Chapter - 7

DISCUSSION

Present studies on “Histomorphology, Ecology and Biochemistry of leaf galls of *Ficus glomerata* Roxb. induced by *Pauropsylla depressa* Crawford”, although, itself are quite explanatory, yet, it demands a critical discussion with the findings of other authors related to psyllids and galls. Hence, chapter wise discussion is being given here.

*P. depressa* (Homoptera - Psyllidae) is a gallinaceous insect which infests the leaves of host plant *Ficus glomerata* Roxb. The pest *P. depressa* affects the growth of the plant by making galls on the leaves as well as reduces photosynthetic activity of such an economically important plant. Gall formation induces the changes in the morphology, histology and biochemical components of the host plant leaves. Plant galls have attracted the attention of naturalists from very early times. Mani, (1973) has described over 750 different insect galls from the Indian flora and out of them 55% of the galls are leaf galls. Singh, (2003) described gall on *Terminalia tomentosa* while, Meera, (2005) made studies on the galls of *Adena cardifolia*. They also pointed out that galls decreases the vigour of the plant.

Transverse sections of the healthy leaf, at the region of the middle vein, revealed an unstratified epidermis which is usually thicker adaxially. The cortical region is composed of lacunar collenchyma below the epidermis, both adaxially, with a greater
number of layers in the latter. The endodermis surrounds the vascular system, showing some sclerified cells. The vascular tissue is externally bordered by several layers of pericyclic fibres. The transverse section at the region of lateral veins revealed a unistratified epidermis with stomata. Stomata are present on the lower epidermis in Ficus plant. Valenzuela, (1998) also reported stomata on the lower side of the same plant. Morphology and anatomy of Richterago riparia Roque leaf were observed by Pinna, et.al., (2002). The presence of a multiple epidermis is rare and is restricted to the leaves of certain families like the Moraceae (Fig’s family and Orchid roots). Thus, two or more layers are derived from the protoderm. A good example of multiple epidermis is found in Ficus (Fig) leaves. The epidermis of Ficus is also known for crystals called cystoliths which are found in certain epidermal cells called lithocysts. The mesophyll is bilateral and there is hardly any difference between the palisade and spongy parenchyma, in Ficus plant. Same finding have also been reported by Malik, (2006). In F. glomerata , the cells of both parenchyma are slightly lobed with reduced intercellular space. Secretory cells are present only in spongy parenchyma. Almeida et.al., (2006) also reported these cells in spongy parenchyma of Vismia guianensis leaf.

Histomorphological changes in the young galled leaves of Alstonia scholaris have also been reported by Mani, (1973). Reduction in the number and size of laminar bundles in infected leaves has been reported by Rangaswami, (1975) and Agrios, (1997). Similarly, Rathore and Singh, (2001) observed undifferentiated shrunken mesophyll cells and reduction in the
vascular tissue in peach leaves infested by an aphid *Brachycaudus halichrysi*. Anatomical studies on leaf galls induced by the cecidonyiidae family (Diptera) indicate profound modifications at the cell and tissue levels, (Kraus et.al., 2003). Histologically, *P. depressa* causes changes in galls of *F. glomerata* leaves. The epidermal cells exhibit no modifications and an incompletely divided primordial chamber with the gall maker 1st instar nymph is observed in the depressed region. The palisade and spongy parenchyma are largely unmodified near to the gall chamber, but in the swelled region, the cells of spongy parenchyma contiguous to palisade parenchyma anticlinally. Sometimes, inter cellular space are present in between the spongy and palisade parenchyma tissues. Chloroplasts may still be present in the neoformed cells. The vascular bundles show modifications. Parenchyma cells also divide in the periclinal direction, separation xylem from phloem. It is interesting to note that the gall under study induced by *P. depressa* exhibit the same structural modifications during the initial development stage. In *F. glomerata* a gall provides nutrition and shelter to the inducing insect and to its progeny as well. Since, *P. depressa* instars derive their nutrition form gall tissue, the gall become a sink for different nutrients and energy that will be for the instar’s growth. Raman, (2003) reported that insects derive their nutrition from gall tissue. The larvae of the galling insects generally feed on a nutritive tissue that internally surrounds the gall chamber. Same finding is discussed by (Mondes de sa, et.al. 2009).

