3.1 INTRODUCTION

For this research project it was necessary to find out from the available sources, data on the pesticide use and Indian agrochemical companies. A detailed literature review was carried out. The research documents, articles and papers listed under reference were reviewed. The findings are summarized below:

Pratik Kadakia, Jeffry Jacob and Mandep Singh Sandhu (2011), of Tata Strategic Management Group (Reference 71), starts with the statistics that India’s present population of 1.18 billion will reach 1.45 billion by 2030. At the same time per capita land is steadily decreasing. They also pointed out that the average yields of crops in India are much lower than the global standards. Moreover, per capita pesticide consumption in India is very low (0.6kg/hectare) as compared to 7 kg/ha in USA and 13 kg/ha in China.

In this paper, the authors started with an introductory note on agrochemicals. The important categories of crop protection chemicals were explained.

Insecticides are used to protect crops by either killing insects or preventing their attack. Fungicides are used to prevent the crops from fungal attack.

Herbicides or weedicides are used to prevent the growth of unwanted weeds.

Biopesticides are derived from natural substances such as animals, bacteria or plants.

Amongst other type of products are nematocides, rodenticides etc are used during storage of crops.

As per Government of India estimate in 2002, crop losses due to non-usage of pesticides were Rs 90,000 crores. The current estimate of loss is Rs 1,40,000 crores (Reference 87).
It has been estimated that the food grain production can go up by 33% from 3 trillion tons to 4 trillion tons by proper usage of crop protection products.

The report states that the global crop protection market size has increased from $25.8 Billion in 2001 to $43.2 Billion in 2009. It then gives detailed global data on pesticide consumption. The report states that the challenges faced by global crop protection industry are market saturation, evolution of biotechnology, stringent Government regulations etc.

In the report, there is detailed discussion on Indian market, industry structure, domestic consumption, product category wise distribution of domestic crop protection market, crop-wise distribution, state-wise distribution, important players and competitive landscape, distribution and sales channel, import/export statistics, future outlook, key growth drivers, key trends and key challenges. The report also profiles few top companies.

M. J. Khan (2012) Editor, Agriculture Today (Reference 51), interviewed, Mr. R. D. Shroff, Chairman, United Phosphorus Limited. UPL is the largest pesticide manufacturer, formulator and exporter in India. It has successfully done backward and forward integration. In an interview, Mr. R. D. Shroff, Chairman of United Phosphorus, gave his views on the importance of pesticide in Indian agriculture. He said: Indian pesticide industry is growing well and the market is expected to grow more than double by 2017. Newer and better products are coming in the Indian market. He feels that with training and education of farmer, India will be able to get rid of poverty and hunger. People responsible for marketing duplicate and spurious pesticides must be punished. Organic farming will result in low yield and increased price. Pesticide companies are making the manufacturing process safer and eco-friendly.

Pradeep P. Dave (2010), President, Pesticide Manufacturers and Formulators Association of India (PMFAI), in his presentation (Reference 69) at China Agrochemical Conference held in Shanghai, informed that the Indian crop protection market consists of Cotton 27%, Fruits and Vegetables 21%, Rice 21%, Wheat and Cereals, 10%, Soybean and Ground nut 4% and others 17%. The crop yields in India are significantly less
compared to the world standard. The advantages of India with respect to agrochemicals are strong domestic market, cost leadership in generics production, easier registration procedure for export and growing awareness about environment, safety and health. The importance of cooperation between India and China were stressed. The two Asian countries should not look at each other as competitor, but should take collaborative approach and remove barriers for Trade and Technology transfer.

**Stephanie A. Toth (2011)** wrote (Reference 88) that population of India has crossed 1.2 billion in 2011 and by 2030, India will become the most populated nation, surpassing China. Currently, the agrochemical market in India is about $3.7 Billion with more than half coming from domestic sales. Agrochemical companies like Krishi Rasayan, AIMCO Pesticides, Willowood are launching new products in the market.

**S. Shanker (2008),** in his report (Reference 87) writes that the Agrochemicals Policy Group has estimated that the crop loss due to pests in 2007 was more than Rs 1,40,000 crores in India. The Group has advocated prudent use of pesticides which will not only cut losses, but will also enhance productivity.

Mr. Ban Ki-Moon, UN Secretary General, said food crisis is looking inevitable in the world and called for efforts to increase production. As per the Chairman of the Agricultural Policy Group crop loss in India was due to the fact that only 25% of the total cultivated area was treated with pesticides.

A comparison of pesticide use in different countries show that, the level of pesticide use in India was only 0.48 Kg per hectare, as compared to 3 Kg in Europe, 4.5 Kg in US and 17 Kg in Taiwan. As a result, crop yield in India is one of the lowest in the world.

**Revati Kasture, Divyesh Shah, Prajka Karnik (2010),** in their report (Reference 79) reviews the performance of the Indian pesticide industry during 2007-08. It starts with the pesticide industry overview followed by industry features, safety aspects, demand drivers, statistical data on import and export etc.
B. Vasantraj David and Gangadharan Shankar (2012), writes (Reference 9) that the global market for pesticide in 2010 was 44 Billion US dollar. In India, cotton and paddy account for 48% of the total pesticide market. Andhra Pradesh has the largest share of pesticide use, accounting for 22%, followed by Maharashtra (17%). Some of the products which have been registered in India include Acetamiprid, Bifenthrin, Buprofezin, Clothianidin, Difenthiuron, Fipronil, Flubendamide, Propargite, Azoxystrobin, Hexaconazole, Tebuconazole, Tricyclazole, Clodinafop Propargyl, Imazathapyr etc.

Recent trend in India is to use combination products, that is, a mixture of different compounds to have broad spectrum and synergistic effect.

P K Patanjali (2011) reviewed (Reference 63, 64) old formulations and examined the advantages of new formulations over the old one. Old formulations like EC, dust, powder etc are replaced by new formulations like SC, CS, Water dispersible granules etc.

