Chapter - II

Review of Literature
The benzoyl phenyl urea, a chitin biosynthesis inhibitor was first synthesized in early 1970s, at Phillips Duphar, The Netherlands. This chemical was accidently discovered by the investigators while preparing and examining the derivatives of herbicides dichlobenil and fenuron (van Daalen et. al, 1972). These derivatives showed insecticidal properties. The action of these derivatives was limited to moulting process, as the chemical interfered with cuticle deposition. This discovery led further in the bioassay of different groups of chemicals having chitin biosynthesis inhibiting property.

Mulder and Gijswijt (1973) and Wellinga, Mulder and van Daalen (1973) reported the discovery of two new promising insecticides of Benzoyl phenyl urea group which brought about the formation of defective cuticle by interfering with biosynthesis of chitin. These chemicals were synthesized in the laboratory of Phillips Duphar, The Netherlands.

Cupp and O’neal (1973) for the first time reported the morphogenetic effect of juvenile hormone analogue (ZR-512 and ZR-515) on larvae Solenopsis richteri (Forel) and S. invicta (Buren). This chemical was capable of preventing pupation and proved consistently effective when administered topically and orally.
Post and Vincent (1973) found that benzoyle phenyl urea group restricts growth of the insect and do not cause direct larval intoxication. However, mortality occurs at a post treatment moult, in the larval or pupal stage at lower concentration.

According to Wright (1974) the insect growth regulator [N-(4-chlorophenyl)-N-(2,6-difluorobenzoyl)-Urea] prevents the emergence of Musca domestica L., and Stomoxys calcitrans (L) when applied topically at a rate of 1 mg/ft² at breeding surface area in a cattle feed plot and at a waste water treatment plant observed 90% control of house flies. This chemical cause a disruption in the cuticle formation of the house fly during larval-pupal metamorphosis.

Post and Mulder (1974) gave the insecticidal property and mode of action of benzoyle phenyl urea group against Pieris brassicae L. The resulting effect of these was the reduction or suppression of the insect population.

Bijloo (1975) reported, that after ingestion of diflubenzuron, larvae of lepidoptera, coleoptera and diptera were usually unable to complete their next moult properly and died either from cuticle rupture or from starvation.

El-Gindy and Bishara (1975) reported the effects of R-20458, a juvenile hormone analogue on the reproductive biology of the cotton bollworm, Heliothis armigera Hubn. The results revealed that the topical treatment of the 6th instar larvae, prepupae and pupae with juvenoids did not seriously affect percentage of pupation and adult emergence. On the other hand all the J.H. analogues, when tested on the same stage showed high potential as chemosterilants.
Wright (1975) reported that development of *Musca domestica* L. was inhibited when they were fed on the faecal matter of cattle which contained 0.1 and 0.5% of the insect growth regulator TH 60-40 [N-(4-chlorophenyl)-N-(2,6-difluorobenzoyl)-Urea]. The application of TH 60-40 or a mixture of 21.4% styrofas and 5.3% richlorvas (Ravop) as area treatment to larval breeding site (0.05 and 0.75% conc. respectively) inhibited adult emergence throughout the fly breeding season.

Bobaye and Carman (1975) observed that five insect growth regulators (juvenile hormones) activity when tested against the first instar of *Aonidiella auranti* (Maskell), responded in varying degree at all concentrations, resulting in the arrestation of development at certain stage. Most of tested chemicals and in particular methoprene (iso parayle CEE)- 11-methoxy 3,7,11 trimethyl -2-4-dodecadienona) were more effective in inhibiting metamorphosis of the males than that of the females particularly at lower concentration. Substantial response to the compounds was elicited at higher concentration. At the highest concentration level, 100% inhibition of male and female development was achieved with all the chemicals.

Mc Gregor and Kramer (1976) studied the activity of Dimilin against coleoptera in stored wheat and corn. In a laboratory test when 1 to 10 ppm solution of diflubenzuron was applied to wheat or corn, the development of progeny of rice weevil *Sitophilus oryzae* (L), granary weevil, *S. granarius* (L), maize weevil, *S. zeamaiz* Motschulsky, lesser grain borer, *Rhizopertha dominica*
(F), confused flour beetle, *Tribolium confusum* Jacquelinduval and saw toothed grain beetle, *Oryzaephilus surinamensis* (L) was prevented. After pre exposure of the adults to 10 ppm, no progeny of rice weevil, granary weevil and lesser grain borer developed.

Tamaki (1976) evaluated PH 60-40 against Colorado potato beetle *Leptinotarsa decemlineata* (Say) and the Zebra caterpillar *Ceramica picta* Harris, to determine the effect of this compound on the feeding behaviour and concluded that higher the rate of PH 60-40, the less leaf tissue was consumed. Small larvae feeding on plants treated at 500, 250 and 125 ppm consumed 95, 88 and 26% less tissue respectively. This was in addition to disorienting the insect and causing them to fall from the plants. Thus PH 60-40 suppressed feeding activity of those insects remaining on plant.

Urs and Narasimhan (1977) studied the effect of R-20458 on the growth and development of tobacco caterpillar, *Spodoptera litura* and reported that when 5th instar caterpillars were topically treated on the last abdominal segment with various doses, the lower dosages produced malformed pupa or larva-pupa intermediate and higher dosages resulted in super numerary larvae with sluggish activity and practically nonfeeding characters, leading to the death of the insect.

