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MEVE-003
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SUSTAINABLE AGRICULTURAL MANAGEMENT

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MEVE-003
Agriculture and Allied Secto

Block

3

SUSTAINABLE AGRICULTURAL MANAGEMENT

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BLOCK 3 INTRODUCTION

Block 3 deals with Sustainable Agricultural Management. Pests and weeds are some problems faced in the agriculture sector. Therefore, integrated pest management practices based on sound ecological principles is currently used throughout the world. This block emphasises sustainable practices to achieve safety, durability, and profitability through the adoption of novel and innovative pest management tactics and capitalizing the synergies existing between the methods of pest management. The units also discuss how to overcome the ecological problems resulting from the excessive or indiscriminate use of fertilizers, organic manures and the use of biofertilizers for eco-friendly solutions.

Unit 1 deals with Biological Pest Control. The unit explains that biological control employs biological agents to reduce the damage caused by the pests and insects to tolerable levels. This unit emphasizes the principles of biological pest control, and different biocontrol agents like parasitoids, predators, and microbial agents from the perspectives of its importance on agricultural landscape, mass production and rational use.

Unit 2 deals with Botanicals in Agricultural Management. It discusses that historically, plant extracts and their parts have been utilised for pesticidal control. The plant kingdom offers a rich source of a wide range of structural biodiversity of natural secondary metabolites. One of the most recent trends in fungal and insect pest control is to reduce heavy reliance on synthetic pesticides and to move towards biodegradable substances. The unit also emphasizes that over 6000 plant species have insecticidal properties and most of them are widely applied in traditional farming systems. But only a handful of them have been scientifically validated and documented for insecticidal activity. Plant researchers estimate that nearly two-thirds of the world's plant species consist of various medicinal features and out of these reportedly 1500 species of plants have insecticidal values. The unit elaborates on the different types of botanicals used for safe farming practices in the agriculture sector.

Unit 3 deals with Biofertilizers and Manures. The unit explains that the indiscriminate use of fertilizers and other agrochemicals to increase the yield has resulted in contamination of surface and ground water, deteriorating soil quality, reduced biodiversity, increased air pollution and suppressed ecosystem functioning and thereby affecting environmental health. The unit emphasizes that organic manures are the valuable byproduct of farming and allied industries and are derived from animal and plant residues which can be used to replenish soil nutrients and also meet the crop demand in an eco-friendly way.

Unit 4 deals with Conservation Agriculture. The unit explains that conservation agriculture is driven by the principles of no tillage, residue management, and variety and diversity in crop rotation. Tillage is one of the fundamental practices of agricultural management which involves the physical manipulation of the soil for improving soil fertility. The unit discusses that the adverse impacts due to repeated tillage includes soil compaction, soil loss and declining soil fertility. Finally the unit summarizes the principles of conservation agriculture and conservation tillage; and influence of tillage on soil properties and plant growth and productivity.

Unit 5 deals with Organic Farming for Environmental Health. The unit explains that the products obtained under organic farming do not contain any chemical or its residue and are safe for human consumption. They are also safe for the environment where either their wastages or by-products are released. It also helps to build sufficient humus in the soil. It also explains that due to sufficient amount of humus, the soil is capable of sequestering carbon dioxide from the atmosphere. The unit summarizes the benefits of organic farming in managing the environmental and human health.

UNIT 1 BIOLOGICAL PEST CONTROL

Structure

1.1 INTRODUCTION

Agriculture is at crossroads. Agriculture is facing immense challenge to feed the growing population in the back drop of changing climate, declining soil productivity, and changing pest dynamics. In fact, insect pests and weeds are construed as important constraints to global agricultural production. Integrated Pest Management based on sound ecological principles is currently in vogue extensively throughout the world. Integrated Pest Management aims to achieve safety, durability, and profitability through the adoption of novel and innovative pest management tactics and capitalizing the synergies existing between the methods of pest management. Among the tactics available in the domain of pest management, biological pest control holds prominence from the perspective of agricultural sustainability. The use of natural enemies like parasitoids and predators as biological pest control agents is increasing in the back drop of increasing sustainability concerns in agricultural production system. The basic knowledge of natural-enemy biology and ecology is the foundation upon which the application of biocontrol rests. This unit emphasizes the principles of biological pest control, and different biocontrol agents like parasitoids, predators, and microbial agents from the perspectives of its importance on agricultural landscape, mass production and rational use.

1.2 OBJECTIVES

After studying this unit, you should be able to:

- define biological pest control;

- identify the factors governing biological pest control and qualities of a successful biocontrol agent;
- explain the parasitoids, predators and microbial agents.

1.3 CONCEPT OF BIOLOGICAL PEST CONTROL

Biological pest control is recorded as early as fourth century in China, where in ants were used to control citrus crop pests. Nevertheless, biological pest control was established as one of the best management tactics in 1888 in USA, when C.V. Riley and Albert Koebele successfully introduced Vedalia beetle *Rodolia cardinalis* to control Cottany cushion scale *Icerya Purchasi.* Further, insects were also used to control weeds like prickly pear cactus, Klamath weed, musk thistle, etc.

Biological control of pest is often called as biocontrol. It is the purposeful use of an organism or organisms to eliminate locally undesirable organisms or reduce its population to a level such that it is incapable of causing economic damage. Biological control aims at utilization of natural enemies like parasitoids, predators and pathogens to reduce the damage caused by the pest to tolerable levels. So the principles of population equilibrium and population regulation form bedrock of biological pest control.In other words, biological control endeavours to regulate pest population densities through the adoption of ecological principles.

The aim of biological pest control is to establish a self-sustaining system, which in turn delve on the factors like reproductive ability of and, food supply for natural enemies. Pest-natural enemies population dynamics involves fluctuations in the populations of prey and predator. When the pest population increases, the population of predator/natural enemies also increase due to copious availability of food leading to pest suppression. Subsequently, due to the unavailability of food, natural enemies population dwindle, which would enable the pest to reemerge with vigour and establish itself in the system. Such interaction leads to fluctuation in the pest and natural enemies and this forms the theory behind biological pest control.

Biological pest control is successful in crops that possess high tolerance limit to insect injury. Additionally, this pest management strategy is more suitable to crops having long crop duration and significant economic value. As regards natural enemies, the factors driving the success of biological control are availability of food source, non-application of pesticides that has potential to affect the non-target organisms like natural enemies, absence of hyperparasites, etc. Further, it is reported that the introduced crop pests are controlled/managed by the use of imported natural enemies due to the host specificity, and pest-natural enemies interactions.

Shift from myopic perspective of bitrophic interaction to tritrophic interaction provided the fillip to success of biological pest control. The natural enemies involved in the tritrophic interaction or biological control are essentially adapted to wide environmental conditions, and possess narrow host specificity. Natural enemies to be effective in pest control must have high fecundity, shorter life cycle, and marked host searching capacity. Enabling features of natural enemies like mass production in laboratory conditions, and lack of hyper-parasites are preferred for successful biological pest control programme.

As regards the techniques of biological control, three techniques are important. First relies on conservation and encouragement of indigenous available natural enemies through environmental manipulation, etc. Secondly, introduction or at times importation of natural enemies into a new locality is adopted as a strategy to control introduced pests. Thirdly, augmentation through inoculative release or inundative release is important to augment the population of natural enemies in the ecosystem to achieve effective control of pests.

1.4 AGENTS OF BIOLOGICAL CONTROL

Natural enemies in the agro-ecosystem renders invaluable ecosystem services by holding the pest population levels well below the economic threshold levels, where no economic damage occurs. However, in order to achieve higher efficiency in using the biocontrol agents, attempts are needed to augment the natural enemy population or numbers, and greatly enhance their predation rates. Although, natural populations of parasitoids and predators are found to subdue pest populations, at times, there is a need to augment the populations of natural enemies so as to avoid the economic damage. Further, mapping the factors influencing biological control, deciphering the complex pest dynamics in the agroecosystems which quite often sport ephemeral habitats, are significant.

1.5 PARASITOIDS

Parasitoids and predators are paramount in the domain of biological control of pests and hence as synergistic impact in Integrated Pest Management (IPM) strategies. Additionally, the benefits accrued with parasitoids and predators and ecological balance connotations and perspectives, underlines its primacy in pest control. Also, this strategy aid IPM through conservation, introduction, andaugmentation.

A parasitoid is "an insect parasite of an arthropod which is parasitic on immature stages and adults are free living". As a matter of fact, most of the insects belonging to the orders Hymenoptera and Diptera of Class Insecta are parasitoids. The free living adult parasitoid spy on the environment to look for suitable host and lay the eggs. Parasitoids either penetrate the body integument and lay eggs inside the host or lay eggs outside the host body in such a manner that the eggs are attached to the host body. Young emerging larvae feed on host tissues and metamorphose into an adult. In the process of development of young larvae, the parasitoid gradually weakens and kills the host insect. Parasitoids are used frequently for the control of crop pests. The preference for parasitoids as agents of biological control emanates from the characters like requirement of one host for complete developement, narrow host range, host specificity, economical as parasitoid population can be maintained at low numbers, and survivability. Nevertheless, the use of parasitoids also faces constraints like host searching is by female adults only, and host searching is influenced by weather and other environmental conditions. Incidentally, best searching female species are poor layers.

Table 1.1: Parasitoids as agents of biological control

Type	**Parasitoids**	**Pest**
Egg parasitoid	*Trichogramma chilonis*	Cotton bollworm, Sugarcane internode borer, Paddy leaf folder
	Trichogramma japonicum	Rice stem borer *Scirpophaga incertulas*
	Trichogramma remus	Tobacco caterpillar
Egg-larval parasitoid	*Chelonus blackburni*	Cotton spotted bollworm *Earias insulana*
Larval parasitoid	*Bracon hebetor, Bracon brevicornis, Eriborus trochanteratus, Goniozus nephantidis*	Coconut black headed caterpillar *Opisina arenosella*
	Sturmiopsis inferens	Sugarcane early shoot borer
	Campoletis chloridae	*Helicoverpa armigera*
	Platygaster oryzae	Rice gall midge *Orseolia oryzae*
	Cotesia plutella	*Plutella xylostella*
Larval - Pupal parasitoid	*Isotima javensis*	Top shoot borer of sugarcane, *Scirpophaga nivella*
	Eucelatoria bryani	*Helicoverpa armigera*
Pupal parasitoid	*Brachymeria nephantidis, Trichospilus pupivora, Tetrastichus israeli*	Coconut black headed caterpillar

Source: Ragumoorthi et al. 2003

1.5.1 Mass Production of Parasitoids

In order to augment the population of parasitoids in the agroecosystem, mass production is essential. In most of the cases, *Corcyra cephalonica*, popularly calledRice moth is preferred as a host for mass production of parasitoids.

Generally, the larvae of rice moth are reared on cereals like Bajra. The bajra grains are sterlised to remove harmful microbes. The broken grains (2.5 kg) along with groundnut powder (100 g) and powdered yeast tablet (5 g) are taken in a tray (45 cm x 30 cm x 10 cm). To avoid mite infection, 0.05 per cent of Steptomycin sulphatespray is administered @ 5 g per tray. Rice moth eggs @ 0.5 cc (8000 - 9000 eggs)/tray are uniformly mixed with bajra grains and the trays are covered with cloth. The adult moth emerges after about 45 days after inculation of rice moth eggs in the bajra grain medium. The rice adult moths are collected are placed in the mating drum and the eggs are collected and sieved. Rice moth eggs are sterilized under UV light and the sterlized eggs are sprinkled on the egg cards. These egg cards exposed to egg parasitoid, *Trichogramma spp.,* in a poly bag and after about four days, the parasitized eggs turn to black colour. The egg cards are released in the field by stappling the parasitized eggs onto the leaves. In order to control Sugarcane internodes borer, the recommended dose is 1 cc of parasitized eggs per release per acre. Six releases are recommended for the control of pest at 15 days interval. Similarly for other crops, the dose and release schedule are recommended after intensive study.

The egg-larval parasitoid, *Chelonus blackburni* is mass produced by using rice moth eggs. In case of egg-larval parasitoid, though the parasitoid parasitises the egg stage, the parasitoid life cycle will complete only in the larval stage of the host. The parasitoid adults are placed in a conatiner along with the rice moth egg cards for 24 hours. Then the egg cards are taken to another container containing broken grains. The parasitoids develop inside the Corcyra larvae and rests in small white cocoons. The adult parasitoid emerges from the cocoon after about 20 days. The adult parasitoid *C. blackburni* are released in the cotton field at the rate of one parasitoid/plant to control cotton spotted bollworm *Earis insulana.* Similarly the larval parasitoids like *Eriborus trochanteratus, Goniozus nephantidis* are mass produced using corcyra larvae. About 10 corcyra larvae are parasitised by an adult parasitoid. The parasitised corcyra larvae are reared with broken grains and the parasitised cocoon are diligently collected and allowed for adult emergence. The adult parasitoids are then released in the field for pest control. For instance, the adult larval parasitoid *Goniozus nephantidis* is released in the coconut garden for control of coconut black headed caterpillar, *Opisina arenosella.* As regards the mass production of pupal parasitoids, like *Trichospilus pupivora* and *Tetrastichus israeli,* the parasitoids are mass produced using the pupae of the host insect. The pupae of the host insect are parasitised by the adult parasitoid when both are kept in the tube. The parasitoid emerges from the pupa after completing its development in the host pupa. The adult parasitoids are released in the coconut garden for controlling *Opisina arenosella* at the rate of 20 adults per tree.

