Chapter - 5

DISCUSSION

5.1. Yield loss assessment due to key insect pest infestation:

The typical environmental conditions in the terai agro-ecological situation of West Bengal favoured infestation of important insect pests of cucurbitaceous crops. During the course of present investigation they have been found to infest both bitter gourd and pumpkin throughout the cropping season in a greater or lesser extent. The key pests were epilachna beetle, *Henosepilachna vigintioctopunctata* (Fab.), red pumpkin beetle, *Aulacophora* (*Raphidopalpa*) *foveicollis* (Lucas.) and melon fruit fly, *Bactrocera cucurbitae* (Coq.). Average population of epilachna beetle and red pumpkin beetle per pit (two plants) was recorded 4.47 and 3.58 on bitter gourd and 5.17 and 5.17 on pumpkin respectively. While the melon fruit fly found to cause 24.83 and 29.83% fruit damage (in number) on the crops respectively. It also revealed that the yield of crops (bitter gourd and pumpkin) was related directly with the insect-pest and disease incidence. Both the treatments i.e. only insect-pest control and combination of insect pest and disease control resulted in suppression of pest population. Lower level of pest population caused less damage to the crop, less number of fruits got infested that ultimately reflected in higher yield. On the contrary, only disease control did not able to affect pest populations that remain statistically at par with the untreated control. But where insecticidal control was coupled with disease control, significantly higher yield was recorded in both bitter gourd and pumpkin that might be due to suppression of disease causing organisms.

Final fruit yield is a function of cumulative effects of various yield parameters that are usually influenced by several biotic stresses. From critical analysis of the results delineated in the previous chapter showed that in bitter gourd 19.53 and 24.95% yield loss could have been avoided with only insect pest management and both insect pest and disease management respectively. In case of pumpkin also, 31.77 and 46.03% avoidable yield loss was recorded with only insect-pest management and both insect-pest and disease management respectively. This phenomenon clearly indicated the seriousness of insect pest problem in profitable cultivation of bitter gourd and pumpkin in the agro-ecological region under consideration. It becomes also evident that a considerable portion of yield could have been saved through proper management practices. Influence of the key insect-pests on the yield of bitter gourd and pumpkin has been depicted in fig-7-10.

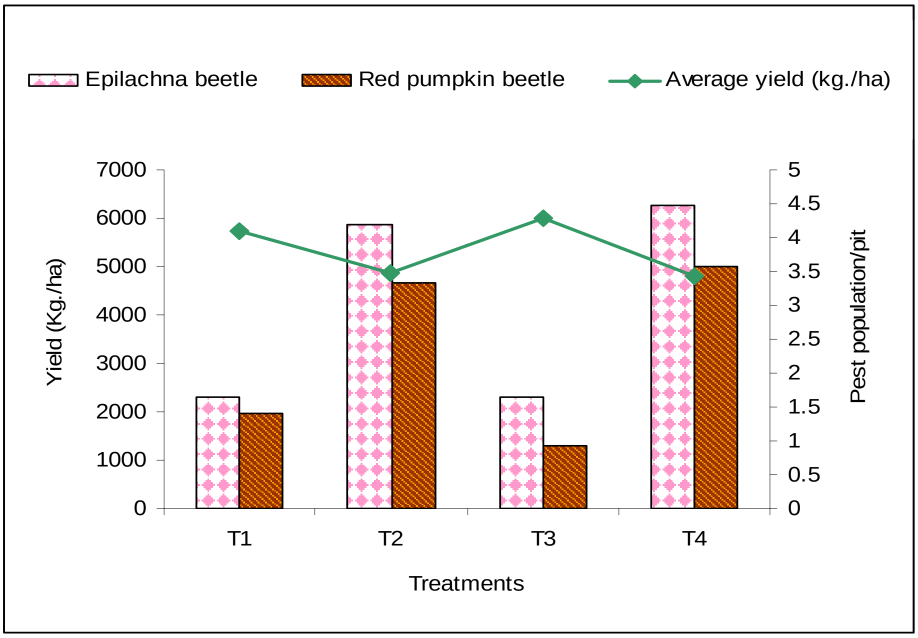

Fig-7: Average yield (kg/ha) of bitter gourd as influenced by epilachna beetle and red pumpkin beetle.

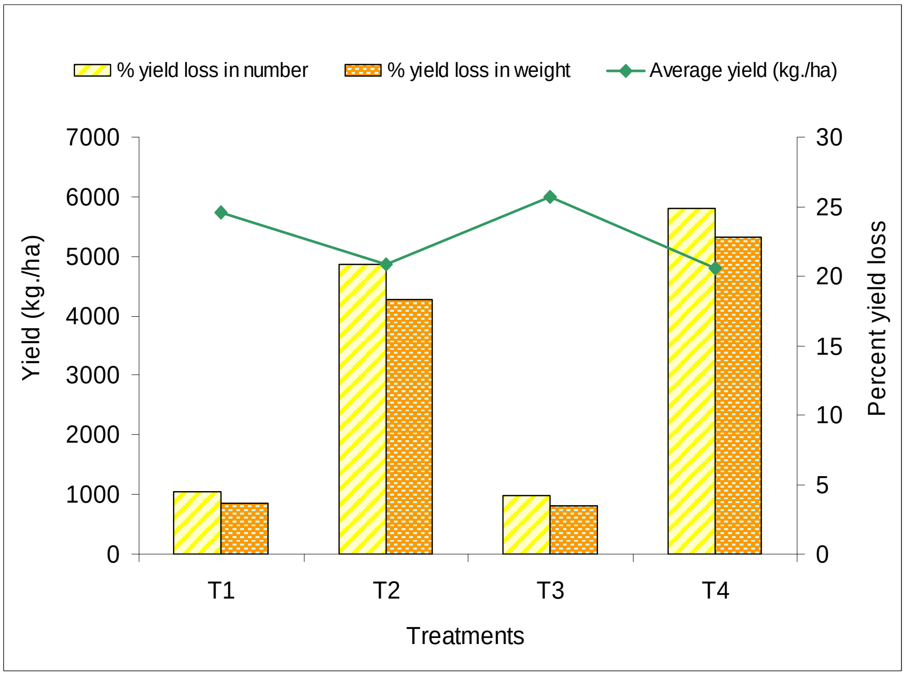

Fig-8: Average yield (kg/ha) of bitter gourd as influenced by melon fruit fly infestation

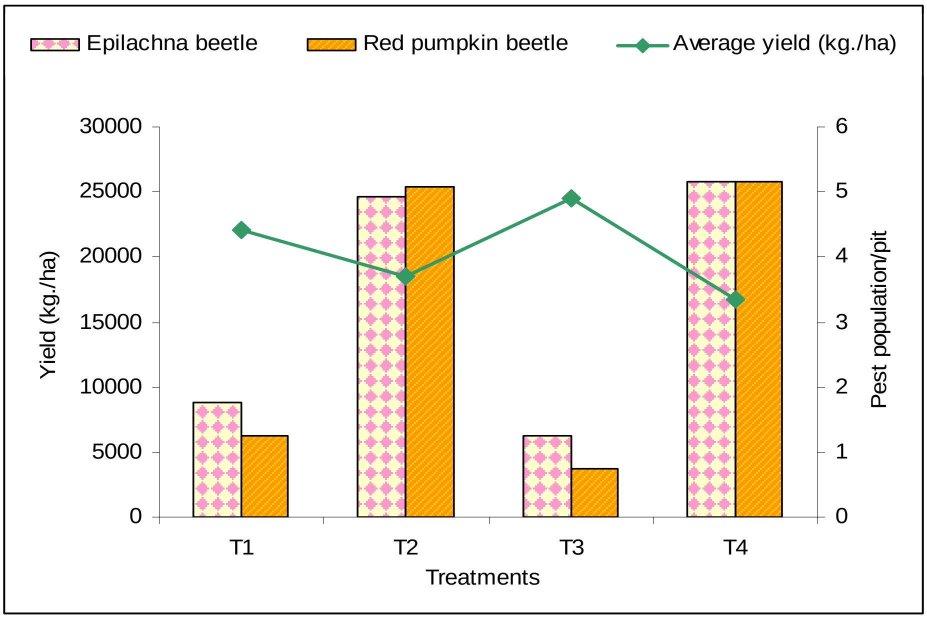

Fig-9: Average yield (kg/ha) of pumpkin as influenced by epilachna beetle and red pumpkin beetle.

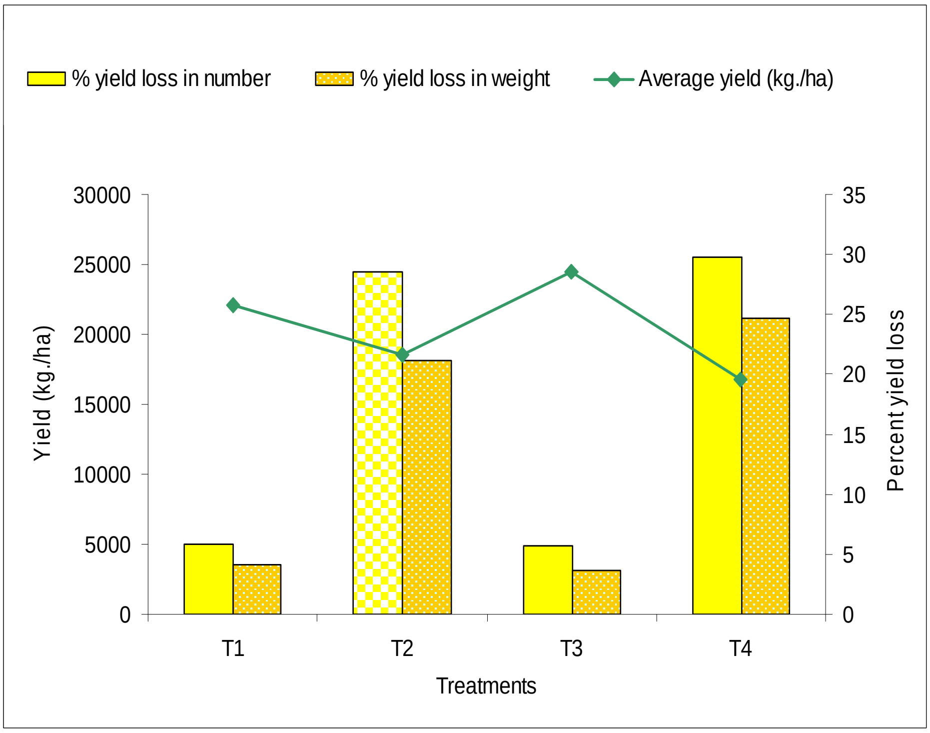

Fig-10: Average yield (kg/ha) of pumpkin as influenced by melon fruit fly infestation.

[**T_1**: Only insect-pest control (Carbofuran 3G @ 0.8 kg/ha at 20 days of sowing followed by spraying with chlorpyriphos 20EC @ 2.00ml/l of water at fortnightly interval and poison baiting with mollasses and spinosad), **T_2**: Treated with only fungicide (Blitox50WP @ 2gm/l of water)

T_3: T_1+T_2, **T_4**: Untreated (Control)]

Earlier, Singh *et al.* (2000), Dhillon *et al.* (2005a) and Sapkota *et al.* (2010) recorded 27-31%, 30-100% and 32.9% yield losses on cucurbits respectively due to attack of cucurbit fruit fly depending upon cucurbit species and the season. Thus, findings of the present investigation are more or less in agreement with the previous reports. However, the results contradicted with Hollingsworth (1997) who reported that 95% of bitter gourd in New Guinea, 90% snake gourd and 60-87% pumpkin fruits in Soloman Island was infested by melon fruit fly that are much more than the present findings. In Pakistan also, Anwar (1956) revealed 60% loss to melon due to melon fruit fly infestation. This variation in extent of yield loss caused by melon fruit fly might be due to variation in experimental location, crops and the season in which it was grown.

Not much works have so far been carried out regarding crop loss assessment caused by epilachna beetle on cucurbitaceous vegetables. However, Rajagopal and Trivedi (1989) reported that the beetle may damage up to 80% of plants depending on place and season.

The results of crop loss assessment due to red pumpkin in the present study contradicted with the findings of Thapa and Neupane (1992) who reported that bitter gourd seedlings were completely free from the beetle damage. However, on pumpkin 5-10 adults/plant were recorded which is in agreement with the present findings. The difference with bitter gourd might be due to seasonal fluctuation of the pest.

From overall observation of the results it appeared that melon fruit fly, epilachna beetle and red pumpkin are the major pests of bitter gourd and pumpkin that cause considerable damage to the crops and create hindrances in obtaining optimum yield. It has also been detected that adoption of appropriate plant protection measure reflected in considerable yield gain over unprotected crop. Thus, to realize optimum yield potentiality of these vegetables under terai agro-ecological region of West Bengal, India the crops need to be protected from their infestation.

5.2. Economic threshold level (ETL) of some key pests of cucurbits:

The earlier concept of ‘pest control’ aiming cent percent elimination of pests from the agricultural ecosystem was replaced by the term ‘pest management’. The idea as expressed by Pierce (1934) with regard to the assessment of insect damage and initiation of control measures become one incentive for the development of a concept of economic injury level. The concept of economic injury level was formally proposed by Stern *et al.* (1959). As per his version, economic threshold level (ETL) is nothing but the number of insect (density or intensity) when management action should be undertaken to prevent the increasing pest population from reaching economic injury level (EIL). Thus, determination of economic threshold level (ETL) is an essential step in decision making for undertaking viable management strategy against the pest.

5.2.1. ETL of melon fruit fly on the basis of fly density:

5.2.1.1. Bitter gourd, *Momordica charantia* Linn.

It appeared from the results that trap catches (mean±S.D.) of melon fruit fly were differed from location to location that varied from 5.00±1.73 to 26.33±8.08 fly/trap/day on bitter gourd. Percentage yield loss due to fruit fly infestation was also varied. In the plots that kept under complete protection, percent yield loss was recorded lowest (6.33%). The fact with regard to marketable yield was noted just reverse as that of infested yield and percent yield loss.

From the economic analysis of crop production revealed that the economic threshold level (ETL) of melon fruit fly infesting bitter gourd under terai agro-ecological condition was 1.46 catch/trap/day. The correlation co-efficient (r) between trap catch of fly and marketable yield (in kg/ha) of bitter gourd was found significantly negative (r = -0.9314). The R^2 value determined as 0.8685 which indicated that 86.85% variation in marketable yield could be accounted for fly density in the field.

5.2.1.2. Pumpkin, *Cucurbita pepo* Linn.:

Variations in trap catches of melon fruit fly in different locations of the study area were found to differ in case of pumpkin also. Total yield of pumpkin was recorded lower in the locations where fly catch were noted high. Highest percentage yield loss was observed as 49.67. Percent yield loss was recorded lowest (3.67%) in the plot that kept under complete protection. The fact with regard to marketable yield was noted just reverse as that of infested yield and percent yield loss.

The correlation co-efficient (r) between the trap catch of fly and marketable yield (in kg/ha) of pumpkin was found significantly negative (r= -0.9046). Thus, the marketable yield and trap catch of melon fruit fly were inversely related with each other.