Allan Knowles (2011) discusses future (Reference 2) technology for environment friendly pesticide formulations. The old liquid formulation technologies were based on solvents (For example EC). These lead to volatile organic compounds emission and may increase dermal toxicity. Also, there is possibility of fire hazard. These are now replaced by water based liquid formulations such as, SC (Suspension concentrates), EW (Oil-in-water emulsions), SE (Suspo-emulsions), ME (Micro-emulsions), FS (Flowable suspensions) etc.

For solid products, the old formulations included dust formulations like DP, WP. These products led to dust hazards and are difficult to handle. These are now being replaced by water dispersible granules (WDG), water soluble granules (WSG) and microcapsules (CS).

There is also move to safer additives and adjuvants.

G.Nicollier (2011) (Reference 35) critically analyses steps involved in developing new agrochemicals.
He says that the key considerations in finding a new pesticide are: (a) Better efficacy than the existing product (b) New mode of action (c) Business potential (d) Better toxicological profile. A large number of compounds are screened and shortlisted molecules go to the next stage. Here the compounds are tested in greenhouse and in the field under different climatic and soil conditions. The best candidate after this stage then goes for the acute and long term toxicological studies along with environmental and eco-toxicological studies. It is estimated that the cost of introducing a new product is around $250 million. The new products have to compete with generic products. New regulatory systems have also been implemented.

In earlier days, new products were registered worldwide and for many crops. Now the registration is in selected countries and limited major crops. The new agrochemicals are more complex in chemical structure and costlier to make.

**R. Raghavan (2012)** reviewed ((Reference 77) the speeches delivered during 13\textsuperscript{th} Annual Chemical Weekly Business Outlook Conference held in Mumbai on April 24 and 25, 2012.

The Indian specialty chemical market, including agrochemicals, is about $20 Billion and as per Ms Suman Misra, this has the potential to reach $90 Billion by 2020. As per Mr. Dilip Chandwani, the demand will grow, but supply from India may not grow in the same rate and substantial import may be required.

Mr. B.L. Bajaj discussed about the growth strategy for specialty chemical industry and Mr. S. Despande discussed about the importance of innovation for sustainable business growth. Dr. Peter Nightingale spoke about challenges and opportunities in the contract research business. Nisha J. Nair’s topic was key opportunities and challenges for Asian agrochemical industry. She spoke about the strength and weakness of Chinese and Indian companies. Ms Komal Shah discussed about the role of intellectual property in enhancing competitiveness in the chemical industry. Bipulbehari Saha reviewed the status of Indian agrochemical industry.
Timothy N. Troy (2011) says (Reference 96) that worldwide use of fungicides will increase faster as compared to insecticides and herbicides.

Five fungicides which are used in large quantity worldwide are: Azoxystrobin, Pyraoxystrobin, Mancozeb, Chlorothalonil and Copper containing fungicides. The farmers want fungicides that will be useful against a number of diseases, rather than a single disease. BASF, the multinational company has introduced, a new product called Xemium which is a broad spectrum fungicide for a number of crops. Matthew Phillips, partner at the reputed consultancy agency Phillip McDougall says that China, India and Brazil will drive the growth for agrochemicals including fungicides.

Elmo Beyer and Forest Chumley (2000) have analysed (Reference 31) the future direction of crop protection industry. They point out that the strong competitive forces in agrochemical market have led to mergers, acquisitions, joint ventures and alliances. Secondly, biotechnology is playing an increasingly important role for agriculture. The fields of Chemistry and biotechnology have converged, leading to the new discipline chemo-genetics. The crops are engineered with improved features like grain quality, oil content etc by manipulating the gene. These genes can be turned on by chemical switches, at the right time to yield maximum value of the crop.

Claudio Mereu (2011) discusses (Reference 20) about the new pesticides regulation that became effective in Europe.

Regulation 1107/2009, which is concerned with placement of plant protection products in the European market became effective from 14 June, 2011. For obtaining approval of an active substance, the applicant has to submit a dossier of the substance which will include full information on the nature and composition of the substance, details of experiments carried out on crops, safety data and method of measurement.

David Frabotta (2011) reviewed (Reference 24) R&D expenditure in pesticide companies.
As per data collected by his magazine, the compounded average growth rate during 2000 to 2009 has been 2.3% in agrochemical R&D expenditures.

Nigel Utley (2011) reviewed (Reference 58) the product Picolinafen’s use for broadleaf weed control.

Picolinafen is a selective, post-emergence, herbicide for use on wheat, barley and other crops. It is used for control of meadow grasses and annual broad-leaved weeds. The chemistry of manufacture is relatively straightforward. The generic manufacturers can target this product when it becomes off patent.

Stefanie A. Toth (2011) discusses (Reference 89) how illegal trade with counterfeit products are threatening industry profits.

It is estimated that Rs 20,000 crore of spurious pesticide products are going to global pesticide market every year. The incidence of counterfeiting is increasing. Use of these spurious products, damage the crop, and affect the environment and consumer health. In cross country operation, the dishonest traders ship the bottles, label and products separately. These are then assembled together and packed for sale to innocent farmers. Training farmers to buy products of reputed companies from reliable distributors can help. China has recently started cracking down heavily on the counterfeit product manufacturer after its image was tarnished in the international market by illegal trade of spurious pesticides.

S.D. Wale and A. G. Chandlele (2010) evaluated (Reference 83) a new product in the India market, Fipronil 80WG, against diamond back moth on cabbage.

The bio-efficacy of Fipronil 80 WG against diamond back moth on cabbage was studied. All the results showed improved result in reducing diamond black moth population. There was no phytotoxic effect at dose levels upto 300 gram active ingredient per hectare.
Vibhab K. Singh and V. S. Pundhir (2010) carried out (Reference 99) field evaluation of new fungicide molecules for the management of late blight of potato.