In the histology of mature gall of *F. glomerata*, a layer of sclerenchymatous cells develop surrounding the pear shaped gall
cavity which open through an ostiole on the ventral side of the leaf. Similar, structure has also been reported in the galls of *Alstonia scholaris* by Mani, (1973). Reduction in the number and size of laminar bundles in gall has been reported by Rangaswami, (1975) and Agrios, (1978). In *F. glomerata* spongy parenchyma cells under go to hypertrophy and hyperplasia stage, but, lateron the palisade parenchyma also undergoes to hyperplasia. , mesophyll tissue is present in form of thin layer but the parenchyma cells were thick in mature gall. Vascular bundles are scattered irregularly in the gall parenchyma tissue. Similary, Rathore and Singh, (2001) have observed undifferentiated mesophyll cells and reduction in the vascular tissue in peach leaves, infested by an *Brachycaudus halichrysi*. In *F. glomerata*, sclerenchyma layer is assumed to function as a protective mechanism against parasitoid, providing mechanical rigidity of gall tissues. In *C. langsdroffii* the nutritive tissue maintained the same characteristics either in mature gall (M G) which could be related to the maintenance of the cells high metabolic activity due to the feeding activity of the larvae, (Vechi, 2004). In M G epidermal cells were remarkably more papilose and sharper, covered with thicker cuticle at the ostiolar region. According to Arduin *et al.* (2007), in *Baccharis dracunculifolia* (Asteraceae), the dermal system of the mature gall was composed of a single layered epidermis.

In the histology of old galls of *F. glomerata*, the cells organelles like, mitochondria, chloroplasts degenerate or disappear. Protoplast also much reduced in old galled tissues. Syrop (1975) have also shown degeneration of chloroplast in
mesophyll cells of peach leaves infected by the fungus *Taphrina deformans*. Our result’s are in agreement with the observation of these authors. De Bruyn *et.al.* (1998), Fink (1999)) and Kraus *et.al.* (2002). It is interesting to note that in *F. glomerata*, the phloem in the vascular bundles is oriented closer to the larval chamber than to the xylem, which is reverse from the normal plant tissue. In cecidomyiidae galls (Weng, 2003) reported phloem in the vascular bundles in oriented closer to the larval chamber than the xylem in the enclosed type of galls.

There is a good variation in the shape, size and types of the galls induced by psyllids on various host plants. In *Ficus glomerata* Roxb. (Family - Moraceae) gall is induced by *Pauropsylla depressa* Crawford a gallinaceous insect (Homoptera - Psyllidae). These galls are spherical, globular, unilocualr or multilocular. Galls are present on the dorsal surface of the leaf and opening of the gall is on ventral side. In *F. glomerata* galls, ventral projection of gall is pointed and in case of mature gall it is having a miniaperture or lacerated opening through which the 5th instar nymph comes out for moulting. Young gall of *F. glomerata* measure, 1.5 to 2 mm. in diameter, mature gall measure, 6 – 8 mm in diameter, old gall measure, 10 – 12 mm diameter and agglomerated masses may reach up to 14 to 53 mm. in diameter.

Rahman (1932) described the gall of *P. depressa* as a pointed, sphere projection above the leaf surface. Beenson (1941) reported large bladder shaped thin walled galls of *Pnacopteran lentiginosum* on the leaves of *Garuga pinnate*. Mani (2000) recorded, cone like galls induced on the vegetative shoot apical meristems of *Mangifera indica* by *Apsylla cistellata*. Singh (2003)
reported leaf role epiphyllous inrolling of two margins towards the midrib, irregularly swollen twisted globose gall of *T. hirsute* on *T. tomentosa*. Chen (2005) reported that most psyllid galls are monolocular, only one instar develops inside the gall. *Pauropsylla triozoptera* develop conical galls on *Ficus ampelas* and *Ficus irisaria* (Moraceae). Desley (2009). Inbar et.al. (2010) regarded aphid infected galls in the mediterranean forest as cauliflower shape. Thus, shape size and types of galls produced by insects is variable on different plant species.

In *Ficus glomerata*, leaf galls induced by *P. depressa* are green in colour, which provide mechanical support for the formation of food. In winter season, green colour turns, pinkish red, due to formation of phenolic compounds which helps in trapping sun heat. Some galls may change colour during their development, especially from green to red. Galls also change colour, with the developmental stage of insect (*P. depressa*) which is present inside the gall. When 1\textsuperscript{st} and 2\textsuperscript{nd} instar nymph is present, colour of gall is green, 3\textsuperscript{rd} instar nymph, colour of gall is pale green, 4\textsuperscript{th} instar nymph, colour of gall is pale green with brownish spot and 5\textsuperscript{th} instar nymph, colour of gall is brown and finally to brownish black (when gall is empty, hard and woody). Minimum number of gall per leaf recorded as 1 and maximum as 145.