1.6 PREDATORS

Generally, predators are large sized insects that seize/capture and devour harmful insect pests. Examples of predators are Coccinellid beetles from Order Coleoptera, etc. Predators are "free-living organisms throughout its life. It kills its prey and may require more than one prey to complete its life cycle". Predators have long life cycle and usually are larger in size than the prey. Unique characters of predators like exceptional vision, well developed locomotory organs, mobility, stinging property, fast flying ability aid them to seize and kill the insects with ease. The mouth parts are also well developed. Normally the prey is eaten immediately.

Table 1.2: Insect predators as agents of biological control

Name of Insect predator	Prey Insect
Coccinella septumpunctata *C.Rependa* *Rodolia cardinalis* *Crytolaemus montrouzieri*	Aphids, Grape vine mealy bug, Cottony cushion scale
Parena lacticincta *Paederus fuscipes* *Rhinocoris fuscipes* *Platymeris laevicollis*	*Nilaparvata lugens,* *Cnaphalocrocis medinalis,* *Opisina arenosella* *Helicoverpa armigera*
Chrysoperla carnea	Aphids, scales

Source: Ragumoorthi et al. 2003

Check Your Progress 1

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1) What are the special characters of predators?

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....

2) Why parasitoids are preferred as agents of biological control of pests?

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1.7 MICROBIAL CONTROL

Microbial control is defined as "control of pests by the use of microorganisms like viruses, bacteria, protozoa, fungi, rickettsia and nematodes or their products". The microbes that are used for microbial control can be categorised into two groups based on their entry into the pest. They are ingested microbes and penetrating microbes. While the former refers to the microbes that enter into the pest body through the food, the latter refers to the microbes that enter into the pest body through the body integuments. As regards the positive attributes for successful microbial control, the pathogens need to be virulent; cost effective; specific to the host; atmost safety to the non-target organisms.

1.7.1 Viruses

Viruses are organsims which are sub-microscopic, obligate and pathogenic. Though, viruses belonging to more than 11 families are reported to be pathogenic to insect pests, viruses belonging to the Baculoviridae family are popular and are known to cause viral diseasesamong the lepidopterans. Important examples in this category are NPV (Nuclear Polyhedrosis Virus), CPV (Cytoplasmic Polyhedrosis Virus) and GV (Granulosis Virus).

NPV infected lepidopteran larvae/caterpillar loses appetite and becomes sluggish. The site of multiplication is cell nucleus of fat body, epidermis and blood cells. It turns into pink colour and the fragile larvae rupture to release "virus occlusion bodies" which has polyhedral structure. The unique symptom of virus infection is "Tree top disease" or "Wipfelkrankeit" wherein the dead larvae are found hanging from the tree top/ plant tops. E.g: NPV of *Helicoverpa armigera, Spodoptera litura*, etc. In case of CPV, the spherical virions are occluded singly in the polyhedral inclusion bodies. As the term suggest, the site of multiplication is cytoplasm of midgut epithelium. Important example in this category is CPV of *Trichoplusia ni.* As regards the GV, the virions are occluded singly in the capsules. Interestingly, the site of multiplication is cell nucleus or cytoplasm. E.g: GV of *Chilo infuscatellus.*

1.7.2 Bacteria

Bacteria are group of micro-organisms that microscopic in nature. This group of micro-organisms also affect the insect pest and hence bacteria is also utilised for the control of crop pest in the biological control programme.

Table 1.3: Bacteria as a biocontrol agent

Type	**Bacteria**	**Pest**	**Disease**
Spore forming (Obligate)	*Bacillus popillae*	Japanese Beetle	Milky disease (blood of the infected beetle turns into milky white)
Spore forming (Facultative) Crystalliferous (crystal has endotoxin)	*Bacillus thuringiensis var. israelensis*	Mosquitoes	-
	Bacillus thuringiensis var. kurstaki	*Plutella xylostella; Helicoverpa armigera*	- -
Spore forming (Facultative) Non-Crystalliferous	*Bacillus cereus*	Coleopteran, Lepidopteran and Hymenopterans	-
Non-spore forming	Serratia entomophila	Grass grub	

Source: Ragumoorthi et al. 2003

1.7.3 Fungi

This group of micro-organisms are facultative and cause mycosis. Important fungus from the point of view biological control is as follows:

Table 1.4: Fungi as a biocontrol agent

Fungi	**Scientific name**	**Pest**
Green muscardine fungus	*Metarhizium anisopliae*	*Nilaparvatha lugens*, rice leaf folder, rhinoceros beetle
White muscardine fungus	*Beauveria bassiana*	*Spodoptera litura*, Castor semilooper
White halo fungus	*Verticillium lecanii*	*Coccus viridis*, whitefly

Source: Ragumoorthi et al. 2003

Besides virus, bacteria and fungi, organisms like protozoans (e.g *Nosema heliothidis* on *Helicoverpa armigera*), rickettsiae, nematodes also act as microbial agents for pest control.

Check Your Progress 2

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1) What are the site of multiplication of NPV, CPV and GV?

....

....

....

2) What is tree top disease

....

....

....

1.8 LET US SUM UP

Agriculture faces challenges to increase agricultural production, and to meet the food demand of growing human population. Additionally, changing climate and rising demands for agriculture resources places at most stress on agricultural production system. Changing climate, pest resurgence, insecticide resistance, and environmental ill effects of rampant pesticide use, are cause of concern to reckon with in this century. The biotic stress of late has increased due to climate change impacts. The traditional way of pest control using chemical method are not feasible both economically, and environmentally leading to an urge to find out an alternate pathway for agricultural growth with due respect for environment. Further, more than control of biotic pest, management of pest is gaining importance as it is more environment friendly and also it factors in ecological principles which aid in the sustainability of ecosystem. The agriculture interventions and strategies in the Integrated Pest Management are based upon the premise that the insect pest has natural enemies which keep a tab on the pest population. Integrated Pest Management further focuses not on pest control but management of pest below economic threshold level. The fact is any intervention that enables pest population to be less than the ETL is preferred. In this regard, biological pest control is hallmark of IPM. Biological pest control has immense potential as it imbibes principles of sustainability.We have studied in this unit about the role of biological pest control in agricultural production and the positivity of natural enemies as agents of biological control. This can be summarised in the following points:

- Definition of biological pest control along with conceptual understanding of the biocontrol.
- Understanding the factors governing biological pest control.
- Parasitoids, predators and microbial organisms as successful agentsof biocontrol.

1.9 KEY WORDS

Microbial control: Control of pests by the use of microorganisms like viruses, bacteria, protozoa, fungi, rickettsia and nematodes or their products.

Predators: A free living organism throughout its life. It seizes and kills its prey. In order to complete its growth and development, it feeds on more than one prey.

Parasitoids: Insect that parasitizes other insect arthropods. These are parasitic in its immature stage, but are free-living as an adult.

1.10 REFERENCES AND SUGGESTED FURTHER READING

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1.11 ANSWERS TO CHECK YOUR PROGRESS

Answers to Check Your Progress 1

Your answers should include the following points:

1. Predators are large sized insects that seize/capture and devour harmful insects pests. Characters like exceptional vision, well developed locomotory organs, mobility, stinging property, well developed mouth parts, fast flying ability aid the predators to prey on crop pest.

2. The preference for parasitoids as agents of biological control emanates from the characters like requirement of one host for complete development, narrow host range, host specificity, economical as parasitoid population can be maintained at low numbers, and survivability.

Answers to Check Your Progress 2

Your answers should include the following points:

1. While the site of multiplication of NPV is cell nucleus of fat body, epidermis and blood cells, the site of multiplication of CPV is cytoplasm of midgut epithelium. On the other hand, the site of multiplication of GV is cell nucleus or cytoplasm.

2. NPV infected lepidopteran larvae/caterpillar loses appetite and becomes sluggish. It turns into pink colour and the fragile larvae rupture to release "virus occlusion bodies" which has polyhedral structure. The unique symptom of virus infection is "Tree top disease" or "Wipfelkrankeit" wherein the dead larvae are found hanging from the tree top/ plant tops. E.g: NPV of *Helicoverpa armigera*, *Spodoptera litura*, etc.

UNIT 2 BOTANICALS IN AGRICULTURAL MANAGEMENT

Structure

2.0 INTRODUCTION

Agricultural system laid down the roots of human civilisation. Agriculture was a chance innovation of hunter-gatherers that occurred around 11,000 years ago. Primitive farmers learned and acquired skills of securing desired food by growing edible plants and breeding animals. This led to a rather progressive sedentary lifestyle of Neothilic societies. Agriculture by definition implies "crop and animal husbandry (including fisheries) produce" capable of providing basic food and nourishment requirements to mankind.

Figure 2.1: Technological advancement of Agriculture over the centuries

This era began the transition from a nomadic lifestyle of hunting and gathering to a sedentary and organised agricultural lifestyle. These primitive farmers were intelligent enough to select easily harvestable crops such as Wild wheat. Subsequently, they began growing rice and millet. Archaeologists discovered remnants of Neothilic rice paddies in Chinese swamps considered to be 7,700 years old.

In India agriculture began around 9000 BC during Indus valley civilisation. Indus cotton production was a noted and established industry at that time. Mixed farming was practiced by Indian natives, which soon spread to adjoining South Asian Countries. They were also known to practice rainwater harvesting technology and operate irrigation from rivers. This period was followed by Vedic *krishi* period in between 1500-500 BC. The inhabitants were known as Aryans meaning cultivators (arya means to stir/plough soil). Vedic *krishi* was a highly sustainable form of agriculture. It advocated for maintenance of soil fertility and potentiality. Since then, Indian agriculture has kept pace with the all the technological advancement over the years (Figure 2.1).

2.1 OBJECTIVES

After learning this unit you should be able to:

- understand food security and adverse effect of green revolution;
- explain the side effects of chemical pesticides;
- describe the occupational hazards due to pesticidal exposure;
- comprehend sustainable agriculture;
- describe organic farming;
- understand biopesticides and integrated pest management;
- describe the indigenous traditional knowledge; and
- explain significant botanicals.

2.2 FOOD SECURITY AND ADVERSE EFFECT OF GREEN REVOLUTION

Self-sufficiency in terms of food security is a matter of immense concern for India. After 70 years of independence, also a larger fraction of our population remains severely affected by malnutrition, poverty and unemployment. Surplus amounts of funds were allocated to irrigation and agricultural sectors after independence by late Indian Prime minister Shri JL Nehru (Figure 2.2). Almost 6 million children die every year globally due to starvation and malnutrition. While, India's situation is quite pitiable with 28.5% million undernourished inhabitants in global hunger index (IFPRI, 2016: www.http://ghi.ifpri.org/). At the global level situation is grim, 868 million people undernourished out of which 850 million are from developing countries.

In 2050, meat and dairy product consumption would rise by 173% and 158%, respectively worldwide. To feed the anticipated 9 billion world population, agricultural produce requires a rise of 60% by 2050. When it comes to Indian women, situation is even more deplorable with roughly 36% of underweight women of childbearing age. Ensuring food security of 17% of world's population and feeding 10.71% of world's livestock with 2.4% of world's geographical area and 4% of its water resources is the major challenge before India (Tiwari et al., 2014). 15-25% potential crop production gets damaged owing to pests, diseases and weeds. Keeping pace with such challenging times our country will have to raise its agricultural production together with productivity to ensure food and nourishment security of the nation.

An elaborative increase in production of food grains particularly rice and wheat through usage of selecting of high-yielding varieties and heavy application of fertilisers and pesticides to meet the rising food demand is termed as green revolution. The green revolution that created a surge in high yields and quantity during 1960- 1970had caused a paralysed and fatigued agricultural system along with several environmental damages. In 1962, Rachel Carson published the book"Silent Spring", in which she mentioned problems that could arise from the indiscriminate use of pesticides. This book inspired widespread concern about the impact of pesticides on the human health and the environment. The expanding population growth led to agriculture intensification and extensification earlier which relied heavily on chemical fertilizers and pesticides.

2.3 SIDE EFFECTS OF CHEMICAL PESTICIDES

Several studies have reported induced oxidative stress following organophosphorus insecticides contact. It affects intracellular Ca^{+2} influx resulting in cholinergic hyperactivity and activation of proteolytic enzymes and nitric oxide synthase generating free radicals. For instance, fenitrothion causes severe histopathological effects on the liver, lungs and kidneys due to ROS generation through presence of pesticide residue via Cytochrome P_{450} metabolism.

Pesticides have also been reported to act as "serious endocrine disruptors" in humans and wildlife. They affect regular functioning of hormones either by underproduction, overproduction, blockage or disruption of hormone receptors in living species. Reportedly, DDT had severe estrogenic action on reproductive system of mammals and birds. Apart from posing serious threats to human health, pesticides hold adverse effects on the surrounding environment i.e. water, soil and air spoliation, toxic effects on non-target organisms. In particular, inappropriate use of pesticides accounts for undesired effects on non-target organisms such as reduction of beneficial species populations, water contamination from pesticide drift, air toxicity from volatile pesticides, damage on non-target plants from herbicide drift and herbicide residues. Most of the toxic pesticide hazards on the environment are related to interactions between the physicochemical properties of the applied pesticide, soil physical properties, crop species and the climatic conditions.