From critical analysis of the findings of present investigation it was revealed that the economic threshold level (ETL) of melon fruit fly infesting pumpkin under terai agro-ecological condition was 1.80 catch/trap/day. The R^2 value was determined as 0.8182. The value indicated that 81.82% variation in marketable yield was influenced by the melon fruit fly density in the field condition and the rest was by the reasons other than fly incidence.

5.2.1.3. Trend analysis of the effect of melon fruit fly density:

Trend lines obtained in bitter gourd and pumpkin (fig-11) showed that 86.97 to 95.95% marketable yield is mainly influenced by fly catch per trap per day. Moreover, in pumpkin marketable yield found to increase exponentially within a range of fly catch from 1.33-15.33 adult male per trap per day.

In pumpkin lowest marketable yield was obtained (7708.05kg/ha) when fly catch/trap/day was noted 15.33. However, upon reaching at higher asymptote fly density have no influence. But in bitter gourd, the quadratic equation tends to be linear within a range of 1.33-26.33 fly per trap per day.

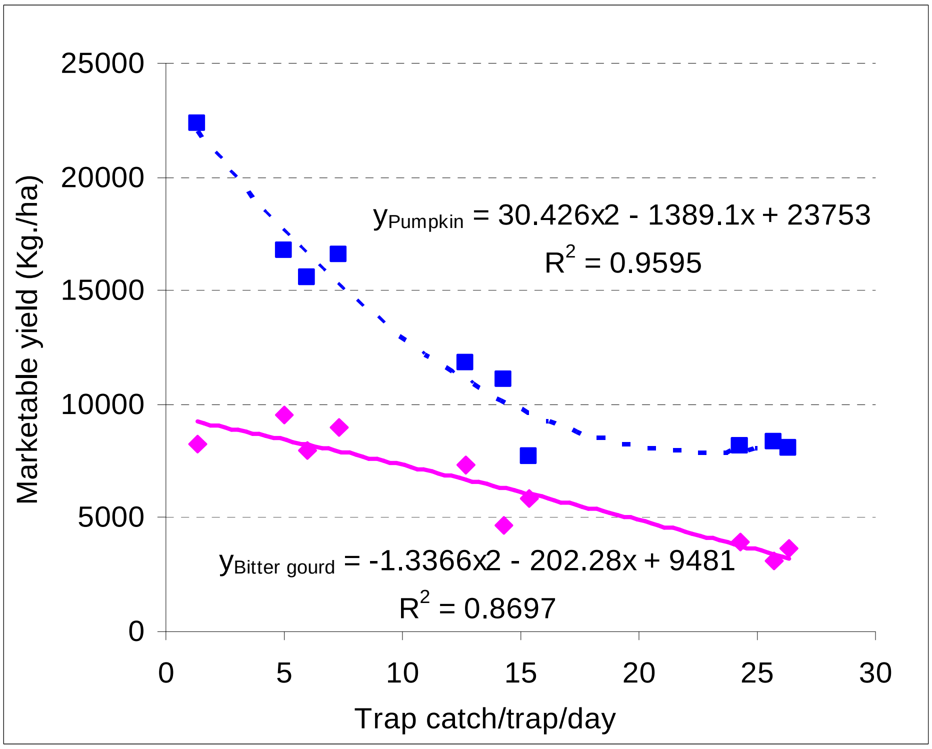

Fig-11: Trend of marketable yield as influenced by fly catch/trap/day.

The model as revealed in the results can be utilized to calculate ETL at various densities of melon fruit fly males that might be helpful in decision taking for adopting pest management programme. Qureshi *et al.* (1976) stated that **t**he economic threshold level of melon fruit fly is often based on the number of fruits infested in a given area and for monitoring melon fruit fly population several workers used pheromone trap (Inayatullah *et al.*, 1988, Pawar *et al.*, 1991, Liu and Lin, 1993 and Zaman, 1995). Khan (1987) opined that **a**dult density of the fly responsible for causing 10% fruit infestation was recognized as economic threshold level (ETL). But, it is evident that management cost as well as market price of the produce varied from place to place and even season to season in a particular location. Considering this phenomenon, the ETL was determined as per the procedure laid by Pedigo (1991). The correlation co-efficient between density of adult melon fruit fly and marketable yield was found significantly negative in both the cases of bitter gourd and pumpkin (r = -0.9314 and -0.9046 respectively). Similar observation was also derived by Inayatullah *et al.* (1991).

Results of the present study showed that the crop protection measures should be initiated on reaching 1.46 number catch/trap/day (@10 traps/ha) in bitter gourd and 1.80 in pumpkin in order to prevent the population in reaching economic injury levels. The results are not in corroboration with the findings of Inayatullah *et al.* (1991) who found the ETL of melon fruit fly as 7 /trap/day. This non-corroboration might be due to difference in management cost of the pest, market price of the produce and change in agro-ecological location of the study.

5.2.2. ETL of melon fruit fly on the basis of pupal density in soil:

5.2.2.1. Bitter gourd, *Momordica charantia* Linn.:

It appeared that pupal density/unit soil sample (1 ft X 1 ft X 12 cm) varied from 0.40 to 2.40 in the farmers' fields at different villages on bitter gourd. The correlation co-efficient (r) between the pupal density of fly per unit soil sample and marketable yield (in kg/ha) of bitter gourd was found significantly negative (r= -0.8516). Thus, it becomes evident that the marketable yield and pupal density of melon fruit fly in field soil were inversely related with each other.

The economic threshold level (ETL) of melon fruit fly (with respect to pupal density/unit soil sample) infesting bitter gourd under terai agro-ecological condition was determined as 0.20 number of pupal harvest/unit soil. The R^2 value was determined as 0.7413.

5.2.2.2. Pumpkin, *Cucurbita pepo* Linn.:

Minimum pupal density was noted in the field that kept under complete protection (0.12 per unit soil sample) while maximum was recorded at village Bagroa (2.39) followed by Jagyanarayanerkuthi (2.36) and Panishala (2.21). Total yields were obtained higher at Pundibari (233.20 q/ha) as well as in the field maintained under complete protection (229.52 q/ha). On the other hand, lower yield was obtained from the fields where higher pupal density was noted.

The correlation co-efficient (r) between the pupal density of fly and marketable yield (in q/ha) of pumpkin was found significantly negative (r= -0.8773). Thus, the marketable yield and pupal density of melon fruit fly in field soil were inversely related with each other.

The economic threshold level (ETL) of the fly (with respect to pupal density/unit soil sample) infesting pumpkin under terai agro-ecological condition is 0.23 number of pupal harvest/unit soil. The R^2 value was determined as 0.7697. That is, 76.97% variation in yield was accounted for the pupal presence and density thereof in field soil.

5.2.2.3. Trend analysis of the effect of pupal density in soil:

Two quadratic equations obtained from trend analysis (fig-12 and 13) re-confirmed that pupal density in soil governed the fruit infestation to the extent of 77.73 and 84.72% in pumpkin and bitter gourd respectively. This is applicable within a range of 0.4 to 2.40 number puparia per unit soil. However, in bitter gourd it was found that after reaching lower asymptote the curve tends to rise, i.e. it could be inferred that marketable yield of bitter gourd, below 5034.53 kg/ha hardly matters with the increase in pupal density and there might have other reason(s) for fluctuation in degree of fruit infestation. On the other hand, in pumpkin the quadratic equation tends to be linear within a range of 0.12 to 2.39 puparia/unit soil.

The linear correlation between the number of puparia per unit (1ft X 1ft and 10cm) soil sample and yield of squash was earlier determined by Inayatullah *et al.* (1991) in Pakistan. In the present study the ETL value in respect of pupal harvest per unit soil sample (1ft X 1ft and 12cm) was determined as 0.20 and 0.23 on bitter gourd and pumpkin respectively. The values are much less than that of Inayatullah *et al.* (1991) who derived the same as 0.74. The possible explanation is that in the present study market price of the produce was high or cost of management of pest was low. On the contrary, the reverse was the case in previous findings. Change of agro-ecological location might also be an important contributory factor for this phenomenon.

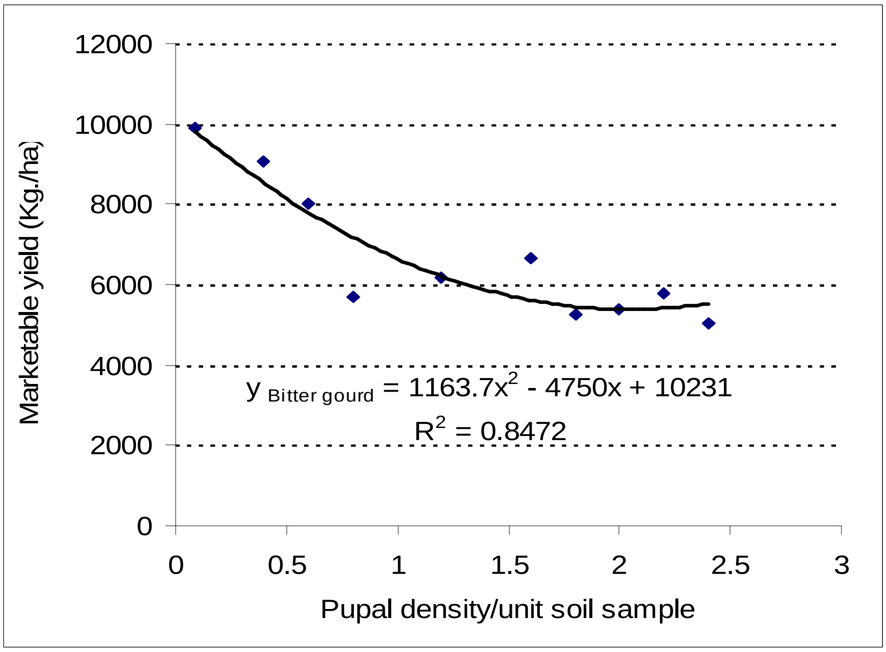

Fig-12: Trend of marketable yield of bitter gourd as influenced by pupal density in soil.

5.2.3. ETL of epilachna beetle, *Henosepilachna vigintioctopunctata* (Fab.) (Coccinellidae: Coleoptera):

5.2.3.1. Bitter gourd, *Momordica charantia* Linn.:

Significant differences were noted in various intensity of infestation by the beetle. Yield was recorded as 81.69, 79.35, 78.99 and 76.46 q/ha when 1, 2, 3, and 4 larva per plant respectively were released. Minimum yield (72.36 q/ha) was observed in treatment T_6 where 5 larva per plant were released. Yield reduction over control was derived as 5.71, 8.05, 8.41 and 10.94 q/ha in T_2, T_3, T_4 and T_5 respectively. Maximum reduction in yield over control was noted in T_6 where larval density was highest (5 larva /plant).

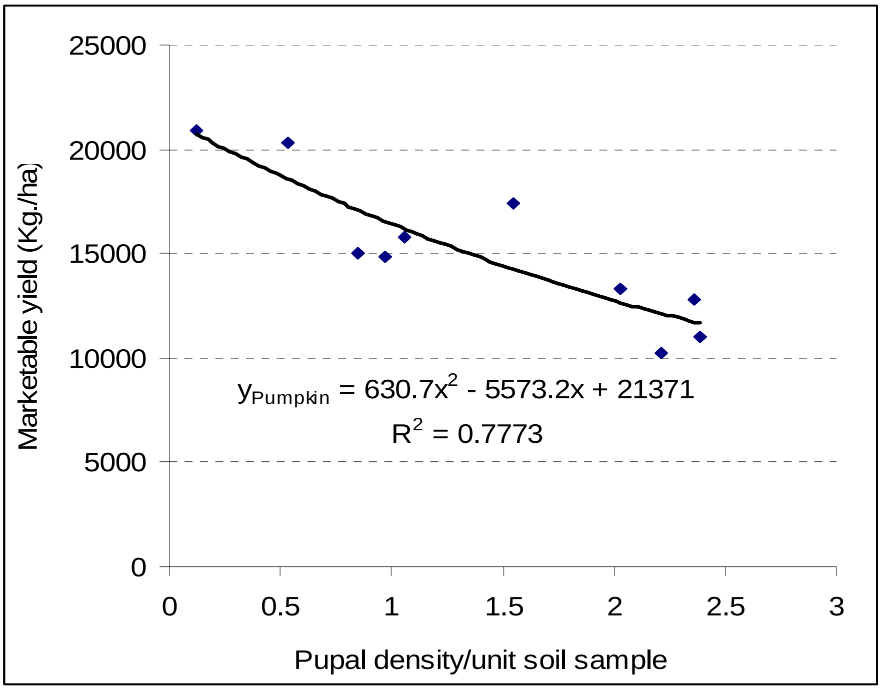

Fig-13: Trend of marketable yield of pumpkin as influenced by pupal density in soil.

The correlation co-efficient (r) between the larval density of epilachna beetle/plant and total yield (in kg) of bitter gourd was found significantly negative (r = -0.9655) indicating that they are inversely related with each other.

The economic threshold level (ETL) of epilachna beetle infesting bitter gourd under terai agro-ecological condition of West Bengal was obtained 1.31 larva /plant. The R^2 value was determined as 0.9321 which indicated 93.21% variation in yield of bitter gourd accounted for the beetle infestation and rest 6.79% accounted for the factors other than this. Thus it may be inferred that plant protection measures for managing this notorious pest to be initiated when the beetle incidence per plant reaches 1.31 larva per plant.

5.2.3.2. Pumpkin, *Cucurbita pepo* Linn.:

It revealed from the results that yield of pumpkin was found to decrease with the increase in larval density per plant. Marked differences in yield were noted in various intensity of infestation. Yield of pumpkin fruits was recorded as 202.89, 198.51, 197.23 and 194.19 q/ha when 1, 2, 3, and 4 larva per plant were released respectively. Minimum yield (189.31 q/ha) was observed in treatment T_6 where 5 larva per plant were released. Yield reduction over control was derived as 0.28, 4.66, 5.94 and 8.98 q./ha in T_2, T_3, T_4 and T_5 respectively. Maximum reduction in yield over control was noted in T_6 (13.86 q/ha) where larval density was highest (5 larva /plant). The correlation co-efficient (r) between the larval density of epilachna beetle/plant and total yield of pumpkin fruits was determined significantly negative (r = -0.9755). Thus, it becomes clear that yield and larval density/plant were inversely related with each other. Increase in larval density will result in decrease in yield and vice-versa.

The yield reduction by unit insect damage was obtained as 2.76 q/ha. It appeared from the present investigation that the economic threshold level (ETL) of epilachna beetle infesting pumpkin under terai agro-ecological condition of West Bengal was 1.98 larva /plant. The R^2 value was determined as 0.9517.

5.2.3.3. Trend analysis of epilachna beetle density:

Two quadratic equations were derived between marketable yield and number of larva per plant for bitter gourd and pumpkin separately (fig-14). It revealed from the trend lines that larval density per plant governed the amount of marketable yield to the tune of 93.71 to 97.81% which was applicable within a range of 0.00 to 5.00 larva /plant. It was also affirmed that tend of the trend lines were linear within that range.

