

## CHAPTER 2

### 2.0 REVIEW OF LITERATURE

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#### 2.1 The status of resistance- A global view

Agriculture has always been the backbone of a country's economy. Since the human race came into existence, agriculture played a vital role in creating a balance in food chain. There were challenges related to the development of agriculture with the growing economy. One of them was attack of pests in agricultural fields, which was considered as a natural phenomenon and a part of food chain. As the farming gained impetus, there were positive and negative effects.

The first ever case of resistance was reported by an entomologist Melander (1914) from Washington Agricultural Experimental station. He asked "Can insects become resistant to sprays?" This was one of the most vital question of the 19<sup>th</sup> century, which created a huge clamour among the scientists and agriculturists community. This question created a spark whose flames are still burning. He tested the effect of a chemical lime sulphur which is an inorganic against scale insect. The results indicated resistance in a hemipteran insect pest *Aspidiotus perniciosus* commonly referred to as San Jose Scale. With this began the era of resistance development. "The failure of entomologists generally to anticipate the development of resistance to insecticides as a consequence of one of the basic tenets of biology- the principle of natural selection" said by Smallman (1964). The rapid and large- scale usage of insecticides lead to the development of resistance.

Wilson (1974) from Division of Land use research, CSIRO, Canberra city (Australia) testified the development of resistance in lepidopteran pests, in the 19<sup>th</sup> century itself. *Helicoverpa armigera*, which was a widespread crop pest, had developed resistance to DDT and taxoaphene.

In the famous book entitled “Changing Role of Insecticides” Metcalf (1980) from Department of Entomology, University of Illinois has reported the problem of resistance. The insecticides have caused harm from bacteria to mammals and human beings. The number of species of arthropods developing resistance to insecticides showed a huge rise in the DDT era. DDT was which was initially used in military of United states for the control of malaria, typhus, but later on due to its toxic effects, there was a strict ban imposed. The toxic effects of DDT included the development of resistance in different insect families belonging to the class Arthropods. The number of cases of resistance in Arthropod families kept on increasing. The data reflected 12 arthropod families affected by resistance in 1948. This increased to 16 families in 1951 followed by 25 families in 1954. There were then 76 families resistant by 1957 rising to the number of 137 families. Lastly the values of 159, 224 and 364 number were attained in the years 1960, 1963 and 1976 respectively.

Gunning and co-researchers Easton, Greenup, & Edge (1984) from Department of Agriculture, The Tamworth Agricultural institute, Australia tested the efficacy of synthetic pyrethroids on different strains of *Helicoverpa armigera*. There was resistance developed in some of the strains of the insect pest from Emerald, Queensland in Australia. There was 50-fold resistance developed against Fenvalerate and 10-fold resistance against Permethrin.

In lepidopteran pest *Plutella xylostella*, there were studies carried out in Department of Entomology, University of Hawaii. Tabashnik, Schwartz, Finson, & Johnson, 1990 reported that there was development of resistance to *Bacillus thuringiensis*. The lethal concentration values for the susceptible population had much higher as compared to the resistant population (25-30 times).

In continuation of this research, Tabashnik, Cushing, & Johnson (1987) from Department of Entomolgy, University of Hawaii tested the efficacy of DDT, Diazinon, Permethrin and Fenvalerate. The maximum resistance ratios at LC50 were 130 for DDT, 15 for Diazinon, 5 for Permethrin and 3 for Fenvalerate. Hence the cases reported were increasing constantly, year by year.

Alfonso-Rubí, Ortego, Castañera, Carbonero, & Díaz (2003) reported cross resistance spectrum of malathion- resistant strain of *Sitophilus oryzae* (L.). These were all reported from different parts of world like China, Japan, India, and The United States of America.

Resistance development in all the classes of pests was slowly developing with the gradual increase in usage of insecticides belonging to various groups. The future was less known to the farmers due to less knowledge about the negative impacts of these insecticides and high yields of the crops. The quality of life was being compromised by the rampant use of such insecticides.