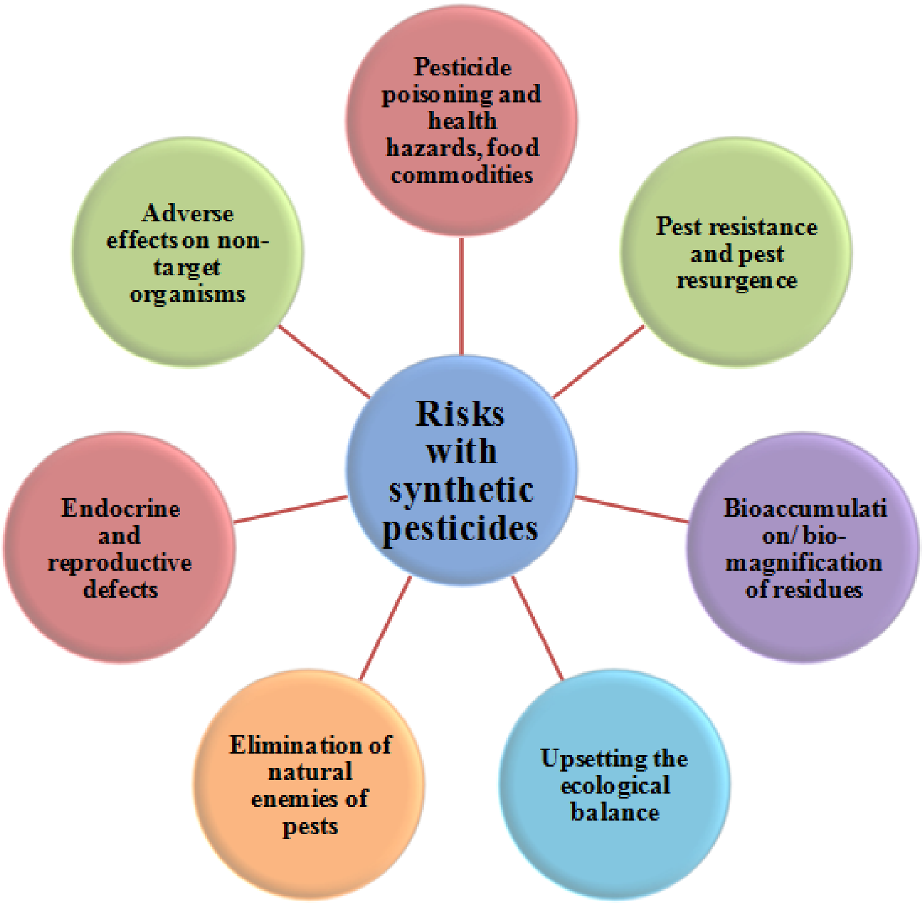

Figure 2.2 Environmental ill-effects of chemical pesticides

2.3.1 Occupational Hazard due to Pesticidal Exposure

Additionally, pesticides pose severe apprehension about health threats cause of exposure of end users while mixing and applying pesticides or working in treated lands. Erroneous application, improper storage, reuse of toxic containers for edible and drinking material can cause accidental poisoning. Frequently, pesticide applications indirectly harm beneficiary natural enemies of pests and raises growth probability of pesticide resistant species. Furthermore, well aware farmers tend to often fall prey to such inappropriate practices during pesticide application (Lee et al., 2004).

2.4 SUSTAINABLE AGRICULTURE

A Sustainable agricultural model preserves both quantity and quality of agricultural produce for a prolonged time period without any unjustified resource exhaustion and vitality loss (Figure 2.4).

The key principles of sustainable agriculture are:

- It promotes belowground interactions to achieve efficient precision with resilience
- integration of biological and ecological processes such as nutrient cycling and nitrogen fixation,
- soil regeneration, fertility and vitality is secured.
- Minimizing usage of environmentally harmful and unsafe and non-renewable inputs
- Inclusion of productive usage of indigenous traditional knowledge and in-built skills of farmers to improve self-reliance
- Utility of traditional and regional practices of agriculture which have been considered ecologically sound and known for enhancing buffering property of agro-

The idea of agricultural sustainability, though, does not mean ruling out any technologies or practices on ideological grounds. If a technology works to improve productivity for farmers and does not cause undue harm to the environment, then it is likely to have some sustainability benefits.

2.4.1 Organic Farming

Organic farming largely relies on preventive measures for plant protection, therefore the use of pesticides is low and potential risks to human health are largely avoided. Among indigenous technologies used by farmers, use of panchagavya has been given importance since age old days. In Sanskrit, panchagavya means the blend of five products obtained from cow. It is proved to be an efficient plant growth stimulant that enhances the biological efficiency of crops and the nutritional quality of the fruits and vegetables. Panchagavya is prepared by using the ingredients viz., cowdung, cow urine, cow milk, curd made from cow milk, ghee made from cow milk for 15-20 days incubation. Presence of naturally occurring beneficial microbes predominantly lactic acid bacteria, yeast, actinomycetes etc have been reported in panchagavya.

Check Your Progress 1

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. What is green revolution?

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2. Why is food security a global concern?

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3. What are deleterious side effects of pesticides on a) Human health b) Environment?

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4. What is Panchgavya and how it is constituted?

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2.5 BIOPESTICIDES AND INTEGRATED PEST MANAGEMENT

Integrated pest management **(**IPM) aims for agricultural management of pests and pathogens well below economic losses and maintaining aesthetic and functional quality of crop produce, instead of total eradication of causal agent. In nutshell, it combines best practices of physical, chemical and cultivation methods of pest and disease control.

The main IPM principles utilises:

- Synthetic pesticides having high levels of selectivity and are low risk compounds (synthetic insect growth regulators)
- Selection and cultivation of resistant plant varieties
- Regular practice of certain disease suppressing cultivation methods (crop rotation, intercropping, mixed cropping)
- Physical methods (tillage, mowing and mechanical weeders)
- Utilisation of natural products (botanicals)
- Biological control with the aid of natural enemies (parasitoids, predatory insects and mites, parasites and microbial pathogens)

Biopesticides are derived from a living, natural source capable of inhibiting a pests and pathogens at which they are aimed at. On the basis of active substances, biopesticides fall into three different types according to the active substance: (i) microorganisms (*Pseudomonas* sp. and *Trichoderma harzarium*; (ii) biochemical pesticides (1,8-cineole) and (iii) Plant incorporated protectants (Bt toxin).

Historically, plant extracts and their parts have been utilised for pesticidal control. In olden times, head lice were treated by application of pyrethrum flower extract in Persia (Addor, 1995). Romans were earliest to utilise rosemary, juniper and other aromatic plants for fumigation of their granaries. In order to survive, plants have evolved production of secondary chemical compounds as a defence mechanism against herbivores, pests and pathogens. Post Second World War usage of synthetic chemical insecticides was made rampant without thinking much about their futuristic effects. Before the Second World War, four main groups of compounds were in fact commonly used: nicotine and alkaloids, rotenone and rotenoids, vegetable oils and pyrethrum and pyrethrins. These were first generation of pesticides however, due to their toxicity to off target species and chemical instability, decline in their commercialization and usage occurred. Post Second World War saw second generation of pesticides consisting of organochlorides, organophosphates, and carbamates. They became successful due to ease of application, storage, were less expensive and were produced in high quantities and were able to meet the demands.

The plant kingdom offers a rich source of a wide range of structural biodiversity of natural secondary metabolites. One of the most recent trends in fungal and insect pest control is to reduce heavy reliance on synthetic pesticides and to move towards biodegradable substances. Synthetic pesticides of broad spectrum have been widely used as the main tools for controlling weeds, and fungal and insect pest, which are highly toxic to many living organisms as well as to the environment. Hence, new biorational and specific trends to pest control should be developed. Reportedly, over 6000 plant species have insecticidal properties and most of them are widely applied in traditional farming systems. Moreover, a handful of them have been scientifically validated and documented for insecticidal activity. Plant researchers estimate that nearly two-thirds of the world's plant species consist of various medicinal features and out of these reportedly 1500 species of plants have insecticidal values. Though as compared with synthetic compounds their efficacy and effect is slower in action, however, they are imperative for environmental and health safety purposes.

The botanical pesticides are biodegradable and harmless to the environment. Furthermore, unlike conventional pesticides that are based on a single active ingredient, plant derived pesticides consist of an assortment of chemical entities which act either concertedly or synergistically. However, unlike any other thing they also have certain limitations and disadvantages.

Disadvantages

1. They are slow in their action and usually act as deterrents and repellents.
2. They can be rapidly degraded by high temperature and UV light.
3. Botanical pesticides are also toxic to other animals.
4. Many insecticidal plants are considered endangered and permissions are needed to cultivate them commercially (*Vellozia gigantea* of Brazilian Rupestrian grasslands).
5. Most of them have no established residue tolerances.
7. Botanicals being of natural origin cannot be assumed safe unless validated.

Check Your Progress 2

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. Define integrated pest management (IPM).

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2. Cite the principles of IPM.

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2.6 ESSENTIAL OILS- A BRIEF ACCOUNT

Essential oils are volatile and colourless liquids at room temperature. They are lipophilic, soluble in almost all organic solvents and have density lower than unity (except cinnamon). Essential oils are synonym with the word *essence*, since each one has a distinctive odor. They are highly inflammable, have a refractive index and a high optical activity. They have been reported to be synthesised in almost all plant organs e.g. flowers, leaves, twigs, seeds, fruits, rhizomes, wood, or bark and are secreted from oil, resin ducts and trichomes. Historically, essential oils were earliest reported from eastern Asia (India and Persia) 2000 years back. In the 13th century, essential oils were widely prepared in European pharmacies and their relevant pharmacological effects were duly noted down in pharmacopoeias. In 16thcentury the term "essential oil" was contrived by Swiss physician Paracelsus von Hohenheim, as a bioactive component of plant under investigation, which he called "*Quinta essentia*". Further, scope of essential oils was widened into perfumes, cosmetics, and food flavourings.These oils are complex blend of many different compounds. Presently literature documents 3000 essential oils from 2000 plant species belonging to 60 families and around 10% of them are industrially significant.

Essential oils are a complex assortment of secondary metabolites of variable chemical classes. Majority of the bioactive essential oils are terpenoids such as hemiterpenes, monoterpenes, diterpenes and Sesquiterpenes (Figure 2.6). Terpenoids are produced in two different subcellular compartments independently, fromisopentenyl diphosphate (IPP) precursorin the cytosol bymevalonic acid pathway while in plastids; it is derived from pyruvate and glyceraldehyde- 3-phosphate via the methyl-erythritol-phosphate (MEP) pathway. Specific metabolites (IPP) facilitate the "crosstalk" between these two pathwaysfrom plastids to cytosol (Figure 2.7). Essential oils are highly variable in their composition and their yield also varies depending upon the extraction technique utilised. The biological activities exhibited by EOs are cytotoxicity, insecticidal, insect repellency, allelopathy, antimicrobial, antioxidant and anti-inflammatory. Prior to commercial usage at large, toxicity profiling of the essential oil should be carried out; although toxicity data of a particular essential oil varies according to composition which in turn is hugely dependent on multiple factors.

Check Your Progress 3

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. What are essential oils?

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2. Describe role of essential oils in pest and disease management?

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Various biopesticides promoting International Organisation

BioProtection Global

This international organisation was conceived at the Annual Biocontrol Industry Meeting (ABIM) 2015 in Basel, Switzerland. It works to bring harmonization of regulatory laws of different countries for biological pesticides. The organisers constructively raise and resolve issues, on policies and regulations (http://www.bpia.org/mission/).

International Biocontrol Manufacturers Association

This association is governed under Belgian laws. It is an amalgamation of various manufacturing and R&D companies involved with biocontrol agents. The alliance creates awareness programmes for biological pesticides for application in IPM and organic farming (http://www.ibma-global.org/en/organisation).

Online Information Service for Non -Chemical Pest Management in the Tropics

It is a web-based knowledge system for educating trainers, extension workers and farmers in agriculture regarding biological processes for management of various pests and diseases in a safe, effective, and ecologically sound way. (http://www.oisat.org/).

The International Organization for Biological Control

IOBC consists of volunteers promoting environmentally safe practices for pest and disease control. Members work in an establishment in IOBC by exchanging and sharing their individualistic experiences that contributes to the promotion of biological control at a global scale (http://www.iobc-global.org/).

Bio-Pesticides Database

University of Hertfordshire created a disseminating database of expert base knowledge and updated information regarding traditional agricultural pesticides (PPDB) and veterinary substances (VSDB) (https://sitem.herts.ac.uk/aeru/bpdb/).

ICAR-The National Research Centre for Integrated Pest Management

The institute formulates Information and Communications Technology (ICT) based monitoring and surveillance of pests; conducts R&D of smart IPM technologies for agricultural crops created by Indian council of agricultural research. They also provide validation of on-farm IPM technologies. Also, they function as liaison between various research and academic institutes and carry out capacity building (http://www.ncipm.org.in).

2.7 INDIGENOUS TRADITIONAL KNOWLEDGE

Indigenous Knowledge (IK) can be defined as the foundation for the ethnic groups for grass root level decision making in the areas like food security, human and animal health, natural resource management, environment conversation and other vital economic and social activities. IK is the most significant tool that adds into the efficiency, effectiveness and sustainability of the development of the communities practicing that knowledge.

Brief case study On IK

Dried leaves of *Azadirachta indica* are mixed with sundried grains and stored into traditional storage containers. This practice is common amongst tribes of Central Gujarat. Another way of using *Azadirachtaindica* A Juss is by adding dried leaves of *Azadirachta indica* A Juss to a mixture of loam, cowdung and husk which is used to cover inner and outersurfaces of storage containers which provides protection against pest. Likewise, fresh leaves of *Calotropis procera* are collected and dried in shed for application as a pest repellant. These leaves are then spread on the inner surface of the storage containers such a way that they cover the whole inner surface of the container in which seeds are stored.

2.8 BRIEF ON SIGNIFICANT BOTANICALS

Dear learners let us now read about brief on significant botanicals in the following:

2.8.1 Nicotine

Nicotiana tabacum, containing nicotine as a bioactive alkaloid has been found very effective as an insecticide. The mode of action of nicotine is that of a nerve toxin in both mammals and insects. It adheres at acetylcholine receptors competing with acetylcholine (neurotransmitter) which leads to uncontrolled nerve firing.

