Studies on biology of *Etiella zinckenella* Treiteischke on lentil and evaluation of lentil genotypes against this pest

BY
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CERTIFICATE-I

This is to certify that this thesis entitled **"Studies on biology of *Etiella zinckenella* Treiteischke on lentil and evaluation of lentil genotypes against this pest"** submitted for the degree of **Master of Science** in the subject of **Entomology** of the **Chaudhary Charan Singh Haryana Agricultural University, Hisar**, is a bonafide research work carried out by **Mr. Gulshan Kumar**, Admn. No. **2014A33M** under my guidance and supervision and that no part of the thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been duly acknowledged.

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CERTIFICATE-II

This is to certify that this thesis entitled **"Studies on biology of *Etiella zinckenella* Treiteischke on lentil and evaluation of lentil genotypes against this pest"** submitted by **Mr. Gulshan Kumar**, Admn. No. **2014A33M.** The Student's Advisory Committee has approved the thesis to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** in partial fulfillment of the requirements for the degree of **Master of Science** in the subject of **Entomology**, after an oral examination on the same.

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Place: Hisar ***Gulshan Kumar***

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CHAPTER-I

INTRODUCTION

Pulses are principal source of dietary protein and therefore, constitute chief ingredient of vegetarian diet in developing countries like India. In addition to being a good source of dietary proteins and income to farmers, pulses play an important role in sustainable crop production. They are an important component of cropping systems to maintain soil health because of their ability to fix atmospheric nitrogen, extract water and nutrients from deeper layers of soil, and add organic matter into soil through leaf drop. The major pulse crops grown in India are chickpea, pigeonpea, lentil, mungbean, urdbean and fieldpea.

Lentil (*Lens culinaris* Medikus), locally known as Masoor, is an important *rabi* season pulse crop which is grown in North America, Southern Europe, North Africa, West Asia and northern and central parts of India. Lentil is a rich source of proteins (25 per cent) and is considered as an important source to overcome the problem of malnutrition due to protein gap. Bahl *et al.* (1993) reported that lentil is probably the oldest of grain legumes to be domesticated. Seed which is rich in protein, carbohydrate and calories as compared to other legumes and that is why it is the most desired crop in many legume producing regions. In India, it is grown on an area of 1.60 million hectares with an average production of 0.94 million tonnes, and productivity level of 591 kg /ha (Anonymous, 2011). In Haryana, it is cultivated on an area of 4.1 thousand ha with production and productivity of 3.2 thousand tonnes and 780 kg/ha, respectively (Anonymous, 2008).

Poor crop management along with abiotic and biotic stresses are the major constraints in its production. Among the biotic constraints, insect pests play a major role in its yield reduction. About three dozen insect pests have been reported to infest lentil under field and storage conditions (Hariri, 1981), out of which 21 species have been reported from India alone (Lal, 1992). However *Aphis craccivora* Koch (Thakur *et al*.,1984), Phycitid, *Etiella zinckenella* Treit. (Singh and Dhooria, 1971) and bruchid, *Callosobruchus chinensis* Linn. (Staneva,1982) have been reported as insect major pests of lentil in India.

Among the above pests, *Etiella zinckenella* is a polyphagous pest attacking many cultivated crops such as medics, clovers, lucerne, fieldpeas, lentils and soybean (Hopkins, 2003). *Etiella zinckenella* infests lentil at flowering and pod formation stages and is considered as main reason of low productivity, besides reduction in yield and quality of the grains is also affected. In India, it has been reported to infest 11.4 and 50.9 per cent of lentil and pea pods, respectively, resulting in yield losses of 10.6 and 23.9 per cent (Singh and Dhooria, 1971). Sandu and Verma (1968) observed that 12 to 15 per cent pods of lentil were

infested by *E. zinckenella*. Infestation of this pest has been reported up to17.5 per cent in Haryana (Jaglan *et. al*., 1993). On the basis of biological parameters *viz.* number of eggs, higher hatching, shorter larval period with lower larval and pupal mortality and higher per cent adult emergence, pea was found be more suitable host of *Etiella zinckenella* in comparison to gram by Bhadauria *et al*. (1998).

A few aphids recorded on leguminous crops, *Aphis craccivora* Koch. appears to be highly important both from geographical distribution and damage points of view (Gupta *et al*.1985). Lentil aphid, *Aphis craccivora* Koch (Hemiptera: Aphididae) has become a major pest of lentil in last few years. Aphids are able to multiply quickly so a moderate infestation can become a damaging population in less than a week. Aphids damage lentils mostly by direct feeding. Direct feeding by aphids includes sucking sap from leaves, stems, blossoms and pods. Aphid population and rate of infestation are very much dependent on sowing time (Islam *et al*., 1991) as it was found that, sowing of lentil by mid November received poor aphid infestation. Plants heavily infested are stunted and produce fewer and smaller pods and seeds. *Helicoverpa armigera* is also highly polyphagous and also a serious pest of lentil crop. Pod borer, *Helicoverpa armigera* infest many host plants, especially lentil in West Asia and the Indian subcontinent. Van Emden *et al*. (1988) have reported that *Heliothis armigera* is an important pest of lentil crop. High polyphagy, mobility and fecundity are major factors contributing to the serious pest status of *H. armigera*.

It is well known that the morphological and biochemical factors significantly affect insect biology. Earlier studies on biology of *E. zinckenella* were conducted on older varieties. However, over the years some new lentil genotypes have come up. So, it was considered worthwhile to study biology of this pest on recently recommended varieties. Likewise, response of this pest to the currently available genotypes also needs to be studied, so that resistance sources against this pest could be identified. Since, apart from *E. zinckenella* a number of other pests also attack lentil crop, observations on their occurrence and population dynamics may greatly help in development of a more effective integrated pest management strategy against them. Therefore, in view of the above considerations, the following studies were undertaken with the following objectives:

1. To study the biology of lentil pod borer, *Etiella zinckenella* Treit.
2. To evaluate the advanced breeding cultivars of lentil against *Etiella zinckenella.*
3. To study the population dynamics of major insect pests of lentil.

CHAPTER-II

REVIEW OF LITERATURE

The available literature pertaining to the biology, evaluation of germplasm against lentil pod borer, *Etiella zinckenella* and population dynamics of major insect pests of lentil is scanty as indicated by the scrutiny of relevant work. However, the available information from India and abroad is reviewed, summarized and presented below.

2.1 Biology of lentil pod borer, *Etiella zinckenella* Treit.

2.1.1 Adult stage

2.1.1 (a) Pre-oviposition and oviposition periods

Abul-Nasr and Awadalla (1957) reported that the pre-oviposition period of *E. zinckenella* ranged from 2 to 5 days. Stone (1965) found that it was 1 to 44 days. Hattori and Sato (1983a) observed that 55 per cent of mated females began to oviposit on the first day after mating, the remaining did so on the second to ninth day. Further, they observed that mated females laid considerable number of eggs during the first day under dark conditions and the oviposition rate decreased thereafter. Jaglan *et al.* (1996) reported that the pre-oviposition period of *E. zinckenella* ranged from 1 to 2 days and oviposition and post oviposition periods varied from 2-3 days and 1-2 days, respectively on lentil.

2.1.1 (b) Egg laying behavior

Abul-Nasr and Awadalla (1957), Popova (1957) and Kakoty (1968) reported that female laid the eggs singly or in small groups on different plant parts on broadbean. Singh and Dhooria (1971) observed that eggs were laid singly on lentil pods and in masses of 2-27 on pea pods. Stone (1965) found that deposition of eggs was either around the mid rib or under and around the calyx of limabean. Parvin (1981) noticed that eggs were laid on flowers and unripe pods of soybean. Hattori and Sato (1983b) suggested that texture was more important stimulus than odour for oviposition. Hattori (1986) reported that maximum number of 4 eggs were laid on each pod of soybean. Hattori (1988) further reported that the oviposition behavioural sequence was triggered by plant odour, water vapour and mechanical stimuli.

2.1.1 (c) Fecundity

Abul-Nasr and Awadalla (1957) counted daily oviposition per female varying from 2 to 70 eggs with a total of 47 to 178 eggs in her life time. They also observed that female oviposited 27 to 45 eggs when food was withheld. Singh and Dhooria (1971) studied the fecundity of the female moth of *E. zinckenella* and reported 70.4 and 5.7eggs, respectively. Hattori and Sato (1983a) reported that females laid on an average 70.8 eggs and 112.9 in 1980

and 1981, respectively. Jaglan *et al.* (1996) reported that the average fecundity per female was 62.7 and 64.8 eggs on lentil and pea, respectively.

2.1.1 (d) Adult longevity and behavior

Abul-Nasr and Awadalla (1957) concluded that longevity of both male and female moth ranged from 8 to 20 days. According to Popova (1957) the males lived for 10 to 35 days while females lived for 14 to 30 day. Naito (1961) reported that at 25^0C, longevity of fed adults of *E. zinckenella* was 13 days against 9.5 days of unfed moths. He further reported that on an average temperature of 30 ^{0}C adult life was 5-7 days. Singh and Dhooria (1971) recorded an average life span of fed and unfed female moths as 4.6 and 3.0 days, respectively, whereas, in male it was 3.6 and 2.1 days, respectively. They added that adult longevity was 5.2 days on lentil and 7.42 days on pea sources. Adult longevity on different host plants was statistically at par. Szeoke and Takacs (1984) reported that adult activity of *E. zinckenella* was highly dependent on climatic factors and adults were positively phototrophic. Adults showed peak activity at dry pod stages (Armstrong, 1988). Jaglan *et al.* (1996) reported that females survived longer than males on pea as well as lentil. Taghizadeh *et al*. (2012) reported that the female and male life spans were longest on soybean cultivars '032' (55.84±0.27 and 56.80±0.10 days) and shortest on 'Clark' (51.18±0.11 and 52±0.13 days), respectively.

2.1.2 Egg stage

2.1.2 (a) Incubation period

Incubation period of *E. zinckenella* was reported to be 6 to 7 days (Kakoty, 1968) and 5.3 days (Singh and Dhooria, 1971). Abul-Nasr and Awadalla (1957) studied the egg duration at controlled temperatures and found that it was 5 days at 25^0C and 5.6 days at 26. 5^0C, while Bindra and Singh (1969) found the incubation period of this pest as 5 and 33 days at 22^0C and 13.5^0C, respectively. Naito and Har nato (1985) recorded that the egg stage of this pest was 4.2 days at room temperature.

2.1.2 (b) Per cent hatchability

Stone (1965) and Bindra and Singh (1969) reported that 69 to 70 per cent of the eggs hatched. However, under laboratory conditions 92.8 per cent of the eggs hatched (Singh and Dhooria, 1971).

2.1.3 Larval stage

2.1.3 (a) Larval period

According to Abul-Nasr and Awadalla (1957), Peiu (1967) and Kakoty (1968) larval stage of *E. zinckenella* was completed in 10 to 17 and 15 to 23 days, respectively. Bindra and Singh (1969) reported that on an average, the larval stage lasted for about a month. Singh and Dhooria (1971) opined that larval development was shortest on pea (12.68 day) and longest on lentil (18.37 days). These workers also reported that food type significantly

affected the larval period. Taghizadeh *et al*. (2012) reported that the larval period ranged from 13.42±0.10 days on 'Clark' to 16.28±0.14 days on '033' on soybean cultivars, respectively.

2.1.3 (b) Larval behaviour

Abul-Nasr and Awadalla (1957) reported that larvae fed on flowers and buds of the host plants after hatching and later on bored into the green pods and started feeding on growing seeds. Sandhu and Verma (1968) also noticed that larvae bored into the pods and fed on the developing seeds of lentil. Singh and Dhooria (1971) reported that freshly hatched caterpillars constructed a web type structure through which they entered the pod and seeds in an infested pod of lentil. Singh and Dhooria (1971) reported the webbing of 2 to 4 pods of lentil by later stage of caterpillar. Naito and Harnoto (1985) reported that newly hatched larvae moved around a soybean pod for a longer time.

2.1.3 (c) Per cent larval survival

Singh and Dhooria (1971) concluded that only 50 per cent of the freshly emerged caterpillars could successfully gain entry in to the pods. High mortality was apparently due to the hardness of pod cover as fully formed pea pods were used. These workers further worked out 91.67 per cent larval survival on lentil and 100 per cent on pea and the percentage larval survival on different host plants ranged from 75 to 100 per cent. As per these workers crop type did not significantly affect the per cent larval survival.

2.1.4 Pre-pupal and pupal stages

2.1.4 (a) Pre-pupal stage

Pre-pupal period was recorded to 2 days in May to August and 72 days in winter(Abul-Nasr and Awadalla, 1957) , 20 days (Bindra and Singh, 1969) and 2 to 4 days (Singh and Dhooria, 1971). Singh and Dhooria (1971) also reported that during this stage caterpillars contracted in size and changed its colour to yellowish green. Edmonds *et al*. (2000) reported that the pre-pupal and total egg-to-adult development periods of female *E. zinckenella* were significantly shorter than for males.

2.1.4. (b) Pupation behaviour

Abul-Nasr and Awadalla (1957), Stone (1965), Singh and Dhooria (1971) and Parvin (1981) reported that pupation occurred in soil at a depth of 2-4 cm in the cocoons. Abul-Nasr and Awadalla (1957) also found that the resting caterpillars in cocoons shrunk considerably in size and ultimately the caterpillar's skin got spilt and pupa was exposed.

2.1.4 (c) Pupal period

Leonard and Mills (1931) and Cheu (1943) reported that pupal period ranged from 9 to 20 days in summer and it was considerably prolonged in cool weather. However, Popova (1957) recorded that pupal stage lasted 26 to 29 days in summer and 31 to 53 days in winter months. This stage lasted for 16 to 101 days (Stone, 1965). Kakoty (1968) observed that the pupal duration was 10 to 13 days in March under laboratory conditions. According to Singh

and Dhooria (1971), pupal period was 17.00 days on lentil and 14.78 days on pea. These workers also reported that pupal period was shortest on gram (13.1 days) as compared to other foods and the food type significantly affected the pupal period. Under constant temperature conditions, pupal period was 9 days at 29^0 C (Abul-Nasr and Awadalla, 1957), 61.5 days at 14.9^0C, 25-27 days at 25^0C and 10-11 days at 30^0C (Singh and Dhooria, 1971) .

2.1.5 Adult emergence

Singh and Dhooria (1971) observed that moths emerged at night or in early hours of the morning. Abul-Nasr and Awadalla (1957) recorded 100 per cent adult emergence in March at a mean temperature of 19.2^0C, 87 per cent in July at 29^0C and 50 per cent in February at 17.9^0C. Singh and Dhooria (1971) observed 79.17 per cent adult emergence on lentil and 100 per cent of pea.

2.1.6 Sex ratio

Abul-Nasr and Awadalla (1957) reported that males outnumbered the females, as they constituted 53 per cent of the population. Singh and Dhooria (1971) also expressed similar views i.e. on an average 54.4 per cent of the emerged moths were males in the field cage and almost same number of males emerged under laboratory conditions. According to Popova (1957), sexes were equally distributed in the field.

2.1.7 Description of various life stages

2.1.7 (a) Egg

Abul-Nasr and Awadalla (1957) and Stone (1965) observed that eggs were slightly elliptical in outline and glistening white in colour. Eggs were 0.6 to 0.7 mm long and 0.30 to 0.35 mm broad. Dhooria and Singh (1971) recorded the oval shape of eggs and glistening white colour and the eggs were attached firmly on the host. The average length and breadth of eggs were 0.51 and 0.34 mm, respectively.

2.1.7 (b) Larva

Stone (1965) reported that most of the first instar caterpillars were 1.00 mm long while Dhooria and Singh (1971) observed that newly hatched caterpillars measured on an average 0.87 mm in length and 0.13 mm in width. It was yellowish in colour with a black shinning head. Pale yellow legs and prologs were well developed. Dhooria and Singh (1971) measured full grown caterpillar as 15.25 ± 0.43 mm long and 2.93 ± 0.08 mm broad. Full grown larva was rosy in colour and longitudinal strips were not visible. Head was honey yellow in colour.