Resistance studies were being conducted in different parts of the world after the reports of the scientific community and the agriculturalists. There was a widespread research initiated in all countries of world. Due to this there was awareness created, but it took a lot of time to understand the effectiveness of any insecticide which was sprayed by farmer in lure of getting control of various pests

Cahill and his co-researchers Byrne, Gorman, Denholm, & Devonshir (1995) from Department of Biological and ecological Chemistry, IACR- Rothamsted, Harpenden, United Kingdom performed an extensive research work in laboratory. Their work was on resistance in 11 populations of *Bemisia tabaci* (Whitefly). Insecticides belonging to different groups like Organophosphates and pyrethroid were selected. Insecticides like Bifenthrin, Etofenprox, Chlorpyrifos, Profenofos, Monochrotophos and Profeno cyper mix were used. Organophosphates and Pyrethroids indicated high level of resistance.

Tang, Gong, & You (1988) from various institutes of university in the region of Beijing and China, did a collaborative work. They stated that insecticide resistance had begun in early 1960's, when Parathion and Demeton (phosphorothioate insecticide) failed to control different pests like cotton *Aphis gossypii* and BHC failed to control the paddy stem borer, *Scirpophaga incertulas*. By the year 1986 the resistance cases reported were significantly increased and this was an alarming situation for the entire country of China. The species, *Aphis gossypii* showed resistance to Demeton ( 6-12 fold), Parathion (23 fold), Dimethoate (5 fold), Phosphamidon, an organophosphate (11 fold),

Carbaryl (9 fold), Deltamethrin (11- 100 fold) and Carbofuran (10-30 fold) in different provinces of China like Hebei and Shanxi (1964), Shanghai (1975-1977), Shandong(1985), Henan and Hubei (1986) respectively. Another lepidopteran pest like *Heliothes armigera* had developed 115-136-fold resistance against DDT in the provinces of Henan and Hubei in the year 1982. Similar cases of resistance were reported in different countries in different pests for varied classes of insecticides.

Xianchun and co-researchers (1997) from agriculture Universities in various provinces of Nanjing, Jiangsu Zhejiang, Anhui Province, China exhibited piece of research work around resistance development. In their study, they reported resistance against the pest *Pectinophora gossypiella* in different strains belonging to Qunli (Lishui County, Jiangsu province), the four field strains from Anqing (Anhui province), Jiangling (Hubei province), Cixi(Zhejiang province) and Tongzhou(Jiangsu province) It had developed 185, 6.7, 698 and 249-fold resistance, respectively, to Deltamethrin.

## **2.2 Insecticide resistance- The Indian Scenario**

In India, the resistance had been developed in various pests, which were important for public health. Rajindar, P., Sharma, M. I. D., & Krishnamurthy (1952) from Gurunanak Dev University, Amritsar, Punjab reported, the major pests affected were *Culex fatigans* and its different strains.

Due to the outbreak of malarial diseases, there was usage of DDT which later developed resistance in various insect pests. The cases of resistance were reported in different parts of India, which started from Uttar Pradesh, Bihar, Maharashtra, Gujarat, some parts of Tamilnadu.

Verma, A. N., & Sandhu (1968) from Punjab Agriculture University, Ludhiana, reported that there was failure of control against the resistance species of *Plutella xylostella* (Diamondback moth) in Punjab, Haryana against the insecticides sprayed to control the pests. The insecticides mainly belonged to the classes of Pyrethroids, Organophosphates and Carbamates.

Pradhan, S., Jotwani, M. G., & Sarup (1963) showed the appearance of pesticide resistance of DDT and BHC in agriculturally important pests like Singhara beetle *Galerucella birmanica*.

Mehrotra (1989) from Division of Entomology, IARI, New Delhi, summarized the phenomenon of resistance appearing in 27 insect pests. 14 were pests of public health importance, 6 pests were belonging to stored pests' category and 7 were dominant pests of agricultural crops. The insect pests were Singhara Beetle, Tobacco caterpillar, Diamond back moth, Gram pod borer, Aphids and Jassids. The insecticides against which the resistance had developed were mainly DDT, BHC and organophosphates.

There were reports of resistance even in the stored grain pests. Bhatia and SK Pradhan (1972), also reported resistance developed in *Tribolium castaneum* against DDT. Bansode and Bhatia (1976) tested the efficacy of Malathion in rice weevil the grubs had developed resistance against insecticide Malathion. Similarly, Sharma, D. R. and Kalra (1998) observed and reported rapid increase in resistance developed in *Trogoderma granarium* against Malathion.