Flint and Smith (1977) also observed the first instar larvae and adult *Pectinophora gossypiella* (Saunders) by giving (Thompson-Hayward) TH 60-40 [N-(4-chlorophenyl)-N-(2,6 diflurobenzoyl)- Urea] in either diets or on treated surfaces. Reduction in emergence by 64% from control levels was observed on 1
ppm in larvae diet and greater doses greatly reduced larval development. However, exposure of first instar for 24 h to 9 bait formulation, containing 10,000 ppm of Th 60-40 on cotton leaves brought down the number of larvae surviving to 5th stage by 25%. Continuous exposure of adults of TH 60-40 either in diet or on treated surface caused a gradual loss of fertility during a 4 to 6 days period.

Calkins, Hill, Hue Hel and Mitchell (1977) worked on the egg viability and larval development of Herbst. When adults were fed diflubenzuron, the effects were not long lasting. The diflubenzuron did not affect the fecundity much. It did affect the development of the larvae inside the fruit severely during egg, stage or at moulting. When 0.25% granules of diflubenzuron was added to soil at the rate of 358 ppm, no emergence of adult was observed. This showed that diflubenzuron did not breakdown in the environment and its activity persisted. In another test diflubenzuron was mixed with unsterilized soil at the rate of 108, 54, 35, 21.74, 5.43, 4.34, 2.17 or 1.09 ppm to see that minimum amount of material needed for adverse effect on pupation and eclosion. The data so obtained showed that LD 50 was calculated 0.14 ppm. So very low doses can cause high mortality rate.

Sundaramurthy and Balasubramanian (1978) studied the effect of Dimlin on tobacco caterpillar, Spodoptera litura under induced hyper hormone condition and came to the conclusion that when 6th instar larvae of S. litura were treated with 1 ug Dimilin, caused 99.60% inhibition of pupal formation and the phenyl urea under hyper hormone condition resulted in high degree of inhibition.
by producing more larval-pupal deformities and inhibited the completion of moulting in super larvae.

Abid, Ghobrial, El Haideri and Abbs (1978) reported the effect of dimilin on 3rd instar larvae of spiny boll worm *Earias insulana* Boised. in the laboratory. After treating the larvae, it was observed that the moulting could not be completed normally, because of the inability in completely shedding of the exuvia. Other abnormalities in mouth parts, thoracic region and abdominal region were also seen, leading to the death of the insect. Affected larvae lived from 4 to 5 days of post treatment and severely deformed individuals frequently died within 3 days and when 12.5 mg/larva was applied, it was seen that 42.5% of the larvae died within 7 days.

Abo-Elghar, Radwan and Ammar (1978) observed on the morphogenetic activity of an IGR compound PH 60-40 on newly formed *Spodoptera littoralis* pupae treated topically and concluded that newly formed pupae of *S. littoralis* were highly sensitive to the PH 60-40, when it was applied topically. It was evident that actual graduation in the morphogenesis effect increased with increased dosages. The PH 60-40 showed its action at 0.05% as all emerged moths were either deformed or dead.

Ascher, Wysoki, Nemny and Gur-Telzak (1978) observed that the aqueous diflubenzuron suspension was moderately toxic to *Boarmia selenaria* larvae for contact treatment and the topical application against large larvae. He
also observed that small larvae of *B. selenaria* fed for 4 days on the suspension
dipped lucerns leaves suffered from severe developmental disturbances.

**Flint, Smith, Noble, Shaw, DeMilo and Khalil (1978)** evaluated that
diflubenzuron (N\([(4\text{-chlorophenyl) amino] carbonyl})-2,6 diflubenzamide) [AB-
29054]; EL – 494 (N\([(5\text{- (4-bromophenyl)-6-methyl-2-pyrozynyl} amino]
 carbonyl] –2,6-dichlorobenzamide); EL-588 (2,6-dichloro-N\[(5\text{- (4-chlorophenyl} 
2-pyrozynyl} amino] carbonyl] benzamide), Al3 63220 (N-[(4-bromophenyl)
 amino] carbonyl); 2,6-difluorobenzamide) and Al3 63223 (2,6-difluoro –N-[(4-
(trifluromethyl phenyl] amino] carbonyl] benzamide] prevented development of
adult pink boll worm *Pectinophora gossypiiella* (Saunders), when they were fed
on larval diet at 1-10 ppm. Contact experiments with adult moths indicated little
activity upto 18 mg/cm² except for Al3 63220 & Al3 63223 which caused
significant mortality after one week exposure to treated cage surface.
Diflubenzuron and EL –494 were tested for systemic activity by treating foliage
of cotton plants at the rates upto 15.2 mg/plant without effect on subsequent
development of the pink boll worm. A further test in field cages using 2
compounds at a rate of 0.11 kg/ha indicated that diflubenzuron was superior to
EL-494 for control of the cotton leaf perforator *Bucculatrix thruberiella* Busck,
but either compound had only activity against the pink boll worm.