Three new fungicide molecules, Mandipropamed 250 Sc @0.16%, Folio Gold @0.2% and Ridomil Gold @ 0.25% were used. The three new products were found to be very effective against late blight pathogen. These products helped to reduce severity of the disease and improve yield.

Yashika Singh, Sanketh Arouje, Tejal Hadkar, Dipshikha Biswas, Janit Mahadevia (2010), in the report (Reference 102), dealt with pesticide consumption in India, industry size and structure, performance of the pesticide industry, characteristics of the pesticide industry, R&D requirement, consumption trend of pesticides, segment wise domestic consumption of pesticides, state wise demand, demand drivers, exports and imports, pesticide regulations, and challenges and opportunities for pesticide industry in India.

D.K. Vaish and A.P. Sinha (2006) wrote a report (Reference 28) on the evaluation of fungal antagonists against *Rhizoctonia solani* which causes yield loss in rice. In addition to chemical pesticide, biological treatment is also helpful for the treatment of the disease. The authors tested 13 isolates of *Gilocladium* spp and 4 isolates of Aspergillus niger.

S. K. Sharma and G. K. Gupta (2006) reviewed (Reference 84) different fungicides against soybean rust. The most serious disease of soybean, known as soybean rust may cause yield loss from 10 to 80%, depending on the severity of attack. Many fungicides have been tried for controlling the disease, of which triazoles have been found to be most effective.

K. L. Jat, P. D. Sharma, M. S. Chauhan and Ravinder Singh (2004) discussed (Reference 43) effect of some new insecticides on whitefly population. The white fly is a serious pest for cotton. Field trials were conducted to study the bio-efficacy of new chemicals Thiomethoxam, Acetamiprid, Difenthuron and Imidaclorpid. These were compared with existing products. It was found that Thiamethoxam and Difenthuron gave much better control of whitefly population as compared to the existing products.
Andrea Klosterman Haris (2008) discusses (Reference 4) the fast progress made by the Indian pesticide company United Phosphorus Limited. UPL is now the fifth largest generic agrochemical manufacturer in the world. Mr. Jai Shroff said, “We believe the way forward for UPL is to grow organically, though there are certain markets like Latin America and China where we may look at more acquisitions to jump-start our business”.

Alan Knowles (2008) reviewed (Reference 3) the current developments in formulations technology of pesticides. There are a wide variety of formulations already available and a number of new types of formulations which have been recently introduced. At the same time, there is increasing demand to introduce formulations which are more safe than the old formulations. The application rate should also be low. It should be also effective in the lowest dosage rate. To meet all these demands, new types of pesticide formulations have been developed. This includes SC, SP, EW and aqueous formulations.

Bikramjit Sinha and Indranil Biswas (2008) discusses (Reference 12) on the importance of bio-pesticides in Indian agriculture and rural development, particularly as a component of the Integrated Pest Management System. But there are certain limitations like availability of bio-pesticides. As per the paper, India occupies a relatively better position in the area of bio-pesticides in terms of growth of usage and research publications in this field.

David Frabotta (2011) expresses the opinion (Reference 23) that globally, the crop input sector is expected to grow and prosper due to the following reason: (a) To meet the requirement of increasing population, more food, feed, fiber and fuel have to be produced. (b) The demand for vegetables is growing at an unprecedented rate in BRIC countries, which will catalyse fungicides business. (c) In Africa, there is ample scope for crop input sector as not much has been done so far.

Secondly, consolidation is taking place in the industry. This will help large companies to become more competitive and price will come back to realistic levels.
Thirdly, efficient companies are diversifying their portfolio. The fungicide business is growing fast. Blockbuster products like Azoxystrobin are going off patent within few years which will open up opportunity for generic companies.

**Stephanie A. Toth (2011)** analyses (Reference 90) reason for inflation in food prices across the globe. The demand for food product is rising across the world. But increase in production rate is not fast enough to match increase in demand. This is resulting in rise in price of food products across the world. Rising prices and increasing demand is suffocating global food supply. Everybody is worried what is going to happen in the near future.

**A. Vivek and P. Venkata Ramana (2011)** discussed (Reference 1) the role of input technology management in food security Issues. There is steady decrease in land available for cultivation over last six decades. This is due to urbanization, industrialization and land erosion. Hence, increasing crop productivity is necessary to ensure food security. Integrated Crop Management will help in this direction. There is a need to make Indian farmers aware about new innovations of agriculture.

**M. J. Khan (2012)**, editor of “Agriculture Today” says (Reference 49 and 50) that pests and diseases affect crop output by reducing production and inflicting diseases. It is estimated that about 15-25% of food produced by farmers are destroyed by pests and diseases. If, worldwide, only the fungal diseases are controlled in five important crops, namely, rice, wheat, maize, potato and soybeans, it can feed more than 60 crore people. There is considerable benefit as compared to cost incurred in using pesticides. The cost benefit ratio is 1:26 in ground nut, 1:7 in rice and 1:12 in mustard.

By 2050, there will be 900 crore people. This will require the farm productivity to increase. Crop protection will assume greater significance in future.

The effect of five weedicides, namely, Alachlor, Glyphosate, Diuron, Pendimethalin, and Paraquat were tested. Analysis of results showed that, Alachlor was best followed by Diuron and then Paraquat.

3.2 PESTICIDES (CROP PROTECTION CHEMICALS):

Pests are any organisms, insects, rodents, weeds, fungus etc which are destructive to cultivated plants and crops.

Pesticides or Crop Protection Chemicals are defined as: “Any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest, diseases, unwanted species of plants or animals causing harm during, or otherwise interfering with, the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal foodstuffs, or which may be administered to animals for the control of insects or other pests in or on their bodies. The term includes substances intended for use as plant growth regulator, defoliant, desiccant or agent for preventing the premature fall of fruit, and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport” (Reference 17).