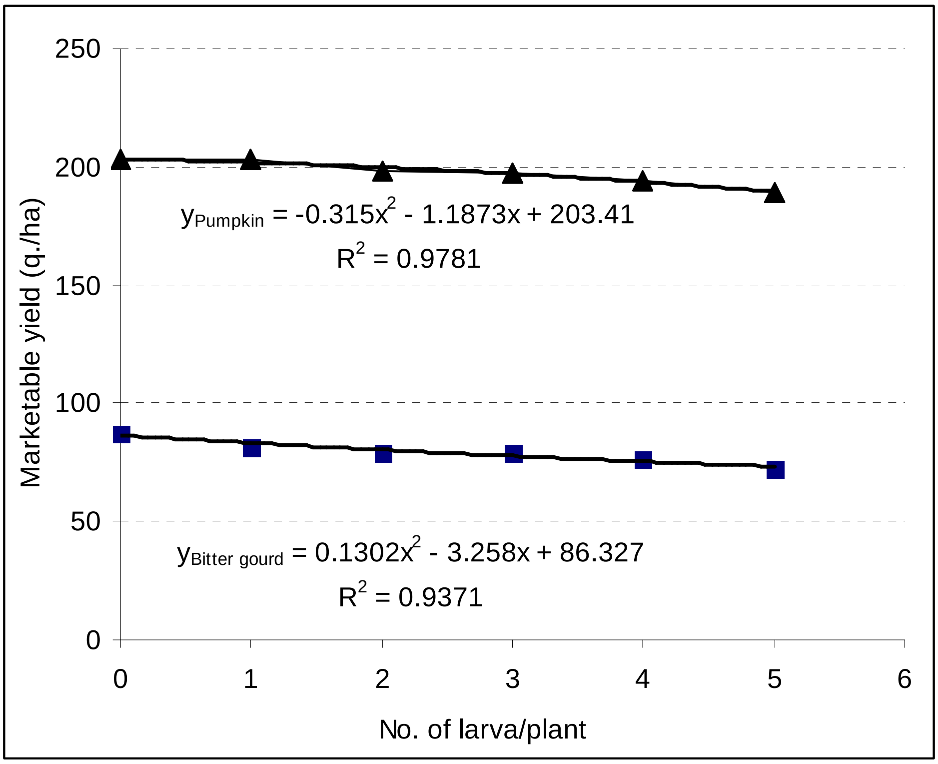

Fig-14: Trend of marketable yield and larval density of epilachna beetle.

In the present study ETL value of the grubs of epilachna beetle were derived as 1.31 and 1.98 /plant on bitter gourd and pumpkin respectively. Very few works with regard to economic threshold level of epilachna beetle on cucurbits have so far been conducted especially in the agro-ecological region under consideration. From the present findings it may be opined that control measures need to be initiated when larval population of the beetle will reach at 1.31 and 1.98/plant on bitter gourd and pumpkin respectively under terai agro-ecological region condition of West Bengal. However, the result of the study could not be compared with other works.

5.3. Biology of the key pests of cucurbits:

The knowledge of biology and biometrics of insect pests is helpful in developing efficient management strategy that may prevent wasteful use of costly as well as hazardous chemicals. It tells about the developmental stages, their duration, time of occurrence and the time they damage our crops. The internal feeders have to be targeted at their adult stage before inserting their eggs within the economic part of the plant; otherwise the feeding stage of the pest will place themselves within the fruits and become inaccessible to insecticides. Moreover, some insect-pests pupate under the soil and if we know their pupation time, we would be able to undertake deep ploughing operation of the soil to destroy them and thus protect our crops from emerging adults that may invade the crops. It can also help in predicting pest outbreak and population build up.

5.3.1. Melon fruit fly, *Bactrocera cucurbitae* (Coq.) (Tephritidae: Diptera):

Results of the present investigation on morphometrics, life stage duration, fecundity, survivability and sex ratio etc. on bitter gourd and pumpkin revealed minor variation. It becomes evident from the Fisher's "t" test analysis of the mean observations recorded on two hosts of melon fruit fly, that there exist no significant differences almost in all the cases. Only the adult longevity and total life period of male flies were found significantly higher on bitter gourd than pumpkin. Adult longevity of male flies was noted 31.00 and 27.20 days on bitter gourd and pumpkin respectively. Total life period (egg to death of adult) was recorded 46.00 days on bitter gourd and 43.30 days on pumpkin that are significant at 1% level of significance. Similar observations were also recorded earlier by Back and Pemberton

(1917), Lall and Sinha (1959), Narayanan and Batra (1960), Doharey (1983), Shivankar and Dumbre (1985), Patel (1989) and Koul and Bhagat (1994).

Morphometric parameters determine growth and development of an insect that ultimately resulted from nutrient intake from the host concerned. The degree of preference or non-preference of host by the insect plays vital role in this aspect. Better growth and development may be the result of preference of the host and vice versa. Again, shorter developmental period, longer life period, low mortality also is the reflections of better nutrition and preference of host by the insect. Thus, it may be inferred that the preferred hosts gave rise to more developed insect with shorter developmental period, longer life period and lower mortality. From this point of view, it has become evident that both bitter gourd and pumpkin are more or less equally preferred by the melon fruit fly. Earlier, Butani (1975a) found that its preferred hosts were musk melon, bitter gourd and snake gourd. Likewise, Singh *et al.* (2000) also reported 31.27% and 28.55% infestation on bitter gourd and water melon respectively. However, the findings are not in conformity with Gupta and Verma (1978) and Pareek and Kavadia (1994) who found pumpkin as the least preferred host of melon fruit fly.

5.3.2. Epilachna beetle, *Henosepilachna vigintioctopunctata* (Fab.) (Coccinellidae:Coleoptera):

Morphometric parameters of different life stages of epilachna beetle were studied on bitter gourd and pumpkin. Results of the study on morphometrics of egg, grub, pupa and adult (both male and female) indicated no major variations in their development when reared on two individual hosts. The critical analysis of means of the parameters showed that there exist no significant differences in their growth and development using bitter gourd and pumpkin as host. Duration of different life stages, fecundity, hatchability, larval mortality and sex ratio also reflected the same phenomenon. Only the pupal mortality was noted significantly higher on pumpkin (10.00%) as compared to that of bitter gourd (6.25%) at 1% level of significance. Thus it becomes evident that both the hosts are more or less equally preferred by epilachna beetle, reflected in similar growth and developmental pattern.

Most of the previous studies regarding biological parameters and host preference of epilachna beetle were conducted on solanaceous crops. However, Austin (1925) observed 5 to 7 days of incubation period of *Epilachna dodecastigma* on cucurbitaceous plants.

On the other hand, Hossain *et al.* (2009) studied the impacts of different host plants on growth and development of *Epilachna dodecastigma* in Bangladesh and observed that the length and breadth of egg were highest in teasel gourd (1.09±0.04 and 0.38±0.05 mm), which were statistically identical to those of sponge gourd and bitter gourd. The length and breadth of final instar grubs were highest feeding on leaves of sponge gourd (7.90±0.27 mm, 6.95±0.43 mm), which were statistically identical to teasel gourd (7.82±0.38 mm, 6.93±0.09 mm) and bitter gourd (7.71±0.09 mm, 6.83±0.38 mm). The lowest length and breadth of grub were measured when fed on yard long bean (5.32±0.22 mm, 3.20±0.13 mm). Total duration of grub was the highest on sponge gourd (11.38±0.53 days), which was followed by bitter gourd (11.05±0.82 days). Teasel gourd showed significantly lowest grub duration (9.58±0.33 days). The length and breadth of pupae developed from teasel gourd were highest and lowest measurement of the pupa was observed on yard long bean. Pupal period was highest on bitter gourd (5.50±0.24 days), and lowest in case of yard long bean leaf (4.15±0.94 days). The authors also opined that the variation in morphometrics of different growth stages of the beetle may be due to the suitability and nutritional quality of host plants as food. Thus, results of the present investigation are in conformity with those findings.

5.4. Population dynamics of different key pests of cucurbits:

Before developing a sound insect pest management programme for a specific agro-ecosystem, it is necessary to have basic information on the incidence of the pest in relation to weather parameters that help in determining appropriate time of action to be undertaken. Thus, understanding seasonal fluctuation of insect pest population in the field will certainly contribute a lot to the sustainable management for the pest. In view of this, a regular surveillance and monitoring programme for the key pests of cucurbitaceous vegetables is necessary in order to develop a forecasting system through manipulating crop phenology and insect pests' incidence to avoid synchronization of peak period of infestation and vulnerable stage(s) of the crop. So as to achieve this important objective, the population fluctuation of the key pests of cucurbitaceous vegetables were studied and impact of different weather parameters thereof were worked out. The experiment was conducted with a view to provide basic guideline for future development of sustainable pest management of cucurbitaceous vegetables.

5.4.1. Melon fruit fly, *Bactrocera cucurbitae* (Coq.) (Tephritidae : Diptera):

The melon fruit fly remains active throughout the year on one or the other host. The fly population was recorded comparatively lower during the investigation year 2008 than that of 2007. It was also noted from the mean incidence obtained from two consecutive years of study that activity of the fly was lowest during cold months of the year. Afterwards, the population started increasing and attained its peak during 20^{th} to 25^{th} standard weeks i.e. during warm seasons of the year. Fluctuation in population of the fly may be due to prevalence of congenial environmental conditions or fruiting and flowering time of the hosts concerned. Population fluctuation of melon fruit fly during the year of study has been depicted in fig-15.

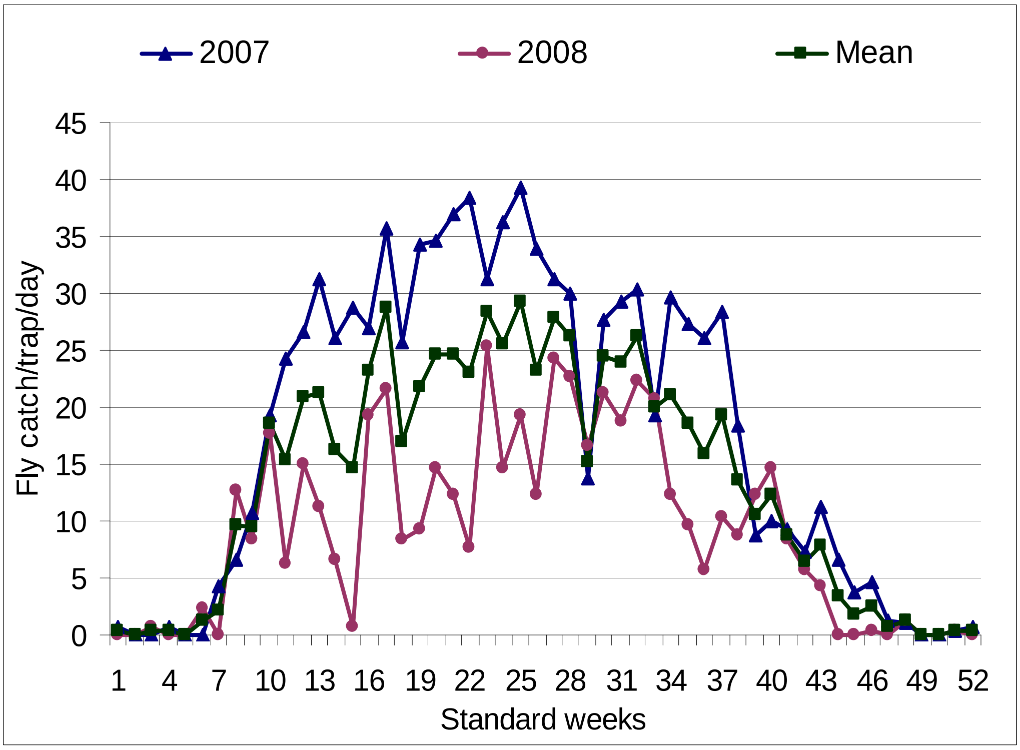

Fig-15: Pattern of incidence of melon fruit fly, *Bactrocera cucurbitae* (Coq.)

Virakthamath and Babu (2004) assessed the field incidence and population dynamics of fruit flies *Bactrocera dorsalis, B. zonatus and B. cucurbitae* and recorded peak population during 44^{th} and 9^{th} standard weeks in Dharwad, India. The peak activity of melon fruit fly, *B. cucurbitae* was found in April-May, when the weather remained warm (26.2-38.0 ^{o}C) and humid (90% relative humidity) as stated by

Patnaik *et al.* (2004). Fruit fly infestation was recorded highest during the *kharif* season followed by summer and *rabi* seasons as reported by Banerji *et al.* (2005). Similar observations were also noted by Borah (1996), Nath and Bhusan (2006b) in India and Mahmood and Mishkatullah (2007) in Pakistan. Dhillon *et al.* (2005b) observed that during severe winter months, the fly hide and huddle together under dry leaves of bushes and trees. During hot and dry seasons the fly take shelter under humid and shady places feeding on honey dew of aphids and infest the fruit plants. Thus, the findings of the present investigation are in agreement with that of previous workers.

5.4.1.1. Influence of meteorological parameters on the incidence of melon fruit fly:

It appeared from the analysis of cuelure capture data that all the meteorological parameters contribute significantly toward increasing or decreasing melon fruit fly population. It has been found that the mean maximum, minimum temperature showed positive and significant correlation (r = +0.7376 and +0.7596 respectively) with the fruit fly caught per trap per day. However, temperature gradient correlated negatively (r = -0.4789) with the fly population. Relative humidity (minimum, maximum and gradient) influenced fruit fly population significantly. Maximum and humidity gradient negatively correlated (r= -0.4249 and -0.5481 respectively) with the fly catch, whereas minimum relative humidity showed positive correlation (r= +0.44). Rainfall inflicted positive impact on the fly incidence that showed positive correlation (r= +0.4367). The possible reason of positive correlation between minimum humidity and fly incidence may be due to higher rainfall that indirectly leads to increase in relative humidity of the environment. The numerical values of correlation co-efficient and respective regression equations have been presented in table-27.

From statistical analysis it was found that the combined linear effects of the environmental factors under consideration contribute significantly to the variation in trap catch of melon fruit fly. The R^2 value as determined indicated 76% variation in trap catches of melon fruit fly can be accounted for by a linear function involving temperature (maximum, minimum), RH (maximum, minimum), rainfall and total sunshine hour/day. Other contributing factors to the variation in trap catches might be the availability of crops or availability of fruiting and flowering stages(s) of the crop.

Although the crop and the insect species was different, yet, similar results were reported by Liu and Yen (1982) who claimed that the population of oriental fruit fly was related to the ripening of citrus fruits in Taiwan. Thus findings of the present study are in agreement with this.

Table-27: Correlation co-efficient and regression equation between meteorological parameters and melon fruit fly incidence.