Colour in galls is due to accumulation of plant derived pigments in their tissue. For example, the red galls of wasps (cynipidae) induced on oaks contain high levels of carotenoids, (Czeczuga, 1977). Only few authors casually mentioned the nature and putative function of gall coloration. Hence, it has been suggested that the red colour of several oak wasp galls attract

Ecological studies of psyllid galls plays vital role in the control stratigies of psyllid pests and scarce information is available on this aspect regarding various psyllids. In *P. depressa* this aspect is being dicussed in relation to few other studies made on psyllids.

*P. depressa* galls occur on *Ficus glomerata* throughout the Saharanpur district and adjacent areas. On a host plant distribution of galls of *P. depressa* varies depending upon the photoperiod received by different sides and parts of the plant. Maximum galls are found in middle area of east, west and south directions. Minimum at bottom and canopy as well. In North direction minimum galls are formed, as this side gets less sunlight. Female of *P. depressa* lays eggs on the dorsal side of the leaf. After hatching first instar nymph of *P. depressa* begins sucking plant sap from the leaf at one spot. In doing so, nymph injects saliva containing growth inducing hormones and enzymes which stimulates gall formation.

Maximum infestation of *P. depressa* galls on *F. glomerata* leaves occurs in this region at Saharanpur, during August to October at the temperature ranging from 19ºc to 32ºc and relative humidity 55 to 93% R. H. Minimum infestation was observed in the months of March to June at 13ºc to 39ºc and 13 to 78% R. H. The rise in temperature and fall in R.H., effected the survival of this psyllid, although, the pest remained throughout the season but the number of galls was very less. Beeson, (1941) reported that *Psylloplecta* sp. began to form galls on *Shorea robusta* in winter which developed fully in February and adult emerge in March. In this region, at Saharanpur temperature starts increasing from March to June and in May and June temperature
reaches to peak level and R.H. remained low, which influences gall formation by *P. depressa* and number of galls decreases. During July to October, due to rains the environmental conditions become suitable for the survival of pest. Ossisanya (1974) said that, *D. eastopi* showed successively larger peaks in late January or early February, the smallest populations were in mid or late March. *D. harrisoni* showed peaks in late July or early August and late October or early November the second peak being the largest. Eggs laid by *P. depressa* in November on the leaves of *F. glomerata* undergo for diapause and hatch in mid February and begins next cycle of population. Maximum eggs of *P. depressa* occur during mid July to mid October. Higher number of eggs was seen on the ventral side of the leaf near the midrib and side veins as well as near the ventral projection of the galls. Eggs were also observed occasionally on the dorsal side of the leaf. Lee and Wen, (1980), observed that percent damage reached to peak from May to July and from October to January; egg density was highest in November, upper and lower surfaces respectively in *Pauropsylla nigra*. Yasuda and Trusumachi (1988) observed that in *Leucaena* psyllid, *Heteropsylla cubana* between late July and the end of September, the population decreased possibly due to high temperatures which are unsuitable for reproduction. In *P. depressa* galls, during November to February as the temperature decreased, number of galls also decreased. Only older galls were seen on the leaves during winter. Mohammed and Sheet (1989) said that, *Agonoscena targionii* galls occurred between second week of May and forth week of October with peak abundance during the forth week of September. Vilajeliu et.al. (1998) observed in *Cacopsyolla pyri* that the greatest populations of pear psylla were reached in June and in
October and lowest during winter months. Souliotis and Tsougianni, (2000) studied the population dynamics of some psyllid in two pistachio orchards in Greece. He mentioned that Agonoscena pistaciae increase rapidly from mid August onwards, Singh, (2003) studied the seasonal cycle of Trioza hirsute, and said that gall formation in this psyllid begins in late April with the appearance of new foliage on host plant T. tomentosa. Gall formation increases from late June onward. In rainy months there is an increase in nymphal density and adult population. Maximum instars occur during July to October, while adults are found from June to late November. No adults or nymphs are found during late December to mid April. In P. depressa galls are reduced during unfavourable condition (winter months, November to mid February). Longevity of adults increased from 1 to 4 days to 1 to 12 days in winter. Goncalves et.al. (2009) noted a unique seasonal cycle in a leaf gall of Rollinia laurifolia by Pseudotectococus rolliniae and said that due to leaf fall, gall shifted to stem in dry season for dormancy. Pranual et.al. (2010) recorded seasonal variation of black fly (Diptera – Simuliidae). Thus, seasonal cycle in different psyllids is variable and climate dependent.