Pesticides are applied on seed, soil and crops to prevent the damage from pests.

3.2.1 MAJOR CATEGORY OF PESTICIDES:

The major categories of pesticides are:

- Insecticides
- Fungicides
- Herbicides
- Bactericides
- Rodenticides
- Bio-pesticides
- Fumigants
Plant Growth Regulators

3.2.1.1 **INSECTICIDES:**
Insecticides protect crops by killing insects or preventing their attack. Insecticides may attack a particular type of insect or could be broad spectrum. (Reference 13, 14, 34, 45, 57, 67, 68, 78, 80).

3.2.1.2 **FUNGICIDES:**
Fungicides are used to prevent the deterioration of crops due to fungi infestation. They are classified as protectant or eradicant. Protectant fungicides prevent or inhibit fungal growth. Eradicant fungicides kill the pests on application. (Reference 27, 29, 30, 76, 92, 100).

3.2.1.3 **HERBICIDES:**
Herbicides are used to prevent the growth of unwanted plants in a crop field. Herbicides could be selective, which kill the unwanted plants without any harm to the crop, or non-selective, which kill all the plants. (Reference 37).

3.2.1.4 **BACTERICIDES:**
Bactericides are used to prevent the attack of harmful bacteria. (Reference 53, 56, 98).

3.2.1.5 **RODENTICIDES:**
Rodenticides are used to prevent the attack of rodents during storage of crops.

3.2.1.6 **BIO-PESTICIDES:**
Bio-pesticides are derived from natural sources like plants, animals, and bacteria. Bio-pesticides are considered as eco-friendly and easy to use.
3.3 PESTICIDE FORMULATION:

3.3.1 INTRODUCTION

In a pesticide formulation, one or more chemicals which are the active ingredients (A.I.) are mixed with other ingredients which have no pesticide action. (Reference 7, 8, 41, 72, 91).

Active ingredients are the chemicals that control the pest. For example, Propiconazole, Isoproturon, Sulfosulfuron and others.

Inert ingredients are primarily carriers and solvents. For example, Solvent C-IX Distillate in Emulsifiable Concentrates or Surfactants in Glyphosate formulations etc.

3.3.2 WHY PESTICIDES ARE TO BE FORMULATED? (Reference 63, 64)

- Formulations make handling of pesticides easier.
- Inert ingredient make measuring and mixing pesticides simpler.
- To provide for safety
- Makes the Active Ingredient work better
  - Better penetration
  - More selectivity
  - Increased effectiveness
3.3.3 FACTORS AFFECTING SELECTION OF PESTICIDE FORMULATION:

The factors affecting selection of pesticide formulation are:

- Chemical properties of the pesticide
- Physical properties of the pesticide
- Toxicological profile of the active ingredient
- Effectiveness of the pesticide against the pest
- Environmental factors
- Dose required
- Equipment for application

3.3.4 TYPES OF FORMULATIONS

3.3.4.1 SOLID/DRY FORMULATIONS

3.3.4.1.1 Bait or Particulate (B):

- Mixture of large particles with edible material.
- Bait for insects or rodents
- Active Ingredient is normally less than 5 %.

Advantages:

- Easy to spot treatment
- Coverage not critical
- Effective control of pest
Disadvantages:

- Pets and children may eat it
- Odour of dead pest

### 3.3.4.1.2 Pastes, gels and other injectable baits:

- Pastes and gels are mainly used in the pest control industry for ants and cockroaches.
- They are designed to be injected or placed inside small cracks & crevices where insects tend to hide or travel.
- Two basic tools are used – Syringes and Bait guns.

Advantages:

- Odorless, produce no vapour, have low human toxicity and last for long periods.
- Very accurate in their placement and dosage.
- Easily placed in insect harborage for maximum effectiveness.

Disadvantages:

- Can become contaminated from exposure to other pesticides and cleaning products.
- When exposed to high temperature, gels can run and drip. They may stain porous surfaces.

### 3.3.4.1.3 Dry Flowable (DF)/Water Dispersible Granules (WDG):

- A powder which is wettable is formulated as small pellets or granules.
- The percentage of active ingredient is high, often as much as 90% by weight.
- They are mixed with water for application

Advantages:

- Easy to handle.
- Less dust
Disadvantages:
- Tank with agitator is required.

3.3.4.1.4 Dust or Powder:
- In this formulation, active ingredient is mixed with inert ingredients such as talc, chalk, clay, volcanic ash etc and ground into fine powder.
- Concentration of active ingredient is low.
- No dilution needed before use.
- It is widely used as seed treatment.
- Particle size: preferably in the range of 30-50 microns.

Advantages:
- Ready to use.
- Low cost equipment

Disadvantages:
- Dust problem
- May drift
- Does not stick to surface.
- Irritation of eye, nose, throat and skin may happen

3.3.4.1.5 Granules and Pellets:
- Larger particle size.
- Dilution not required before use.
- Active ingredient in the range of 1 - 15% by weight.
Advantages:
- Ready to use
- As particles are heavy, low drift hazard
- Slower break down and longer action

Disadvantages:
- It may not adhere to foliage or other uneven surfaces
- May need moisture to activate pesticide.

3.3.4.1.6 IMPREGNATED FERTILIZER:
- Fertilizer containing insecticides, fungicides and herbicides.
- Agricultural soil application.

Advantages:
- Simultaneous control of pests while applying fertilizer on crops or lawns.
- No dust problem.

Disadvantages:
- Low concentration.

3.3.4.1.7 SOLUBLE POWDER (SP):
- It forms clear solution with water
- Active ingredient is 15-95% by weight
- There are only a few pesticides which are soluble powders

Advantages:
- High active ingredient concentration

Disadvantages:
- Inhalation hazard during mixing
### 3.3.4.1.8 WATER SOLUBLE PACKETS OR BAGS (WSP):

- Pre-weighted amounts of dry active formulation.
- Usually pellets
- Packaged in water-soluble plastic bags that dissolve in water.