Ramakrishnan et al., (1984) from Division of Entomology, IARI New Delhi reported resistance in Lepidopteran pest *Spodoptera litura* developed against different insecticides Malathion, Pyrethrum, Lindane, Endosulfan and Carbaryl. The values came out be 5.7-fold, 14.7-fold, 16.3-fold, 85.9-fold and resistant respectively in the district of Andhra Pradesh in southern part of India. Hence the resistance had developed against pyrethroids and organophosphates.

There were different reports of resistance indicated by different locations in various institutions. Efficacy of HCH (Hexachlorocyclohexane) was tested against *Spodoptera litura* by Srivastava, B. K., & Joshi, 1965. After this, there were cases of resistance were reported in states of Haryana and Andhra Pradesh in *S.litura* against HCH, Malathion and carbaryl by (Ramakrishnan et al., 1984) from Indian Agricultural Research Institute, New Delhi.

In the year 1976, there were reports of resistance in Diamond back moth *Plutella xylostella* by Chawla, R. P., & Kalra in 1976 from Department of Entomology, Punjab Agricultural University, Ludhaina.

There was 38.4 fold resistance observed in *Corcyra cephalonica* for the insecticide Lindane (Shukla, R. M., & Srivastava, 1982). As the years passed, in 19<sup>th</sup> century, more and more cases were reported in various pests-lepidopterans, storage pests, beetles, aphids, whiteflies and the list was adding exponentially. There was resistance developed in *Tribolium castaneum* against DDT to the extent of 2.3- fold and Malathion to the extent of 37.8- fold in the year 1971 (Bhatia, S. K., Yadav, T. D., & Mookherjee, 1971).

In the 20<sup>th</sup> century the indications of insecticides resistance were reflected from each part of India. Hence slowly the impact of resistance development was covering a wide spectrum of the biological community ranging from house pests to agricultural pests and also extended to animals. The scenario was widening day by day, year by year. Similarly, there were cases of resistance reported for different pests in various parts of India like Southern India, Western India and Northern parts of India.

There was resistance developed in *Bemisia tabaci* (Whitefly) in the region of Guntur, Andhra Pradesh. It had developed the resistance of 3.37, 3.12, 1.59 and 1.41-fold resistance to Cypermethrin, Monocrotophos, Acephate and Triazophos respectively at LC after the year 1993 (Balakrishnan, N., Subbaratnam, G. V., & Madhumathi, 2002).

Dhuria & Gujar, 2011 from Division of Entomology, IARI, New Delhi showed the first ever case resistance evolved in field population of *Pectinophora gossypiella* (Pink bollworm). This resistance was against Bt toxin Cry1Ac. It was observed in the district of Amreli, one of the districts of Gujarat in western India. The median lethal concentration of Cry1Ac for five-day-old larvae (LC50) was significantly higher for insects derived in 2008 from Amreli than for any of the other field populations tested from four locations in India named Adilabad in Telangana, Akola in Maharashtra, Delhi and Guntur in Andhra Pradesh. The LC50 values being 0.037ppm, 0.059 ppm, 1.54 ppm, 0.042 ppm and 0.056 ppm in Adilabad, Akola, Amreli, Delhi and Guntur. Hence these were the various reports of resistance from various locations.

In yet another studies, there was efficacy testing of some insecticides for the population of *Leucinodes orbonalis*. This study indicated the values of 0.1% Spark (combination of deltamethrin and triazophos), 0.07% Polytrin

(combination of cypermethrin and profenophos), 0.09% Lethal super (combination of cypermethrin and chlorpyrifos). The results showed that Spark was the most effective insecticide combination. Thus, such studies showed the effectiveness of insecticides combination in controlling the fruit borer (Kumar, B. A., Rao, B. N., & Sriramulu, 2000). But injudicious use, may have developed resistance in the pest in near future. Hence it was recommended by the scientists working on such research areas, to limit the usage and strictly to be used according to the formulated doses.