2.1.7 (c) Pupa

Dhooria and Singh (1971) noticed that pupation took place in an earthern cocoon which was 11.37 ± 0.29 mm long and 5.79 ± 0.17 broad. The cocoon was constructed from soil particles which were tightly cemented together except at its front end where the particles were kept loose and pupa was of obtect type which was 8.64 mm long and 2.79 mm broad.

2.1.7 (d) Adult

Dhooria and Singh (1971) observed female moth measured 20.08 mm in wing expanse and 11.4 mm in length, forewings were grayish in colour, long and narrow in shape and of almost even width. There was a broad white stripe extending from base along the costa to apex on the forewing. These workers also distinguished the sexes on the basis of the structure of the antennae. In case of male, antenna was broadened at the base and possessed large second flagellar segment which was curved and was provided with long hairs. During rest, the antennae were kept in the middle of folded wings and thus became rather undetectable.

2.2 Evaluation of lentil genotypes against *Etiella zinckenella*

Kooner *et al.* (1977) reported that lentil cultivar, P 927 was found to be the most promising cultivar, as it harboured 62.5 per cent less infestation of pods by *E. zinckenella* and gave 41.15 per cent more grain yield as compared to the local variety L 9-12. The cultivar P 202 was found to be the next promising line followed by P 927.

Kooner *et al.* (1978) reported considerable variability among the 809 cultivars of lentil collected from 25 countries with regard to the degree of infestation of pods caused by *E. zinckenella* . The infestation of pods by the lentil pod borer in different cultivars varied from 3.5 to 9 per cent as against 11.6 per cent in local cultivar i.e. L 9-12 (check). They further mentioned that 84 cultivars showed promise against the pest incidence, as these lines had the pod infestation below 10 per cent as against the maximum of 82.2 per cent.

Jaglan *et al*. (1993) screened 79 genotypes of lentil against *Etiella zinckenella*. The studies revealed that genotype LH 90-39 was having minimum pod infestation (4.1%) and maximum pod infestation was observed in DPL 26 (17.5%)

Sahoo and Senapati (2000) observed that there was a positive correlation between seed width and incidence of pod borers (0.01 to 0.492) except for *Maruca vitrata* (-0.080). On contrary, seed length had a negative effect on incidence of most of borer species except *H. armigera* (0.069) and *Lampides boeticus*. Both the seed volume and seed weight had the differences but not significant negative relationship with the incidence of *M.testutalis*, *G.critica*, *E.atmosa*,*T. cajaninae* and borer complex. There was positive effect of these morphological features with the occurrence *of H. armigera, L.boeticus,Etiella zinckenella and Callosobruchus maculates.*

Singh *et al*. (2004) evaluated 19 early maturing field pea genotypes (dwarf) and thirteen late maturing genotypes (tall) against pea leaf miner *Chromatomyia horticola* and pod borer *E. zinckenella* and revealed that per cent pod damage by pod borer in early maturing genotypes was minimum (1 per cent) in Pant P-11, HUDP-15, LFP-283, KPMR-526 and KPMR-593and maximum in HUDP 17(4 per cent). None of the genotype was completely free from incidence of pod borer however, early maturing genotypes showed less pod borer attack as compared to late maturing genotypes.

Dashad *et al*. (2005) evaluated the response of small seeded lentil cultivars with varying maturity periods (18 short, 19 medium and 13 long duration genotypes) to infestation by *E. zinckenella* during the *rabi* season of 2001-02, and higher larval population was observed in short duration genotypes (7.18 larvae/plant), compared to medium and long duration ones (6.94 and 6.55 larvae/plant).

Kooner *et al*. (2006) conducted an experiment on screening of lentil germplasm against pod borer, *Etiella zinckenella* and found that entry LL 699 had least pod damage followed by LL 874 and LL 885.

Amro *et al*. (2007) evaluated three soybean varieties and two cultivars for the resistance status of the selected soybeans against the lima bean pod borer *Etiella zinckenella* and the whitefly *Bemisia tabaci*. In respect to *E. zinckenella* the obtained results indicated that the tested soybean varieties Clark, Giza22 and Tono equipped higher infestation by this insect with an average 4.30, 3.54 and 9.13%, respectively, than the tested cultivars Hagen32 and S5 by 2.38 and 3.21%, respectively. The highest damage percentage appeared on Tono variety by 9.30% while, the lowest one appeared on Hagon32 cultivar by 1.97%. High compatibility is recorded between the resistance status of the tested soybeans and the mean numbers of *E. zinckenella* individuals attacking the developing pods. The newly produced cultivars Hagen32 and S5 presented some sort of resistance and appeared as moderately resistant cultivars. However, the soybean varieties Clark, Giza22 and Tono appeared as relatively resistant, susceptible and highly susceptible varieties, respectively

Singh *et al*. (2013) screened 20 genotypes of fieldpea against pea leaf miner, *Chromatomyia horticola*; pea aphid, *Acyrothosiphon pisum* and pea pod borer, *Etiella zinckenella*.and on the basis of pod damage they found highly resistant genotypes LFP-477 and IRCP-10 with no pod damage. The genotypes Pant P-183, Pant P-184, RFP-61, KPMR-913 and VL-54 showed 1.91% pod damage. The highest pod damage per cent were in HFP-716 (12.0%) and HFP-4 (11.94 %). The highest yield was obtained in LFP-477 (23.78 q/ha), while the lowest yield was obtained in HFP-4 (6.0 q/ha).

2.3 Population dynamics of major insect pests of lentil.

Sharma *et al*. (1994) reported that population of *aphis craccivora* reacted sharply to the changing weather factors like temperature and relative humidity .These weather parameters collectively accounted for a wide fluctuation in aphid population from 31.55 to as high as 99.96 per cent depending on crop type (lentil,lathyrus and fababean) and the phase of the pest population(ascending, oscillating, and descending phase).correlation coefficient (r) between aphid population clearly indicated that maximum, minimum and mean temp. did not show any uniform trend. During the ascending phase, aphid population on all the three crops had positive association and in the oscillating phase, pest population showed significantly positive relationship with maximum and minimum temperature prevailing during the period of its infestation.

Bijjur and verma (1995) reported that aphid population on pea showed a gradual increase and reached a peak (188 aphids/plant) during 64 DAS in the first year and 230 aphids/ plants during 92 DAS in second year. With rise in temperature population showed a decreasing trend in both years and was supported by negative correlation studies between aphid population and mean maximum temperature (-0.652) and positive correlation with wind speed (0.402) and in case of *H.armigera* correlation studies indicated significant negative correlation with minimum temperature (-0.632) and rainfall (-0.748). But the multiple linear regression analysis indicated that none of the weather parameters explained the population dynamics of this pest.

Kumar and Nath (2003) observed the infestation of *H.armigera* in pigeonpea from seventh standard week in February till the first half of April, and population had non-significant negative correlation with morning, evening relative humidity.

Chandel *et al.* (2005) reported population of *H. armigera* was 4 larvae/10 plants in 1st fortnight of January and attained its peak in 2nd fortnight of February and March. There was a significant positive correlation between both maximum and minimum temperatures. The 'r' values were (0.125) of maximum temperature and (0.073) minimum temperature, respectively. The larval population increased suddenly with the temperature ranged between 28.6^{o}C - 32.4^{o}C was favourable for the growth and development of larvae. There was decrease in larval population with increase in temperature ranges between 32.6^{o}C – 38.0^{o}C.

Hossain *et al*. (2006) reported relative abundance of lentil aphid, *Aphis craccivora* Koch on lentil and yield at different sowing dates during *rabi* season of 1999-2000 and 2000-2001. Lentil aphid appeared in field in the first week of January. The maximum aphid population (15.82/twig) was recorded in the first week of February 2000-2001, but the population reached to the peak was in the last week of January in 1999-2000, subsequently rainfall caused a sudden reduction of aphid population in latter dates. Aphid population and infestation increased with the delayed dates of sowing. The crop sown in November received

less aphid infestation and consequently produced higher yield than the crop sown in December. During 1999-2000, the avoidable yield loss due to aphid infestation was recorded 0.90 to 6.78% and in 2000-2001 it was 2.65 to 9.00% depending on the different dates of sowing. Avoidable yield loss was less in November sowing crop than the crop sown in December. On the other hand, yield increased by 0.91 to 7.27% and 2.72 to 9.89% in 1999-2000 and 2000-2001 respectively, due to protection measures taken against aphids and this was also depend on different dates of sowing.

Kant *et al*. (2007) studied population dynamics of *Helicoverpa armigera* on chick pea in higher density crop and revealed that higher population of larvae were harboured more than low plant density crop. Larval population build up in chick pea started during 9th standard week at vegetative stage of the crop and reached its maximum during 14th and 15th standard week, there after the larval population declined after 19th standard week. Pupal population could be observed from 12th standard week with a highest population at pod maturation stage. Pod damage at crop maturation stage ranged between 17 to 45%. Maximum temperature and wind velocity were found positively correlated with pupal population.

Pawar *et al.* (2007) at Parbhani, Maharashtra studied the correlation and regression coefficient of larval population of *H. armigera* on pigeonpea with maximum and minimum temperature and maximum and minimum humidity, which was found significant.

Prasad *et al*. (2008) conducted field studies for seven years (1999 to 2005) to study the effect of abiotic parameters on the activity of *Aphis craccivora* Koch using multiple regression and correlation analyses. *A craccivora* was present throughout the year on groundnut and widely fluctuated from season to season. However, the intensity was greater during *rabi* followed by *kharif* and summer. Correlation studies revealed that morning and evening relative humidity were significantly positive while minimum temperature showed significant negative correlation during *rabi*. In *kharif*, minimum temperature and rainfall had significant negative correlation. During summer, maximum and minimum temperatures, morning and evening relative humidity and wind velocity showed significant negative correlation whereas, remaining parameters fail to show any significant correlation with aphid population. The coefficient of determination between weather parameters and aphid population during *rabi*, summer and *kharif* seasons was 15.47%, 44.58 % and 12.70 % respectively over seven years of study, suggesting the importance of these parameters in influencing the abundance of *A. craccivora*

Chatar *et al.* (2010) conducted an experiment to study the population dynamics of chickpea pod borer, *Helicoverpa armigera* (Hubner) on chickpea revealed that the pest appeared from 2nd week of December and attained a peak of 3.12 larvae per plant during 2nd week of January. The pest was active during the last week of December to 3rd week of January. Later on, the pest population declined gradually towards the maturity of the crop.

Correlation of *H. armigera* with different weather parameters indicated that maximum temperature exhibited highly significant negative correlation (r= -0.7514) with larval population of *H. armigera*, whereas, minimum temperature (r= -0.5771) and mean temperature (r= -0.6836) exhibited significant negative correlation. However, the pest population showed highly significant positive correlation with morning relative humidity (r= 0.7098), evening relative humidity (r= 0.7293) and mean relative humidity (r= 0.8063).

Patel *et al.* (2010) observed peak activity of *A. craccivora* during eleventh meteorological week. The *A. craccivora* first appeared during third week of February, slowly increased in subsequent weeks and reached to its maximum (10.22 aphids/10 cm twig) level during third week of March. Significant negative correlation existed between A. craccivora incidence on cowpea and maximum (r= -0.790), minimum (r = - 0.882) and average temperature (r = - 0.854) as well as bright sunshine hours (r = - 0.839).

Dhaka *et al*. (2011) conducted an experiment to study the seasonal incidence of *E. zinckenella* and *H. armigera* on vegetable pea during *rabi* 2008-09 and 2009-10. Peak incidence of *E. zinckenella* as well as *H. armigera* larvae was recorded during first week of February during both the years. During study period *E. zinckenella* ranged from 0.00 to 18.67 whereas, *H. armigera* ranged from 0.00 to 17.67 larvae per ten plants. Maximum temperature (r= -0.543 & -0,568) for *E. zinckenella* and r= -0.497 & -0.522 for *H. armigera* showed the negative significant correlation with incidence of larvae during 2008-09 and 2009-10, respectively. Rainfall (r=0.374 & 0.388) showed the positive non-significant correlation with incidence of larvae *E. zinckenella* during 2008-09 and 2009-10 and also found positively correlated with the incidence of larvae of *H. armigera* with r=0.382 and 0.396 during 2008-09 and 2009-10, respectively. Whereas, maximum relative humidity indicated positive significant relation with incidence of *E. zinckenella* larvae (r=0.012) during 2008-09 and was negatively correlated with incidence of same pest during 2009-10 with r= -0.672. Relation between field incidence of *E. zinckenella* larvae were found to be positively correlated during 2008-09 and negatively correlated during 2009-10 with minimum humidity. However, relation between incidence of larvae of *H. armigera* with minimum relative humidity (r = 0.183 & -0.388) was positive during 2008-09 and negative during 2009-10.

Ugale *et al.* (2011) conducted an experiment for monitoring the population dynamics of gram pod borer, *Helicoverpa armigera* (Hubner) at Nashik during Rabi season 2007-08 and found that the pest gradually decreased and reached at rock bottom level of 2 moths during 3 rd week of March, 2008, when maximum and minimum temperatures were of 36.3 0C and 20.8 0C with morning and evening relative humidity of 57.8 per cent and 24.4 per cent respectively. The moth emergence was found to be negatively and significantly correlated with the maximum temperature (r =-0.62) and minimum temperature (r =-0.75) while there was significant relationship between relative humidity and pest incidence.

Kumar and Durairaj (2012) studied population dynamics of gram pod borer, *Helicoverpa armigera* on chickpea using sex pheromone lures developed at Tamil Nadu Agricultural University, Coimbatore. Result showed that the peak emergence of *H. armigera* adults during 51st (8.25 moths /trap/ week) and 52nd (8.00 moths) standard weeks followed by 1st standard week (7.25 moths). The correlation and regression analysis indicated that the emergence of *H. armigera* adults had a significant negative association with minimum temperature while, other parameters (maximum temperature, relative humidity, rainfall and rainy days) had no influence on *H. armigera* activity. The simple liner regression analysis showed a R2 value of 0.528 revealing that 52.8% of the variation in the trap catches of *H. armigera* was influenced by minimum temperature alone.

Mallikarjuna *et al.* (2012) conducted an experiment and found that *Helicoverpa armigera* Hubner as the major pest of dolichos bean. and its numbers and dominance overwhelmingly prepondered over other species. The incidence of *H. armigera* started from pod formation stage and reached peak during second week of November (Pod maturing stage) 2008 with a mean of 80.5 larvae per 10 plants, significantly higher from other weeks and the incidence of *Etiella zinckenella* peaked during first week of December, 2008 with a mean of 31.50 larvae per 10 plants.

Ali *et al*. (2013) revealed that *A. craccivora* had three peaks on faba bean for each season the first peak was during the fourth week of December, the second peak was in the second week of February, where the last peak was in the first week of March (2010–2011 season), The three peaks of 2011-2012 were recorded in the first week of January, the fourth week of February and the second week of March 2012. There was one peak only on cowpea in the third and fourth week of July in 2011 and 2012, respectively.

Fargalla and Fahim (2014) showed the contrast differences for the population density of eggs and larvae of *E. zinckenella* in the two studied seasons. The eggs were recorded on the 2nd week of June and larvae were appeared with few numbers in the 2nd week of June in the both locations. The eggs of *E. zinckenella* peaked on 1st week of July whereas the larval population peaked during 3rd week of July in both seasons. Fluctuation of daily mean temperatures showed negative relation on *E. zinckenella* population during the studied periods in the two locations. Calculated DDU confirmed the variability of insect population in the two locations and growing seasons. Results indicated positive relationships between accumulated DDU and the population density of *E. zinckenella* in the two ecosystems during two successive seasons.

Kumar and Kumar (2015) conducted experiments during *Kharif* season of 2007-2008. The pest population was recorded in cowpea field aphids, jassid, thrips and pod borer and its highest population 116.20/15 cm shoots tip, 8.6/compound leaves, 5.87/flower bud and 0.73/flower bud and 1.8/pod, respectively. Abiotic factors like temperature, relative humidity,

extent and distribution of rainfall, sunshine hour etc. influenced the infestation and stabilization of various insect pests in cowpea. The populations of aphids and pod borer were influenced positively by relative humidity.

