UNIT 10 OFF-FARM INPUTS

Structure

10.1 INTRODUCTION

For successful farming, various inputs are required to be applied in the soil and the crops. Small and marginal farmers usually use the on-farm produce and wastes as inputs but for successful commercial farming, major inputs are brought from outside the farm and are called **off-farm inputs**. These inputs are usually energy intensive and produced mainly in the urban regions.

The major off-farm inputs are **fertilizers**, **pesticides, oils**, and **farm machinery**. In the last unit of this block, we discuss the issues and challenges pertaining to the use of these off-farm inputs.

In this block you have developed an understanding of the major environmental concerns pertaining to the use of natural resources in agriculture. In the next block, we discuss ways of meeting the challenges and devising strategies for eco-friendly agriculture.

Objectives

After studying this unit, you should be able to:

- describe different types of fertilizers and their functions in the soil and crops;
- analyse the environmental impact of fertilizer use;
- describe different types of pesticides, and the hazards involved in application of pesticides; and
- discuss the functions and environmental impact of different types of agricultural machineries.

10.2 FERTILIZERS AND CHEMICALS

We are faced today with the challenge of increasing agricultural productivity as land is limited and the population is increasing steadily. An intensive use of land and judicious use of irrigation, fertilizers, high-yielding seeds, pesticides and better agronomic practices seems to be one of the ways out. For example, in India, where the average fertilizer application is as low as 92 kg/ha, one tonne of nitrogen can substitute for 20 to 25 hectares of land under unmanured wheat or paddy. An additional production of one million tonnes of N would mean creation of the equivalent of 20 million hectares of unmanured wheat land.

Thus, a balanced use of fertilizers allows for greater productivity from the same area of land. Fertilizer use substitutes labour and improves its output. For instance, the overhead labour costs on land, tillage, irrigation, weed control and seeding will not vary much whether one produces 10 quintals or 50 quintals yield per hectare. Thus, by the use of fertilizers, the same field can produce 50 quintals per hectare by using approximately the same amount of labour. This is one way of improving the productivity of man hours used in agriculture in South Asian Countries.

The rapid increase in production brought about by the high-yielding varieties could not have been possible without the use of heavy doses of fertilizers. The main superiority of the high-yielding varieties lies in higher response per unit nutrient as compared with local varieties. Moreover, the high-yielding varieties can stand heavier doses of fertilizer without lodging. Thus, more fertilizer means more production.

Fertilizers also increase the efficiency of irrigation water and in fact irrigation without fertilizers is like a resource wasted. On a most conservative estimate, it is evident that if adequate fertilizer is available for the entire irrigated area, food production can be easily trebled as compared to the present level. Thus, the easiest solution of the food problem in these countries lies in the **balanced use of fertilizers.**

However, the indiscriminate use of fertilisers and their negative impact on the environment has led to many misconceptions about their use.

Some Wrong Notions about Fertilizer Use

As far as the use of fertilizers is concerned, a major issue today is that it may spoil the farmer's land, which is so very precious to him and which is his heritage from generations.

What we need to remember is that the balanced and scientific use of fertilizers containing nitrogen (N), phosphorus (P) and potassium (K) will not create any problems but any long-term use of nitrogen or any other single fertilizer alone can cause imbalance of nutrients. Thus, it is very essential to make use of modern tools such as frequent soil testing and keep checking the nutrient status of soil.

Long-term experiments conducted in many parts of India as well as other countries have clearly shown that with balanced fertilization not only continuous high production is maintained but soil fertility is also improved. However, a wrong selection of fertilizers, without the knowledge of the soil test values, can create other fertility problems. For instance, in a highly acid soil or low pH, continuous use of ammonium sulphate may cause reduction of pH and thus may affect availability of many nutrients. Likewise, indiscriminate use of high doses of phosphates can reduce availability of zinc in soils which have marginal supply of the nutrient. It hardly needs to be emphasized that **fertilizer application requires sound knowledge in order to derive maximum benefit.**

The second misconception about fertilizers is that these can be used only for irrigated soils and their use is dangerous for unirrigated soils, particularly low rainfall areas.

As far as unirrigated areas are concerned, if the crop is sown in proper moisture, the fertilizer applied acts as an insurance against drought. **The dose of fertilizer and the method of application has to be carefully selected depending primarily on the rainfall pattern and seasonally available soil moisture conditions**. The foliar application of fertilizers is the surest way of making the best use of fertilizers under unirrigated conditions.

The third notion about fertilizers is that they are expensive. No doubt, fertilizers in developing countries cost much more than in many advanced countries, but the investment on fertilizers produces the best dividends. The dividends increase as the price of the produce increases.

10.2.1 Types of Plant Nutrients and their Sources

Plants require 16 essential nutrients to grow of which carbon, hydrogen and oxygen are taken from the air and soil water, while the other 13 are supplied by the soil. On the basis of the amounts in which these 13 elements are taken up by the crop plants, they are classified as follows:

Primary nutrients (N, P, and K): These nutrients are taken up by the crop plants in the largest amount and are the nutrients most commonly applied almost each crop season unless organic farming is practiced. The materials containing one or more of these three nutrients are known as fertilizers. Some fertilizers do contain some secondary and micronutrients also.

Secondary nutrients (Ca, Mg, and S): The nutrients Calcium (Ca), Magnesium (Mg) and Sulphur (S) are taken up in the next largest amounts next only to N and K, but their uptake is not as high.

Micro-nutrients: There are several micro-nutrients with different functions.

The important functions and deficiency symptoms of essential plant nutrients are given in Table 10.1.