**Grosscurt (1979)** investigated the larvicidal and ovicidal mode of action
of diflubenzuron. On larvae, it acts as stomach poison but some times exhibits
contact activity. All instars can be controlled but older instar are generally less
susceptible than younger ones. He also reported, after exposure of *Leptinotarsa decemlineata* larvae, distortion in newly deposited cuticular layer, ovicidal effect resulted from direct contact of diflubenzuron with eggs or from contamination of females by contact or feeding.

Reed and Boss (1979) studied the effect of diflubenzuron on food consumption by the soyabean looper and came to the conclusion that food consumption of treated 5th instar larva was less than that of untreated larvae over equal units of time, regardless of the length of survival time.

Nateson and Balasubramanian (1980) studied the effect of diflubenzuron on pupae of *Spodoptera litura* (F) and found that when the pupae of different ages were dipped in different concentrations of diflubenzuron solution for 10 seconds, caused pupal mortality, partial emergence and malformed adults. The susceptibility of pupae decreased with increase in their age.

Chattoraj and Dwivedi (1980) reported the toxic effect of penfluron on *S. litura* and found that when the chemical was applied topically at 0.0015, 0.15, 0.30 or 0.45/ug larvae to final instar larvae, mortality averaged 68, 84, 90 and 100% respectively as compared with 10% for no treatment. They also observed 100% sterility with the lower doses of penfluron i.e. 0.0045/ug/larva. Penfluron was more active on males than females.

Wright, Roberson and Dawson (1980) studied the effect of diflubenzuron on sperm transfer, mortality and sterility when given to adults of *Anthonomous grandis* (Boheman). On the basis of mortality, sterility and transfer
of sperm, a level of either 50 or 100 ppm diflubenzuron given in diet for 5 days plus irradiation with 10 krad of gamma irradiation on the 6th day, produced sterile male and female boll weevils. Higher level of diflubenzuron reduced sperm transfer. The feeding of diflubenzuron in the adult diet did not contribute to adult mortality but significantly lowered egg hatching & larval development.

Mitsui et al. (1980) found that when diflubenzuron was applied topically or orally to the final instar of Munduca larvae, the cuticle production was inhibited. After topical application of 5 μg diflubenzuron to the newly moulted 5th instar larvae, the rate of cuticle deposition decreased to two-third of normal thickness. It inhibited both endocuticle deposition and ecdysterone initiated pupal cuticle synthesis by the epidermis. Both effects were due to inhibition of glucose or glucosamine incorporation into chitin.

Mitsui, Nobusawa and Fukami (1981) studied the effect of diflubenzuron on chitin synthesis and chitin synthetase activity during the last larval instar of Mamestra brassicaceae (L.). In vivo, the compound inhibited chitinous cuticle formation. It appears that diflubenzuron blocks the terminal polymerisation step in chitin synthesis.

Madrid and Stewart (1981) studied the impact of diflubenzuron spray on gypsy moth paratoids in the field. It was observed that diflubenzuron for control of Lymantria dispar (L.) was applied once at 0.03 kg. a.i. in 4.76 litre water/ha. Larval mortality of L. dispar was high, about 50% after 1 week and 100%
after 10 days. *Apanteles melangshelus* (Ratz.) mortality was about 80% after 2 weeks, Tachinids showed 100% mortality.

**Abdelmonem** and **Mumma (1981)** studied the comparative toxicity of some moult inhibiting insecticides to the gypsy moth, *Lymexylia dispar* (L.). Third and fifth-instar larvae were fed on diet containing various concentrations (0.06 to 0.8 ppm) on the moulting-inhibiting compounds. The larvae scored for moulting abnormalites. EC 50s value for diflubenzuron for failure of 3rd instar to moult to the fourth were 0.176, 0.513 and 0.052 ppm, and for failure to moult to the fifth instar were 0.075, 0.175 and 0.009 ppm, respectively. EC 50s for the failure of fifth instars to moult to pupae (males) or to the sixth instar (females) were 0.094, 0.531 and 0.122 ppm, respectively. Continuous feeding of third instars until pupal formation on diet containing diflubenzuron resulted in the lower EC 50s of 0.009 and 0.006 ppm respectively. Diflubenzuron was most toxic to third instars. They also noted that some larvae appeared to moult normally but failed to eat resulting in their death.

**Ascher** and **Eliyahu (1981)** investigated the residual contact toxicity of triflumuron (BAY SIR-8514) a chitin synthesis inhibitor, on *S. littoralis* larvae in the laboratory. The larvae were confined on the treated glass for 90 min and subsequently kept on lucerne foliage. The ED 50 for cumulative mortality upto the adult was 0.0017 g/m² for larvae weighing 100 mg and 0.004 g/m² for those weighing 200 mg. when administered in this way, the toxicity of triflumuron was considerably greater than diflubenzuron.
Rabindra and Balasubramanian (1981) studied the effect of diflubenzuron on the castor semilooper, *Achoea janata* Linn. It was noted that the lowest concentration tested (0.05 g/litre) inhibited moulting and caused 96% mortality, while concentration of 1.0g/litre caused 100% mortality. Various morphological deformities were also observed in pupa from treated larvae.