Ecological parameters, temperature and R.H are two important abiotic factors which influence the insect population built up. Temperature plays a vital role in the development of nymphal stages of P. depressa within the gall and survival of adults. Lower lethal temperature for the adults of P. depressa is observed as 0ºc. Maximum infestation occurs at the temperature ranging from 19ºc to 32ºc and minimum at 13ºc to 39ºc. Maximum survivability of P. depressa was recorded at 25ºc. Yasuda and Trusumachi (1988) observed that growth period of luecaena psyllid Heteropsylla cubana
was prolonged at temperature > 28ºc and the emergence rate was decreased at 30ºc.

Al-Marouf (1990) suggested that egg and nymphal populations were significantly positively correlated with temperature and negatively with relative humidity. In *F. glomerata* when the temperature is low, the gall formation decreases but at slight high temperature gall formation increases. Patil *et al.* (1994) observed in *Heteropsylla cubana* that 25ºc and 84% R.H did not effect egg hatching, nymphal survival and adult emergence. Kato *et al.* (1999) mentioned maximum survival of *Psylla* sp. at 70 ± 10% R.H in laboratory. In case of *P. depressa* galls, optimum temperature was recorded as 25ºc and R.H 70%. Sahu and Mandal, (1999) suggested that high temperature and low R.H during premonsoon months and heavy monsoon showers had detrimental effect on pest activity. Singh, (2003) noticed the maximum survival of *T. hirsute* at 70 – 90% R.H. Thus, there is a variation of R.H levels at which maximum survival of psyllids occur. Dhiman and Arora, (2004) also reported similar affect of temperature and R.H on galls developed on the leaves induced by *P. depressa*. According to Radjabi, (2008) temperature is the best indicator for explaining defferences observed among locations. The typical effect of temperature on insect developmental rate follows a sigmoid pattern. In *P. depressa*, temperature has direct effect on the adults and indirect through gall wall on the nymphs. In field, minimum temperature 18 – 25ºc occurs during November to February. At this temperature range due to poikelothermal nature of the *P. depressa*, adults hibernate and eggs under go for diapause, when temperature begins to rise from March onward, diapause of eggs ii broken and adults come out of their hide

Galls are formed by insect feeding or egg laying activity. Either mechanical damage or salivary secretions (introduced by insects) initiate increased production of normal plant growth hormones. These plant hormones cause localized plant growth that can result in increases in cell size (Hypertrophy) and cell number (Hyperplasia) cells, tissues or organs of plants. *P. depressa*, gall formation makes the leaves; unfit to be used as fodder for cattle and cultivation of the lac. Moreover, galls affect the vegetative growth of the plant as these reduces the photosynthetic areas of plant. In severe infestation distortion of leaves occur and plant growth is also stunted

Gerling *et.al.* (1976) suggested that most of the galls did not cause appreciable damage to the general health of the plants, but growth stunting resulted from stobilus galls made by *Psectrosema* sp. Lee and Wen, (1980) reported that in *Pauropsylla nigra* nymphs damaged the leaves by feeding on their surfaces which resulted in the development of sooty mould in moist conditions. Mensah and Madden, (1992) observed that severely affected plants lost turgor, stopped growing and shed leaves. Severe infestations reduced vegetative growth. Few authors (Cappuccino 1993, Cappuccino and Martin 1994, Kudo 1994, Larsson *et.al.* 1997, Alper 1998, Martinsen *et.al.* 2000) reported that, leaf shelters, such as leaf rolls and leaf galls made by herbivorous insects are later used by other arthropods as microhabitats. For example, Akimoto (1981) reported that the aphid *Eriosoma yangi* inhabited leaf roll galls on elm trees made other *Eriosoma* species. Singh, (2003) mentioned the affect of galls of *T. hirsuta* on *T. tomentosa* plant almost similar to *P. depressa*. 
Dhiman and Arora (2004) also mentioned the affect of galls of *P. depressa* on *F. glomerata* plant and said that vigour of the plant is reduced. Thus, gall formation on plant leaves greatly reduce the vitality and growth of the plant.

