (Table 4.1.1.5a).

With regard to the pattern of incidence of tingid bug population over the entire tomato growing season *i.e.* from 10th-19th standard week (Table 4.1.1.5b), maximum level of population was recorded from 12th-15th standard week, the highest number was 2.78/leaf on 15th standard week.

Table 4.1.1.5a : Incidence and relative occurrence of tingid bug (*Urentius hystricellus* Richter) population at different times of planting on tomato

Year	Pest Population / Planting	Standard Week											
		10	11	12	13	14	15	16	17	18	19	20	21
1997-98	P_3		1.00	2.33	2.67	2.00	1.67	0.84	0.55				
	P_4	0.56	0.84	0.98	1.02	2.28	2.78	1.78	0.64	0.44	0.11		
1998-99	P_3		0.50	1.83	1.15	2.33	1.22	0.67	0.55				
	P_4	0.33	0.75	0.83	0.89	1.50	2.60	1.08	0.78	0.67	0.37	0.16	0.01
Mean of two years	P_3		0.75	2.08	1.91	2.16	1.45	0.76	0.55				
	P_4	0.44	0.80	0.91	0.95	1.89	2.69	1.43	0.71	0.56	0.24		

Table 4.1.1.5b Seasonal incidence of tingid bug (*Urentius hystricellus* Richter) on tomato

Standard Week	Tingid bug /leaf		
	1997-98	1998-99	Mean
10	0.56(1.03)	0.33(0.91)	0.44(0.97)
11	1.00(1.22)	0.75(1.12)	0.87(1.17)
12	2.33(1.68)	1.83(1.15)	2.08(1.61)
13	2.67(1.78)	1.15(1.28)	1.91(1.55)
14	2.28(1.67)	2.33(1.68)	2.31(1.68)
15	2.78(1.81)	2.60(1.76)	2.69(1.79)
16	1.78(1.51)	1.08(1.26)	1.43(1.39)
17	0.64(1.07)	0.78(1.13)	0.71(1.10)
18	0.44(0.97)	0.67(1.08)	0.56(1.03)
19	0.01(0.71)	0.37(0.93)	0.24(0.86)
20		0.16(0.81)	
21		0.01(0.71)	

Figure in parenthesis indicate square root transformed value.

During the period of maximum incidence, the important weather parameters were as followed; average temperature 20.74-26.06^{0}C, r.h. 67.21-83.43%, sunshine hour/day 3.13-8.53 hr/day and the total rainfall was 299.40mm.

During 1998-99, highest tingid bug population was found 2.33/leaf on 14th standard week and 2.60/leaf on 15th standard week on P_3 and P_4 crop (Table 4.1.1.5a), with mean 0.70/leaf and 0.85/leaf bug population respectively (Table 4.1.1.12), while the population was appeared on 11th and 10th standard week in P_3 and P_4 crops.

The population was appeared only on later part of the crop growing season *i.e.* from 10th standard week and was most active (2.60 bug/leaf) on 15th standard week (Table 4.1.1.5b). However, higher population level was maintained from 12th to 17th standard week when average temperature, average r.h. and sunshine hr/day ranged from 22.45 to 28.86^{0}C, 63.57 to 74.28%, 2.71 to 8.48 hr/day respectively and the total rainfall was 176.70mm.

Mean data of two years revealed that (Figure 4.1.5a) the population was totally absent in 1st two crops. On P_3 and P_4 crop the highest population being found on 14th standard week (2.16/leaf) and on 15th standard week (2.19/leaf) respectively (Table 4.1.1.5a). The P_4 crop had significantly more number of mean tingid bug (1.00/leaf) followed by (0.86/leaf) in P_3 crop (Table 4.1.1.15).

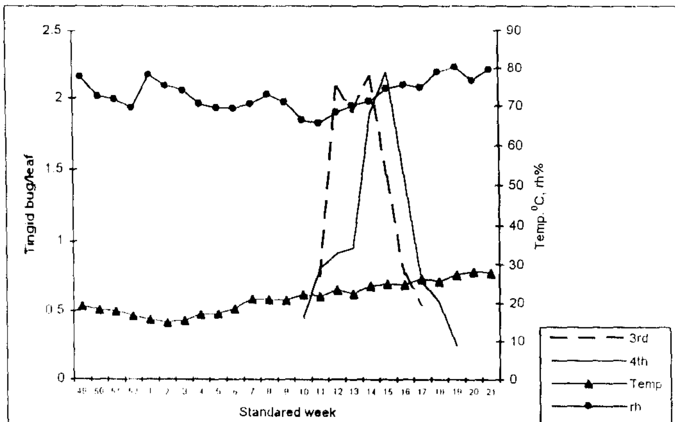


Fig : 4.1.5a Incidence and fluctuation of tingid bug (*Urentius hystricellus* Richt.) population (average)at different time of planting on tomato

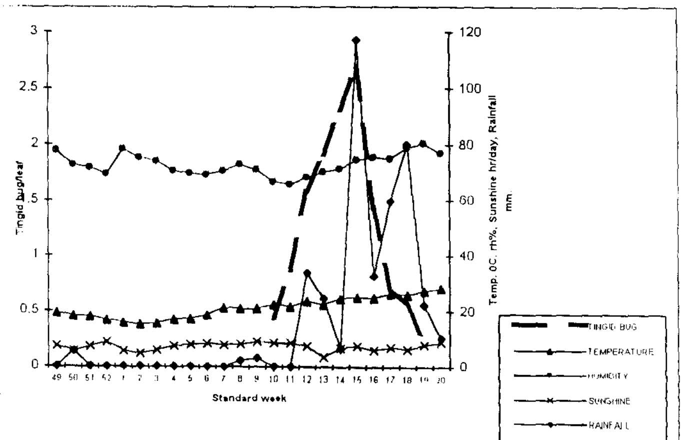


Fig 4.1.5b seasonal incidence of tingid bug (*Urentius hystricellus* Richter) population (average) on tomato

An analysis of mean tingid bug population for the entire crop growing season showed that a high population was maintained from 12th to 17th standard week *i.e.* during March-April (Figure 4.1.5b). During this period the average temperature, r.h. and sunshine hr/day ranged from 21.60 to 26.19^{0}C, 65.39

to 75.43%, 3.39 to 8.49 hr/day respectively and the total rainfall was 273.15mm. Peak population was recorded 2.69/leaf on 15th standard week *i.e.* early April (Table 4.1.1.5b).

A correlation between weather parameters and tingid bug population on different crops revealed that (Table 4.1.1.8) for P_3 crop the relation was significantly negative with maximum r.h. and r.h. gradient but with the temperature gradient and average r.h. the relation were non-significant and negative. Whereas, maximum, minimum and average temperature and minimum r.h. showed non-significant and positive correlation with tingid bug population. In case of P_4 crop the population was non-significant and positively correlated with maximum and average temperature and temperature gradient but had a non-significant negative correlation with maximum, minimum, average r.h. and r.h. gradient and minimum temperature.

Furthermore the relation between tingid bug population with prevailing weather conditions during the entire crop growing season revealed that the population was found significantly positive with maximum, minimum and average temperature and total rainfall, while maximum r.h. and r.h. gradient showed a significant negative correlation. The population had a negative and non-significant correlation with temperature gradient , average r.h. and sunshine hr/day (Table 4.1.1.10).

4.1.1.6 Hadda beetle (*Henosepilachna vigintioctopuctata* Fabr.)

Hadda beetle or Epilachna beetle is an important polyphagous pest. Its activity on tomato was recorded only on the late season crop.

During 1997-98 hadda beetle population was recorded only on P_4 crop and the mean population was 0.27/plant (Table 4.1.1.11). Its incidence was initiated on 14th standard week and remained active till 17th standard week, highest being (1.05/plant) on 15th standard week (Table 4.1.1.6a and 6b). During the period of its activity the important weather parameters were recorded, 22.10-26.48^{0}C average temperature, 72.07-83.43% average r.h., 3.13-8.53 hr/day average sunshine and 222.40mm total rainfall.

During 1998-99 the incidence was recorded on P_1 and P_4 planted crop. The P_1 and P_4 crop witnessed mean population attack of 0.69 beetle/plant and 1.28 beetle/plant respectively (Table 4.1.1.12). In P_1 crop the population was maintained only for a short period, during early part of the season, highest being on 49th standard week (3.00/plant). While on P_4 crop the population level was observed during later part of the season. The

Table 4.1.1.6a : Incidence and relative abundance of hadda beetle (*Henosepilachna vigintioctopunctata* Fabr.) population at different times of planting on tomato

Year	Pest Population / Planting	Standard week													
		49	50	51	52	1	2	14	15	16	17	18	19	20	21
1997-98	P_4							0.33	1.05	0.67	0.52	0.10	0.01		
1998-99	P_1	3.00	2.08	1.78	1.00	0.77	0.29								
	P_4							0.28	4.73	2.00	3.00	2.83	1.40	0.84	0.33
Mean of two years	P_1	1.50	1.04	0.89	0.50	0.38	0.14								
	P_4							0.31	2.89	1.33	1.76	1.48	0.75		

Table 4.1.1.6b Seasonal incidence of hadda beetle (*Henosepilachna vigintioctopunctata* Fabr.) on tomato

Standard Week	Hadda beetle/plant		
	1997-98	1998-99	Mean
49		3.00(1.87)	1.50(1.41)
50		2.08(1.61)	1.04(1.20)
51		1.78(1.51)	0.89(1.18)
52		1.00(1.22)	0.50(1.00)
1		0.77(1.13)	0.38(0.94)
2		0.29(0.89)	0.14(0.80)
14	0.33(0.91)	0.28(0.88)	0.14(0.80)
15	1.05(1.24)	4.73(2.29)	2.89(1.84)
16	0.67(1.08)	2.00(1.50)	1.33(1.35)
17	0.52(1.01)	3.00(1.87)	1.76(1.50)
18	0.10(0.77)	2.83(1.82)	1.47(1.40)
19	0.00(0.71)	1.40(1.38)	0.75(1.12)
20		0.84(1.16)	
21		0.33(0.91)	

Figure in parenthesis indicate square root transformed value.

pest appeared in 14^{th} standard week (0.28/plant) and on the next week the population (4.73/plant) reached at the maximum level (Table 4.1.1.6a).

With regard to the entire crop-growing season, the pest was recorded for a short period at the early part of the season. After a gap of about three months the pest reappeared to tomato plant on 14^{th} standard week and reached at maximum level (4.73/plant) in the next week. High population level was maintained till 19^{th} standard week and declined thereon (Table 4.1.1.6b).

An analysis of pooled mean data for two years revealed that only P_1 and P_4 crops witnessed mean hadda beetle incidence of (0.34/plant and 0.77/plant respectively) where the highest population was 1.50/plant on 49^{th} standard week on P_1 crop (Figure 4.1.6a) and 2.89/plant on 15^{th} standard week on 4^{th} or P_4 crop (Table 4.1.1.6a).

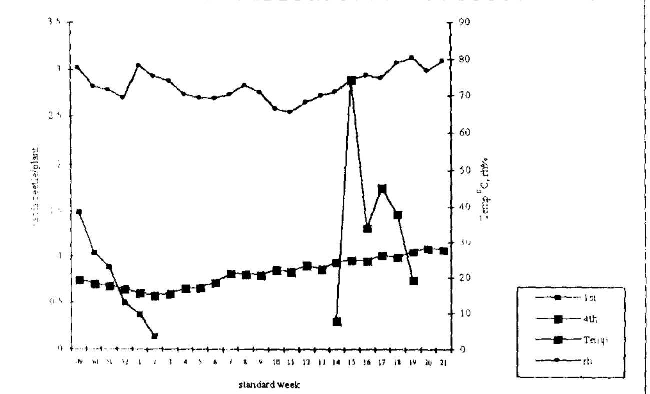


Fig 4.1.6a Incidence and fluctuation of hadda beetle (*Henosepilachna vigintiopunctata* Fabr.) population (average) at different time of planting on tomato

Considering overall activity of hadda beetle on tomato crop during the total crop growing season (Table 4.1.1.6b) it is observed that the population was present only for few weeks during early part of the season *i.e.* from 49^{th} to 2^{nd} standard week (Figure 4.1.6b). Higher population was maintained from 15^{th} to 18^{th} standard week *i.e.* from April to May, with maximum being 2.89/plant in 15^{th} standard week, when average temperature, r.h. and sunshine hr/day were ranged from 14.97 to 19.14^{0}C, 69.29 to 78.17%, 4.54 to 8.67 hr/day and the total rainfall was 5.30mm respectively.

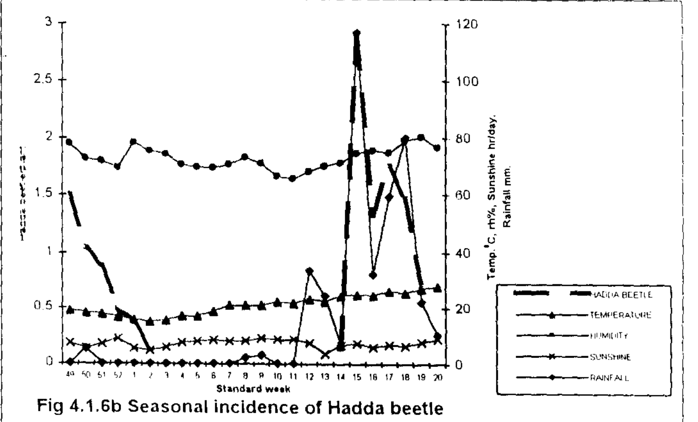


Fig 4.1.6b Seasonal incidence of Hadda beetle (*Henosepilachna vigintioctopunctata* Fabr.) population (average) on tomato

Studies on correlation between hadda beetle population on different crops and the prevailing weather parameters, it is observed that in P_1 crop population was non-significant and remained negatively correlated with maximum temperature and temperature and r.h. gradient, while minimum and average temperature and maximum and average r.h., were positive and non-significantly correlated and minimum r.h. had a significant positive correlation (Table 4.1.1.8). In case of P_4 crop, population was positive and significantly correlated with maximum, minimum and average temperature and r.h. respectively. r.h. gradient had a significant negative correlation but temperature gradient had positive and non-significant relation to hadda beetle population.

When the total crop growing season was taken into account hadda beetle population was significant and positively correlated with maximum, minimum and average temperature and minimum and average r.h. and total rainfall. Temperature and r.h. gradient were negative and significantly correlated with hadda beetle population, while maximum r.h. and sunshine hr/day had a non-significant negative correlation (Table 4.1.1.10).

4.1.1.7 Natural enemies

Natural enemies, *viz*, various parasites, predators, spiders, pathogens play important role in natural suppression of pest population. Their abundance was not only depends on prevailing weather conditions but also availability and size of pest (prey/host) population in the crop ecosystem. Under present investigation population of different predators which were more during the crop growing period was recorded with an objective to get an idea about their activity to formulate future pest management strategy considering their role and activity. The incidence of *Menochilus sexmaculata., Coccinella septempunctata* and different species of spiders, which were relatively more dominant natural enemies in this area.

4.1.1.7a *Menochilus sexmaculata*

The activity and population of *M. sexmaculata.* was dependent on prevailing weather condition as well as size of pest population. Since the populations of prey-pest species namely aphid and white fly were comparatively lower in both the years studied, population of *M. sexmaculata* was also very low.

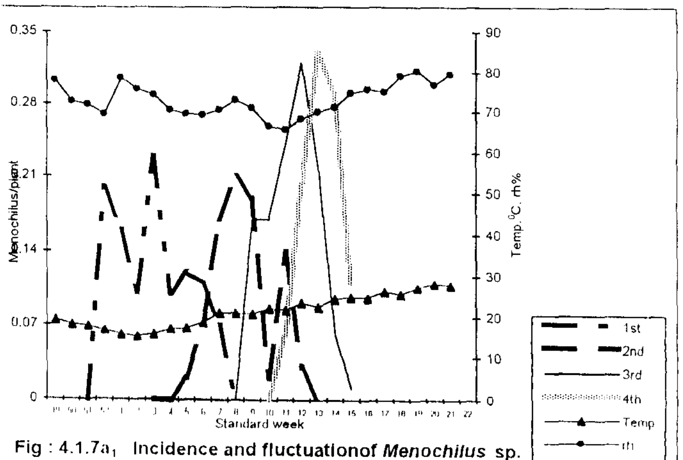


Fig : 4.1.7a$_1$ Incidence and fluctuationof *Menochilus* sp. population (average)at different time of planting on tomato

Table 4.1.1.7a1 : Incidence and relative abundance of *Menochilus sexmaculata* population at different times of planting on tomato

Year	Planting \ Pest population	Standard week																
		51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1997-98	P_1		0.22	0.19	0.20	0.28	0.18	0.12	0.09	0.05	0.00							
	P_2							0.05	0.10	0.20	0.15	0.21	0.00	0.15	0.02			
	P_3											0.25	0.23	0.20	0.30	0.25	0.02	
	P_4												0.00	0.12	0.22	0.44	0.33	0.09
1998-99	P_1	0.01	0.17	0.12	0.00	0.17	0.02	0.11	0.13	0.09	0.01							
	P_2							0.00	0.03	0.15	0.27	0.17	0.03	0.13	0.05	0.01		
	P_3									0.00	0.00	0.09	0.12	0.29	0.33	0.18	0.09	0.01
	P_4												0.00	0.00	0.17	0.22	0.25	0.12
Mean of two years	P_1	0.00	0.20	0.16	0.10	0.23	0.10	0.12	0.11	0.07	0.00							
	P_2							0.02	0.07	0.17	0.21	0.19	0.02	0.14	0.03	0.00		
	P_3									0.00	0.00	0.17	0.17	0.24	0.32	0.22	0.06	0.01
	P_4												0.00	0.06	0.20	0.33	0.29	0.11

Table 4.1.1.7a$_2$ Seasonal incidence of *Menochilus sexmaculata* on tomato

Standard Week	*Menochilus* / plant		
	1997-98	1998-99	Mean
51	0.00(0.71)	0.01(0.71)	0.00(0.71)
52	0.22(0.85)	0.17(0.82)	0.20(0.84)
1	0.19(0.83)	0.12(0.79)	0.16(0.81)
2	0.20(0.84)	0.00(0.71)	0.10(0.77)
3	0.28(0.88)	0.17(0.82)	0.23(0.85)
4	0.18(0.82)	0.02(0.72)	0.10(0.77)
5	0.12(0.79)	0.11(0.78)	0.12(0.79)
6	0.10(0.77)	0.13(0.79)	0.11(0.78)
7	0.20(0.84)	0.15(0.81)	0.17(0.82)
8	0.15(0.81)	0.27(0.88)	0.21(0.84)
9	0.21(0.84)	0.17(0.82)	0.19(0.83)
10	0.23(0.85)	0.12(0.79)	0.17(0.82)
11	0.20(0.84)	0.29(0.89)	0.25(0.87)
12	0.30(0.89)	0.33(0.91)	0.32(0.91)
13	0.44(0.97)	0.22(0.85)	0.33(0.91)
14	0.33(0.91)	0.25(0.87)	0.29(0.89)
15	0.09(0.77)	0.12(0.79)	0.11(0.78)

Figure in parenthesis indicate square root transformed value.

However activity of this predator was recorded on all crops planted at different time irrespective of their size of population.

Pooled mean data of two years showed that the activity of the predator (Figure 4.1.7a$_1$) was initiated on tomato on 52nd, 5th, 9th and 11th standard week of P_1 to P_4 crops respectively. From overall observations the size of the predators was recorded relatively higher at the earlier part of P_1 crop and later part of P_4 crop and became least on P_2 and P_3 planted crop which might be due to both influence of prevailing weather conditions and size of prey-pest population. It has also been observed that duration of their activity was longer on P_1 and P_2 crop (8 weeks) and relatively shortened on late-planted crops for 6 weeks on P_3 and for 5 weeks on P_4 crops. (Table 4.1.1.7a). The population was higher 0.10/plant in P_3 crop and minimum being 0.07/plant in P_2 crop. In 1997-98 as well as 1998-99, *M. sexmaculata* population was maximum in P_3 crop (0.13/plant and 0.08/plant respectively). (Table 4.1.1.11-4.1.1.13).

With regard to incidence of *M. sexmaculata* during the entire crop growth season it has been observed that the population was recorded in both the year and was followed similar pattern. The population (Figure 4.1.7a$_2$) was initiated on 52nd standard week and after successive increase the population reached at the maximum level on 13th standard week. Relatively higher population was observed from 12th to 14th standard week (Table 4.1.1.7a$_2$). During this period the average temperature, r.h. and sunshine hr/day was 14.97-24.24^{0}C, 65.39-78.17%, 3.39-8.94 hr/day respectively and the total rainfall was 191.55mm.

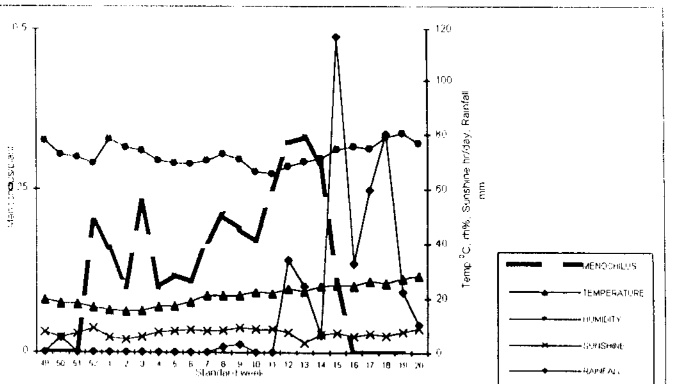


Fig 4.1.7a$_2$ Seasonal incidence of *Menochillus* sp. population (average) on tomato

From correlation studies it was found that, maximum, minimum and average temperature had non-significant negative correlation with *M. sexmaculata* population in 2nd to 4th plantings. In P_1 crop the population remained negatively and significantly correlated with maximum and minimum temperature and positively and non-significantly correlated with r.h., minimum, average and gradient but significantly and positively with r.h. maximum. In P_2 crop the population varied non-significant and positively with r.h. maximum and gradient, while r.h. minimum and average had non-significant and negative correlation. In P_3 crop the population had a significant negative correlation to r.h. maximum, minimum and average but r.h. gradient showed non-significant positive correlation. In case of P_4 crop r.h. maximum had significant and negative correlation and r.h. minimum and average had non-significant and negative correlation. Population was found to have non-significant positive correlation with r.h. gradient in all the crops. (Table 4.1.1.9).

In consideration with entire crop growing season *M. sexmaculata* population had non-significant and positive correlation with maximum, temperature, r.h. gradient and average sunshine hr/day. Minimum and average temperature and total rainfall varied non-significantly and negatively with *M. sexmaculata* population, whereas maximum, minimum and average r.h. had a significant negative correlation with *M. sexmaculata* population. (Table 4.1.1.10).

4.1.1.7b *Coccinella septempunctata*

Like *Menochilus sexmaculata*, the activity and population of *Coccinella septempunctata* also depended on the prevailing weather condition and availability of prey-pest population. Pooled mean of two years data showed that the population (Figure 4.1.7b$_1$) was absent altogether in P_1 crop and appeared on 8th, 7th and 10th standard week on P_2 to P_4 crop. The population level was higher on P_3 crop (0.13/plant) and lasted for 8 weeks. The P_2 and P_4 crop observed their activity (0.09/plant and 0.05/plant respectively) (Table 4.1.1.11-4.1.1.13) for 6 weeks. However the population level was least on 4th planted crop. (Table 4.1.1.7b$_1$).

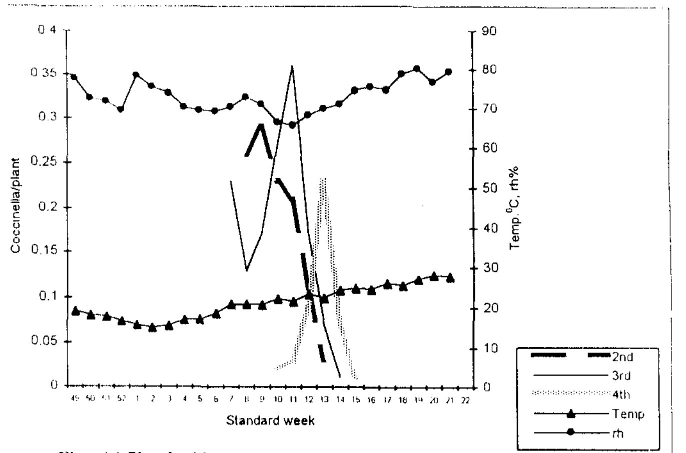


Fig : 4.1.7b$_1$ Incidence and fluctuation of *Coccinella* sp. population (average)at different time of planting on tomato

The relative fluctuation of mean *C. septempunctata* population during the entire crop growing season of two years studied, revealed that the population was initiated on 7th standard week and continued upto 15th standard week *i.e.* upto 3rd week of March, (Figure 4.1.7b$_2$) when average temperature, r.h. and sunshine hr/day were ranged from 20.68 to 24.84°C, 65.39 to 74.43%, 3.39 to 8.94 hr/day respectively and the total rainfall was 186.25mm. The population became maximum on 11th standard week

Table 4.1.1.7b₁ : Incidence and relative abundance of *Coccinella septempunctata* at different times of planting on tomato

Year	Pest population / Planting	Standard week 7	8	9	10	11	12	13	14	15
1997-98	P_2		0.30	0.24	0.20	0.23	0.12	0.02		
	P_3	0.33	0.15	0.25	0.30	0.40	0.21	0.05		
	P_4				0.00	0.00	0.09	0.33	0.13	0.03
1998-99	P_2		0.22	0.39	0.27	0.18	0.11	0.05		
	P_3	0.13	0.11	0.09	0.25	0.33	0.13	0.09	0.02	
	P_4				0.05	0.06	0.09	0.13	0.00	0.00
Mean of two years	P_2		0.26	0.29	0.23	0.21	0.11	0.03		
	P_3	0.23	0.13	0.17	0.27	0.36	0.17	0.07	0.01	
	P_4				0.02	0.03	0.09	0.23	0.07	0.01

Table 4.1.1.7b₂ Seasonal incidence of *Coccinella septempunctata* on tomato

Standard Week	*Coccinella* /plant 1997-98	1998-99	Mean
7	0.33(0.91)	0.13(0.79)	0.23(0.85)
8	0.30(0.89)	0.22(0.85)	0.26(0.87)
9	0.25(0.87)	0.34(0.92)	0.29(0.89)
10	0.30(0.89)	0.27(0.88)	0.28(0.88)
11	0.40(0.95)	0.33(0.91)	0.36(0.93)
12	0.210.84)	0.13(0.79)	0.17(0.82)
13	0.33(0.91)	0.13(0.79)	0.22(0.85)
14	0.13(0.79)	0.02(0.72)	0.06(0.75)
15	0.03(0.74)	0.00(0.71)	0.01(0.71)

Figure in parenthesis indicate square root transformed value.

Table 4.1.1.9 Correlation between natural enemy population on tomato crops at different time of planting and prevailing weather conditions

Planting / Weather Parameters	*Menochilus*				*Coccinella*			Spider			
	P1	P2	P3	P4	P2	P3	P4	P1	P2	P3	P4
Max. temp. ^{0}C	-0.675*	-0.139	-0.265	-0.228	-0.307	-0.559*	-0.298	-0.836*	-0.830*	-0.096	0.581*
Min.temp. ^{0}C	-0.762*	-0.036	-0.321	-0.374	0.152	-0.779*	-0.346	-0.878*	-0.915*	0.017	0.795*
Temp. grad. ^{0}C	-0.158	0.416	0.310	0.303	0.274	0.805*	0.202	-0.305	0.622*	-0.870*	-0.782*
Ave. Temp. ^{0}C	-0.480	-0.043	-0.314	-0.400	0.225	-0.736*	-0.414	-0.310	-0.883*	0.067	0.770*
Max. rh %	0.515*	0.229	-0.573*	-0.709*	-0.112	0.065	-0.730*	0.845*	0.791*	-0.447	0.619*
Min rh %	0.076	-0.313	-0.546*	-0.264	-0.254	-0.993*	-0.939*	0.343	-0.728*	0.207	0.625*
rh grad %	0.177	0.292	0.145	0.034	0.072	0.764*	-0.606*	0.080	0.826*	-0.380	-0.538*
Ave. rh %	0.201	-0.109	-0.784*	-0.394	-0.330	-0.861*	-0.912*	0.466	-0.068	-0.263	0.654*

* Significant

(0.36/plant). So the population was found mainly on middle part of the crop-growing season. (Table 4.1.1.7b$_2$).