2.8.2 Rotenone

It is an isoflavonoid secreted in belowground parts i.e. roots/ rhizomes of legumes *Lonchocarpus*, *Derris* and *Tephrosia*. Rotenone acts by inhibiting cellular respiration. It inhibits electron transport in mitochondrial cells by interfering with NADH dehydrogenase enzyme. Its toxic effects are exerted primarily on neurons that cause immediate cessation of feeding.

2.8.3 Sabadilla

Seeds of the medicinal plant *Schoenocaulon officinale* are source of a botanical pesticide known as Sabadilla. It is applied in a powdered form by grinding seeds. It has been found to be highly effective in controlling thrips and bioactive components are alkaloids. In insects, it leads to loss of nerve function, paralysis and death. Usually no residues are left post application since it is degraded rapidly in the sunlight.

2.8.4 Ryania

It is another noted botanical obtained by grinding the stems of a tropical tree *Ryaniaspeciosa* that belongs to family Flacourtiaceae. Its powdered form interferes with calcium release in muscle tissue. It has been found to be highly toxic to moths and borers and thrips, particularly to codling moth, *Cydiapomonella*. Ryania is a slow-acting stomach poison.

2.8.5 Pyrethrinsare of Broad Classes: Synthethic andNatural

Natural pyrethrins are made from powdered and dried flower head of the pyrethrum plant *Chrysanthemum cinerariaefolium* belonging to family Asteraceae. The pyrethrins exert their toxicity by disrupting sodium and potassium ion exchange process in nerve fibers of insects thereby interrupting the normal transmission of nerve impulses. While synthethic pyrethroids are chemical derivatives made from oleoresin extract of *C.cinerariaefolium.*

2.8.6 Pongamiaglabra

It is also known as “karanj” belonging to family Leguminosae has been found effective against insect pests of stored grains, field and plantation crops and also in household commodities. This tree is widely distributed in India and its seeds are rich in oils. Its fixed oil, various organic extracts such as methanol, ethanol, ethylacetate seed and leaf extract etc. have been documented to act as repellents, oviposition deterrents, antifeedants and larvicidal against a rather wide range of insect pests i.e. leaf borers, grass-hoppers, caterpillars and leafhoppers.

2.8.7 Madhucaindica

It is also known as “**Mahuca**” belongs to Sapotaceae family. Its seed cake is rich in sugars, nitrogen and proteins. The plant extracts has been found effective as plant growth promoter. Plant extracts are rich in saponins which have been found to possess antifungal, nematicidal and moluscicidal activity. The cake has been used as a low grade fertilizer, bio-pesticide, included in animal feed (up to 20 %).

2.8.8 Curcuma longa

Also known as “Turmeric” was originated in Asia, specifically in Indian sub-continent, belongs to Zingiberaceae family. Turmeric oil and its organic/ aquaeous extractives have been found be effective as insect repellent and growth inhibitors. The bioactive components are collectively called “curcuminoids” largely comprising of curcumin—I, II, III. The rhizome powder of this plant when amended withpiperonyl butoxide (syngeristic compound) has shown significant efficacy as insect growth regulator and antifeedant agent.

2.9 CASE STUDY: *OCIMUM* SP.: STORE-HOUSE OF BIOPESTICIDES

Biochemical biopesticides derived from Lamiaceae family (Lavender, rosemary, sage and thyme) have been well documented in literature. The literature compiled in the case study summarises the intensity and impact of research carried out with respect to biopesticidal efficacy (fungicidal, adulticidal, larvicidal, nematicidal, antihelminthic, ovicidal, oviposition deterrence, repellency, acaricidal, antileishmanial, trypanocidal) exhibited by organic, aqueous extracts and essential oils of all *Ocimum* sp.

In a study *Ocimum sanctum* extracts were compared with other plants for testing their efficacy against stored grain pests. The study depicted that extracts had highest oviposition deterrence against *Callosobruchus chinenesis*. Likewise, organic extracts of different plant parts of *O. sanctum* and *O. canum* were tested for antifeedant and larvicidal activity against *Helicover paarmigera* and *Syleptaderogata*. MeOH and EtOAc flower extracts of *O. canum* displayed highest larvicidal activity towards agricultural pests *Helicover paarmigera* and *Syleptaderogata*. While, acetone extract of *O. sanctum* was best against *S. derogata* comparable with methanolic peel extract of *Citrus sinensis* L. Also, extracts of *O. sanctum, O. canum, O. gratissimum, O. basicilium and O. selloi* have been found highly effective against vector mosquitoes i.e. *Anopheles* ap., *Culex* sp. and *Aedes* sp. Studies reported here hold the merits of further be taken for performance on field level conditions. Organic plant extracts should also be tested for phytotoxicity and effect on plant growth before being recommended for use in plant protection.

Ocimum sp. has been found to be very effective in treatment post harvest pathogens. Essential oils and their individual components of *O. kilimandscharicum* and *O. kenyense* were tested for their efficacy against *Sitophilus zeamais* M. and *Rhyzoperthadominica* F. Best results shown were that of complete mortality of *S. zeamais* in a mixture of 1,8-cineole and methyl chavicol as compared with 44% mortality of former component alone (Bekele and Hassanali 2001). Edapho-climatic conditions considerably influence the yield and biological activities of essential oils. Interestingly a relative study of bioactivity of EOs extracted from 18 different *O. basilicum* accessions against stored grain pest *Callosobruchus maculatus* was investigated. It emphasised the impact of geographical location on chemical composition and bioactivity of EOs extracted. Most repellent and toxic EO containing linalool was reported in samples collected from Afghanistan.

2.10 LIMITATIONS AND FUTURE PERSPECTIVES

The actual impediment in effective functioning of biopesticide is the mammoth unpredictability of the efficacy which is highly interdependent on both biotic and abioticfactors (temperature, moisture, host species, nutritional status and relative humidity) (Sundin et al. 2009). Keeping the fitness, survival and release of any biopesticide is challenging for any bioformulation manufacturer in highly fluctuating phyllospheric, rhizospheric and indigenous microbiota at the site of application. Possibly, certain antagonist chemicals can be utilised as an additive ingredients or as performance enhancersin viable formulation. In order to raise acceptability and applicability of biopesticides in farming practices it is imperative to amend functional biomolecules/botanicals with highly efficacious plant growth promoting microbes which are more successful at disease management in comparison to cell based formulations.

Although remarkable progress has been made by researchers worldwide on knowledge creation and technology development of biopesticides in last few decades along with limitations inclined with it. Biopesticides should not be projected as only available solution or know-how as a future picture of crop protection and disease management. However, biopesticides must be rigourously brought into mainstream agriculture as a part of the equivalent measures simultaneously to conventional pesticides creating a model where each category deserves its own place.

Particularly, the high costs related to the registration of new BIs limit commercialisation of

new products. These costs must be reflected by manufacturers in the final price of their products, which then become competitive for synthetic insecticides only with difficulty. Higher prices of these products are given especially by their limited production and thus by the need to grow a sufficient amount of plant materials in the required quality and quantity of the active substances. Another factor that restricts efficacy is a relatively short time of persistence of the effect of phytochemicals, which is caused either by rapid biodegradation in the environment (e.g. azadirachtin, pyrethrin) or rapid release in the surrounding environment (e.g. monoterpenes). However, stability in the environment and prolonged persistence time have been studied recently and in some cases even addressed in various formulations.

2.11 LET US SUM UP

With this unit, readers are made aware and abreast with the significant role of the botanicals in sustainable agriculture. Many plant varieties have shown their potency as an alternative to chemical pesticides. Widespread pesticides and pathogenic activities have been exhibited by *Ocimum*sp. EOs and plant extracts. The findings discussed in the unit describe various chemical components of plant extracts and essential oils having pesticidal activity. Most of the studies have been reported from vedickrishi and usage of Panchgavya also, which are traditional agricultural knowledge of India. Therefore, botanicals developed by using plant base are organic and environmentally friendly. All of these aspects should encourage the development and use of “green pesticides” that do not harm the environment.

2.12 KEY WORDS

Neothilic societies: Inhabitants of Mediterranean and Asian region who domesticated animals (Cows, goats and sheep) and plants (Wheat, barley and legumes) by honing their stone-made tools in 12,000 BC.

Rainwater harvesting: The process of accumulation and storage of rainwater for later onresuse.

Intensification: The process of increasing agricultural production manifold/ unit of inputs applied.

Extensification: The process of increasing arable agricultural land by deforestation and urbanisation.

Off target/ Non-target effects: It means to have broad spectrum activity. They are toxic or lethal in effect not only to the pests they were aimed for but also to other insects.

2.13 REFERENCES AND SUGGESTED FURTHER READINGS

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2.14 ANSWERS TO CHECK YOUR PROGRESS

Answers to Check YourProgress 1

1. Your answer should include the following points:

1. Usage ofhigh-yielding crop varieties alongwith injudicious application of fertilisers and pesticides to meet the rising food demand is termed as green revolution.

2. It has been projected that by year 2050 human population will reach 9 billion and agricultural produce requires a rise of 60%, hence food security is a huge issue.

3. On humans it can cause accidental poisoning b) it disrupts soil physical properties, crop species and the climatic conditions.

Answers to Check YourProgress 2

1. Your answer should include the following points:

1. IPM combines best practices of physical, chemical and cultivation methods of pest and disease control.

2. Main principles of IPM are integration of low risk synthetic pesticides, cultivation of resistant crop varieties and certain cultivation practices such as crop rotation, intercropping, mixed cropping

3. Essential oils are lipophilic, colorless liquids with unique aroma, chemically rich in terpenoids.

4. Essential oils of many plants have been reported to have antifeedant and repellent activities against insects and pest eg. basil oil (*Ocimum* sp.).

UNIT 3 BIOFERTILIZERS AND MANURES

Structure

3.0 INTRODUCTION

The most important challenge to mankind in the twenty first century is to feed the rapidly growing population especially in developing countries without deteriorating environmental health. At present, millions of people are suffering from hunger to chronic malnutrition. The indiscriminate use of fertilizers and other agrochemicals to increase the yield has resulted in contamination of surface and ground water, deteriorating soil quality, reduced biodiversity, increased air pollution and suppressed ecosystem functioning and thereby affecting environmental health. The term "fertilizer" is used for "fertilizing material or carrier", which refers to a substance which contains one or more of the essential elements (nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, iron, manganese, molybdenum, copper, boron, zinc, chlorine, sodium, cobalt, vanadium and silicon). Excessive use of fertilizer, if poorly managed will lead to leaching in the soil, volatilization, acidification and emission of ammonia, methane, nitrous oxide and elemental nitrogen from the soil system due to denitrification. The water soluble nutrient through leaching cause eutrophication manifested by luxuriant growth of algae and other water weed posing alarming threat to human and aquatic health. To overcome the ecological problems resulting from the excessive or indiscriminate use of fertilizers, organic manures and biofertilizers are the sustainable solution by increasing efficient nutrition availability in the soil in an environmental friendly way. The organic manures contribute to soil fertility by providing mineral nutrient after decomposition and improve the physical, biological and chemical properties of soil. During the decomposition of organic matter, organic acid is released which help in dissolving minerals slowly and also make them available to the plants. Biofertilizer on the other hand defined as “microbial inoculants containing living microorganisms that colonize the plant roots or plant interiors and promote growth by increasing the availability or supply of primary nutrients to the target crops, when applied onto the soils, seeds or plant surfaces”. These are promising technology to reduce the use of conventional inorganic fertilizer for sustainable crop production. This unit will give you an overview of manures and biofertilizers for sustainable agriculture management.

3.1 OBJECTIVES

After completing this unit, you will be able to:

- list the different types of manures;
- classify different types of biofertilizers;
- explain the nitrogen fixing biofertilizers and phosphorus contributing biofertilizers.

3.2 MANURES

Crop husbandry relies on the use of chemical fertilizers to increase crop productivity for feeding the increasing population however the use of chemical fertilizers and pesticide cause tremendous harm to environment. Organic manures are the valuable byproduct of farming and allied industries and derived from animal and plant residues. Organic manures are either plant or animal based wastes, containing nutrients that can be used to replenish soil nutrients and also meet the crop demand.

3.3 TYPES OF ORGANIC MANURES

Based on the nutrient concentration, and nature of manures, organic manures can be grouped into bulky organic manures and concentrated organic manures.

3.3.1 Bulky Organic Manures

Organic manures are bulky in nature but supply plant nutrients in small quantities of plant nutrient. As the bulky organic manures contain small percentage of plant nutrients, large quantities of manure are applied to the soil. Though the nutrient content is less, the manure provides favourable soil ecosystem for the crop growth and development. Common bulky organic manures are farmyard manure, green manure, green leaf manure, and rural/ urban compost.

Bulky organic manures are preferred on account of the following enabling features.

- In addition to supplying macronutrients like nitrogen, phosphorus, potassium, these manures supply essential micronutrients;

- Soil ecosytem functioning is emblematic of interactions and inter-relationships among the components of soil environment. The bulky organic manures favours and enhances the activities of soil microbiota, resulting in maintenance of ecological integrity of the soil ecosystem. Soil microbiota augments the nutrient availability.
- Improvement in the biological properties of soil due to the organic manures enables favourable soil physical and chemical properties. Soil physical properties like soil structure, porosity, water holding capacity of the soil, etc are markedly improved due to the manure applications.
- Additionally, the chemical properties of soil like cation exchange capacity are improved in the manure applied soils.
- Favourable soil microbiota controls to an extent the population of soil borne fungi and other parasitic organisms.