In case of *P. depressa* no true diapause occurs as the nymphs reside within the galls. Galls are indirectly affected by cold weather. During winter, nymphs only prolonged the nymphal period. During low temperature, in the morning, evening, cloudy and foggy days of winter, adult’s *P. depressa* hide within the crevices of the bark of tree trunk. In the process of hibernation, insects ‘sleep’ through cold weather. In true hibernation the insect appear dead. There is no movement and it takes a long time for it to wake up. Adults of *P. depressa* hibernate during winter months, November to mid February. Mathur (1935) observed that the *Phylloplecta hirsuta* hibernate in winter. Kumar *et al.* (1989) mention that in *T. obsolata* diapause occurs in nymphal stage. Mohammed and Sheet, (1989) observed that the adult of *Agonoscena targionii* overwintered under bark until the end of April. Lababidi and Zebitz, (1995) mentioned that the *Pistachio* psyllid overwintered as adult under bark from the end of October to the end of March. Singh, (2003) reported in *T. hirsuta* that there is not hibernation in adult stage. Arora (2004) also reported same type of hibernation in *P. depressa*. Denlinger and David, (2007) mentioned that insects in diapause characteristically feed very little or not at all, thus, they are largely or totally depend on reserve energy. In case of gall inducing insects, they can be hibernate in any stage of development such as – egg, larva, pupa or adult. Same observations are recorded by Xing Fu Jiang *et al.* (2010) suggested that in *L. sticticalis* low temperatures in winter play
an important role in diapause under natural conditions. Joshua, (2010) mentioned that, during diapause, insect undergo a variety of molecular and biochemical changes in development, reduce metabolism, tolerate high temperatures and increase their ability to maintain water balance.

Insect migration is the seasonal behaviour for getting better feeding, breeding and shelter sites. The distance can vary from species to species, but in most cases these movements involve large number of individuals. Migratory behaviour is persistent and straightened out movement effected by the animals own locomotary exertions or by its active embarkation on a vehicle. According to Kennedy, (1985) it depends upon some temporary inhibition of station, keeping responses but promotes their eventual disinhibition and recurrence. In P. depressa, nymphs are not migratory forms as they reside, inside the gall. However, 1st instar after hatching from the egg travels a short distance on the host leaf and choose suitable feeding site and develops gall. Mature 5th instar nymph come out through the lacerated opening of the gall and travel a short distance and then moult’s into imago. Adults have fully developed wings and is the true migratory form. In favourable conditions it takes long flights ranging from few meters to several thousand meters or up to kilometers. Migration in psyllids has not been much studied and only, Singh, (2003) mentioned in T. hirsuta that besides local flights it takes long flights up to several kilometers in adverse climatic conditions like P. depressa. Similarly, according Chapman et.al. (2010) many insects undertake long range seasonal migrations to exploit temporary breeding sites hundreds or thousands of kilometers apart.
The morphology and histology of highly organized insect galls have been studied in detail for over 100 years, yet the insect elicited gall inducing factors (cecidogens) remain unknown. Substances such as amino acids, proteins, sugars, phenols, enzymes and digestive enzymes of the insect saliva and guts, reports on the biochemical alteration in plant galls are rare.

Plant galls induced by *P. depressa on F. glomerata* are remarkably close associations between the insect and host plant, in which the plant produces an abnormal growth of tissue in response to a specific stimulus from the invading organism. Thus, gall former has the ability to manipulate the growth and development of plant tissues. Manipulation of the host plant by the gall former may extend to control over the chemical composition of gall tissue.

Insect galls are usually induced by chemicals injected by the larvae or the adults of the insects into the plants and possibly mechanical damage. After the galls are formed the larvae develop inside until fully grown. Insect secretions as amino acids, phenolic compounds and phenol oxidases pectinases and proteases may be involved in cecidogenesis.

In case of *F. glomerata* gall, the quantitative changes in amino acids spectrum in both healthy and infected leaves as shown in the result clearly indicated that healthy leaves posses 9 amino acids as against 12 present in galls. The additional ones are Alanine, Threonine and Tyrosine. According to results, gall tissues also exhibited a marked increase in the quantities of Cystine, Lysine and Phenylalanine as compared to those of healthy tissues. Gall tissue is generally, though, to be relatively high in nutrients and low on
secondary compounds, compared to healthy plant tissue. Gall tissue represents a higher quality food source than healthy plant tissue.