The population varied positively and non-significantly with minimum and average temperature and temperature gradient, and r.h. gradient but related non-significant and negatively with maximum, minimum and average r.h. and maximum temperature in P$_2$ crop. In P$_3$ crop, the population became significant and negatively correlated with maximum, minimum and average temperature, minimum and average r.h., while both the r.h. and temperature gradient showed significant and positive correlation. In case of P$_4$ crop, temperature maximum, minimum and average was found to have non-significant and negative correlation while r.h. maximum, minimum, average and r.h. gradient had significant negative correlation with *C. septempunctata* population. (Table 4.1.1.9).

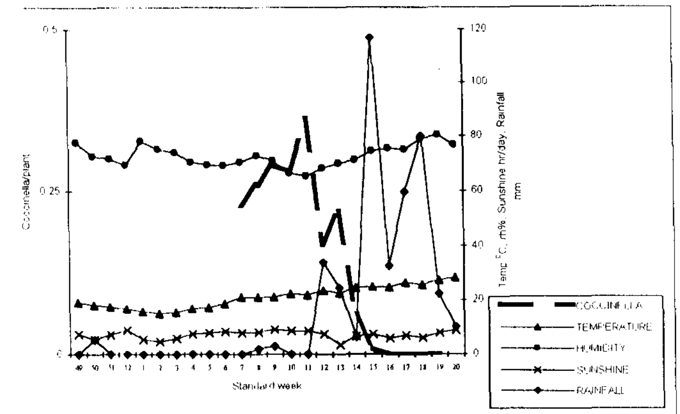


Fig 4.1.7b$_2$ Seasonal incidence of *Coccinella* sp. population (average) on tomato

From correlation studies of *C. septempunctata* population with the prevailing environmental condition althrough the crop growing season it is found that the population was non-significant and positively correlated with minimum, and average temperature, r.h. gradient, while r.h. maximum, minimum and average had a significant negative correlation. Temperature maximum and gradient and sunshine hr/day showed positive and significant correlation but the population varied non-significantly and negatively with total rainfall. (Table 4.1.1.10).

4.1.1.7c Spider

Various species of spider played an important role in natural suppression of pest population, particularly, the smaller ones like aphids, thrips, jassids, white flies, mites etc. Their activity was recorded on all crops planted at different time in each of the year studied. Pooled mean data of two years revealed that the population level was initiated (Figure 4.1.7c$_1$) with the appearance of prey-pest population, *i.e.* on 49th, 3rd, 7th and 10th standard week on P$_1$ to P$_4$ crop respectively. Population level was higher in earlier part of P$_1$ and P$_2$ crop but on P$_4$ crop higher population was observed on later part of season. It has also been observed that the duration of their

Table 4.1.1.7c_1 : Incidence and relative abundance of spider population at different times of planting on tomato

Year	Pest population / Planting	Standard week																								
		49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1997-98	P_1	0.15	0.30	0.33	0.78	0.92	0.84	0.78	0.67	0.70	0.67	0.55	0.45	0.25	0.13	0.02										
	P_2							0.84	1.00	0.75	1.00	0.60	0.25	0.33	0.42	0.32	0.16	0.02	0.01							
	P_3											0.33	[illegible]	0.35	0.53	0.43	0.75	0.60	0.53	0.35	0.15					
	P_4														0.21	0.39	0.50	0.45	0.61	0.78	1.00	1.22	0.98	0.67		
1998-99	P_1	0.67	0.50	0.72	1.21	0.88	0.53	1.17	0.98	0.67	0.27	0.33	0.40	0.28	0.15	0.03										
	P_2							0.75	0.80	0.60	0.98	0.50	0.17	0.20	0.39	0.29	0.12	0.09	0.05							
	P_3											0.00	0.06	0.33	0.45	0.39	0.60	0.58	0.44	0.39	0.25					
	P_4														0.17	0.23	0.69	0.57	0.78	0.64	0.75	2.17	1.33	1.00	0.98	0.84
Mean of two years	P_1	0.41	0.40	0.53	0.99	0.90	0.69	0.98	0.83	0.68	0.47	0.44	0.42	0.26	0.14	0.02										
	P_2							0.80	0.90	0.68	0.99	0.55	0.21	0.26	0.41	0.30	0.14	0.06	0.03							
	P_3											0.17	0.23	0.34	0.49	0.41	0.67	0.59	0.49	0.37	0.20					
	P_4														0.19	0.31	0.60	0.51	0.70	0.71	0.87	1.70	1.15	0.83		

activity was longer on P_1 crop (15 weeks) and relatively shortened to late planted crops (12 weeks) for P_2 and 10 weeks for P_3 and P_4 crop respectively. (Table 4.1.1.7c1). Spider population was recorded higher on P_4 crop (0.77/plant) which was significantly higher than other crops. Significantly lowest population was found on P_3 crop (0.41/plant) which was closely followed by P_2 crop with 0.43/plant. However, there was no significant difference in population level between P_2 and P_3 crops. While the P_1 crop recorded 0.58/plant. (Table 4.1.1.11-4.1.1.13).

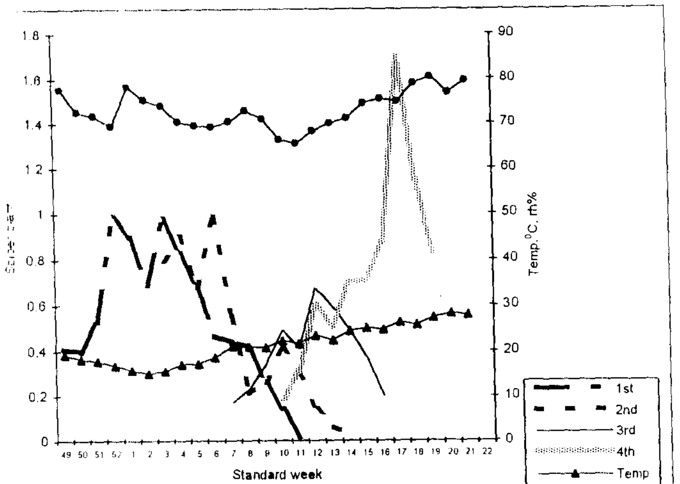


Fig : 4.1.7c1 Incidence and fluctuation of Spider population (average)at different time of planting on tomato

With regard to the incidence of spider population, over the entire crop growing season *i.e.* from December to May, the population level was found to fluctuate with the availability of prey-pest population and followed similar pattern of incidence in both the year studied. The population was initiated (Figure 4.1.7c2) on 49th standard week and reached at maximum level on 17th standard week (1.70/plant) and remained higher (1.16/plant) till 18th standard week when (Table 4.1.1.7c2) average temperature 25.62-26.19°C, average r.h., 74.82-78.86%, average sunshine hr/day 6.10-6.77 hr/day and total rainfall was 139.45mm respectively.

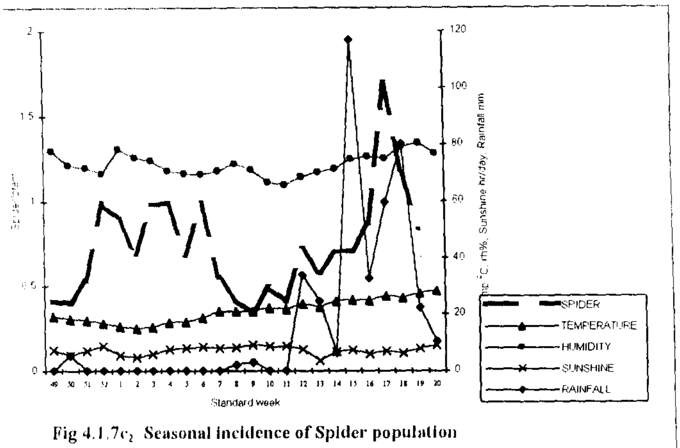


Fig 4.1.7c2 Seasonal incidence of Spider population (average) on tomato

Correlation analysis showed that the spider population had significant negative correlation to maximum and minimum while temperature average and gradient showed non-significant negative correlation. The population had positive and significant relation with maximum r.h. but minimum, average r.h. and r.h. gradient had non-significant positive correlation in P_1 crop. in P_2 crop the population showed a significant negative correlation with maximum minimum, and average temperature and minimum r.h., while maximum r.h., temperature and r.h. gradient respectively had

Table 4.1.1.7c$_2$ Seasonal incidence of spider population on tomato

Standard Week	Spider /plant		
	1997-98	1998-99	Mean
49	0.15(0.81)	0.67(1.08)	0.41(0.95)
50	0.30(0.89)	0.50(1.00)	0.40(0.95)
51	0.33(0.91)	0.72(1.10)	0.53(1.01)
52	0.78(1.13)	1.22(1.31)	0.99(1.22)
1	0.92(1.19)	0.88(1.17)	0.90(1.18)
2	0.84(1.17)	0.53(1.01)	0.69(1.09)
3	0.78(1.13)	1.17(1.29)	0.98(1.22)
4	1.00(1.22)	0.98(1.22)	0.99(1.22)
5	0.75(1.12)	0.60(1.05)	0.68(1.09)
6	1.00(1.22)	0.98(1.22)	0.99(1.22)
7	0.60(1.05)	0.50(1.00)	0.55(1.02)
8	0.45(0.97)	0.40(0.95)	0.42(0.96)
9	0.35(0.92)	0.33(0.91)	0.34(0.92)
10	0.53(1.01)	0.45(0.97)	0.49(0.99)
11	0.43(0.96)	0.39(0.94)	0.41(0.95)
12	0.75(1.12)	0.69(1.09)	0.72(1.10)
13	0.60(1.05)	0.57(1.03)	0.58(1.04)
14	0.61(1.05)	0.78(1.13)	0.70(1.10)
15	0.78(1.13)	0.64(1.07)	0.71(1.10)
16	1.00(1.22)	0.75(1.12)	0.87(1.17)
17	1.22(1.31)	2.17(1.63)	1.70(1.48)
18	0.98(1.22)	1.33(1.35)	1.16(1.29)
19	0.67(1.08)	1.00(1.22)	0.84(1.16)
20		0.98(1.22)	
21		0.84(1.16)	

Figure in parenthesis indicate square root transformed value

Table 4.1.1.10 Correlation coefficient of insect-pests and natural enemy population on tomato crops with prevailing environmental condition throughout the growing season

Weather Parameters	Pests and Natural enemies								
	Aphid /leaf	Whitefly /plant	Mined leaf %	Bored fruit %	Tingid bug /leaf	Hadda beetle /plant	*Menochilus* /plant	*Coccinella* /plant	Spider /plant
Maximum temperature ^{0}C	-0.085	-0.121	0.871*	0.907*	0.615*	0.338*	0.011	0.345*	0.069
Minimum temperature ^{0}C	-0.311*	-0.405*	0.923*	0.903*	0.591*	0.503*	-0.172	0.072	0.286
Temperature gradient ^{0}C	0.542*	0.688*	-0.587*	-0.537*	-0.281	-0.544*	0.395*	0.411*	-0.512*
Average temperature ^{0}C	-0.220	-0.290	0.923*	0.924*	0.616*	0.443*	-0.096	0.193	0.198
Maximum rh %	0.374*	0.285	-0.765*	-0.718*	-0.830*	-0.020	-0.447*	-0.458*	0.672*
Minimum rh %	-0.487*	-0.649*	0.509*	0.477*	0.246	0.588*	-0.428*	-0.415*	0.326*
rh Gradient %	0.580*	0.683*	-0.762*	-0.704*	-0.562*	-0.518*	0.183	0.168	-0.253
Average rh %	-0.286	-0.476*	0.137	0.141	-0.140	0.546*	-0.601*	-0.590*	0.330*
Sunshine hr/day	0.419*	0.559*	-0.111	0.110	-0.263	-0.138	0.035	0.340*	-0.143
Rainfall (mm)	-0.344*	-0.469*	0.702*	0.629*	0.562*	0.786*	-0.228	-0.209	0.401*

* Significant

significant and positive correlation. In P_3 crop the population remained negative and non-significantly correlated with maximum temperature, r.h. maximum, average and gradient, while minimum and average temperature and minimum r.h. showed positive and non-significant correlation. During higher period of incidence *i.e.* in case of P_4 crop the maximum, minimum, average, temperature and r.h. respectively showed significant and positive correlation with the spider population but temperature and r.h. gradient showed a significant negative correlation (Table 4.1.1.9).

Regarding population fluctuation with weather condition during the total crop- growing season, the population was found non-significantly and positively to correlated maximum, minimum and average temperature. R.h. gradient and sunshine hr/day had a non-significant negative correlation but temperature gradient had a significant negative correlation. Maximum, minimum and average r.h. and total rainfall had significant and positive correlation with spider population. (Table 4.1.1.10).

4.1.2. Yield of tomato at different times of planting

Yield of tomato varied significantly with four different planted crops in two years. In 1997-98, P_1 crop yielded significantly higher 65 t/ha over all other plantings and gradually decreased with the advancement of season. Therefore, yield of tomato was recorded minimum 31.00 t/ha from P_4 crop. (Table 4.1.1.11).

In 1998-99, P_1 crop also yielded significantly more (89.25 t/ha) followed by (57.87 t/ha and 55.92 t/ha) in P_2 and P_3 crop respectively. With gradual decrease, yield became lowest 45.43 t/ha in P_4 crop. (Table 4.1.1.12).

Pooled mean data of two years revealed that P_1 crop produced highest (77.12 t/ha) yield. The yield decreased gradually on subsequent plantings 49.00 t/ha on P_2 crop and 47.05 t/ha on P_3 crop. A relatively lowest yield was obtained from 4th planted crop (38.21 t/ha), which might be due to more abundance of pest population in last planted crop as compared to other planted crops. The 1st planted crop suffered by less pest attack that resulted in better yield over other plantings. (Table 4.1.1.13).

4.1.3 Phenological relation with relative abundance of pest population

Among the different pest mentioned above, tingid bug population was totally absent in P_1 and P_2 crops whereas, hadda beetle population remained absent in P_2 and P_3 crops, it would be better to say that the activity of these two pest species influenced more on prevailing weather

Table 4.1.1.11 Relative abundance (mean) of insect-pests, natural enemies and yield of tomato crops in different times of planting during 1997-98

Planting	Aphid /leaf	Whitefly /plant	Mined leaf %	Bored fruit % in no.	Bored fruit % in wt.	Tingid bug/leaf	Hadda beetle /plant	*Menochilus* /plant	*Coccinella* /plant	Spider /plant	Yield t/ha
P_1	0.18	0.23	2.70	8.16	7.98	0.00	0.00	0.10	0.00	0.54	65.00
	(0.82)	(0.85)	(1.79)	(2.94)	(2.91)	(0.71)	(0.71)	(0.77)	(0.71)	(1.02)	
P_2	1.92	0.72	25.63	10.74	10.22	0.00	0.00	0.07	0.09	0.48	40.13
	(1.55)	(1.10)	(5.11)	(3.35)	(3.27)	(0.71)	(0.71)	(0.75)	(0.77)	(0.99)	
P_3	1.68	0.67	49.47	11.91	11.00	1.01	0.00	0.13	0.17	0.48	38.19
	(1.25)	(1.08)	(7.07)	(3.52)	(3.39)	(1.23)	(0.71)	(0.79)	(0.82)	(0.99)	
P_4	0.07	0.04	60.72	13.70	13.00	1.14	0.27	0.12	0.06	0.68	31.00
	(0.75)	(0.73)	(7.82)	(3.77)	(3.67)	(1.28)	(0.88)	(0.79)	(0.75)	(1.09)	
SEM(±)	0.008	0.007	0.027	0.251	0.223	0.010	0.003	0.007	0.004	0.012	0.649
CD at 5%	0.024	0.021	0.081	0.753	0.669	0.030	0.009	N.S.	0.012	0.036	1.947

Figure in parenthesis indicate square root transformed value

Table 4.1.1.12 Relative abundance (mean) of insect-pests, natural enemies and yield of tomato crops in different times of planting during 1998-99

Planting	Aphid /leaf	Whitefly /plant	Mined leaf %	Bored fruit % in no.	Bored fruit % in wt.	Tingid bug/leaf	Hadda beetle /plant	*Menochilus* /plant	*Coccinella* /plant	Spider /plant	Yield t/ha
P_1	0.36 (0.93)	0.23 (0.85)	3.87 (2.09)	8.51 (3.00)	8.10 (2.93)	0.00 (0.71)	0.69 (1.09)	0.06 (0.75)	0.00 (0.71)	0.63 (1.06)	89.25
P_2	1.74 (1.50)	0.57 (1.03)	28.86 (5.42)	11.27 (3.50)	10.74 (3.35)	0.00 (0.71)	0.01 (0.71)	0.06 (0.75)	0.09 (0.77)	0.38 (0.94)	57.87
P_3	1.45 (1.39)	0.42 (0.97)	37.78 (6.19)	12.09 (3.55)	11.98 (3.53)	0.70 (1.09)	0.0 (0.71)	0.08 (0.76)	0.10 (0.78)	0.34 (0.92)	55.92
P_4	0.10 (0.77)	0.06 (0.75)	41.83 (6.51)	12.68 (3.63)	12.00 (3.54)	0.85 (1.16)	1.28 (1.33)	0.05 (0.74)	0.03 (0.73)	0.85 (1.16)	45.43
SEM(±)	0.008	0.006	0.016	0.0325	0.128	0.006	0.0037	0.005	0.0036	0.007	0.822
CD at 5%	0.024	0.018	0.048	0.0978	0.384	0.019	0.011	N.S	0.0108	0.021	2.467

Figure in parenthesis indicate square root transformed value

Table 4.1.1.13 Relative abundance (mean) of insect-pests, natural enemies and yield of tomato crops in different times of planting (pooled mean of two years)

Planting	Aphid /leaf	Whitefly /plant	Mined leaf %	Bored fruit % in no.	Bored fruit % in wt.	Tingid bug/leaf	Hadda beetle /plant	*Menochilus* /plant	*Coccinella* /plant	Spider /plant	Yield t/ha
P_1	0.27 (0.87)	0.23 (0.85)	3.28 (1.94)	8.34 (2.97)	8.04 (2.92)	0.00 (0.71)	0.34 (0.92)	0.08 (0.76)	0.00 (0.71)	0.58 (1.04)	77.12
P_2	1.83 (1.52)	0.65 (1.07)	27.24 (5.27)	11.00 (3.39)	10.28 (3.31)	0.00 (0.71)	0.00 (0.71)	0.07 (0.75)	0.09 (0.77)	0.43 (0.96)	49.00
P_3	1.56 (1.44)	0.54 (1.02)	43.63 (6.64)	12.00 (3.54)	11.49 (3.46)	0.86 (1.16)	0.00 (0.71)	0.10 (0.77)	0.13 (0.80)	0.41 (0.95)	47.05
P_4	0.08 (0.76)	0.05 (0.74)	51.27 (7.19)	13.19 (3.70)	12.50 (3.61)	1.00 (1.22)	0.77 (1.13)	0.09 (0.76)	0.05 (0.74)	0.77 (1.12)	38.21
SEM(±)	0.015	0.007	0.33	0.036	0.142	0.007	0.004	0.005	0.003	0.014	0.393
CD at 5%	0.045	0.021	0.10	0.115	0.426	0.021	0.012	N.S	0.009	0.042	1.257

Figure in parenthesis indicate square root transformed value

conditions than the crop growth stage and also found no specificity on crop growth stage or age of crop. While the incidence of remaining insect-pests species namely, aphid, white fly, leaf miner and fruit borer were recorded on all crops planted at different times and their relative abundance was largely determined by weather vis-à-vis crop growth stage or crop-phenology. Relative preference of plant parts by the pest species was also influenced by crop growth stage. Therefore, stage vulnerability is dependent greatly on crop-insect-phenological relationship.

4.1.3.1 Aphid (*Aphis gossypii* Glover)

Aphid, one of the most striking sucking pest was found more abundant during early growth stage *i.e.* before fruit bearing, in all the plantings as compared to the later stage of crop growth *i.e.* fruiting stage in both the years studied. Significant variation in pest population between different crop growth stage, planting time and their interaction was also observed.

In 1997-98, significantly higher aphid population was recorded (1.54/leaf) during early growth stage as compared to 0.38/leaf during later stage of crop growth. Variation in pest population in both the stages of different crops was highly significant. The highest aphid population was recorded on early stage of P_3 crop (3.24/leaf) followed by 2.52/leaf on P_2 crop; while in fruiting stage significantly higher aphid population (1.31/leaf) among different crops was recorded on P_2 crop over other crops. Pest population was always recorded significantly lower on both the stages of crop, 0.12/leaf and 0.01/leaf respectively (Table 4.1.3.1).

During 1998-99 also, significantly higher aphid population was recorded before fruiting stage of all the crops (1.64/leaf) over later stage of crop growth *i.e.* fruiting stage (0.19/leaf). Significantly higher aphid population 2.89/leaf was recorded from P_2 crop on early crop growth stage (before fruiting) closely followed by 2.85/leaf on P_3 crop. However, there was no significant difference in aphid population between two aforementioned crops. The fruiting stage of P_2 crop recorded the highest (0.59/leaf) aphid population over other crops. Here again P_4 crop had significantly lower population in both the crop growth stages *i.e.* before fruiting and fruiting stage, 0.19/leaf and 0.01/leaf respectively. (Table 4.1.3.2).

Pooled mean data of two years revealed that during before fruiting stage mean aphid population in four different crop was higher (1.59/leaf) as against later stage of crop growth *i.e.* fruiting stage (0.28/leaf). Before fruiting stage of P_3 crop and fruiting stage of P_2 crop scored highest aphid

Table 4.1.3.1 Effect of crop phenology on relative occurrence of pest population on tomato crops as influenced by different times of planting during 1997-98

Planting \ Mean pest population	Aphid /leaf			White fly/plant			Mined leaf %		
	Before fruiting	Fruiting	**Mean**	Before fruiting	Fruiting	**Mean**	Before fruiting	Fruiting	**Mean**
P_1	0.28 (0.88)	0.08 (0.76)	**0.18** **(0.82)**	0.31 (0.90)	0.14 (0.80)	**0.23** **(0.85)**	0.51 (1.00)	4.89 (2.32)	**2.70** **(1.79)**
P_2	2.52 (1.73)	1.31 (1.34)	**1.92** **(1.55)**	0.84 (1.16)	0.61 (1.05)	**0.72** **(1.10)**	2.17 (1.63)	49.10 (7.04)	**25.63** **(5.11)**
P_3	3.24 (1.93)	0.12 (0.78)	**1.68** **(1.25)**	1.14 (1.28)	0.19 (0.83)	**0.67** **(1.08)**	27.41 [illegible]	71.53 (8.48)	**49.47** [illegible]
P_4	0.12 (0.78)	0.01 (0.71)	**0.07** **(0.75)**	0.07 (0.75)	0.01 (0.71)	**0.04** **(0.73)**	39.25 (6.30)	82.19 (9.09)	**60.72** **(7.82)**
Mean	**1.54** **(1.43)**	**0.38** **(0.94)**		**0.59** **(1.04)**	**0.24** **(0.86)**		**17.33** **(4.22)**	**51.93** **(7.24)**	

Figure in parenthesis indicate square root transformed value

	Aphid/leaf			**Whitefly/plant**			**Mined leaf %**		
	C	P	C x P	C	P	C x P	C	P	C x P
SEM ±	0.006	0.008	0.012	0.005	0.007	0.010	0.019	0.027	0.038
CD at 5%	0.024	0.047	0.050	0.020	0.041	0.042	0.076	0.158	0.158

C= Crop growth stage, P= Planting time, C x P = Interaction between crop growth stage and planting time

population (3.05/leaf and 0.95/leaf respectively). The mean aphid population before fruiting stage of P_2 and P_3 planted crops (2.70/leaf and 3.05/leaf) varied non-significantly among themselves. However, both the stages of P_4 crop witnessed lowest mean aphid population, 0.15/leaf and 0.01/leaf respectively. (Table 4.1.3.3).

4.1.3.2 White fly (*Bemisia tabaci* Genn.)

Another sucking pest, white fly was also found more abundant during early growth stage (before fruiting) than the later (fruiting) stage of crop growth. Mean white fly population varied significantly among different crop growth stage as well as over different time of planting in both the stages.

During 1997-98, significantly higher mean number of white fly 0.59/plant was recorded on before fruiting stage over fruiting stage (0.24/plant) in all the crops. Relatively higher white fly population was observed 1.14 /plant in P_3 crop, followed by 0.84/plant in P_2 crop. While in fruiting stage, P_2 crop witnessed highest white fly population of 0.61/plant (Table 4.1.3.1).

During 1998-99, mean white fly population was markedly dominant in earlier part of crop growth stage (0.44/plant) as compared to the later stage (0.20/plant) in all the four different crops. Higher mean white fly population was recorded on P_2 crop in the early stage of crop growth, (0.74/plant). Variation in mean white fly population in two stages of crop growth was not significant on P_2 crop 0.60/plant and 0.54/plant in before fruiting and fruiting stages respectively. Here also the P_4 crop housed lowest number of pest population (Table 4.1.3.2).

Analysis of pooled mean data for two years study revealed that mean white fly population for four plantings was recorded higher (0.51/plant) in before fruiting stage, while during fruiting stage, it was only 0.22/plant. Significantly higher level of white fly population (0.94/plant) was recorded before fruiting stage of P_3 crop followed by 0.72/plant on P_2 crop. Population level although was observed lower on fruiting stage than earlier stage of growth but significantly higher population was recorded in P_2 crop (0.58/plant) and it was only 0.14/plant on both P_1 and P_3 crop (Table 4.1.3.3).