Table 10.1: Plant nutrients, their functions and deficiency symptoms

Type of Nutrient	Functions in Plants	Deficiency Symptoms
Primary Nutrients		
Nitrogen	Synthesis of amino acids, proteins, chlorophyll, nucleic acids, coenzymes	Light-green coloured leaves, lower leaves turn yellow and die in severe deficiency
Phosphorus	Metabolic transfer processes, ATP, ADP, photosynthesis, and respiration; component of phospholipids	Purplish leaves, especially on the margins
Potassium	Involved in sugar and starch formation; lipid metabolism and nitrogen fixation; neutralize organic acids	Marginal burning of leaves, curling of leaves
Secondary nutrients		
Calcium	Component of cell walls; cell growth and cell division; cofactor for some enzymes.	Failure in the development of terminal bud, dead spots in the mid rib of some plants. In corn, tip of the new leaves may be covered with a sticky, gelatinous material that causes them to adhere to one another
Magnesium	Components of chlorophyll, hence essential for food synthesis in plants	Light green leaves and yellowing of leaves similar to N. In rapeseed the leaves are cupped inward

Micronutrients		
Zinc	Formation of auxins and chloroplasts; carbohydrate metabolism; stabilizing and structural orientation of membrane proteins	Stunted growth, pale to white colouration of young leaves white colouration of young leaves-white bud and white streaks in leaves of corn; brownish red (rusty) discolouration of leaves in rice known popularly as "Khaira" disease in rice. Corn, beans, citrus and rice are indicator plants for zinc deficiency
Manganese	Photosynthesis-evolution of oxygen, oxidation-reduction processes, decarboxylation and hydrolysis reactions	Intravenous discolouration green veins against a pale backgrounds; whitening and abscission of leaves, grey speck of oats, marsh spots of peas
Iron	Structural component of cytochromes, perrichrome, and haemoglobin and thus involved in oxidation – reduction reactions in respiration and photosynthesis	Yellowing or whitening of young leaves. In severe deficiency in rice nurseries, or direct-seeded rice or sorghum fields the entire plants may turn pale or white. Pale yellow inter-veinal chlorosis in stem
Copper	Constituent of chlorophyll, catalyst for respiration, carbohydrate, and protein metabolism	Stunted growth, terminal leaf buds die, leaf tips become white, and leaves are narrowed and twisted
Boron	Involved in germination and pollen tube growth; fruiting, cell division, nitrogen metabolism	Terminal buds die, rosette formation, flower or fruit shedding
Molybdenum	Essential component of nitrate reductase and nitrogenase, thus important in N fixation by legumes	Resembles N-deficiency symptom, 'whip tail' disease of cauliflower
Chlorine	Involved in the evolution of oxygen in photosystem II of photosynthesis, raising cell osmotic pressure	Chlorotic leaves, some leaf necrosis.

We also list the sources of primary, secondary and micronutrients (Table 10.2).

Table 10.2: Some commonly available sources of plant nutrients

Nutrient	Material	Content (%)
Nitrogen (N)	Ammonium sulphate	21
	Ammonium nitrate sulphate	30
	Ammonium chloride*	25-26
	Anhydrous ammonia	82
	Calcium ammonium nitrate (Ammonium nitrate with lime)	20.5
	Calcium cynamide	22
	Sodium nitrate	16
	Urea	45-46

	Urea sulphate	30-40
	Urea-ammonium nitrate (solution)	28-32
	Ammonium sulphate	23.7
	Ammonium phosphate sulphate	15.5
Nitrogen Phosphate (NP)	Ammoniated ordinary super phosphate	4
	Monoammonium phosphate	11
	Diammonium phosphate	18-21
	Ammonium phosphate sulphur	13-16
	Ammonium polyphosphate solution	10-11
	Urea-ammonium phosphate	21-38
	Urea-phosphate	17
	*66% Chloride	
Phosphate (P)	Ordinary super phosphate	13.9
	Concentrated super phosphate	1.5
Potassium (K)	Potassium sulphate	17.6
	Potassium magnesium sulphate	22.0
Calcium (Ca)	Agril. limestone	80-95 $CaCO_3$
	Basic slag & delomite	20-45 CaO
	Gypsum	40 CaO
	Single superphosphate	25-30 CaO
	Rock phosphate	40-48 CaO
Magnesium (Mg)	Magnesite	40 NgO
	Magnesium sulphate (Magsulf)	16 MgO
	Devimicroshakti	2 Mg
	Multiplex	10 MgO
	Aries Chelamag	5 Mg
	Dolomite	5-20 MgO
	LCFC slag	7 MgO
Sulphur (S)	Ammonium sulphate	24
	Single super-phosphate	12
	Potassium sulphate	18
	Ammonium phosphate sulphate	15
	Gypsum or calcium sulphate	18
	Iron pyrites	22-24
	Elemental sulphur	85-100
	Magnesium sulphate	13
	All sulphate salts of micronutrients	13-19
Boron (B)	Borax (deca)	11.3
	Borax (penta)	15.0
	Boric acid	17.5
	SOLUBOR	20.5
	Boronated gypsum	1.5-3.0
Copper (Cu)	Copper sulphate	24
	Aries chelacor (Chelated)	6
	Chelekta 25 (Chelated)	12
	Devimicroshakti	5
	Multiplex	8
Iron (Fe)	Ferrous sulphate	19
	Amity clawfer	12
	Chelekta 10	12
	Devimicroshakti	5
	Chelated iron	12

Manganese (Mn)	Manganese sulphate	30.5
	Aries Mn-chel	11
	Chelekta-20 (Chelated)	12
	Devimicroshakti	5
	Multiplex chelated	12
Molybdenum (Mo)	Ammonium mollybdate	54
	Devimicroshakti	5
	Multiplex nitrofix	
Zinc (Zn)	Zinc sulphate	21
	Zinc spray	4
	Amity clawzin (Chelated)	12
	Aries chelamia	12
	Chelekta-5	12
	Devimicroshakti (WSP)	113
	Multiplex (Chelated)	12
	Zimin-F (Chelated)	12
Chlorine (Cl)	Potassium Chloride	48
	NPK Complexes	variable

All nitrogenous fertilizers are produced from ammonia gas. Over 90 million mega grams (Mg) of nitrogen are commercially fixed each year world wide for use as fertilizers.

Fertilizers and Crops

A study conducted by FAO shows that there is a highly significant relationship between fertilizer consumption and crop yields in different countries of the world. A strong parallelism between the fertilizer consumption and crop production has been observed in India as well (see Table 10.3).

Table 10.3: Responses (kg grain/kg N) of different varieties of rice and wheat to nitrogen

	Dose kg N/hectare	High-yielding variety	Local best variety
Rice	40	19.22	17.90
	80	16.53	13.54
	120	12.98	9.20
	160	11.73	7.89
Wheat	20	24.10	13.30
	40	20.20	10.40
	80	12.30	4.70
	100	8.40	1.80

Yield response

A farmer is often disappointed in the response of the crop to the fertilizer because there are several factors other than soil fertility that limit production. Some of them can be removed or overcome but others have to be accepted as a part of the uncertainties associated with farming. Some important factors, which affect the profitability of fertilizers, are:

- tillage practices,
- drainage,
- weed control,
- insect and disease control,
- variety,
- climate,

- irrigation,
- soil pH,
- plant density,
- planting date,
- lodging, and
- dose, method and time of fertilizer application.