Thus, in India, various states in northern, southern, western and eastern states had started to report the insecticide resistance cases. There were many states from southern India like Tamilnadu, Andhra Pradesh, Hyderabad, Telangana, Kerala, and its villages, which had indicated the resistance levels slowly increasing in economically important crop- pests. Similarly, on the western side of India, the states like Rajasthan, Maharashtra, and Gujarat had started reporting about the insecticide resistance scenarios in various pests which were attacking the economically important crops. From the 19<sup>th</sup> century onwards, the usage of insecticides to control these pests, was at the peak. Similarly, on the eastern and northern side the states like Assam, Bihar, Madhya Pradesh, Punjab, Haryana was also seeing the gradual development of insecticide resistance in various pests. In lure of getting quick control, the farmers were using the pesticides, without understanding the dosage labels, and this majorly led to resistance development. For some pests, which were polyphagous, the resistance was observing a frame shift from one crop to another. This was becoming even more dangerous, day by day, year by year.

Peshin, R., Kranthi, K. R., & Sharma, 2014 from different institutions did a collaborative work. These institutions were University of Agricultural Sciences and Technology of Jammu, Chatha; Central institute for Cotton Research, Nagpur and Krishi Vigyan Kendra from Jammu, Chatha. They stated that Pesticide use increased from 10,993 metric tons in the mid-1960s to approximately 80,000 metric tons in the 1990s which were called the pesticide era, as there was highest usage of pesticides in various regions of India. The major insecticide groups were Organophosphates, Carbamates, Synthetic Pyrethroids and chlorinated hydrocarbon insecticides. Resistance was likely to

begin with the first application of insecticide, but the rate of resistance development was very slow which went unnoticed for several years.

Out of all these resistance cases, the most acute was that pest which had highly affected the economically important crop i.e cotton. This pest was *Spodoptera litura*, commonly named as the tobacco cut worm. Hence my focus was shifting slowly to this pest and the damage caused by this pest in various regions (India and outside India).

### 2.3 Insecticides used against pest *Spodoptera litura*

Table 1 Summary of insecticides sprayed in India against *Spodoptera litura*

| Sr. no | Insecticide name   | Location                 | Efficacy/Resistance developed if any  | Year      | Reference   |
|--------|--|--------------------------|---|-----------|---|
| 1      | Endosulfan, Carbaryl, Malathion                            | West Bengal              | Resistant   | 1970      | Mukherjee, A. B., & Srivastava, 1970                            |
| 2      | Endosulfan, Carbaryl, Malathion                            | Haryana                  | Resistant   | 1971      | Verma, A. N., Verma, N. D., & Singh, 1971                       |
| 3      | Endosulfan, Carbaryl, Malathion                            | Andhra Pradesh           | 56- fold resistance   | 1984      | Ramakrishnan et al., 1984                                       |
| 4      | Endosulfan, Quinalphos                                     | Andhra Pradesh           | 1-13-fold resistance  | 1997      | Armes, N. J., Wightman, J. A., Jadhav, D. R., & Ranga Rao, 1997 |
| 5      | Cypermethrin, Chlorpyrifos                                 | Andhra Pradesh           | 45-148- fold resistance   | 1987      | Kranthi et al., 2002  |
| Sr. No | Insecticide name   | Location                 | Efficacy/ Resistance developed if any   | Year      | Reference   |
| 6      | Endosulfan   | Karimnagar (North India) | 92-fold resistance  | 1998      | Kranthi et al., 2002  |
| 7      | Endosulfan   | Bhatinda                 | 27-fold resistance  | 1998      | Kranthi et al., 2002  |
| 8      | Chloranthranilide<br>Flubendiamide,<br>Emamectin benzoate, | Gujarat                  | 0.006% concentration – 93.58% mortality<br>0.001% concentration- 93.17% mortality | 2011-2012 | Bhadane, Kumar, & Acharya, 2016                                 |

|    |  |                        |   |      |  |
|----|--|------------------------|---|------|--|
|    | Cypermethrin,<br>Chlorpyrifos  |                        | 0.005%<br>concentration-<br>92.87% mortality<br>0.016%<br>concentration-<br>84.95% mortality<br>0.05%<br>concentration-<br>83.80% mortality |      |  |
| 9  | Flubendiamide  | Raichur<br>(Karnataka) | LC50 – 2.66 ppm<br>on castor, 2.81 ppm<br>on sunflower, 2.82<br>ppm on groundnut,<br>2.86 ppm on onion,<br>2.90 ppm on<br>cabbage           | 2014 | Tukaram, A.H.,<br>Hosamani,<br>A.C., Naveena,<br>R.,<br>Santoshagowda,<br>2014 |
| 10 | Chloranthranilide<br>Flubendiamide<br>Spinosad<br>Novaluron<br>Chlorpyrifos<br>Emamectin<br>Benzoate | Junagadh<br>(Gujarat)  | Relative toxicity<br>0.69<br>0.86<br>0.17<br>0.65<br>1<br>2.84  | 2015 | Nukala &<br>Acharya, 2015  |