Segistan, et. al. (1982) studied the effect of diflubenzuron on the reproduction and larval development of *S. frugiperda*. The larvae of different instars (1st, 3rd, 5th & 6th) were confined for 48h with maize leaves previously dipped in 0.0625-2 ppm, diflubenzuron. The larvae were most susceptible 10 days after hatching (in the 5th instar) at which time food consumption was greatest. Mortality at moulting was higher among larvae on treated than on untreated leaves (only 12.66% of the larvae exposed to the compound in the 5th instar completed their development to the adult stage); and the compound caused growth deformities and abnormalities. Workers found that the compound caused complete sterility in the males and partial sterility in females developing from these larvae. Both fecundity and fertility were reduced by the compound.

Lim and Lee (1982) studied the toxicity of diflubenzuron on *Oxya japonica* (Willemse) and its effect on moulting. A laboratory evaluation of the acute toxicity of diflubenzuron against the final stage of *Oxya japonica* nymphs showed that it was more effective in preventing the development of the nymphs into the adults when applied topically, than injected. Histological studies also revealed that treated nymphs subsequently died before or during ecdysis suffered
from severe endocuticular lesions, although these nymphs appeared normal externally.

Moffitt, Mantey and Tamaki (1983) reported the effect of TH-60-43, TH-60-44 penfluron and diflubenzuron on oviposition by treating adults and on subsequent egg hatch of the codling moth, *Cydia pomonella*. They found that TH-60-44 was most effective in reducing the hatching of eggs from treated adults. With TH-60-43 and penfluron, egg hatch was reduced only when the female of each mating pair was treated. Topical application of diflubenzuron to adults moderately reduce egg hatch and also reduced oviposition by females. None of these compounds adversely affected mortality, life span or mating propensity of adults.

Velcheva (1983) studied the insecticidal activity of diflubenzuron against larvae of the cabbage moth, *Mamestra brassicae*, in laboratory and field tests at concentrations of 25, 37.5, 75, 250, 375 and 750 ppm. In the laboratory, 100% larval mortality occurred on the 4th day after treatment with 750 ppm, on 7th day with 75, or 375 ppm, on the 8th day with 250 ppm and on the 10th day with 37.5 or 25 ppm. In the field test they observed 100% mortality of the 3rd instar larvae 7 days after application of the compound at 750 ppm. It was also seen that 20 days after application larval mortality had fallen to 58.62% and the surviving larvae pupated normally and had no visible morphological abnormalities.

Knapp and Herald (1983) evaluated the effect of two other chitin synthesis inhibitors BAY SIR-8514 and Penfluron on egg eclosion and F1 larval
development of the face-fly by exposure of adult files to treated surface and concluded that inhibition of egg hatch and F₁ larval mortality were dependent on exposure time, concentration, mating regime and elapsed time after exposure.

Chockalingam, and Krishnan (1984) determined the effect of oral administration of sublethal doses of diflubenzuron on the energy budget of 5th instar larvae of Ergolis merione in the laboratory. The LD 50s for larvae treated for 24, 48, 72 and 96h were 52.56, 27.76, 13.60 and 8.76 / ug/larva, respectively. Treatment with the highest sublethal does (3.4 ug/larva) reduced the food consumption rate by 33.34%, the assimilation rate by 21.82% and the conversion rate by 65.64%. Diflubenzuron administered with the food not only reduced larval growth but also affected the growth and emergence of adults, causing morphological abnormalities.

Soltani (1984) reported that when diflubenzuron fed to adults of Tenebrio molitor, reduced the longevity and weight of the adults and the thickness of the post ecdysial adult cuticle. It also affected the production of the peritrophic membrane. The loss of weight and the decrease of longevity of the treated adults may have been because of alterations to the peritrophic membrane caused by the inhibition of chitin biosynthesis by diflubenzuron.

Swamy and Punnaiah (1984) determined the toxicity of sprays of triflumuron (SIR – 8514) to eggs, 3rd instar larvae and pupae of the polyphagous pest, Spodoptera litura. (F). They observed that direct application at 0.065% completely inhibited egg hatch. Direct application at 0.0325% and
indirect application (by feeding) at 0.065% gave complete mortality of the 3rd instar larvae, while direct and indirect application at 0.13% gave complete mortality of last instar larvae. All treated pupae completed their development, though some of the subsequent adults were malformed with treatments at higher concentration.

Soltani, Besson and Delachambre (1984) reported that application of diflu benzuron on newly emerged pupae of Tenebrio molitor (L) dipped, in it, disturbs the pupae and adult development. Four main types of treated insects were obtained according to the external morphology; blocked pupae, adult unable to ecdysed. The proportion of the four types varied with the time of treatment during the pupal life, when diflubenzuron was administered at 10g/litre concentration to the newly emerged pupae.

Abdel, Negm, Saleh (1985) evaluated the effect of the insect growth regulators, methoprene, diflubenzuron and triflumuron SIR – 8514 on 5th instar larvae and 5 day old pupae of the Egyptian cotton leaf worm, S. littoralis (Boisd). The larvae were fed for 24h on castor leaves which had been immersed in various concentration of the insect growth regulators for approximately 15 seconds and 5-days old pupae were treated by dipping. Symptoms of larval treatment included a retention of larval characters in the pupal stage, inhibited adult emergence and production of an additional larval instar. Treatment at both the larval and pupal stages resulted in reduced fecundity and egg hatch and increased sterility in the adult. Diflubenzuron was the most potent sterilant.
Tiwari (1985) studied the effect of dimilin on the consumption and utilization of dry matter and dietary constitution of castor, *Ricini communis* Linn. by the castor semilooper, *Achoea janata*. It was seen that there was no difference between treated and untreated adults with regard to consumption index growth rate, approximate digestibility, efficiency of conversion of ingested food (ECI), efficiency of conversion of digested food (ECD) or utilization of nitrogen. Treated insects had a greater lipid balance than untreated ones. The value of ECI and ECD in relation to conversion of food lipid and of carbohydrate were greater in untreated than for treated insects.