**Advantages:**
- Reduce handling hazards associated with highly toxic pesticides.
- Plastic-like covering of bag acts as a barrier.

**Disadvantages:**
- Packets dissolve when exposed to water
- Bags or packets are usually premixed at a specific rate.

### 3.3.4.1.9 WETTABLE POWDER (WP):

- It contains a wetting and dispersing agent and 5 to 95% of active ingredient by weight.
- Forms suspension in water

**Advantages:**
- Easy to measure and store
- Relatively less harmful to plants, animals and surfaces than ECs
- Less absorption by human skin and eyes

**Disadvantages:**
- Inhalation hazard
- Constant agitation
- Difficult to mix in hard water
- Abrasive to pumps and nozzles
- Visible residues
3.3.4.2 LIQUID FORMULATIONS:

3.3.4.2.1 AEROSOL:

- These may be used either as space sprays for flying insects or as residual sprays. Usually these are used against insects, but some are designed for plant diseases or weed killers.

**Advantages:**
- Ready to use
- Easy to store
- Retain potency
- Less absorption by human skin and eyes

**Disadvantages:**
- Very restricted use
- May cause inhalation injury

3.3.4.2.2 EMULSIFIABLE CONCENTRATES (EC):

- It contains an emulsifier and organic solvent.
- The formulation contains 25 to 75% of active ingredient by weight.

**Advantages:**
- Easy to handle, transport, and store.
- A high concentration of active ingredient.
- Little agitation required
Disadvantages:
- Easily absorbed through skin.
- Flammable.
- May be corrosive.

3.3.4.2.3 MICRO-ENCAPSULATED SUSPENSION:
- A formulation which slowly releases active ingredient.
- The liquid or dry pesticide particles are covered by a plastic coating to produce a microencapsulated formulation. Encapsulation makes time release possible.

Advantages:
- It is safer for applicators to mix and apply, particularly when the pesticide is highly toxic.
- Delayed or slow release of the active ingredient prolongs its effectiveness, allowing for fewer and less precisely timed applications.
- The pesticide volatilizes more slowly, and less is lost from the application site.
- These formulations often reduce injury to plants.

Disadvantages:
- Somewhat more expensive
- Breakdown of the microencapsulated materials to release the pesticide sometimes depends on weather conditions.
- May clog nozzle screens

3.3.4.2.4 SUSPENSION CONCENTRATE (SC):
- A colloidal suspension of finely ground active ingredient in a liquid.
- Requires dilution before use.

Advantages:
- Since the powder already is suspended in water, no inhalation hazard.
• Do not require agitation during application due to the extremely small size of the suspended particle.

Disadvantages:
• Active ingredient may settle out of formulation - difficulty in removing last trace of the product from the container.

3.3.4.2.5 SOLUTION (S):

• This is a solution of active ingredient in water.
• Diluted with more water before applying.

Advantages:
• It is easy to handle
• Little agitation required
• Easy for equipment
• No residue left in the container

Disadvantages:
• Readily absorbs into skin

3.3.4.2.6 FLOWABLES / LIQUID SUSPENSION (F/L):

• The active ingredient is impregnated on a substance such as clay and ground to very fine powder. The powder is often suspended in a small amount of liquid.
• The resulting liquid product is quite thick. So further dilution is required.
• These formulations require moderate agitation to keep them in suspension and leave visible residues.
• Flowable and liquid suspension are easy to handle and apply.
• Flowable and liquid suspensions settle out in their containers. It is always necessary to shake thoroughly before pouring and mixing.

3.3.4.2.7 ULTRA-LOW VOLUME (ULV):

• It has very high concentration of active ingredient.
• For application, both aircraft and ground equipment may be used

Advantages:
• There is no plugging of screens and nozzles.
• Not abrasive to equipment.

Disadvantages:
• It requires special equipment for application
• Potential chance of drift.

3.3.4.2 GAS FORMULATIONS:

3.3.4.2.1 FUMIGANTS:

• It contains liquids or solids which are easily volatile and releases gas.
• Some fumigants are solids that sublime and turn into gas in presence of atmospheric moisture.
• Others fumigants are liquids under pressure.
• The fumigants can be used to treat objects (e.g., furniture), structures, commodities, and soil for pest insects and other vermin.
• Example: Phosphine, Chloropicrin, Sulfonyl fluoride.
Advantages:

- It can enter into tight areas where other formulations are ineffective.
- It is effective against many pests.

Disadvantages:

- For application, special equipment and protective clothing is required.
- Besides pests, all living organisms will also be affected, if proper precaution is not taken.

3.3.5 OTHER INGREDIENTS IN PESTICIDE FORMULATION

3.3.5.1 ADJUVANTS:

- Adjuvants are additives that are added to a spray solution in order to enhance or modify the performance of the spray mixture.
- The adjuvants help the pesticide spread more evenly to cover leaves or penetrate better the outer layer of a plant or insect.
- Adjuvants may also help the pesticide stick to a plant in such a way that it can be contacted by an insect.

3.3.5.1.1 TYPES OF ADJUVANTS:

- Surfactants
- Penetrants
- Stickers
- Acidifiers/Buffers
- Drift Retardants
- Spreaders
**Surfactant**

- Surfactant is a word derived from the term "Surface-Active Agent".
- Surfactants are adjuvants that reduce the surface tension of water or increase its wettability. They help the emulsifying, spreading, wetting, or other surface-modifying properties of liquids.