3.3.2 Concentrated Organic Manures

Organic manure that are concentrated in nature and containing higher percentage of plant nutrient than bulky organic like nitrogen, phosphorous and potash are known as concentrated organic manure. Plant originated or plant based manures can be divided into edible oil cake and non-edible cake oil. Common edible oil cakes are sesamum cake, groundnut cake, linseed cake, etc. whereas non-edible cakes are neem cake, castor cake, cotton seed cake, etc. On the other hand, animal originated concentrated organic manures are bone meal, fish meal, hoof meals, blood meals and poultry manures, etc.

Farm Yard Manure:

Farmyard manure or FYM is the traditional manure and is readily available to farmers. It is the product of decomposition of liquid and solid excreta of the livestock, stored and dried in farm. A portion of cattle dung is used as fuel in rural farms. Farmyard manure mainly constitutes the decomposed mixture of farm animal waste like dung and urine; and roughages and dry fodder, and litter that are left over in the cattle shed. Generally, the during the storage of manures at the field, the nutrients are lost due to the processes like volatilization, leaching, and microbial action. The loss of nutrients can be minimized by adopting care and improved methods of composting. On an average, a well rotted FYM contains 0.5% N, 0.25 P2O5 and 0.5% K2O. Based on this data, we can estimate that an average dressing of 25 tonnes per hectare of farmyard manure supplies 112 kg of N, 56 Kg of P2O5 and 112 kg of K2O. Nitrogen is very slow acting and less than 30 percent of it is generally available to the first crop. About 60 to 70 percent of the phosphate and about 75 percent of the potash become available to the immediate crop. The rest of the plant nutrient becomes available to the subsequent crop. This is called as residual effect.

Compost

Compost manures are the decayed refuse like leaves, twigs, roots, stubble, bhusa, crop residue, degradable kitchen waste, etc. The process of decomposition is increased by adding nitrogenous material like cowdung, or fertilizers. A large number of soil microorganisms feed on these waste and convert it into well rotted manure. In other words, we can construe compost as well rotten organic matter obtained from waste. Farm wastes like trash, straw, weed plants, etc can be converted into farm compost. Organic wastes or the wastes of biological/animal/agro-industry origin can be converted to valuable manure by composting. Sources of organic waste may be classified as:

Agriculture: Crop residues (paddy,straw, sugarcane, trash etc), weeds, etc.

Animal Husbandry: Dairy, goat / sheep, poultry, piggery, etc.

Agro-industries: Sugar Indutry (Pressmud), coir Industry (Coir pith), fruits/ vegetables processing industries, sago industry, etc.

Municipal Activities: Household /municipal solid waste, market waste (vegetable/ fruit / flower market), etc.

On an average, the nutrient composition of farm compost in percentage terms is: "0.5 per cent N, 0.15 per cent P2O5 and 0.5 per cent K2O". Town compost prepared from town refuses like street sweepings, human wastes, and dustbin refuse contains nutrients on an average "1.4 per cent N, 1.00 per cent P2O5 and 1.4 per cent K2 O". Farm compost is generally prepared by digging trenches with dimensions 4.5 m to 5.0 m x 1.5 m to 2.0m x 1.0 m to 2.0m and placing the wastes layer by layer. On each layer, cow-dung slurry is sprinkled so as to provide the microbiota for composting. Normally, the trenches are filled upto 0.5 m above the ground and it is plastered so as to minimise the loss of nutrients and to provide favourable environmental conditions for composting. By six months, the C: N ratio would be narrowed down and the compost would be ready for soil application. Compost has the unique ability to improve the properties of soils and growing media physically and nutritionally and biologically. Some of the benefits using compost are:

- Improves the soil structure, porosity, bulk density, and other physical properties thus creating a better plant root environment.
- Increases moisture infiltration and permeability of heavy soils, thus reducing erosion and runoff.
- Improves water-holding capacity, thus reducing water loss and leaching in sandy soils.
- Supplies a variety of macro- and micro-nutrients.
- May control or suppress certain soil-borne plant pathogens.
- Supplies significant quantities of organic matter.
- Improves cation exchange capacity (CEC) of soils and growing media, thus improving their ability to hold nutrients for plant use.
- Supplies beneficial micro-organisms to soils and growing media.
- Improves and stabilizes soil pH.
- Can bind and degrade specific pollutants.

Vermicompost

Vermicomposting or worm composting is the decomposing of organic waste with earth worms. Vermicomposting creates a fine black granular substance called 'castings'. Worm castings are an excellent source of slow-release soil nutrients for plants or lawns. Vermicompost is a nutrient rich, natural fertilizer and soil conditioner that sustain healthy plant life and vital plant growth. Worm fertilizer adds beneficial microorganisms and soil fauna that help to breakdown organic materials and convert nutrients into a more available form for plants. Vermicompost improves soil structure, and aeration as well as increases water-holding capacity in the soil and plants grow stronger and have deeper root systems for better drought tolerance and disease resistance. Vermicompost contains major and minor nutrients in plant-available forms, enzymes, vitamins and plant growth hormones. Studies have shown that as food passes through the worm's body, the worms have an amazing ability to eliminate pathogens and carcinogens in the soil. Earth worms (Eisenia foetida) are some of the best natural fertilizer producers in the world.

Green Manure

Green manure crops are grown to increase or replenish the soil organic matter content. Green manuring is a process where in the green manure crops incorporated in the cropping system are either brought from outside or grown in-situ. Green leaf manuring involves collection of green biomass from wastelands, bunds, and from nearby location, and incorporating into the soil. Essentially, both green manure and green leaf manuring involves soil incorporation of green biomass that are young and amenable for quick microbial decomposition. Crops belonging to leguminous family are capable of nitrogen fixation and hence green manure crops belong mostly to the leguminous family. Important green manure crops are Sesbania aculeata, Sesbania speciosa, Crotalaria juncea, Tephrosia purpurea, Indigofera tinctoria, Centrosema pubescens, Stylosanthes hamata, Phaseolus trilobus, etc. Green leaf manure crops include Glyricidia, Ipomoea cornea, Cassia auriculata, Derris indica, Azadirachta indica, Thespesia populnea, Pongamia glabra, Calotropis, etc.

Benefits of green manuring include the following:

1. The foremost advantage is the green manuring aids in the improvement of physical, chemical and biological properties of soil.
2. Organic matter is replenished through green manuring in the arable crop field and thus maintaining the soil organic carbon which is pivotal for the functioning of soil ecosystem.
3. On account of symbiotic relationship of green manure crops mainly in the leguminous family with nitrogen fixing organisms, the green manuring improves soil nitrogen content.
4. Green manures acting as a food source for soil microbiota, pave way for enhanced microbial mediated decomposition of organic matter.
5. Soil structure improvement due to green manuring improves greatly soil tilth.
6. Green leaf manure like Azadirachta indica, Pongamia glabra has been reported to have a control on insect pests.
7. Growing of green manure crops aid in translocation or movement of nutrients from deeper soil layers to the surface.

8. As regards the soil amelioration, green manuring aids in reclamation of sodic soils.

Sheep and Goat Manure

The droppings of sheep and goat and other ruminants has manurial value. As regards the farmyard manure, sheep and goat manure has higher percentage of NPK. Average composition of N, P2O5 and K2O in goat and sheep dung comprised 0.65%, 0.5 %, and 0.03 % and that in urine 1.7 %, 0.02 % and 0.25 % respectively. Sheep and goat manure are incorporated to the crop field either through sheep penning or through application of decomposed waste material collected from the animal sheds.

Poultry Manure

Poultry manure is a rich organic manure. As the liquid and solid excreta are excreted together, the nutrient composition is much higher as compared to other animal based organic manure. The deep litter comprised 3.03 per cent N, 2.63 per cent P2O5 and 1.4 per cent K2O.

Sewage and Sludge

Sewage is used water and waste substances that are produced by human action and factories, and industries. These wastes called sewage is collected through sewers or special pipes. Since it posses varying amounts of nutrients, they are used for irrigation of fodder crops or vegetable crops mainly in the outskirts of the city. The solid matter that settle or accumulates at the bottom of the settling tank is called sludge which too has manure value. Nevertheless, application of sewage results in soils getting sewage sick as the colloidal particles present in the sewage clogs the soil pores. Repeated application of sewage results in problematic soils. Hence, pretreated sewage is normally advocated for irrigation of plants meant not for human consumption.

Oil-cakes

Oil seeds are rich with manurial ingredients. So, by product that is left after oil extraction called oil-cakes are much sought after in crop husbandry. Oil-cakes are rich in nitrogen, phosphorus and potassium as well. Due to manurial property, oil cakes are used as manure. However, cost of the oil cake also needs to be taken before application. Oil-cakes can be classified based on their edible property into edible and non-edible oil cake. Edible oil-cakes are preferred as cattle feed as their consumption improve the cattle health and productivity. Further, it is profitable to use edible oil-cakes as cattle feed. Examples of edible oil-cakes are groundnut cake, coconut cake, etc. On the other hand, non-edible oil cakes that are not used as feed, include neem cake, castor cake, mahua cake, etc. Oil-cakes are quick-acting organic manure, as the nitrogen present in the oil cake is readily available to crop plants. It is reported that solvent-extracted oil cakes are quick-acting as compared to the expeller pressed oil-cakes. As a manure, powdered oil-cakes are applied to the soil well before sowing so that it is well decomposed before sowing. Average nutrient content of different edible oil-cakes are presented in the table.

Table 3.1: Nutrient content (%) of edible oil-cakes

Type	N %	P2O5 %	K2O %
Castor-cake	5.5-5.8	1.8	1.0
Coconut cake	3.0-3.2	1.8	1.7
Cotton seed cake (Decorticated)	6.5	2.8	2.1
Dhupaka-cake	1.1	0.2	-
Groundnut-cake (decorticated)	7.8	1.5-1.9	1.4
Linseed-cake	5.5	1.4	1.2
Niger-cake	4.8	1.8	1.3
Neem-cake	5.2	1.0	1.4
Rape-seed-cake	5.1	1.8	1.0
Safflower-cake (Decorticated)	7.8	2.2	2.0
Sesamum-cake	6.2	2.0	1.2

Source: Gaur et al., 2013

Meal Group of Organic Manures

Meal group of organic manures are markedly important on account of their inherent manurial properties. This group includes blood-meal, horn- and hoof-meal, meat meal, and fish-meal. Horn- and hoof-meals are prepared by cooking the horns and hooves of the dead animals or slaughtered animals in bone digester; and drying and powdering the cooked meal. Common meal is bone meal which is known to be rich in phosphorus. Bone-meal is available as raw bone-meal and steamed bone-meal. Bone-meal prepared from old animals posses more of phosphoric acid. It can be applied to all soils. Crops like wheat, paddy, sugar cane, etc., are found to respond positively to bone-meal.

Table 3.2: Nutrient Content (%) of Meal Group of Manures

Type	N %	P2O5 %	K2O %
Blood-meal	10-12	1.2	1
Fish-meal	4-10	3.9	0.3-1.5
Meat meal	10.5	2.5	0.5
Raw bone-meal	3-4	20-25	-
Horn- and hoof-meal	13	-	-
Steamed bone-meal	1-2	25-30	-

Source: Gaur et al., 2013

Check Your Progress 1

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. What are bulky organic manure ?

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2. What are concentrated organic manure ?

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3.4 BIOFERTILIZERS

"Biofertilizers are ready to use live formulations of such beneficial microorganisms, which on application to seed, root or soil mobilize the availability of nutrient by their biological activity in particular and help to build up the microflora and soil health in general. On application, it enhances the growth of the plants, increases the yield and also improves soil fertility and reduces pollution". In other words, biofertilizers are defined as preparations containing living cells or latent cells of efficient strains of microorganism that help plant uptake of nutrients by their interactions in the soil or interactions in the rhizosphere when applied through seed or soil. They increase the extent of the availability of nutrient in a form which can be easily assimilated by plants. They are eco-friendly and low cost source of plant nutrients and hence used as an alternative to chemical fertilizers. Biofertilizers if used regularly increases yield, and resistance to environmental stresses such as drought, extreme heat, early frost, pest and disease problem. The biofertilizer is a large population of a specific or a group of beneficial microorganism for enhancing the productivity of soil either by fixing atmospheric nitrogen or by solubilizing soil phosphorous or by stimulating plant growth through synthesis of growth promoting substances.

Bio-fertilizers are bacteria, algae and fungi and may broadly be classified into two categories namely Nitrogen fixing organisms like Rhizobium, Azotobacter, Azospirillum, Acetobacter, Blue Green Algae and Azolla; and Phosphorous solubilisers/mobilisers like phosphorus solubilizing microorganisms and Vesicular Arbuscular Mycorrhiza. Recently, the Potash mobilisers like Frateuria aurentia, Zinc and Sulphur solubilisers like Thiobacillus species and manganese solubiliser fungal culture like Pencillium citrinum have also been identified for commercial operations.