Meteorological factors		Correlation co-efficient	Regression equation
Temperature(^oC)	Maximum	+0.7376 *	y=2.02x + 44.36
	Minimum	+0.7596 *	y=1.41x + 13.43
	Gradient	-0.4789 **	y= -1.66x + 29.56
Relative Humidity (%)	Maximum	-0.4249 *	y= - 1.01x + 107.88
	Minimum	+0.4366 *	y= 0.36x + 11.46
	Gradient	-0.5481*	y= - 0.42x + 23.49
Rainfall (mm.)		+0.4367 **	y=0.04x + 11.20
Sunshine hour per day		+0.3753 **	y=1.35x + 21.57

* Significant at 5% level of significance ** Significant at 1% level of significance

The multiple regression analysis of melon fruit fly activity and the environmental parameters revealed the following relationship:

$$Y=9.081+4.884x_1^{*}+3.751x_2^{*}-1.326x_3^{*}+0.594x_4^{*}+1.802x_5^{**}+2.071x_6^{**}$$

Where, Y= trap catch of melon fruit fly/trap/day

x_1=Temperature (maximum)

x_2=Temperature (minimum)

x_3=Relative humidity (maximum)

x_4=Relative humidity (minimum)

x_5=Rainfall

x_6=Total sunshine hour/day

The R^2 value was determined as 0.76.

The fly populations round the year as influenced by temperature, relative humidity, rainfall and sunshine hour per day have been presented in fig-16a-d.

Mahmood *et al.* (2002) noted that all abiotic factors contribute significantly towards increasing or decreasing of fruit fly catch by sex attractant. Marked effects of temperature and rainfall on the population dynamics of the fruit flies, *B. dorsalis, B. cucurbitae* and *B. tau* was also noted by Deng *et al.* (2006). Pawar *et al.* (1991)

reported significant positive correlation of melon fruit fly population with minimum temperature, relative humidity and rainfall.

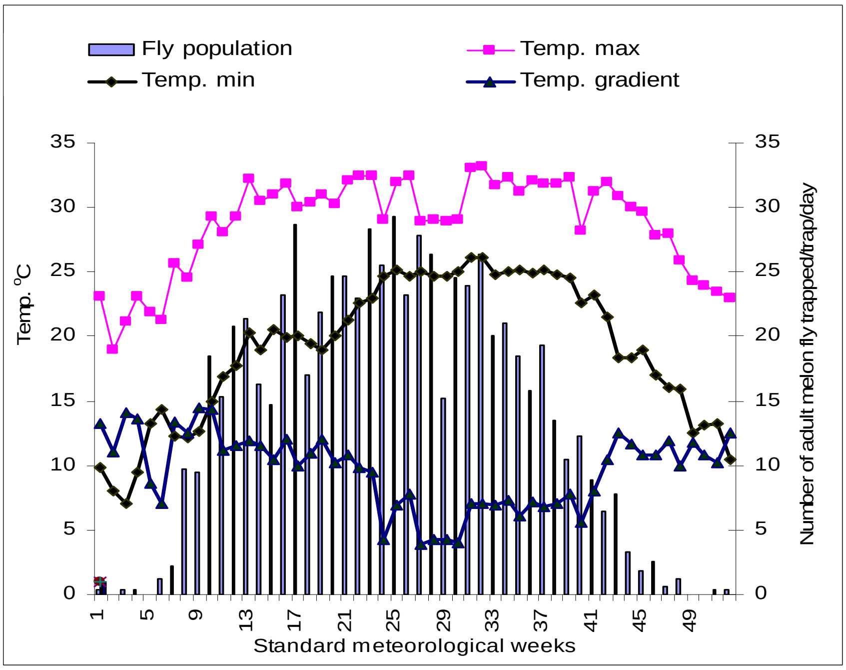

Fig-16a: Influence of temperature on the incidence of melon fly, *B. cucurbitae* (Coq.)

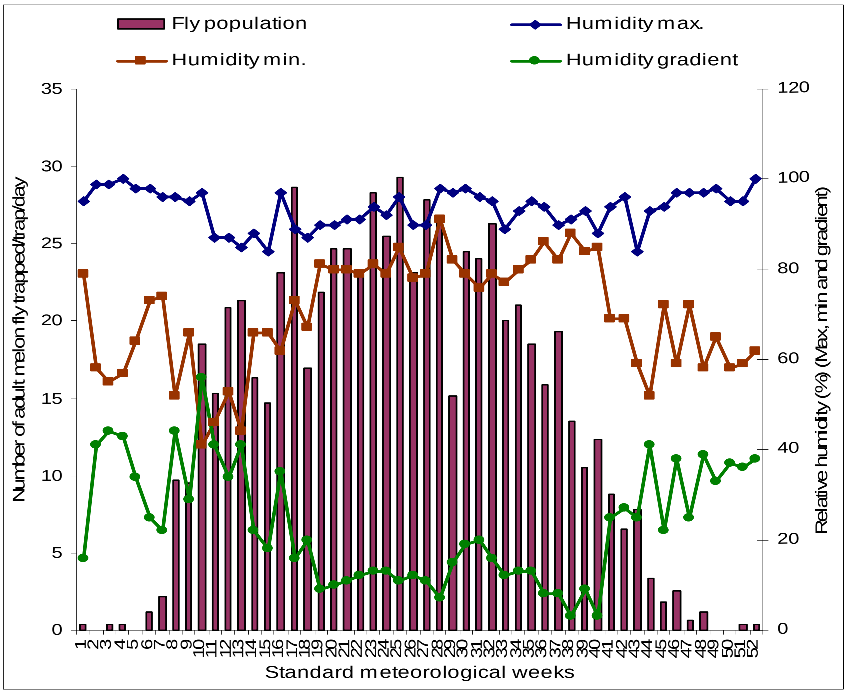

Fig-16b: Influence of relative humidity on the incidence of melon fly, *B. cucurbitae* (Coq.)

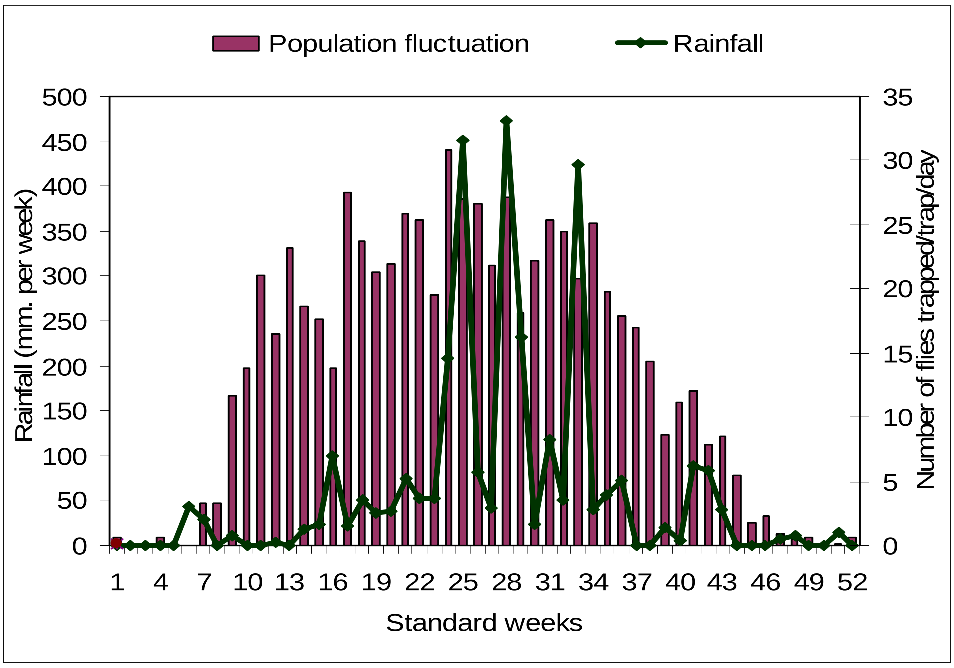

Fig-16c: Influence of rainfall on the incidence of melon fly, *B. cucurbitae* (Coq.) (Coq.)

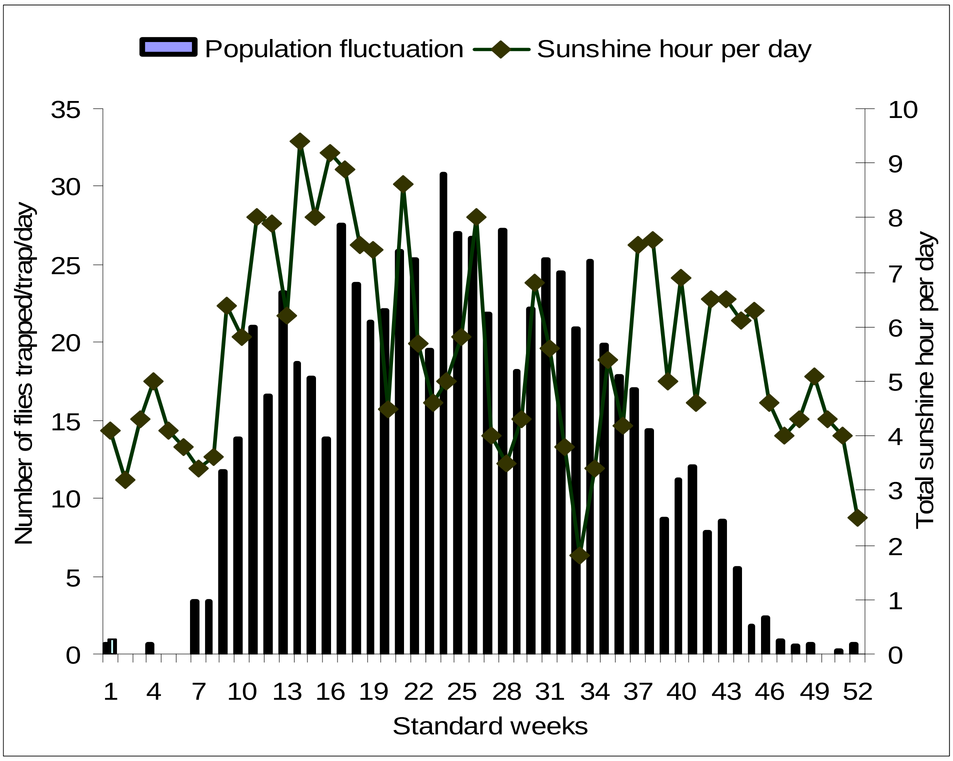

Fig-16d: Influence of sunshine hour on the incidence of melon fly, *B. cucurbitae* (Coq.)

While in Pakistan, Mahmood and Mishkatullah (2007) stated that population dynamics of the genus *Bactrocera* was found to be regulated depending on the host fruit maturity, temperature and rainfall. Vayssieres *et al.* (2009) indicated the influence of major climatic factors on the population fluctuation of the fly. Likewise, Gupta and Bhatia (2000) and Singh and Naik (2006) found significant positive correlation with maximum and minimum temperature but humidity had negative correlation. Positive and significant correlation between rainfall and fly activity was observed by Shukla and Prasad (1985) and positive correlation between relative humidity and fly population during summer and negative during rainy season was noted by Nath and Bhusan (2006b).

In the present investigation the findings are more or less in corroboration with the observations of previous workers. Temperature and humidity gradient showed negative correlation with the fly incidence upon which little works have so far been conducted. From the overall findings of this study it may be opined that the cropping season should be adjusted in such a fashion so that there should have an asynchrony between reproductive stage of the crop and fly incidence. This might be helpful in avoiding fly infestation on the crops. As the cucurbits are basically summer season crops, thermo and photo insensitive high yielding cultivars will safely be incorporated in this tactic.

5.4.2. Epilachna beetle, *H. vigintioctopunctata* (Fab.) (Coccinellidae: Coleoptera):

In the present investigation the pattern of population incidence during 2008 differed to some extend from that of 2007. Analysis of two years (2007-08) observation on population fluctuation of epilachna beetle revealed that lower population was prevailed from January onwards up to March and increased during April-May. Then the population started decreasing and fluctuated during May-September (15^{th} to 41st standard week) being lowest in 32^{nd} standard week and highest during $30\text{-}31^{st}$ standard week. Population peak was noted in 14^{th} standard week (during April). Incidence of epilachna beetle during the year of investigation has been depicted in fig-17.

Incidence of epilachna beetle varied from place to place and from year to year due to variations in the prevailing environmental conditions as stated earlier by Konar and Mahasin (2002). Seasonal occurrence of the beetle was studied by Venkatesha (2006) on a medicinal plant, *Withania somnifera* in Bangalore (Karnataka, India) during 2004-05 and noticed peak population in August. Tripathi and Misra (1991) in a study conducted in the field in North-Eastern Uttar Pradesh, India and found that the populations were high in the period from late July to October and low in December and January. Rajagopal and Trivedi (1989) found peak period of infestation by the epilachna beetle in July-August and also opined that peak period of infestation varies from region to region. Results of the present investigation are also in conformity with the earlier records. Minor deviations might be due to regional variation as well as phenology of the crop under consideration.

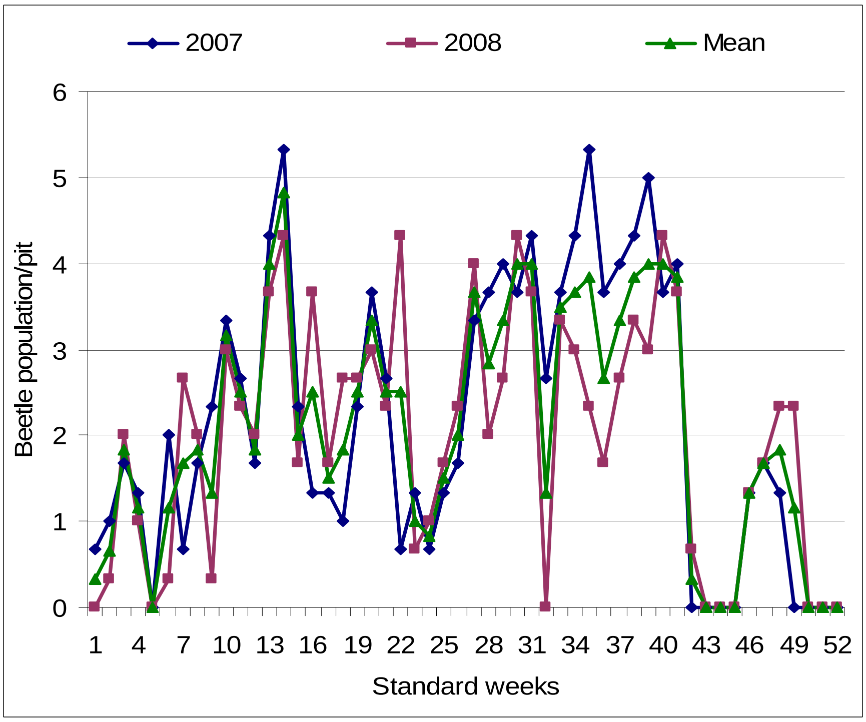

Fig-17: Pattern of incidence of epilachna beetle, *H. vigintioctopunctata* (Coq.)