4.1.3.3 Leaf miner (*Liriomyza trifolii* Burgess)

Leaf damage due to leaf miner was relatively more abundant during later stage of crop growth *i.e.* during fruiting stage of all crops planted at

Table 4.1.3.2 Effect of crop phenology on relative occurrence of pest population on tomato crops as influenced by different times of planting during 1998-99

Planting \ Mean pest population	Aphid /leaf			Whitefly/plant			Mined leaf %		
	Before fruiting	Fruiting	**Mean**	Before fruiting	Fruiting	**Mean**	Before fruiting	Fruiting	**Mean**
P_1	0.61 (1.05)	0.11 (0.78)	**0.36** **(0.93)**	0.31 (0.91)	0.15 (0.81)	**0.23** **(0.85)**	0.22 (0.85)	7.51 (2.83)	**3.87** **(2.09)**
P_2	2.89 (1.84)	0.59 (1.04)	**1.74** **(1.50)**	0.60 (1.05)	0.54 (1.02)	**0.57** **(1.03)**	0.25 (0.87)	57.47 (7.61)	**28.86** **(5.42)**
P_3	2.85 (1.83)	0.04 (0.73)	**1.45** **(1.39)**	0.74 (1.11)	0.09 (0.77)	**0.42** **(0.96)**	13.23 (3.71)	62.34 (7.93)	**37.78** **(6.19)**
P_4	0.19 (0.83)	0.01 (0.71)	**0.10** **(0.77)**	0.09 (0.77)	0.03 (0.73)	**0.06** **(0.75)**	16.28 (4.10)	67.37 (8.24)	**41.83** **(6.51)**
Mean	**1.64** **(1.46)**	**0.19** **(0.83)**		**0.44** **(0.97)**	**0.20** **(0.84)**		**7.50** **(2.83)**	47.92 (6.96)	

Figure in parenthesis indicate square root transformed value

	Aphid/leaf			**Whitefly/plant**			**Mined leaf %**		
	C	P	C x P	C	P	C x P	C	P	C x P
SEM ±	0.006	0.008	0.012	0.004	0.006	0.093	0.011	0.016	0.022
CD at 5%	0.024	0.047	0.048	0.016	0.034	0.370	0.046	0.094	0.092

C= Crop growth stage, P= Planting time, C x P = Interaction between crop growth stage and planting time

Table 4.1.3.3 Effect of crop phenology on relative occurrence of pest population on tomato crops as influenced by different times of planting (pooled mean of two years)

Mean pest population / Planting	Aphid /leaf			Whitefly/plant			Mined leaf %		
	Before fruiting	Fruiting	**Mean**	Before fruiting	Fruiting	**Mean**	Before fruiting	Fruiting	**Mean**
P_1	0.44 (0.97)	0.09 (0.77)	**0.27 (0.87)**	0.31 (0.90)	0.14 (0.80)	**0.23 (0.85)**	0.86 (0.93)	6.20 (2.59)	**3.28 (1.94)**
P_2	2.70 (1.79)	0.95 (1.20)	**1.83 (1.52)**	0.72 (1.10)	0.58 (1.04)	**0.65 (1.07)**	1.21 (1.31)	53.28 (7.33)	**27.24 (5.27)**
P_3	3.05 (1.88)	0.08 (0.76)	**1.56 (1.44)**	0.94 (1.20)	0.14 (0.80)	**0.54 (1.02)**	20.32 (4.56)	66.94 (8.21)	**43.63 (6.64)**
P_4	0.15 (0.81)	0.01 (0.71)	**0.08 (0.76)**	0.08 (0.76)	0.02 (0.71)	**0.05 (0.74)**	27.75 (5.32)	74.78 (8.68)	**51.27 (7.19)**
Mean	**1.59 (1.44)**	**0.28 (0.88)**		**0.51 (1.01)**	**0.22 (0.84)**		**12.41 (3.59)**	**50.30 (7.13)**	

Figure in parenthesis indicate square root transformed value

	Aphid/leaf			**Whitefly/plant**			**Mined leaf %**		
	C	P	C x P	C	P	C x P	C	P	C x P
SEM ±	0.011	0.015	0.021	0.005	0.007	0.011	0.023	0.033	0.046
CD at 5%	0.032	0.043	0.061	0.014	0.020	0.032	0.067	0.095	0.133

C= Crop growth stage, P= Planting time, C x P = Interaction between crop growth stage and planting time

different time. Percentage of leaf miner incidence varied significantly with crop growth stage as well as with different planting time.

During 1997-98, higher magnitude of leaf miner infestation of all the crops was recorded during fruiting stage (51.93%) than before fruiting stage (17.33%) of the crop. Interaction of pest population between different time of planting and crop growth stage revealed that the higher leaf miner infestation was found on the before fruiting stage of P_4 crop (39.25%), followed by (27.41%) on P_3 crop and minimum being (0.51%) on P_1 crop. Fruiting stage of P_4 crop was also suffered more leaf miner attack (82.19%) which was significantly higher among the different crops planted at different time and this was followed by P_3 crop (71.53%). Significantly lowest infestation was recorded from P_1 crop in both the stages, 0.51% and 4.89% respectively. (Table 4.1.3.1).

In 1998-99, leaf miner infestation was also significantly higher during fruiting stage (47.92%) as compared to 7.50% on early stage of crop growth. Fruiting stage of P_4 crop witnessed significantly higher by the leaf miner (67.37%) closely followed by P_3 (62.34%) and P_2 (57.47%) crop. Before fruiting stage higher level of miner infestation was recorded (16.28%) on P_4 crop (Table 4.1.3.2).

Analysis of pooled mean data of leaf miner infestation over two years also revealed that the infestation was relatively more during fruiting stage (50.30%) than early stage *i.e.* before fruiting (12.41%) in all the crop. The variation in leaf miner incidence over different time of planting in both the stages was significant. The P_4 crop was damaged significantly higher by leaf miner incidence 27.75% and 74.78% during early stage *i.e.* before fruiting and fruiting stages respectively and minimum being 0.86% and 6.20% on early and later stages of crop growth respectively on P_1 crop (Table 4.1.3.3).

4.1.3.4 Fruit borer (*Helicoverpa armigera* Hubner)

Fruit borer though a polyphagous pest, is very specific to the food *i.e.* fruit of tomato, and therefore, its incidence was totally confined to the fruiting stage. However a significant variation in the level of infestation over crops planted at different time was observed. Pooled mean data of two years revealed that the highest level (13.19%) of fruit damage per cent (in number) was recorded on P_4 crop and minimum being 8.34% on P_1 crop followed by P_2 (11.00%) and P_3 (12.00 %) crop (Table 4.1.1.15).

4.2 Bio-Ecology of Important Insect-Pests of Tomato

Among the different insect-pests attacked tomato plants tomato fruit borer *(Helicoverpa armigera)*, leaf miner *(Liriomyza trifolii)* and white fly *(Bemisia tabaci)* have been regarded to be the important ones causing considerable damage to the plants. Fruit borer attack the fruits and make them unfit for consumption, leaf miner cause damage to the leaves by mining into the leaves that affect photosynthetic activity of the plants and white fly cause complete loss in three ways through direct desapping leading into devitalization of plant, interference of photosynthetic activity through favouring development of shooty mould and transmitting leaf curl viral disease. Keeping this view in mind an attempt was made to study the biology of these aforesaid pest species as influenced by the prevailing weather under laboratory conditions in different period of the year. The information from present experiment will substantiate to justify pest-population fluctuation under field condition.

4.2.1 Tomato fruit borer (*Helicoverpa armigera* Hubner)

The moths are nocturnal in habit. The adult (moth) came out during night and copulation takes place on dark conditions. Female laid eggs at the next day after mating, singly on the wall of jars. Eggs were round and greenish yellow in colour which changed into yellowish white just before hatching.

4.2.1.1 Incubation period

The period of incubation varied significantly in different seasons, the lowest being (3.75 days) during April-May when temperature ranged from 25.83 to 31.33°C and the r.h. was 71.00%, while the highest being 5.10 days during February-March having temperature ranging 20.92 to 24.50°C and r.h. 62.21% respectively (Figure 4.2.1.1). The average incubation period was 4.29 days. Correlation studies showed that the incubation period was correlated negatively and significantly to the maximum, minimum and average temperature but non-significantly and negatively to average r.h. (Table 4.2.1 and 4.2.1a).

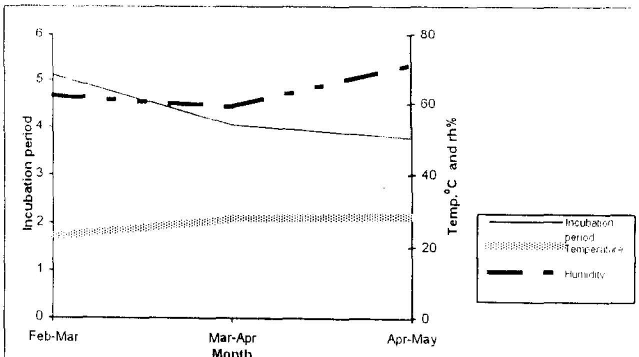


Fig. 4.2.1.1 Incubation period of fruit borer (*Helicoverpa armigera*)

Table- 4.2.1 Duration of different developmental stages of fruit borer *(Helicoverpa armigera)* on tomato under laboratory conditions

Month	Average duration (days)							
	Incubation	Larval	Pupal	Preoviposition	Oviposition	Adult Male	Adult Female	Life cycle
February-March	5.10 (4.5-5.5)	21.33 (18-24)	16.33 (14.0-18.50)	1.67 (1.00-2.50)	5.15 (4.5-5.5)	5.67 (4.5-6.5)	10.00 (9-11)	43.36 (37.50-50.50)
March-April	4.03 (3.5-5.0)	19.00 (17-21)	14.66 (12-17)	2.10 (1.50-3.00)	6.40 (4.5-7.0)	5.00 (4.0-6.0)	9.00 (8.5-10.5)	40.76 (34.00-46.00)
April-May	3.75 (3.5-4.5)	16.50 (15-18)	10.00 (9-11)	1.93 (1.00-3.00)	5.00 (3.0-6.0)	4.33 (3.5-5.5)	8.10 (7.5-9.0)	31.43 (28.50-36.50)
Mean	4.29	18.94	13.66	1.90	5.52	5.00	9.03	38.52

Figure in parenthesis indicates ranges of developmental periods

4.2.1.2 Larval period

Freshly hatched larvae yellowish white in colour but gradually turned greenish. Full-grown caterpillars were apple green in colour with whitish and dark gray broken longitudinal stripes. Three days before pupation larvae stopped feeding; became sluggish and entered into pre-pupal condition.

The larval period varied with the seasons. It was the highest during February-March (21.33 days) and the lowest during April-May (16.50 days), while during March-April it was 19.00 days. However average duration being 18.94 days. Longer larval duration was recorded when the temperature ranged from 23.27 to 26.54°C and r.h. 65.93% respectively. At 26.67-30.23°C temperature and 69% r.h. larval duration was the shortest 16.05 days. Correlation studies showed that larval period had a non-significant negative relation to temperature (maximum, minimum and average) and average r.h. (Table 4.2.1 and 4.2.1a).

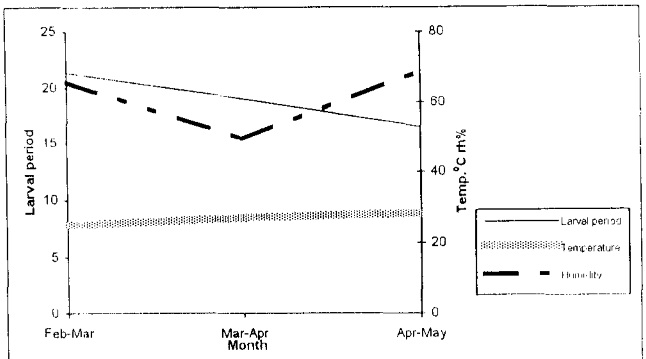


Fig 4.2.1.2 Larval period of fruit borer (*Helicoverpa armigera*)

4.2.1.3 Pupal period

The caterpillar fed, grown and lived within the fruit keeping the posterior part of the body outside the fruit and when became fully grown came out from the fruits and pupated in soil. Average pupal duration was 13.66 days while longer period was 16.33 days, when prevailing temperature range was 24.27 to 28.07°C and r.h. was 58.00% respectively during February-March. But during April-May the duration was shortened to 10.00 days at 28.50-31.50°C temperature and 68.21% r.h. (Figure 4.2.1.3). From correlation studies it was found that the pupal period was non-significant and negatively correlated with maximum, minimum and average temperature and average r.h. (Table 4.2.1 and 4.2.1a).

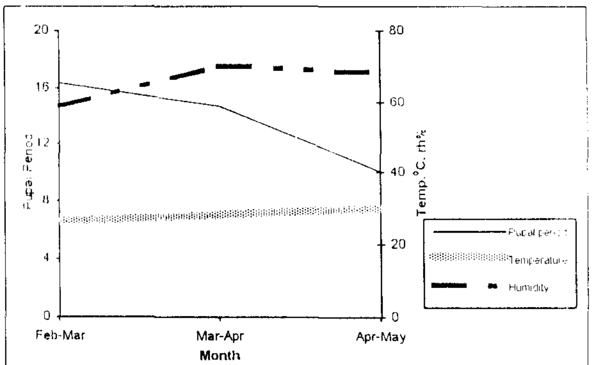


Fig 4.2.1.3 Pupal period of fruit borer (*Helicoverpa armigera*)

Table – 4.2.1a Correlation co-efficient (r) between duration of different stages of life cycle of fruit borer *(Helicoverpa armigera)*and mean weather parameters

Weather Parameters	Incubation	Larval	Pupal	Preoviposition	Oviposition	Adult Male	Adult Female	Life cycle
Maximum temperature ^{0}C	-0.998* (24.50-31.33)	-.0710 (26.54-30.23)	-0.725 (28.07-31.50)	0.176 (30.50-32.25)	0.831* (28.20-32.00)	-0.539 (29.36-30.75)	-0.937* (28.58-32.00)	-0.876* (26.47-31.03)
Minimum temperature ^{0}C	-0.983* (20.92-25.83)	-.0726 (23.27-26.67)	-0.753 (24.27-28.50)	0.180 (26.50-28.50)	0.972* (25.50-28.75)	-0.842* (25.57-27.50)	-0.170 (25.58-28.36)	-0.943* (23.61-27.58)
Average temperature ^{0}C	-0.991* (22.71-28.58)	-0.718 (24.91-28.45)	-0.742 (26.17-30.00)	0.178 (28.50-30.37)	0.902* (26.85-30.37)	-0.702 (27.46-29.12)	-0.557 (27.08-29.93)	-0.911* (25.04-29.31)
Average r.h.%	-0.444 (59.00-71.00)	-0.153 (49.42-69.00)	-0.237 (58.21-70.25)	0.176 (40.00-63.25)	0.118 (49.60-71.00)	-0.760 (55.00-63.87)	-0.978* (48.31-79.33)	-0.958* (56.74-64.55)

* Significant

Figure in parenthesis indicate prevailing temperature (^{0}C) and relative humidity (r.h.%) of respective stage of development and life cycle at the time of rearing

4.2.1.4 Preoviposition period

Preoviposition period varied with season and showed a positive correlation with maximum, minimum and average temperature and average

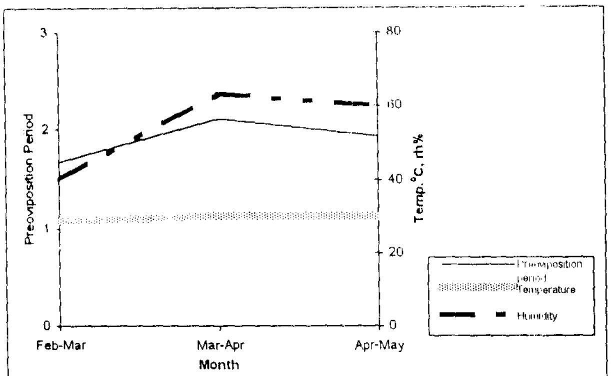


Fig 4.2.1.4 Preoviposition period of fruit borer
(Helicoverpa armigera)

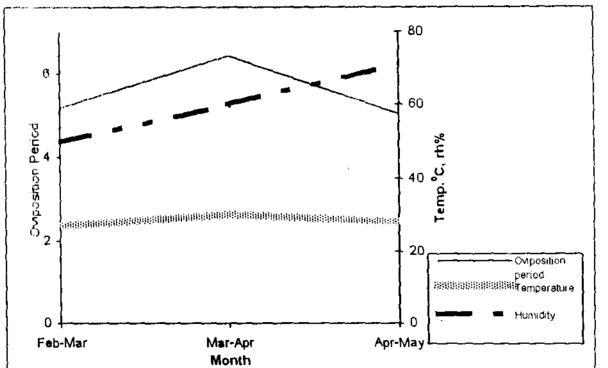


Fig 4.2.1.5 Oviposition period of fruit borer
(Helicoverpa armigera)

r.h.. Preoviposition period was longer during March-April (2.10 days) followed by April-May (Figure 4.2.1.4), (1.93 days) while during February-March the period was the shortest (1.67 days) (Table 4.2.1 and 4.2.1a).

4.2.1.5 Oviposition period

Oviposition period continued (Figure 4.2.1.5) for 5.15 days during February-March; 6.40 days during March-April and 5.00 days during April-May. On an average the oviposition period was 5.52 days. It had a significant positive correlation with temperature (maximum, minimum and average) but non-significant and positive correlation with r.h. (Table 4.2.1 and 4.2.1a).

4.2.1.6 Adult longevity

The average longevity of male moth was recorded 5.00 days. During February-March, March-April and April-May it was 5.67 day, 5.00 days and 4.33 days respectively (Figure 4.2.1.6a). The longevity of female moth was

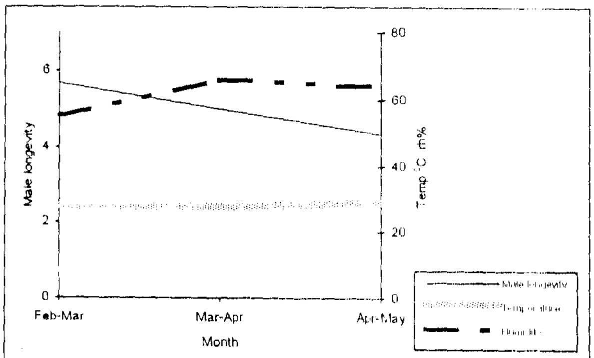


Fig 4.2.1.6a Adult male longevity period of fruit borer
(Helicoverpa armigera)

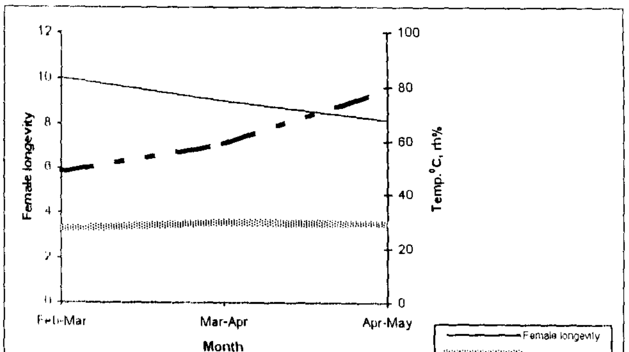


Fig 4.2.1.6b Adult femle period of fruit borer
(Helicoverpa armigera)

some how more than male and the highest duration was recorded 10.00 days during February-March, 9.00 days during March-April and 8.10 days during April-May (Figure 4.2.1.6b). Longevity of male and female moths were negatively correlated with temperature (maximum, minimum and average) and average r.h. *i.e.* adult life prolonged with the decrease of temperature and r.h. (Table 4.2.1 and 4.2.1a).

4.2.1.7 Life cycle

Duration of life cycle also varied in different season, shortest (31.43 days) at 27.58-31.03^{0}C temperature and 64.55% r.h. being in April-May and longest (43.36 days) at 23.61-26.47^{0}C temperature and 56.74% r.h. in February-March (Figure 4.2.1.7). Average duration of life cycle for three generations studied was found 38.52 days. From correlation studies it was found that total life cycle had significantly negative correlation with maximum, minimum and average temperature and average r.h. (Table 4.2.1 and 4.2.1a).

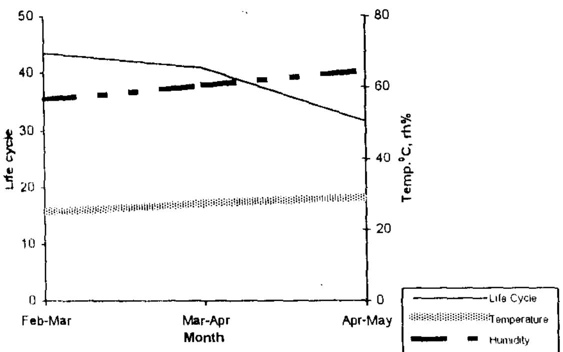


Fig 4.2.1.7 Life cycle period of fruit borer (*Helicoverpa armigera*)

4.2.2 Leaf miner (*Liriomyza trifolii* Burgess)

The dipteran fly usually mated partly in the air. Female started laying of eggs one day after mating. The eggs were laid singly in a small number of the punctures made with the help of ovipositor. Eggs were yellowish white in colour.

4.2.2.1 Incubation period

The average incubation period varied over season, the lowest being recorded 2.63 days (at 27.17-30.08^{0}C and 66.92% r.h.) during April, followed by 3.00 days during March, 3.05 day during March-April and the highest being 4.07 days when temperature ranged from 25.10 to 28.40^{0}C and the r.h. was 59.10% respectively (Figure 4.2.2.1). Average incubation period was recorded 3.18 days. Correlation of important weather parameters with incubation period showed a negative correlation to temperature (maximum, minimum and average) as well as average r.h. (Table 4.2.2 and 4.2.2a).

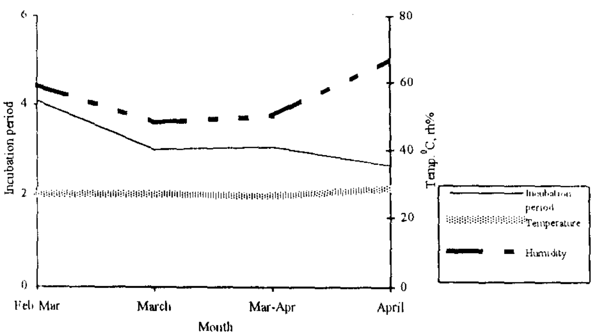


Fig 4.2.2.1 Incubation period of leaf miner (*Liriomyza trifolii*)

Table- 4.2.2 Duration of different developmental stages of leaf miner *(Liriomyza trifolii)* on tomato under laboratory conditions

Month	Average duration (days)							
	Incubation	Larval	Pupal	Preoviposition	Oviposition	Adult Male	Adult Female	Life cycle
February-March	4.07 (3.00-5.50)	6.50 (5.50-7.50)	10.00 (9.00-12.00)	1.65 (1.00-2.00)	2.50 (1.75-3.00)	4.00 (3.00-6.00)	6.00 (5.00-7.50)	22.25 (18.50-27.00)
March	3.00 (2.00-4.50)	7.00 (5.50-8.00)	8.00 (7.50-9.50)	1.25 (1.00-2.00)	2.75 (2.00-3.50)	3.10 (2.50-4.00)	5.25 (4.00-6.00)	19.25 (16.00-24.00)
March-April	3.05 (2.50-4.00)	6.00 (5.00-7.50)	8.12 (7.50-9.50)	1.50 (1.00-2.00)	3.00 (2.50-3.50)	4.06 (3.50-5.50)	6.15 (5.50-7.00)	18.65 (16.00-23.00)
April	2.63 (1.75-3.50)	5.00 (3.50-6.00)	7.05 (6.50-8.00)	1.00 (0.50-1.50)	1.50 (1.00-2.50)	2.12 (1.50-3.00)	3.00 (2.00-4.00)	15.68 (12.25-19.00)
Mean	**3.18**	**6.12**	**8.29**	**1.35**	**1.44**	**4.42**	**5.10**	**18.95**

Figure in parenthesis indicate ranges of duration of developmental stages.

4.2.2.2 Larval period

After hatching, the larvae (maggot) started feeding cell sap and also started mining. Maggots were shining yellow in colour. Duration of maggot was also depended on seasonal variation. The highest duration was observed during March (7.00 days) at 25.75-29.75°C temperature and 59% r.h. (Figure 4.2.2.2), while the lowest being 5.00 days during April at 25.82-30.26°C temperature and 70.33% r.h.. Minimum and average temperature and average r.h. had non-significant negative correlation to maggot duration. But maximum temperature showed significant negative correlation to larval (maggot) duration (Table 4.2.2 and 4.2.2a).

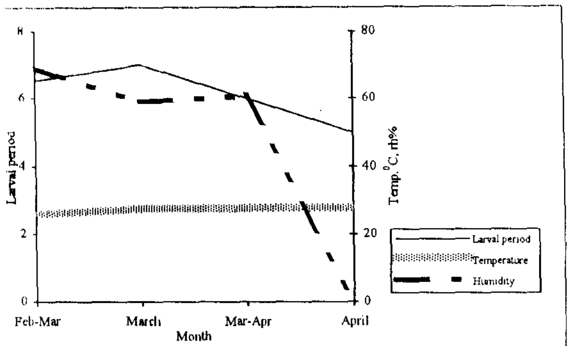


Fig 4.2.2.2 Larval period of leaf miner (*Liriomyza trifolii*)

4.2.2.3 Pupal period

The maggot came out of the mine to pupate and the pupation took place in the glass jar. Pupae were dark brown in colour and drum shaped. Pupal period varied with seasons and average duration being 8.29 days. The pupal duration was the maximum (10.00 days) during February-March (at 24.0 to 28.17°C temperature and 50.80% r.h.) (Figure 4.2.2.3) and the minimum was (7.05 days) being during April (at 28.87 to 31.62°C temperature and 59.10% r.h.). The pupal period was non-significantly and negatively correlated with temperature (maximum, minimum and average) and average r.h. *i.e.* pupal duration decreased with the increase of temperature and r.h. (Table 4.2.2 and 4.2.2a).

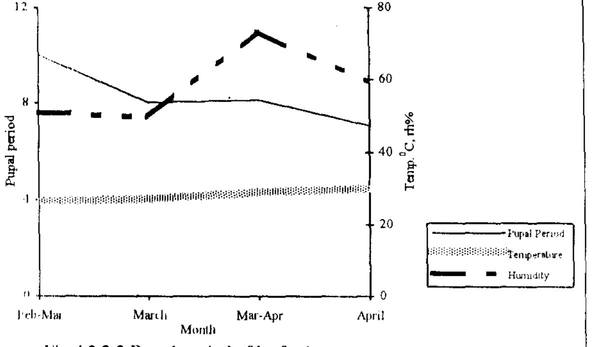


Fig 4.2.2.3 Pupal period of leaf miner (*Liriomyza trifoli* i)

4.2.2.4 Preoviposition period

Preoviposition also varied with the season and weather parameters. The highest preoviposition period (1.65 days) was recorded during February-March having temperature ranges 24.50 to 29.00°C and 50% r.h. while the minimum of 1.00 day (Figure 4.2.2.4) at 28.00 to 32.00°C temperature and 79% r.h. during April. This period showed non-significant

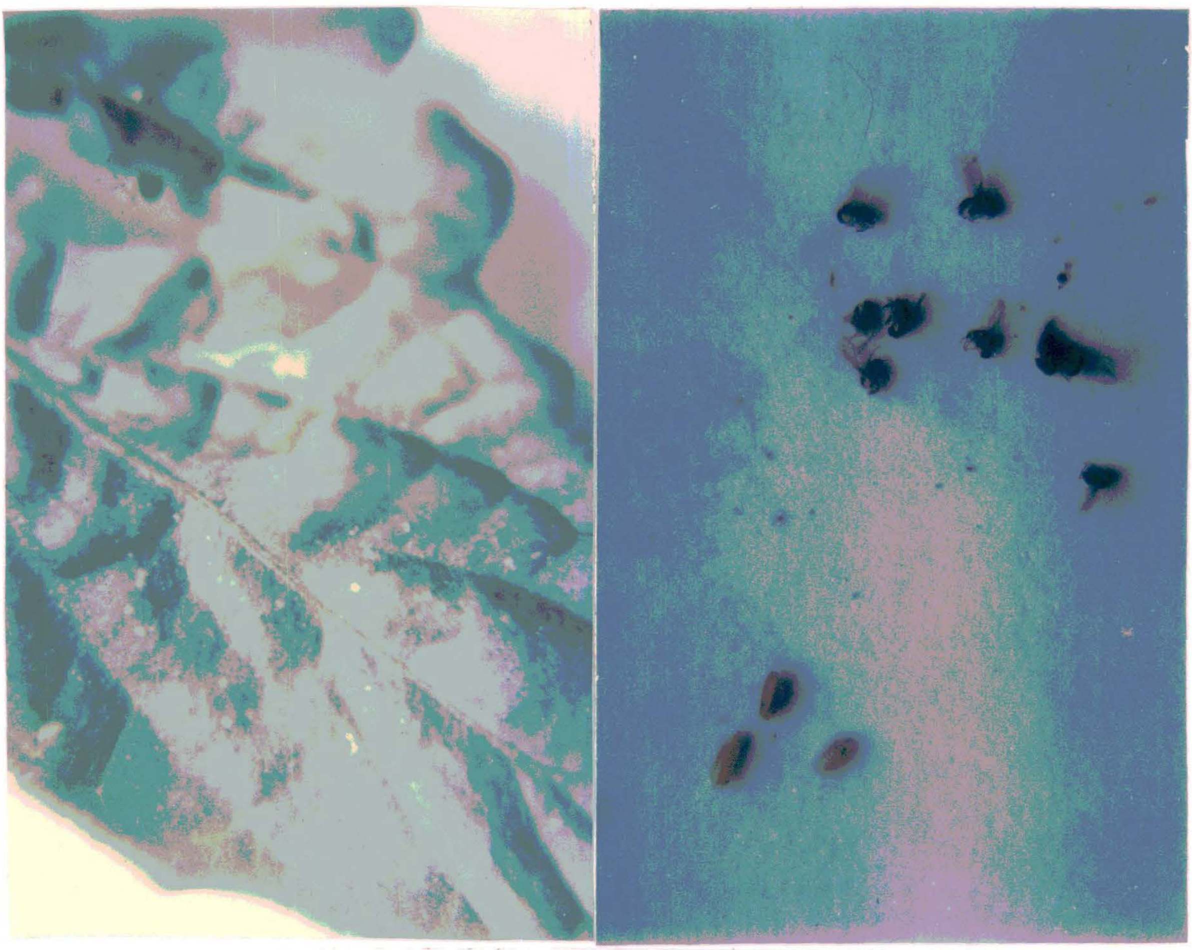
Table – 4.2.2a Correlation co-efficient (r) between duration of different stages of life cycle of leaf miner *(Liriomyza trifolii)* and mean weather parameters

Weather Parameters	Incubation	Larval	Pupal	Preoviposition	Oviposition	Adult Male	Adult Female	Life cycle
Maximum Temperature ^{0}C	-0.592 (24.50-27.17)	-0.434 (24.36-26.30)	-0.840* (28.17-31.62)	-0.495 (28.75-32.00)	-0.904* (29.50-31.00)	-0.920* (29.00-32.00)	-0.691 (29.00-31.00)	-0.895* (28.21-30.99)
Minimum temperature ^{0}C	-0.481 (28.00-30.08)	-0.326 (27.28-30.26)	-0.765 (24.00-28.87)	-0.480 (24.50-28.75)	-0.855* (25.50-27.50)	-0.597 (24.83-28.00)	-0.538 (24.71-27.50)	-0.846* (24.57-27.46)
Average temperature ^{0}C	-0.537 (26.25-28.62)	-0.397 (25.82-28.04)	-0.766 (26.09-30.25)	-0.500 (26.75-30.00)	-0.913* (27.63-29.25)	-0.773 (26.92-30.00)	-0.625 (27.10-29.25)	-0.877* (26.39-29.22)
Average r.h.%	-0.063 (48.00-66.92)	-0.621 (59.00-70.33)	-0.344 (49.43-59.10)	-0.669 (46.00-79.00)	-0.801* (50.00-76.00)	-0.286 (49.75-66.25)	-0.754 (51.33-77.00)	-0.267 (51.54-65.65)

* Significant

Figure in parenthesis indicate prevailing temperature (^{0}C) and relative humidity (r.h.%) of respective stage of development and life cycle at the time of rearing

Photograph showing different life stages of fruit borer



Photograph showing different life stages of leaf miner
(Eggs and larvae within the leaf)

negative correlation to temperature (maximum, minimum and average) and average r.h. (Table 4.2.2 and 4.2.2a).