Singh *et al*. (2015) conducted an experiment and revealed that maximum prevalence of *H. armigera* larvae was noticed at podding stage of chickpea with abrupt temperature rise by 5^0C in February. Temperature (Max & Min) exhibited a significant positive role on the larval population of the pest and relative humidity did not play any precise function in the multiplication and parasitization of *H. armigera*. The sunshine (hrs.) revealed significant positive association with pest, and longer sunshine hours marred the parasitization. Rainfall (mm/week) apparently did not expose any consistence role either with pest population or parasitoids.

Tambe and Kadam (2015) conducted studies on seasonal abundance of aphids and their natural enemies in relation to the climatic factors were undertaken on lucerne Average count of cowpea aphid (*A. craccivora*) was much low as compared to pea and spotted aphids. Cowpea aphid showed two population peaks, from 1st week of January, 2006 to 2nd week of February, 2006 and last week of December, 2006 to 2nd week of February, 2007. During these peaks, higher population was observed in 4th week of January, 2006 (17.50 aphids/tiller) and 3rd week of January, 2007 (23.50 aphids/tiller), respectively. The correlation coefficient of aphids on lucerne plant with meteorological parameters studies indicated that average number of pea aphid, spotted aphid and cowpea aphid per tiller showed highly significant negative correlation with minimum temperature. However, spotted aphid and cowpea aphid showed significant negative correlation with maximum temperature.

CHAPTER-III

MATERIAL AND METHODS

The investigations on "Studies on biology of *Etiella zinckenella* Treiteischke on lentil and evaluation of lentil genotypes against this pest" were carried out in the laboratory of Department of Entomology and Reseach farm of Pulses Section, Department of Genetics and Plant Breeding during the *rabi,* 2015-16. The details of each experiment are as follows:

3.1 Biology of lentil pod borer, *Etiella zinckenella* Treit.

Various biological aspects of *E. zinckenella* were studied in the laboratory, Department of Entomology at 28±1^{0}C and 60-70% humidity on lentil (cv. Garima). Initially a good number of full grown larvae of *E. zinckenella* were collected during March, 2016 from lentil and fieldpea plots. These were further reared in battery jars (20 × 15 cm), under the normal laboratory conditions to obtain the adults by supplying fresh pods of lentil to developing larvae till pupation (Plate 1). The freshly formed pupae were transferred into separate jars for the emergence of adults and were covered with muslin cloth. All further observations on biology of *E. zinckenella* were carried out simultaneously on the adults obtained from these jars.

The observations on longevity of adults, pre-oviposition, oviposition and post-oviposition period and fecundity were recorded on ten pairs (males and females) of newly emerged adults from lentil fed larvae. The newly emerged moths were segregated into males and females on the basis of structure of antennae. In case of male moth, antennae were widened at the base towards inner margin and possessed large second flagellar segment which was elongated, curved and provided with long hairs. The pairs of moths were released in individual battery jars (20×15 cm) which contained fresh twigs, pods and paper strips for egg laying. Cotton swabs dipped in 10 per cent honey solution were provided as food for the adults. The mouth of jars was kept closed with a piece of muslin cloth and it was held in position with the help of the rubber band. The eggs laid by female moths on the leaves, pods, walls of the battery jars and on muslin cloth were removed gently with the help of moist camel hair brush and kept for observing incubation and per cent egg viability.

3.1.1 Pre-oviposition, oviposition and post-oviposition period

For recording observations on pre-oviposition, oviposition and post-oviposition period ten pairs of newly emerged males and females were released individually into separate specimen jars containing fresh twigs of lentil for egg laying. The twigs were replaced daily and cotton swab dipped in 10 per cent honey solution, squeezed and kept in hanging position inside each specimen jar which served as food for the moths. The pre-oviposition period was recorded by counting the the number of days between the emergence of an adult female and the start of egg laying. Oviposition period was recorded by observing the duration between laying of first egg to last egg. Post-oviposition period was recorded by counting number of days between last egg laid till the death of female after copulation was over.

3.1.2 Fecundity

The total fecundity of each female was recorded during its oviposition period. Average fecundity of these females was calculated.

3.1.3 Adult longevity

The duration of adult life was recorded from the day of emergence of adults till death. The adults were observed and their mortality was recorded daily. Data thus obtained was converted into adult longevity.

3.1.4 Incubation period

The incubation period was counted as the duration in days after egg laying till their hatching. For finding out the incubation period five batches, having 50 eggs were observed. Average incubation period was calculated.

3.1.5 Per cent hatchability

Per cent hatchability was calculated on the basis of the number of eggs hatched successfully into first instar larvae.

3.1.6 Larval duration and number of instars

The larval duration was recorded as the duration in days from the hatching of eggs till the formation of pre-pupae. For studying the larval duration and number of instars, observations were recorded on 15 larvae. The newly hatched larvae of *E. zinckenella* were individually placed in separate glass vials (7×2.5 cm) having the pods of lentil as food. The food was replaced daily. To find out duration of different larval instars, observation on moulting were taken daily. To detect exuviae/moulted head of first and second instars a binocular microscope was used. For third, fourth and fifth larval instars, the exuviae was clearly visible with naked eyes. The durations of different larval instars and total larval period were recorded.

3.1.7 Pre-pupal and Pupal period

Duration in days from stoppage of feeding by last larval instar and its becoming sluggish with reduced body size to pupal formation was considered as pre-pupal period. The

time taken from pupal formation till emergence of moths was considered as pupal period. In each of five observations, ten individuals were studied and pupal periods were calculated. Pupation occurred in the pods as well as in battery jars. In some cases pupation occurred within a thin whitish covering. Pupation also occurred in soil by making cocoon with soil particles. In each of five battery jar a 6 cm soil layer was kept and full grown larvae or pre-pupae were allowed to pupate in it.

3.1.8 Per cent adult emergence

Five observations comprising of ten freshly formed pupae were recorded, and per cent adult emergence was calculated.

3.1.9 Sex ratio (F: M)

The sex ratio was determined by examining the pupae and it was later confirmed by adult emergence. At pupal stage both sexes were distinguished by observing the distance of anal and genital opening. More distance was observed between anal and genital openings in female than in male pupae. Sexes of adult moths were distinguished by the structure of antenna and posterior end of abdomen. The abdomen of male moth was lesser in width than female and provided with yellowish irregular tuft of hairs**.**

3.1.10 Measurements of various developmental stages.

Ten specimens of each life stage of *E.zinckenella i.e* egg, larva, pupa and adult were preserved, measured and studied in detail. The eggs, different larval instars and pupae were preserved in 70 percent alcohol with few drops of glycerol. While adults were killed in cyanide killing bottle and were spreaded with the help of spreading board and stored in insect collection box for further studies. The eggs, first to second instar larvae, pupae and adults were measured under a stereoscopic binocular microscope with the help of ocular micrometer. However, rest of the larval instars were measured with the help of vernier caliper.

3.2 Evaluation of lentil genotypes against *E. zinckenella*

Genotypes: 20 genotypes were evaluated against *E. zinckenella* under field conditions.
Sowing Time: 16 November, 2015
Spacing: 30 cm × 10 cm
Plot Size: Three rows of 4 meter length
Replications: 3
Design: Randomized Block Design (RBD)
Test Insect: *Etiella zinckenella* Treit.
Location: Pulse Section, Deptt. of Genetics & Plant Breeding, CCS HAU, Hisar.

3.2.1 Screening of lentil genotypes against *E.zinckenella*

Susceptibility of various genotypes of lentil to the pest attack was compared on the basis of per cent infestation of pods. The pod damage was recorded at two stages i.e. green

pod and maturity stage. For this purpose, 50 pods were collected from each replication and examined for the borer damage. On the basis of total pods and infested pods, per cent pod damage was calculated and at mature pod stage, genotypes were characterized into different categories on the basis of Pest Susceptibility Rating. (Lateef and Reed, 1980)

3.2.2 Correlation of morphological parameters of lentil genotypes with the incidence of *Etiella zinckenella*

Observation was also recorded on the following morphological characters:- Days to 50% flowering, Pod length, Pod wall thickness, Number of grains/pod, Days to maturity, and number of trichomes on pod and were correlated with the per cent pod damage at green and mature pod stage.

3.2.2.1 Days to 50 per cent flowering

Plants were randomly selected at the time of flowering and bloomed plant were counted daily. The observations were recorded till 50 per cent flowering was attained.

3.2.2.2 Pod Wall thickness of different genotypes of lentil

Pod wall thickness was measured from randomly selected 10 pods of each genotype. Hand cut cross section of 10 pods were taken and measured with the help of vernier calliper. At First, vernier calliper was tared to reduce any technical error and then walls of pods were put in between the vernier calliper and readings were recorded on the scale in millimetres by gently turning the scroll on the caliper

3.2.2.3 Pod length

Pod length of randomly selected 10 pods of different genotypes was measured with the help of Vernier calliper. Firstly, vernier calliper was tared to reduce any technical error and then pods were put horizontally in between the vernier calliper and length was recorded on the scale in millimetres by gently turning the scroll on the caliper.

3.2.2.4 Total number of seeds per pod

Total number of grains per pod was counted from randomly selected 10 pods of each genotype.

3.2.4.5 Days to maturity of different genotypes of lentil

Days to maturity of different genotypes were counted as days from date of sowing to maturity of the crop. Observations were recorded from all the three replications and average of three was considered as days to maturity.

3.3. Population dynamics of major insect pests infesting lentil.

Variety **:** Garima

Plot size **:** 15m × 15m

Time of sowing**:** 16November, 2015

Observations:

Studies on the population dynamics of major insect pests infesting lentil *viz*., *E. zinckenella*, *Helicoverpa armigera*, *Aphis craccivora*, were undertaken on lentil crop. Variety "Garima" was sown on 16th of the November. The crop was kept under regular observations. As and when pest appeared on the crop, data w.r.t the same was recorded at weekly intervals till maturity of crop. Visual observations of *Aphis craccivora* were recored per five plants after selecting middle twigs of each plant and nymph as well as adult population were counted from each twig by using hand lens. Larval population of *H. armigera* was recorded by ground sheet method after selecting five plants randomly at each spot. Total fifteen observations were recorded after selecting fifteen spots. For *E. zinckenella* five plants were selected randomly and all the pods were plucked and larval population was counted after disecting the pods. At maturity, the pods having the faecal material of *E. zinckenella,* webbing and exit holes of lentil pod borer (Plate1, 2 & 3) were considered as infected pods.

3.4 Statistical analysis

The data collected during present studies were statistically analyzed. Correlations of population of *E. zinckenella*, *Helicoverpa armigera* and *Aphis craccivora*, during different observation periods with different meteorological parameters were worked out. Regression analysis between *E. zinckenella*, *Helicoverpa armigera*, *Aphis craccivora*, populations with meteorological parameters was worked out using SPSS 16.0 version.. The data obtained during the evaluation of different genotypes against *E. zinckenella*, were tabulated and subjected to analysis. The critical differences were calculated at 5% level of significance.

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Plate 1: Webbing of lentil pods

Plate 2: Faecal matter indicating infestation of *E.zinckenella* in lentil

Plate 3: Exit holes on pods made by lentil pod borer

CHAPTER-IV

EXPERIMENTAL RESULTS

The investigations on"Studies on biology of *Etiella zinckenella* Treiteischke on lentil and evaluation of lentil genotypes against this pest" were carried out in the laboratory of Entomology and at Reseach farm of Pulses Section, Department of Genetics and Plant Breeding during the *rabi* 2015-16. The results achieved during the investigation are presented and explained under the following headings:

4.1 Biology of lentil pod borer, *Etiella zinckenella* Treit.

4.1.1 Pre-oviposition period, Oviposition period and Post oviposition period

4.1.2 Fecundity and adult longevity of *Etiella zinckenella*

4.1.3 Incubation period and per cent hatchability

4.1.4 Larval period

4.1.5 Pre-pupal and pupal period

4.1.6 Per cent adult emergence

4.1.7 Sex Ratio

4.1.8 Mating period

4.1.9 Total life cycle

4.1.10 Measurements of different developmental stages

4.2 Evaluation of lentil genotypes against *E. zinckenella*

4.2.1 Screening of lentil genotypes against *E.zinckenella*

4.2.2 Correlation of morphological parameters of lentil genotypes with the incidence of *Etiella zinckenella*

4.3 Population dynamics of Major insect pests of Lentil

4.3.1 Population dynamics of *Aphis craccivora* infesting lentil

4.3.2 Population dynamics of *Etiella zinckenella* and *Helicoverpa armigera* infesting lentil

4.3.3 Multiple regression analysis of pest population and abiotic factors

4.1 Biology of lentil pod borer, *Etiella zinckenella* Treit. on lentil

The biology of lentil pod borer was carried out in the laboratory of the Department of Entomology, Chaudhary Charan Singh, Haryana Agricultural University, Hisar.

4.1.1 Pre-oviposition period, Oviposition period and Post oviposition period

Ten pairs of *E. zinckenella* were released in glass jars (20×15cm), one pair in each jar and observations were recorded for Pre-oviposition period, Oviposition period and Post oviposition period. On perusal of data presented in table 1, the pre-oviposition period ranged from 1 to 2 days (average 1.3 days). The oviposition period varied from 2 to 3 days (average 2.3 days) and post oviposition period varied from 1 to 2 days (average 1.4 days).

Table 1: Pre-oviposition period, oviposition period and post- oviposition period of *Etiella zinckenella*

Females Observed	Pre-oviposition period (days)	Oviposition period (days)	Post-oviposition period (days)
1	1	3	1
2	2	3	2
3	1	2	2
4	2	2	2
5	2	2	1
6	1	2	1
7	1	2	1
8	1	3	1
9	1	2	2
10	1	2	1
Mean ±SD	**1.3±0.5**	**2.3±0.5**	**1.4±0.5**
Range	**1-2**	**2-3**	**1-2**

4.1.2 Fecundity and adult longevity of *Etiella zinckenella*

Observations recorded on eggs showed that, eggs were laid on muslin cloth, paper strips as well as on the plant parts supplied for food in the battery jars. Mostly eggs were laid singly on pods (Plate 4), flowers, calyx and leaves of lentil. The freshly laid eggs of lentil pod borer were oval in shape and whitish in colour which changed to orange before hatching. The data pertaining to Table 2 indicate that a single female laid 46 to 65 eggs (average 56.3 eggs) during her total life time. None of the females deposited any egg on the first day of emergence, *i.e* all females started ovipositing one day after emergence. The data pertaining to adult longevity of *Etiella zinckenella* revealed that longevity of male moths varied from 3 to 5 days (average 4.1 days) and longevity of female moths varied from 5 to 6 days (average 5.6 days). Hence males are short lived than females.

Table 2: Fecundity and adult longevity of *Etiella zinckenella*

Pairs observed	Eggs/ female	Longevity of Male moths	Longevity of Female moths
1	48	5	5
2	65	4	5
3	58	3	6
4	59	3	6
5	56	4	6
6	52	4	6
7	46	4	5
8	63	4	6
9	60	5	6
10	56	5	5
Mean ±SD	**56.3±6.2**	**4.1±0.7**	**5.6±0.5**
Range	**46-65**	**3-5**	**5-6**

4.1.3 Incubation period and hatchability of eggs.

The incubation period was counted as the duration in days after egg laying till their hatching. For finding out the incubation period five batches, having 50 eggs were observed. Average incubation period was calculated and per cent hatchability was calculated on the basis of the number of eggs hatched successfully into first instar larvae. It is evident from Table 3 that incubation period ranged from 5.18 to 5.38 days (average 5.24 days) and per cent hatchability varied from 74 to 92 days (average 81.6 days).