**Properties:**

- Increased absorption and coverage
- Increased wetting in short time
- Nonionic for greatest compatibility

**Silicone Surfactants:**

**Properties:**

- Reduces surface tension, quickens spreading
- Speeds herbicide uptake, improves control
- Low use rates and concentrations
- Herbicide control of even tough, mature weeds.
**Surfactant Blends:**

**Properties:**

- Combines the features of silicone surfactants and Ethylated Seed Oils
- Reduced droplet surface tension plus superior penetration of leaf cuticles
- Used with grass and broadleaf herbicides
- No foaming problems

**Penetrant:**

- A penetrant is a material that enhances the ability of a pesticide to enter a substrate or penetrate a surface.
- Penetrants, such as crop oil concentrates, and seed oils are usually used with herbicides to help enter waxy leaves or woody plant tissue.

**Crop Oils and Crop Oil Concentrates:**

- Used to penetrate waxy leaf surfaces
- Good for evergreen brush, tough weeds
- Works with oil-water emulsifiable mixes

**Stickers:**

- Help pesticides to stay on the plants or other surface.
- Spreader-stickers are combined products that provide better spray coverage and adhesion.
- These are more commonly used with fungicides and insecticides.
**Acidifiers / Buffers:**

- Surfactant blends that reduce surface tension and reduces spray pH
- Increases the performance of some herbicides, for example, Glyphosate

**Drift Retardants:**

- Reduce pesticide drift.
- Small, fine drops with diameters of 100 microns or less tend to drift away from targeted areas.

**Spreaders:**

- Assist in the even distribution of the spray solution over the target.
3.4 GLOBAL PESTICIDE MARKET OVERVIEW

GLOBAL PESTICIDE MARKET SIZE:
The global pesticide (agrochemical) market in 2011 at distributor level is estimated as $50.305 billion (1 Billion $ = Rs 5500 crore) (Reference 65,66). In this, conventional crop protection accounts for $44.015 (which grew by 14.9% over the previous year) and non-crop agrochemical market $6.290 billion (which grew by 7.0% over the previous year). The non-crop sector includes home, garden, nursery, ornamental, turf, rodenticide, wood preservative, stored grain, public health, post harvest protectants etc.

The growth of the global pesticide market during last 5 years is shown in the next table (Reference 65, 66):

**Table No. 2: CROP PROTECTION MARKET VALUE AT DISTRIBUTION LEVEL:**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>SALES (CONVENTIONAL)</td>
<td>33390</td>
<td>40475</td>
<td>37860</td>
<td>38315</td>
<td>44015</td>
</tr>
</tbody>
</table>

3.4.1 LEADING MULTINATIONAL COMPANIES IN AGROCHEMICALS:
The six multinational companies controlling majority share of the global agrochemical market are:

1. Syngenta
2. BASF
3. Monsanto
4. Bayer
5. Dow
6. Dupont.
Other prominent companies are: Nufarm, Makteshim Agan, FMC, Sumitomo, Arysta, United Phosphorus Limited (UPL), Cheminova, ISK, Nihon Nohayku, Nissan, Mitsui Chemicals, Kumiai and Sinochem.

3.4.2 SALES FIGURE OF LEADING MULTINATIONAL COMPANIES:

The sales figure for 2011 of these companies are as follows (Reference 65, 66):

**Table 3: 2011 Sales and Sales Growth data of major global agrochemical companies (excluding seeds):**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Company name</th>
<th>Sales ($ Million)</th>
<th>Sales growth over previous year</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Syngenta</td>
<td>10162</td>
<td>14.5</td>
</tr>
<tr>
<td>02</td>
<td>Bayer</td>
<td>8950</td>
<td>10.0</td>
</tr>
<tr>
<td>03</td>
<td>BASF</td>
<td>5793</td>
<td>8.4</td>
</tr>
<tr>
<td>04</td>
<td>Dow Agro Sciences</td>
<td>4581</td>
<td>12.4</td>
</tr>
<tr>
<td>05</td>
<td>Monsanto</td>
<td>3472</td>
<td>20.1</td>
</tr>
<tr>
<td>06</td>
<td>Dupont</td>
<td>2905</td>
<td>16.0</td>
</tr>
<tr>
<td>07</td>
<td>MAI</td>
<td>2503</td>
<td>14.8</td>
</tr>
<tr>
<td>08</td>
<td>Nufarm</td>
<td>2111</td>
<td>5.4</td>
</tr>
<tr>
<td>09</td>
<td>Sumitomo</td>
<td>1723</td>
<td>7.8</td>
</tr>
<tr>
<td>10</td>
<td>FMC</td>
<td>1465</td>
<td>18.0</td>
</tr>
<tr>
<td>11</td>
<td>Arysta</td>
<td>1463</td>
<td>25.0</td>
</tr>
<tr>
<td>12</td>
<td>UPL</td>
<td>1400</td>
<td>29.9</td>
</tr>
<tr>
<td>13</td>
<td>Cheminova</td>
<td>999</td>
<td>7.0</td>
</tr>
<tr>
<td>14</td>
<td>ISK</td>
<td>441</td>
<td>12.9</td>
</tr>
<tr>
<td>15</td>
<td>Nihon Nohayku</td>
<td>463</td>
<td>11.3</td>
</tr>
<tr>
<td>16</td>
<td>Nippon soda</td>
<td>459</td>
<td>16.5</td>
</tr>
<tr>
<td>17</td>
<td>Kumiai</td>
<td>458</td>
<td>20.8</td>
</tr>
<tr>
<td>18</td>
<td>Sipcam</td>
<td>455</td>
<td>17.3</td>
</tr>
<tr>
<td>19</td>
<td>Mitsui Chemical</td>
<td>445</td>
<td>15.0</td>
</tr>
<tr>
<td>20</td>
<td>Nissan</td>
<td>424</td>
<td>8.2</td>
</tr>
</tbody>
</table>
FIG. 1: 2011 Sales data of major global agrochemical companies (excluding seeds):

![Bar chart showing sales data for various companies in 2011](image)

FIG. 2: 2011 Sales data of major global agrochemical companies (excluding seeds):

![Bar chart showing sales data for various companies in 2011](image)
FIG. 3: 2011 Sales growth data of major global agrochemical companies (excluding seeds):

![Bar chart showing sales growth over previous year for major agrochemical companies.]