The most important factor determining the profitability is the price of the produce. The high-yielding varieties and high prices of the produce have boosted the application of fertilizers in developing countries in the last few years.

You may now like to concretise what you have studied in this section. Attempt the following SAQ.

SAQ 1

Classify fertilizers according to their nutrient content. What are the functions of N P K and what are their sources?

10.2.2 Pollution due to Fertilizers

Fertilizers, no doubt, are important in intensive agriculture. When applied to soil, they meet the nutrient needs of the crop. The fertilizer use efficiency (FUE) depends on the type of management practices adopted. However, the crop does not take up the entire quantity of applied fertilizer. Some quantity is retained by the soil, which can be washed down by erosion or drainage water into water sources or can also be lost into atmosphere in the form of gas. Up to a certain level, all fertilizers are safe but when they exceed a certain limit, they pollute the atmosphere, water sources and soil. The major nutrients that are supplied through fertilizers are nitrogen, phosphorus and potassium and we briefly describe how they pollute the environment.

Nitrogen and **phosphorus** can contribute to both surface and ground water pollution.

Nitrogen is mostly taken up by crops either in the form of ammonia or nitrate. Nitrates are taken up by most crops except paddy, which takes nitrogen in the form of ammonia. Nitrate itself is not toxic. In fact, it has its own medicinal importance in treating kidney stones. Nitrate becomes a problem only when it is converted into nitrite. Nitrates are soluble in water; hence some quantity of nitrates is lost in runoff water leading to pollution of surface water sources like lakes, ponds, tanks etc. In India, farmers have a practice of letting off water from one rice field to another field during flood irrigation. This leads to the loss of applied nitrogen. Thus, the plants do not use a significant amount of nitrogen. The lost nitrogen pollutes both surface and ground water resources.

Phosphorus losses may take place basically through soil erosion by water as it moves down into the soil. Since the soil solution is generally low in phosphorus, its downward movement is also insignificant. The loss of this nutrient by soil erosion can be controlled by different crop rotations.

Nutrient loss of **potassium** mostly occurs through soil erosion and leaching. Control measures like proper crop rotation, avoiding fallow, soil and water conservation measures easily reduce potassium losses and the pollution created by it.

Surface water pollution usually occurs during rainfall. The surface runoff carries sediment, pathogens, chemicals absorbed in sediments, dissolved chemicals (such as nutrients and pesticides), heavy metals, and easily oxidizable organics into adjacent water ways. Dissolved chemicals may also percolate through the soil to ground water, and be discharged in sub-surface flows.

Nutrient pollution of ground water involves sub-surface transport to water bearing zones. The transport and fate of nitrogen in the sub-surface is dependent upon the form in which nitrogen enters and various biological conversions, which may take place. **There are two forms of nitrogen that result in ground water pollution: ammonium ions and nitrates**. Ammonium ions can be introduced directly from fertilizer applic ations, or they can be generated within the upper layers of soil from the ammonification process, i.e., the conversion of organic nitrogen to ammoniac nitrogen.

Denitrification or the reduction of NO_3 to N_2O or N_2 is the only mechanism by which NO_3 concentration in the percolating (and oxidized) irrigation water can be decreased. It has been seen that the agricultural residues of nitrogen and phosphorus enter into the surface and ground waters from run off and leaching losses and from movement of sediments into surface waters. The total amount of the nitrogen and phosphorus that can be lost from agricultural lands depends upon a number of factors. For instance, for the cropland, these include

- application rates,
- soil properties,
- terrain,
- soil erosion,
- crop management practices, and
- amount of rainfall.

Soil sediments enter into water from all agricultural segments, and these act as a transport agent of plant nutrients, heavy metals and pesticides. Any practice that increases or reduces sediment transport affects the pollutant transport accordingly.

It is important to note that the potential environmental effects of pollutants from agriculture often cannot be assessed separately. Various other sources of pollutants lie within the common environmental receptors like streams, rivers, lakes etc. Consequently, synergistic effects occur and associated environmental implications may result. By volume, sediment is the major pollutant in surface water, and it is also the transport agent for other residues. Sediment obstructs the drainage and irrigation canals, fills the reservoirs and lakes, and creates turbidity. Therefore, it is an economic issue to clear the canals and reservoirs that have deposition of sediments.

The surface and ground waters show increased salinity from irrigation practices. However, there is no danger to human health from increased salinity in surface waters. Its control also is primarily an economic issue since it involves industrial water treatment costs. High salinity levels can result in unpleasant taste and hardness, and loss of aesthetic quality. Salt build up in ground water can reduce crop yields, and crop production can become economically infeasible in areas of toxic salt levels.

Increased levels of nitrogen compounds and phosphates in surface waters may lead to excessive algal growth which then increases the dissolved oxygen in water. The resultant stagnation in shallow water can cause increased mosquito population and their consequent threat to health, a decrease in fish populations and other aquatic life, an overall decrease in animal and human water use and taste and odours. If there is a movement of ground water containing high concentrations of nitrates into well waters, then there is a major direct threat to humans from nitrat es. In this context, it is important to note that the upper safety limit has been set at 10 mg of nitrate expressed as N per litre. But many wells as well as water from some surface sources exceed these limits.

You may like to stop for a while to recapitulate what you have studied in this section.

SAQ 2

a) What is the role of sediments in surface and ground water pollution?
b) How do nitrogen residues from agriculture pollute the environment?

10.2.3 Chemicals: Diesel, Petrol and Natural Gas

Oils play an important role in agriculture as direct off-farm inputs for irrigation, running HSD pump sets, HSD engines and tractors as well as in agro-processing industries. Diesel, petrol and natural gas are used to fulfil energy requirements of various stages of production in agriculture.

Fig.10.1: Diesel, petrol and natural gas are used to run agricultural machinery

The total power (energy) available for Indian agriculture through various sources is given in the Table 10.4.

Table 10.4: Sources of energy in agriculture

Sources	Human	Animal	Oil engines / Tractors	Electric engines	Total
Total H.P. (in crores)	1.40	3.78	0.93	0.26	6.37
Percentage of total	22.0	59.0	0.15	4	100

It is important to know about the fuel characteristics as all these fuels pollute air and efforts are on to find a mix of fuels or a fuel that causes minimum pollution.

Fuel quality: A good fuel contains a combination of good volatility, high antiknock value and chemical purity.