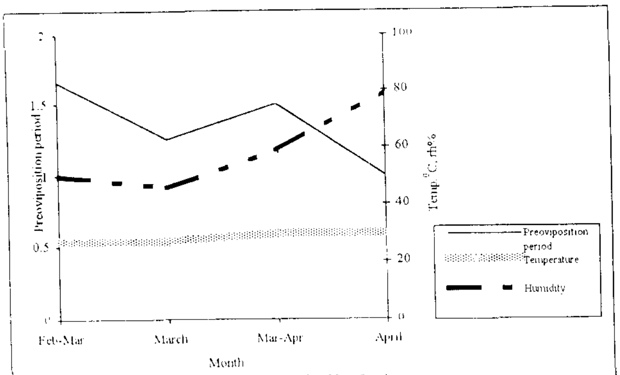


Fig 4.2.2.4 Preoviposition period of leaf miner
(*Liriomyza trifolii*)

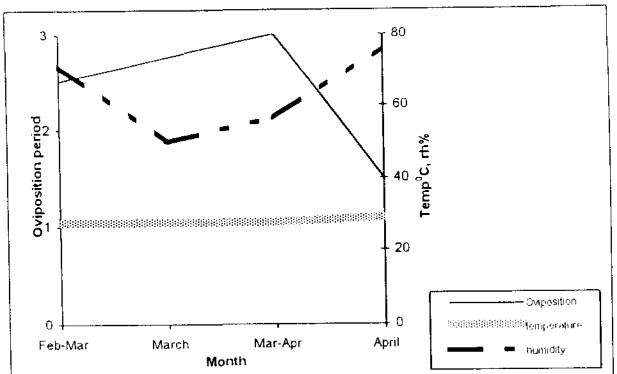


Fig 4.2.2.5 Oviposition period of leaf miner
(*Liriomyza trifolii*)

4.2.2.5 Oviposition period

The female on an average laid eggs for 1.44 days. This period varied with season and continued for 3.00 days (Figure 4.2.2.5) during March-April (at 26.00 to 29.50^{0}C temperature and 56.50% r.h.) and the lowest 1.50 days during April. This period was found significant and negatively correlated with maximum, minimum and average temperature and r.h. (Table 4.2.2 and 4.2.2a).

4.2.2.6 Adult longevity

The male fly lived for 4.42 days on an average. The higher

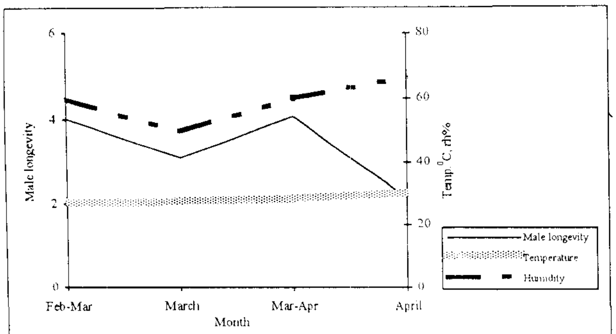


Fig 4.2.2.6a Male longevity of leaf miner
(*Liriomyza trifolii*)

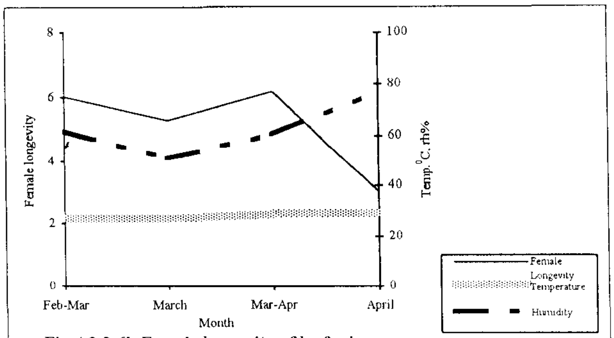


Fig 4.2.2.6b Female longevity of leaf miner
(*Liriomyza trifolii*)

duration of 4.06 days (Figure 4.2.2.6a) was recorded during March-April but the shorter being during April (2.12 days). The longevity of female fly was somehow more than males and the highest duration was recorded 6.15 days (Figure 4.2.2.6b) during March-April while it was the shortest (3.00 days) during April. The average longevity of female fly was 5.10 days. Longevity of male and female fly had non-significant negative correlation to all the weather parameters like maximum, minimum and average temperature and average r.h. (Table 4.2.2 and 4.2.2a).

4.2.2.7 Life cycle

The average duration of life cycle was 18.96 days. Duration of life cycle was minimum 15.68 days during April, when temperature ranged 27.46 to 30.99°C and average r.h. 65.65% and maximum during February-March 22.25 days when temperature ranged from 24.57 to 28.21°C and average r.h. was 54.72% respectively (Figure 4.2.2.7). The average duration of life for four generations was significantly and negatively correlated with temperature but negatively and non-significantly to r.h. (Table 4.2.2 and 4.2.2a).

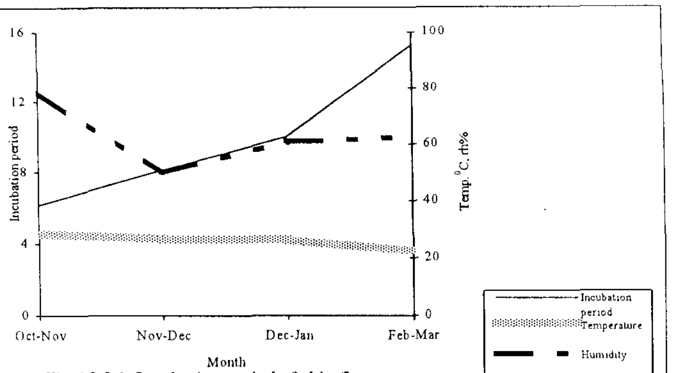


Fig 4.2.3.1 Incubation period ofwhitefly (*Bemisia tabaci*)

4.2.3 Whitefly (*Bemisia tabaci* Gennadius)

Females laid eggs singly on the underside of the leaves. Eggs were stalked, pear-shaped and light yellow in colour at first but turned into light brown later on.

4.2.3.1 Incubation period

Incubation period varied with seasons. The lowest period 6.15 days (at 27.25 to 30.00°C temperature and 79% r.h.) was observed during October-November and the highest being 15.25 days (Figure 4.2.3.1) (at 20.36 to 24.43°C temperature and 62.66% r.h.) during February-March. Average incubation period was recorded 9.87 days. Correlation between important weather parameters with incubation period showed significant negative correlation with maximum, minimum and average temperature but non-significant negative correlation to average r.h. (Table 4.2.3 and 4.2.3a).

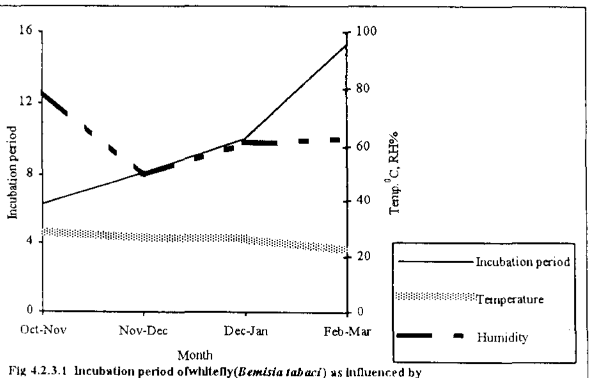


Fig 4.2.3.1 Incubation period ofwhitefly(*Bemisia tabaci*) as influenced by temperature and relative humidity

4.2.3.2 Nymphal period

On hatching, the nymphs were settled themselves underside of the leaves and fed on cell sap. The nymphs were oval shaped and scale like.

Table 4.2.3 Duration of different developmental stages of white fly (*Bemisia tabaci*)) on tomato under laboratory conditions

Month	Average duration (days)							
	Incubation	**Nymphal**	**Pupal**	**Preoviposition**	**Oviposition**	**Adult Male**	**Adult Female**	**Life cycle**
October-November	6.15	8.30	4.00	1.12	2.32	4.50	7.12	19.57
	(5.50-7.00)	(7.50-9.00)	(3.00-5.00)	(1.00-2.00)	(1.75-3.00)	(4.00-5.50)	(6.50-8.00)	(17.00-23.00)
November-December	8.10	10.00	5.05	2.00	3.57	6.00	8.50	25.15
	(7.00-9.00)	(9.00-11.00)	(4.50-6.00)	(1.50-3.00)	(3.00-4.50)	(5.00-7.00)	(7.50-9.00)	(22.00-29.00)
December-January	10.00	18.50	7.25	3.00	5.00	12.50	14.00	40.00
	(9.50-11.00)	(18.00-19.00)	(6.50-8.00)	(2.75-4.00)	(3.00-6.00)	(11.75-13.00)	(12.00-16.00)	(36.75-42.00)
February-March	15.25	16.35	6.00	2.50	4.00	7.35	10.00	38.75
	(14.50-16.00)	(15.75-17.00)	(5.00-7.00)	(2.00-3.50)	(3.50-4.50)	(7.00-8.50)	(9.00-12.00)	(37.25-43.50)
Mean	**9.87**	**13.29**	**5.57**	**2.15**	**3.72**	**7.59**	**9.91**	**30.87**

Figure in parenthesis indicate ranges of duration of developmental stages

The average nymphal period for four generations studied was recorded 13.29 days. During December-January the highest nymphal period was observed (Figure 4.2.3.2) 18.50 days (at 22.00 to 25.00^{0}C temperature and 60% r.h.) and the lowest being 8.30 days in October-November (at 27.50 to 29.00^{0}C temperature and 68.50% r.h.). It had significant negative correlation with maximum, minimum and average temperature but average r.h. had non-significant negative correlation with nymphal period (Table 4.2.3 and 4.2.3a).

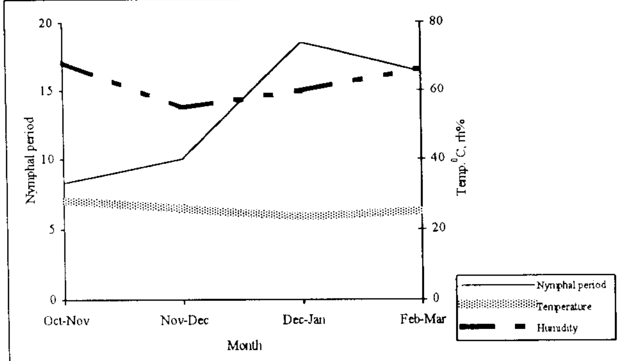


Fig 4.2.3.2 Nymphal period of white fly (*Bemisia tabaci*)

4.2.3.3 Pupal period

Pupae stopped feeding and turned white in colour. This period was also varied from season to season and the average of 5.57 days was observed for four generations studied. The maximum being 7.25 days (Figure 4.2.3.3) during December-January (at 19.50 to 24.50^{0}C temperature and 58% r.h.) and the lowest being 4.00 days when temperature ranged from 27.17 to 29.75^{0}C and average r.h. was 62% respectively during October-November. Pupal period showed significant negative correlation with maximum, minimum and average temperature and average r.h. (Table 4.2.3 and 4.2.3a).

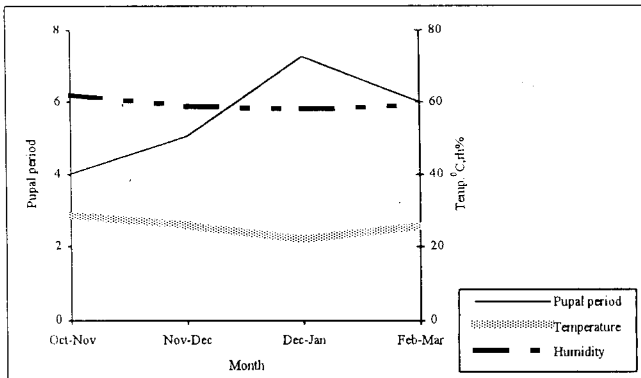


Fig 4.2.3.3 Pupal period of white fly (*Bemisia tabaci*)

4.2.3.4 Pre-oviposition period

Preoviposition period was also varied over seasons and was

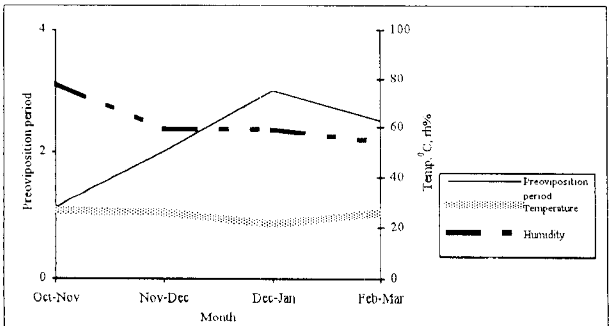


Fig 4.2.3.4 Preoviposition period of white fly (*Bemisia tabaci*)

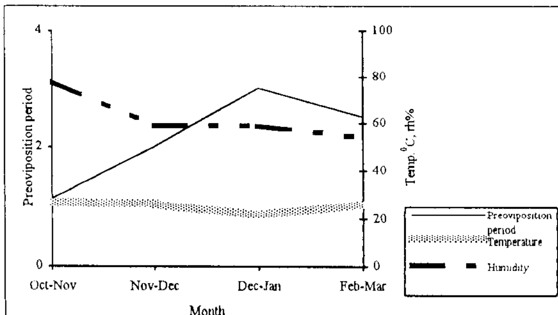


Fig 4.2.3.4 Preoviposition period of white fly (*Bemisia tabaci*)

Table – 4.2.3a Correlation co-efficient (r) between duration of different stages of life cycle of white fly (*Bemisia tabaci*) and mean weather parameters

Weather Parameters	Incubation	Larval	Pupal	Preoviposition	Oviposition	Adult Male	Adult Female	Life cycle
Maximum temperature ^{0}C	-0.861* (24.43-30.00)	-0.894* (25.00-29.00)	-0.969* (24.50-29.75)	-0.670 (24.00-28.25)	-0.781 (24.00-28.50)	-0.931* (24.00-28.50)	-0.907* (25.50-28.67)	-0.951* (25.60-29.20)
Minimum temperature ^{0}C	-0.937* (20.36-27.25)	-0.917* (22.00-27.50)	-0.961* (19.50-27.17)	-0.876* (19.00-26.00)	-0.915* (19.50-26.25)	-0.976* (19.00-26.17)	-0.952* (19.50-25.00)	-0.944* (21.13-26.98)
Average temperature ^{0}C	-0.990* (22.39-28.62)	-0.911* (23.50-28.25)	-0.965* (22.00-28.46)	-0.804* (21.50-27.00)	-0.866* (21.75-27.37)	-0.983* (21.50-27.25)	-0.933* (21.50-26.75)	-0.947* (23.36-28.09)
Average r.h.%	-0.678* (50.00-79.00)	-0.673 (55.00-68.50)	-0.884* (58.00-62.00)	-0.225 (54.00-78.00)	-0.468 (56.00-76.00)	-0.493 (52.43-67.00)	-0.298 (59.00-74.00)	-0.856* (55.75-71.87)

* Significant

Figure in parenthesis indicate prevailing temperature (^{0}C) and relative humidity (r.h.%) of respective stage of development and life cycle at the time of rearing observed 2.15 days on an average. The maximum preoviposition period 3.00 days was observed during December-January and the minimum being 1.12 days (Figure 4.2.3.4) during October-November (Table 4.2.3).

4.2.3.5 Oviposition period

This period was also varied with season. The female on an average laid egg for 3.72 days. The longest period was recorded 5.00 days during December-January (Figure 4.2.3.5) and the lowest was being 2.32 days during October-November (Table 4.2.3).

Both the preoviposition and oviposition period was significantly and negatively correlated with maximum, minimum and average temperature but average r.h. had non-significant negative correlation (Table 4.2.3a).

4.2.3.6 Adult longevity

Flies were minute, covered completely with a white waxy bloom. Females lived longer than the males.

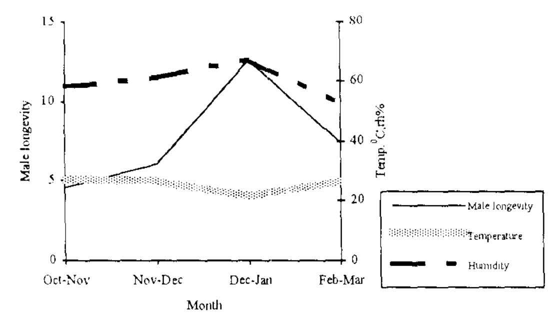


Fig 4.2.3.6a Male longevity of white fly (*Bemisia tabaci*)

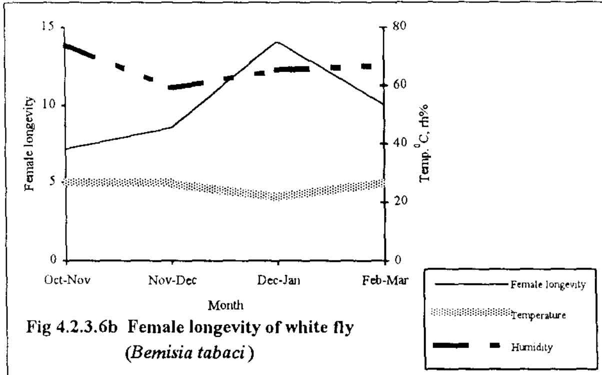


Fig 4.2.3.6b Female longevity of white fly (*Bemisia tabaci*)

The average longevity of adult male and female were recorded 7.59 and 9.91 days respectively. However during October-November it was 4.50 days while it was 12.50 days (Figure 4.2.3.6a) during December-January for male. The longevity of female was 14.00 days during December-January and 7.12 days during October-November (Figure 4.2.3.6b). From correlation studies it was observed that the longevity of male and female had a significant negative correlation with maximum, minimum and average temperature while average r.h. showed non-significant and negative correlation (Table 4.2.3 and 4.2.3a).

4.2.3.7 Life cycle

It was also varied with seasons; the minimum duration of the life cycle was recorded 19.57 days during October-November when temperature ranged 26.98 to 29.20^{0}C and average r.h. was 71.87%. The longest duration of life cycle (Figure 4.2.3.7) was recorded 40.00 days during December-January at 21.13 to 25.60^{0}C temperature and 60.58% average r.h.. The average duration of life cycle for four generation studied was 30.87 days. Duration of life cycle had significant negative correlation with maximum, minimum and average temperature and average r.h. (Table 4.2.3 and 4.2.3a).

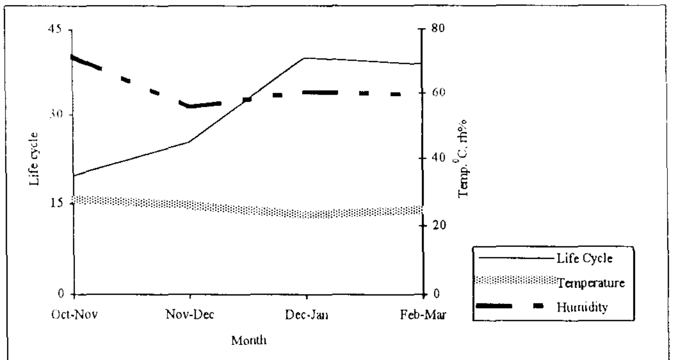


Fig 4.2.3.7 Life cycle period of white fly (*Bemisia tabaci*)

4.3 Assessment of Crop Loss of Tomato Caused by Important Insect-pests

4.3.1 Winter crop

This is the normal growing season of tomato. The relative occurrence of the pests as well as natural enemies during this season was lower than the other seasons. Since the crop is grown in normal growing season and suffered from low level of pest infestation growth and development was adequate resulted higher productivity to tomato. Details of the results on pest incidence, occurrence of natural enemies, extent of damage and assessment of crops loss is furnished below pest wise over varieties.

4.3.1.1. Open pollinated variety cv. Pusa Ruby

Aphid (*Aphis gossypii* Glover)

The population was recorded too low during winter season in all the three years (Table 4.3.1.1a-4.3.1.1d) studied.

Average aphid population in three years revealed that the combined insecticidal and fungicidal and insecticidal application alone suppressed the population significantly (0.08/leaf and 0.09/leaf respectively) over untreated control (0.27/leaf). Fungicidal application alone had no significant effect on suppression in aphid population (0.25/leaf) over untreated control (Table 4.3.1.1d).

White fly (*Bemisia tabaci* Genn.)

The white fly population was always lower in winter season but was recorded higher in 1996-97 as compared to 1997-98 and 1998-99 (Table 4.3.1.1a-4.3.1.1d). Pooled mean data of the three years observation showed that malathion @ 0.05% alone as well as in combination with dithane M-45 @ 2gm/l significantly suppressed the white fly population 0.23/plant and 0.20/plant respectively over untreated control (0.52/plant) and fungicidal treatment alone (0.49/plant) (Table 4.3.1.1d).

Leaf miner (*Liriomyza trifolii* Burgess)

Infestation of leaf miner *(Liriomyza trifolii)* was low in all the three years studied, but relatively higher level of attack was observed in 1996-97 (Table 4.3.1.1a-4.3.1.1d).

Pooled mean data of three years revealed that application of malathion @ 0.05% and in combination with fungicide dithane M-45 @ 2gm/l resulted in significant suppression of leaf miner infestation (1.13% and 1.03%

Table 4.3.1.1a Level of pest population and assessment of crop loss of open pollinated variety (Pusa Ruby) of tomato (winter season) in 1996-97

Treatments	Aphid / leaf	Whitefly / plant	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.31 (0.90)	0.78 (1.13)	2.35 (1.68)	8.68 (3.08)	7.80 (2.82)	0.47 (0.98)	0.61 (1.05)	42.26	-	-
Insecticidal control	0.11 (0.78)	0.40 (0.95)	1.50 (1.41)	5.02 (2.35)	4.52 (2.24)	0.25 (0.87)	0.29 (0.89)	48.47	Sig (t=3.23)	12.81
Fungicidal control	0.29 (0.89)	0.75 (1.12)	2.30 (1.67)	8.73 (3.04)	7.74 (2.87)	0.45 (0.97)	0.55 (1.02)	46.36	N.S. (t=2.416)	8.84
Insecticidal and Fungicidal control	0.10 (0.77)	0.35 (0.92)	1.35 (1.36)	4.98 (2.34)	4.38 (2.21)	0.20 (0.84)	0.25 (0.87)	53.17	Sig (t=4.345)	20.52
SEM (±)	0.007	0.023	0.039	0.018	0.055	0.032	0.070	1.389	-	-
CD at 5%	0.021	0.071	0.117	0.056	0.168	0.098	0.214	4.251		

Figure in parenthesis indicate square root transformed value

Table 4.3.1.1b Level of pest population and assessment of crop loss of open pollinated variety (Pusa Ruby) of tomato (winter season) in 1997-98

Treatments	Aphid / leaf	Whitefly / plant	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.21 (0.84)	0.36 (0.94)	1.20 (1.30)	5.50 (2.45)	5.00 (2.35)	0.18 (0.82)	0.68 (1.09)	33.33	-	-
Insecticidal control	0.07 (0.75)	0.16 (0.82)	1.03 (1.24)	3.39 (1.97)	3.00 (1.87)	0.10 (0.77)	0.32 (0.91)	36.79	Sig (t=4.396)	9.40
Fungicidal control	0.19 (0.83)	0.33 (0.93)	1.11 (1.27)	5.30 (2.41)	4.75 (2.29)	0.16 (0.81)	0.58 (1.04)	38.62	Sig (t=3.987)	13.70
Insecticide and Fungicidal control	0.05 (0.74)	0.14 (0.81)	0.90 (1.19)	3.21 (1.93)	2.85 (1.83)	0.09 (0.77)	0.30 (0.89)	42.00	Sig (t=4.714)	20.53
SEM (±)	0.006	0.010	0.020	0.032	0.034	0.030	0.060	1.236		
CD at 5%	0.021	0.029	0.060	0.095	0.104	0.092	0.184	3.783		

Figure in parenthesis indicate square root transformed value

Table 4.3.1.1c Level of pest population and assessment of crop loss of open pollinated variety (Pusa Ruby) of tomato (winter season) in 1998-99