Lecheva (1985) studied the biological action of diflubenzuron. When this chemical was applied under laboratory and controlled field condition at 0.08, 0.1 and 0.12% on larvae of *Operophtera brumeta* and *Eranis bajaran*, the mortality rate of the treated 2nd instar larvae was 76.8% while that of 3rd and 4th instar larvae was 50.60%. The effect of the compound on the physiological process of the insects increased and was greatest shortly before the pupal stage, as a result of which, only abnormal pupae were obtained, which died. In the field, the compound was most effective, when applied to apple trees flowering and larvae were in the 2nd and 3rd instar.

El-Sayed (1985) reported the effect of diflubenzuron on larvae and adults of *Spodoptera littoralis* (Boisd). The LC50 of diflubenzuron for 4th instar larvae exposed to treated leaves for 24h and 48h, were 0.004 and 0.0006%, respectively. Fourth instar larvae surviving treatment with diflubenzuron had reduced larval
and subsequent population and adult emergence. Such effects were in proportion to the period of exposure to treated larvae and the concentrations used.

*Radwan et al (1986)* reported that the 4th instar larvae of *Spodoptera littoralis* were fed on castor and bean leaves treated with the chitin-biosynthesis disrupting agents, diflubenzuron and its analogue, SIR-8514 (triflumuron). There was a reduction in the consumption of food. Considerable decrease in growth rate was also recorded. The efficiency of converting ingested and digested food into the body substance also showed an obvious reduction, especially in the larvae, fed on diflubenzuron treated leaves.

*Rao, KumaraSwamy and Balasubramanian (1987)* studied the effect of dimilin on the feeding behaviour of *Cnaphalocrosis medinalis*, after ingestion or topical application or dipping larvae in diflubenzuron, at 1,50, 100, 150, 200, 250 and 500 ppm. Feeding by larvae was reduced, following treatment with 1ppm but was stimulated by concentration upto 100 ppm and then decreased, bringing about variation in values of ID50 (50%, inhibition dose). Ingestion and topical application of diflubenzuron to 2nd and 3rd instar larvae, resulted in less than 50% inhibition even at 500 ppm. For 4th and 5th instar larvae, the lowest ID 50s were recorded with the larvae dip method (204.2 and 77.6 ppm, respectively, and the highest value with the ingestion method 426.6 and 169.8 ppm, respectively).

*Raja et. al. (1987)* reported the effect of methoprene on the sequestration of haemolymph proteins by the fat bodies of *Chilo partellus*. In the laboratory, newly ecdysed 5th instar larvae were treated topically with 1 /µl of 2, 1.5 or 1 ppm
methoprene. Treatment at all 3 concentrations resulted in the larval-pupal intermediates and supernumerary larvae. This morphogenetic effect was accompanied by inhibition of the uptake of storage protein by the fat bodies.

Srivastava and Khan (1988) reported that penfluron was highly toxic to the larvae of Pericallia ricini (Fabr.). Complete larval mortality was recorded at 0.028/µg/cm², residual level, though the prepupal formation took place in some of the treated larvae at this level. A residual deposit of 2.8% µg/cm² incompletely inhibited even prepupal formation. At high residual deposit, no deformity was seen, instead high or complete lethal action was observed. The reason for the deformity at lower concentration may be due to inhibiting property of penfluron in biosynthesis of chitin. At higher concentration the chitin deposition was completely checked showing complete lethal action of the chemical. However, at lower concentration the chitin deposition was partially disturbed restricting the larva to moult into pupa, producing larva-pupa intermediate.

Khan and Srivastava (1988) reported that when the last instar larvae of P. ricini (Fabr.) treated with different concentrations of penfluron, complete larval mortality was recorded at 0.01% level. The prepupal, pupal and adult deformity also occurred as a result of the chemical. The maximum deformity was recorded at lower concentrations. The larval and pupal life span was increased by 29.52 and 38.46%, respectively, where as adult life was decreased by 54.54%. The survival period of adults was decreased as concentrations were raised to higher level.
Somasundaram and Chockalingam (1988) studied the impact of diflubenzuron on the feeding physiology of *Papilio demoleus*. Topical application and oral administration of diflubenzuron on the feeding budget in the 5th-instar larva was done. The LD50 and LC50 of diflubenzuron were 13.50 and 9.00 ug/larva, respectively, after a period of 48h. Of the 2 modes of application, topical application produced 50% mortality at a comparatively low dose of 900 ug/larva. The growth efficiency was reduced by 44.54% in oral administration and 38.19% in topical application at the highest sublethal doses of 2.7 and 1.8 ug/larva, respectively, compared with that of control larvae. In addition, the compound produced morphological abnormalities in the adult.