3.6 SYMBIOTIC SYSTEM

Biofertilizers contain living microbial inoculants or group of microorganism which play a crucial role in the soil fertility management. They are either free living or having symbiotic association along root zones in soil. Biofertilizers can be grouped in many ways based on their structure and function. Biofertilizers may be grouped as the following based on the nutrient that they fix or mobilize:

Nitrogen fixers: Free living, Symbiotic, Associative, Endophytic

Phosphate solubilizers: VAM Fungi, Ectomycorhizal, Ericoid mychorhiza, Orchid mychorhiza

Plant growth promoting Rhizobacteria

Silicate and Zinc solubilizers

On the other hand, biofertilizers can also be grouped based on the organisms involved in biofertilizer preparation:

Bacterial biofertilizers: e.g. Rhizobium, Azospirillum, Azotobactor, Phosphobacteria

Fungal Biofertilizers: e.g. Mycorrhiza

Algal Biofertilizers: e.g. Blue green algae

Table 3.3: Micro-organisms used as bio-fertilizers

Contributing plant nutrient	**Micro-organisms**	**Crops benefitted**
Nitrogen	1. Symbiotic	
	A. Rhizobium (with legume)	Gram, pea, lentil, red gram, green gram, groundnut, soybean
	B. Azolla (water fern- Anabaena azollae symbiosis)	paddy
	2. Associative symbiosis Azospirillum finger millet	Paddy, sugarcane, maize,
	3. Non-symbiosis	
	A. Heterotrophs E.g. Azotoba cter	Vegetable crops, wheat, paddy
	B. Photo-autotrophs E.g. Blue-green algae	paddy
Phosphorus	1. Phosphate solubilizers and mineralizers	
	A. Fungi: Aspergillus, Penicillium	For all crops
	B. Bacteria: Bacillus, Pseudomonas	For all crops
	2. Phosphate absorber (Root fungus symbiosis)	
	A. Ectomycorrhizae Pisolithus, Rhizopogon	For all crops
	B. Endomycorrhizae: Glomus, Gigaspora	For all crops

Source: ICAR, Handbook of Agriculture, 2013

In this unit, further discussion on biofertilizers would be on the basis of symbiotic, non-symbiotic and phosphate solubilizing/ mobilizing properties of microorganisms.

3.7 NON-SYMBIOTIC SYSTEM

Rhizobium

It belongs to Rhizobiaceae family and fixes 5-100 kg/ha of atmospheric nitrogen. Rhizobium inoculants because of their ability to fix atmospheric nitrogen in symbiotic association with leguminous plants not only meets the nitrogen requirement of the plants, but also the symbiotic system leaves behind sizeable amount of nitrogen for the succeeding crops. The popularity of legume inoculants is related to cropping system including legumes and cereals practiced since time immemorial.

Pulses, soybean and groundnuts occupy nearly 25 million/ha in India and the bacteria present in the nodules of these plants fix the atmospheric nitrogen to meet their needs. Nevertheless, the Rhizobium bacteria present in the nodules of these crops are not always efficient. Therefore, the competitive, efficient bacteria are isolated, screened, selected, and produced as carrier based inoculant. These inoculants can be used for treating legume seeds so that when the seeds germinate and plants grow, the efficient and infective strains of Rhizobium bacteria are present in abundance near the roots of the plants to form efficient pink nodules. Rhizobium isolated from root nodules is screened for efficiency through pot and field trials. Rhizobium belongs to the family Rhizobiaceae. There are 3 genera:

- Azorhizobium : It is used for stem nodulation
- Bradyrhizobium: It is useful against cowpea, gram, red gram, green gram, ground nut, etc.
- Rhizobium: It is useful against pea, lentil, lotus, berseem, etc.

Frankia

It exhibits non-leguminous symbiosis. Nearly 120 species, mainly trees and shrubs are known to harbour nitrogen fixing bacteria in their root nodules which are not rhizobia. An actinomycete is known to develop association with non-leguminous plants namely Alnus, Casuarina, Ceanothus, Eleagnus, Myrica, Hippophae, Purshia, etc. and the causal organism is named as Frankia. The non-leguminous nitrogen fixing systems are of modest agricultural importance because their potential is not widely known. The extent of nitrogen gain by such Angiosperms varies enormously depending on soil type, climate conditions and age of the plants.

Azolla

It belongs to family Azollaceae and is a free floating water fern in symbiosis with Anabaena azollae (Cynobacterium) and appreciable amount of nitrogen is fixed in the rice fields. Azolla was used as biofertilizer in some parts of India and South-East Asian countries. The association is utilizing the energy from photosynthesis to fix atmospheric nitrogen which may average from 40-60 kg N/ha/rice crop depending upon the soil, temperature, light intensity and phosphorus content since its survival is difficult at high temperature and soils low in available phosphorus. Azolla forms a symbiotic association with the green algae Anabaena azollae, which fixes atmospheric nitrogen giving the plant access to the essential nutrients.

3.8 NON-SYMBIOTIC SYSTEM

Dear learners let us now read about non- symbiotic systems in the following sentences.

Azotobactor are free living nitrogen fixing, chemo heterotrophic bacteria which are used as biofertilizers in the cultivation of most of the crops. The use of Azotobacter helps in saving 10 to 20 kg N/ha. It produces growth promoting substances which improve seed germination and growth of extended root system. It produces polysaccharides which improve soil aggregation. Azotobacter suppresses the growth of saprophytic and pathogenic micro-organism near the root system of crop plants. Azotobacter technology has not been received favourably in the western countries where farmers go for heavy applications of chemical fertilizers. But in a country like India where application of chemical fertilizers in rainfed cultivated area is low and in irrigated areas its application is much less as compared to developed countries, the benefits associated with Azotobacter use have been reported. Thus saving of 10-20 kg nitrogen/ha as chemical fertilizer to small and marginal farmers will be a great relief. Azotobacter helps in maintaining better plant population, growth and will be a great relief. Azotobacter helps in maintaining better plant population, growth and yield of the crops e.g. sorghum, maize, mustard and cotton, besides vegetable crops (tomato, potato, etc.). In general, in cereals, the yield increases are of the order of 15 to 30% and 10 to 20% in cash crops.

Azopirillium

The bacteria have been found to live within the roots of sorghum, pearl millet (bajra), and ragi plants. They belong to family Spiriliaceae, and the Azosprillium are chemoheterotrophic and associative in nature. They fix atmospheric nitrogen @ 15-30 kg N/ha and secrete growth regulating substances like auxin, gibberlins and cytokinin. The use of Azosprillium inoculants help in increasing yield of millets. It is also recommended for rice, maize, wheat and sugarcane crops and a co-inoculant for legumes.

Blue green algae

Blue green algae (BGA) also known as cyanobacteria form non-fibrous slimy growth on the ground, and on the surface of soil and water. They have striking similarities with bacteria except they have oxygen evolving photosynthesis. They are cosmopolitan in distribution and have ability to survive in extreme climatic conditions. They predominantly multiply vegetatively through fragmentation. A sexual reproduction is brought about by formation of exospores, endospores and akinetes. None of the BGA has sexual reproduction and form motile stages. Unlike the green algae, their food reserve is glycogen, which does not react with iodine to form violet colour. They belong to 8 different families, phototrophic in nature and produce auxin, indole-acetic acid and gibberellic acid, fix 20-30 kg N/ha in wet land rice fields. Application of BGA increases paddy yields by 15-20%. The species of blue-green algae which are known to fix atmospheric nitrogen are classified into 3 groups

(i) Heterocystous- aerobic forms

(ii) Aerobic unicellular foms and

(iii) Non- heterocystous filamentous, microaerophilic forms.

The composite inoculation of blue green algae may consist of the cultures viz. Nostoc, Anabaena, Calothrix, Tolypotrix, Plectonema, Gloeocapasa, Oscillatoria, Clindrospermum, Aulosira, and Scytonema. The term algal fertilizer was coined in early 60s to embody such blue green algae which have the capacity to metabolize molecular nitrogen and bring about an addition to the nitrogen level of soil.

3.9 PHOSPHATE SOLUBILIZING/MOBILIZING BIOFERTILIZERS

Phosphorus is one of the most important plant nutrients and may be a critical nutrient for the optimum growth of plants. Most of our soils are low in available form of phosphorus and require phosphorous application. The proliferation of efficient strains of phosphate solubilizing microorganisms in the rhizophere of crops will render insoluble soil phosphates available to plants due to production and secretion of organic acids by them. The use of this biofertilizer will also increase the availability of phosphates from rock phosphate applied directly even to neutral to alkaline soils or when used for preparation of phosphor-compost. Rock phosphate is recommended in acidic soils as phosphate fertilizer.

Phosphate solubilizing microorganisms

Phosphate solubilizing microorganisms are a group of heterotropic microorganism constituting mostly bacteria and fungi, having the capability to solubilize insoluble phosphate and making them available to plants. These include Bacillus megatherium, Bacillus subtilis, Bacillus circulance, Baciilus polymixa, Pseudomans stratra, and fungi Penicillium digitatum and Aspergillus awamori. Phosphate solubilizing microorganisms play an important role in plant nutrition through the increase in P uptake by the plant and also as plant growth promoting microorganism.

Mycorrhiza

Mycorrhiza means fungus root, was first applied to fungus free associations described in 1985 by the German forest pathologist A.B. Frank. Mycorrhizae are mutualistic symbiotic association formed between many plants roots and certain fungi. There are 4 main mycorrhizae viz. ecto, vesicular arbuscular (VA), ericoid and orchidaceous. In Ectomycorrhiza, the fungus forms a compact mantle or sheath over the root surface and the hyphae grow out into the soil. These are generally found in forest trees including many gymnosperms (e.g. pines, spruce, fir, larch) and angiosperms (e.g. oak, beech, eucalyptus, poplar). The mycorrhizal hyphae assume at least partly the functions of root hairs. Pinus spp. showed better results with VAM as symbiont. The ectomycorrhizal fungi help the plants in phosphorus uptake through increased surface area of absorption, offer protection from some soil-borne plant pathogens and enhance rooting and survival of cuttings through production of growth hormones.

Vesicular Arbuscular Mycorrhiza (VAM)

These are obligate symbiont with a loose network of hyphae in soil and extensive growth within the cortex of the plant. In the host cells, they produce highly branched hyphal structures, called arbuscules and also vesicles. This occurs in most angiosperms as well as gymnosperms, pteridophytes and bryophytes. Most plant species particularly leguminoseae and graminae are normally mycorrhizal. Crops where VAM infection showed better results are sorghum, barley, upland rice, cassava, grape vine, olive, citrus, cocoa, tobacco, cotton, sugarcane, pineapple, lettuce, onions, cowpea, soybean, straw berries, apple, rubber, coffee, tea, papaya, oil palm and various ornamental bulbs. The hyphae of arbuscular mycorhhizae fungi produce glomalin which may be one of the major stores of carbon in soil. VAM fungi can neither be cultured in the absence of living root nor isolated on agar plates by standard microbiological techniques. It is now well established that many plant roots cannot grow adequately without VAM fungi, especially in phosphate-deficient soils. In view of this, their impact in tropical agriculture will be greater than in temperate conditions.

Check Your Progress 2

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. Name any one of the actinomycetes that can fix atmospheric nitrogen?

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2. What are phosphate solubilizers ?

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3.10 LET US SUM UP

Agricultural production increased in the recent past increased due to technology intensive agricultural activity. Use of synthetic fertilizers is perhaps essential for growing fertilizer responsive crop varieties. Nevertheless, the environmental concerns associated with excessive use of synthetic fertilizer brought to the forefront the need for an alternative to synthetic fertilizer. Manures and biofertilizers are exceedingly important as they have potential to cater to the demands of agriculture and also maintenance of ecological integrity of soil ecosystem. We have studied in this unit about the role of manures and biofertilizers in augmenting agricultural production and benefits of using the same in agroecosystem. This can be summarised in the following points:

- Scientific underpinnings of manures and biofertilizers.
- Types of manures from the perspective of nutrient composition, and bulkiness of the manure
- Classification of biofertilizers pesticides based on micro-organisms, and association between host crop and microbial inoculants.

3.11 KEY WORDS

Biofertilizers: Microbial inoculants are preparations containing latent cells of efficient strains of nitrogen fixing microorganisms used for seed or soil application with the objective of increasing the numbers of such microbes in soil or rhizosphere.

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3.13 ANSWERS TO CHECK YOUR PROGRESS

Answers to Check Your Progress 1

1. Y our answers should include the following points:

   Bulky organic manures are manures that are bulky in nature but supply plant nutrients in small quantities. Farmyard manure (FYM), compost and green manure are the most important and widely used bulky organic manures. Application of bulky organic manures greatly improves the physical, chemical and biological properties of soil.

2. Concentrated organic manures are concentrated in nature and contain higher percentage of plant nutrients. Plant based manures can be divided into edible oil cake and non-edible cake oil. Common edible oil cakes are sesamum cake, groundnut cake, linseed cake, etc. whereas non-edible cakes are neem cake, castor cake, cotton seed cake, etc. On the other hand, animal originated concentrated organic manures are bone meal, fish meal, hoof meals, blood meals and poultry manures, etc.

Answers to Check Your Progress 2

1. Your answers should include the following points:

   Frankia is an actinomycetes that develop association with non-leguminous plants namely Alnus, Casuarina, Ceanothus, Eleagnus, Myrica, etc. Nearly 120 species, mainly trees and shrubs are known to harbour the actinomycetes in their root nodules which are not rhizobia.

2. Your answers should include the following points:

   Phosphate solubilizers are a group of heterotropic micro-organisms, having the capability to solubilize insoluble phosphate and thereby making the phosphate available to plants. Examples of phosphate solubilizers include Bacillus subtilis, Bacillus circulance, Bacillus megatherium, Baciilus polymixa, Pseudomans stratra, and fungi Penicillium digitatum and Aspergillus awamori.

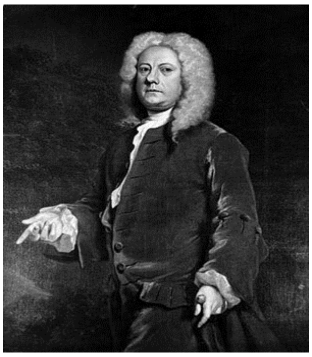
UNIT 4 CONSERVATION AGRICULTURE

Structure

4.0 INTRODUCTION

The need to increase agricultural production to meet the growing population in the backdrop of finite agricultural resources, realisation of ill effects of industrial agriculture, and declining soil fertility and productivity paved way for a novel concept called conservation agriculture. Conservation agriculture is driven by the principles of no tillage, residue management, and variety and diversity in crop rotation. Tillage is the primary step in agriculture. It includes varied operations like field preparation, incorporation and mixing of crop residues, planting, compaction of loose soils, mixing of manures, fertilizers and pesticides, weed control, reclamation and management of problem soils, etc. So the term tillage encompasses wide variety of agricultural soil management practices and the tillage operation per se had evolved with the development of agricultural technology and agricultural intensification. Tillage operation influences the physical, chemical and biological proportion of soil and aim at providing favorable soil environment for crop production. It is considered as a single most expensive component of crop production. Of late, due to explicit disadvantages observed in chemical intensive agriculture practices and global environmental change like climate change and global warming, tillage practices are suitably modified to conserve the valuable soil resources and to augment the carbon sequestration in soils. In this backdrop, the conservation practices are developed aiming at safe crop production without any ecological harm. In this unit, we would endeavour to know the underpinnings of conservation agriculture; principles of conservation agriculture and conservation tillage; and influence of tillage on soil properties and plant growth and productivity.