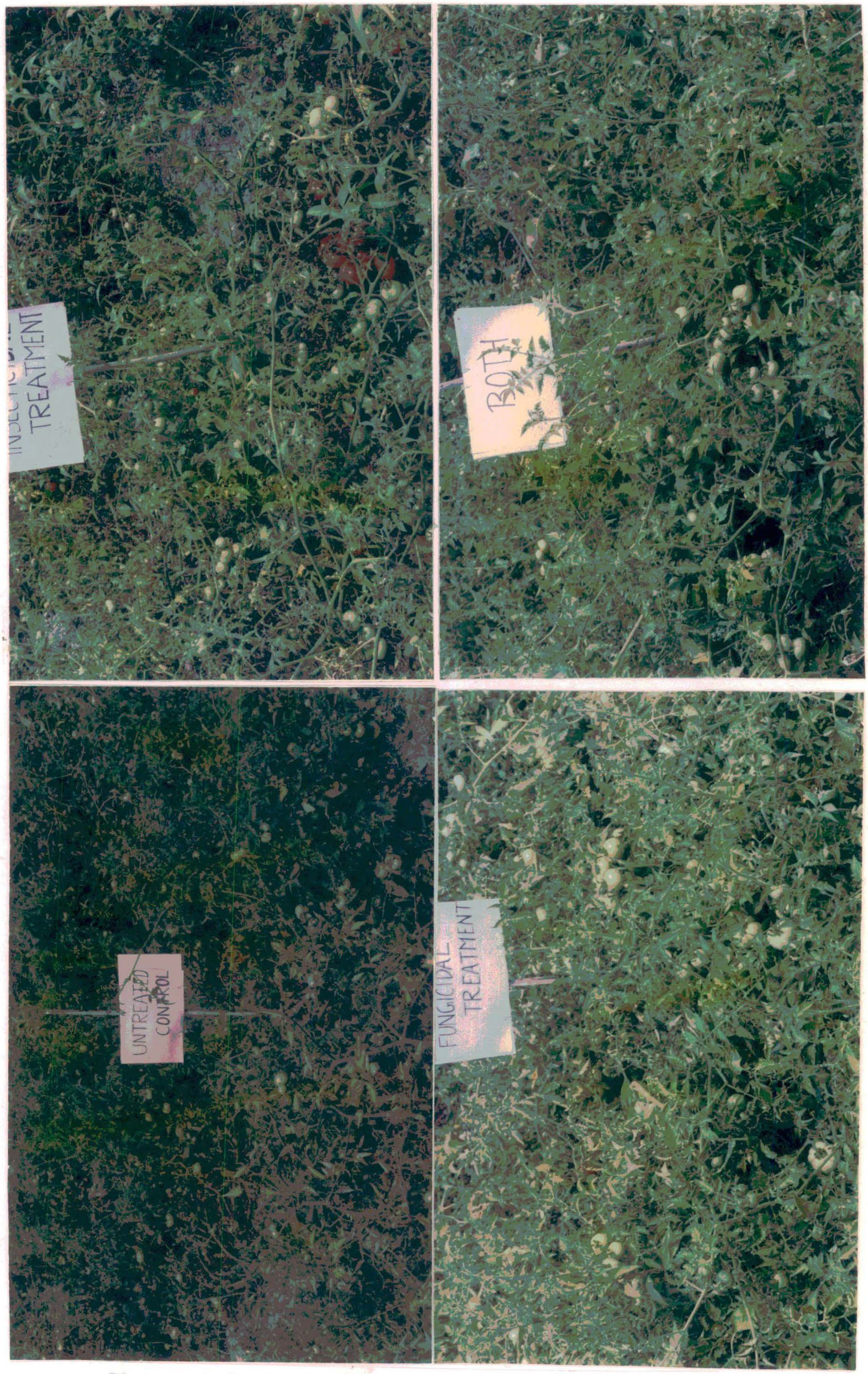
Treatments	Aphid / leaf	White fly / plant	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.29 (0.89)	0.38 (0.94)	1.35 (1.36)	6.96 (2.73)	6.32 (2.61)	0.20 (0.84)	0.75 (1.12)	54.65	-	-
Insecticidal control	0.09 (0.77)	0.12 (0.79)	0.85 (1.16)	3.89 (2.10)	3.53 (2.01)	0.10 (0.77)	0.37 (0.93)	60.67	Sig (t=5.267)	9.59
Fungicidal control	0.27 (0.88)	0.35 (0.92)	1.29 (1.34)	6.84 (2.71)	6.21 (2.59)	0.19 (0.83)	0.69 (1.09)	56.87	N.S. (t=2.20)	3.55
Insecticide and Fungicidal control	0.08 (0.76)	0.10 (0.77)	0.83 (1.15)	3.69 (2.05)	3.35 (1.96)	0.08 (0.76)	0.33 (0.91)	62.61	Sig (t=6.067)	12.39
SEM (±)	0.006	0.006	0.011	0.021	0.007	0.028	0.056	1.238	-	-
CD at 5%	0.018	0.018	0.033	0.064	0.021	0.086	0.171	3.[788		

Figure in parenthesis indicate square root transformed value

Table 4.3.1.1d Level of pest population and assessment of crop loss of open pollinated variety (Pusa Ruby) of tomato (winter season) in (pooled mean of three years)

Treatments	Aphid / leaf	White fly / plant	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.27 (0.88)	0.52 (1.04)	1.63 (1.46)	7.05 (2.75)	6.37 (2.62)	0.28 (0.89)	0.68 (1.09)	43.48	-	-
Insecticidal control	0.09 (0.77)	0.23 (0.87)	1.13 (1.28)	4.10 (2.14)	3.68 (2.04)	0.15 (0.81)	0.33 (0.91)	48.65	Sig (t=6.46)	10.63
Fungicidal control	0.25 (0.87)	0.49 (1.02)	1.57 (1.44)	6.96 (2.73)	6.24 (21.60)	0.27 (0.88)	0.61 (1.05)	47.28	Sig (t=5.00)	8.04
Insecticide and Fungicidal control	0.08 (0.76)	0.20 (0.85)	1.03 (1.24)	3.96 (2.11)	3.53 (2.01)	0.12 (0.79)	0.29 (0.89)	52.59	Sig (t=8.93)	17.32
SEM (±)	0.005	0.011	0.016	0.021	0.022	0.025	0.048	0.774	-	-
CD at 5%	0.016	0.034	0.050	0.063	0.067	0.076	0.147	2.368		

Figure in parenthesis indicate square root transformed value



Photograph showing different treatments of yield loss assessment of tomato crop on open pollinated variety (Pusa Ruby)

Fruit borer (*Helicoverpa armigera* Hubner)

Fruit boring, caused by *Helicoverpa armigera,* was also low during winter crop, however, its infestation was at a lower level in 1997-98 as compared to 1996-97 and 1998-99 (Table 4.3.1.1a-4.3.1.1d).

Analysis of pooled data of three years showed that although dithane M-45 @ 2gm/l application alone had no significant effect on the suppression of fruit borer (in number) (6.96%) over untreated control (7.05%) but its combination with malathion @ 0.05% suppressed the infestation to a level of 3.96% (in number) over untreated control, followed by malathion @ 0.05% alone (4.10%). Similarly only 3.68% and 3.53% bored fruits by weight was obtained from malathion @ 0.05% alone and its combination with dithane M-45 @ 2gm/l over untreated control (6.37%) (Table 4.3.1.1d).

Natural enemies

M. sexmaculata and spiders of different species were the most dominant predators recorded during the course of investigation on tomato crops (Table 4.3.1.1a-4.3.1.1d). In general the population level was always lower but the number was further lowered in malathion treated plots as compared to the untreated ones.

Yield and gain over control

In 1997-98, though the pest population was lower but yield was also lower as compared to other two years. In this year 42.00 t/ha, 38.62 t/ha, 36.79 t/ha and 33.33 t/ha (Table 4.3.1.1a) yield was obtained from insecticidal, fungicidal and their combined treatment and untreated control respectively. Average yield for three years from insecticidal control resulted significantly higher (48.65 t/ha) than in untreated control (43.48 t/ha), where as, fungicide alone also yielded higher which might be due to control of disease which ultimately reflected in elevated yield of tomato (47.28 t/ha). The combined effect of both the insecticide and fungicide together resulted in significantly higher yield of tomato. (52.59 t/ha) which certainly due to simultaneous suppression of pests and diseases. (Table 4.3.1.1d).

Gain in yield over control was varied in years. The maximum percentage of gain in yield due to insecticide application over control was obtained in 1996-97 (12.81%) followed by 9.59% and 9.40% during 1998-99 and 1997-98 respectively. (Table 4.3.1.1a-4.3.1.1d).

However, gain in yield over control was recorded significantly higher during 1996-97 and 1997-98 (20.52 and 20.53% respectively) which might be due to combined suppression of pests and diseases more particularly due to severity of diseases on these two years. Under present investigation on an average 10.63% yield was gained from insecticidal application over control and 17.32% from combined application of both insecticide and fungicide. (Table 4.3.1.1d).

4.3.1.2. Hybrid cv. Abinash-II

Aphid (*Aphis gossypii* Glover)

In case of hybrid, aphid population was lower in all the years studied (Table 4.3.1.2a-4.3.1.2d). Highly significant suppression of aphid population was observed from insecticidal and combined insecticidal and fungicidal application (0.07/leaf and 0.05/leaf) as against the untreated one (0.24/leaf).

White fly (*Bemisia tabaci* Genn.)

The white fly population was recorded higher in 1996-97 over other two years (Table 4.3.1.2a-4.3.1.2d). From the pooled mean data (Table 4.3.1.2d) it was observed that malathion @ 0.05% alone and in combination with dithane M-45 @ 2 gm/l lowered down the pest population significantly (0.12/plant and 0.10/plant) over untreated control (0.34/plant).

Leaf miner (*Liriomyza trifolii* Burgess)

Leaf miner population was moderate in all the three years (Table 4.3.1.2a-4.3.1.2d), but a relatively, higher population was observed in 1996-97. From the analysis of pooled mean data of three years (Table 4.3.1.2d) it was found that malathion @ 0.05% alone and in combination with dithane M-45 @ 2gm/l significantly suppressed the leaf miner population to 3.50% and 3.69% respectively over untreated control (5.33%).

Fruit borer (*Helicoverpa armigera* Hubner)

Out of three years studies fruit borer infestation was higher in 1996-97, as compared to 1997-98 and 1998-99. (Table 4.3.1.2a-4.3.1.2d). Pooled mean data for three years (Table 4.3.1.2d) revealed that significantly higher suppression of fruit borer (4.09% in no., 3.94% in wt. and 3.87% in no., 3.77% in wt. respectively) was obtained from malathion @ 0.05% and its combination with dithane M-45 @ 2gm/l over untreated control (7.62% in no. and 7.42 in wt.) which was directly reflected on the higher gain in fruit yield over untreated control.

Natural enemies

Insecticidal spray not only suppressed the pest population but also adversely affect the natural enemy population, however, natural enemy population was in general at a low level in plots where pesticides were applied (Table 4.3.1.2a-4.3.1.2d).

Table 4.3.1.2a Level of pest population and assessment of crop loss of hybrid (Abinash-II) of tomato (winter season) in 1996-97

Treatments	Aphid / leaf	White fly / plant	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.26 (0.87)	0.60 (1.05)	6.56 (2.66)	9.00 (3.08)	8.69 (3.03)	0.43 (0.96)	0.52 (1.02)	74.00	-	-
Insecticidal control	0.07 (0.75)	0.23 (0.85)	4.23 (2.17)	5.10 (2.37)	4.92 (2.33)	0.21 (0.84)	0.23 (0.86)	85.36	Sig (t=8.94)	13.31
Fungicidal control	0.24 (0.86)	0.58 (1.04)	6.45 (2.64)	8.98 (3.08)	8.65 (3.02)	0.37 (0.94)	0.49 (0.90)	82.32	Sig (t=4.78)	10.11
Insecticide and Fungicidal control	0.06 (0.75)	0.20 (0.84)	4.08 (2.14)	5.00 (2.35)	4.82 (2.31)	0.18 (0.82)	0.20 (0.83)	92.87	Sig (t=12.38)	20.32
SEM (±)	0.016	0.006	0.030	0.030	0.078	0.056	0.056	0.761	-	-
CD at 5%	0.047	0.020	0.090	0.090	0.239	0.171	0.171	2.329		

Figure in parenthesis indicate square root transformed value

Table 4.3.1.2b Level of pest population and assessment of crop loss of hybrid (Abinash-II) of tomato (winter season) in 1997-98

Treatments	Aphid / leaf	White fly / plant	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.21	0.18	4.23	6.01	5.89	0.14	0.58	62.33	-	-
	(0.84)	(0.82)	(2.17)	(2.55)	(2.53)	(0.80)	(1.04)			
Insecticidal control	0.05	0.05	3.58	2.78	2.72	0.08	0.28	69.25	Sig	9.93
	(0.74)	(0.74)	(2.02)	(1.81)	(1.79)	(0.76)	(0.88)		(t=4.046)	
Fungicidal control	0.19	0.17	4.10	5.80	5.82	0.13	0.54	72.45	Sig	13.97
	(0.83)	(0.82)	(2.14)	(2.51)	(2.51)	(0.79)	(1.02)		(t=7.047)	
Insecticide and	0.04	0.04	3.30	2.62	2.57	0.07	0.24	80.66	Sig	22.73
Fungicidal control	(0.73)	(0.73)	(1.95)	(1.76)	(1.75)	(0.75)	(0.86)		(t=10.93)	
SEM (±)	0.006	0.004	0.025	0.029	0.048	0.012	0.032	1.227	-	-
CD at 5%	0.017	0.013	0.076	0.087	0.147	0.037	0.098	3.757		

Figure in parenthesis indicate square root transformed value

Table 4.3.1.2c Level of pest population and assessment of crop loss of hybrid (Abinash-II) of tomato (winter season) in 1998-99

Treatments	Aphid / leaf	White fly / plant	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.25 (0.87)	0.23 (0.85)	5.21 (2.39)	7.85 (2.39)	7.69 (2.86)	0.16 (0.81)	0.52 (1.01)	84.91	-	-
Insecticidal control	0.08 (0.76)	0.07 (0.75)	3.26 (1.94)	4.39 (2.21)	4.17 (2.16)	0.10 (0.77)	0.23 (0.85)	94.25	Sig (t=5.076)	9.91
Fungicidal control	0.23 (0.85)	0.21 (0.84)	5.12 (2.37)	7.80 (2.88)	7.64 (2.85)	0.15 (0.81)	0.49 (0.99)	89.27	Sig (3.89)	4.88
Insecticide and Fungicidal control	0.06 (0.75)	0.06 (0.75	3.11 (1.90)	4.00 (2.12)	3.92 (2.10)	0.09 (0.77)	0.20 (0.84)	98.20	Sig (9.04)	13.53
SEM (±)	0.006	0.008	0.020	0.023	0.031	0.018	0.028	0.940	-	-
CD at 5%	0.017	0.025	0.060	0.069	0.095	0.055	0.086	2.877		

Figure in parenthesis indicate square root transformed value

Table 4.3.1.2d Level of pest population and assessment of crop loss of hybrid (Abinash-II) of tomato (winter season) (pooled mean of three years)

Treatments	Aphid / leaf	White fly / plant	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.24 (0.86)	0.34 (0.92)	5.33 (2.41)	7.62 (2.85)	7.42 (2.81)	0.24 (0.86)	0.57 (1.03)	73.75	-	-
Insecticidal control	0.07 (0.75)	0.12 (0.79)	3.69 (2.05)	4.09 (2.14)	3.94 (2.11)	0.13 (0.79)	0.26 (0.87)	82.95	Sig (t=7.67)	11.09
Fungicidal control	0.22 (0.85)	0.32 (0.91)	5.22 (2.39)	7.53 (2.83)	7.37 (2.81)	0.22 (0.84)	0.53 (1.01)	81.01	Sig (t=5.937)	9.34
Insecticide and Fungicidal control	0.05 (0.74)	0.10 (0.77)	3.50 (2.00)	3.87 (2.09)	3.77 (2.07)	0.11 (0.78)	0.23 (0.85)	90.53	Sig (t=14.69)	18.58
SEM (±)	0.005	0.003	0.014	0.018	0.025	0.021	0.029	0.402	-	-
CD at 5%	0.014	0.019	0.045	0.056	0.076	0.064	0.089	1.228		

Figure in parenthesis indicate square root transformed value

Yield and gain over control

Inter year variation in yield of tomato (Table 4.3.1.2a-4.3.1.2d) was observed under present studies and the yield was higher (84.91-98.20 t/ha) in 1998-99. Suppression of insect-pests through the use of insecticide (malathion @0.05%) always resulted higher yield than fungicide alone, except 1997-98, where higher yield was obtained due to control of disease (72.45 t/ha) rather than insect control (69.25 t/ha).

From the foregoing discussion on incidence of different pests it is found that yield of tomato was directly related with abundance of different pests. Incidence of different pests species, their relative abundance in different year under different management practices showed highly significant variation in yield of tomato. Thus, it can, therefore, be said in other words that 11.09% loss in tomato yield can be avoided or can be saved from the application of recommended insecticide, 9.34% from fungicide and 18.58% from both insecticide and fungicide.

4.4.2 Spring-summer crop

Spring-summer is the out of normal crop growing season of tomato practised in some pockets of terai region more particularly after the introduction of hybrids. Also some open pollinated variety like Pusa Ruby has been raised during off-season. Growth of plant vis-à-vis productivity of tomato at this season are far below than in normal crop growing season. The pest structure as well as magnitude of pest infestation was somehow different and also higher. The insect pests in this season were namely tingid bug (*Urentius hystricellus* Richt) leaf miner (*Liriomyza trifolii* Burgess) and fruit borer (*Helicoverpa armigera* Hubner) only. The relative occurrence of different insect-pest species, and their natural enemies, extent of damage and assessment of loss caused by them in a complex on two different varieties having different genetical make up is described below.

4.3.2.1 Open pollinated variety cv. Pusa Ruby

Tingid bug (*Urentius hystricellus* Richt)

The population of tingid bug (*Urentius hystricellus* Richt.) was moderate in all the three years studied. In 1997-98 , the population level was higher than other two years. (Table 4.3.2.1a-4.3.2.1d) Pooled mean data of the three years showed that malathion @0.05% suppressed tingid bug population significantly (0.55/leaf), although the lowest population being recorded from combined application of malathion 0.05% and dithane M-45 @ 2gm/l (0.51/leaf) over untreated control

Table 4.3.2.1a Level of pest population and assessment of crop loss of open pollinated variety (Pusa Ruby) of tomato (spring-summer season) in 1996-97

Treatments	Tingid bug / leaf	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	*Coccinella* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	1.16	20.37	13.37	12.52	0.23	0.20	0.90	17.22	-	-
	(1.29)	(4.57)	(3.72)	(3.61)	(0.85)	(0.84)	(1.18)			
Insecticidal control	0.53	13.00	8.50	7.90	0.12	0.12	0.45	22.93	Sig	24.90
	(1.01)	(3.67)	(3.00)	(2.90)	(0.79)	(0.79)	(0.97)		(t=18.66)	
Fungicidal control	1.10	20.00	12.78	11.90	0.21	0.19	0.86	20.37	Sig	15.44
	(1.26)	(4.53)	(3.64)	(3.52)	(0.84)	(0.83)	(1.17)		(t=7.50)	
Insecticide and	0.50	12.87	8.23	7.71	0.10	0.10	0.42	25.11	Sig	31.42
Fungicidal control	(1.00)	(3.66)	(2.95)	(2.87)	(0.77)	(0.77)	(0.96)		(t=23.14)	
SEM (±)	0.008	0.133	0.033	0.028	0.019	0.013	0.006	0.292	-	-
CD at 5%	0.026	0.399	0.099	0.085	0.058	0.039	0.018	0.892		

Figure in parenthesis indicate square root transformed value

Table 4.3.2.1b Level of pest population and assessment of crop loss of open pollinated variety (Pusa Ruby) of tomato (spring-summer season) in 1997-98

Treatments	Tingid bug / leaf	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	*Coccinella* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	1.64	22.87	11.50	10.00	0.27	0.25	0.87	10.00	-	-
	(1.46)	(4.83)	(3.46)	(3.24)	(0.88)	(0.87)	(1.17)			
Insecticidal control	0.84	15.10	7.50	6.50	0.13	0.12	0.47	13.23	Sig	24.41
	(1.16)	(3.95)	(2.83)	(2.65)	(0.79)	(0.78)	(0.98)		(t=13.08)	
Fungicidal control	1.56	21.37	11.25	9.75	0.25	0.23	0.85	12.17	Sig	17.84
	(1.43)	(4.68)	(3.43)	(3.20)	(0.87)	(0.85)	(1.16)		(9.09)	
Insecticide and	0.76	15.00	7.25	6.32	0.11	0.10	0.43	14.60	Sig	31.51
Fungicidal control	(1.12)	(3.94)	(2.78)	(2.61)	(0.78)	(0.77)	(0.96)		(t=16.65)	
SEM (±)	0.010	0.034	0.024	0.030	0.025	0.008	0.003	0.237	-	-
CD at 5%	0.031	0.105	0.074	0.092	0.076	0.024	0.009	0.727		

Figure in parenthesis indicate square root transformed value

Table 4.3.2.1c Level of pest population and assessment of crop loss of open pollinated variety (Pusa Ruby) of tomato (spring-summer season) in 1998-99

Treatments	Tingid bug / leaf	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	*Coccinella* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.86	16.87	8.20	7.45	0.24	0.10	0.95	18.68	-	-
	(1.16)	(4.17)	(2.96)	(2.82)	(0.86)	(0.77)	(1.20)			
Insecticidal control	0.29	7.20	4.88	4.45	0.12	0.06	0.43	24.00	Sig	22.17
	(0.89)	(2.77)	(2.32)	(2.22)	(0.78)	(0.75)	(0.96)		(t=15.03)	
Fungicidal control	0.83	16.67	8.00	7.25	0.23	0.09	0.90	20.65	Sig	9.54
	(1.15)	(4.14)	(2.92)	(2.78)	(0.85)	(0.77)	(1.18)		(t=8.92)	
Insecticide and Fungicidal control	0.27	7.00	4.67	4.25	0.10	0.05	0.40	26.55	Sig	29.64
	(0.88)	(2.74)	(2.27)	(2.18)	(0.77)	(0.74)	(0.95)		(t=16.46)	
SEM (±)	0.006	0.028	0.024	0.038	0.016	0.012	0.026	0.343	-	-
CD at 5%	0.017	0.087	0.072	0.116	0.049	0.037	0.049	1.050		

Figure in parenthesis indicate square root transformed value

Table 4.3.2.1d Level of pest population and assessment of crop loss of open pollinated variety (Pusa Ruby) of tomato (spring-summer season) (pooled mean of three years)

Treatments	Tingid bug / leaf	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	*Coccinella* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	1.22	20.04	11.02	9.99	0.25	0.18	0.91	15.30	-	-
	(1.31)	(4.53)	(3.39)	(3.24)	(0.86)	(0.83)	(1.19)			
Insecticidal control	0.55	11.77	6.96	6.28	0.12	0.10	0.45	20.05	Sig	23.69
	(1.02)	(3.50)	(2.73)	(2.60)	(0.80)	(0.77)	(0.97)		(t=13.53)	
Fungicidal control	1.16	19.35	10.68	9.63	0.23	0.17	0.87	17.73	Sig	13.71
	(1.29)	(4.46)	(3.34)	(3.18)	(0.85)	(0.82)	(1.17)		(t=12.33)	
Insecticide and	0.51	11.62	6.72	6.09	0.10	0.08	0.42	22.09	Sig	30.74
Fungicidal control	(1.00)	(3.48)	(2.69)	(2.57)	(0.77)	(0.76)	(0.96)		(t=37.97)	
SEM (±)	0.004	0.020	0.014	0.078	0.013	0.010	0.024	0.235	-	-
CD at 5%	0.011	0.061	0.043	0.238	0.039	0.030	0.073	0.719		

Figure in parenthesis indicate square root transformed value

(1.22/leaf). However, the fungicide, dithane-M-45 @ 2 gm/1 had no significant effect on suppression of tingid bug population.

Leaf miner (*Liriomyza trifolii* Burgess)

Leaf miner population was recorded highest during 1997-98 followed by 1996-97 and 1998-99(Table 4.3.2.1a-4.3.2.1d). Analysis of pooled data of three years revealed that malathion significantly suppressed the leaf miner population 11.77% than in the untreated control (20.04%) but could not protect the leaf from miner infestation fully.

Dithane M-45 in combination with malathion resulted best effect on population suppression (11.62%) although the difference from malathon alone was not significant. Role of fungicide on leaf miner population suppression, although very low , was also evidence when it was applied alone (19.35%) over untreated control (20.04%) and the difference was marginally significant.

Fruit borer (*Helicoverpa armigera* Hubner)

Fruit borer directly responsible for damaging tomato fruits was recorded proportionately higher in 1996-97 over the other two years. Analysis of pooled mean data for three years revealed that the level of bored fruit percentage (in number) due to application of malathion, dithane M-45 alone and their combination was significantly more (6.96%, 10.68% and 6.72% respectively) than untreated control (11.02%), and bored fruit (in weight) (6.28%, 9.63% and 6.09% respectively) over untreated one (9.99%). However, fungicide also had a little effect on fruit borer suppression.

Natural enemies

Composition of natural enemies like *M. sexmaculata., C. septempunctata* and spider of different species were significantly lower in malathion treated plots indicating killing of natural enemy population by insecticides and malathion can not be recognized as a safe insecticide (Table 4.3.2.1a-4.3.2.1d) to natural enemies.

Yield and gain over control

Higher pest population during 1997-98 resulted lower yield of tomato. Comparatively higher yield in 1996-97, 1998-99 was might be due to lower incidence of insect-pests (Table 4.3.2.1a-4.3.2.1d). So it can be said that the yield of tomato was directly related to the relative abundance of insect-pests. Analysis of pooled mean data showed that application of malathion not only suppressed the pest population but also augmented in yield of tomato. Thus significantly better yield was obtained through application of malathion

(20.05 t/ha) and being highest from combined malathion and dithane M-45 treated plot (22.09 t/ha) as compared to untreated control (15.30 t/ha). A yield of 17.73 t/ha was recorded from fungicide treated plots. This might be due to control of diseases that ultimately increased yield of tomato.

The incidence of different pest species, in different years under different management practices showed highly significant variation in yield of tomato fruits. It was observed from the above results that 23.69% and 13.71% gain in yield was obtained from application of insecticide and fungicide separately. However, higher gain in yield (30.74%) was obtained when both insecticide and fungicide were applied together. So, in other word it can be said that, 23.69%, 13.71% and 30.74% yield loss can be avoided by applying insecticide, fungicide and their combination (Table 4.3.2.1d).

4.3.2.2 Hybrid : Abinash-II

Tingid bug (*Urentius hystricellus* Richter)

Lower level of tingid bug population was observed in 1998-99 as compared to 1996-97, 1997-98 (Table 4.3.2.2a-4.3.2.2d). Analysis of data of three years (Table 4.3.2.2d) showed that the combined application of insecticide and fungicide lowered down tingid bug population (0.38/leaf) significantly over untreated control (0.94/leaf), whereas, insecticide and fungicide alone suppressed (0.41/leaf) and (0.89/leaf) bug population significantly as in case of untreated control (0.94/leaf).

Leaf miner (*Liriomyza trifolii* Burgess)

The infestation of serpentine leaf miner was high in all the three years but being higher in 1997-98, over other two years. (Table 4.3.2.2a-4.3.2.2d). From over all studies of three years (Table 4.3.2.2d) it is observed that malathion when applied alone or in combination with dithane M-45 suppressed at a level of 35.86% and 35.52% leaf mining respectively, over untreated control (60.36%). Fungicide alone had no significant effect on suppression of leaf miner and 59.36% damaged leaf was recorded from the plots treated with dithane M-45 @ 2gm/l.