According to Miles and Lloyd, (1967), increase in the number as well as the quantity of these amino acids in the gall tissues may be due to breakdown of proteins into utilizable units by the enzyme protease, secreted by the salivary glands of the midge. The decrease in the quantity of proline can be explained on the basis that it is a result of response of plant parts for physiological stress, (Levitt, 1972). On the other hand, it is shown decrease under pathological stress, by Singh et.al. (1981). According to Hartley, (1998) several studies have found that gall tissue is high in nutrients and low in secondary compounds. On the other hand, according to showler, (2001), the higher quantities and more diverse accumulations of free amino acids in pigweed leaves occur. Koyama and Akimoto, (2004) observed that the aphid galls accumulate high concentration of amino acids. Khattab and Ibrahim, (2005) observed that the decrease in Ca, Mg, pigments levels, amino acids, lignin, total soluble protein were obtained in the diseased leaves compared with the healthy leaves. Meon et.al., (2008), noted the concentration of free proline was highest in eggs and eggs sacs and in the galls as compared to uninfected portions of roots of infected tomato plants. Ayman (2009) mentioned that the role of AA (amino acids) in plant diseases may be due to the correlation between these acids and plant health. Amino acids are used both for the production of new cell biomass and to produce energy.

There was a marked decline in total proteins in the galls of *F. glomerata* induced by *P. depressa*. The decline in the quantity of proteins in the infected tissues is largely due to their hydrolysis by
the enzyme, protease produced by the salivary glands of the *P. depressa*. This findings also supported by the Miles, (1968); Uritani, (1976) and Chauhan *et al.* (1984). According to Kinsella, (1970), proteins are the primarily body building block sources for new tissue, in plants, animals and human beings. The *P. depressa* feeds on leaf cell sap that are rich in carbohydrates, proteins and fats. As the insect feeds, it injects growth inducing chemicals into the plant tissues. The injected chemicals cause plant cells to abandon their normal growth pattern. This creates enlarged cells that divide until an abundance of recognized tissue surrounds the insect. Gall inducing insects may control plant development in different ways, including directly disrupting the plant’s hormonal balance or altering the cells. Insect feeding or egg laying may form galls.

Quantity of total proteins is considerable low in galled leaves as compared to healthy one. It is believed that the salivary secretion of the insect consists of protease enzyme, due to which the proteins in the tissue are hydrolyzed into simpler components. It has been generally concluded by many workers that the loss in the levels of total proteins in the host is mainly due to the breaking of complex proteins into simpler units, (Rangaswami, 1975 and Rathore and Singh, 2001). Complete protein can be found in some plant sources such as Buckwheat, henseed and amaranth (JADA, 2003; CDCP, 2008). According to Ghaly and Alkoaik, (2010) pumpkin leaves recorded the highest protein yield (11.75%) followed by amaranth us (10.5%).

Quantity of total phenolic compound in gall tissue of *F. glomerata* increase as compared to healthy once. The increase is this quantity may be attributed to defence mechanism. Phenolic compound in
galled tissue have earlier been reported by Miles, (1968), Uritani, (1976) and Purohit et.al. (1979). Phenolic compound play an essential role in gall initiation. According to Bilgrami and Verma, (1979) and Mehrotra and Aggrawal, (2003), the resistance to disease caused either by the fungi or the aphids is due to the presence of higher amounts of phenols. Thus, increased quantity of total phenolics in the gall infested by *P. depressa* is basically for providing resistance against insect infestation. Huang and Backhouse, (2005) and Raghvendra et.al. (2007) said that, phenolic compound are among the most influential and widely distributed secondary products in the plants. Such compounds govern disease resistance in many crop plants. Marmit, *et.al.* (2008) mentioned that, total phenols (odihydroxy phenol and peroxidase) higher in gall tissue, while polyphenol oxidase activities were recorded higher in normal leaf tissue. Hameed, (2009) recorded in his work, total phenolic contents and free radical activity of certain *Egyptian Ficus* species leaf samples. According to Kumar, *et.al.* (2010) phenolic compounds have been noticed most influential secondary products in determination of resistance in pearl millet plants.