5.4.2.1. Influence of meteorological parameters on the incidence of epilachna beetle:

Impact of weather parameters on the incidence of epilachna beetle was assessed by correlation studies. Correlation between population of the beetle and important meteorological parameters revealed that the incidence of the beetle have a significant positive correlation with temperature (minimum and maximum), relative humidity (R.H.) (minimum) and rainfall, while negative correlation was obtained with temperature (gradient), relative humidity (R.H.) (minimum and maximum) and total sunshine hour per day. It also appeared that mean maximum, minimum temperature showed positive and significant correlation (r = +0.5059 and +0.5720 respectively) with the incidence of epilachna beetle. However, temperature gradient have negative (r = -0.4234) correlation. Relative humidity (minimum, maximum and gradient) also influenced the beetle population to a great extent. Maximum and minimum relative humidity have positive correlation (r= 0.3424 and 0.3571) with the beetle incidence, whereas humidity gradient showed negative correlation (r= -0.4014). Rainfall inflicted positive impact on the incidence of epilachna beetle that showed positive correlation (r = +0.3592). However, a non-significant positive correlation with the incidence of beetle was derived with sunshine hour/day (table-28).

Table-28: Correlation co-efficient and regression equation between meteorological parameters and epilachna beetle incidence.

Meteorological factors		Correlation co-efficient (r)	Regression equation
Temperature (°C)	Max	+0.5059 *	Y= 0.198x+3.314
	Min	+0.5720 *	Y= 0.145x+0.679
	Gradient	-0.4234 **	Y= - 0.199x+4.002
Relative humidity (%)	Max	+0.3424 **	Y= 0.921x+6.248
	Min	+0.3571 **	Y= 0.039x+0.698
	Gradient	-0.4014 **	Y= - 0.042x+3.070
Rainfall		+0.3592 **	Y= 0.037x+1.969
Total sunshine hour/day		+0.2425 NS	Y=0.134x+1.766

* Significant at 5% level ** Significant at 1% level NS, Not significant

The multiple regression analysis of epilachna beetle incidence and the environmental parameters revealed the relationship as follows:

$$Y=1.482+1.083x_1^{*}+0.981x_2^{*}+1.054x_3^{**}+0.035x_4^{**}+0.306x_5^{**}+0.208x_6$$

Where, Y= Number of beetle/pit (two plants/pit)

x_1=Temperature (maximum)

x_2=Temperature (minimum)

x_3=Relative humidity (maximum)

x_4=Relative humidity (minimum)

x_5=Rainfall

x_6=Total sunshine hour/day

The R^2 value was determined as 0.71.

From the statistical analysis it was found that the combined linear effects of the environmental factors under consideration contribute significantly to the variation in number of beetle/plant. The R^2 value indicated that 71% variation in beetle population can be accounted for by a linear function involving temperature (maximum, minimum), R.H. (maximum, minimum), rainfall and total sunshine hour/day. Incidence of the pest in relation to temperature, relative humidity, rainfall and sunshine hour per day has been presented in fig-18a, 18b, 18c and 18d respectively.

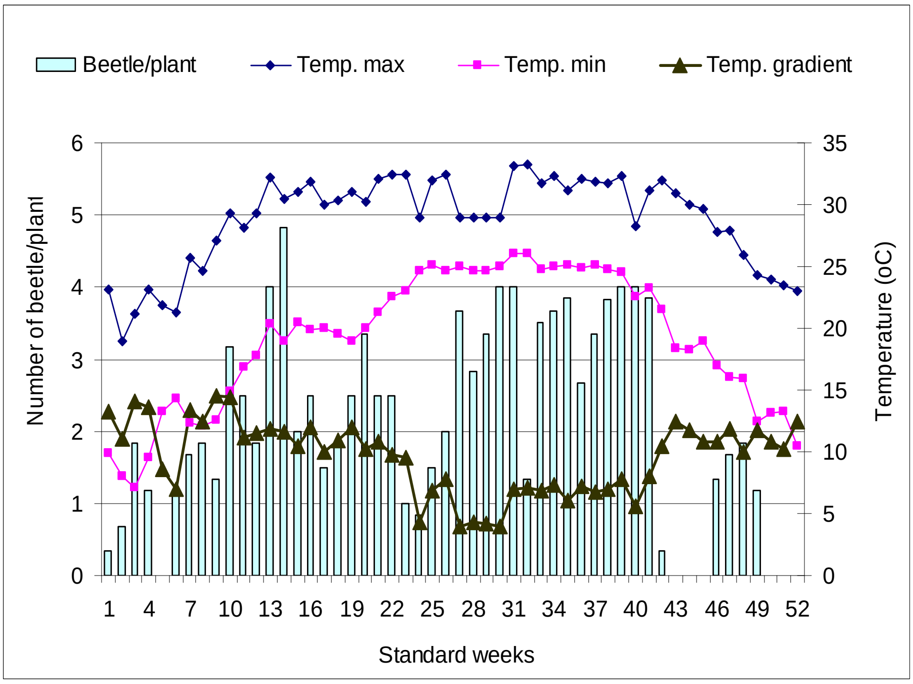

Fig-18a: Influence of temperature on the incidence of epilachna beetle, *H. vigintioctopunctata* (Fab.)

The mature larvae and adults of epilachna beetle were moderately affected by high temperature and low humidity as revealed by Grewal (1988). In the present study, the major meteorological parameters contributed significantly on the population fluctuation of the beetle. Richards and Filewood (1993) found that temperature had a greater influence on daily mortality rates of the beetle and they also noted that above and below that temperature growth rates decreased and mortality increased. Hence, in the present population study, peak period observed during 14th to 41st standard week (April to August) i.e. during the warmer months of the year and lower population during cooler months conform the findings of earlier workers in this regard.

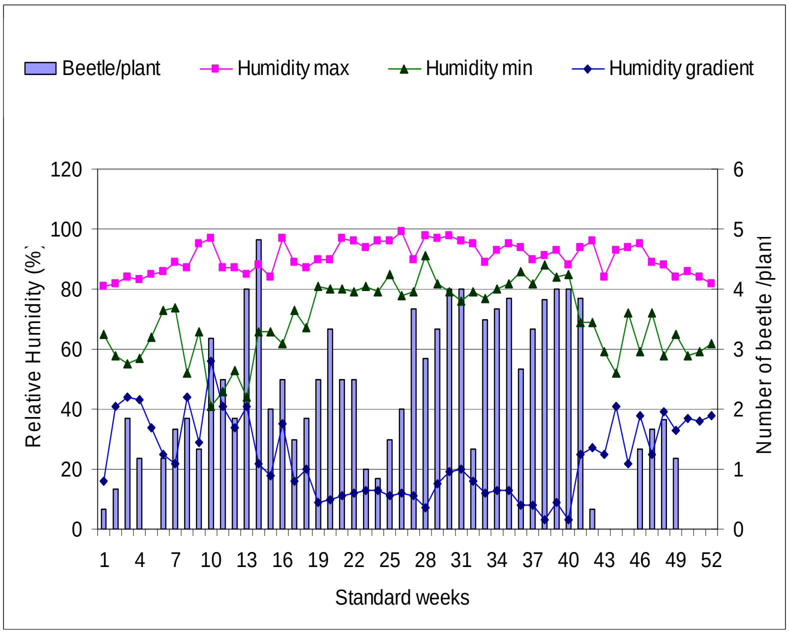

Fig-18b: Influence of relative humidity (%) on the incidence of epilachna beetle, *H. vigintioctopunctata* (Fab.)

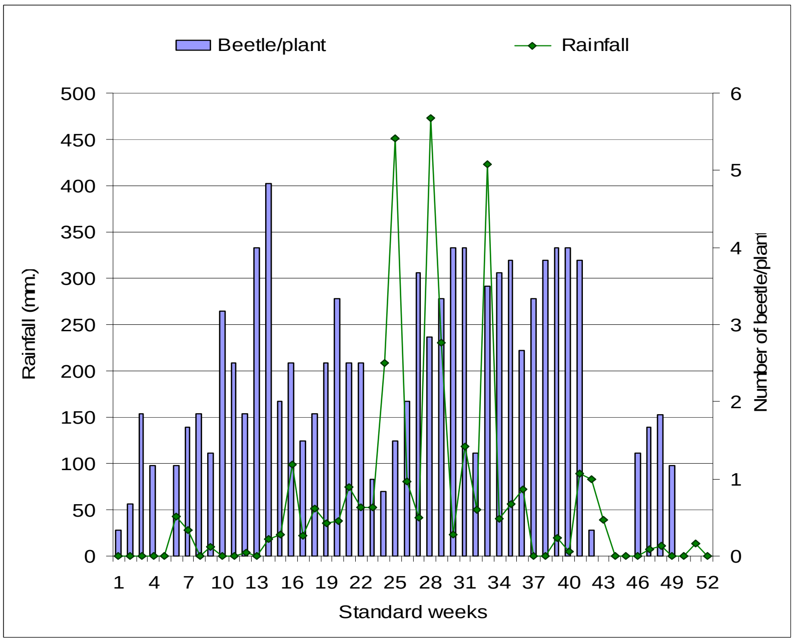

Fig-18c: Influence of rainfall on the incidence of epilachna beetle, *H. vigintioctopunctata* (Fab.)

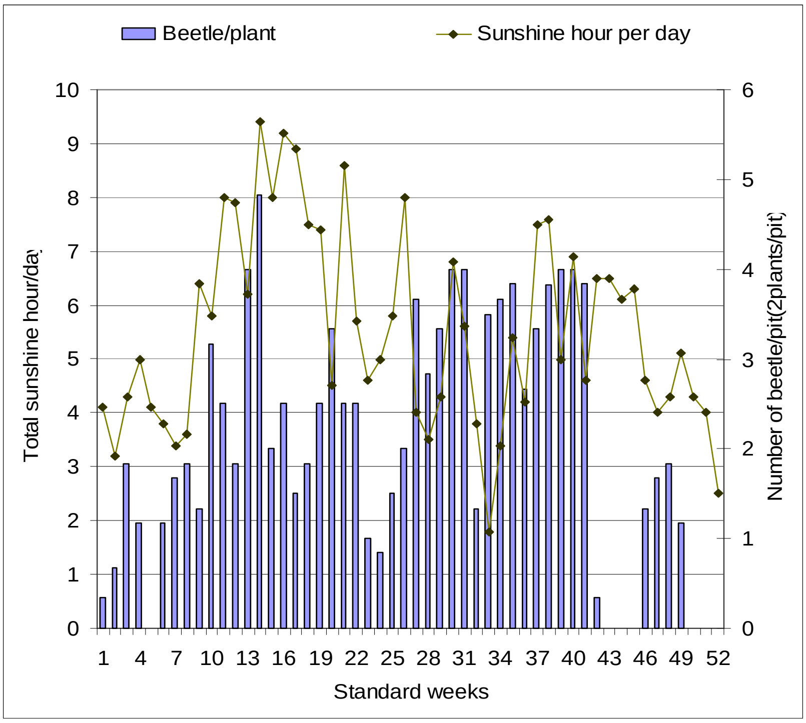

Fig-18d: Influence of sunshine hour/day on the incidence of epilachna beetle, *H. vigintioctopunctata* (Fab.)

5.4.3. Red pumpkin beetle, *Aulacophora foveicollis* (Lucas.) (Chrysomellidae: Coleoptera):

The chrysomelid, red pumpkin beetle is an important foliage feeding insect-pest of cucurbitaceous vegetables. The pattern of population fluctuation differed during 2007 and 2008 and intensity of population during 2008 was recorded to some extent lower than that of 2007. The population of the beetle remained considerably throughout the year in both the year of study except during second fortnight of December to the beginning of January in 2007 and during 28th standard week in 2008. Analysis of two years (2007-08) observation revealed that lower population was prevailed from the end of November onwards up to beginning of January and increased during February-April. Thereafter, the population fluctuation was more frequent during May-October being lowest in 28th and 50th standard week (both 0.50 beetle/pit). No population was recorded in the last fortnight of December up to first week of January. Population peak was noted in 31st standard week (3.67 beetle /pit). Pattern of incidence of the beetle during 2007-08 and their mean have been presented diagrammatically in fig-19.

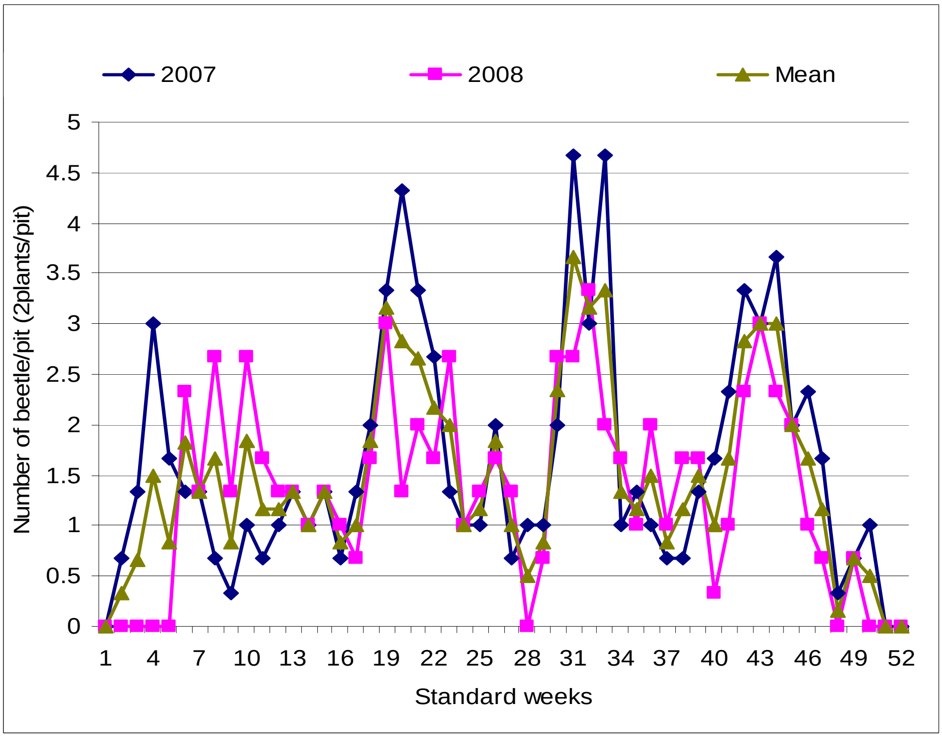

Fig-19: Pattern of incidence of red pumpkin beetle, *A. foveicollis* (Lucas.)

The survey work conducted by Roy and Pandey (1991) in India showed round-the-year activity of the beetle, being most dense in August and least in December. Population of red pumpkin beetle on cucumber was significantly higher in June and July sown crop as compared to that of April - May sown crop (Borah, 1997) and Butani (1975b) opined that the fact might be due to peak activity of this pest during rainy season. It was observed that infestation of the beetle was high from 7 May to 18 June, while from 25 June to 13 August 1998, the population gradually declined in the Peswar Valley of Pakistan (Saljoqi and Khan, 2007). However, Butani (1975a) observed that the beetles become active from March to October. Findings of the present investigation are not in agreement with Borah (1997) but partially accorded with Roy and Pandey (1991). But the observations recorded by Butani (1975a) are in conformity with the present findings.

5.4.3.1. Influence of meteorological parameters on the incidence of red pumpkin beetle:

It was revealed from the simple correlation studies that correlation co-efficient between incidence of the beetle and temperature (minimum and maximum) was positive and significant (r= +0.5576 and +0.4167 respectively) and non-significant but negative correlation (r = -0.0692) was found between population incidence and temperature gradient. Relative humidity (maximum and minimum) correlated positively with the beetle population (r = +0.3889 and +0.1768 respectively) and RH gradient correlated negatively (r = -0.2175). Rainfall also influenced the beetle population positively (r = +0.1198) whereas sunshine hour per day related negatively (r = -0.0546) with the incidence of the beetle (table-29).