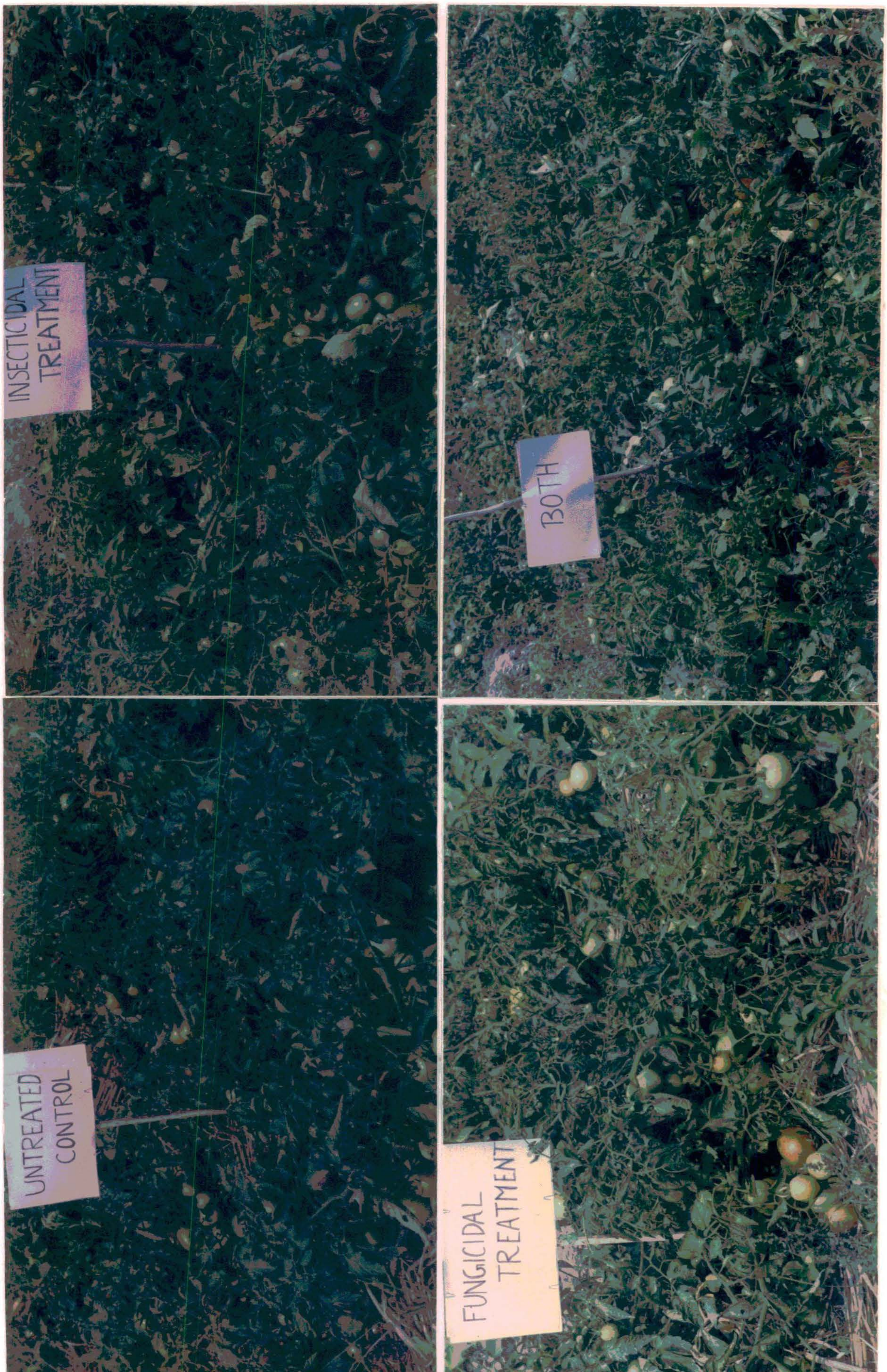
Fruit borer (*Helicoverpa armigera* Hubner)

Fruit damage due to borer was observed more in 1996-97 over the other two years (Table 4.3.2.2a-4.3.2.2d). Pooled mean data showed (Table 4.3.2.2d) that significantly lower fruit damage (in number) (8.29%, 7.79% and 12.68%) was recorded from insecticidal, fungicidal and their combined treated plots respectively over control (12.96%). Similarly 7.35% and 7.10% bored fruit (by wt.) was recorded from malathion treated plot as compared to

Table 4.3.2.2a Level of pest population and assessment of crop loss of hybrid (Abinash-II) of tomato (spring-summer season) in 1996-97

Treatments	Tingid bug / leaf	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	*Coccinella* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	1.02	61.97	14.85	13.91	0.20	0.16	0.80	41.00	-	-
	(1.23)	(51.93)	(3.92)	(3.80)	(0.84)	(0.81)	(1.14)			
Insecticidal control	0.48	40.90	9.70	8.17	0.11	0.09	0.36	56.00	Sig	26.79
	(0.99)	(39.76)	(3.19)	(2.94)	(0.78)	(0.77)	(0.93)		(t=8.89)	
Fungicidal control	0.98	61.10	14.22	13.75	0.18	0.15	0.75	45.78	Sig	10.44
	(1.22)	(51.41)	(3.84)	(3.77)	(0.82)	(0.81)	(1.12)		(t=3.87)	
Insecticide and	0.45	40.12	9.18	8.00	0.09	0.08	0.33	61.70	Sig	33.55
Fungicidal control	(0.97)	(39.30)	(3.11)	(2.92)	(0.77)	(0.76)	(0.91)		(t=11.88)	
SEM (±)	0.011	0.497	0.070	0.052	0.013	0.011	0.020	1.101	-	-
CD at 5%	0.032	1.491	0.200	0.159	0.039	0.034	0.061	3.369		

Figure in parenthesis indicate square root and angular transformed value whichever applicable



Photograph showing different treatments of yield loss assessment of tomato crop on hybrid (Abinash-II)

Table 4.3.2.2b Level of pest population and assessment of crop loss of hybrid (Abinash-II) of tomato (spring-summer season) in 1997-98

Treatments	Tingid bug / leaf	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	*Coccinella* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
untreated	1.14	63.11	13.27	11.72	0.24	0.20	0.75	30.56	-	-
	(1.28)	(52.60)	(3.71)	(3.49)	(0.86)	(0.84)	(1.12)			
Insecticidal control	0.53	42.78	8.80	7.95	0.12	0.11	0.42	42.00	Sig	27.24
	(1.01)	(40.85)	(3.05)	(2.91)	(0.78)	(0.78)	(0.96)		(t=6.97)	
Fungicidal control	1.06	61.12	13.04	11.60	0.22	0.19	0.73	37.87	Sig	19.30
	(1.25)	(51.43)	(3.68)	(3.48)	(0.85)	(0.83)	(1.11)		(t=9.18)	
Insecticide and	0.50	43.12	8.20	7.65	0.10	0.10	0.39	47.78	Sig	36.04
Fungicidal control	(1.00)	(41.05)	(2.95)	(2.85)	(0.77)	(0.77)	(0.94)		(t=12.85)	
SEM (±)	0.011	0.702	0.039	0.042	0.055	0.006	0.023	1.252	-	-
CD at 5%	0.033	2.107	0.118	0.128	0.168	0.018	0.070	3.832		

Figure in parenthesis indicate square root and angular transformed value whichever applicable

Table 4.3.2.2c Level of pest population and assessment of crop loss of hybrid (Abinash-II) of tomato (spring-summer season) in 1998-99

Treatments	Tingid bug / leaf	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	*Coccinella* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.65 (1.07)	56.01 (48.45)	10.76 (3.36)	9.76 (3.20)	0.20 (0.84)	0.08 (0.76)	0.84 (1.16)	45.43	-	-
Insecticidal control	0.21 (0.84)	23.91 (29.27)	6.38 (2.62)	5.95 (2.54)	0.12 (0.78)	0.04 (0.73)	0.38 (0.94)	59.67	Sig (t=9.82)	23.86
Fungicidal control	0.63 (1.06)	55.85 (48.36)	10.78 (3.36)	9.72 (3.20)	0.19 (0.83)	0.07 (0.75)	0.80 (1.14)	50.85	Sig (t=4.90)	10.66
Insecticide and Fungicidal control	0.20 (0.84)	23.32 (28.88)	6.00 (2.55)	5.65 (2.48)	0.10 (0.77)	0.03 (0.73)	0.36 (0.93)	65.00	Sig (t=14.63)	30.11
SEM (±)	0.009	0.77	0.029	0.056	0.023	0.016	0.034	0.741	-	-
CD at 5%	0.028	2.32	0.088	0.171	0.070	0.049	0.104	2.267		

Figure in parenthesis indicate square root and angular transformed value whichever applicable

Table 4.3.2.2d Level of pest population and assessment of crop loss of hybrid (Abinash-II) of tomato (spring-summer season) (pooled mean of three years)

Treatments	Tingid bug / leaf	Mined leaf %	Bored fruit % in No.	Bored fruit % in Wt.	*Menochilus*/ plant	*Coccinella* /plant	Spider / plant	Yield (t/ha)	Value of significance	% gain over control
Untreated	0.94 (1.20)	60.36 (50.98)	12.96 (3.67)	11.80 (3.51)	0.21 (0.84)	0.15 (0.80)	0.80 (1.14)	39.00	-	-
Insecticidal control	0.41 (0.95)	35.86 (36.79)	8.29 (2.96)	7.35 (2.80)	0.12 (0.78)	0.08 (0.76)	0.39 (0.94)	53.18	Sig (t=10.27)	26.66
Fungicidal control	0.89 (1.18)	59.36 (50.39)	12.68 (3.63)	11.69 (3.49)	0.19 (0.83)	0.14 (0.80)	0.76 (1.12)	44.83	Sig (t=6.87)	13.01
Insecticide and Fungicidal control	0.38 (0.94)	35.52 (36.58)	7.79 (2.88)	7.10 (2.76)	0.09 (0.77)	0.07 (0.75)	0.36 (0.93)	58.16	Sig (t=18.60)	32.94
SEM (±)	0.004	0.39	0.034	0.068	0.031	0.008	0.013	0.598	-	-
CD at 5%	0.011	1.18	0.104	0.208	0.095	0.024	0.039	1.833		

Figure in parenthesis indicate square root and angular transformed value whichever applicable

control (11.80%) which ultimately resulted higher gain in fruit yield directly from malathion treated plots.

Natural enemies

Pooled data for the three years (Table 4.3.2.2a-4.3.2.2d) showed that insecticides not only suppressed insect pest population but also lowered down natural enemy population namely *M. sexmaculata,, C.septempunctata* and spider, which was in general at low level during the period of investigation.

Yield and gain over control

In 1998-99 relative abundance of pest population was lower as compared to other two years which was ultimately reflected on elevated yield of tomato. In 1997-98 yield was lowest which might be due to higher incidence of pests and diseases. (Table 4.3.2.2a-4.3.2.2d). Pooled mean data of three years (Table 4.3.2.2d) revealed that, the insecticidal application alone yielded significantly higher (53.18 t/ha) over untreated control (39.00 t/ha). Fungicide also resulted better yield (44.83 t/ha) over untreated one, as it control the disease, one of the important component cause yield loss. The combined application of the both insecticide and fungicide resulted significantly superior yield over all other treatments (58.16 t/ha) which was due to simultaneous suppression of pests and diseases together.

It is also observed from above results that 26.66% and 13.01% gain in yield was obtained from insecticidal and fungicidal measures respectively and combined malathion and dithane M-45 together resulted 32.94% gain in yield. So in other words it can be said that 26.66%, 13.01%and 32.94% yield loss can be avoided or saved by applying insecticide, fungicide and their combination respectively.

4.4. Evaluation of Tomato Varieties against Insect-Pests, Natural Enemies and Yield

Selection of crop varieties from available sources having multi-pest and disease resistant/tolerant builds up the basic component of integrated pest management over which other feasible components can be articulated. Use of tolerant, even less susceptible varieties always bear less number of insect-pest and thereby can be suppressed easily with various other means befitting pest management. Growing of tolerant varieties, at least less susceptible ones is not only economically viable to the resource poor farmers but also easily adaptable and is a sustainable strategy.

In view of foregoing discussion seven tomato varieties predominant in different tomato growing areas in terai zone of West Bengal were primarily chosen for evaluation under present investigation, to find out variety/varieties having high yield potential with low pest hazards, at least from key ones to achieve ultimate objective of incorporation of tolerant/ less susceptible variety/varieties, as a basic component for future IPM programme. Keeping parity with the objective delineated above, the experiment was conducted during 1996-1999 in winter season (normal growing season). Among the different insect-pests attacking tomato, aphid (*Aphis gossypii* Glover), white fly *(Bemisia tabaci* Genn.), leaf miner (*Liriomyza trifolii* Burgess) and tomato fruit borer (*Helicoverpa armigera* Hubner) were found potential ones, appeared in all the three years studied. In addition to insect-pests, their natural enemies namely, *M. sexmaculata* and various species of spiders active during the period were also observed. Therefore, insect-pests reaction on different tomato varieties and relative abundance of natural enemies along with yield of tomato from different varieties forms the present text, which is being discussed as follows.

The population of all the pest species under present investigation was always at a lower level since the crop was raised during winter season.

4.4.1 Aphid (*Aphis gossypii* Glover)

Aphid population was also low and varied significantly among the varieties in all the years. In 1996-97 minimum aphid population was observed on Kubergeeta (0.22/leaf) closely followed by Rasika (0.23/leaf) which were significantly lower over all other varieties studied. Population level was significantly highest on Pusa Ruby (0.33 /leaf) followed by Divya (0.30/leaf) (Table 4.4.1).

Photograph showing different tomato cultivars.

In 1997-98, aphid population in general was lower and minimum aphid population was recorded on Arjuna (0.15/leaf) closely followed by Kubergeeta (0.16/leaf). The aphid population on these two varieties was significantly lower over other varieties. Significantly highest population was again observed on Pusa Ruby (0.25 aphid/leaf), followed by Divya (0.23/leaf) (Table 4.4.2).

In 1998-99, lower aphid population was again observed on Kubergeeta (0.20 aphid/leaf) which was closely followed by Rasika (0.21/leaf). The difference in aphid population between these two varieties over others was significant. The highest population was observed on Pusa Ruby (0.29/leaf) which was again followed closely with Divya and difference over other varieties was significant (Table 4.4.3).

Analysis of pooled mean data for three years revealed that the aphid population although in general was at a lower level (Figure 4.4.1) but significantly lower population was observed on Kubergeeta (0.19/leaf), closely followed by Rasika (0.20/leaf). This result was consistent in all the three years studied. Similarly, like three individual years significantly highest aphid population was recorded on Pusa Ruby (0.29/leaf), followed by Divya (0.27 aphid/leaf) (Table 4.4.4).

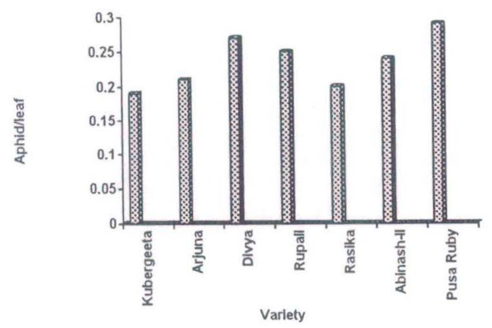


Fig.4.4.1 : Evaluation of varieties against aphid *Aphis gossypii* Glov.)

A comparative study on two sets of varieties (open pollinated and hybrid) revealed that open pollinated variety Pusa Ruby (0.29/leaf) under study was more susceptible to aphid population than hybrids (0.22-0.30/leaf). Aphid population in general; was observed lower on all hybrids but being lowest on Kubergeeta (0.19/leaf) and highest on Divya (0.27/leaf) among the hybrids. It can therefore, be said that among the hybrid under present studies Kubergeeta and Rasika were less susceptible/tolerant and Divya was more susceptible to aphid.

4.4.2 White fly (*Bemisia tabaci* Genn.)

Although white fly is an important and key pest of tomato particularly due to transmission of leaf curl viral disease but its population was always at a lower to moderate level in all the three years studied. However, white fly population was varied among the varieties in all the three years. In 1996-97

Photograph showing different tomato cultivars

Table 4.4.1 Evaluation of tomato varieties against insect-pests natural enemies and yield in 1996-97

Varieties	Aphid /leaf	White fly /plant	Mined Leaf %	Bored fruit% in no.	Bored fruit% in wt.	*Menochilus* /plant	Spider /plant	No. of fruits /plant	No. of bored fruit /plant	Ave. fruit wt.(gm)	Fruit wt per plant (kg)	Yield (t/ha)
Kubergeeta (F$_1$ Hybrid)	0.22 (0.84)	0.70 (1.10)	2.85 (1.83)	9.00 (3.08)	7.20 (2.77)	0.27 (0.88)	0.44 (2.77)	93.40	9.65	85.00	5.80	75.67
Arjuna (F$_1$ Hybrid)	0.26 (0.87)	0.73 (1.11)	2.45 (1.72)	13.21 (3.70)	10.56 (3.33)	0.24 (0.86)	0.40 (0.95)	79.64	10.50	112.67	6.80	82.14
Divya (F$_1$ Hybrid)	0.30 (0.89)	0.69 (1.09)	2.53 (1.74)	10.28 (3.28)	8.25 (2.96)	0.29 (0.89)	0.37 (0.93)	65.92	6.80	92.82	5.27	70.84
Rupali (F$_1$ Hybrid)	0.27 (0.88)	0.77 (1.13)	2.75 (1.80)	12.90 (3.66)	10.32 (3.29)	0.26 (0.87)	0.43 (0.96)	89.29	11.51	103.00	6.17	77.49
Rasika (F$_1$ Hybrid)	0.23 (0.85)	0.75 (1.12)	4.20 (2.17)	13.77 (3.78)	11.02 (3.39)	0.25 (0.87)	0.42 (0.96)	93.17	12.83	81.65	5.18	53.60
Abinash-II (F$_1$ Hybrid)	0.26 (0.87)	0.65 (1.07)	5.50 (2.45)	9.20 (3.11)	7.36 (2.80)	0.30 (0.89)	0.40 (0.95)	91.28	8.40	100.00	6.28	77.93
Pusa Ruby (Open Pollinated)	0.33 (0.91)	0.88 (1.17)	2.20 (1.64)	8.50 (3.00)	6.80 (2.70)	0.38 (0.94)	0.51 (1.00)	138.08	14.74	38.75	3.24	46.27
SEM (±)	0.007	0.009	0.038	0.034	0.049	0.024	0.030	1.7076	0.1768	1.442	0.063	1.038
CD at 5%	0.023	0.027	0.110	0.100	0.140	0.069	N.S	4.935	0.511	4.167	0.018	3.001

Figure in parenthesis indicate square root transformed value

significantly lowest white fly population (0.65/Plant) was recorded on Abinash-II and highest being on Pusa Ruby (0.88 White fly/plant) (Table 4.4.1).

In 1997-98 minimum population was observed both on Divya and Abinash II (0.18/plant) and highest being Pusa Ruby (0.36/plant). The white fly population in general was lower in this year (Table 4.4.2).

In 1998-99 low population level was again observed on Abinash-II (20/plant) closely followed by Divya (0.21/plant). The difference in population of these two varieties over others was significant. Highly significant white fly population was again observed on Pusa Ruby (0.38/plant) and among the hybrids higher population was recorded on Rupali (0.27 /plant) (Table 4.4.3).

Analysis of pooled data for three years studies revealed that significantly lowest population was observed on Abinash-II (0.34 /plant) (Figure 4.4.2) . In other words it can be said that Abinash-II was less susceptible to white fly. Pusa Ruby was observed most susceptible among the varieties studied and a significantly highest population (0.54/plant) was recorded on this variety (Table 4.4.4).

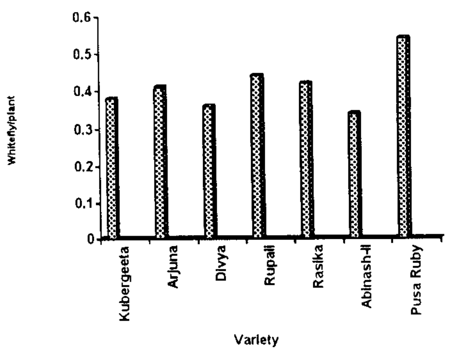


Fig.4.4.2 : Evaluation of varieties against white fly (*Bemisia tabaci* Genn.)

In can therefore, be said that among the two sets of varieties (open pollinated and hybrid) open pollinated (Pusa Ruby) was more susceptible than hybrids (0.34-0.44 /leaf) and among the hybrids Abinash-II was found least susceptible/tolerant over other hybrids and Rupali (0.44 /leaf) became more susceptible.

4.4.3 Leaf miner (*Liriomyza trifolii* Burgess)

Since the studies were made in normal crop growing season *i.e.* during winter, the level of infestation in general was lower. In 1996-97 significantly lowest leaf miner infestation was recorded on Pusa Ruby (2.20%), followed by Arjuna (2.45%). Significantly highest leaf miner infestation was recorded on Abinash-II (5.50%) followed by Rasika (4.20%) (Table 4.4.1).

In 1997-98, leaf miner infestation was in general lower which might be due to climatic influences. Pusa Ruby was again found significantly least sufferer (1.12%) and Abinash-II was recorded worst sufferer significantly from leaf miner over all other varieties studied (Table 4.4.2).

Like previous year, the activity of leaf miner in 1998-99 was in general lower. Significantly lowest leaf miner infestation (1.21%) was again observed on Pusa Ruby and highest being on Abinash-II (4.91%) (Table 4.4.3).

Studies from the pooled data of three years revealed that following consistently lower infestation from leaf miner Pusa Ruby (1.51%) became appeared as least susceptible to leaf miner which is also significantly superior over all other varieties studied, so far as leaf miner infestation is concerned. On the contrary, consistently higher leaf miner infestation was observed on Abinash-II, which ultimately reflected on pooled data (4.80%). Thus, Abinash-II can be considered as most susceptible to leaf miner (Figure 4.4.3). Although, leaf miner infestation was lower on Arjuna (1.73%), Divya (1.86%) and Rupali (1.96%) but the differences in level of infestation from Pusa Ruby (1.51%) was significant. It can, therefore, be said, that in general the hybrids were more susceptible to leaf miner than open pollinated, Pusa Ruby. However, among the hybrids Arjuna, Divya and Rupali was less susceptible to leaf miner infestation (Table 4.4.4).

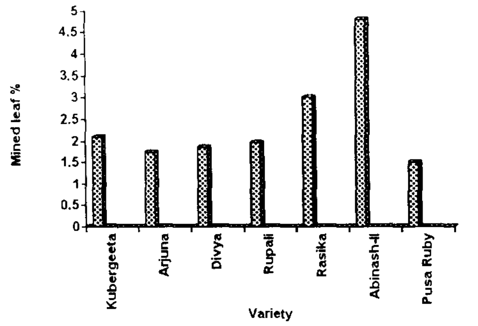


Fig.4.4.3 : Evaluation of varieties against Leaf miner (*Liriomyza trifolii* Burg.)

4.4.4 Fruit borer (*Helicoverpa armigera* Hubner)

4.4.4a Bored fruit (in number)

Bored fruit percentage (in number) varied over varieties in three years. In general higher fruit borer attack was recorded in 1996-97 over the other two years under present studies. Significantly lower fruit borer infestation was recorded in Pusa Ruby (8.50%) followed by Kubergeeta (9.00%) and Abinash-II (9.20%). The hybrid Rasika suffered maximum due to fruit borer infestation (13.77%), closely followed by Arjuna (13.21%) and Rupali (12.90) (Table 4.4.1).

In 1997-98, fruit borer infestation in general was lower as compared to other two years studied. Among the hybrids Rasika again showed more susceptibility against fruit borer and was recorded 8.30% bored fruit (in number) followed by Rupali (7.50%) and Arjuna (7.34%). Lowest fruit borer infestation was recorded on Kubergeeta (6.00%) and Abinash-II (6.21%) and

Table 4.4.2 Evaluation of tomato varieties against insect-pests natural enemies and yield in 1997-98

Varieties	Aphid/leaf	Whitefly/ plant	Mined leaf %	Bored fruit% in no.	Bored fruit% in wt.	*Menochilus* /plant	Spider/ plant	No. of fruits/ plant	No. of bored fruit/ plant	Ave. fruit wt.(gm)	Fruit wt. per plant (kg)	Yield (t/ha)
Kubergeeta (F_1 Hybrid)	0.16 (0.81)	0.22 (0.84)	1.50 (1.41)	6.00 (2.55)	4.68 (2.88)	0.08 (0.76)	0.45 (0.97)	56.43	3.82	83.67	4.59	60.00
Arjuna (F_1 Hybrid)	0.15 (0.81)	0.27 (0.88)	1.25 (1.32)	7.34 (2.80)	5.73 (2.50)	0.07 (0.75)	0.42 (0.96)	49.83	3.56	110.00	6.04	73.00
Divya (F_1 Hybrid)	0.23 (0.85)	0.18 (0.82)	1.35 (1.36)	6.67 (2.68)	5.20 (2.39)	0.10 (0.77)	0.40 (0.95)	39.82	2.66	90.00	4.33	58.21
Rupali (F_1 Hybrid)	0.22 (0.84)	0.28 (0.88)	1.42 (1.39)	7.50 (2.83)	5.85 (2.52)	0.09 (0.77)	0.46 (0.98)	54.69	4.10	100.00	5.05	63.44
Rasika (F_1 Hybrid)	0.17 (0.82)	0.25 (0.87)	2.60 (1.76)	8.30 (2.97)	6.47 (2.64)	0.08 (0.76)	0.45 (0.97)	61.25	4.52	80.00	4.90	50.69
Abinash-II (F_1 Hybrid)	0.21 (0.84)	0.18 (0.82)	4.00 (2.12)	6.21 (2.59)	4.84 (2.31)	0.10 (0.77)	0.48 (0.99)	55.89	3.47	100.00	5.22	64.80
Pusa Ruby (Open Pollinated)	0.25 (0.87)	0.36 (0.93)	1.12 (1.27)	5.20 (2.39)	4.06 (2.14)	0.15 (0.81)	0.54 (1.02)	101.10	5.00	37.21	2.60	34.28
SEM (±)	0.006	0.007	0.025	0.028	0.062	0.011	0.030	0.752	0.042	1.1716	0.018	1.240
CD at 5%	0.016	0.020	0.072	0.080	0.179	0.032	N.S	2.174	0.113	3.385	0.051	3.585

Figure in parenthesis indicate square root transformed value

there have no significant difference in level of infestation between two varieties. However, lowest fruit borer infestation was recorded on Pusa Ruby (5.20%) like other year (Table 4.4.2).

In 1998-99, Pusa Ruby was found least susceptible again to fruit borer attack (in number) (7.29%) and Rasika recorded maximum (9.00%). Divya (8.04%) and Rupali (8.09%) witnessed higher fruit borer infestation but difference in bored fruit percentage (in number) between two hybrids was non-significant (Table 4.4.3).

Analysis of pooled data of three years revealed (Figure 4.4.4a) that minimum fruit borer infestation was found on open pollinated variety, Pusa Ruby (7.00%) which was significantly lowest over all other varieties. Significantly higher fruit borer infestation was recorded from Rasika (10.36%) followed by Arjuna (9.58%) and Rupali (9.50%). Kubergeeta (7.60%) and Abinash-II (7.75%) was found moderately tolerant (Table 4.4.4).

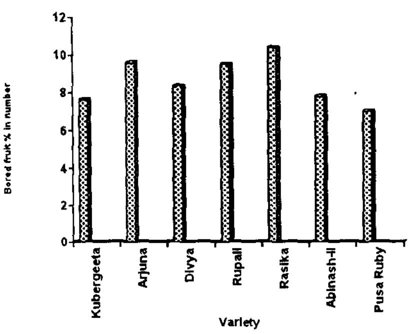


Fig.4.4.4a : Evaluation of varieties against fruit borer (*Helicoverpa armigera* Hb.)

4.4.4b Bored fruit (in weight)

Since bored fruit (in weight) is directly related with fruit boring in number, it followed almost similar pattern to that of fruit boring (in number).

There was marked difference of fruit borer infestation on weight basis among different varieties of tomato under present investigation. It is already been discussed that fruit borer infestation in general was more in 1996-97 over the other two years. Rasika was found severely attacked by this pest in all the years 11.02%, 6.47% and 7.38% in 1996-97, 1997-98, and 1998-99 respectively. Whereas, the open pollinated variety Pusa Ruby was found least (Figure 4.4.4b) susceptible against fruit borer in all the three years and accounted 6.80%, 4.06% and 5.98% fruit damage in weight respectively (Table 4.4.1-4.4.4).

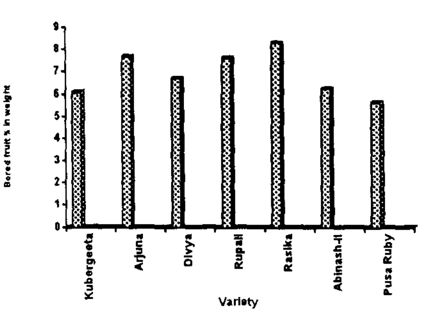


Fig.4.4.4b : Evaluation of varieties against fruit borer (*Helicoverpa armigera* Hb.)