Volatility of the fuel: The vaporising of fuel at a given temperature is called ***volatility***. It is measured by means of the distillation test on the fuel. It indicates the operative characteristics of the fuel inside the engine. Petrol which shows lower initial and final boiling points compared to other fuels, vaporises at a lower temperature.

Octane number: It is the standard yardstick for measuring knock characteristics of fuels. The percentage by value of iso-octane (C_8H_{18}) in a mixture of iso-octane and normal heptane (C_7H_{16}) is called the octane number. The higher the octane number, the better is the fuel.

You have learnt in Unit 9 that these fuels are non-renewable sources of energy. It is desirable to minimise their use in agriculture and build up a renewable energy resource based farm economy.

10.3 PESTICIDES

The term pesticide literally means "killer of pests". **A pesticide is any substance used for controlling, preventing, destroying, repelling, or mitigating any pest**. Thus, many chemicals such as attractants, repellents, chemo-sterilants, hormonal agents, etc., are also designated as pesticides, although from a strictly technical viewpoint they may not be directly involved in killing the pest. Recently, terms like agrochemicals or bio-regulators have been proposed to describe pesticides. Many kinds of pesticides are in use today, though they can generally be classified into a few categories.

The agricultural sector uses around 250 pesticides of which 100 are insecticides. In India, insecticides constitute above 80% of total consumption of pesticides, though it is still very low (570 g per hectare) compared to the developed countries. For example, in USA, it is 2.3 kg/ha (4-6 times more than India) and in Japan it is 10 kg/ha (20 times more than India). Although pesticide consumption in South Asian countries is less as compared to Western countries and has not reached alarming levels, yet, the residual effects are already being seen in vegetables, fruits, etc.

Pesticides though applied for pest control also harm the non-targeted groups. Their residues build up in food items and ultimately reach human beings. Many beneficial organisms living in soil like nitrogen fixing bacteria, algae, earthworms, etc. are also affected by application of pesticides. Apart from this, pesticide residues persist in soils for several years and organisms develop resistance to them. Thus, the toxic persistent organic pollutants (POPs) are of great environmental concern. As they move up the food chain, there is an increase in their concentration, i.e., they have high BCF (bio concentration factor) values.

Pesticide use is also associated with pesticide resistance, health damage and loss of biodiversity. Due to wider use of stronger pesticides, an ever-increasing number of species of insects (over 900 now against 182 in 1965), pathogens and weeds are becoming resistant to these chemicals.

10.3.1 Types of Pesticides

Pesticides may be classified in several ways, according to their

- method of entry
- functions,
- mode of action,
- target pathogens, and
- chemical structures.

Some chemicals are legally classed as insecticides but these do not necessarily kill the pest.

Method of entry: Pesticides can enter into the body of the target organism through various channels, and are categorised as stomach poisons, contact poisons, and inhalation poisons or fumigants. This kind of classification has some limitations since, at present, there are many compounds which can act both as stomach and contact poisons, and others which can act in all categories;

Functions: The broad classification of pesticides according to their functions is given in Table 10.5.

Table 10.5: Pesticide grouping according to their broad functions

Pesticides	Functions
Attractants	Attract insects
Chemo-sterilants	Sterilize insects, birds or rodents and prevent reproduction
Insect growth regulators	Stimulate or retard growth of insects, interrupt normal development
Pheromones	Released by one individual and affect the physiology or behaviour of another individual of the same species (e.g., females emit it to call males for copulation).
Repellents	Repel insects, mites and ticks, or vertebrate pests such as dogs, rabbits, birds, deer; prevent damage by rendering the commodity unattractive, unpalatable or offensive.

Mode of action: Pesticides may be classified in two ways - by selectivity and by site of interaction with pests:

- ***by selectivity*** – the degree to which a pesticide discriminates between target and non-target organisms.

  selective : affects a very narrow range of species other than the target pest.

  non-selective : kills a very wide range of plants, insects, fungi etc.

- ***by site of interaction with pest***

  systemic : the pesticide is absorbed by the pest/plant and moves around within the pest/plant system to reach parts of the pest/plant remote from the point of application.

  contact : the pesticide directly affects the parts of the plant, insect, to which it is applied. It causes localized damage to the plant or animal tissue on contact.

Target pathogen: The classification of the pesticides also depends on the pathogens they kill as shown in the Table 10.6.

Table 10.6: Pesticide classification as per target pathogens

Pesticide Class	Acts on
Acaricide/Miticide	Mites
Algicide	Algae
Avicide	Birds
Bactericide	Bacteria
Fungicide	Fungi
Herbicide	Weeds
Insecticide	Insects
Molluscicide	Snails and slugs
Nematicide	Nematodes
Ovicides	Eggs
Piscicide	Fish
Predicide	Predators
Rodenticide	Rodents
Silvicide	Tress and brush
Termiticide	Termites

Chemical structures: Pesticides are classified according to their chemical nature and have been given in Table 10.7 with a few examples.

Table 10.7: Classification of pesticides according to chemical structure

Group	Examples
Organochlorines	DDT group such as DDT, DDD, (TDE), methoxychlor, HCH; texaphene; cyclodienes such as aldrin, dieldrin, heptachlor, heptachlor epoxide, isodrin, endrin, chlordane, mirex
	1. Phosphates such as dichloros, monocrotophos;
	2. Phosphorothionates such as parathion, methyl parathion;
	3. Fenitrothion, diazinon, chlorpyrifos;
	4. Phosphorothiolates such as profenophos; phosphorotiolothioates such as a malathion, dimethoate, prothiophos, azinphos-methyl;
	5. Phosphonates, Phosphonothionates and phosphonothiolothionates such as trichlorfon, EPN, fonofos;
	6. Phosphoroamidates such as monitor, acephate, salithion;
Carbamates	1. Aryl carbamates such as carbaryl, propoxur, carbosulfan, aminocarb, BPMC; 2. Oxime carbamates such as aldicarb, methomyl; 3. N, N-dimethyl carbamates such as pirimicarb;
Pyrethroids	Such as allethrin, tetramethrin, cypermethrin, deltamethrin, fenvalerate, fluvalinate, etofenprox;
Nitrogenous	1.Nicotine; neonicotinoids such as imidacloprid;
Inorganics	Chlordimeform, Sodium fluoride;