Table 3: Incubation and per cent hatchability of *Etiella zinckenella*

Eggs batch	No. of eggs observed	Average incubation period (days)	Per cent hatchability
1	50	5.20	84
2	50	5.27	80
3	50	5.38	74
4	50	5.18	92
5	50	5.18	78
Mean±SD		**5.24±0.09**	**81.6±6.8**
Range		**5.18-5.38**	**74-92**

4.1.4 Larval period

Observations on duration, number of instars and total larval period (Plate 5) were recorded on 15 freshly hatched larvae. The data mentioned in the table 4 revealed that the larvae passed through five instars before entering pupal stage.Newly hatched larva was tiny, yellowish in colour with with black shinning head. First instar larvae lasted for 1 to 2 days (average 1.53 days) and second instar larvae were creamish to brownish in colour and blackish head, which remained for 2 to 3 days (average 2.6 days) to become third instar. The third instar larvae were much longer than preceding instars and took 3 to 4 days (average 3.5 days). Fourth instar was having yellowish head with black spots on vertex and lasted for 3 to 4 days (average 3.7 days). Fifth instar was pink in colour with yellowish head. Each thoracic leg of larva was five segmented and the abdominal prolegs were present on third to sixth and tenth abdominal segments and it remained for 5 to 6 days (average 5.5 days). The total larval period ranged from 15 to 19 days (average 16.9 days). The first instar completed its stage comparatively in shorter period than rest of the instars

Table 4: Larval period of *Etiella zinckenella*

Larvae observed	Duration of larval instars (days)					Total larval period (days)
	1st	2nd	3rd	4th	5th	
1	2	2	3	4	6	17
2	2	2	4	4	6	18
3	1	3	4	4	6	18
4	1	2	4	4	6	17
5	1	2	4	4	6	17
6	1	2	4	3	6	16
7	1	2	3	3	6	15
8	1	3	3	4	5	16
9	2	3	3	4	5	17
10	2	3	3	4	5	17
11	2	3	4	4	5	18
12	2	3	3	4	5	17
13	1	3	4	3	5	16
14	2	3	4	4	6	19
15	2	3	3	3	5	16
Mean±SD	**1.53±0.5**	**2.6±0.5**	**3.5±0.5**	**3.7±0.4**	**5.5±0.5**	**16.9±1**
Range	**1-2**	**2-3**	**3-4**	**3-4**	**5-6**	**15-19**

4.1.5 Pre-pupal and pupal period

Duration in days from stoppage of feeding by last larval instar and its becoming sluggish with reduced body size to pupal formation was considered as pre-pupal period. The time taken from pupal formation till emergence of moths was considered as pupal period. Pupation took place on glass jars, soil, muslin cloth and tissue paper (Plate 6) In each of five observations, ten individuals were studied and pupal periods were calculated. Based on morphological characters, it was found that pupa were dark brown in colour with six hook

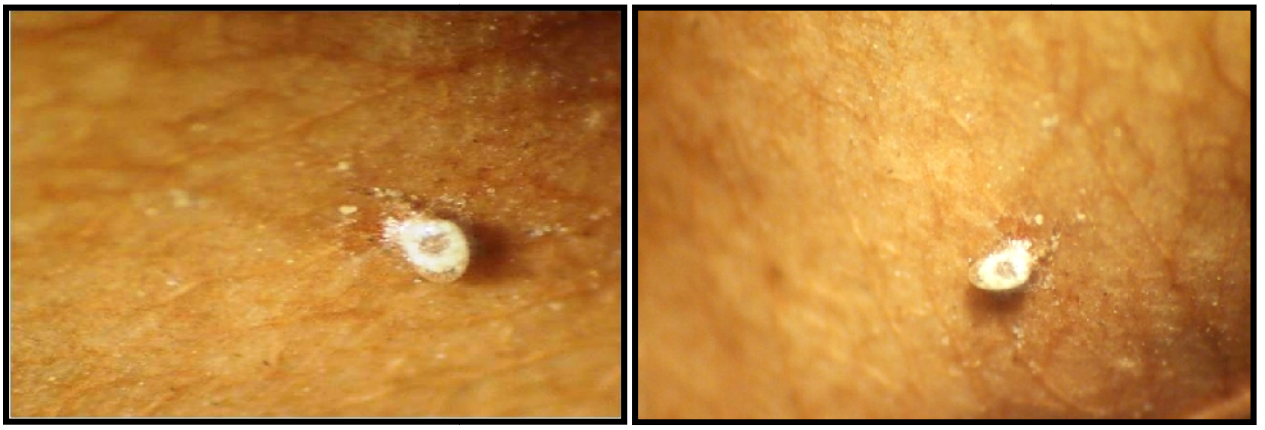


Plate 4: Eggs of *Etiella zinckenella*

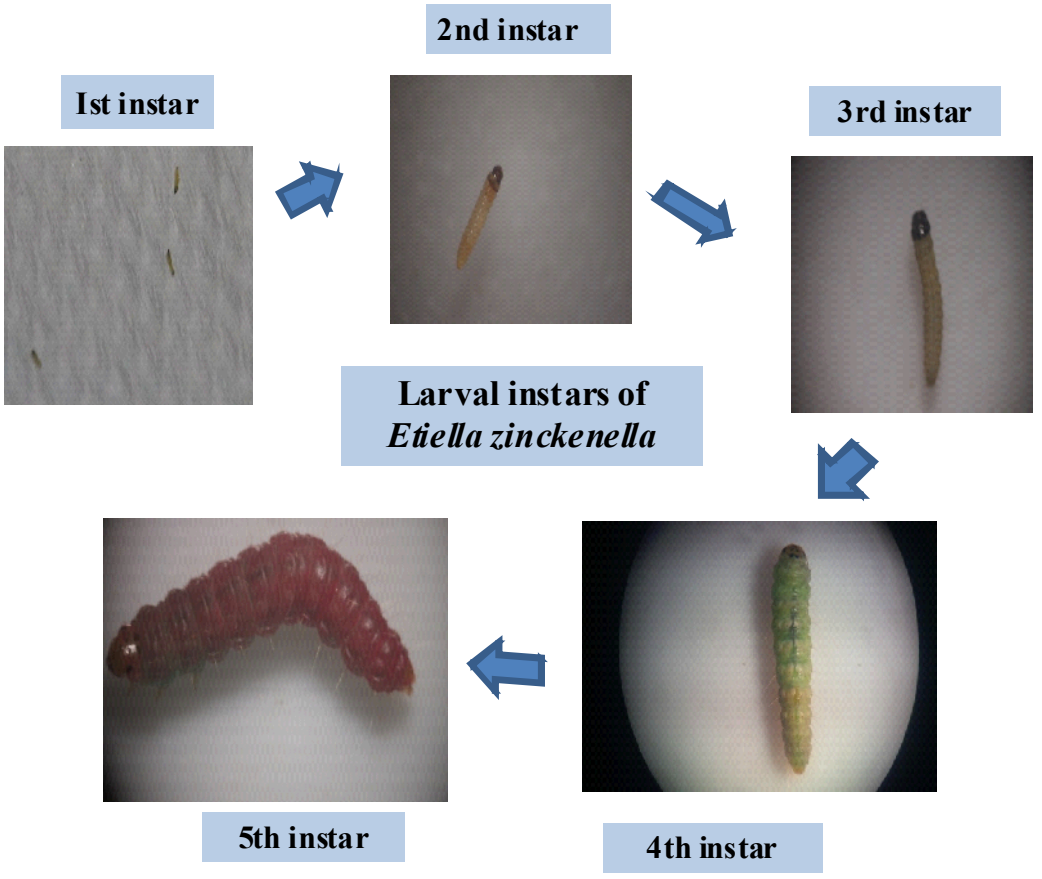
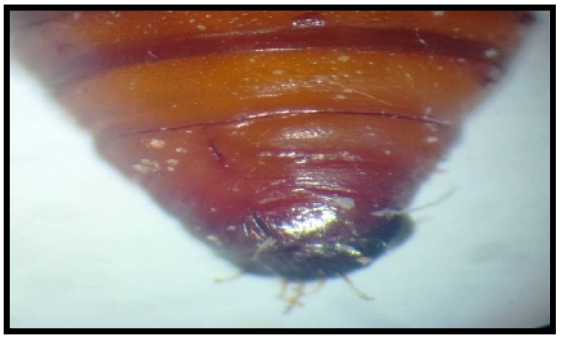
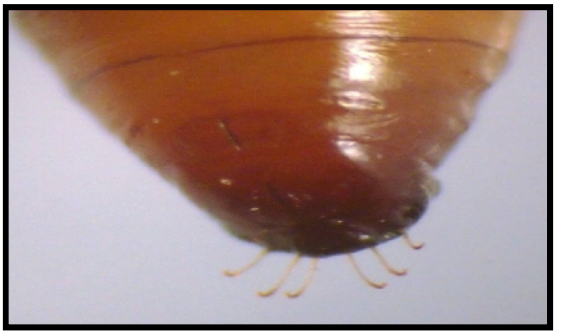


Plate 5: Larval instars of *Etiella zinckenella*

Plate 6: Thin white cocoon and pupa of *Etiella zinckenella*





Female pupa **Male pupa**

Plate 7: Sex differentiation at pupal stage

Male **Female**

Plate 8: Adults of *Etiella zinckenella*

shaped fine spines at the posterior end. Sexes were differentiated at pupal stage on the basis of differences in slit distance (Plate 7).

Table 5: Pre-pupal and Pupal period of *Etiella zinckenella*

Sr.No.	No. of Pupae observed	Average pre-pupal period (days)	Average pupal period (days)
1	10	1.9	12.7
2	10	2.3	13.1
3	10	2.0	13.9
4	10	1.9	14.4
5	10	2.1	12.8
Mean±SD		**2.04±0.2**	**13.38±0.7**
Range		**1.9-2.3**	**12.7-13.9**

Observations given in Table 5 revealed that average pre-pupal period ranged from 1.9 to 2.3 days (average 2.04 days) and data in table revealed that average pupal period varied from 12.7 days to 13.9 days (average 13.38 days).

4.1.6 Per cent adult emergence

The data pertaining to adult emergence is depicted in Table 6 and data revealed that per cent adult emergence ranged from 80 to 100 per cent (average 88 per cent).

Table 6: Adult emergence of *Etiella zinckenella*

Sr. No.	No. of pupae observed	Per cent adult emergence
1	10	80
2	10	80
3	10	90
4	10	90
5	10	100
Mean±SD		**88±8.4**
Range		**80-100**

4.1.7 Sex Ratio

The male and female moths emerged from the pupae were segregated on the basis of structure of antennae and shape of abdomen (Plate 7). It is evident from the table 7 that males outnumbered the females. The average percentage of males and females was 56.7and 43.3, respectively. Average female to male ratio was 1.0 to 1.4.

Table 7: Sex ratio of *Etiella zinckenella*

Sr. No.	No. of pupae observed	No. of adults emerged	No. of males	No. of females	Per cent males	Per cent females	Sex Ratio (F:M)
1	10	8	5	3	62.5	37.5	1.0 : 1.7
2	10	8	4	4	50.0	50	1.0 : 1.0
3	10	9	5	4	55.6	44.4	1.0 : 1.3
4	10	9	5	4	55.6	44.4	1.0 : 1.3
5	10	10	6	4	60	40	1.0 : 1.5
Total		**44**	**25**	**19**			
Average					**56.7±4.3**	**43.3±4.3**	**1.0 : 1.4**

4.1.8 Mating period

. The mating occurred only at night or in dark places or early hours in the morning. These studies were carried with 10 pairs of adults. The data presented in table 8 indicate that mating period of *Etiella zinckenella* varied from 43 to 63 minutes (average 51.5 minutes). It was observed that that most of the adults paired on first night after emergence and remaining did on second night. The unmated females did not lay any egg. The insects were found copulating in captivity.

Table 8: Mating period of *etiella Zinckenella*

Pairs observed	Duration of mating (minutes)
1	58
2	63
3	43
4	37
5	54
6	61
7	38
8	62
9	46
10	53
Mean ±SD	**51.5±9.9**

4.1.9 Total life cycle

Ten observations were taken for recording the total duration of life cycle of *E. zinckenella*. Data pertaining to total life cycle (Table 9) showed that the life cycle of this insect ranged from 37 to 45 days (average 40.9 days).

Table 9: Total life cycle of *Etiella zinckenella*

Sr. No. (Pairs observed)	Egg (Days)	Larva (Days)	Pupa (Days)	Adult (Days)	Total (Days)
1	5	17	14	5	41
2	4	16	14	3	37
3	4	15	14	6	39
4	6	16	13	6	41
5	6	17	13	6	42
6	5	17	13	5	40
7	5	18	13	4	40
8	6	17	15	3	41
9	5	16	16	6	43
10	5	19	15	6	45
Mean±SD	**5.1±0.7**	**16.8±1.1**	**14±1.1**	**5±1.2**	**40.9±2.2**

4.1.10 Measurements of various developmental stages

4.1.10 (a) Egg

The freshly laid eggs of *E.zinckenella* were whitish in colour which changed to orange colour before hatching. They were oval in shape. Length of egg ranged from 0.47 to 0.57 mm (average 0.51 mm) and width of egg ranged from 0.30 to 0.40 mm (average 0.35 mm). (Table 10).

4.1.10 (b) Larva

First instar larva was yellowish in colour with black shining head. First instar larvae when reared on lentil pods ranged from 0.85 to 0.95 mm in length (average 0.89 mm) and 0.12 to 0.17 mm in width (average 0.15 mm). Second and third larval instars were creamish to brownish in colour with blackish head. Second and third instars ranged from 2.67 to 2.98 mm (average 2.83 mm) and 6.14 to 6.33 mm (average 6.22 mm) in length and 0.70 to 0.87 mm(average 0.78 mm) and 1.43 to 1.56 mm(average 1.49 mm) in width, (Table 10) respectively.

Fourth larval instar was having yellowish head with black spots on vertex. Forth larval instar ranged from 11.24 to 11.34 mm (average 11.29 mm) in length and 2.14 to 2.25 mm (average 2.21 mm) in width. The fifth instar was dark pink in colour with yellowish head. Each thoracic leg of larva was five segmented and abdominal prolegs were present on third to sixth and tenth abdominal segments. One pair of thoracic spiracles were located on lateral sides from first to eighth segments. Fifth instar ranged from 15.28 to 15.38 mm (average 15.33 mm) in length and 2.84 to 2.92 mm (average 2.89 mm) in width.

Table 10: Measurements of different developmental stages of *Etiella zinckenella* fed on lentil

Sr. No.	Number observed	Developmental Stage	Average length (mm)	Range	Average width (mm)	Range
1.	**10**	**Egg**	0.51±0.04	0.47-0.57	0.35±0.03	0.30-0.40
2.		**Larva**				
	10	**1st instar**	0.89±0.03	0.85-0.95	0.15±0.02	0.12-0.17
	10	**2nd instar**	2.83±0.12	2.67-2.98	0.78±0.05	0.70-0.87
	10	**3rd instar**	6.22±0.09	6.14-6.33	1.49±0.05	1.43-1.56
	10	**4th instar**	11.29±0.03	11.24-11.34	2.21±0.04	2.14-2.25
	10	**5th instar**	15.33±0.02	15.28-15.38	2.89±0.03	2.84-2.92
3.		**Pupa**				
	10	**Female pupa**	8.74±0.11	8.61-8.97	2.61±0.10	2.51-2.84
	10	**Male pupa**	8.80±0.23	8.72-9.14	2.67±0.13	2.48-2.77
4.		**Adult**				
	10	**Female**	11.34± 0.18	10.78-11.48	21.13±0.26	20.79-21.23
	10	**Male**	12.20± 0.16	11.56-12.52	22.09± 0.29	21.92-22.29

Head capsule width of 1st,2nd,3rd,4th and 5th instar when reared on variety Garima ranged 0.08 to 0.12 mm(average 0.10 mm), 0.45 to 0.53mm (average 0.50 mm), 0.77 to 0.89 mm(average 0.82 mm), 0.89 to 0.98 mm (average 0.94 mm) and 1.17 to 1.23 mm (average 1.20 mm), respectively.