The results of present investigation showed that, there was a marked decline in the quantities of reducing sugars in galled leaf. On the other hand, the amount of soluble sugars (non – reducing sugars) in galls increased significantly. The increase in the quantity of total sugars, especially the soluble sugars (non - reducing) in large number of infested leaf has been attributed to the conversion of polysaccharides into sugars. This finding is also supported by the Miles, (1968). Galls have often been described as physiological sinks. Increase in sugar content might be due to accumulation of
these substances. This accumulation may involve the translocation of soluble sugars from the neighboring healthy tissues to the physiological sinks. This view is supported by the finding of Shaw and Samborski, (1956). High sugar contents in young and mature galls may be due to increased metabolic activity under stress which may in turn be responsible for additional synthesis of sugar.

The quantity of total soluble sugar was considerable high in gall tissue as compared to normal leaf tissue. According to Mehrotra and Agarwal, (2003) sugar has large numbers of stereoisomer, because they contain several asymmetric carbon atoms, Parashar et.al. (2008) maintained that, total soluble sugars and reducing sugars were recorded higher in blight infected plant parts. According to Berber et.al. (2009) sugars contents crucially decreased in bacterium infected plants compared to the normal plants. This finding is supported by Shehu et.al. (2010). The total carbohydrate increased in infected onion leaves compared to healthy leaf.

The pH of gall of *F. glomerata* gradually changes as the development of nympha! instars of *P. depressa* inside the gall proceed. The change in pH occurs from 7.0 to 6.4, 6.0 and 5.6 as young, mature and old galled tissue. The finding of Clark, (1920) are same as in *F. glomerata* gall, and reported that the gradual decrease of the pH value in the galls in a centrifugal direction from the larva, is from 7.0 to 5.6. According to Tetlow and Farrar, (1993), the pH of apoplastic sap extracted from rust infected leaves was increased to pH 6.6 to 7.3. Mark et.al. (1998) mentioned that pH of xylem sap increased from 5.9 to 6.9. The reduction in leaf elongation rate (LER) was correlated with the increase in sap pH. pH had no effect on the relative water content or bulk abscisic acid (ABA).
concentration of the growing zone of these leaves. According to Keller, et.al. (2005) with advancing foliar age or time of exposure, the pH values rose slightly on the surface of the leaves. However, emissions from the motorway lowered the pH on the leaf surface.

The levels of IAA in the gall tissues of *F. glomerata* increased as compared to those in the healthy leaves. Miles and Lloyd, (1967) and Schaller, (1968) have reported the presence of high amounts of IAA in the infested tissues. The decline in the quantity of tryptophan in the present studied material may also be held responsible for an increase in IAA levels as earlier suggested by Waziri, et.al. (1974). According to him, increases the permeability of the cells which in turn enhance water quantity in the gall tissues as is also presently observed. However, it is surprising to observe the increase in the levels of IAA oxidase in galls. There is no plausible explanation to this except that this may be due to the presence of higher substrate levels to act upon. According to Miles, (1989) IAA probably involved in the growth of galls. Mapes and Davies, (2001a, 2001b) mentioned the enzymes activity in insect gall formation. A high concentration of ABA (abscisic acid) was obtained in the infested leaves compared with that healthy ones by Hopkin and Huner, (2004).

Singh, et.al. (2005) was of the opinion that after a period of active photosynthesis, the sites of local infection contained less starch than the neighbouring non infected tissues. Thus, infection decreased the rate of starch synthesis and translocation, conceivably starch was retained in the infected areas because, enzymes concerned were inactivated. Marmit and Sharma, (2008) reported the quantitative estimation of some metabolites and enzymes in insect induced leaf
galls of *Mangifera indica*. The parameter’s assayed were total soluble sugar, reducing sugar, starch, α amylase activity and invertase activity compared to normal tissues. Galls showed significantly higher contents to total sugar, starch, α amylase and invertase enzymes activity and lower content of reducing sugar. Sharifi and Ebrahimzaadeh (2010) said that, Peroxidase (POD), Catalase (CAT) and Polyphenoloxidase (PPO) all the enzymes had a similar pattern of changes, according to which their concentrations increased in the first stages of development and then decreased (in roots). The other hand, the enzyme concentration decreased and then increased during shoot formation. Slatnar, *et al.* (2010) discussed the enzyme activity of the phenyl propanoid pathway as a response to apple scab infection.

Thus, the present studies on ‘Histomorphology, Ecology and Biochemistry of leaf galls of *Ficus glomerata* Roxb. induced by *Pauropsylla. depressa* Crawford’ are quite useful and will help in finding suitable control measure of gall forming insect by developing some biochemicals.