Do you know?



Jethro Tull is considered as the Father of tillage. He proposed that plants absorb minute soil particles for their growth and development. So, he suggested that thorough ploughing operations are necessary to break the soil particles into finer particles. The food for the plants, he claimed, were the soil particles which the plants devoured through the “lacteal mouths” of their roots.

This could be achieved by adopting tillage practice, which would break the clods and open up the soil to create pore spaces. Therefore, to increase the plant growth, it was necessary to improve the contact between roots of the plant and soil and also make available more of fine particles to the plant roots. Jethro Tull authored the book “The New Horse-Hoeing Husbandry”. Initially, Tull’s ideas were not universally accepted and were severely criticized by those who rejected his concepts of plant growth. Although, his theory was found to be incorrect, tillage operations are important for providing suitable seed bed, weed free environment and optimum soil environmental condition for initial establishment of crop plants. It was not until the second half of eighteenth century that his method began to spread, mainly through the efforts of Hamel de Manceau, Balduin, Coke and Smyth and Knapp.

4.1 OBJECTIVES

After completing this unit, you will be able to:

- state the principles of conservation agriculture;
- describe the types of conservation tillage;
- explain the influence of tillage on soil properties; and
- describe the influence of tillage on crop growth and productivity.

4.2 PRINCIPLES OF CONSERVATION AGRICULTURE

Food and Agriculture Organisation (FAO) introduced the concept of conservation agriculture as a “resource-efficient agriculture crop production based on integrated management of soil, water, biological resources combined with external inputs”. Conservation agriculture is based on the “principles of continuous residue cover, minimum soil disturbance, and diverse crop rotation” (Reicosky, 2015). Soil cover through live cover crops or mulches, enable soil protection from erosion, improvement of soil organic carbon and conservation of soil moisture. Diverse crop rotation involving leguminous crops enhances greatly the functioning of soil ecosystem. “No tillage” as a principle reduces soil and carbon loss, and also this agriculture intervention improves soil health.

4.3 TILLAGE

Tillage is defined as the physical manipulation of soil to provide favourable soil environment for the growth and production of crop plants. The basic aim of tillage is to obtain a desirable soil tilth. Soil tilth is used to describe the fitness of soil to plant growth and yield. Tillage is the cause and tilth is the effect. Tillage process involves primary (to break soil into clods) and secondary (to pulverize soil) operation. Since the tillage operation involve considerable amount of energy, time and cost, the tillage operation are modified to increase the efficiency of tillage operations. Tillage requirements are highly crop and soil specific. Tillage operations are performed on crop field by taking into account two distinct zones namely planting zone and management zone. In the planting zone, the tillage operation aim to provide optimum soil condition for seed germination and seedling growth. On the other hand, the management zone includes inter-row space which demands maximum water infiltration and minimum weed infestation.

4.4 OBJECTIVES OF TILLAGE

The basic objective of tillage is to obtain good soil tilth for crop husbandry. The objective of tillage depends on soil properties, climatic conditions, the crop chosen for cultivation and the socio-economic status of the farmers. The various objective of tillage are detailed below for better understanding of the basic principle behind tillage operations.

1. Preparation of seed bed with optimum tilth for plant growth and yield. Tillage operations influence the soil-air-water relation which is important for seed germination and early establishment of crop plants. Tillage operations are normally performed when the soil is in the friable consistency so that the physical properties of soil particularly soil aggregation is improved.

2. Weed control is another important objective of tillage. Tillage or cultural practices form an important component in the Integrated Weed Management. Tillage operations manages the weed population by physical destruction of weed plants, bringing to the soil surface and desiccating the regenerative organs of a plant like stolons, runners, etc. and by reducing the weed seed bank in the soil. Additionally, early establishment of crop

plants and proper spatial arrangement of crop plants (optimum spacing) considerably reduces the weed growth in the crop field.

3. Tillage operations are also performed with an objective of soil conservation in the hilly regions.

4. Tillage can aid in sequestering carbon in the form of or organic residues which will improve immensely the soil properties.

5. The organic and inorganic materials like manures, fertilizer, soil amendments, conditioners, etc. are incorporated by specially designed tillage implements.

4.5 FEATURES OF GOOD SOIL TILTH

Soil tilth is a significant soil characteristic reflecting a suitable combination of physical properties like texture, structure, etc. Good soil tilth aid in synergizing the interaction among physical, chemical and biological processes taking place in soil. The important features of good soil tilth are as follows.

- Provide maximum possible infiltration of water and moderate water retention
- Good soil tilth offers minimum resistance to root penetration.
- Provide maximum resistance to soil erosion caused by water and wind.
- Provide moderate gas exchange between soil environment and atmosphere.
- Provide favorable condition for microbial activities and crop residue management.

4.6 TYPES OF TILLAGE

Tillage operations can be grouped into two types based on the operation performed either before sowing or after sowing. Preparatory cultivation is a group of tillage operations performed before sowing the crop, and after cultivation refers to the tillage operations performed after sowing the crop.

Preparatory Cultivation:

Preparatory cultivation includes three distinct operation namely primary tillage, secondary tillage and layout of seedbed. These are series of operations carried out during the intervening period between the harvests of a crop and sowing of the succeeding or next crop. Preparatory cultivation intends to prepare a favourable seed bed for uniform germination and successful crop establishment.

Primary Tillage:

The primary tillage refers to the ploughing of the soil using different types of primary tillage implements with an objective of removing soil physical constraints like soil compaction and uprooting of perennial weeds and stubbles. The soil compaction is symptomatic of poor soil aeration, soil moisture and soil structure. So, primary tillage aims to break open the compact soil, loosen the soil, reduce the bulk density and create porosity to increase infiltration. Ploughing also should ensure inversion of the soil and soil homogeneity in the plough layer.

- Ploughing operations should be performed at the optimum moisture content. The optimum soil moisture range for effective ploughing is between 25 to 50 per cent depletion of available soil moisture. Ploughing under dry soil condition results in large sized clods and increase in erodibility of soil. On the other hand, ploughing under wet conditions encounters difficulty in ploughing and it would lead to soil compaction below the zone of ploughing (plough sole) and on drying, the soil becomes hard.
- The optimum depth of ploughing is decided by the effective root zone depth of the crops. The monocotyledon crops having adventitious root system demand only shallow ploughing. The crops with tap root system demand deep ploughing.
- The number of ploughings depends on the soil type, weed infestation, the previous crop grown, the fineness of the required soil tilth, etc. Generally, three to four ploughings are recommended.

Secondary Tillage:

The tillage operations performed on the soil after primary tillage are known as secondary tillage. Usually after primary tillage operations, the field may be with large clods and uprooted weeds. To break the clods, Disc harrow, Cultivators, etc. are used. Harrowing is normally done to a shallow depth to crush the clods and to uproot the remaining weeds and stubble. After breaking and crushing the clods, the field is ready for sowing. Sowing is also considered part of the secondary tillage. The seedbed is prepared based on the crop requirement and soil and climatic conditions. For the crops like soybean, wheat, etc. flat leveled seedbed is normally prepared. Broad bed and furrows (BBF) are recommended for growing crops in the rainy season where the drainage is a problem. For the crops like sorghum, maize, etc. the ridges and furrows are recommended.

After Tillage:

The tillage operations that are carried out in the standing crop are called after tillage. It includes side dressing of fertilizer, earthing up and intercultivation. Earthing up is performed using a country plough or ridge plough to provide extra support against lodging for the sugarcane crop. For the tuber crops like potato, earthing up operation helps to provide more soil volume for better growth of tubers.

Check Your Progress 1

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. What is conservation agriculture?

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2. What are the principles of conservation agriculture?

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3. What is tillage?

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4.7 CONSERVATION TILLAGE

Conservation tillage is a comprehensive term encompassing all tillage practices which is less intensive than conventional tillage. The Conservation Technology Information Centre (CTIC) in Indiana, has categorically defined conservation tillage as tillage and planting system in which at least 30% of soil surface is covered by plant residue after planting to reduce erosion by water. In other words, conservation tillage demands for less manipulation of soil by retaining crop residues on the soil surface. Also, the numbers of tillage operations are reduced as compared to conventional tillage by combining the farm operations. The main purpose of conservation tillage is to conserve soil, moisture and organic matter content of soil. As stated before, the conservation tillage can be considered as a consequence to the negative effects of conventional tillage and the prime importance bestowed on soil health and soil productivity. The conservation tillage was developed successfully because of the development in broad spectrum herbicides, crop residue management and multi functional tillage implements.

The Conservation Technology Information Centre (CTIC) has classified the conservation tillage into four subtypes:

a. No-tillage, (Zero tillage, sod planting, eco fallow, chemical fallow, direct drilling)

b. Reduced tillage

c. Stubble mulch tillage

d. Ridge tillage

Advantages of Conservation Tillage:

1. Conservation tillage augments the soil organic mater content and aids in soil carbon sequestration.

2. It enhances the activity of soil organisms which helps in cycling of nutrients and providing available form of nutrients for crop growth.

3. The soil erosion caused by wind and water is reduced because of retention of crop residues on the soil surface and minimum disturbance of soil.

4. In this type of tillage practice, the soil physical properties like soil structure, soil consistency are improved.
5. Improvement of soil physical properties helps in soil moisture conservation.
6. Minimum number of tillage operations are envisaged in the conservation tillage practice lowers the cost of cultivation and mechanical pressure on soil.

Disadvantages of Conservation Tillage:

1. Sowing operation requires special planting equipments.
2. The crop residues retained on the soil surface may harbour pest and disease causing organisms.
3. The pesticide residues may cause phytotoxicity to the succeeding crops.

DO YOU KNOW?

Resource Conserving Technologies and Conservation Agriculture

Resource Conserving Technologies (RCT's) refer to those practices that enhance resource- or input-use efficiency. Few examples of RCTs are as follows.

- New varieties that use nitrogen more efficiently
- Zero or reduced tillage practices that save fuel and improve plot-level water productivity
- Land leveling practices that help save water.

On the other hand, conservation agriculture practices will only refer to the RCTs with the following characteristics:

- Soil cover, particularly through the retention of crop residues on the soil surface;
- Sensible, profitable rotations; and
- A minimum level of soil movement, e.g., reduced or zero tillage.

Source: Abrol et al., 2005

4.7.1 No-tillage

In this tillage system, there is no seedbed preparation except for opening the soil to place the seeds at the optimum depth. The seeds are either placed into the soil by punching holes in the soil or broadcasted on untilled soil. The weeds present on the field are controlled by the herbicides which in effect replace the tillage operation. The residues left over on the soil surface conserve soil moisture, reduces soil erosion and improve the soil productivity. The recycling of nutrients is ensured by the increased soil microbial activity on the decaying crop residues. In the southern state of Tamil Nadu, the pulse crop is grown as a relay crop over the rice stubbles. In this case, the quick growing pulse crop utilizes the available soil moisture and soil nutrients.

Advantages of No-tillage:

1. No-tillage method of conservation tillage conserves soil moisture by improving soil physical properties and drastically reducing the evaporation losses.
2. Since the soil is covered with the residues, the soil erosion by wind and water is reduced as compared to conventional tillage.
3. No-tillage system saves the energy, labour and time.
4. Soil fertility and soil productivity are enhanced because of increased activity of beneficial soil micro-organism and earthworms.

Limitations of No-tillage system:

1. Residues retained on the soil may act as alternate/alternative hosts to disease causing organisms. The residues may also carry eggs and young ones of insect pest. So, Integrated Pest Management is a challenge in No-tillage system.
2. In poorly drained soil, No-tillage system aggravates the problem by reducing the evaporation losses. This will affect the early establishment of the subsequent crop.

ACTIVITY

Resource Conservation Technologies in the Indo-Gangetic plains

Resource conservation technologies like zero-till planting of wheat, bed planting of crops, laser aided land leveling etc. have emerged as a major response to stagnating crop yields and declining profitability of rice-wheat cropping system farmers in the Indo-gangetic plains. The adoption of new resource conservation technologies is found to benefit the farmers by enhancing agricultural productivity through improving the input use efficiency.

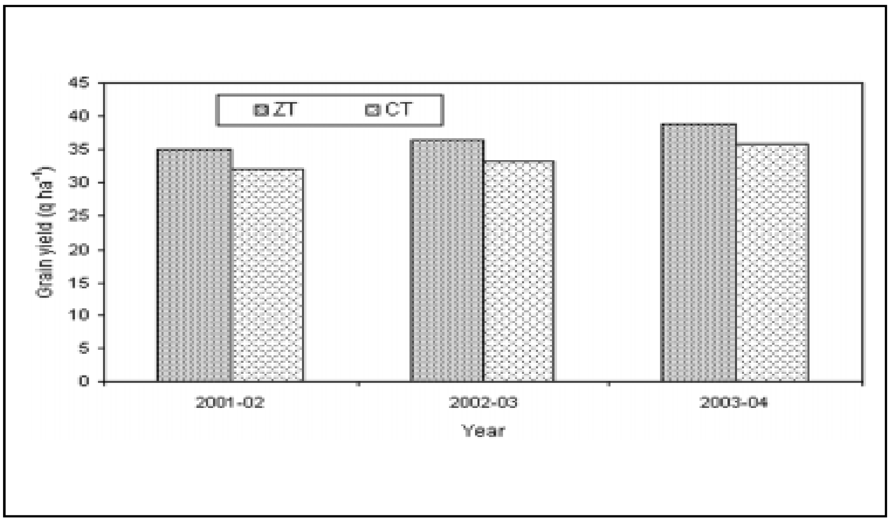

Figure 4.1: Year-wise average productivity of wheat based on demonstrations conducted under NATP project during 2001-02, 2002-03 and 2003-04, respectively.