GAB Aergics	Avermectins;
Respiratory inhibitors	Electron transport inhibitors such as rotenone, fenazaquin, pyridaben, phosphine; uncouplers such as dinitrophenols;
Insect growth regulators	juvenile hormone mimies (juvenoids) such as methoprene, pyriproxyfen; ecdysone regulators such as tebufenozide; benzoylphenyl ureas such as dimilin;
Chemosterilants	Alkylating agents such as apholate, thiotepa, metepa; antimetabolites such as 5-fluorouracil; antibiotics such as cycloheximide; colchicines; triphenyltin; urea, thiourea; s-triazine compounds;
Attractants	Methyl eugenol; pheromones such as grandlure;
Synergists	Piperonyl butoxide, sesamex;
Fumigants	Hydrogen cyanide, phosphine (from aluminium phosphide); methyl bromide, ethylene dibromide;
Nematicides	Methyl bromide, ethylene dibromide;
Miticides	1. Diarylcarbionols such as dicofol; 2. organic sulphur compounds such as chlorfenson; 3. phenolics such as binapacryl; 4. organotin compounds such as cyhexatin; 5. antibioticssuch as avermectins, milbemycins;
Molluscicides	Metaldehyde, clonitralid;
Avicides	4-Aminopyridine;
Rodenticides	Red squill, phosphorus, barium carbonate, zinc phosphide, anti coagulants such as warfarin;

For effective control of pests in the crop environment, the following general guidelines must be followed:

- Correct identification of pest species,
- Assessment of level of pest infestation,
- Selection of appropriate pesticide for pest species present,
- Application at correct time (Pre-emergence or post-emergence),
- Application of correct dose,
- Adequate treatment of the area,
- Consideration of weather factor (no rain forecast or no strong wind),
- Consideration of age of some pests (e.g., weeds are easier to control when they are young),
- Consideration of ground cover and soil type (organic soil and clay soil absorb pesticides)

We will now discuss the impact of pesticides on the environment. But before studying further, you may like to consolidate your understanding of pesticides.

SAQ 3

a) Define the term pests in relation to agriculture. Give examples.

b) Classify pesticides according to their

   i) Mode of action, and
   ii) Hosts involved.

10.3.2 Environmental Impact of Pesticides

Pesticide usage has aided in increasing agricultural productivity but has also proved detrimental to health and environment.

There are several types of potential hazards associated with the use of pesticides. People exposed to some highly toxic compounds may suffer short-term or long-term health problems. Excessive residues in the environment may contaminate water supplies and lead to lower water quality. They may contaminate our food through excessive residues on sprayed crops. Pesticides may cause injury to the non-target organisms such as bees, birds, other wildlife, and natural enemies of insects. Improperly applied pesticides may cause damage to treated surfaces, or through drift to surfaces adjacent to treated areas. Some pesticides may be phytotoxic, that is, injurious to crops and ornamental plants.

In sum, pesticides result in

- The destruction of non-target organisms;
- Deposition of residues that magnify in food chains and eventually injure predatory animals at the top, including human beings; and
- Direct health effects on pesticide users.

Most pesticides adversely affect the environment including air, soil, water and a large number of living organisms. The major concern related to pesticide usage on natural environment arises from the fact that pesticides can be transferred from their original application sites to other locations. There are numerous transport mechanisms that can lead to surface and ground water pollution, soil pollution and air pollution.

Fig.10.2: Aerial spray of pesticides

Not all the pesticide that is sprayed in a given location actually remains in that area. It is estimated that as much as 55% of the applied pesticide may leave the treated area due to spray drift, volatilization, leaching, run-off, and soil erosion. Some of this drift may move to adjacent areas and contaminate residences, water bodies, other crops, forest trees, and wildlife.

Pesticides when applied to soil may be utilized or lost by different ways. Adsorption of pesticides by soil micro-organisms like nitrification bacteria, soil fungi and actinomycetes affects the processes of nitrification, ramification, decomposition of organic matter etc. Insecticides and fungicides affect these processes more than herbicides. The negative effects of pesticides on soil micro-organisms are temporary and after a few days or a few weeks, populations of organisms generally recover. But care should be taken to apply the pesticides only at recommended levels.

Pesticides like trifluralin, PCNB, DDT, dieldrin, etc.are volatile, i.e., they vaporize and pollute the air.

Pesticides have been detected in ground water in many parts of the world They are known to percolate with irrigation water and pollute ground water. These chemicals, even though present in minute quantities (in parts per billion) can pose a serious threat to living organisms in the long run. In ground water contamination, the pollutant percolates through a top layer of soil, and then penetrates through a protective layer (the unsaturated zone) eventually reaching groundwater either in its original form or as a breakdown product.

This process is usually slow and time consuming during which the pollutant may undergo various physical, chemical and biological modifications. It is very likely that the pollutants, which are being detected in groundwater today, originated from carelessness and indifference to environmental sanitation many years ago.

Several pesticides have been detected in soil and in groundwater. It has been shown that the spread of pollutants in the area occurs by horizontal migration of the organic contaminants deep in the aquifer. Surface water pollution occurs due to runoffs from agricultural fields when it rains.

Once in aquatic systems, pesticides are either broken down to simpler, less toxic compounds, or remain in the medium. They can also move back into the atmosphere by volatilisation and condensation, in which case they recycle back to water bodies by fallout due to wind, rain, snow, and dust storms. The effects of pesticide pollution on aquatic systems depend on the chemical characteristic of the compound, its stability and persistence in water, its water solubility, its potential for uptake and bio concentration into aquatic organisms, and the physical characteristics of the ecosystem, such as size, form, and location.

Pesticides and Non-target Groups

Non-target organisms include human beings, plants and animals in or near a treated area that are not intended to be controlled by pesticide application. Human exposure to pesticides may be accidental, work-related, due to food contamination, improper use in the home, and through contact with non-food items.

There are several ways by which pesticides can enter the body. It can be through the skin (dermal); through the mouth (oral); through the lungs (respiratory); and through the eyes (ocular). Breathing or swallowing pesticides, and spilling or splashing pesticides into the eyes or onto the skin may cause injury. Some pesticides are very toxic and can cause poisoning at low doses, while others, of low toxicity, require substantial amounts to cause injury.

In this context, we should also learn to distinguish between **toxicity** and **hazard**

Toxicity is the innate capacity of a substance to cause injury to living organisms and is characterized in terms of acute, chronic, local, or systemic effects. **Hazard** is a function of toxicity. It involves the likelihood of injury or danger that may arise from the degree of exposure to the chemical under defined circumstances.

Therefore, hazard to human beings must be considered strictly in relation to the chemical's usage. Some highly toxic compounds may be considered safe if their usage involves little or no exposure of the applicator or the people in the vicinity. For example, highly toxic rodenticides are considered safe if used properly, because of little likelihood that people may come in contact with them.