The various insecticides used in lure of getting control over the notorious pest, *Spodoptera litura* are listed as the below table. These values are based on independent research works carried by different scientists in different regions of India. The number of sprays done, in these regions and the resistance developed against these insecticides are summarized in the below table (Table 1). Various insecticides were used in every nooks and corner of the world for brining control on the pest through Chemical method of Integrated Pest Management strategy. It was unfortunate to see the increasing trend in the usage of insecticides belonging to various groups.

Hence in this manner, the pattern and the types of insecticides used for control of *S.litura* had become very prevalent in all the regions of India. It had become need of hour to study about the resistance pattern of selected insecticides in this pest, as it was very little known to the scientist's community, which could then be passed to the agricultural farming community. Moreover, less knowledge about insecticide groups according to their individual modes of action, improper mixing of insecticides without understanding the labels of pesticides, were all the points which gave me inspiration to work in this area.

## **2.4 Damage caused by *Spodoptera litura* in Vadodara (Gujarat, India)**

During the agricultural survey of the fields around the district of Vadodara, there were some remarkably important things noted down. The district of Vadodara was covered by agricultural fields on all the outer sides. These areas were Chhani, Savli, Waghodia, Padra, which were small talukas having a small population mainly of farming community. But along with this, there were various industries in these areas. The industrialization had its pros and cons. The harmful gases released by these industries had a negative impact on the crops in surrounding areas. When the farmers were interviewed for the type of insecticides used for the control of this pest, there were some stories unfolded slowly. The farmers had little knowledge about the resistance being developed against the insecticides which were used to control the pest.

In different crops like Cotton, Castor, cabbage, maize there were different insecticides used. These ranged from Cypermethrin, Chlorpyrifos, Spinosad, Emamectin benzoate, Chloranthranilide, Abamectin, Avermectin, Flubendiamide and a lot more of them. These insecticides belonged to various groups like Carbamates, Organophosphates, Pyrethroids, cyclodeines. The farmers were totally unaware of modes of action of these insecticides, and there was spraying of tonnes of these insecticides.

Just because they were giving a good control on the pest. *Spodoptera litura*, was attacking the castor at 2-3 leaf stage, while it attacked cotton when it was 10 day old. Similarly, in maize, the pest attacked at the time of whorl formation. Hence it used to go unnoticed sometimes to the farmers. In some of the fields of Castor in Waghodiya district, there were some specific patches of the entire field which were damaged completely. The egg masses were seen on underneath leaf of Castor and by the time the farmer realized that it was the attack of this pest, there were 1000's of hatching larva emerging and infesting the entire field. In some fields of Savli and Chhani, there were pupae of this pest seen in soil. Thus, studies of resistance had become vital. The amount of resistance developed in this pest and the generation turn-over was very less known.

The damage caused by this pest had created a concern in local farmers. In response to this situation, they switched to spraying of various classes of insecticides to the agricultural crops. The sprays done for the control had other detrimental effects which were not foreseen by the local people as well as farmer community. The residual limits of these insecticides were also varying between 30 -45 days. This was very harmful from the point of view of human health, as well as soil health. As the soil had traces of these insecticides leached after non-judicious and back to back sprays of pesticides.

Hence the practical surveys as well as literature surveys were very helpful for the background of the whole research studies. The review of literature showed to what extent the work has been done in the field of resistance. There was a need to even work more in this area, so that such studies could be helpful for in the practical application – The scenario in fields.

The insecticides mentioned earlier namely Cypermethrin, Chlorpyrifos, Spinosad, Emamectin benzoate, Chloranthranilide, Abamectin, Avermectin, Flubendiamide belonging to various groups like Carbamates, Organophosphates, Pyrethroids, cyclodeinines were extensively used in different areas of Gujarat. The farmers had very less knowledge about the mixing of pesticides and its applications.

Hence literature review played an important role in knowing the background of the work done in the field of insecticide as well as the toxic effects caused by the same in long run.