Khan and Srivastava (1989) reported the biological effect of diamino-furyl-s-triazine, used larval residual and adult feeding treatment, on the larval development and mortality of *Euproctis icillia* Stoll. The compound was highly toxic to the larval stage, effective growth inhibitor and successful sterilant in adult stage of *E. icillia* Stoll. It produced maximum 88.88% and minimum 33.33% net mortality at 12.0 and 0.0012 /ug/cm² level of residual deposit, respectively. Besides, different types of deformities were exhibited at lower concentrations; high concentration produced complete lethal action. The chemical significantly increased larval and pupal survival period and reduced the adult life span. The maximum larval and pupal survival period was increased upto 54.54 and 69.23%, respectively, but the adult life span was decreased maximum by 13.75%.
Srivastava and Srivastava (1990) reported that the reduction in food consumption, weight loss during exposure period and reduction in growth rate occurs, when third and fifth instar larvae of *Pericallia ricini* (Fabr.) were fed on castor (*Ricinus communis*) leaves dipped in different concentrations of diamino-furyl-s-triazine. Maximum reduction in total food consumption noted was 63.40% at 0.01% level, in third instar larval feeding treatment. During the exposure period, larvae lost their weight (maximum by 36.46% in third instar larvae). Maximum reduction in larval growth was also recorded in third instar larvae, which was 63.08% at 0.01% level. With the increase of concentration, the reduction in food consumption and growth rate was increased considerably. The chemical was more active on third instar than fifth instar larvae.

Gupta and Verma (1991) studied the effect of three 1-(2,6-disubstituted benzoyl)-3-phenyl urea compounds, namely, penfluron, diflubenzuron and AI3-63220 on pupae of *Corcyra cephalonica*. The compound caused complete mortality when pupae were dipped in 100ppm acetone solution. The mortality increased with increase in concentration from 10 to 100 ppm. The fecundity and egg viability of adults emerged from treated pupae was reduced significantly with penfluron resulting in maximum net control of reproduction (70.1%), followed by diflubenzuron (24.8%) and AI3-63220 (23.9%), at 40 ppm.

Masih (1992) studied the biological interaction of insect growth regulators with lepidopterous pests namely, *Eubroctis icilia* Stoll and *Euproctis fraterna*
MO. of the family Lymantriidae. The pests were administered with the insect growth regulators (penfluron and diamino-furyl-S-triazine) by feeding and residual technique. He observed that the insect growth regulators proved as high toxicant causing remarkable mortality in immature stages. Various degree of morphological abnormalities were also noticed. Food consumption was very much reduced. Chemicals affected the development of normal adults as growth of the treated larvae was reduced extremely in comparison to control.

**Sharma (1993)** observed the effects of certain insect growth regulators on the growth and development of *Utetheisa pulchella* Linn. She found that the diflubenzuron, penfluron and diamino-furyl-S-triazine were high powered toxicant in adult feeding and residue film treatment. All chemicals affect the growth and development of *U. pulchella* significantly.

**Arora and Co-researchers (1993)** tested diflubenzuron for its toxicity to egg, grubs and cocoons of *Chrysoperla carnea*. Applications of DFB to 0-1, 1-2, and 2-3 old eggs of *C. carnea* resulted in 38.4, 21.6 and 24.8% mortality. Delayed mortality in larval stage was also observed and was highest (49.6%) in the treatment of older (2-3 days) eggs. Feeding of larvae on DFB (0.1%) treated eggs of *Corcyra ephalonica* resulted in complete mortality by the 5th day. In contrast to this, cocoons sprayed with 0.1% DFB yielded more than 70% normal adults.
Singh et al. (1993) tested nine insecticides, cypermethrin, carbaryl, deltamethrin, diflubenzuron, endosulfan, fenvalerate, fluvalinate, monocrotophos and quinalphos against 2-day old eggs of *Helicoverpa armigera* and all except endosulfan were also tested against 1 day old eggs of *Earias uittella*. Diflubenzuron had no significant effect on egg hatch in *H. armigera*, while all the other treatments significantly reduced egg hatch.

Gupta and other workers (1994) showed that the *Corcyra cephalonica* was quite capable of developing resistance to the diflubenzuron. So this compound yet not widely used for the control of pests.

Ogisso and Asayama (1994) reported the effect of flinoxiculve on 4\(^{th}\) and 5\(^{th}\) instar silkworm larvae which resulted in a large proportion of larvae failing to spin cocoons. When fed on artificial diet containing moulting hormone, the larvae began to spin cocoon of normal size.

Mridula Gupta and Co-workers (1994) studied the effects of diflubenzuron on eggs of *Diacrisia obliqua* in the laboratory. Eggs aged 0-24, 48-72 and 96-120 h were dipped for 2 min. in 5, 25, 50, 100, 250, 500 and 100 - ppm diflubenzuron. The LC\(_{50}\) was 29.5, 90.0 and 680 ppm for 0-24, 48-72, 96-120 h old eggs, respectively. Abnormal adults emerged from 0-24 h old eggs treated with 100 p.p.m. diflubenzuron.
Wang *et al.* (1995) studied the effects of diflubenzuron on cuticle proteins and chitin in last instar larvae of *Mythimna separata*. They observed that diflubenzuron reduced the contents of various cuticle proteins. Diflubenzuron inhibited the synthesis of cuticular chitin and protein and also changed the structure of the complex of chitin-protein. At the initial moult stage in the 6th instar, the contents of DNA and RNA were increased but later RNA decreased rapidly and so did the ratio of RNA:DNA.