4.1.10 (c) Pupa

The pupa of *E. zinckenella* was of obtect type. The freshly formed pupa was greenish in colour which changed to brownish after 6-7 hours. Before one to two days of adult emergence, pupae became dark brown in colour. The pupa had well defined dark brown coloured spiracles situated dorsally on second to eighth abdominal segments. Six hook-shaped fine spines were present at the posterior end of the abdomen. The sexes at pupal stages were determined on the basis of distance between anal and genital opening. In male pupa, the genital opening was present on ninth abdominal segment while in female this opening was located on eighth abdominal segment. The anal opening was present on tenth abdominal segment in both the sexes. Therefore, more distance between the anal and genital opening was present in female pupae than male pupae. Length of male pupae ranged from 8.72 to 9.14 mm (average 8.80 mm) and in case of female pupae it ranged from 8.61 to 8.97 mm (average 8.74 mm). Width of male pupae ranged from 2.48 to 2.77 mm (average 2.67 mm) and in case of female pupae it ranged from 2.51 to 2.84 (average 2.61 mm). Weight of male pupae ranged

from 0.036 to 0.051 g (average 0.042 g) and weight of female pupae ranged from 0.037 to 0.044 g (average 0.040 g).

Table 11: Head capsule width and pupal weight of *Etiella zinckenella* fed on lentil

Sr. No.	Insect stage	Number observed	Mean±SD	Range
Larvae*				
1	**1st instar**	10	0.10±0.02	0.08-0.12
2	**2nd instar**	10	0.50±0.04	0.45-0.53
3	**3rd instar**	10	0.82±0.06	0.77-0.89
4	**4th instar**	10	0.94±0.03	0.89-0.98
5	**5th instar**	10	1.20±0.04	1.17-1.23
Pupae**				
6	**Male pupae**	10	0.042±0.01	0.036-0.051
7	**Female pupae**	10	0.040±0.01	0.037-0.044

***Width of Head capsule in mm. **Weight of Pupae in grams**

4.1.10 (d) Adult

The male and female moths were greyish in colour. The female moths were slightly smaller than male moths. The compound eyes were prominent and were bigger in males with more ocular distance than female moths. The forewings were longer and narrower than the hind wings which were hyaline and provided with long hairs at their inner margins. There was a white band along the costal margin of each forewing. The sexes in adult stages were distinguished on the basis of structure of antenna and sizes of abdomen (Plate 8). In case of male moth, the pedicel of each antenna was broadened at the base having a projection at its inner margin and in case of female the antennal projection was absent. The abdomen of male moth was lesser in width and and provided with yellowish irregular tufts of hairs at anal end. In female moth, the abdomen was more wider than that of male and with tufts of yellowish hairs of regular length at the posterior end. The male moths ranged 11.56 to 12.52 mm (average 12.20 mm) in length and 21.92 to 22.29 mm (average 22.09 mm) in width. The female moths ranged from 10.78 to 11.48 mm (average 11.34 mm) in length and 20.79 to 21.23 mm (average 21.13 mm) in width.

4.2 Evaluation of lentil genotypes against *E. zinckenella*

4.2.1 Screening of lentil genotypes against *E. zinckenella*

Susceptibility of various genotypes of lentil to the pest incidence was compared on the basis of per cent infestation of pods. The pod damage was recorded at two stages i.e. green pod and maturity of crop, respectively. For this purpose, 50 pods was collected from each

replication and examined for the borer damage. On the basis of total pods and infested pods, per cent pod damage was calculated.

4.2.1.1 Screening of lentil genotypes at Green pod stage

The results achieved under these studies are presented in Table 12. The data revealed that among the 20 genotypes screened under field conditions against *Etiella zinckenella,* pod infestation ranged from 2.0 to 12.0 per cent at green pod stage (Table 12). The genotypes FLIPILL 6089 and L 4096 were found to be least infested having 2.0 per cent pod damage and were statistically at par with LL 1136, RKL 608-1, RKL 1-32, RKL 1003-33D, IL 2010-75L, HM-1, having 3.3, 2.7, 2.7, 4.0, 2.3 and 3.3 per cent pod damage, respectively. Maximum infestation (12.0 per cent) was observed in the genotypes JL 3 and PL 105 which was statistically at par with Garima, Sapna, RKL 23C-274, RKL 45-10,IPL 406 and DPL 62 having 9.7, 8.7, 9.3,10.0, 11.3, 8.7, and 12.0 per cent pod damage, respectively. Genotypes IPL 315, IPL 81, PRECOZ, FLIPILL 6089 and LH 07-26 were intermediate in their reaction to pest infestation.

4.2.1.2 Screening of lentil genotypes at Maturity of crop

At harvesting stage of the crop, 50 pods were plucked from randomly from each genotype and per cent pod damage was calculated. Pod infestation of lentil genotypes ranged from 4.0 to 24.0 per cent at mature pod stage (Table 12). The genotype RKL 1-32 was found to be least susceptible having 4.0 per cent pod damage and it was statistically at par with genotypes RKL 608-1, FLIPILL 6089, RKL 1003-33D and L 4096LL 1136 having 5.3, 4.7, 6.0 and 4.7 per cent pod damage , respectively. Maximum pod infestation was observed in genotype IPL 406 (24.0 Per cent) which was statistically at par with JL 3, RKL 45-10 and PL105 having 22.7,20.0 and 18.7 per cent pod damage, respectively. The remaining genotypes i.e LL 1136, DPL 62, IPL 315, IPL 81, PRECOZ, IL 2010-75L, RKL 23C-274, Sapna, Garima, HM-1 and LH 07-26were intermediate in their reaction to pest infestation.

On the basis of Pest susceptibility rating at maturity of crop, keeping lentil variety Garima as a check. PSR against *E. zinckenella* varied from 2 to 9. 7 genotypes were categorized as least susceptible having PSR rating 2 to 3(Table 13), 9 genotypes were categorized as moderately susceptible having PSR rating 4 to 6 and 4 genotypes having PSR rating 7 to 9 were indicated as highly susceptible.

4.2.2 Correlation of morphological parameters of lentil genotypes with the incidence of *Etiella zinckenella*

Different morphological characters of different genotypes *viz.,* days to 50% flowering, pod length, number of grains per pods, pod wall thickness and days to maturity were recorded and correlated with per cent pod damage.

Table 12: Screening of lentil genotypes against the incidence of *Etiella zinckenella*

Sr. No.	Genotypes	Per cent pod damage at green pod stage	Pest Susceptibility Rating	Per cent pod damage at maturity stage	Pest susceptibility Rating (PSR)**
1	**LL 1136**	3.3 (10.40)*	3	7.3 (15.67)*	3
2	**JL 3**	12.0 (19.98)	8	22.7 (28.42)	8
3	**DPL 62**	8.7 (16.65)	6	14.7 (22.44)	6
4	**IPL 315**	4.7 (12.03)	4	7.3 (15.67)	3
5	**IPL 81**	5.3 (13.29)	4	9.3 (17.70)	4
6	**IPL 406**	11.3 (19.55)	7	24.0 (29.31)	9
7	**RKL 45-10**	10.0 (18.19)	6	20.0 (26.48)	8
8	**PRECOZ**	6.0 (14.04)	4	13.3 (21.19)	5
9	**RKL 608-1**	2.7 (9.26)	3	5.3 (13.29)	3
10	**FLIPILL 6089**	2.0 (6.55)	2	4.7 (12.41)	3
11	**RKL 1-32**	2.7 (9.26)	3	4.0 (10.89)	2
12	**RKL 1003-33D**	4.0 (11.28)	3	6.0 (14.17)	3
13	**L 4096**	2.0 (6.55)	2	4.7 (12.41)	3
14	**IL 2010-75L**	2.7 (9.26)	3	16.0 (23.54)	6
15	**RKL 23C-274**	9.3 (17.52)	6	12.7 (20.65)	5
16	**Sapna**	8.7 (16.74)	6	16.7 (24.05)	6
17	**HM-1**	3.3 (10.40)	3	9.3 (17.70)	4
18	**LH 07-26**	6.7 (14.92)	4	14.7 (22.36)	6
19	**PL 105**	12.0 (20.08)	8	18.7 (25.39)	7
20	**Garima**	9.7(17.62)	-	16.0(23.46)	-
	SEm(±)	**(1.73)**		**(1.52)**	
	CD (p=0.05)	**(5.13)**		**(4.36)**	

* Values in parentheses are angular transformed values
** PSR- Pest susceptibility rating (1-9 scale where 1= Resistant and 9= Susceptible)

Table 13: Characterization of lentil genotypes against the incidence of *Etiella zinckenella*

Sr. No.	Name of Genotype	PSR*	Category of infestation	No. of Genotypes
1.	LL 1136, IPL 315, ,RKL 608-1, FLIPILL 6089, RKL 1-32, RKL 1003-33D, L 4096	1-3	Least Susceptible	7
2.	DPL 62, PRECOZ, IL 2010-75L, RKL 23C-274, Sapna, Garima, LH 07-26, HM-1, IPL81	4-6	Moderately Susceptible	9
3.	JL 3, IPL 406, PL 105, RKL 45-10	7-9	Highly Susceptible	4

*PSR-Pest Susceptibility Rating

Fifty per cent flowering

Significant difference in 50 per cent flowering of different genotypes was recorded and it ranged from 69 to 101 days. Genotype JL3 flowered earliest *i.e* 69 days. Late flowering was recorded in genotype LL 1136 *i.e* 101 days. The data revealed that although there was negative correlation but it was not significant with green damaged pods as well as mature damaged pods.

Pod length

Maximum pod length was recorded in IPL 406 (14.42 mm) and it was statistically at par with genotypes RKL 45-10 (14.08 mm), RKL 1003-33D (14.11 mm) and PL 105 (14.17 mm).Minimum pod length was recorded in FLIPILL 6089 (12.11 mm) and it was statistically at par with genotype LL 1136(12.14 mm), DPL 62 (12.31 mm), IPL 81 (12.63 mm), PRECOZ (12.42 mm), RKL 608-1(12.42 mm), RKL 1-32 (12.69 mm), RKL 23C-274(12.70) and HM-1(12.45 mm) .The data revealed that there was positive and significant correlation between pod length and green as well as mature damaged pods (r=0.5479*).

Number of seeds per pod

Non- significant difference was recorded with between the number of seeds per pod and mature damaged pods. The number of seeds per pod varied from 1.3 to 2.0. Minimum number of grains were recorded in RKL 23C-274 (1.3 seeds/ pod). Maximum number of grains were recorded in JL 3, FLIPILL 6089, Sapna, HM-1(2 seeds/ pod), which is statistically at par with IPL 315(1.9), IPL 406 (1.8), RKL 45-10(1.8), PRECOZ (1.8), RKL 1003-33D(1.7), L 4096(1.9), IL 2010-75L (1.8), Garima (1.9), KH 4096 and 07-26 (1.7) and PL 105(1.7).The data revealed that there was no significant correlation with mature damaged pods.

Table 14: Correlation of morphological parameters of lentil genotypes with *E.zinckenella*

Sr.No.	Genotype	Days to 50 % flowering	Days to maturity	Pod length (mm)	Pod wall thickness (mm)	No. of seeds per pod
1	**LL 1136**	101	140	12.14 (3.48)	0.36 (1.17)	1.6 (1.61)
2	**JL 3**	69	132	12.92 (3.59)	0.35 (1.16)	2.0 (1.73)
3	**DPL 62**	86	135	12.31 (3.51)	0.33 (1.15)	1.6 (1.61)
4	**IPL 315**	86	136	12.91 (3.59)	0.31 (1.14)	1.9 (1.70)
5	**IPL 81**	85	133	12.63 (3.55)	0.31 (1.15)	1.6 (1.61)
6	**IPL 406**	86	136	14.42 (3.80)	0.33 (1.15)	1.8 (1.67)
7	**RKL 45-10**	75	125	14.08 (3.75)	0.30 (1.14)	1.8 (1.67)
8	**PRECOZ**	85	125	12.42 (3.52)	0.39 (1.18)	1.8 (1.67)
9	**RKL 608-1**	81	130	12.42 (3.52)	0.28 (1.13)	1.6 (1.61)
10	**FLIPILL 6089**	89	129	12.11 (3.48)	0.27 (1.13)	2.0 (1.73)
11	**RKL 1-32**	79	130	12.69 (3.56)	0.32 (1.15)	1.5 (1.58)
12	**RKL 1003-33D**	87	135	14.11 (3.76)	0.34 (1.16)	1.7 (1.64)
13	**L 4096**	72	137	13.16 (3.63)	0.35 (1.16)	1.9 (1.70)
14	**IL 2010-75L**	87	124	13.12 (3.62)	0.24 (1.11)	1.8 (1.67)
15	**RKL 23C-274**	70	121	12.70 (3.56)	0.32 (1.15)	1.3 (1.52)
16	**Sapna**	88	134	13.31 (3.65)	0.29 (1.13)	2.0 (1.73)
17	**Garima**	85	134	13.12 (3.62)	0.35 (1.16)	1.9 (1.70)
18	**HM-1**	87	136	12.45 (3.53)	0.29 (1.14)	2.0 (1.73)
19	**LH 07-26**	87	138	13.47 (3.67)	0.30 (1.14)	1.7 (1.64)
20	**PL 105**	86	138	14.17 (3.76)	0.36 (1.17)	1.7 (1.64)
SEm (±)		**0.89**	**0.18**	**(0.03)**	**(0.01)**	**(0.04)**
CD (P= 0.05)		**2.55**	**0.51**	**(0.09)**	**(0.03)**	**(0.11)**
r value green pod stage		**-0.2866**	**0.0056**	**0.5144***	**0.3569**	**0.0104**
r value mature pod damage		**-0.1831**	**-0.0914**	**0.5479***	**0.1376**	**0.1785**

***** Significant at (p= 0.05)

Pod wall thickness

Observations on pod wall thickness revealed that there was significant difference in different genotypes which it ranged from 0.24 mm to 0.36 mm. Minimum pod wall thickness was recorded in IL 2010-75L (0.24 mm) and it was at pat with genotypes RKL 608-1(0.28), FLIPILL 6089(0.27 mm), IL 2010-756(0.24 mm) and Sapna(0.29 mm). Maximum pod wall thickness was recorded in LL 1136(0.36 mm) and PL105 (0.36 mm) and it was statistically at par with genotypes JL 3(0.35 mm), DPL 62(0.33mm), IPL 81(0.31 mm), IPL 406(0.33 mm), RKL 1-32(0.32 mm),RKL 1003-33D(0.34 mm), L 4096(0.35 mm), RKL 23C-274(0.32 mm),Garima(0.35 mm), HM 1(0.29 mm),PL 105(0.36 mm) and LH 07-26(0.30 mm). The data revealed that there was no significant correlation with mature damaged pods.

Days to maturity

The data on days to maturity was recorded of different genotypes of lentil and it ranged from 121 days to 140 days. Genotype RKL 23C-274 (121 days), matured earliest. Maximum day to maturity was recorded in LL 1136(140 days). No significant correlation could be recorded between days to maturity of the crop and mature damaged pods.

4.3 Population dynamics of major insect pests of lentil

An experiment on studies of population dynamics of major insect pests *viz*., *E. zinckenella*, *Helicoverpa armigera*, *Aphis craccivora*, was conducted. on lentil crop. The crop was kept under regular observations, as and when pest appeared on the crop. Visual observations of *Aphis craccivora* were recored per five plants after selecting middle twigs of each plant and nymph as well as adult population were counted from each twig by using hand lens. Larval population of *H. armigera* was recorded by ground sheet method after selecting five plants randomly at each spot. Total fifteen observations were recorded after selecting fifteen spots. For *E. zinckenella* five plants were selected randomly and all the pods were plucked and larval population was counted after disecting the pods. At maturity, the pods having the faecal materialof *E.zinckenella* were considered as infected pods.

4.3.1 Population dynamics of *Aphis craccivora* infesting lentil

Population dynamics of *Aphis craccivora* in relation to different weather parameters is represented by Fig. 1. Details of the weather parameters during course of study are given in appendix-I.