Table-29: Correlation co-efficient and regression equation between meteorological parameters and red pumpkin beetle incidence.

Environmental parameters		Correlation co-efficient (r)	Regression equation
Temperature	Maximum	+0.5576 *	Y=0.138x+2.471
	Minimum	+0.4167 **	Y=0.070x+1.149
	Gradient	-0.0692 ^{NS}	Y=-0.022x+1.694
Relative humidity (%)	Maximum	+0.3889 **	Y=0.069x+4.808
	Minimum	+0.1768 ^{NS}	Y=0.013x+1.572
	Gradient	-0.2175 ^{NS}	Y=-0.015x+1.843
Rainfall		+0.1198 ^{NS}	Y=0.012x+1.429
Total sunshine hour/day		+0.0546 ^{NS}	Y=-0.021x+1.612

* Significant at 5% level ** Significant at 1% level ^{NS}, Not significant

The multiple regression analysis of red pumpkin beetle population and the environmental parameters revealed the following relationship:

$$Y=0.984+1.326x_1^{*}+1.095x_2^{**}+0.532x_3^{**}+0.057x_4+1.039x_5+0.934x_6$$

Where, Y= Number of beetle/pit (two plants/pit)

x_1=Temperature (maximum)

x_2=Temperature (minimum)

x_3=Relative humidity (maximum)

x_4=Relative humidity (minimum)

x_5=Rainfall

x_6=Total sunshine hour/day

R^2 value, that the co-efficient of determination was derived as 0.73.

From statistical analysis it was found that the combined linear effects of the environmental factors under consideration contribute significantly to the variation in beetle population in the field. The R^2 suggested 73% variation in number of beetle

/plant can be accounted for by a linear function involving temperature (maximum, minimum), RH (maximum, minimum), rainfall and total sunshine hour/day.

The incidental pattern of red pumpkin beetle as influenced by the environmental parameters has been presented in fig-20a-d. Very few works have so far been conducted with regard to the impact of meteorological parameters of the population dynamics of the beetle. Population density of the beetle was correlated with both temperature and rainfall by Roy and Pandey (1991) and observations noted by the authors are in corroboration with the present findings.

From the overall findings of this study with regard to population dynamics of foliage feeders (of cucurbits) it may be inferred that warmer month to be avoided for cultivation of these vegetables. This would result in asynchronization of cropping season and pest incidence. Here also, thermo and photo insensitive high yielding cultivars may be incorporated.

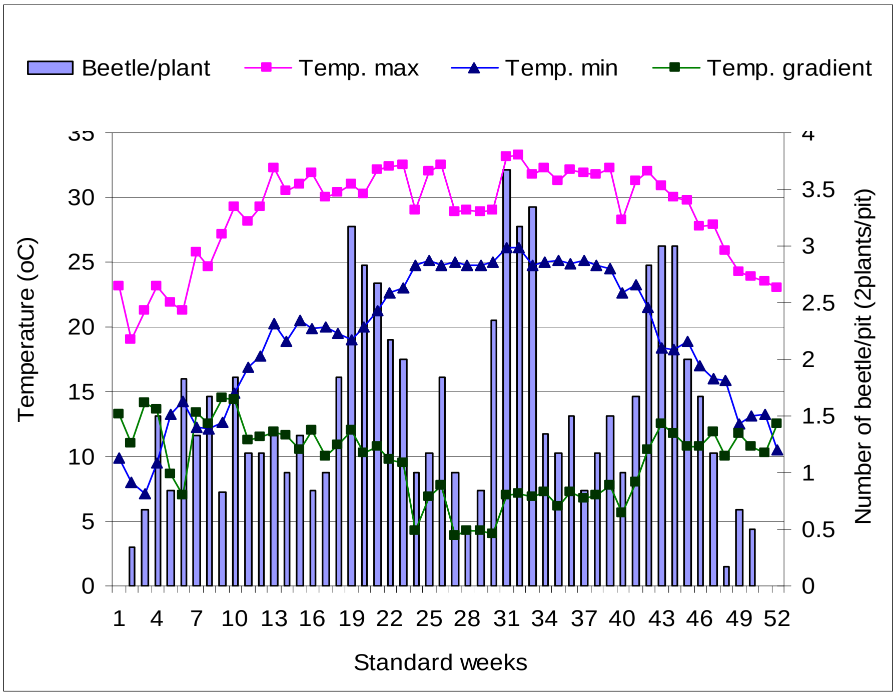

Fig-20a: Effect of temperature on the incidence of red pumpkin beetle, *A. foveicollis* (Lucas.)

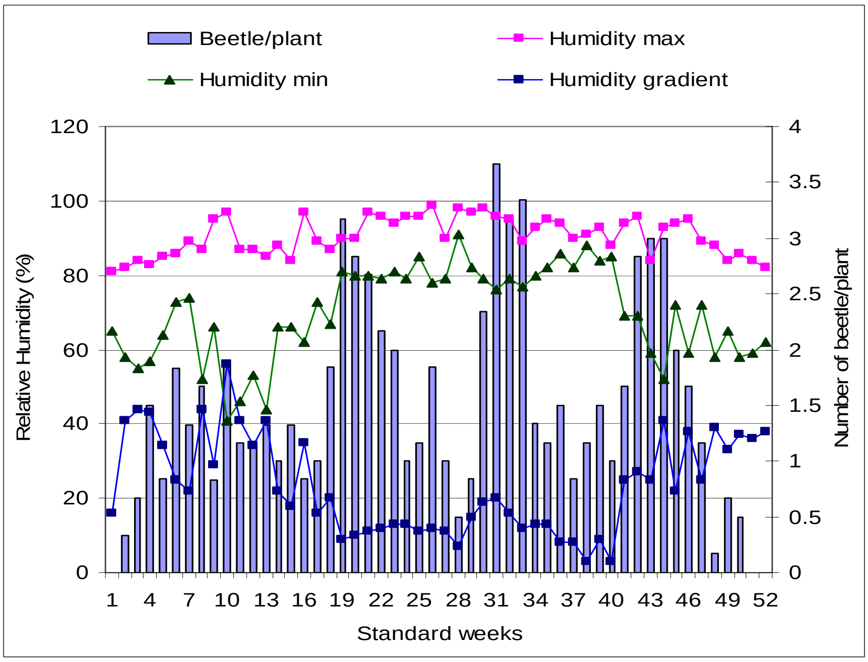

Fig-20b: Effect of relative humidity on the incidence of red pumpkin beetle, *A. foveicollis* (Lucas.)

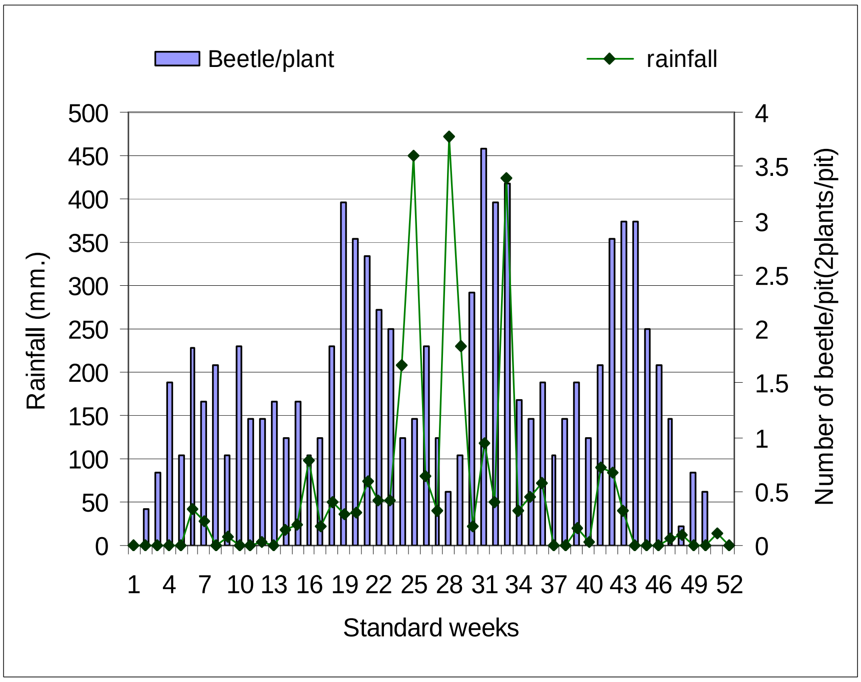

Fig-20c: Impact of rainfall on the incidence of red pumpkin beetle, *A. foveicollis* (Lucas.)

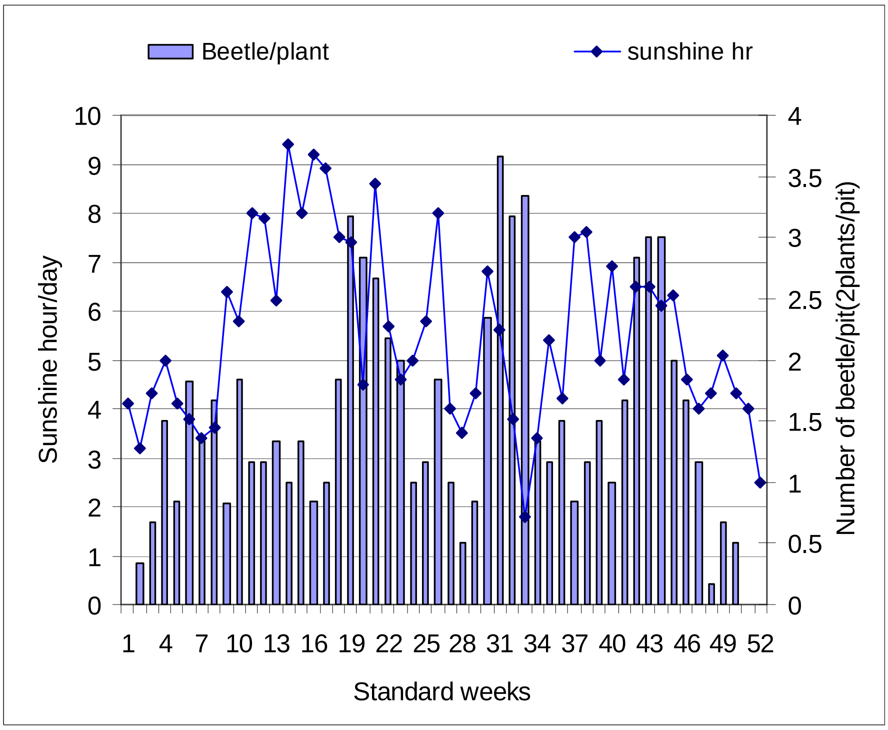

Fig-20d: Impact of sunshine hour on the incidence of red pumpkin beetle, *A foveicollis* (Lucas.)

5.5. Behavioural characteristics of melon fruit fly, *Bactrocera cucurbitae* (Coq.):(Tephritidae: Diptera):

5.5.1. Depth of pupation:

Life history of melon fruit fly, the dreaded insect pest of cucurbitaceous vegetable is very peculiar. The maggots after getting matured within the infested fruit come out of it and spend a brief dispersal period. Then the mature third instar maggot burrows into soil and pupate therein. Thus, there remains a bright possibility of management targeting the late instar maggot and pupae by exposing them to unfavorable environmental conditions during pupation. Type of soil and moisture content therein are also play important role on successful pupation and eclosion of the adult fly. An estimate of pupation depth of the fly is important for optimizing soil control and in developing non-chemical and sustainable management practice.

It appeared from the results that, depth of pupation of mature maggots were affected by both soil type and its moisture content. There was no pupa found on the surface in sandy loam soil in any moisture level (0 to 100%). Most of the larvae found to pupate within 6 cm depth levels of both sand and sandy loam soil. No pupa was recorded beyond 6 cm depth both in case of sand and sandy loam at moisture levels 0 to 20%, but in case of sand maximum depth of pupation was up to 12 cm at 60 and

80% moisture. On the other hand, in case of sandy loam soil maximum depth of pupation was recorded up to 10 cm. depth. Results suggest that the depth of pupation might be influenced much due to variation in soil moisture. In soils that received no water or too much water might affect the larvae by desiccation or drowning.

The findings of the present investigation are in agreement with Hennessey (1994), Hodgson *et al*. (1998), Hou *et al*. (2006) and Alyokhin *et al.* (2001) who opined that majority of the larvae pupate within 3-5 cm depth in soil. Depth of pupation was also found to be influenced significantly by the variation in moisture level of the pupation medium as determined by Ibrahim and Mohammad (1978). All the pupae emerged from 6 cm depth level at lower moisture level (0% and 20%) of the pupation medium which is in agreement with the findings of Jackson *et al.* (1998) while Hou *et al.* (2006) detected that some larvae pupate deeper in soils having 10 and 20% moisture levels. The authors also suggested that in the event of little available water for pupal development, larvae tend to enter deeper into the soil to seek more water. A few larvae pupate on the soil surface at 0% moisture level which is not in agreement with the findings of Hodgson *et al.* (1998) who observed in Maxico Agricultural habitats that no pupae of fruit fly, *Anastrepha* spp. were found on the surface. Thus the present observations contradict with the findings of Hou *et al.* (2006) and it might be explained that at 0% moisture content the dry soil particles adhere on the body of larvae and thus restrict their movement within the soil.

The findings with regard to depth of pupation of melon fruit fly might be helpful in formulating efficient cultural management practices.

5.5.2. Activity of melon fruit fly during the day:

Activity of fly varies during different hours of the day. The chemical component cuelure [4-(p-acetoxyphenyl)-2-butanone], which is used in monitoring the fly is much more volatile. So determination of peak activity hour of the fly may be helpful in limiting exposure period of the chemical in the environment to enhance its shelf life.

Analysis of round the day data on trap catch revealed that the male adult flies remain active from 06:00 hours to 18:00 hours of the day. As per the trap-catch observations the flies were not active during 18:00 to 06:00 hours i.e. at night were.

But during morning hours, between 06:00 to 08:00 hours the large number(19.00 flies/trap/2hours) of flies captured by cuelure traps and in the evening hours between 16:00 to 20:0, 18.33 flies were trapped per 2 hours. The catch from 08:00 to 16:00 hours ranged from 7.33 to 12.66 flies/trap/2hours (Fig-21). Findings of the present study on daily activity rhythm of *B. cucurbitae* adults are in agreement with Arakaki *et al.* (1984). The field studies with *Bactrocera cucuminata* conducted by Raghu and Clarke (2003) also showed that there remain significant diurnal patterns in the abundance and behaviour of the Dacine fly.

Results of the present investigation indicated that there remains a possibility to enhance the shelf life of the volatile "cuelure" by using it only at day time. At night hours it may be kept in air tight container so as to protect it from volatilization. This will certainly contribute a lot in improving economic viability of the plant protection measure.