FIG. 4: 2011 Sales growth data of major global agrochemical companies (excluding seeds):

![Bar chart showing sales growth over previous year for additional agrochemical companies.]

- Sales growth over previous year

3.4.3 DISTRIBUTION OF PRODUCT CATEGORY GLOBALLY
(Reference 65,66):

The distribution of product category during 2011 was as follows:
- Herbicides: 44.4%  
- Insecticides: 26.4%  
- Fungicides: 26.4%  
- Others: 2.8%

**FIG. 5: DISTRIBUTION OF PRODUCT CATEGORY GLOBALLY**

3.4.4 GROWTH OF AGROCHEMICAL SECTOR (Reference 65, 66):

The growth of the agrochemical sector globally, in different product sectors from 2006 and 2010 are shown in Table 4:

**Table 4: GROWTH OF AGROCHEMICAL SECTOR GLOBALLY**

<table>
<thead>
<tr>
<th>Change</th>
<th>Herbicide</th>
<th>Insecticide</th>
<th>Fungicide</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011/2010 (%)</td>
<td>12.8</td>
<td>16.5</td>
<td>17.3</td>
<td>11.2</td>
</tr>
<tr>
<td>2011/2006 (%)</td>
<td>5.7</td>
<td>9.5</td>
<td>10.1</td>
<td>2.9</td>
</tr>
</tbody>
</table>
FIG. 6: GROWTH OF AGROCHEMICAL SECTOR GLOBALLY
(2011/2010)

Herbicides | Insecticides | Fungicides | Others
---|---|---|---
12.8 | 16.5 | 17.3 | 11.2

FIG. 7: GROWTH OF AGROCHEMICAL SECTOR GLOBALLY
(2011/2006)

Herbicides | Insecticides | Fungicides | Others
---|---|---|---
5.7 | 9.5 | 10.1 | 2.9
3.4.5. GLOBAL DISTRIBUTION OF PRODUCTS BY CROP SEGMENT (Reference 65, 66):

**Table 5: GLOBAL DISTRIBUTION OF PRODUCTS BY CROP SEGMENT IN VALUE TERMS**

<table>
<thead>
<tr>
<th>CROP SEGMENT</th>
<th>% CONTRIBUTION IN VALUE TERMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits &amp; Vegetables</td>
<td>24.4</td>
</tr>
<tr>
<td>Cereals</td>
<td>17.7</td>
</tr>
<tr>
<td>Soyabean</td>
<td>12.1</td>
</tr>
<tr>
<td>Maize</td>
<td>11.3</td>
</tr>
<tr>
<td>Rice</td>
<td>10.5</td>
</tr>
<tr>
<td>Cotton</td>
<td>5.7</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>3.6</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>2.9</td>
</tr>
<tr>
<td>Sugarbeet</td>
<td>1.8</td>
</tr>
<tr>
<td>Sunflower</td>
<td>1.2</td>
</tr>
<tr>
<td>Others</td>
<td>8.8</td>
</tr>
<tr>
<td>Total</td>
<td>100% ($44,015 Million)</td>
</tr>
</tbody>
</table>
3.4.6 CROP SEGMENTS BY GROWTH RATE (GLOBAL) (Reference 65,66):

Table 6: GROWTH RATE OF DIFFERENT CROP SEGMENTS -

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>Fungicide</td>
<td>64</td>
<td>108</td>
<td>68.8</td>
<td>1</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>Insecticide</td>
<td>227</td>
<td>364</td>
<td>60.4</td>
<td>2</td>
</tr>
<tr>
<td>Soybean</td>
<td>Insecticide</td>
<td>990</td>
<td>1454</td>
<td>46.9</td>
<td>3</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>Insecticide</td>
<td>177</td>
<td>246</td>
<td>39</td>
<td>4</td>
</tr>
<tr>
<td>Soybean</td>
<td>Fungicide</td>
<td>1161</td>
<td>1568</td>
<td>35.1</td>
<td>5</td>
</tr>
<tr>
<td>Sugarbeet</td>
<td>Insecticide</td>
<td>58</td>
<td>68</td>
<td>34.5</td>
<td>6</td>
</tr>
<tr>
<td>Maize</td>
<td>Fungicide</td>
<td>398</td>
<td>520</td>
<td>30.7</td>
<td>7</td>
</tr>
</tbody>
</table>
3.4.7 GLOBAL DISTRIBUTION OF PLANTED AREAS BY MAJOR CROP SEGMENTS:

TABLE 7: PLANTED AREA 2011 BY CROP SEGMENT (MILLION HECTARE)

<table>
<thead>
<tr>
<th>CROP</th>
<th>WHEAT</th>
<th>MAIZE</th>
<th>RICE</th>
<th>SOYA</th>
<th>COTTON</th>
<th>RAPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLANTED AREA</td>
<td>221.7</td>
<td>169.3</td>
<td>160.2</td>
<td>103.1</td>
<td>35.7</td>
<td>33.1</td>
</tr>
</tbody>
</table>

FIG. 10: PLANTED AREA 2011 BY CROP SEGMENT (MILLION HECTARE)
3.4.8 COUNTRYWISE SALES OF CROP PROTECTION PRODUCTS:

TABLE 8: COUNTRYWISE SALES OF CROP PROTECTION PRODUCTS ($ MILLION):