Data presented in Table 15 revealed that population (nymph+adult) of the pest was recorded on the crop from 1st to 13th meteorological standard weeks (SW) after which there was no activity of pest. The population of *Aphis craccivora* appeared in the 1st standard week (1.74 aphids/5 plants) with rise in minimum temperature. Peak activity of pest was recorded during 7th SW with a population of 78.0 aphids/ 5 plants when the maximum temperature was 21.9 ^{o}C and min. temp.6.2 ^{o}C, relative humidity morning- 92.3% and evening-53%, sunshine hours was 6.7 hrs and rainfall was 5.3 mm. The population remained below 13.07aphids /5 plants during the 11th to 13th SW

Table 15: Population dynamics of *Aphis craccivora* during *rabi*, 2015

Date of observation	Standard week	Mean Population of aphids/ 5 plants
04-01-2016	1st	1.74
07-01-2016	2nd	11.05
18-01-2016	3rd	33.24
25-01-2016	4th	38.52
01-02-2016	5th	41.60
08-02-2016	6th	52.45
15-02-2016	7th	78.00
22-02-2016	8th	57.53
29-02-2016	9th	22.07
07-03-2016	10th	13.07
14-03-2016	11th	0.30
21-03-2016	12th	0.20
28-03-2016	13th	0.00

There was significant negative correlation of aphid population with the Temperature (Tmax. & Tmin.), (r = -0.5015** and r = -0.6138*, respectively) (Table 16). Relative humidity (%) morning, relative humidity (%) evening, sun shine hours and rainfall had non-significant correlation with *Aphis craccivora* population.

Table16: Correlation of Aphid population with weather parameters on lentil

Weather parameter	*Aphis craccivora* population
Temperature (maximum)	-0.5015**
Temperature (minimum)	-0.6138*
Relative humidity (%) Morning	0.3153
Relative humidity (%) Evening	0.1788
Sun shine hours	-0.1727
Rainfall (mm)	-0.1511

*Significant at P= 0.05
**Significant at P=0.1

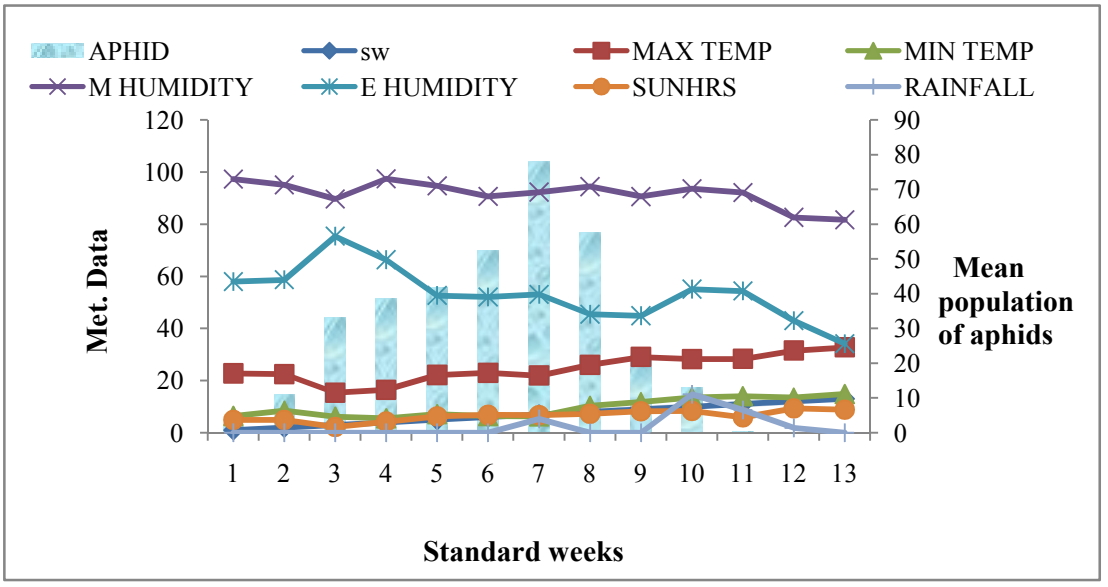


Figure 1: Correlation between weather parameters and aphid population.

4.3.1.1 Natural enemies

Population of coccinellids was recorded on the lentil plants but it was negligible.

4.3.2 Population dynamics of *Etiella zinckenella* and *Helicoverpa armigera* on lentil

Larval population of *Helicoverpa armigera* and *Etiella zinckenella*(larvae+ faecal material) were recorded from 6th to 14th meteorological standard weeks (SW). Larval population of *Helicoverpa armigera* and *Etiella zinckenella* appeared in 6th standard week with onset of flowering and pods. Increase in larval population populations were recorded in 8th standard week for both the pests.(Fig.1 and Fig. 2). Peak of *Etiella zinckenella* population was found during 12th SW with a population of 11 (larvae+ faecal material)/ plant when the temperature (max.) was 31.5 °C and min. temp.13.4 °C, relative humidity morning- 82.6% and evening-42.9%,sunshine hours was 9.3 hrs and rainfall was 1.8 mm.and Peak of *Helicoverpa armigera* population was found during 9th SW with a population of 0.83 larvae / 5plant when the temperature (max.) was 29 °C and min. temp.11.7 °C, relative humidity morning- 90.6% and evening-44.8%,sunshine hours was 8.2 hrs and there was no rainfall.

Correlation of *Etiella zinckenella* population with various environmental factors revealed that *Etiella zinckenella* population had significant positive correlation both with temperature (Tmax. & Tmin.), (r = 0.8251*and r = 0.8481* respectively) (Table 18). relative humidity (%) morning, relative humidity (%) evening, sun shine hours and rainfall had non-significant correlation with *Etiella zinckenella* population.

Correlation of *Helicoverpa armigera* population with various environmental factors revealed that *Helicoverpa armigera* population had non- significant correlation with temperature (Tmax. & Tmin.),) (Table 18), relative humidity (%) evening, sun shine hours and rainfall and was positively associated with relative humidity (%) morning.

Table 17: Population dynamics of *Etiella zinckenella* and *Helicoverpa armigera* infesting lentil during *rabi*, 2015

Date of observation	Standard weeks	Mean population of *E.zinckenella* / plant	Mean larval population of *H.armigera* / 5 plant
11-02-2016	6th	0.2	0.13
18-02-2016	7th	0.4	0.33
25-02-2016	8th	1.4	0.53
03-03-2016	9th	3.2	0.83
10-03-2016	10th	7	0.33
17-03-2016	11th	9.8	0.27
24-03-2016	12th	11	0.27
31-03-2016	13th	10.6	0.2
07-04-2016	14th	9.2	0.07

Table 18: Correlation of *Etiella zinckenella* and *Helicoverpa armigera* population with weather parameters on lentil

Weather parameter	*Helicoverpa armigera* Population	*Etiella zinckenella* Population
Temperature (maximum)	-0.2205	0.8251*
Temperature (minimum)	-0.2249	0.8481*
Relative humidity (%) Morning	0.5172	-0.5731
Relative humidity (%) Evening	0.1614	-0.4574
Sun shine hours	0.2371	0.3403
Rainfall (mm)	-0.0619	0.1632

*significant at (P = 0.05)

4.3.2.1 Natural enemies

Egg masses, larvae and pupae of *E. zinckenella* were collected from field & kept under regular inspection. No parasitization was found. Few larvae of *H.armigera,* 1st and 2nd instar were parasitized by *Campoletis chloridae.*

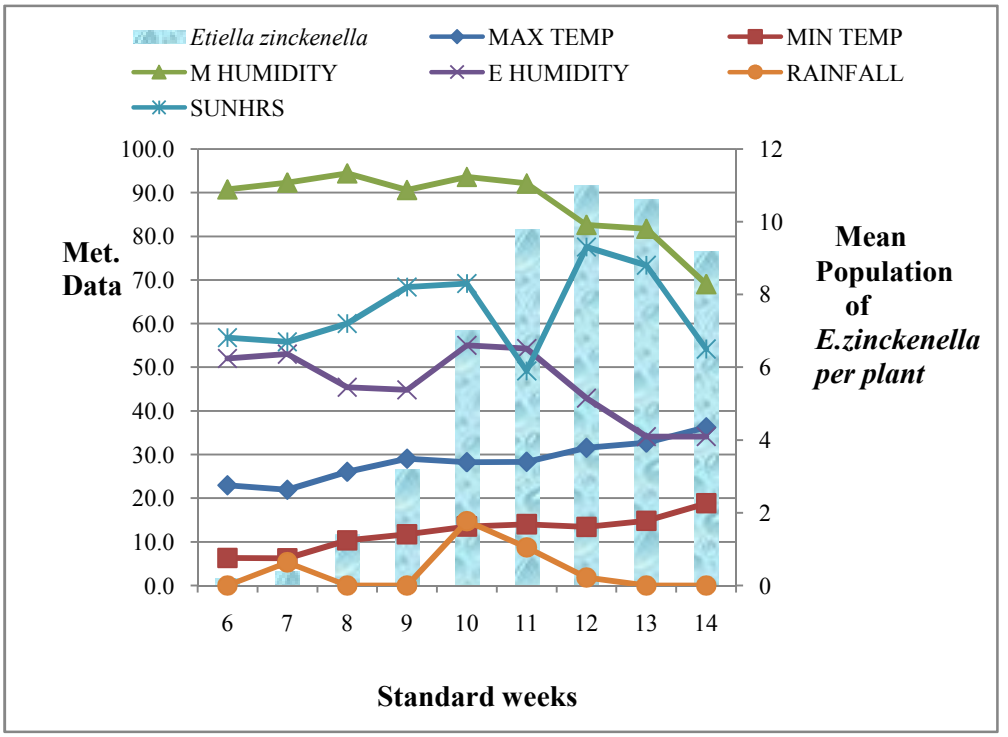


Figure 2: Correlation between weather parameters and *Etiella zinckenella* population.

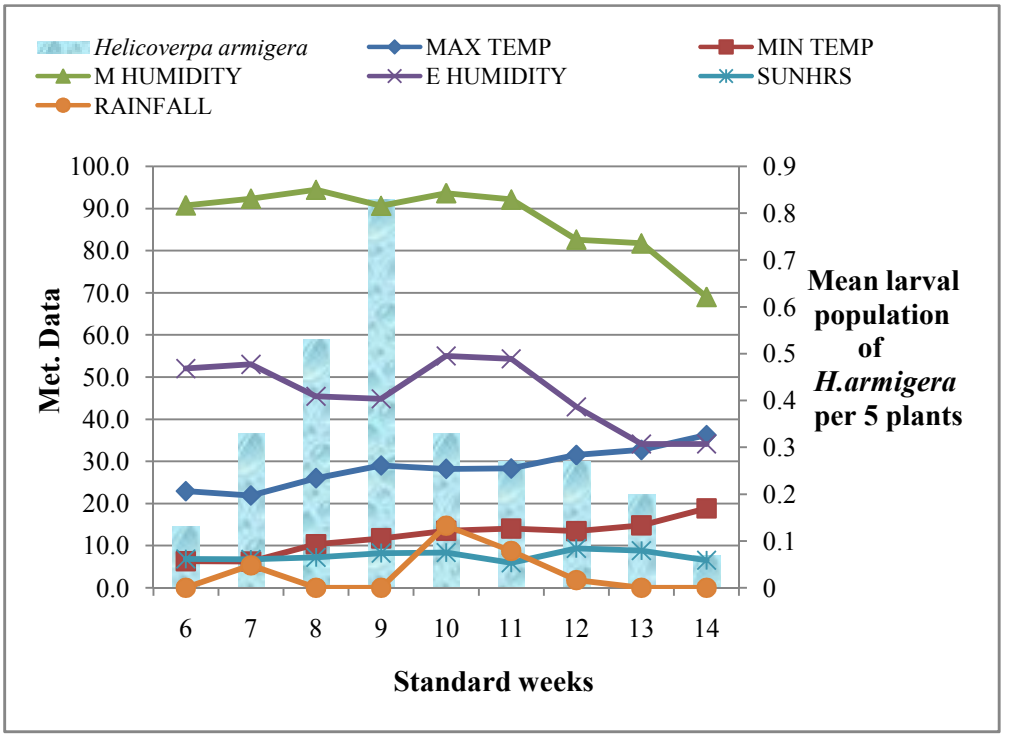


Figure 3: Correlation between weather parameters and *Helicoverpa armigera* population.

4.3.3 Multiple Regression Analysis between pest population and abiotic factors

The multiple regression analysis, which explained the average relationship between *Aphis craccivora* and weather parameter *i.e*. the amount of changes in *Aphis craccivora* population per unit change in weather parameters, indicated that there was significant 81% (regression equation Y1) contribution of these factors (R^2 = 0.81) for variability in *Aphis craccivora* population (Table 19).

Out of 81% variability in *Aphis craccivora* population due to various abiotic factors, temperature (maximum) and temperature (minimum) accounted for 39 % variability,and these were the most important factors affecting *Aphis craccivora* abundance.

The multiple regression analysis, which explained the average relationship between *Etiella zinckenella* and weather parameter *i.e*. the amount of changes in *Etiella zinckenella* population per unit change in weather parameters, indicated that there was significant 80% (regression equation Y3) contribution of these factors (R^2 = 0.80) for variability in *Etiella zinckenella* population (Table 19).

Table 19: Multiple regression analysis between pest population and abiotic factors on lentil

Insect	Regression equations	R^2
Aphis craccivora	Y1= 571.23-12.88 X1+0.58X2-0.51X3-4.24 X4+5.01 X5+2.97X6	0.81
Helicoverpa armigera	Y2= -11.02+0.37 X1-0.31 X2+0.08 X3-0.01 X4-0.21 X5+0.03X6	0.66
Etiella zinckenella	Y3= -42.53+1.53X1-0.50 X2+0.02 X3+0.15 X4+0.18 X5+0.25 X6	0.80

*significant factors

X1 = Temperature (maximum), X2 = Temperature (minimum), X3 = Relative humidity (morning), X4 = Relative humidity (evening), X5 = Sun shine hours, X6 = Rainfall (mm)

Out of 80% variability in *Etiella zinckenella* population due to various abiotic factors, temperature (maximum) and temperature (minimum) accounted for 72 % variability, and these were the most important factors affecting *Etiella zinckenella* abundance.

The multiple regression analysis, which explained the average relationship between *Helicoverpa armigera* and weather parameter *i.e*. the amount of changes in *Helicoverpa armigera* population per unit change in weather parameters, indicated that there was 66% (regression equation Y2) contribution of these factors (R^2 = 0.80) for variability in *Helicoverpa armigera* population (Table 19).

CHAPTER-V

DISCUSSION

The results obtained from the investigations carried on "Studies on biology of *Etiella zinckenella* Treiteischke on lentil and evaluation of lentil genotypes against this pest" are discussed in this chapter under the following headings:

5.1 Biology of lentil pod borer, *Etiella zinckenella* Treit.

5.1.1 Pre-oviposition period, Oviposition period and Post oviposition period

5.1.2 Fecundity and adult longevity of *Etiella zinckenella*

5.1.3 Incubation period and per cent hatchability

5.1.4 Larval period

5.1.5 Pre-pupal and pupal period

5.1.6 Per cent adult emergence

5.1.7 Sex Ratio

5.1.8 Mating period

5.1.9 Total life cycle

5.1.10 Measurements of different developmental stages

5.2 Evaluation of lentil genotypes against *E. zinckenella*

5.2.1 Screening of lentil genotypes against *E. zinckenella*

5.2.2 Correlation of morphological parameters of lentil genotypes with the incidence of *Etiella zinckenella*

5.3 Population dynamics of major insect pests of lentil

5.1 Biology of lentil pod borer, *Etiella zinckenella* Treit.

5.1.1 Pre-oviposition period, Oviposition period and Post oviposition period

The pre-oviposition period ranged from 1 to 2 days (average 1.3 days). The oviposition period varied from 2 to 3 days (average 2.3 days) and post oviposition period varied from 1 to 2 days (average 1.4 days). Abul-Nasr and Awadalla (1957) and Hattori and Sato (1983a) reported that pre-oviposition period ranged from 2 to 5 and 1 to 9 days, respectively hence support the present investigations. Jaglan *et al.* (1996) reported that the oviposition and post oviposition periods varied from 2-3 days and 1-2 days, respectively on lentil which are in conformity with the present investigation.