Table 4.4.3 Evaluation of tomato varieties against insect-pests, natural enemies and yield in 1998-99

Varieties	Aphid /leaf	Whitefly/ plant	Mined leaf %	Bored fruit% in no.	Bored fruit% in wt.	*Menochilus*/ plant	Spider/ plant	No. of fruits/ plant	No. of bored fruit/plant	Ave. fruit wt.(gm)	Fruit wt. per plant (kg)	Yield (t/ha)
Kubergeeta (F$_1$ Hybrid)	0.20 (0.84)	0.22 (0.84)	1.92 (1.56)	7.80 (2.88)	6.40 (2.63)	0.11 (0.78)	0.54 (1.02)	96.00	7.50	85.65	6.93	90.60
Arjuna (F$_1$ Hybrid)	0.22 (0.84)	0.24 (0.86)	1.50 (1.41)	8.20 (2.95)	6.72 (2.69)	0.09 (0.77)	0.67 (1.08)	84.75	6.83	113.89	8.10	97.88
Divya (F$_1$ Hybrid)	0.28 (0.88)	0.21 (0.84)	1.69 (1.48)	8.04 (2.92)	6.59 (2.66)	0.13 (0.79)	0.54 (1.02)	67.75	5.42	92.75	6.28	84.41
Rupali (F$_1$ Hybrid)	0.25 (0.87)	0.27 (0.88)	1.70 (1.48)	8.09 (2.93)	6.63 (2.67)	0.09 (0.77)	0.62 (1.06)	93.05	7.33	102.23	7.35	92.34
Rasika (F$_1$ Hybrid)	0.21 (0.84)	0.25 (0.87)	2.23 (1.65)	9.00 (3.08)	7.38 (2.81)	0.10 (0.77)	0.57 (1.03)	98.07	8.20	81.65	6.17	63.87
Abinash-II (F$_1$ Hybrid)	0.25 (0.87)	0.20 (0.84)	4.91 (2.32)	7.85 (2.89)	6.44 (2.63)	0.11 (0.78)	0.60 (1.05)	95.08	7.21	100.07	7.48	92.86
Pusa Ruby (Open Pollinated)	0.29 (0.89)	0.38 (0.94)	1.21 (1.31)	7.29 (2.79)	5.98 (2.55)	0.18 (0.82)	0.71 (1.10)	143.80	10.42	38.60	3.86	55.14
SEM (±)	0.007	0.008	0.032	0.030	0.060	0.016	0.028	0.8416	0.2564	0.724	0.029	1.244
CD at 5%	0.020	0.023	0.092	0.086	N.S	0.046	0.081	2.432	0.7409	2.093	0.086	3.595

Figure in parenthesis indicate square root transformed value

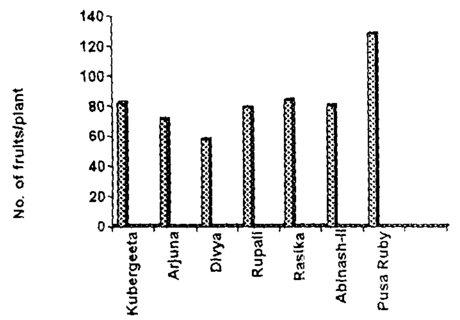


Fig. 4.4.8 No. of fruits/plant of different varieties

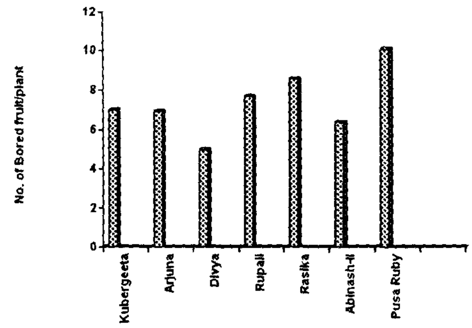


Fig. 4.4.9 No. of Bored fruit/plant of different varieties

The difference laying between two parameters namely fruit boring in number and weight might be due to size *i.e.* weight of individual fruits which is inherent character of any variety (Table 4.4.1-4.4.4).

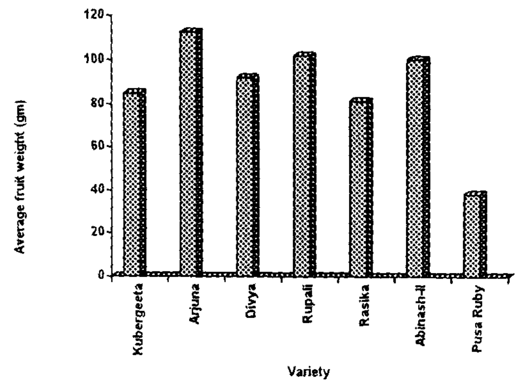


Fig. 4.4.10 Average fruit weight (gm) of different varieties

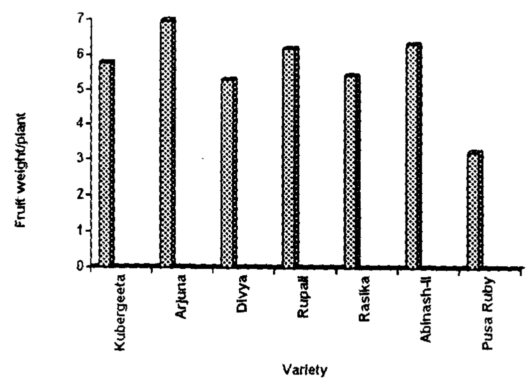


Fig. 4.4.11 Fruit weight/plant of different varieties

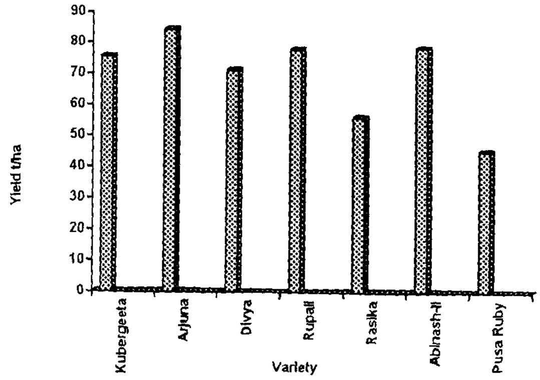


Fig. 4.4.12 Yield of different varieties

Since number, size as well as weight of fruit are the important yield attributes of tomato which are also inherent capacity of any variety. Therefore, number of fruits per plant and average fruit weight although varied over years but followed a similar pattern consistently in all the three years which has also been reflected in pooled mean data of three years. In Table 4.4.4 it is very prominent that number of fruits/plant varied significantly over the varieties. The highest significant number of fruits per plant was observed in Pusa Ruby (127.66) and the lowest being 57.83 on Divya. However, among the hybrids highest number of fruits was recorded on Rasika (84.16). It is

Table 4.4.4 Evaluation of tomato varieties against insect-pests, natural enemies and yield (pooled mean of three years)

Varieties	Aphid /leaf	Whitefly /plant	Mined Leaf %	Bored fruit% in no.	Bored fruit% in wt.	*Menochilus* /plant	Spider /plant	No. of fruits /plant	No. of bored fruit /plant	Ave. fruit wt.(gm)	Fruit wt per plant (kg)	Yield (t/ha)
Kubergeeta (F$_1$ Hybrid)	0.19 (0.83)	0.38 (0.94)	2.09 (1.61)	7.60 (2.85)	6.09 (2.57)	0.15 (0.81)	0.48 (0.99)	81.94	6.99	84.77	5.77	75.42
Arjuna (F$_1$ Hybrid)	0.21 (0.84)	0.41 (0.95)	1.73 (1.49)	9.58 (3.17)	7.67 (2.86)	0.13 (0.79)	0.50 (1.00)	71.40	6.93	112.19	6.98	84.34
Divya (F$_1$ Hybrid)	0.27 (0.88)	0.36 (0.93)	1.86 (1.54)	8.33 (2.97)	6.68 (2.68)	0.17 (0.82)	0.44 (0.97)	57.83	4.96	91.86	5.29	71.15
Rupali (F$_1$ Hybrid)	0.25 (0.87)	0.44 (0.97)	1.96 (1.57)	9.50 (3.16)	7.60 (2.85)	0.15 (0.81)	0.47 (0.98)	79.01	7.65	101.74	6.19	77.76
Rasika (F$_1$ Hybrid)	0.20 (0.84)	0.42 (0.96)	3.01 (1.87)	10.36 (3.30)	8.29 (2.96)	0.14 (0.80)	0.50 (1.00)	84.16	8.52	81.21	5.42	56.05
Abinash-II (F$_1$ Hybrid)	0.24 (0.86)	0.34 (0.94)	4.80 (2.30)	7.75 (2.87)	6.21 (2.59)	0.17 (0.82)	0.49 (0.99)	80.75	6.36	100.02	6.32	78.33
Pusa Ruby (Open Pollinated)	0.29 (0.89)	0.54 (1.02)	1.51 (1.42)	7.00 (2.74)	5.61 (2.47)	0.24 (0.86)	0.59 (1.04)	127.66	10.05	38.19	3.23	45.23
SEM (±)	0.004	0.007	0.015	0.020	0.024	0.012	0.019	1.101	0.158	1.113	0.037	0.630
CD at 5%	0.011	0.019	0.042	0.058	0.068	0.035	0.055	3.181	0.458	3.215	0.106	1.820

Figure in parenthesis indicate square root transformed value

interesting to note here that Arjuna though produced lower number of fruit per plant (71.40) but due to larger size of fruit as well as weight (112.19 gm) fruit yield per plant (6.98 Kg.) and yield (84.34 t/ha) was significantly highest. On the contrary Pusa Ruby though produced significantly largest number of fruits (127.66) but fruit weight per plant (3.23 Kg.) and yield was (45.23 t/ha) lowest due to smaller size vis-à-vis lower weight of fruit (38.19 gm). Abinash-II recorded 80.75 fruits/plant and yielded 78.33 t/ha closely followed by Rupali with 79.01 fruits/plant and 77.76 t/ha yield. It is interesting to note here that bored fruit in number and weight was though minimum on Pusa Ruby, from which it has been designated as less susceptible to borer but number of bored fruit per plant was at a maximum (10.05) even highly significant over all other varieties. On the contrary the number of bored fruit/plant was minimum on Divya (4.96) although it was designated as moderately susceptible to borer considering percentage of fruit boring in number (8.33%) and weight (6.68%). Therefore, based on number of fruit boring per plant Pusa Ruby was the most susceptible and Divya was less susceptible. Considering overall performance Arjuna and Abinash-II can be considered as better varieties because of their higher yield and less susceptibility to borer (Figure 4.4.8-4.4.12).

4.4.5 Natural enemies

Some naturally occurring insect parasites, predators, spiders and disease causing organisms play important role in natural suppression of pest population under field conditions. Like any living organisms, their activities though depend on prevalent weather condition but also varied with crop phenology as influenced by variety vis-à-vis availability and size of predator-prey population in crop ecosystem. Under present investigation population of dominant predators acting upon different insect species was taken into account. Among them *Menochilus sexmaculata.* and different species of spiders were more prominent during the course of investigation.

4.4.5a *Menochilus sexmaculata*

M. sexmaculata is a potential predator feeding upon aphids, thrips, white fly and other soft bodied insects. There was significant differences in predatory population on different varieties in all the three years. The population was comparatively higher in 1996-97 over other two years. In all the three years the open pollinated variety Pusa Ruby provided shelter of higher number of *M. sexmaculata* 0.38, 0.13 and 0.18 per plant respectively. On the contrary lower incidence of *M. sexmaculata* population was recorded on Arjuna 0.24, 0.07 and 0.09 per plant respectively. Higher population of *M. sexmaculata* on Pusa Ruby might be due to dense canopy (Figure 4.4.6) providing better shelter by the plants of the variety. Moreover, higher population of prey like aphid and white fly as witnessed on Pusa Ruby further favoured build up of higher predatory population (Table 4.4.1-4.4.4).

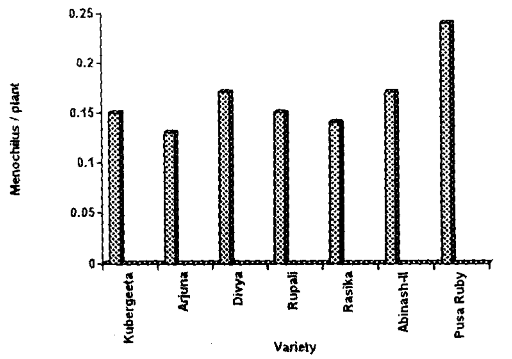


Fig.4.4.6 : Evaluation of varieties against *Menochilus* sp.

4.4.5b Spider

Unlike *M. sexmaculata* spider population in general were recorded higher in 1998-99 over 1997-98 and 1996-97 which might be due to antagonism between two predatory fauna or other factors like weather that also influence the size of population. Spider population was also varied significantly among the varieties over the years studied. Population of spider in general was found higher in varieties having more prey (insect-pests) population. Analysis of pooled mean data for three years revealed that maximum population was found on Pusa Ruby 0.59/plant. While the population in three years 1996-97, 97-98 and 98-99 were recorded and 0.51, 0.54 and 0.71 per plant respectively (Figure 4.4.7). The hybrid Divya showed minimum spider population per plant (0.44 only). While in three years it was recorded 0.37, 0.40 and 0.54 per plant during 1996-97, 1997-98 and 1998-99 respectively (Table 4.4.1-4.4.4).

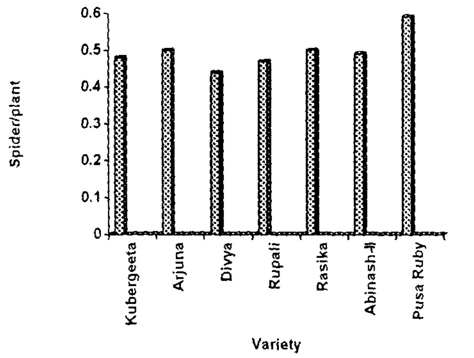


Fig 4.4.7 Evaluations of varieties against spider

It can, therefore, be said that because of dense canopy providing better shelter and higher prey-insect population on Pusa Ruby higher predatory population was recorded. With regard to years an interesting scene had been observed. A reverse level of population of two dominant predators *Menochilus* and spider was witnessed in the three years, which might be due to antagonism between two predatory faunas. However, it needs further investigation.

4.5. Management of Insect-Pest Complex of Tomato through Pesticides

Pesticides essentially are important tool and also indispensable to the modern agriculture. However, indiscriminate and judicious use of broad spectrum and highly toxic pesticides and its over dependence in agriculture pose a threat to the pest management system, human health and environment. The problem is more acute to the perishable vegetable crop like tomato, which are plucked at frequent interval and consume raw or after little cooking. In view of this the experiment has been conducted to evaluate the pesticides more effective against pest of tomato and safer to natural enemies, human health and environment. Keeping parity with the objectives delineated above pesticides of different origin have been evaluated. Among them two were synthetic organophosphate, namely malathion and DDVP, widely recommended for controlling pests of vegetables considering their shorter persistently and low mammalian toxicity to avoid residual toxic hazard from the fruits plucked at frequent interval. Rest of all were biologically originated and safer to human health and environment. Among them, azadirachtin, a botanical pesticide, *Bacillus thuringiensis* var. *kurstaki* a bacteria, pathogenic to insect, *Beauveria bassiana* an entomogenous fungus, nuclear polyhedrosis virus (NPV) an entomogenous virus and avermectin a microbial toxin produced by a soil actinomycetes species (*Streptomyces avermitilis*). Variation in relative efficacy among different pesticides over years indicates that some of them though do not control pest population totally but ultimately resulted in higher productivity of tomato. However, among the pesticides evaluated, avermectin and DDVP performed well in pest-suppression, which is reflected in yield also.

Among the different insect-pests considered for investigation, leaf miner and fruit borer was found to be the major ones causing damage to tomato plant (leaves) and fruits respectively. However aphid, white fly, jassid and hadda beetle population was lower even on untreated control, so they were regarded as the minor pest. Another, minor insect-pest tingid bug although present in small number but present althrough the season. Considering the relative potentialities to cause damage due to higher level of infestation, the discussion of the present experiment is concentrated mainly to the relative efficacy of the pesticides against the key pests namely leaf miner and fruit borer and the minor one tingid bug only.

4.5.1 Leaf miner (*Liriomyza trifolii* Burgess)

The newly introduced dipteran pest of tomato in India (Lakshminarayana *et al.* 1992; Pawar, 1992; Shankar *et al.* 1992 and Srinivasan 1992) damaged mostly the full grown plants and hamper the photosynthetic activity of the plants which ultimately leads in lower fruit yield (Jhonson *et al.* 1983). The difference in toxicity of pesticides and their efficacy at different days after spraying vis-à-vis interaction between pesticides and their efficacy on different time series against leaf miner population was significant in all the three years studied. The relative efficacy of pesticides in 1997-98 towards suppression of pest level was relatively lower over the other two years.

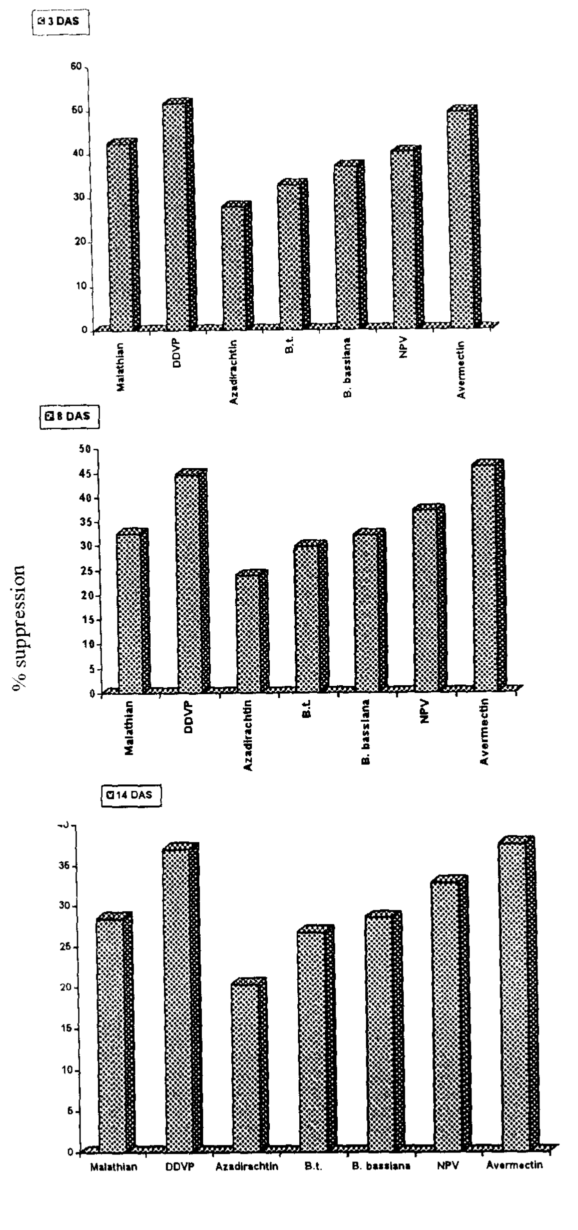


Fig. 4.5.1 Efficacy of pesticides against leaf miner (*Liriomyza trifolii* Burgess)

DDVP @ 0.05% and avermectin @ 0.01% among the seven pesticides studied provided maximum suppression of leaf miner population on tomato (Figure 4.5.1) (44.39% and 44.18% respectively), and there was no significant difference in the effectiveness between these two. NPV @ 250LE/ha, *Beauveria bassiana* @ 10^7 conidia/l and malathion @ 0.05% were found to suppress to a level of 36.60% , 32.41% and 34.41% leaf miner respectively but the effectivity among these treatments was non-significant . The minimum level of suppression was recorded from azadirachtin @ 1500ppm (24.13%) followed by Bacillus *thuringieusis* var. *kurstaki* (5 x 10^7 spores/mg) @ 1 gm./l (29.69%) control (Table 4.5.1).

Table 4.5.1 Efficacy of pesticides against leaf miner (*Liriomyza trifolii* Burgess) on tomato

Pesticides and their concentration	Suppression of population (%)															
	3 DAS				8 DAS				14 DAS				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Malathian @ 0.05%	42.67 (40.78)	38.98 (38.63)	45.33 (42.32)	**42.33 (40.59)**	33.21 (35.19)	29.94 (33.17)	34.33 (35.87)	**32.49 (34.75)**	27.78 (31.81)	24.76 (29.84)	32.67 (35.86)	**28.40 (32.20)**	34.55 (36.00)	31.23 (33.97)	37.44 (37.73)	**34.14 (35.92)**
DDVP @ 0.05%	53.73 (47.14)	45.32 (42.31)	56.06 (48.48)	**51.58 (45.90)**	46.39 (42.93)	39.62 (39.01)	47.88 (43.78)	**44.63 (41.92)**	36.70 (37.29)	35.08 (36.32)	39.10 (38.70)	**36.96 (37.44)**	45.61 (42.48)	40.00 (39.24)	47.68 (43.67)	**44.39 (41.78)**
Azadirachtin @ 1500ppm	27.87 (31.86)	25.47 (30.31)	30.22 (33.35)	**27.85 (31.85)**	23.67 (29.11)	23.84 (29.23)	24.17 (29.45)	**23.89 (29.26)**	18.67 (25.60)	22.03 (27.99)	20.37 (26.83)	**20.36 (26.82)**	23.40 (28.93)	23.78 (29.19)	24.92 (29.95)	**24.13 (29.36)**
Bacillus thuringiensis **(5×10^7 spores/mg) @ 1 gm/l**	33.87 (35.59)	29.04 (32.61)	35.06 (36.31)	**32.66 (34.85)**	29.57 (32.94)	28.28 (32.13)	31.31 (34.02)	**29.72 (33.03)**	24.92 (29.95)	27.03 (31.33)	27.87 (31.86)	**26.70 (31.11)**	29.45 (32.87)	28.11 (32.02)	31.41 (34.09)	**29.69 (33.02)**
Beauveria bassiana **@ 10^7 conidia/ml**	37.27 (37.62)	33.33 (35.26)	39.62 (39.01)	**36.74 (37.31)**	31.67 (32.25)	29.92 (33.16)	34.55 (36.00)	**32.05 (34.48)**	27.26 (31.47)	27.92 (31.90)	30.10 (33.27)	**28.43 (32.22)**	32.07 (34.49)	30.39 (33.45)	34.75 (36.12)	**32.41 (34.70)**
NPV @ 250LE/ha	40.64 (39.60)	36.64 (37.25)	43.04 (41.00)	**40.11 (39.29)**	39.50 (38.94)	31.08 (33.88)	40.60 (39.58)	**37.04 (37.49)**	31.11 (33.90)	30.00 (33.21)	36.84 (37.37)	**32.65 (34.85)**	37.08 (37.51)	32.57 (34.80)	40.16 (39.32)	**36.60 (37.23)**
Avermectin @ 0.01%	50.73 (45.52)	44.59 (41.89)	51.84 (46.05)	**49.05 (44.45)**	47.37 (43.49)	40.77 (39.68)	49.90 (44.94)	**46.01 (42.71)**	36.89 (37.40)	35.88 (36.80)	39.70 (39.05)	**37.49 (37.75)**	45.00 (42.13)	40.41 (39.47)	47.15 (43.36)	**44.18 (41.66)**
Control	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	**40.97 (39.80)**	**36.20 (36.99)**	**43.02 (40.99)**	**40.05 (39.26)**	**35.91 (36.82)**	**31.92 (34.40)**	**37.53 (37.78)**	**35.12 (36.34)**	**29.05 (32.61)**	**28.96 (32.55)**	**32.38 (34.68)**	**30.14 (33.30)**	-	-	-	-

Figure in parenthesis indicate angular transformed value

	96-97			97-98			98-99			Mean		
	A	B	A x B	A	B	A x B	A	B	A x B	A	B	A x B
SEM ±	0.205	0.313	0.5428	0.255	0.390	0.677	0.149	0.228	0.395	0.132	0.202	0.352
CD at 5%	0.937	1.035	1.534	1.165	1.291	1.916	0.682	0.754	1.118	0.606	0.669	0.996

A = Pesticides, B = Days after spraying (DAS), A x B = Interaction between treatments and days after spraying

The efficacy of pesticides against leaf miner was the best at 3 days of spraying (DAS) (40.06%). The effectiveness of pesticides, with gradual decrease, became lowered on 14 days after spraying (30.13%). The highest leaf miner suppression was recorded (40.06%) at 3 days after spraying (DAS), which was significantly superior to 8 DAS (35.12%) and 14 DAS (30.13%) (Table 4.5.1).

With regard to interaction between efficacy of toxicity of different pesticides over different time (Figure 4.5.1), DDVP @ 0.05%, avermectin @ 0.01% were found most effective and suppressed at a level of 51.58 % and 49.05 % respectively at 3DAS. Azadirachtin @ 1500ppm was found least effective (27.85%) followed by *Bacillus thuringiensis* (5 x 10^7 spores/mg)@ 1 gm./1 (32.66%) after 3DAS . At 8 days after spraying (DAS) avermectin @ 0.01% was found to suppress 46.01% which was significantly higher than other pesticides. DDVP @ 0.05% suppressed at a level of 44.63% followed by NPV @ 250LE/ha (37.04%) at 8DAS. The azadirachtin @1500ppm was again recorded least effective (23.89%). The degree of suppression of malathion @ 0.05% (32.49%), *Bacillus thuringiensis* (5 x 10^7 spores/mg)@ 1gm/1 (29.72%) and *Beauveria bassiana* @ 10^7 conidia/1.(32.05%) were although lower of the other pesticides tested ; but were non significant. At 14DAS avermectin @ 0.01%(37.49%) and DDVP @ 0.05% (36.96%) was found significantly superior to all other pesticides but the effectiveness among this two was non-significant . The minimum suppression of leaf miner population was being from azadirachtin @1500ppm (20.36%) again followed by *Bacillus thuringiensis* (5x10^7 spores/mg)@ 1gm/1(26.70%) (Table 4.5.1).

4.5.2 Fruit borer (*Helicoverpa armigera* Hubner)

In 1996-97 bored fruits(in number) was higher than other years but in 1997-98 the suppression level of the pest against different pesticides were lower than the other two years, while higher efficacy of pesticides were found in 1998-99, which might be due to climatic conditions prevailing during the course of investigation.