Exposure also depends on the rate of contamination and time. Thus, actual exposure is the absolute amount of pesticide landing directly on the skin and therefore available for absorption, or present in the air and available for inhalation and ingestion in a given time. Long exposure causes more damage and the pesticide may get deposited in the body fat for a long time.

Pesticides on the skin may cause irritation, dermatitis, or more severe injury upon prolonged exposure. When absorbed through the skin they enter the blood stream and are transported to various organs in the body where they can cause internal poisoning. Pesticides that are more soluble in oil or formulated in petroleum solvents are more readily absorbed than those that are water-soluble.

Oral ingestion may occur by accidentally drinking a pesticide, by splashing spray material into the mouth, or by eating contaminated food or beverage. Smoking while using pesticide may also cause ingestion.

Pesticide dusts or vapours may be inhaled during mixing and loading, during aerosol spraying, and during spray applications in general. Upon entering the lungs, they are quickly absorbed and transported to all parts of the body. For this reason, respirators should always be worn while mixing and loading pesticides, and during their application (see Fig. 10.3).

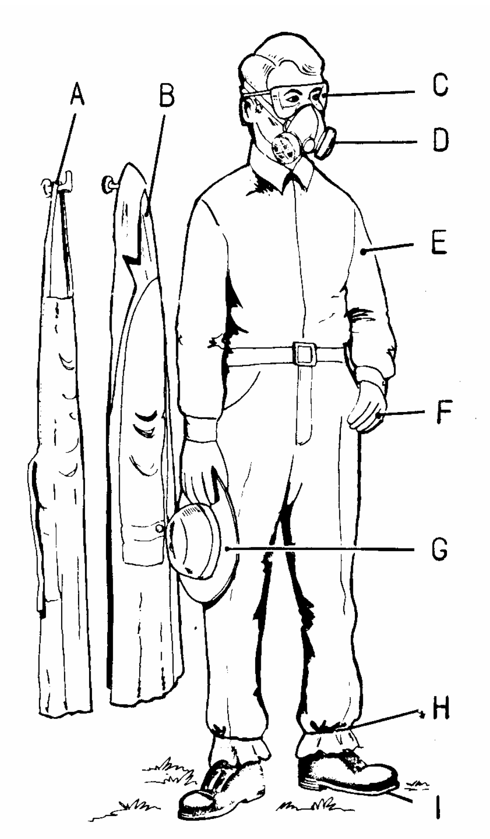


Fig.10.3: Proper gear for spraying pesticides. This includes coats (A, B), goggles (C), respirators (D), jackets (E), gloves (F), hat (G), pants (H), shoes (I)

Serious damage can result from pesticides entering the eyes. Both the pesticides and the organic solvents used to dissolve it can cause serious damage. Besides eye injury itself, the eyes provide another route of pesticide entry into other parts of the body via the blood stream. Pesticide applications from aircraft are more hazardous than ground applications. Of late, a number of insecticides of chlorinated hydrocarbon like DDT, Aldrin, heptachlor, dieldrin have been banned for agricultural use. However, the damage they have already caused to the ecosystem by way of eliminating other animals is enormous. Heptachlor, which was used for fire ant control, killed many raccoons, rabbits, and opossums. The use of heptachlor in seed dressing resulted in the death of some 1300 foxes in England. Dieldrin caused high mortality of fox squirrels, woodchucks, and shrews, and practically eliminated ground squirrels, cottontails, and muskrats from treated areas. Many badgers were also affected after feeding on contaminated wood pigeons that had eaten treated seed. Endrin, another cyclodiene insecticide, proved to be even more toxic to large herbivores. There are no records of wild animals killed from organo-phosphorus or carbamate insecticides, although some insecticides of both groups are quite toxic to wild mammals.

Farm machinery is a major off-farm input that we discuss in the next section. However, we would first like you to attempt an exercise.

SAQ 4

Discuss the short term and long term impact of pesticides on human health.

10.4 FARM MACHINERY

It is commonly believed that farm mechanisation through improved agricultural implements tended to decrease labour employment per hectare. However, as it helped to perform the time-bound operations in time, it made multiple cropping feasible, which, in turn, increased the labour employment. In this way, loss of labour employment due to mechanization was offset by the diversification of cropping. The negative effect of farm mechanization on labour employment could almost be neutralized.

A number of machines are used in various agricultural operations, which we now briefly describe.

10.4.1 Agricultural Operations and Farm Implements

Various agricultural operations and the implements used for them can be classified as follows:

1. **Primary cultivation** involves working the undisturbed soil to loosen it to the required depth and/or to bury trash and to control weeds. Making major soil erosion earth works and land levelling may also be considered under this category. The major implements used for primary cultivation are **country plough**, **mould board plough**, **disc**, **chisel** and **rotary plough**.

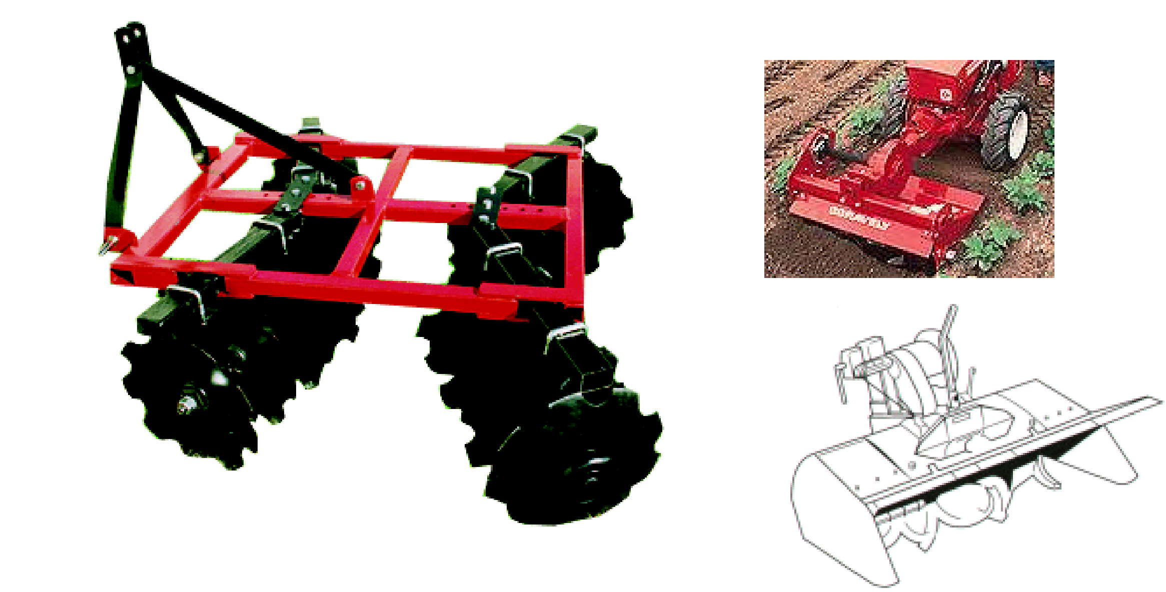
(a) (b)