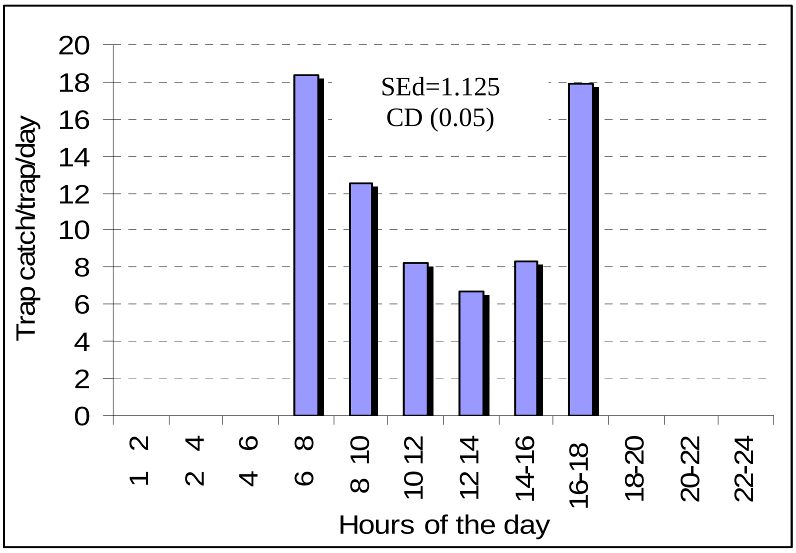

Fig-21: Melon fruit fly activity during the day.

5.5.3. Impact of trap colour in attracting melon fruit fly:

With a view to identify the colour preference of the fly, different coloured cuelure traps were used to catch the fly in field condition. However, the mean values of fly capture data of both summer and rainy season reveals that in orange coloured trap maximum flies (7.63 flies/trap/day) were found to be attracted followed by yellow (7.40 flies/trap/day) colour. However, there exists no significant difference among the two. The mean data also indicated the least acceptability of blue colour

(0.73 flies/trap/day) by male adult melon fly. Fly catch data of opaque (2.87 flies/trap/day), transparent (3.30 flies/trap/day) and violet (2.83 flies/trap/day) traps did not differ significantly at 5% level of significance. The results are also presented graphically in fig-22a.

The importance of visual cues has long been recognised as reported by several authors (Fletcher, 1987, Jang and Light, 1996). The responses of fruit flies to visual stimuli are dependent on colour, shape and size of the stimulus as reported by Katsoyannos (1989). Results of the present study are in agreement with Sarada *et al.* (2001). Vayssieres and Dall (2002) while working with different species of Dacine fruit flies viz. *Bactrocera dorsalis, B. correcta, B. zonata and B. ciliatus,* also found similar results. Robacker *et al*. (1990), Stark and Vargas (1992) opined that reflectance of yellow and orange colour might be a factor in the attractiveness of fruit flies to those colour. However, Rajitha and Virkthamath (2005) observed that orange and green colour traps were more attractive to *Bactrocera dorsalis.* Moreover, combination of visual and olfactory stimuli is needed to elicit high levels of response as compared to each stimulus offered alone (Pinero *et al*., 2006).

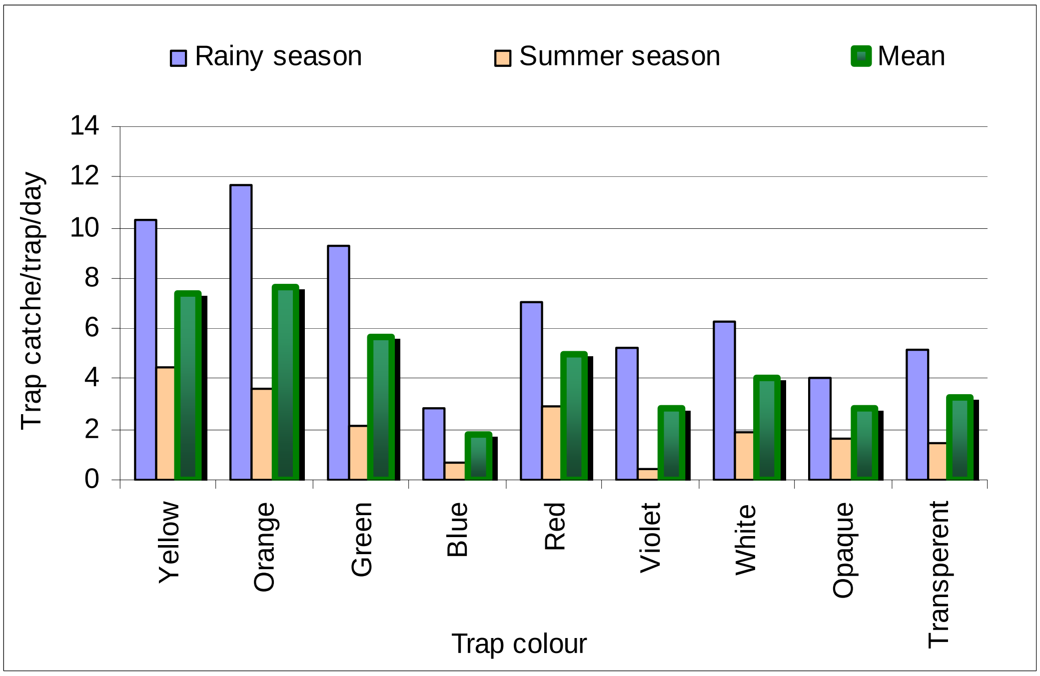

Fig-22a: Effect of trap colour on trap catching of *Bactrocera cucurbitae* using cuelure.

5.5.4. Effect of height of trap placement in attracting melon fruit fly:

Height of trap placement in the field plays an important role in attracting flies. So as to determine the exact level of the canopy at which the melon fruit flies prefer to remain active, cuelure traps were installed at different height from the ground level and trap catch data per trap per day at the respective level of heights were studied. From the results it appeared that trap catches were significantly differed from summer to rainy season as well as with varied height of trap placement. Mean values of both the seasons under investigation revealed that the best height of placing trap is 4′ from the ground level followed by 6′ capturing 11.33 and 9.33 number of flies/trap/day respectively. However, they are statistically at par with each other. The study also revealed that the yellow or orange coloured cuelure traps can be placed at 4-6′ from the ground level to trap more number of melon fruit flies efficiently. The results are also presented graphically in Fig-22b.

The results with regard to height of trap placement and its impact on trap catch, is in corroboration with the previous findings of Jalaluddin *et al.* (1998) who observed increased abundance of *Bactrocera correcta* in the middle zone (1.524-2.135m) of the tree. So, for better efficiency of trapping, orange or yellow coloured trap to be placed at 4-6′ height from ground level.

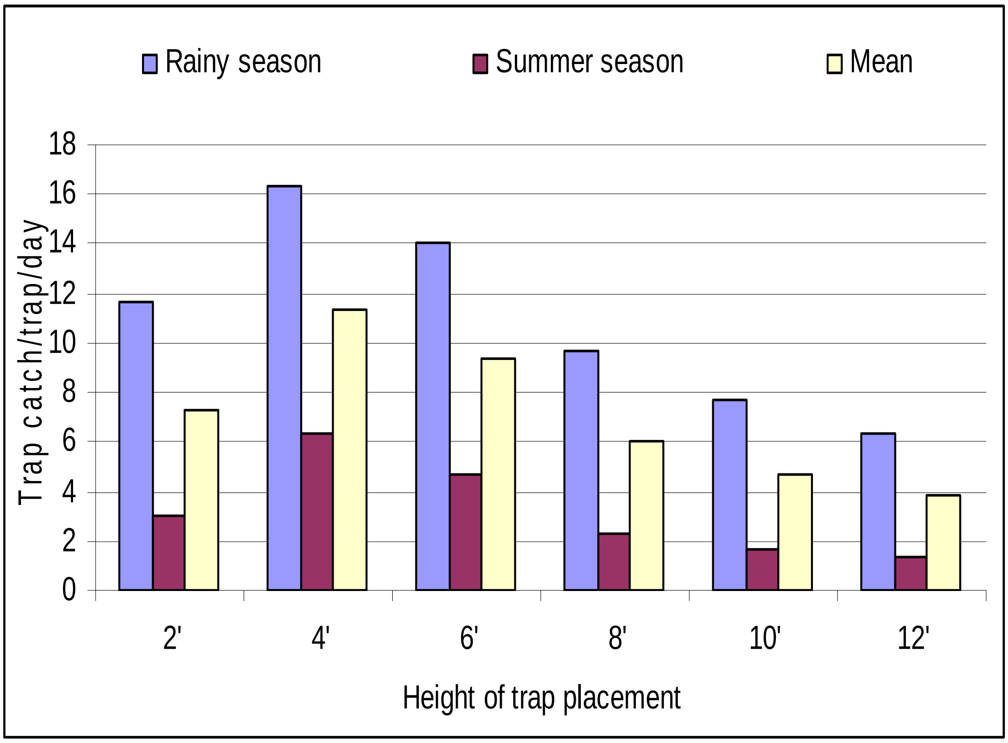

Fig-22b: Effect of trap placement height on trap catching of *B. cucurbitae* using cuelure.

5.6. Effect of bio-physical parameters of bitter gourd cultivars on percent fruit infestation and larval density of melon fruit fly, *B. cucurbitae* (Coq.) (Tephritidae: Diptera):

Maggots of the fly are responsible for damage which feed from within the infested fruits and hence it is very much difficult to control this pest through insecticide application. Thus, development of varieties resistant to melon fruit fly is an important component for integrated pest management of this pest (Panda and Khush, 1995). Cultivation of fruit fly-resistant bitter gourd cultivars are being limited due to lack of adequate information on the sources of resistance, and their influence on pest multiplication (Dhillon *et al.* 2005). The cultivars used in the present investigation included open pollinated, local collections and hybrids.

Larval density per infested fruit increased with the increase in percent fruit infestation as depicted in fig-23. A significant and positive correlation (r = +0.91) between larval density and percent fruit infestation was found to exist.

The regression equation between larval density and percent fruit infestation was determined as: Y= 0.30623x +9.6552 where, Y= Number of maggots (larva) per infested fruit where x = Percent fruit infested by melon fly.

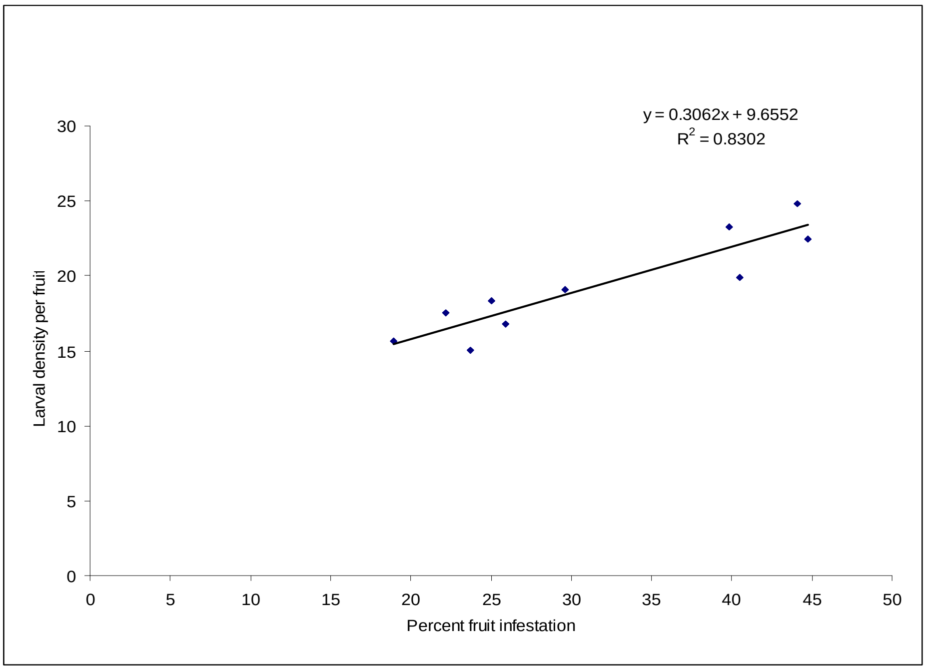

Fig-23: Relationship between percent fruit infestation and larval density/fruit.

5.6.1. Fruit weight:

Percent fruit fly infestation and larval density per infested fruit in different cultivars were positively and significantly (P=0.05) correlated (r = +0.77 and +0.75 respectively) with the fruit weight (table-30). This could be attributed to the availability of sufficient edible material in large sized fruit and affording opportunities for adequate feeding as well as survival of the maggots as noted by Singh and Vashishtha (2002).

5.6.2. Fruit length and diameter:

Both length and diameter of fruit that determine the size of the fruit, found to have significant positive correlation (r = +0.71 and +0.68 respectively. The larval density per infested fruit when correlated with the length and diameter of fruits, a significant and positive association (r=0.71 and 0.59) was observed. Earlier, Dhillon *et al.* (2005c) found that bigger fruits carried more eggs than smaller ones while working on the preference of *C. vesuviana* on Indian jujube fruits.

5.6.3. Ribs density and depth:

There exists a significantly negative correlation (r = -0.78) of percent fruit infested by the fly with the ribs density. However, depth of ribs correlated negatively (r = -0.25) but not significantly. Dhillon *et al.* (2005c) also observed this trend of observation and opined that in general, the number of ridges was greater in resistant and lower in the susceptible one. Larval density per infested fruit also showed negative correlation with ribs density (r = -0.73) and ribs depth (r = -0.18). It may be due to more number of deep ribs per unit area fruit surface, which confer less preference and vice-versa.

5.6.4. **Skin toughness of fruits:**

Fruit toughness was associated negatively and significantly both with percent of fruit infestation (r = -0.80) and larval density per fruit (r = -0.83), i.e. tougher the fruit less was the infestation and larval density.

The interaction between plant herbivore is influenced by several morphological traits that interfere with feeding and oviposition of the insects. Identification of physico-chemical factors involved in host plant selection by insects is an important step in selecting resistant genotype. Chelliah and Sambandam (1971) observed that egg laying by melon fruit fly was 17.77% in fruits having tough rind in *Cucumis callosus* as compared with 87.33% of the fruits of susceptible variety. Cultivars having thick and tough rind fruits resistant to melon fruit fly were earlier reported by Pal *et al*. (1984). In the present investigation, positive association of percent fruit infestation and larval density per fruit were derived with fruit weight, length and diameter. On the contrary, negative correlation were observed with ribs density, ribs depth and skin toughness of fruits and the results are in corroboration with the findings of earlier studies conducted by Dhillon *et al.* (2005a). It may be inferred from the findings that the traits under study can be utilized as markers to select genotypes resistant to melon fruit fly.

Table-30: Individual regression equations of morphological traits associated with percent fruits infested by melon fruit fly.