Kadam *et al.* (1995a) determined the effect of diflubenzuron on newly oviposited eggs, eggs prior to hatching, larval and pupal stages of *Plutella xylostella*. The percentage unhatched eggs ranged from 22.40 to 100.0 and 17.5 to 77.5 at various treatments for newly oviposited eggs and eggs prior to hatching. The percentage larval mortality ranged from 41.67 to 100.0, 6.66 to 100.0, 0.0 to 100 and 0.0 to 66.67 for the first to fourth instars. The percentage adult emergence from treated eggs was 13.33 to 100.0 compared to 100.0 for the untreated control. Affected larvae failed to moult turned black and displayed morphological deformities. Kadam *et al.* (1995b) also concluded that diflubenzuron adversely affected larval growth and weight when applied against castor semilooper.

Gupta *et al.* (1995) studied the effect of diflubenzuron on the larvae of *Corcyra cephalonica* and reported that the early larval stages were found to be more susceptible to the compound than the advanced stages. At low concentration
diflubenzuron was ineffective in causing any mortality in 16 and 30 day old larvae, while development was completely arrested in 2-day old larvae, however, some pupal mortality was observed at these concentrations. The mortality rate was much higher when 16 and 30 days old larvae were fed on higher concentration, however, no adults emerged. Only, males were found malformed.

Staneva and Gencheva (1996) applied Alsystin 25 WP and Dimlin 25 WP at different doses against Grapholitha molesta as a part of an Integrated Pest Management Programme for peaches in fields. Treatments were applied in intervals of 35-38 days. As a result, population of the pest in different season found controlled.

Ishaaya et. al. (1996) found Novaluron as good stomach and contact poison. It was found highly active against lepidopterous larvae (by ingestion) and against nymphs of Bemisia tabaci (by contact). Novaluron was much more active against eggs and larvae of B. tabaci than chlorfluazuron. At a concentration of 1 mg a.i./litre, novaluron reduced adult emergence by w 90%, when first instar larvae were exposed to treated cotton seedlings. Novaluron was also active in suppressing developing stages of the leaf miner, Liriomyza huidobrensis, suppression of about 80% adult formation was obtained at a conc. of 0.8 mg a.i./litre and similar inhibition of pupation and mine formation at a conc. of 20 mg. a.i./litre so it should considerable potential for controlling lepidopteran pests in field crops, vegetables and ornamental plants.
According to Weiland et al. (1996), Dimlin was found to be effective in controlling Spodoptera exigua. Rigo and Goio (1996) reported some growth regulators like esafumuron, triflumuron, teflubenzuron and lufenuron and found effective against the tortricid Cydia molesta and Anarsia lineatella. The best time to apply the growth regulators was established based on the number of adults captured in phenomenon types. Triflumuron was very effective in controlling the pests.

According to Smagghe et al. (1996) Tebufenozide, representing a new group of insect growth regulators with a new and selective mode of action. Administration via larval diet was an effective way to kill last instar larvae of Plodia interpunctella and Ephhestia kuchniella. The LC50 was calculated to be about 0.3-0.6 mg a.i./kg. diet. Treated larvae underwent head capsule apolysis leading the double head capsule formation, lost weight and died without splitting off the cuticle. The salient effects of moulting induction and growth inhibition agree with the specific activity of tebufenozide and confirm its ecdysteroid mimicking action.

Franca and Branco (1996) reported that insect growth regulators affect moulting in lepidopteran, dipteran and hemipteran insects. These insecticides are specially recommended for integrated pest management programmes because they are efficient insect control agents, selective to natural enemies and they confer long term protection to the plants.
Arora et al. (1996) evaluated diflubenzuron in the laboratory against different larval instar of Spodoptera litura using cotton cv. F 414 as a host plant. There was no mortality among the larvae after feeding for 12 h on DFB-treated cotton even at the highest concentration of 0.2%. Larvae feeding for 24, 48 or 72 h on DFB – treated cotton resulted in partial to complete mortality. The increase in feeding period on the treated cotton resulted in a large increase in the toxicity of DFB, a 72 h feeding period on cotton treated with 0.005% DFB resulted in a cumulative mean mortality of 47.33%. In the first to third instar larvae, maximum mortality occurred at the time of next moult. There was delayed mortality at the time of the larval-pupal moult. At the lower concentrations, only delayed mortality was recorded.

Krishnaiah et al. (1996) reported in Andhra Pradesh, India that at a concentration of 0.01%, buprofezin exhibited a high degree of persistent toxicity to nymphs of the rice brown plant hopper and the white backed plant hopper but only moderate toxicity to the green leaf hopper. The synthetic pyrethroids, cypermethrin and deltamethrin showed moderate toxicity to BPH and WBPH but were highly effective against GLH. combinations of Cypermethrin + buprofezin and deltamethrin + buprofezin were highly effective against above mentioned pests. Buprofezin was safe to nymphs and adults of the predater Cyrtorhthinus lividipennis.
Bhattacharaya et al. (1997) evaluated the toxicity of diflubenzuron against larvae of Eublemma amabilis. They used five concentrations ranging from 0.0125 to 0.2% by two methods, oral and topical. Diflubenzuron applied using both method exhibited larvicidal action and caused ecdysial failure which adversely, affected survival. The percentage mortality varied from 56.67 to 93.9 and 46.67 to 90.00 by oral and topical application respectively. Also, 0.05% diflubenzuron sprayed on colonies of K. lacca suppressed population of E. amabilis without affecting K. lacca.