Fig.10.4: Some implements used for primary cultivation: a) traditional mouldboard plough; b) rotary plough

2. **Secondary cultivation** requires working of the loose ended soil into the required clod size and distribution and providing the correct degree of compaction to give good soil contact with the seed or plant with correct permeability to air and water. Machines used in secondary cultivation are **disc harrow**, **cultivators**, **light harrows**, **rotary cultivators** (powered, non-powered).

3. **Planting and transplanting** involve the planting of the seed and seedlings at the correct depth and spacing in the soil. **Seeders** and **seed drills** are used for this purpose.

4. **Crop upkeep operation** includes protection of crops from pests and providing timely nutrition. **Plant protection equipments** include the **seed treating drum** which is required for treating the seed with appropriate fungicides. The drum is mounted on a shaft and placed on a stand for convenient operation by hand. **Sprayers and dusters** (manually operated as well as electrically powered) are used for chemical control of weeds and other pests such as insect, fungus, and diseases.



(a) **(b)**

Fig.10.5: a) Disc harrow; b) Rotary cultivator

Weeding or **controlling of weeds** to avoid significant competition with the crop is done by **mechanical weeders**.

Fig.10.6: A mechanical weeder

Root zone granular fertilizer applicator is used for providing the correct balance of plant nutrients in the soil.

5. **Harvesting** refers to the collection of the required part of the crop for subsequent use e.g., grass cutting, uprooting root crops or grain crops. Harvesters are quite common on big farms.

6. **Processing** of the raw crop to convert into storable, usable or saleable item is done through **threshers** on a mechanised farm.

(a)

(b)

Fig.10.7: a) Harvesting combine; b) thresher

7. **Transport** of material to the required place has to be done at various stages in the process, e.g.,

   - Machines to the field,
   - Crop to farmstead,
   - Produce to market,
   - Production inputs, (seeds, fertilizers and insecticides) to fields.

There are many types and sizes of farm implements available, which have been designed to perform the tasks listed above more easily, quickly and cheaply than can be done manually. Many of these designs have been developed over considerable periods of time to suit particular human, soil and crop conditions.

Contribution of selected farm equipments to agriculture productivity is shown in Table 10.8.

Table 10.8: Increase in productivity due to use of selected farm equipments

Equipment Used	Increase in Productivity (%)
Seed cum fertilizer drill	10-15
Plant protection equipment	10-20
Harvesting and threshing equipment	5-10
Irrigation pumps	10-30

Apart from machines used for operations on and off the field, devices used for irrigation also fall under this category. These are given in Table 10.9 below.

Table 10.9: Water lifting devices by different powers

Human-powered devices	Animal powered devices	Wind powered devices	Water powered devices	Mechanically powered devices or pumps
A. Swing basket	A. Rope and bucket lift	A. Wind mills	A. Water wheel	A. Displacement pump 1. Reciprocating pump 2. Rotary pump
B. Counterpoise Lift	B. Self-emptying bucket lift		B. Hydraulic ram or hydram	
C. Archimedean Screw	C. Two-bucket lift			B. Centrifugal pump
D. Paddle wheel	D. Persian wheel			C. Turbine pump 1. Deep well Turbine pump 2. Submersible pump
	E. Chain pump			D. Propeller pump 1. Axial flow 2. Mixed flow
				E. Airlift pump
				F. Reciprocating pump

Fig.10.8: Some common water lifting devices

Design considerations

You have seen that agricultural implements, in general, are important for carrying out various operations on the land. A farmer spends two thirds to three quarters of his working time with such implements. The existing farm implements require continuous use of only a few muscles. This tires a farmer quickly. So farm implements should be designed in such a way that a farmer uses as many of his muscles as possible to diminish the load on any single muscle.

Damage to health by the use of unsuitable implements generally becomes apparent only after their sole and excessive use over long periods. The constant use of digging hoes and spades can lead to permanent abnormal curvature of the spine. Similarly, implements with very short handles causes pressure on the chest and vertebral column.

Generally implements consist of a working part and a controlling handle firmly joined together by some connective device. Efficiency of an implement depends on the material, handle, its grip, length and balance. Hence, these factors must be taken into consideration while designing and selecting any implement.

10.4.2 Farm Machinery and the Environment

Tillage machinery and tillage practices can either increase or reduce the problem of soil erosion by air. Machines that tend to pulverize the soil or to diminish the vegetative cover increase soil blowing. To be most effective in preventing soil erosion the tillage equipment should do a god job of creating a cloddy surface and at the same time avoid burying the crop residue. The equipment should create a rough, cloddy, and residue covered surface.

Deep ploughing to depths of 30 to 45 cm has become a common practice in the Western countries to improve the wind resistance of sandy soils. Following the sorting action of the wind, many field surfaces have become extremely sandy. Where they are underlain with fine textured material, immediate benefits are associated with burying the surface material that can be eroded, and bringing silt and clay to the surface. Studies on the methods of controlling wind erosion indicate that certain tools nearly meet specific wind erosion control requirements more than others. Residues, for example, are usually best handled with implements having sweep-type furrow openers. Both bullock drawn and tractor-drawn cultivators, equipped with sweep furrow openers, are suitable for this.

The next best implement is a properly angled one-way disc plough, which leaves the material in a partially standing position. The mould board plough does not meet the requirements for preserving residues on the surface. However, if residues are meagre or absent, the plough, under favourable soil surface conditions, produces a rough, cloddy, wind resistant soil surface.

Disk harrow and other vertical disk type tools are not suitable for creating cloddy surfaces and retaining residue on the surface. Their dual function is to reduce the size of clods and bury plant residues. The greatest surface roughness can be created by a lister; hence this tool is particularly suitable where residue covers are poor. Subsurface tillage implements equipped with straight or V-shaped blades or rods undercut land with the minimum disturbance of surface residues. They may maintain 8 to 90 per cent of the residue on the surface after a single operation. However, these implements do not bring many clods to the surface to prevent soil blowing.