5.1.2 Fecundity and adult longevity of *Etiella zinckenella*

A single female could lay 46 to 65 eggs (average 56.3 eggs) during her total life time. None of the females deposited any egg on the first day of emergence, *i.e* all females started

ovipositing one day after emergence. Abul-Nasr and Awadalla (1957) reported 47 to 178 eggs per female which are in conformity with this investigation. The data pertaining to adult longevity of *Etiella zinckenella* reveals that longevity of male moths varied from 3 to 5 days (average 4.1 days) and longevity of female moths varied from 5 to 6 days (average 5.6 days). Hence males are short lived than females. Naito (1961) reported the adult longevity at 30 ^{0}C temperature as 5.7 days which supports the present investigation. Singh and Dhooria (1971) also reported the longevity of adults 5.2 days on lentil and 7.42 days on pea, respectively which is in close agreement with present investigation.

5.1.3 Incubation period and per cent hatchability

The incubation period ranged from 5.18 to 5.38 days (average 5.24 days). These studies are in agreement with the findings of Cheu (1943), Singh and Dhooria (1971) and Popova (1957) also observed incubation period of 4 to 6 days, 5.3 days and 3 to 16 days, respectively. Data pertaining to per cent hatchability indicate that it varied from 74 to 92 days (average 81.6 days).The present results are in agreement to the findings of Singh and Dhooria (1971) who reported that egg viability on an average 92.8 per cent. Stone (1965) and Bindra and Singh (1969) who observed egg hatchability of 69 and 70 per cent, respectively also give partial support to the present investigation.

5.1.4 Larval period

The larvae passed through five instars before entering pupal stage. Newly hatched larva was tiny, yellowish in colour with with black shinning head. First instar larvae lasted for 1 to 2 days (average 1.53 days) and second instar larvae were creamish to brownish in colour and blackish head, which remained for 2 to 3 days (average 2.6 days) to become third instar. The third instar larvae were much longer than preceding instars and took 3 to 4 days (average 3.5 days). Fourth instar was having yellowish head with black spots on vertex and lasted for 3 to 4 days (average 3.7 days). Fifth instar was pink in colour with yellowish head. Each thoracic leg of larva was five segmented and the abdominal prolegs were present on third to sixth and tenth abdominal segments and it remained for 5 to 6 days (average 5.5 days). The total larval period ranged from 15 to 19 days (average 16.9 days). The first instar completed its stage comparatively in shorter period than rest of the instars. Morphological features investigated in the present studies are in corborration with the findings of Cheu (1943), Abul-Nasr and Awadalla (1957), Kakoty (1968) who reported larval period of *E. zinckenella* on different host plants as 11, 10 to 17, and 15 to 23 days, respectively.

5.1.5 Pre-pupal and pupal period

The average pre-pupal period ranged from 1.9 to 2.3 days (average 2.04 days). Observations on pre-pupal period coincides with Abul –Nasr and Awadalla (1957) and Singh and Dhooria (1971) who observed that pre-pupal period was 2 days and 2 to 4 days, respectively and data in table revealed that average pupal period varied from 12.7 days to 13.9

days (average 13.38 days) which was in confirmation with Kakoty (1968) who reported that pupal period ranged from 10 to 13 days in March under laboratory conditions.

5.1.6 Per cent adult emergence

The per cent adult emergence ranged from 80 to 100 per cent (average 88 per cent). The present studies are in agreement with the findings of Abul-Nasr and Awadalla (1957) who reported that per cent adult emergence was 50 to 100 per cent. Singh and Dhooria (1971) also recorded 79.17 per cent adult emergence on lentil and 100 per cent on pea also support the present investigation.

5.1.7 Sex Ratio

Males outnumbered the females. The average percentage of males and females was 56.7 and 43.3, respectively. Average female to male ratio was 1.0 to 1.4.The present investigation derive support from Abul-Nasr and Awadalla (1957) who also observed that the males outnumbered the females as they constituted 53 per cent of population. Singh and Dhooria (1971) also observed 54.4 per cent of emerged moths as males and support the present investigation.

5.1.8 Mating period

The mating period of *Etiella zinckenella* varied from 43 to 63 minutes (average 51.5 minutes). It was observed that that most of the adults paired on first night after emergence and remaining did on second night. The unmated females did not lay any egg. The present studies are in agreement with the studies of Abul –Nasr and Awadalla (1957) and Stone (1965).

5.1.9 Total life cycle

The life cycle of this insect ranged from 37 to 45 days (average 40.9 days). Singh and Dhooria (1971) observed that the *E. zinckenella* completes its life cycle in average (45.84 days), which is in close agreement with the present investigation.

5.1.10 Measurements of different developmental stages

5.1.10 (a) Egg

The freshly laid eggs of *E.zinckenella* were whitish in colour which changed to orange colour before hatching. They were oval in shape. Length of egg ranged from 0.47 to 0.57 mm (average 0.51 mm) and width of egg ranged from 0.30 to 0.40 mm (average 0.35 mm) (Table 10). Abul Nasr and Awadalla (1957) observed the size of egg as 0.6 to 0.7 mm in length and 0.30 to 0.45 mm in width while Singh and Dhooria (1971) reported average length and width as 0.51 mm and 0.34 mm, respectively. So, the present findings are in agreement with those of above authors.

5.1.10 (b) Larva

First instar larvae when reared on lentil pods ranged from 0.85 to 0.95 mm in length (average 0.89 mm) and 0.12 to 0.17 mm in width (average 0.15 mm). Second and third instars ranged from 2.67 to 2.98 mm (average 2.83 mm), and 6.14 to 6.33 mm (average 6.22 mm) in

length and 0.70 to 0.87 mm (average 0.78 mm) and 1.43 to 1.56 mm (average 1.49 mm) in width , respectively. Fourth larval instar ranged from 11.24 to 11.34 mm (average 11.29 mm) in length and 2.14 to 2.25 mm (average 2.21 mm) in width. Fifth instar ranged from 15.28 to 15.38 mm (average 15.33 mm) in length and 2.84 to 2.92 mm (average 2.89 mm) in width. The present findings on size of instars are in accordance with that of Singh and Dhooria (1971) who reported first instar was on an average 0.87 mm in length and 0.13 mm in width whereas, full grown larva measured 15.25 mm in length and 2.93 mm in width. Head capsule width of 1^{st},2^{nd},3^{rd},4^{th} and 5^{th} instar when reared on lentil variety Garima ranged 0.08 to 0.12 mm (average 0.10 mm), 0.45 to 0.53mm (average 0.50 mm), 0.77 to 0.89 mm(average 0.82 mm), 0.89 to 0.98 mm (average 0.94 mm) and 1.17 to 1.23 mm (average 1.20 mm), respectively.

5.1.10 (c) Pupa

The pupa of *E. zinckenella* was of obtect type. The freshly formed pupa was greenish in colour which changed to brownish after 6-7 hours. Before one to two days of adult emergence, pupae became dark brown in colour. Length of male pupae ranged from 8.72 to 9.14 mm (average 8.80 mm) and in case of female pupae it ranged from 8.61 to 8.97 mm (average 8.74 mm). Width of male pupae ranged from 2.48 to 2.77 mm (average 2.67 mm) and in case of female pupae it ranged from 2.51 to 2.84 (average 2.61 mm). The present investigations with respect to size and colour of pupa are in agreement with Singh and Dhooria (1971) who reported that pupa was 8.64 mm in length and 2.79 mm in width. The pupal colour changed from greenish to brown and finally to dark colour before adult emergence. Weight of male pupae ranged from 0.036 to 0.051 g (average 0.042 g) and weight of female pupae ranged from 0.037 to 0.044 g (average 0.040 g).

5.1.10 (d) Adult

The male and female moths were greyish in colour. The female moths were slightly smaller than male moths. The compound eyes were prominent and were bigger in males with more ocular distance than female moths. The forewings were longer and narrower than the hind wings which were hyaline and provided with long hairs at their inner margins. There was a white band along the costal margin of each forewing. The male moths ranged 11.56 to 12.52 mm (average 12.20 mm) in length and 21.92 to 22.29 mm (average 22.09 mm) in width.The female moths ranged from 10.78 to 11.48 mm(average 11.34 mm) and 20.79 to 21.23 mm (average 21.13 mm) in width. The present findings are in agreement with that of Singh and Dhooria (1971) who observed female moth measuring 20.08 mm in wing expanse and 11.4 mm in length and a white stripe was present on the forewing along the costal margin and adults were grayish in colour and sexes were distinguished on the basis of structure of antennae.

5.2 Evaluation of lentil genotypes against *E. zinckenella*

5.2.1 Screening of lentil genotypes against *E. zinckenella* at green pod stage and maturity of crop.

Data reveals that out of twenty genotypes screened under field conditions against *Etiella zinckenella,* pod infestation ranged from 2.0 to 12.0 per cent at green pod stage The genotypes FLIPILL 6089 and L 4096 were found to be least infested having 2.0 per cent pod damage and were statistically at par with LL 1136, RKL 608-1, RKL 1-32, RKL 1003-33D, IL 2010-75L, HM-1, having 3.3, 2.7, 2.7, 4.0, 2.3 and 3.3 per cent pod damage, respectively. Maximum pod infestation (12.0 per cent) was observed in the genotypes JL 3 and PL 105 which was statistically at par with Garima, Sapna, RKL 23C-274, RKL 45-10,IPL 406 and DPL 62 having 9.7, 8.7, 9.3,10.0, 11.3, 8.7, and 12.0 per cent pod damage, respectively. Genotypes IPL 315, IPL 81, PRECOZ, FLIPILL 6089 and LH 07-26 were intermediate in their reaction to pest infestation. At harvesting stage of the crop, 50 pods were plucked from randomly from each genotype and per cent pod damage was calculated. Pod infestation of lentil genotypes ranged from 4.0 to 24.0 per cent at mature pod stage. The genotype RKL 1-32 was found to be least susceptible having 4.0 per cent pod damage and it was statistically at par with genotypes RKL 608-1, FLIPILL 6089, RKL 1003-33D and L 4096LL 1136 having 5.3, 4.7, 6.0 and 4.7 per cent pod damage , respectively. Maximum pod infestation was observed in genotype IPL 406 (24.0 Per cent) which was statistically at par with JL 3, RKL 45-10 and PL105 having 22.7,20.0 and 18.7 per cent pod damage, respectively. The remaining genotypes i.e LL 1136, DPL 62, IPL 315, IPL 81, PRECOZ, IL 2010-75L, RKL 23C-274, Sapna, Garima, HM-1 and LH 07-26 were intermediate in their reaction to pest infestation.

Pest susceptibility rating (PSR) was also worked out at maturity of crop, keeping lentil variety Garima as a check. PSR against *E. zinckenella* varied from 2 to 9. Seven genotypes were categorized as least susceptible having PSR rating 2 to 3, nine genotypes were categorized as moderately susceptible having PSR rating 4 to 6 and four genotypes having PSR rating 7 to 9 were indicated as highly susceptible. Kooner *et al.*(1978) recorded the relative susceptibility of lentil cultivars to borer incidence. Out of 809 cultivars screened , 84 seemed to be promising which were found having less than 10 per cent infestation as against 82.2 per cent. Kooner *et al.* (1977) reported the infestation of pods by this pest ranged from 3.5 to 9 per cent. Jaglan *et al*. (1993) screened 79 genotypes of lentil against *Etiella zinckenella*. revealed that genotype LH 90-39 was having minimum pod infestation (4.1%) and maximum pod infestation was observed in DPL 26 (17.5%). Dashad *et al*. (2005) evaluated the response of small seeded lentil cultivars with varying maturity periods (18 short,

19 medium and 13 long duration genotypes) to infestation by *E. zinckenella* and reported higher larval population in short duration genotypes (7.18 larvae/plant), compared to medium and long duration genotypes (6.94 and 6.55 larvae/plant). Kooner *et al*. (2006) conducted an experiment on screening of lentil germplasm against pod borer, *Etiella zinckenella* and found that entry LL 699 had least pod damage followed by LL 874 and LL 885. So, the present investigation is in accordance with the above authors.

5.2.2 Correlation of morphological parameters of lentil genotypes with the incidence of *Etiella zinckenella*

Different morphological characters of different genotypes *viz.,* days to 50% flowering, pod length, number of grains per pods, pod wall thickness, trichome density, and days to maturity, were recorded and correlated with per cent pod damage.

Pod length

Maximum pod length was recorded in IPL 406 (14.42 mm) and it was statistically at par with genotypes RKL 45-10 (14.08 mm), RKL 1003-33D (14.11 mm) and PL 105 (14.17 mm).Minimum pod length was recorded in FLIPILL 6089 (12.11 mm) and it was statistically at par with genotype LL 1136 (12.14 mm), DPL 62 (12.31 mm), IPL 81 (12.63 mm), PRECOZ (12.42 mm), RKL 608-1(12.42 mm), RKL 1-32 (12.69 mm), RKL 23C-274(12.70) and HM-1(12.45 mm) .The data revealed that there was positive and significant correlation between pod length and green (r= 0.5144*) as well as mature damaged pods (r=0.5479*). and this might be because of big sized pods of lentil provide large surface for larval infestation and sufficient nutrition for the larval growth.

5.3 Population dynamics of major insect pests of lentil

Population (nymph & adult) of the aphid was recorded on the crop from 1st to 13th meteorological standard weeks (SW) after which there was no activity of this pest. The population of *Aphis craccivora* appeared in the 1st standard week (1.74 aphids/5 plants) with rise in minimum temperature. Peak activity of pest was recorded during 7th SW with a population of 78.0 aphids/ 5 plants when the maximum temperature was 21.9 ^{o}C and min. temp.6.2 ^{o}C, relative humidity morning- 92.3% and evening-53%, sunshine hours was 6.7 hrs and rainfall was 5.3 mm. The population remained 13.07aphids /5 plants during the 11th to 13th SW. There was significant negative correlation of aphid population with the Temperature (Tmax. & Tmin.), (r = -0.5015** and r = -0.6138*, respectively). Relative humidity Morning, relative humidity Evening, Sun shine hours and rainfall had non-significant correlation with *Aphis craccivora* population. These findings are in accordance with the studies of Bijjur and verma (1995) who reported that with rise in temperature population showed a decreasing trend in both years and was supported by negative correlation studies between aphid population and mean maximum temperature (-0.652). These studies are also in corroboration with the findings of Prasad *et al*. (2008) who reported that minimum temperature showed

significant negative correlation during *rabi* season. These studies are also in accordance with the findings of Kumar and Kumar (2015) who reported populations of aphids influenced positively by relative humidity. These studies are also in accordance with the findings of Tambe and Kadam (2015) who reported average number of cowpea aphid per tiller showed highly significant negative correlation with minimum temperature However, cowpea aphid showed significant negative correlation with maximum temperature.

Larval population of *Helicoverpa armigera* was recorded from 6th to 14th meteorological standard weeks (SW). Larval population of *Helicoverpa armigera* appeared in 6th standard week with onset of flowering and pods. Peak of *Helicoverpa armigera* population was found during 9th SW with a population of 0.83 larvae / 5plant when the temperature (max.) was 29 ^{o}C and min. temp.11.7 ^{o}C, relative humidity morning- 90.6% and evening-44.8%, sunshine hours was 8.2 hrs and there was no rainfall. Correlation of *Helicoverpa armigera* population with various environmental factors revealed that *Helicoverpa armigera* population had non- significant correlation with Temperature (Tmax. & Tmin.) Relative humidity (%) Evening, Sun shine hours and Rainfall and was positively associated with relative humidity (%) morning. These studies are more or less in agreement with the findings of Chatar *et al.* (2010) who reported the pest population declined gradually towards the maturity of the crop. Correlation of *H. armigera* with different weather parameters indicated that maximum temperature exhibited negative correlation with larval population of *H. armigera*, However, the pest population showed highly significant positive correlation with morning relative humidity (r= 0.7098), evening relative humidity (r= 0.7293) and mean relative humidity (r= 0.8063).