Guo-SJ et al. (1997) conducted laboratory and field trials in China to evaluate the efficacy of organophosphorus synthetic pyrethroid, carbamate, insect growth regulators, antibiotic and botanical insecticides to control Spodoptera litura. Chlorpyrifos beta-cyfluthrin, methomyl and chlorfluazuron were the most effective.

Kumari and Mohamed (1997) observed that the carbohydrate concentration in ovaries from adults of the noctuid Spodoptera mauritia treated as larvae with diflubenzuron was reduced compared with the carbohydrate concentration in ovaries of adults developing from untreated larvae.

Hull and Biddingger (1997) divided the insect growth regulators into four groups based on their mode of action, namely chitin synthesis inhibitors (CHI), Juvenile hormone analogues (JHA), anti juvenile hormones and ecdysone agonists. Field studies were carried out during 1994-96 in two apple orchards in
Pennsylvania, U.S.A., on the effects of the ecdysone agonist confirm on lepidopterous pests and natural enemies unharmed and controlling pests.

Smagghe et. al. (1997) reported that when diflubenzuron was topically applied to larvae of *Spodoptera littoralis* and *Spodoptera exigua*, the estimated LD50 values were similar, reaching 0.47 and 0.44 gva/larvae respectively. In this study, the importance of the rate of uptake and excretion, and of enzymatic metabolism in building up an insecticidal toxicity after topical application on the insect cuticle in both species was evaluated. In general, penetration of DFB in *S. littoralis* was about 2-fold higher than in *S. exigua*, whereas metabolic breakdown was of minor importance in *S. littoralis* as compound with *S. exigua*.

Blumel and Hausdorf (1997) carried out studies on 97 trees in 1995 in Vienna, Austria, to test the effectiveness of three synthetic chitin synthesis inhibitors (Dimlin, Alsystin and Insegar) for the control of *Cameraria ohridella*. Dimlin and Alsystin resulted in 98-100% mortality of larvae, depending on the number of applications.

Cadogan et. al. (1997) conducted a field trial in Canada to determine the efficacy of tebufenozide against *Choristoneura fumiferana* and observed that the spraying of this insecticide effect the development significantly. The larval and pupal weights of treated insects differed significantly. A number of spray applications were found effective in determining a successful application strategy.
Moraschini (1998) reported a new insect growth regulator, showed wide spectrum of activity against many lepidoptera and coleoptera. Its good efficacy, associated with its lack of toxicity against the most common beneficial arthropods. It was found useful in integrated control programmes in the field and greenhouse.

Tembhare (1998) reported that topical application of the Dimlin to 5th instar larvae of Othreis materna resulted in an accumulation of neurosecretory cells and cessation of secretory cells in the corpora allata. The prothoracic glands did not resume growth in Dimlin treated larvae. The results suggested that Dimlin inhibits moulting due to neuro endocrine failure.

Saxena and Khattri (2000) reported that the fourth generation insecticide, penfluron applied by pupal dip method, adult feeding method and residue film method to investigate the effects on growth development against Pericallia ricini F, (Lepidoptera : Arctiidae). Different concentrations (0.0001, 0.001, 0.01, 0.50, and 1.00 per cent) of penfluron were applied in this investigation. One per cent penfluron affected the growth significantly. Larva gained weight 1.67 mg on fifth day, 6.81 mg on tenth day and 20.92 mg on fifteen day i.e., for less in comparison of control experiment (4.30, 22.64 and 110.93 mg on 5th, 10th, and 15th day). One percent penfluron also effected larval period, pupal period and emergence of this insect significantly. At regard to method of application, the pupal dip method proved the most effective.
In the same year Saxena and Khattri also studied effects of diflubenzuron on emergence, longevity and reproduction of *Pericallia ricini* F. (Lepidoptera: Arctiidae) and reported that the diflubenzuron when applied by pupal dip method effect the emergence and longevity both significantly. Emergence and longevity both were found be inversely proportional to the strength of diflubenzuron. One percent diflubenzuron was found to be the most effective. It reduced emergence to about one fifteenth of the natural emergence. It also reduced the longevity by six days in male and female moths. The oviposition and hatching were influence significantly by the diflubenzuron when applied by pupal dip method. One percent diflubenzuron was most successful in reducing the number of eggs laid and hatching of eggs also. It caused about one fourth reduction in oviposition volume and reduced the hatching to 38.4 percent.

Saxena, Kumar and Khattri (2001) studied the effects of diaminofuryl-s-triazine and Benzoyl Phenyl Urea on the growth and reproduction and reported that both fourth generations insecticides effected the same significantly. They found both insect growth regulators were effective in controlling the population of *Pericallia ricini*. 