Morphological traits	Correlation coefficient (r)	Regression equations
Fruit wt.	+0.7675*	Y=1.716x+7.9473
Fruit length	+0.7168*	Y= 0.216x+3.2569
Fruit diameter	+0.6783**	Y= 0.038x+3.1727
Ribs density	-0.7813*	Y= -0.167x+14.60
Ribs depth	-0.2466**	Y= -0.020x+6.083
Skin toughness	-0.8045*	Y= -0.077x+9.6978

* Significant at 5% level. ** Significant at 1% level

Multiple regression equation:

$Y= 0.7676x_1^{*} + 0.7169x_2^{*} + 0.6784x_3^{**} - 0.7813x_4^{*} - 0.2467x_5^{**} - 0.8045x_6^{*}$

Where, Y= Percent fruit infested by melon fly

X_1= Fruit wt.

X_2= Fruit length

X_3= Fruit diameter

X_4= Ribs density

X_5= Ribs depth

X_6= Skin toughness

The R^2 value determined was 0.74.

From the above statistical analysis it was found that the combined linear effects of the morphological traits of bitter gourd fruits contribute significantly to the variation in percent fruit infestation. The R^2 value suggested 74% variation in percent fruit infestation can be accounted for by a linear function involving fruit weight, length, diameter, ribs density, depth and skin toughness.

Table-31: Individual regression equations of morphological traits associated with larval density of melon fruit fly in infested fruits.

Morphological traits	Correlation coefficient (r)	Regression equations
Fruit wt.	0.75123*	Y= 4.997x+34.456
Fruit length	0.71927*	Y= 0.6493x+2.425
Fruit diameter	0.59931**	Y= 0.0991x+2.447
Ribs density	-0.72938*	Y= -0.4649x+18.302
Ribs depth	-0.17760**	Y= -0.0428x+6.2801
Skin toughness	-0.83711*	Y= -0.2371x+11.862

* Significant at 5% level of significance. ** Significant at 1% level of significance.

Multiple regression equation:
$Y= 0.7512x_1^{**} + 0.7192x_2^{**} + 0.5993x_3^{*} - 0.7293x_4^{**} - 0.1776x_5^{*} - 0.8371x_6^{**}$

Where, Y= Larval density/infested fruit
X_1= Fruit wt.
X_2= Fruit length
X_3= Fruit diameter
X_4= Ribs density
X_5= Ribs depth
X_6= Skin toughness
The R^2 value determined was 0.70.

From statistical analysis it was found that the combined linear effects of the morphological traits of bitter gourd fruits contribute significantly to the variation in larval density in infested fruits. The R^2 value indicated 70% variation in larval density in fruits can be accounted for by a linear function involving fruit weight, length, diameter, ribs density, depth and skin toughness.

5.7. Management of the key pests of cucurbit vegetables:

5.7.1. Soil application of different pesticides against melon fruit fly *Bactrocera cucurbiate* (Coq.) (Tephiritidae: Diptera):

Overall mean mortality was recorded highest in the soil treated with DDVP 76EC (63.33%) followed by carbofuran 3G (58.33%) and cypermethrin 10 EC (39.17%). In control only 0.42% maggot mortality was observed which might be treated as natural mortality. Mean mortality of maggots as inflicted by different insecticides were 42.22, 33.89, 25.56 and 16.65% at 1, 3, 5, and 7 days after treatment of soil respectively that clearly reflected decreasing trend of toxicity of insecticidal chemicals over time of application in soil. The only exception was *Metarhizium*

1.15WP that showed the reverse phenomenon. This might be due to gradual multiplication and spread of the entomopathogen after certain lapse of time.

The overall mean deformed puparia was noticed more in *Metarhizium* treated soil (28.75%) followed by carbofuran 3G (20.42%) and cypermethrin 10EC (19.17%) which were also statistically differed from each other.

Maximum mean adult fly eclosion was recorded highest in case of bleaching powder (80.33%) and closely followed by formaldehyde 4.00% (76.33%). On the contrary, minimum was found to observe in DDVP (10.00%) and carbofuran (12.17%). It is, thus, obvious that more the percentage of adult eclosed, less was the larval and pupal mortality and vice-versa, which clearly reflected the toxicity of the insecticides. Effect of different insecticidal chemicals at various dates after application differed from one another significantly. Even the interaction of insecticides and dates after application were also found significant.

Bio-efficacy and persistent toxicity of different insecticides including neem against melon fruit fly were earlier tested by Sood and Sharma (2004). Highest yield and lowest damage were observed in pumpkin when treated with carbofuran @ 1.5 kg a.i./ha at 15 days after germination (Borah, 1998). Neem oil (1.2%) and neem cake (4.0%) have been reported to be as effective as dichlorvos (0.2%) (Ranganath *et al.*, 1997).

Thus, the results of the present investigation are in confirmation with the previous findings of different workers and accordingly could be incorporated for better management of the melon fruit fly so as to reap optimum yield potentiality of the cucurbit vegetables.

5.7.2. Evaluation of suitable bait components against melon fruit fly, *B. cucurbiate* (Coq.) (Tephritidae: Diptera):

5.7.2.1. Evaluation of suitable bait materials:

It become evident from the results that efficacy of all the bait materials tested were gradually found to decrease over time, i.e. at subsequent days after preparation and placement of baits (fig-24). This gradual decrease in efficacy of the baits might be due to evaporation, drying and other environmental factors. It also appeared that among the locally available bait materials tested, mollasses and fermented palm juice showed considerable efficacy in attracting melon fruit fly adults.

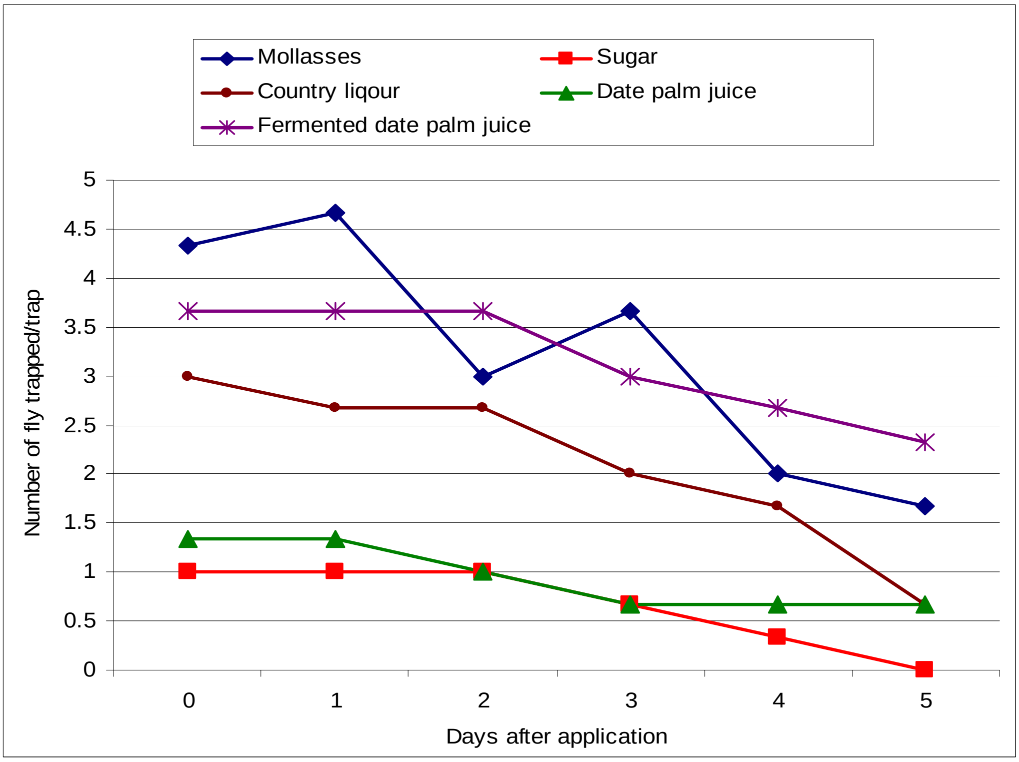

Fig-24: Influence of bait materials on the trap catch of melon fruit fly, *B. cucurbitae* (Coq.)

5.7.2.2. Evaluation of suitable bait toxicant:

Highest overall mean efficacy showed by malathion (12.33 flies / trap) followed by chlorpyriphos+cypermethrin (11.67 flies / trap), and spinosad (10.67 flies / trap), while lowest recorded in case of endosulfan (5.67 flies / trap) that closely followed by cypermethrin (6.40 flies / trap). Significant differences in efficacy observed in different treatments. It was also revealed that efficacy of the toxicants decreased over time after installation of the trap. After twenty days of application, the mean number of flies caught/trap/day was recorded as 1.06 (Fig-25).

Spinosad has its outstanding efficacy against target insect pests (Sparks *et al.*, 1998, Rendon *et al.*, 2000, Burns *et al.*, 2001). Earlier, several workers also found high mortality for mexican fruit fly, *Anastrepha ludens* (Loew) (Prokopy *et al.*, 2000); caribbean fruit fly, *Anastrepha suspense* (Loew) (King and Hennessey, 1996); and mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) (Adan *et al.*, 1996) in feeding trials. In the present investigation highest overall mean efficacy as bait toxicant showed by malathion (12.33 fly/trap/day) followed by chlorpyriphos + cypermethrin (11.67) and spinosad (10.67). On the other hand, Peck and McQuate (2000) demonstrated that bait sprays with malathion or spinosad suppressed *C. capitata* populations. However, malathion seemed to be more effective than spinosad which is in conformation with the present findings. Vargas *et al.* (2001) also found this trend with protein bait sprays and opined that spinosad had less impact than malathion on populations of beneficial braconid parasitoids, *Fopius arisanus* (Sonan). Dow Elanco (1994) demonstrated lower mammalian and environmental toxicity with reduced risk to humans and wildlife than traditional insecticides. Thus, considering environmental and ecological aspects application of spinosad may be identified as a safe alternative for use in bait toxicant for melon fruit fly.

5.7.3. Sanitary measures in managing melon fruit fly, *B. cucurbitae* (Coq.):

5.7.3.1. Depth of burying infested fruits:

No flies were found to eclosed from the infested fruits buried at 50 cm depth from soil surface. In both the cases of bitter gourd and pumpkin zero pupal harvest was recorded from 30±5cm, 40±5cm and 50±5cm depth levels. The trend of observation with regard to effective depth of burying infested fruits was previously recorded by Klungness *et al.* (2005). The authors opined that the adult flies did escape to the surface from beyond the depth of 20 cm. Possibly they might have pupated close to the surface to enable them escape in the environment and also expressed the possibility that these larvae pupated near the buried fruits but were able to escape through crevices created when the soil collapsed on the desiccating infested fruits. Thus the results are in agreement with previous findings.

From the findings of present investigation it may be inferred that the infested fruits to be buried in the soil at a depth more than 40 cm from soil surface. This will prevent coming out of adults in the environment for further infestation that may subsequently result in lowering down in intensity of infestation and optimization in yield.

5.7.3.2. Impact of some sanitary measures.

It revealed from the results that a considerable amount of fly eclosion was taken place when the infested fruits were chopped and treated with spinosad. In case of chopping of fruits the reduction in fly eclosion might be due predation, desiccation and thus creating hindrances in development and pupation of the maggots. On the other hand, survival of maggots even after treating with insecticides (spinosad) showed that it did not affect the maggots efficiently. The possible explanation is that the chopping process may allow the maggots to burrow into the soil beyond the reach of insecticide as opined by Klungness *et al.* (2005).

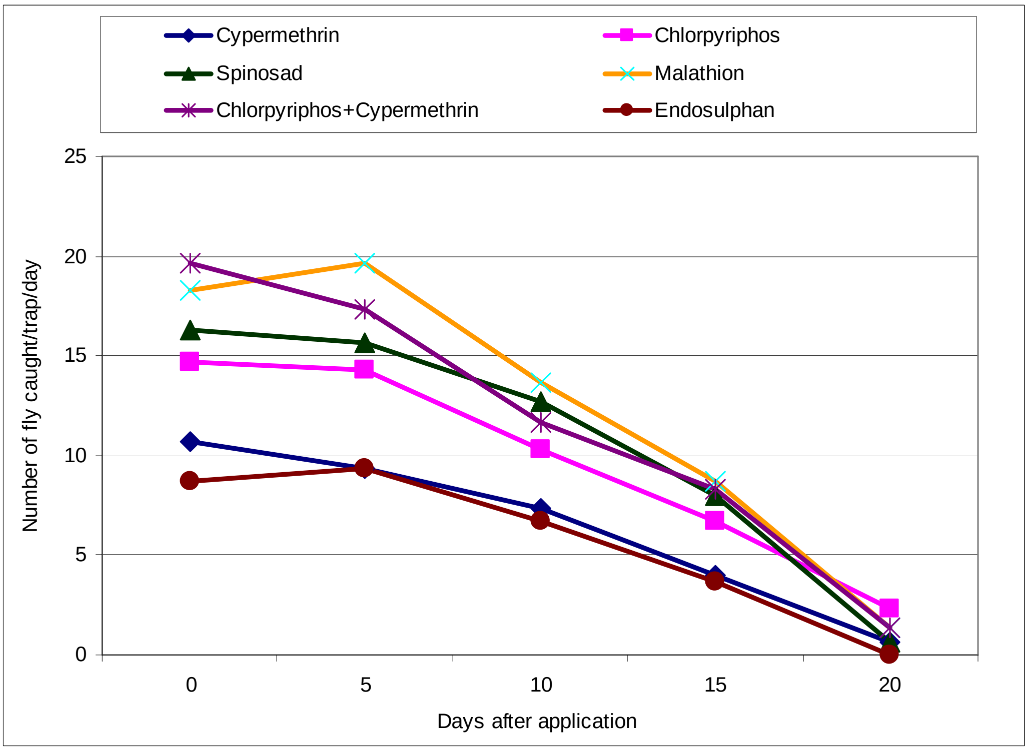

Fig-25: Efficacy of bait toxicants on the trap catch of melon fruit fly, *B. cucurbitae* (Coq.)

5.7.4. Efficacy of *Metarhizium anisopliae* (1.15%WP) on different life stages of epilachna beetle, *Henosepilachna vigintioctopunctata* (Fab.):

From the analysis it was derived that the mortality increases in course of time after application of the entomofungal pathogen in all the developmental stages of the beetle that might be due to establishment, multiplication and spread of the pathogen. The study confirms the potentiality of green muscardine fungus as a biological agent for epilachna beetle and the results are in corroboration with the findings of Konar *et al*. (2005).

5.7.5. Integrated management of melon fruit fly:

Keeping in view the sustainability in management of melon fruit fly, a number of tactics as well as their combinations were evaluated. Significant differences in their efficiency in reducing fly infestation were found among the treatments. In the present study sole installation of cuelure trap resulted in 54.86% reduction in fruit infestation. Maximum protection was observed in the treatment where mass trapping of fly was coupled with burying infested fruits, bait spraying and soil treatment with chlorpyriphos. The treatment showed 85.62% reduction in infestation over control followed by 63.71% where cuelure trap was excluded. Results of the present study are in partial agreement with the findings of Mahmood *et al.* (1995) who found the best control of Dacine fruit fly with trichlorphon in combination with methyl euginol baited trap. In the treatment where cuelure traps were combined with burying infested fruits, bait spraying and soil treatment with insecticide, resulted in maximum protection of crop from the dreaded melon fruit fly. However, highest benefit cost ratio was noted in mass trapping by using cuelure trap.