Etiella zinckenella (larvae+ faecal material) were recorded from 6th to 14th meteorological standard weeks (SW). *Etiella zinckenella* appeared in 6th standard week with onset of flowering and pods. Peak of *Etiella zinckenella* population was found during 12th SW with a population of 11 (larvae+ faecal material)/ plant when the temperature (max.) was 31.5 ^{o} C and min. temp.13.4 ^{o} C, relative humidity morning- 82.6% and evening-42.9%,sunshine hours was 9.3 hrs and rainfall was 1.8 mm.Correlation of *Etiella zinckenella* population with various environmental factors revealed that *Etiella zinckenella* population had significant positive correlation both with Temperature (Tmax. & Tmin.), (r = 0.8251*and r = 0.8481* respectively) Relative humidity (%) Morning, Relative humidity (%) Evening, Sun shine hours and rainfall had non-significant correlation with *Etiella zinckenella* population. But, the present studies do not comply with the findings of Dhaka *et al.* (2011) who observed negative and significant correlation of *E. zinckenella* population with both maximum and minimum temperature and this might be due to climatic variation during the period of investigation.

CHAPTER - VI

SUMMARY AND CONCLUSION

The present studies entitled "Studies on biology of *Etiella zinckenella* Treiteischke on lentil and evaluation of various genotypes of lentil against this pest" was carried out during *rabi* season 2015 at Research farm of Pulses Section, Department of Genetics and Plant Breeding and Laboratory of Department of Entomology, CCS HAU, Hisar. For carrying out these investigations three experiments were conducted *viz.,* Biology of lentil pod borer, Screening of lentil genotypes against incidence of lentil pod borer and population dynamics of major insects pest of lentil.

For conducting biological studies, rearing was done in laboratory at 28±1^{0}C and relative humidity (60-70%). To maintain the culture, a large number of larvae of *E. zinckenella* were collected from infected pods of fieldpea and lentil and were kept in separate battery jars. Results revealed that pre-oviposition, oviposition, post-oviposition period ranged from 1 to 2, 2 to 3 and 1 to 2 days, respectively. Moths oviposited during night and a very few during day. Eggs were laid singly on lentil leaves and pods and were whitish and oval in shape. A single female could lay maximum of 65 eggs and minimum of 45eggs (average 56.3 eggs) during her life time. On lentil, the longevity of male moths was ranged from 3 to 5 days (average 4.1 days) and longevity of female moths varied from 5 to 6 days (average 5.6 days). Incubation period varied from 5.18 to 5.38 days (average 5.24 days). The total larval period ranged from 15 to 19 days (average 16.9 days). Average Pre-pupal period ranged from 1.9 to 2.3 days (average 2.04 days) and pupal period ranged from 12.7 to 13.9 days (average13.38 days). Forty four freshly emerged adults of *Etiella zinckenella* were observed for the determination of sex ratio. Results indicated that males outnumbered the females. The average number of males and females were 56.7 and 43.3, respectively. Average female to male sex ratio was 1.0 to 1.4. It was found that the mating of adults of *Etiella zinckenella* occurred in night or early hours in the morning. Mating period of *E. zinckenella* varied from 43 to 63 minutes (average 51.5 minutes). Results revealed that the total life cycle varied from 37 to 45 days (average 40.9 days). Morphometric studies on *Etiella zinckenella* revealed that the eggs measured 0.47 to 0.57 mm in length (average 0.51 mm) and 0.30 to 0.40 mm in width (average 0.35mm). Average body lengths of 1st, 2nd, 3rd, 4th and 5th instar larvae were 0.89, 2.83, 6.22, 11.29 and 15.33 mm and average body width of 1st, 2nd, 3rd, 4th and 5th instar larvae were 0.15, 0.78, 1.49, 2.21and 2.89 mm. Average head capsule width of 1st, 2nd, 3rd, 4th and 5th instar larvae were 0.10, 0.50, 0.82, 0.94 and 1.20 mm. On an average, male pupa measured 8.80 mm in length and measured 2.67 mm in width and female pupa measured 8.74 mm in

length and measured 2.61 mm in width. On an average male pupa weighted 0.042 g and female pupa was of 0.040 g. On an average, the males were 12.20 mm in length and 22.09 mm in width and female moths ranged from 10.78 to 11.48 mm (average 11.34 mm) in length and 20.79 to 21.23 mm (average 21.13 mm) in width.

Data on screening of lentil genotypes against *Etiella zinckenella* revealed that out of 20 lentil genotypes none was found completely free from the damage of *Etiella zinckenella*. Of the 20 genotypes screened against *Etiella zinckenella* at green pod stage, the infestation ranged from 2.0 to 4.0 per cent, whereas at maturity it varied from 4.0 to 24.0 per cent in different genotypes. Pest Susceptiblity Rating ranged from 2 to 8 at green as well as mature pod stage. Screening at maturity stage indicated that 7 genotypes *viz.,* LL 1136, IPL 315, RKL 608-1, FLIPILL 6089, RKL 1-32, RKL 1003-33D, L 4096 were characterized as least susceptible, 9 genotypes *viz.,* DPL 62, PRECOZ, IL 2010-75L, RKL 23C-274, Sapna, Garima, LH 07-26, HM-1, IPL81 were characterized as moderately susceptible and 4 genotypes *viz.,* JL 3, IPL 406, PL 105, RKL 45-10 were characterized as highly susceptible.

Morphological characters of the genotypes i.e. 50 per cent flowering, number of grains/ pod, pod wall thickness, pod length and days to maturity were evaluated. Days to 50 per cent flowering revealed that there was significant difference in different genotypes and it ranged from 69 to 101 days. Genotype JL3 flowered earliest in 69 days. Late flowering was recorded in genotype LL 1136 in 101 days. Minimum number of grains was recorded in RKL 23C-274 (1.3 seeds/ pod). Maximum number of grains was recorded in JL 3, FLIPILL 6089, Sapna, HM-1(2 seeds/ pod). Minimum pod wall thickness was recorded in IL 2010-75L (0.24 mm) and maximum pod wall thickness was recorded in LL 1136 (0.36 mm) and PL105 (0.36 mm). Genotype RKL 23C-274 (121 days), matured earliest. Maximum day to maturity was recorded in LL 1136(140 days). The data revealed that there was not significant correlation between 50 per cent flowering, number of grains/ pod, pod wall thickness and days to maturity with green as well as mature damaged pods. Maximum pod length was recorded in IPL 406 (14.42 mm) and Minimum pod length was recorded in FLIPILL 6089 (12.11 mm). The data revealed that there was positive and significant correlation between pod length and green (0.5144*) as well as mature damaged pods (r=0.5479*).

For population dynamics studies lentil crop was sown on 16th of November, 2015 in the field measuring 15 × 15 m^2 area. The crop was raised as per recommended agronomical practices but without insecticidal spray. Visual observations of *Aphis craccivora* were recored per five plants after selecting middle twigs of each plant and nymph as well as adult population was counted from each twig by using hand lens. Population (nymph & adult) of the aphid was recorded on the crop from 1st to 13th meteorological standard weeks (SW) after which there was no activity of pest. The population of *Aphis craccivora* appeared in the 1st standard week (1.74 aphids/5 plants) with rise in minimum temperature. Peak activity of pest

was recorded during 7th SW with a population of 78.0 aphids/ 5 plants. There was significant negative correlation of aphid population with both the Temperature (Tmax. & Tmin.), and Relative humidity (%) Morning, Relative humidity (%) Evening, Sun shine hours and rainfall had non-significant correlation with *Aphis craccivora* population.

Larval population of *H. armigera* was recorded by ground sheet method after selecting five plants randomly at each spot. Total fifteen observations were recorded after selecting fifteen spots. Larval population of *Helicoverpa armigera* appeared in 6th standard week with onset of flowering and pods. Peak of *Helicoverpa armigera* population was found during 9th SW with a population of 0.83 larvae / 5plant. Correlation of *Helicoverpa armigera* population with various environmental factors revealed that *Helicoverpa armigera* population had non- significant correlation with Temperature (Tmax. & Tmin.),) Relative humidity (%) Evening, Sun shine hours and Rainfall and was positively associated with Relative humidity (%) Morning. For *E. zinckenella* five plants were selected randomly and all the pods were plucked and larval population was counted after disecting the pods. At maturity, the pods having the faecal material of *E. zinckenella* were considered as infested pods. Population of *Etiella zinckenella* (larvae + faecal material) was recorded from 6th to 14th meteorological standard weeks (SW). Peak of *Etiella zinckenella* population was found during 12th SW with a population of 11 (larvae+ faecal material)/ plant. *Etiella zinckenella* population had significant positive correlation both with Temperature (Tmax. & Tmin.), and Relative humidity (%) Morning, Relative humidity (%) Evening, Sun shine hours and rainfall had non-significant correlation with *Etiella zinckenella* population.

On the basis of results it is concluded that insect laid eggs singly and number of eggs laid per female were 45 to 65. There was five larval instars and total larval period varied from 15 to 19 days. There was a difference in sex ratio, being in favour of males. The lentil pod borer completed its life cycle in 37 to 45 days and the pest completed multiple generations in a year. Out of 20 lentil genotypes none was found completely free from the damage of *Etiella zinckenella*. Of the 20 genotypes screened against *Etiella zinckenella* 7 genotypes *viz.,* LL 1136, IPL 315, RKL 608-1, FLIPILL 6089, RKL 1-32, RKL 1003-33D, L 4096 were characterized as least susceptible, 9 genotypes *viz.,* DPL 62, PRECOZ, IL 2010-75L, RKL 23C-274, Sapna, Garima, LH 07-26, HM-1, IPL81 were characterized as moderately susceptible and 4 genotypes *viz.,* JL 3, IPL 406, PL 105, RKL 45-10 were characterized as highly susceptible. Positive and significant correlation between pod length and pod damage at both green & mature pod stage was observed. Population dynamics studies revealed significant negative correlation of aphid population with the Temperature (Tmax. & Tmin.), significant positive correlation of *E. zinckenella* with the Temperature (Tmax. & Tmin.) and non significant correlation of *H. armigera* population with the abiotic factors.

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Appendix-1

Meteorological Data of Hisar from November, 2016 to April, 2016.

SW	MAXIMUM TEMPERATURE	MINIMUM TEMPERATURE	MORNING HUMIDITY	EVENING HUMIDITY	SUNSHINE HOURS	RAINFALL (mm)
45	28.3	15.3	93.6	40.9	2.8	0.0
46	29.1	12.8	85.9	36.3	7.5	0.0
47	27.7	9.0	90.6	36.1	7.7	0.0
48	25.3	9.5	95.1	50.1	4.2	0.0
49	25.5	8.8	97.3	51.4	5.5	0.0
50	21.4	7.1	94.6	45.3	5.2	0.0
51	20.6	3.5	98.1	44.0	6.2	0.0
52	21.3	4.0	93.0	42.0	6.4	0.0
1	22.7	6.4	97.3	57.9	4.9	0
2	22.4	8.4	95.1	58.6	4.9	0
3	15.3	6.1	89.7	75.3	2.2	0
4	16.4	5.5	97.4	66.3	4.2	0
5	22.1	7.1	94.7	52.6	6.2	0
6	22.9	6.3	90.7	52	6.8	0
7	21.9	6.2	92.3	53	6.7	5.3
8	26	10.3	94.4	45.4	7.2	0
9	29	11.7	90.6	44.8	8.2	0
10	28.2	13.5	93.6	55	8.3	14.7
11	28.3	14	92.1	54.3	5.9	8.7
12	31.5	13.4	82.6	42.9	9.3	1.8
13	32.7	14.8	81.7	34.1	8.8	0
14	36.2	18.8	69	34.1	6.5	0

APPENDIX-2

PEST SUSCEPTIBILITY RATING (PSR): Abott (1925)

Pest susceptibility percentage (PSP) = $\frac{\text{PD* in check genotype – PD in tested genotype}}{\text{PD in check genotype}} \times 100$

PD* = POD DAMAGE

PSR	PSP
1	100
2	75-100
3	50-75
4	25-50
5	10-25
6	-10-10
7	-25- -10
8	-50- -25
9	-50 or less

Lateef and Reed (1980)

ABSTRACT

Title of the thesis	**:**	**Studies on biology of *Etiella zinckenella* Treiteischke on lentil and evaluation of lentil genotypes against this pest**
Full name of the degree holder	**:**	**Gulshan Kumar**
Title of degree	**:**	**Master of Science**
Name and address of Major Advisor	**:**	**Dr. S. S. Yadav** Assistant Professor (Entomology) CCS Haryana Agricultural University, Hisar-125004
Degree awarding University	**:**	CCS Haryana Agricultural University, Hisar Haryana (India)
Year of award of degree	**:**	2016
Major subject	**:**	**Entomology**
Total no of pages in the thesis	**:**	**47 + iv + II**
No. of words in the abstract	**:**	**541**
Key words	**:**	Biology, *Etiella zinckenella*, lentil, population dynamics

The present studies entitled "Studies on biology of *Etiella zinckenella* Treiteischke on lentil and evaluation of various genotypes of lentil against this pest" was carried out during *rabi* season 2015 at Reseach farm of Pulses Section, Department of Genetics and Plant Breeding and Laboratory of Department of Entomology, CCS HAU, Hisar. For conducting biological studies, rearing was done in laboratory at 28±1^{0}C and relative humidity (60-70%). Results revealed that pre-oviposition, oviposition and post-oviposition period ranged from 1 to 2, 2 to 3 and 1 to 2 days, respectively. A single female laid maximum of 65 eggs and minimum of 45 eggs (average 56.3 eggs) during her life time. and eggs were whitish and oval in shape. On lentil, the longevity of male moths ranged from 3 to 5 days (average 4.1 days) and longevity of female moths varied from 5 to 6 days (average 5.6 days). Average incubation period was observed to be from 5.18 to 5.38 days (average5.24 days). The total larval period ranged from 15 to 19 days (average 16.9 days). Average Pre-pupal period ranged from 1.9 to 2.3 days (average 2.04 days) and pupal period ranged from 12.7 to 13.9 days (average13.38 days). Average female to male sex ratio was 1.0 to 1.4 and males outnumbered the females.. Mating period of *E. zinckenella* varied from 43 to 63 minutes (average 51.5 minutes). Results revealed that the total life cycle varied from 37 to 45 days (average 40.9 days). Morphometric studies on *Etiella zinckenella* revealed that the eggs measured 0.47 to 0.57 mm in length (average 0.51 mm) and 0.30 to 0.40 mm in width (average 0.35mm). Average length of 1st, 2nd, 3rd, 4th and 5th instar larvae was observed to be 0.89, 2.83, 6.22, 11.29 and 15.33 mm, respectively and average width of 1st, 2nd, 3rd, 4th and 5th instar larvae were 0.15, 0.78, 1.49, 2.21and 2.89 mm, respectively. Average head capsule width of 1st, 2nd, 3rd, 4th and 5th instar larvae were 0.10, 0.50, 0.82, 0.94 and 1.20 mm, respectively. On an average, male pupa measured 8.80 mm in length and measured 2.67 mm in width and female pupa measured 8.74 mm in length and measured 2.61 mm in width. Average length & width of the male and female moth was 12.20 mm and 22.09 mm and 11.34 mm and 21.13 mm, respectively. Out of the 20 genotypes screened against *Etiella zinckenella* at green pod stage, the infestation ranged from 2.0 to 4.0 per cent, whereas at maturity it varied from 4.0 to 24.0 per cent in different genotypes. Genotypes LL 1136, IPL 315, ,RKL 608-1, FLIPILL 6089, RKL 1-32, RKL 1003-33D, L 4096 were charactersied as least susceptible. Morphological characters of the genotypes i.e. 50 per cent flowering , number of grains/ pod, pod wall thickness, pod length and days to maturity were evaluated and correlated with per cent pod damage at green and mature pod stage. There was positive and significant correlation between pod length and pod damage at both green & mature pod stage. Population dynamics studies revealed significant negative correlation of aphid population with the Temperature (Tmax. & Tmin.), significant positive correlation of *E. zinckenella* with the Temperature (Tmax. & Tmin.) and non significant correlation of *H. armigera* population with the abiotic factors.

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