<table>
<thead>
<tr>
<th>RANK</th>
<th>COUNTRY</th>
<th>2010 ($ MILLION)</th>
<th>2011 ($ MILLION)</th>
<th>% CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BRAZIL</td>
<td>5838</td>
<td>7002</td>
<td>19.9</td>
</tr>
<tr>
<td>2</td>
<td>USA</td>
<td>6323</td>
<td>6700</td>
<td>6.0</td>
</tr>
<tr>
<td>3</td>
<td>JAPAN</td>
<td>3597</td>
<td>3996</td>
<td>11.1</td>
</tr>
<tr>
<td>4</td>
<td>FRANCE</td>
<td>2447</td>
<td>2664</td>
<td>8.9</td>
</tr>
<tr>
<td>5</td>
<td>CHINA</td>
<td>2020</td>
<td>2306</td>
<td>14.2</td>
</tr>
<tr>
<td>6</td>
<td>GERMANY</td>
<td>1650</td>
<td>1927</td>
<td>16.8</td>
</tr>
<tr>
<td>7</td>
<td>CANADA</td>
<td>1245</td>
<td>1340</td>
<td>7.6</td>
</tr>
<tr>
<td>8</td>
<td>AUSTRALIA</td>
<td>1113</td>
<td>1281</td>
<td>15.1</td>
</tr>
<tr>
<td>9</td>
<td>ARGENTINA</td>
<td>1042</td>
<td>1262</td>
<td>23.2</td>
</tr>
<tr>
<td>10</td>
<td>ITALY</td>
<td>1106</td>
<td>1193</td>
<td>7.9</td>
</tr>
<tr>
<td>11</td>
<td>INDIA</td>
<td>1071</td>
<td>1154</td>
<td>7.7</td>
</tr>
</tbody>
</table>

FIG. 11: COUNTRYWISE SALES OF CROP PROTECTION PRODUCTS ($ MILLION):
3.4.9 GLOBAL NON-CROP PESTICIDE MARKET:
Apart from crop segment, pesticides are also used in non-crop segment like turf, golf course, home lawn, public health etc. In this segment, the sales figure for 2011 was $6,290 million, which is in addition to the crop segment of $44,015 million. The non-crop segment grew by 7% in 2011. (Reference 65, 66).

3.5.1 DEVELOPMENT COST OF A NEW PRODUCT

DEVELOPMENT COSTS PER PRODUCT (USD MN)

<table>
<thead>
<tr>
<th>Year</th>
<th>Cost Per Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>152</td>
</tr>
<tr>
<td>2000</td>
<td>184</td>
</tr>
<tr>
<td>2010</td>
<td>256</td>
</tr>
</tbody>
</table>

3.6 MAJOR PESTS IN INDIA: (Reference 18):

TABLE 9: MAJOR PESTS IN INDIA

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Name of the Pest</th>
<th>Crops</th>
<th>Distribution</th>
<th>Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>American bollworm <em>(Helicoverpa armigera)</em></td>
<td>Chick pea, pigeon pea, pea, black gram, green gram, lentil, soybean, cow pea, sorghum, bhendi, maize, tomato, sunflower</td>
<td>Gujarat, Madhya Pradesh, Haryana, Rajasthan, Punjab, Maharashtra, Karnataka, TamilNadu</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>No.</td>
<td>Pest Name</td>
<td>Hosts</td>
<td>Distribution</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-----------</td>
<td>------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Aphids (Aphis gossypi)</td>
<td>Bhendi, Brinjal, Guava, and Sesamum</td>
<td>The pest is distributed throughout India. It is highly destructive in Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Madya Pradesh and Gujarat</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Red cotton bug (Dysdercus cingulatus)</td>
<td>Cotton, Bhendi, Maize, Pearl millet, Hollyhock, Clover, Sorghum and Kapok</td>
<td>Uttar Pradesh, Bihar, Maharashtra, Andhra Pradesh</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Red hairy caterpillar (Amsacta albistriga)</td>
<td>Sorghum, cotton, finger millet, castor and cowpea</td>
<td>Tamil Nadu, Andhra Pradesh, Karnataka</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Fruit fly (Bactrocera dorsalis)</td>
<td>Mango, guava, peach, apricot, cherry, pear, ber, citrus, banana, papaya, avocado, passion fruit, coffee, melons, jack fruit, strawberry</td>
<td>Throughout the India</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Male fly</th>
<th>Female fly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#</td>
<td>Pest Name</td>
<td>Host Plants</td>
<td>Distribution</td>
</tr>
<tr>
<td>----</td>
<td>----------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>6</td>
<td>Pink stem borer (<em>Sesamia inferens</em>)</td>
<td>Sorghum, maize, rice, wheat, sugarcane, pearl millet, ragi and guinea grass</td>
<td>Throughout the India</td>
</tr>
<tr>
<td>7</td>
<td>Brown plant hopper (<em>Nilaparvata lugens</em>)</td>
<td>Rice</td>
<td>Orissa, Kerala, Assam, Andhra Pradesh, Maharashtra, Tamil Nadu, Karnataka, West Bengal, Madhya Pradesh, Uttar Pradesh, Haryana and Punjab</td>
</tr>
<tr>
<td>8</td>
<td>Leaf eating caterpillar (<em>Spodoptera litura</em>)</td>
<td>Tobacco, tomato, banana, citrus, cabbage, cauliflower, colocasia, cowpea, gram, groundnut, castor, cotton, maize, millets, mulberry, bhendi, peas, rice, sorghum, yam</td>
<td>Throughout the India</td>
</tr>
<tr>
<td>9</td>
<td>Leaf hopper (<em>Amrasca devastans</em>)</td>
<td>Cotton, bhendi, brinjal, beans, castor, cucurbits, hollyhock, potato, sunflower</td>
<td>Throughout the India</td>
</tr>
<tr>
<td></td>
<td>White fly \textit{(Bemisia tabasi)}</td>
<td>Cotton, tobacco, brinjal, bhendi, tomato</td>
<td>Throughout the India</td>
</tr>
<tr>
<td>---</td>
<td>----------------------------------</td>
<td>------------------------------------------</td>
<td>---------------------</td>
</tr>
</tbody>
</table>