Bored fruit (% in number) :

Significantly lower number of fruit damage was obtained from the application of avermectin (6.45%) closely followed by NPV (6.53%) and *Bacillus thuringiensis* (6.67%) (Figure 4.5.2a). The difference in fruit boring percentage (in number) among the aforesaid pesticides was non-significant. The highest number of damaged fruit (%) was observed from the treatment of azadirachtin @ 1500 ppm (8.77%). From malathion and DDVP the

Table 4.5.2 Efficacy of pesticides against fruit borer (*Helicoverpa armigera* Hubner) on tomato

Pesticides and their concentration	Bored fruit (%)								Suppression of bored fruit (%)							
	In number				In weight				In number				In weight			
	96-97	97-98	98-99	Mean	96-97	97-98	98-99	Mean	96-97	97-98	98-99	Mean	96-97	97-98	98-99	Mean
Malathian @ 0.05%	9.70 (3.19)	8.60 (3.02)	6.58 (2.66)	**8.29** **(2.96)**	8.17 (2.94)	7.97 (2.91)	5.38 (2.42)	**7.17** **(2.77)**	34.68 (35.82)	33.69 (35.48)	38.85 (38.56)	**35.74** **(36.71)**	41.27 (39.97)	32.00 (34.45)	44.84 (42.04)	**39.37** **(38.86)**
DDVP @ 0.05%	7.52 (2.83)	7.69 (2.86)	5.34 (2.42)	**6.85** **(2.71)**	6.31 (2.61)	7.33 (2.79)	4.21 (2.17)	**5.95** **(2.54)**	49.36 (44.63)	40.71 (39.65)	50.37 (45.21)	**46.81** **(43.18)**	54.64 (47.66)	37.46 (37.74)	56.83 (48.93)	**49.64** **(44.79)**
Azadirachtin @ 1500ppm	10.00 (3.24)	9.22 (3.12)	7.09 (2.75)	**8.77** **(3.04)**	9.14 (3.10)	8.91 (3.07)	6.12 (2.57)	**8.06** **(2.92)**	32.66 (34.85)	28.91 (32.50)	34.11 (35.74)	**31.89** **(34.38)**	34.29 (35.84)	23.98 (29.32)	37.29 (37.64)	**31.85** **(34.36)**
Bacillus thuringiensis **(5 x 10^7 spores/mg) @ 1 gm/l**	7.20 (2.77)	7.62 (2.85)	5.18 (2.38)	**6.67** **(2.68)**	6.51 (2.65)	7.40 (2.81)	4.28 (2.18)	**6.06** **(2.56)**	51.52 (45.87)	41.25 (39.96)	51.86 (46.06)	**48.21** **(43.97)**	53.20 (46.83)	36.86 (37.38)	56.50 (48.73)	**48.85** **(44.34)**
Beauveria bassiana **@ 10^7 conidia/ml**	7.99 (2.91)	8.11 (2.93)	5.74 (2.50)	**7.19** **(2.77)**	7.05 (2.75)	7.72 (2.87)	4.83 (2.31)	**6.53** **(2.65)**	46.20 (42.82)	37.47 (37.74)	46.65 (43.08)	**43.44** **(41.23)**	49.32 (44.61)	34.13 (35.75)	52.56 (46.47)	**45.34** **(42.32)**
NPV @ 250LE/ha	7.18 (2.77)	7.42 (2.81)	4.98 (2.34)	**6.53** **(2.65)**	6.21 (2.59)	7.12 (2.76)	4.10 (2.14)	**5.81** **(2.51)**	51.65 (45.94)	42.79 (40.85)	53.72 (47.13)	**49.39** **(44.65)**	55.36 (48.08)	39.25 (38.79)	58.36 (49.81)	**50.99** **(45.57)**
Avermectin @ 0.01%	7.11 (2.76)	7.32 (2.80)	4.93 (2.33)	**6.45** **(2.64)**	6.03 (2.56)	6.98 (2.73)	4.00 (2.12)	**5.67** **(2.48)**	52.12 (46.22)	43.56 (41.30)	54.18 (47.40)	**49.95** **(44.97)**	56.65 (48.82)	40.44 (39.49)	59.00 (50.18)	**52.03** **(46.16)**
Control	14.85 (3.92)	12.97 (3.67)	10.76 (3.35)	**12.86** **(3.65)**	13.91 (3.79)	11.72 (3.49)	9.76 (3.20)	**11.80** **(3.50)**	-	-	-	-	-	-	-	-
SEM ±	0.158	0.156	0.118	0.095	0.413	0.175	0.246	0.144	0.714	0.795	0.508	0.359	0.961	1.358	0.696	0.604
CD at 5%	0.456	0.451	0.341	0.274	1.193	0.506	0.711	0.416	2.063	2.297	1.468	1.037	2.777	3.924	2.011	1.745

Figure in parenthesis indicate square root and angular transformed value wherever applicable

corresponding values were 8.29% and 6.85% respectively. However, all the pesticidal treatments were significantly superior over untreated control (12.86%)

With regard to suppression of pest population over untreated control, avermectin (49.95%), NPV(49.39%) and Bt. (48.21%) and DDVP (46.81%) have significantly (Figure 4.5.2b) lowered down fruit borer infestation (percentage in number). Azadirachtin @ 1500ppm was found least effective (31.89%) which was closely followed by malathion @ 0.05% (35.74%). Although malathion is largely recommended against fruit borer of tomato because of its lower persistency but it was almost least effective (35.74%) among all the pesticides evaluated under present investigation (Table 4.5.2).

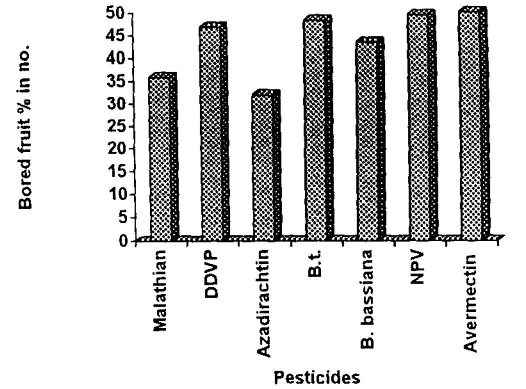


Fig 4.5.2a Efficacy of pesticides against fruit borer (*Helicoverpa armigera*)

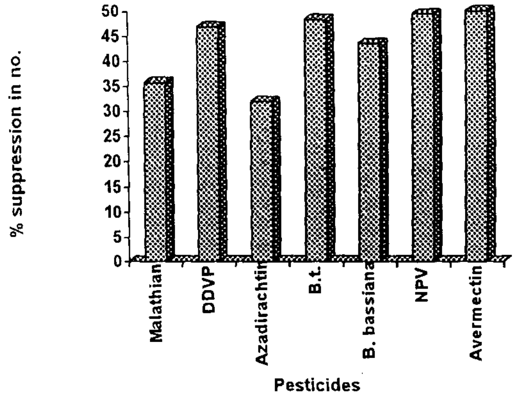


Fig. 4.5.2b Efficacy of pesticides against fruit borer (*Helicoverpa armigera*) (% control)

Bored fruit (% in weight) :

Percentage of bored fruit (in weight) and its suppression followed the same pattern as that of bored fruit percentage in number. Here also avermectin, NPV and DDVP suppressed fruit boring (in weight.) at a level of 5.67%, 5.81% and 5.95% respectively (Figure 4.5.2c). Azadirachtin and malathion application again showed higher level of fruit borer infestation (80.6% and 7.17% respectively) as compared to other pesticidal treatments but the difference from untreated control, (11.80%) was significant. Avermectin @ 0.01%,

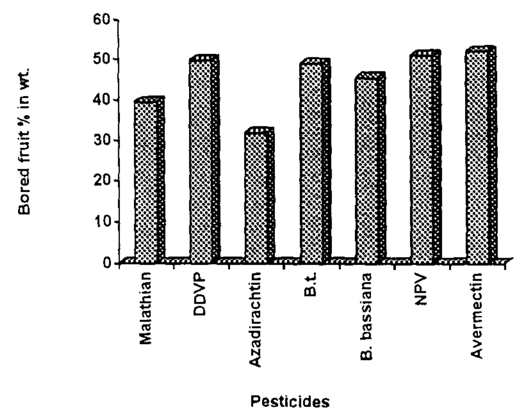


Fig 4.5.2c Efficacy of pesticides against fruit borer (*Helicoverpa armigera*)

NPV@ 250LE/ha and DDVP @ 0.05% suppressed (52.03%, 50.99% and 49.64% respectively) fruit boring (in weight) (Figure 4.5.2d) and the suppression level was superior over other pesticides. The minimum level of fruit borer suppression was observed from azadirachtin @ 1500 ppm (31.85%) which was closely followed by malathion @ 0.05% (39.37%). Here avermectin again proved its superiority over all other pesticides.

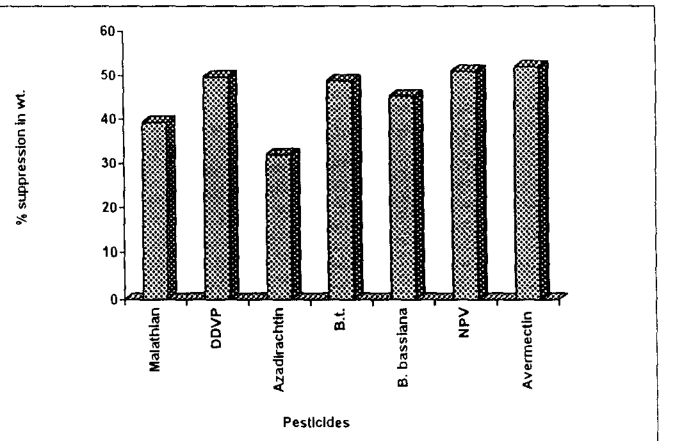


Fig 4.5.2d Efficacy of pesticides against fruit borer (*Helicoverpa armigera*) (% control)

4.5.3 Tingid bug (*Urentius hystricellus* Richter)

Variation among different pesticides, their efficacy on different time series against suppression of tingid bug as well as interaction among the treatments was highly significant. In 1997-98, the suppression level was lower than the other two years. Among the seven pesticides tested DDVP @ 0.05% was found most effective against tingid bug (74.34%), closely but non-significantly followed by avermectin @ 0.01% (74.30%). Malathion @ 0.05% suppressed 64.93%, whereas, three other entomopathogen namely Bt. (5 x 10^7 spores/mg)@ 1gm/l, *Beauveria bassiana* @ 10^7conidia/ml and NPV @ 250LE/ha suppressed at a level of 61.99%, 61.54% and 61.23% respectively. There was no significant difference in suppression level among these three pesticides. The minimum control was found again from azadirachtin @ 1500 ppm (58.60%) (Table 4.5.3).

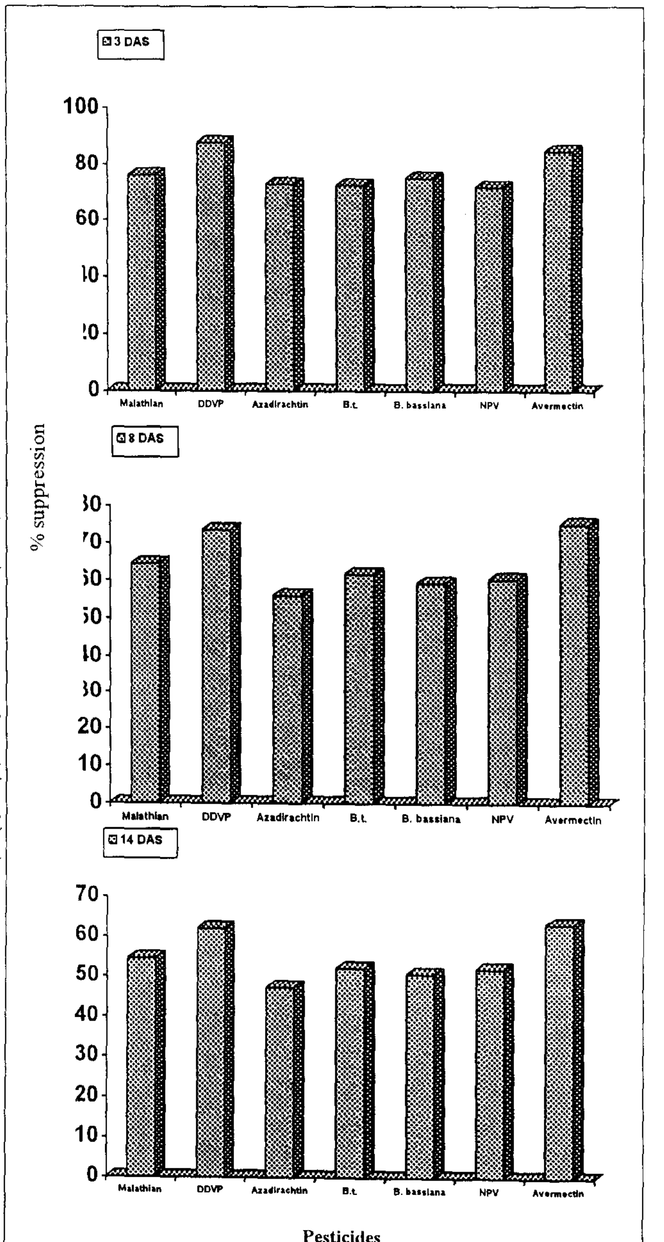


Fig. 4.5.3 Efficacy pesticides against Tingid bug (*Urentius hystricellus* Richt.)

Photograph showing tomato crop treated with different pesticides.

Table 4.5.3 Efficacy of pesticides against tingid bug (*Urentius hystricellus* Richt.) on tomato

Pesticides and their concentration	Suppression of population (%)															
	3 DAS				8 DAS				14 DAS				Grand Mean			
	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**	96-97	97-98	98-99	**Mean**
Malathian @ 0.05%	78.19 (62.16)	68.81 (56.05)	80.72 (63.95)	**75.91 (60.61)**	67.33 (55.14)	53.29 (46.88)	72.67 (58.48)	**64.43 (53.38)**	56.27 (48.60)	46.98 (43.27)	60.14 (50.85)	**54.46 (47.56)**	67.26 (55.09)	56.36 (48.65)	71.18 (57.53)	**64.93 (53.68)**
DDVP @ 0.05%	93.87 (75.66)	72.82 (58.58)	95.98 (78.43)	**87.56 (69.35)**	77.39 (61.60)	63.81 (53.02)	79.39 (63.00)	**73.53 (59.04)**	64.98 (53.72)	53.28 (46.88)	67.55 (55.27)	**61.94 (51.91)**	78.75 (62.55)	63.30 (52.71)	80.97 (64.14)	**74.34 (59.56)**
Azadirachtin @ 1500ppm	73.67 (59.13)	68.88 (56.09)	75.54 (60.36)	**72.70 (58.50)**	56.78 (48.89)	51.37 (45.78)	59.28 (50.35)	**55.81 (48.34)**	47.67 (43.66)	43.51 (41.27)	50.69 (45.39)	**47.29 (43.45)**	59.37 (50.40)	54.59 (47.63)	61.84 (51.85)	**58.60 (49.95)**
***Bacillus thuringiensis* (5 x 10^7 spores/mg) @ 1 gm/l**	76.11 (60.74)	62.14 (52.03)	78.31 (62.24)	**72.19 (58.17)**	63.33 (52.73)	54.38 (47.51)	67.06 (54.97)	**61.59 (51.70)**	53.72 (47.13)	47.38 (43.50)	55.51 (48.16)	**52.20 (46.26)**	64.39 (53.36)	54.63 (47.66)	66.96 (54.91)	**61.99 (51.94)**
***Beauveria bassiana* @ 10^7 conidia/ml**	77.92 (61.97)	66.67 (54.74)	79.52 (63.09)	**74.70 (59.80)**	63.17 (52.63)	49.13 (44.50)	65.18 (53.84)	**59.16 (50.28)**	53.19 (46.83)	41.90 (40.34)	57.20 (49.14)	**50.76 (45.43)**	64.76 (53.58)	52.57 (46.47)	67.30 (55.12)	**61.54 (51.67)**
NPV @ 250LE/ha	74.92 (59.95)	63.16 (52.63)	76.27 (60.85)	**71.45 (57.70)**	62.84 (52.44)	52.14 (46.23)	65.83 (54.23)	**60.27 (50.93)**	54.16 (47.39)	45.62 (42.49)	56.14 (48.53)	**51.97 (46.13)**	63.97 (53.11)	53.64 (47.08)	66.08 (54.38)	**61.23 (51.49)**
Avermectin @ 0.01%	88.67 (70.33)	72.73 (58.52)	92.18 (73.76)	**84.53 (66.84)**	78.19 (62.16)	66.47 (54.62)	80.83 (64.03)	**75.16 (60.10)**	65.19 (53.84)	54.98 (47.86)	69.43 (56.43)	**63.20 (52.65)**	77.35 (61.58)	64.73 (53.57)	80.81 (64.02)	**74.30 (59.54)**
Control	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	**80.48 (63.78)**	**67.89 (55.48)**	**82.65 (65.38)**	77.01 (61.35)	**67.00 (54.94)**	**55.80 (48.33)**	**70.03 (56.81)**	64.28 (53.30)	**56.45 (48.70)**	**47.66 (43.66)**	**59.52 (47.61)**	54.55 (47.61)	-	-	-	-

Figure in parenthesis indicate angular transformed value

	96-97			97-98			98-99			Mean		
	A	B	A x B	A	B	A x B	A	B	A x B	A	B	A x B
SEM ±	0.278	0.425	0.735	0.249	0.381	0.660	0.225	0.343	0.595	0.167	0.256	0.444
CD at 5%	1.27	1.406	2.08	1.137	1.261	1.867	1.028	1.135	1.684	0.763	0.847	1.256

A = Pesticides, B = Days after spraying (DAS), A x B = Interaction between treatments and days after spraying

Regarding efficacy of against tingid bug all the pesticides were most effective (77.10%) at 3DAS. After gradual decrease in efficacy level it became lowered to 64.28% and 54.55% at 8 and 14 days after spraying respectively.

Interaction between toxicity of pesticides (Figure 4.5.3) and efficacy at different time series was also significant among the pesticides evaluated, DDVP @ 0.05% and avermectin @ 0.01% were found most effective over all other pesticides and suppressed 87.56% and 84.53% respectively after 3 DAS. NPV @ 250LE/ha was found least effective (71.45%) followed by Bt.(72.19%) and azadirachtin @ 1500 ppm (72.70%) and the difference on effectiveness between these three was non-significant. At 8 DAS avermectin @ 0.01% was found to suppress 75.16% tingid bug population which was significantly superior to all other pesticides DDVP and malathion @ 0.05% came to the next and suppressed at level of 73.53% and 64.43% respectively and the minimum being from azadirachtin @ 1500 ppm 55.81%. Avermectin @ 0.01% was found significantly effective after 14 DAS (63.20%) over all other pesticides; DDVP @ 0.05% was recorded 61.94% and the efficacy was the lowest in azadirachtin @ 1500 ppm followed by *Beauveria bassiana* @ 10^7conidia/ml (50.76%). Efficacy of avermectin at initial stage was though moderate as compared to DDVP but overall performance was better.

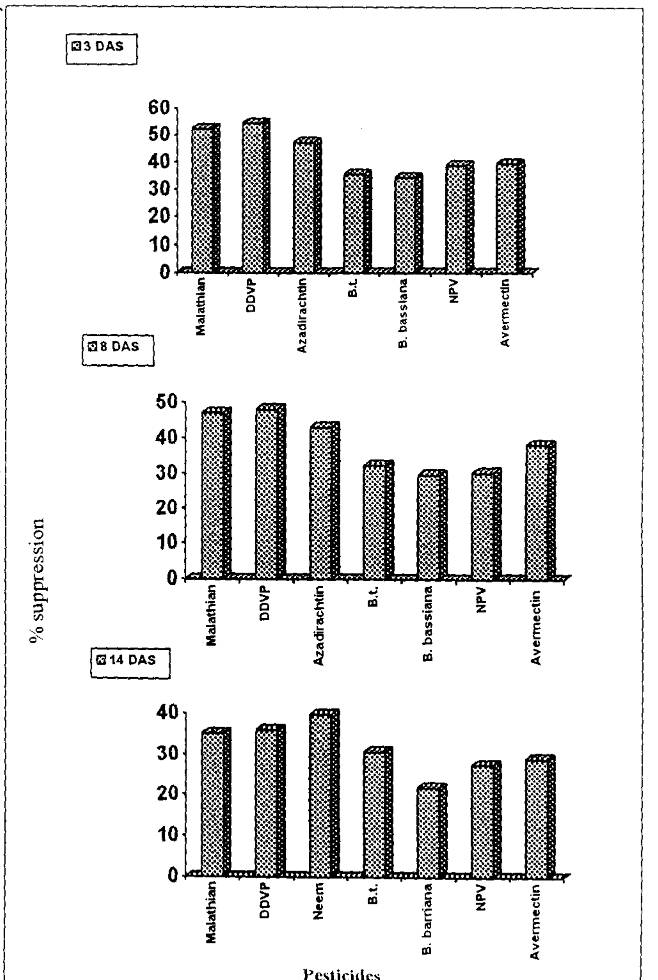


Figure 4.5.3 Efficacy of pesticides against tingid bug (*Urentius hystricullus*) (% control)

4.5.4 Natural enemies

Different pesticidal treatments applied for suppression of ruinous pests also adversely affect the natural enemy populations. Among the different natural enemies recorded in tomato crop ecosystem, spider of different species were predominant.

4.5.4a Spiders

Variation among different pesticides, their efficacy and interaction was highly significant. It was found that none of the pesticides was safer to spider populations, however, pesticides from biological origin were less harmful to spider than the synthetic ones.

Table 4.5.4 Efficacy of pesticides against spiders on tomato

Pesticides and their concentration	Suppression of population (%)															
	3 DAS				8 DAS				14 DAS				Grand Mean			
	96-97	97-98	98-99	Mean	96-97	97-98	98-99	Mean	96-97	97-98	98-99	Mean	96-97	97-98	98-99	Mean
Malathian @ 0.05%	53.80 (47.18)	45.18 (42.33)	56.86 (48.94)	**52.28 (46.31)**	49.24 (44.56)	41.22 (39.94)	50.54 (45.31)	**47.00 (43.28)**	36.75 (37.32)	31.33 (34.04)	37.16 (37.56)	**35.08 (36.32)**	46.93 (43.24)	39.24 (38.78)	48.19 (43.96)	45.12
DDVP @ 0.05%	56.34 (48.64)	50.32 (45.18)	56.33 (48.64)	**54.33 (47.48)**	50.14 (45.08)	45.79 (42.58)	48.07 (43.89)	**48.00 (43.85)**	37.12 (37.54)	34.80 (36.15)	35.81 (36.76)	**35.91 (36.82)**	47.87 (43.78)	43.64 (41.35)	47.23 (43.41)	**46.08**
Azadirachtin @ 1500ppm	50.27 (45.15)	47.24 (43.42)	47.37 (43.49)	**48.26 (44.00)**	44.75 (41.99)	41.57 (40.15)	42.68 (40.79)	**43.00 (40.98)**	40.37 (39.45)	38.66 (38.45)	40.22 (39.36)	**39.75 (39.09)**	45.13 (42.21)	42.49 (40.68)	43.42 (41.22)	**43.68 (41.37)**
Bacillus thuringiensis **(5 x 10^7 spores/mg) @ 1 gm/l**	36.98 (37.45)	32.92 (35.01)	35.49 (36.56)	**35.13 (36.35)**	33.93 (35.63)	29.63 (32.98)	33.13 (35.14)	**32.25 (34.59)**	31.16 (33.93)	28.15 (32.04)	32.64 (34.84)	**30.65 (33.62)**	34.02 (35.68)	30.23 (33.35)	33.75 (35.52)	**32.67 (34.86)**
Beauveria bassiana **@ 10^7 conidia/ml**	43.18 (41.08)	31.52 (34.15)	34.17 (35.77)	**36.29 (37.04)**	30.94 (33.79)	25.84 (30.55)	32.23 (34.59)	**29.67 (33.00)**	23.75 (29.16)	19.38 (26.12)	22.24 (28.14)	**21.79 (27.83)**	29.62 (32.97)	25.58 (30.38)	32.55 (34.70)	**29.25 (32.74)**
NPV @ 250LE/ha	36.25 (37.02)	28.90 (32.52)	38.86 (38.56)	**34.67 (36.07)**	31.61 (34.21)	25.44 (30.29)	33.64 (35.45)	**30.23 (33.35)**	28.82 (32.47)	23.41 (28.94)	30.63 (33.60)	**27.62 (31.71)**	32.23 (34.59)	25.92 (30.61)	34.38 (35.89)	**30.84 (38.73)**
Avermectin @ 0.01%	42.69 (40.79)	41.13 (39.89)	39.57 (38.98)	**41.13 (39.89)**	38.56 (38.39)	37.54 (37.78)	38.26 38.21)	**38.12 (38.13)**	29.45 (32.87)	27.88 (31.87)	30.00 (33.21)	**29.11 (32.65)**	36.23 (37.01)	35.52 (36.58)	35.28 (36.44)	**36.12 (36.94)**
Control	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	**45.64 (42.50)**	**39.60 (39.00)**	**44.09 (41.61)**	**43.16 (14.07)**	**39.88 (39.16)**	**35.29 (36.45)**	**39.79 (39.11)**	**38.32 (38.25)**	**32.49 (34.75)**	**29.08 (32.64)**	**32.67 (34.86)**	**31.42 (34.09)**	-	-	-	-

Figure in parenthesis indicate angular transformed value

	96-97			97-98			98-99			Mean		
	A	B	A x B	A	B	A x B	A	B	A x B	A	B	A x B
SEM ±	0.212	0.315	0.520	0.230	0.400	0.627	0.200	0.325	0.536	0.150	0.215	0.367
CD at 5%	0.968	1.042	1.471	1.0511	1.324	1.774	0.914	1.075	1.516	0.6855	0.712	1.0386

A = Pesticides, B = Days after spraying (DAS), A x B = Interaction between treatments and days after spraying

Among the seven pesticides, *Beauveria bassiana* @10^7conidia/ml, NPV @ 250LE/ha, *Bacillus thuringiensis* (5 x 10^7 spores/mg)@ 1ml/l were found less harmful and suppressed the spider population at a level of 29.25%, 30.84% and 32.67% respectively. Whereas, the synthetic pesticides namely malathion and DDVP @ 0.05% markedly lowered down spider population to 46.08% and 45.12% respectively (Table 4.5.4).

With regard to efficacy of pesticides (Figure 4.5.4) against spider it was observed that killing of spider population was higher at 3 DAS (43.16%) and with gradual decrease in toxicity it became 38.32% at 8 DAS and 31.42% at 14 DAS.

4.5.5. Yield of Tomato

In 1997-98, the yield of tomato was low in all the treatments as compared to other two years (1996-97, 1998-99) that was might be due to prevailing weather conditions during the period of investigation. It is well understood that the yield is directly related to the level of pest suppression as influenced by the application of pesticides which is further depended on their relative toxicity and persistency on different pest species. Therefore, the yield was recorded higher in treatments where pest population was low due to better efficacy of pesticides against pest species.

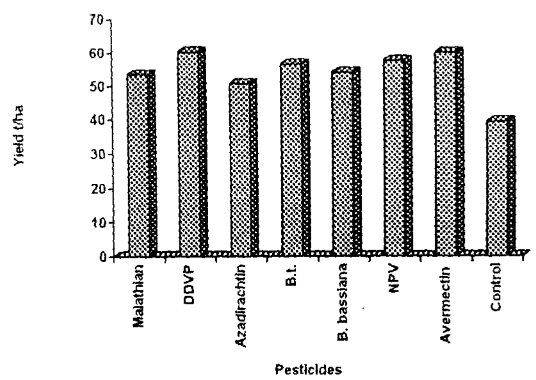


Fig : 4.5.5 Yield of tomato as influenced by pesticidal treatments

Among the seven pesticides (Figure 4.5.5) studied, avermectin @0.01% and DDVP @ 0.05% treated plots yielded significantly higher (59.74 t/ha and 60.26 t/ha respectively) over others. The untreated plot yielded the lowest (39.25 t/ha). Among the pesticides, azadirachtin @ 1500 ppm was found less effective and yield was also lower (50.70 t/ha) than other treatments, followed by malathion @0.05% (53.38 t/ha) and *Beauveria bassiana* @ 10^7conidia/ml (53.92 t/ha). While *Bacillus thuringiensis* (5 x 10^7 spores/mg)@ 1gm/l and NPV @ 250LE/ha yielded 56.45 t/ha and 57.38 t/ha respectively (Table 4.5.5).

Considering health hazard, efficacy in pest suppression and yield of tomato as well as effect on other non-target organisms like natural enemy the biologically originated pesticides, namely avermectin and NPV are the best suited pesticides for IPM programme in tomato.

Table 4.5.5 Effect of pesticides on yield of tomato

Pesticides and their concentration	96-97	97-98	98-99	Mean
Malathian **@ 0.05%**	57.70	43.78	58.67	53.38
DDVP **@ 0.05%**	62.14	48.86	69.76	60.26
Azadirachtin **@ 1500ppm**	57.31	40.28	54.51	50.70
Bacillus thuringiensis **(5 x 10^7 spores/mg) @ 1 gm/l**	59.77	46.30	63.28	56.45
Beauveria bassiana **@ 10^7 conidia/ml**	58.17	44.60	58.99	53.92
NPV **@ 250LE/ha**	59.37	45.79	66.98	57.38
Avermectin **@ 0.01%**	62.06	48.33	68.84	59.74
Control	41.96	31.56	44.43	39.25
SEM (±)	0.847	0.716	1.324	0.662
CD at 5%	2.447	2.069	3.826	1.913