We end this section with an exercise for you.

SAQ 5

Classify different agricultural implements according to their functions.

10.5 OFF-FARM INPUTS AND AIR QUALITY

The use of agricultural technologies affects air quality and air pollution can exert undesirable effects upon agricultural crops and animals. Air is polluted in agricultural activities due to tillage operations, pollutants from open burning, wind erosion and agricultural vehicles used in fields. Harvesting, grain handling and pesticide applications also result in air pollution.

During the tilling operation, dust particles from loosening and pulverization of the soil are introduced into the atmosphere. Open burning of crop residues as well as debris from land clearing operations, represents a potentially significant source of air pollutants from agricultural activities. Ground level open burning is affected by many variables, including wind, ambient temperature, composition and moisture content of the debris burned, as well as compactness of the pile. In general, it can be said that the relatively low temperatures associated with open burning increase the emission of particles, carbon mono-oxide, and hydrocarbons and suppresses the emissions of nitrogen oxides. Particulate emissions represent the primary type of air pollutant resulting from wind erosion. Factors influencing particulate emissions from wind erosion include soil type, precipitation patterns, exposed area and wind speed.

Vehicles used for agricultural operations include diesel-operated pumps, tractors, trucks, etc. The types of air pollutants emitted from such vehicles include carbon monoxide, hydrocarbons, and nitrogen oxides. Harvesting and grain handling can produce large quantities of particulate and hydrocarbon emissions. Further, substantial quantities of pesticides can become air-borne during and following the aerial spraying operations. The key mechanisms for pesticide introduction into the atmosphere include aerial drift and evaporation (volatilisation) from soil and soil and plant surface. Volatilisation is a major pathway of loss of pesticides from soil, and loss is greater from moist soils than from dry soils. The relative amounts of a given pesticide entering the air and surviving to some downwind site depend on the nature of the source (e.g., the type of application in agricultural operations), its physical properties and chemical reactivity, its form once it enters the air, and that which exists throughout the process. One concern pertaining to air borne pesticide residues is related to potential human health effects, particularly for agricultural workers.

Effect of Air Pollution on Crops

In order to understand the effects of air pollutants on agricultural crops, it is necessary to consider the basic structure of plant leaves and the functioning of the various components of a plant leaf. The major plant processes that occur include photosynthesis, transpiration and respiration. Several components of the leaf structure are involved in the photosynthesis process. The leaf veins are involved in moisture and nutrient transport to the leaves from the soil and root system of the plant. The effects of air pollutants on crops must be considered, in terms of environmental factors including temperature extremes, excess water, water deficiency, nutrient deficiency and bacterial or viral disorders.

High temperatures may cause chlorosis, which is reflected by yellowing of the leaves, while low temperatures may also cause chlorosis or necrosis. Excessive water can damage veins of the leaves and lead to plasmolysis, while a water deficient condition is reflected by necrosis. Nutrient deficiencies to plants can cause chlorosis or necrosis, while bacterial and viral disorders may be manifested by plasmolysis. In brief, it can be said that many factors influence the visible response of a given species of plant to a particular pollutant. Among the more important are the age and variety of the plant itself, the concentration of the pollutant, the length of exposure, the vigour of the plant and growing conditions before, during and after exposure. Thus, the environmental factors can act as potentiators for the specific air pollutants in terms of effect, or they can cause some typical symptoms, specific to the type of the pollutant.

Effect of Air Pollution on Animals

Under both acute as well as chronic conditions, air pollutants can affect the animals significantly. In terms of chronic effects, the air pollutants, which have received the utmost attention, include fluorides, arsenic and lead. Air borne fluorides have caused more worldwide damage to domestic as well as farm animals than any other air pollutants. The animals most affected by fluorides include cattle and sheep. The symptoms of fluorosis in cattle are a function of whether there is an acute exposure or a chronic exposure. In general, the acute symptoms may include lameness, stiffness, lack of appetite and thirst, diarrhoea, muscular weakness and possibly death. The chronic symptoms may include skeletal changes, lethargy, emaciation, poor health, and possibly a poor reproductive efficiency.

Fluorosis can result from drinking water with high fluoride contents, which may affect the human being as well as animals. However, it is possible that in some cases diseases and symptoms as indicated above can occur from factors other than exposure to atmospheric fluorides. Some other examples of air pollutants, which have exhibited effects on domestic animals, include ammonia, carbon monoxide, hydrogen sulphide, sulphur dioxide and nitrogen oxides. There is some evidence that ammonia can have harmful effects on poultry, carbon monoxide can affect quite a number of animals and dusts can also affect rabbits, hydrogen sulphide can affect poultry, sulphur dioxide can affect cattle and sheep and nitrogen oxides may also affect quite a number of farm animals.

We now summarize the contents of this unit.

10.6 SUMMARY

- **Fertilizers**, **pesticides**, **chemicals**, **machinery** and **implements** constitute various off-farm inputs. The use of these inputs has lead to a manifold increase in agricultural productivity but has also had harmful impact on the environment.
- Plant nutrients are classified as **primary**, **secondary** and **micro-nutrients** and a large number of chemical fertilizers are used today to supply these nutrients.

- The indiscriminate, unbalanced use of **fertilizers** particularly nitrogen has resulted in soil pollution, and surface and ground water pollution.
- **Diesel**, **petrol**, **kerosene** are chief fuels used for various agricultural operations and adversely impact the air quality.
- Pesticides can be classified in many ways, e.g., according to the **mode of action**, **target population**, **function** and **chemical structures**. The overuse and misuse of pesticides in modern agriculture has resulted in severe ecological damage of water sources, soil and air.
- **Pollution due to pesticide** affects non-target populations, viz., human beings, animals and healthy crops and is a matter of grave concern.
- **Farm machinery** used in various agricultural operations is a major off-farm input. Machine-based operations like tillage result in air and water pollution.
- Off-farm inputs such as the use of chemical energy, tillage and pesticides cause **air pollution** and adversely affect air quality.

10.7 TERMINAL QUESTIONS

1. What are off-farm inputs in agriculture, and why are they called off-farm inputs?
2. Discuss the impact of the overuse or misuse of pesticides on different non-target organisms.
3. Do agricultural implements affect the environment adversely? Justify your answer.
4. Describe the various ways in which off-farm inputs affect air quality.