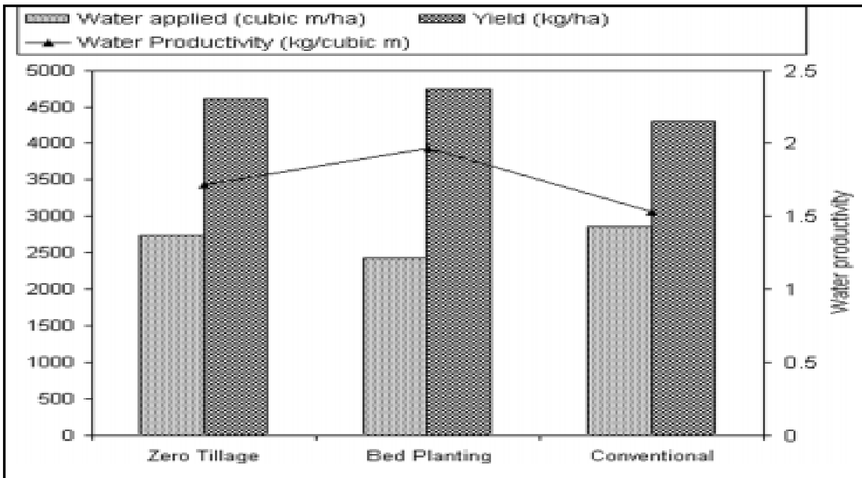

Figure 4.2: Grain yield and water productivity of wheat under different crop establishment techniques.

Source: Malik *et al*., 2005

From the figures, observe the productivity enhancement with respect to Zero tillage over conventional tillage and try to examine the reasons for the same.

Examine the reasons for increase in input use efficiency (water use efficiency) associated with the conservation tillage practices.

4.7.2 Reduced Tillage

It is a tillage system wherein number of tillage operations is reduced and only those tillage operations which are absolutely necessary for crop cultivation are performed. Tillage operations naturally vary with the soil, crop and climatic conditions. The primary tillage and secondary tillage operations are normally combined together to minimize the tillage operation. For example, the land preparation can be combined with sowing operation. Unlike, the No-tillage practice, in the reduced tillage system, the retention of crop residues depends on the specific objectives. If the objective is to conserve soil and moisture in rain fed areas, the crop residues are retained on the soil surface to conserve soil moisture.

Advantages of Reduced Tillage:

1. Reduced tillage save time, energy and labour. It is cost effective too.

2. It reduces the vulnerability of soil to erosion and conserves soil moisture which aid in crop cultivation in rainfed areas.

Disadvantages of Reduced Tillage:

1. Sowing operation is difficult to perform in the presence of crop residues on the soil surface.

2. The residues may act as a substrate for insect pest and diseases.

DO YOU KNOW?

TILLAGE PRACTICES IN DRYLANDS

In the drylands, the kharif crops are grown with the rain water and the rabi crops mainly thrive on the residual soil moisture. Tillage practices in the drylands aim for conservation of soil moisture and minimize the soil loss due to erosion. Tillage before the onset of monsoon with mouldboard plough, chisel plough, disc harrow and blade harrow help in increasing the infiltration rate and also storage of the moisture. The ploughing operations loosened the top 10-15 cm of soil layer and increased the infiltration rate. So, in the drylands, conservation tillage practices like reduced tillage combined with moisture conservation strategies are recommended.

Source : Handbook of Agriculture, ICAR, 2009

4.7.3 Stubble Mulch Tillage

It is a method of conservation tillage practice wherein plant residues or other materials are retained to cover the soil surface. It is also called as mulch farming or ploughless farming. It caters to the objective of soil moisture conservation by controlling soil erosion and reducing evaporation and enhancing infiltration of water. In this tillage practice, the weeds are controlled by employing the surface tillage implements like chisel plough.

Advantages of stubble mulch tillage:

1. Mulch tillage control soil erosion caused by wind and water
2. As compared to the conventional tillage practices, mulch farming minimizes the cost involved in tillage operation by reducing the energy consumption and labor cost.

Disadvantages of Stubble Mulch Tillage:

Like other conservation tillage practices, the problem of insect pest and disease causing organism persist and pest management is undoubtedly an important challenge in crop fields adopting conservation tillage practices.

4.7.4 Ridge Tillage

Ridge tillage is a method of land preparation whereby the top soil is scraped and concentrated in a defined region to deliberately raise the seedbed above the natural terrain. Ridge tillage is adapted to a wide range of soils, crops, rainfall regimes, ecological environments, socio-economic and cultured conditions (Lal, 1990). In this practice, crops may either be grown on ridges or furrows depending on soil moisture conditions. For instances, crops in arid and semi-arid regions are grown in the furrows, which can retain the water during rainy season. Ridge planting is also practiced on sloping agricultural landscapes with slopes less than 7% to conserve soil and water.

Advantages of Ridge-tillage System

1. Ridge planting is considered as an effective strategy for soil and water conservation on sloping landscapes.
2. In the arid and semi –arid regions, rainwater is collected in the furrows and soil moisture content is appreciably improved which helps in crop establishment and profitability of dry land farming system.
3. Cultivating the crop plants on ridge particularly on shallow soils increase the effective rooting volume which will help in water absorption and growth of crop plants.

Limitations:

1. Special tillage implements are required to form ridges.
2. The ridges if maintained for longer period of time in arid and semi-arid regions may exhibit high salt concentration on the ridges due to the upward movement of salts along with water.

DO YOU KNOW?

Laser Land Leveling and Resource Conservation

Land leveling is fundamental to the success of soil and crop management practices. The land leveling has great influence on status of soil moisture, resource use efficiency and crop productivity. The undulated land affects the seed bed preparation, placement of seeds, and early establishment of seedlings and generally show signs of escalated production cost associated with more energy consumption and reduced resource use efficiency. So land leveling is considered important precursor for farm operations. Of late, laser land leveling is found to have more advantages and it is reported that the performance of resource conservation technologies (RCTs) improves to a great extent on leveled fields. Laser assisted precision land has following advantages.

- Increase in the cultivable land area by reducing the number of bunds and channels in the field.
- Reduction in weed population.
- Increase in Crop productivity (The grain yield of wheat was increased from 4.3 t/ ha under traditional leveling to 4.6 t/ ha through precision leveling).
- Increase in water productivity through improved application and distribution efficiency of irrigation water.
- Improved nutrient use efficiency because of uniform distribution of nutrients in the soil water

Source : Jat et al., 2005

Check Your Progress 2

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. What is conservation tillage?

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2. What are the advantages of "No Tillage"?

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4.8 INFLUENCE OF TILLAGE ON SOIL PROPERTIES

Tillage operations influence the soil properties like bulk density, moisture content, structure, organic matter content and activity of soil micro-organisms and macro fauna significantly. Through their effect on three phases of soil (liquid, gas and solid components), tillage practices have considerable effect on seed germination, seedling emergence, root growth and crop productivity.

4.8.1 Soil Compaction

The state of soil compaction affects the soil-air-water-temperature relationships immensely and determines the properties of soil. Soil compaction refers to the increase in the density of soil by a dynamic load. Dynamic load is found to be more effective than the static load in causing soil compaction. In other words, soil compaction is a process by which the bulk density of the soil is increased by removing the air present in the soil pores. The soil compaction occurs either due to the natural conditions or due to improper tillage practices. However, the degree and depth of soil compaction depends on the soil properties like soil texture, soil moisture and on the load due to the machineries and farm implements. It is found that sandy textured soils are not easily compacted as compared to fine textured clayey soils. During the process of soil compaction, solid soil particles are compressed and they are rearranged bringing in changes in the liquid and gaseous component of soil. Because of compression of solid soil particles, the bulk density increases. With respect to moisture content, maximum compaction can be achieved under a given load at proctor moisture content.

Generally, soil compaction is found to be an undesirable soil property by virtue of interfering with the root development of crops and affecting the soil-air-water relationships. Nevertheless, soil compaction is useful in case of coarse textured soils which display characters like low water-retention, high permeability and often shows signs of moisture stress. Soil compaction in course textured soils and loamy sand soils found to increase the productivity of crops like mung-bean, pearl millet, Cowpea, wheat, barley.

4.8.2 Soil Porosity and Bulk Density of Soil

A soil consists of clay, silt, sand and gravel sized particles which are products of weathering, organic materials arising from the growth of flora and fauna in and on the soil, and the soil air and soil water which fill the voids between the solid particles. When the soil is tilled, the solid soil particles rearrange in a random manner and the pore space existing between the soil particles is increased. When the total volume of soil including the void space increases, the bulk density decreases.

Soil loosening decreases bulk density and soil compaction increases the bulk density. Tillage operations have varying effect on the bulk density of the soil. The conservation agricultural practices improve soil porosity and water transmission. The soil porosity changes with tillage practices depending on the change in bulk density. Conservation tillage practices and its associated positive influence on soil organic matter and increase in earth worm activity result in the formation of continuous pore system.

4.9.3 Soil Water

By bringing the changes in the porosity, pore geometry and continuous pore system, tillage practices have far reaching effect on soil hydraulic properties like infiltration, water retention and soil water balance. Increased surface roughness following primary tillage operations results in greater surface storage rain water and thereby, the overland flow is greatly reduced. The surface roughness and loosening influence of tillage encourages infiltration by providing more of macropores in the plough layer. Because of the increased porosity, there is a tendency for the tilled soil to lose water more quickly under the influence of gravitation in the form of gravitational drainage. The positive result from this behavior of the tilled soil is there is less likelihood of water logging in the surface layers.

Table 4.1: Soil properties before and after tillage

Soil properties	Sandy soil		Clay loam	
	Before	**After**	**Before**	**After**
Hydraulic conductivity (cm/hour)	17.64	22.23	1.91	6.08
Random roughness (cm)	1.15	1.75	1.72	2.77
Soil water at saturation (%)	32.00	38.00	40.00	61.00
Bulk density (g/cm^3)	1.42	1.11	1.24	0.80

Source: Reddy and Reddi, 2010.

4.8.4 Soil Aeration

The conventional tillage practices generally support higher proportion of macro-pores which are capable of draining the excess water either after heavy rainfall or irrigation. Tillage operations normally increase total soil porosity. The conventional tillage operation results in higher air-filled porosity or aeration porosity than the conservation tillage practices like No-tillage, minimum tillage, etc. The tillage practices categorically influence the infiltration rate and soil aeration but the degree of the influence depends on tillage intensity, soil structure, soil aggregate stability, soil moisture and organic residues of the soil.

4.8.5 Soil Structure

Crumb and granular structures are highly desirable for crop cultivation. These types of structures occur when the soil is rich in organic matter and are influenced by the tillage and other farm practices. Tillage practices performed at optimum moisture content result in crumb and granular structures. The roughness exhibited by the crumb structure reduces the erodibility and soil erosion through wind and water. Soil structure is destroyed when tillage is performed at unsuitable soil moisture. At times, destruction of the aggregated condition of the soil is desirable for growing specific crops. For instance, the paddy seedlings are transplanted on puddled soil which does not have soil structure. The puddling of the soil is an important operation performed in case of transplanted paddy crop to minimize the percolation losses by destroying the macropores.

4.8.6 Soil Temperature

The primary source of heat energy to soil is sun. The practices that encourage heat absorption and flow in soil and that discouraging heat loss to the atmosphere would help in rise in soil temperature. The soil temperature influences the crop growth indirectly, by affecting the physical, chemical and biological process taking place in the soil and plant. The tillage practices through their influence on soil bulk density, soil aeration, soil compaction, soil aggregate stability, residue management, soil organic matter content brings in changes in the soil temperature. The presence of residues on the soil lowers the soil temperature. On soil compaction, the bulk density and the thermal conductivity of the soil increases due to the decrease in the air filled porosity and increase in the contact between the solid soil particles. The conservation tillage systems result in lower soil temperature.

4.8.7 Soil Organic Matter Content

Soil organic matter content is an essential indicator of soil health. The organic matter content of the soil is an inter play between the accumulation and decomposition of organic matter driven by multitude of soil properties and agricultural practices. The intensive conventional tillage practices and arable cultivation in the long run results in low soil organic matter content due to increased decomposition of organic matter and removal of organic residues in the harvest. The tillage effects on soil micro-organisms occurs through the changes it brings on soil moisture, soil aeration, organic matter content and soil temperature. The microbial population largely depends on the soil organic matter. The conservation tillage practices incorporating residue management found to increase the organic matter content of the soil by decreasing the decomposition rate of organic matter and accumulating the organic load through incorporating the organic residues. Organic matter is generally responsible for the dark brown to dark grey colour of the soil. Conservation tillage practices encourage higher earthworm activity and increases the heterotrophic bacterial population.

4.9 TILLAGE EFFECTS ON CROP GROWTH AND YIELDS

Dear learners let us now read about tillage effects on crop growth and yields in the following lines:

4.9.1 Seed Germination and Early Crop Establishment

The seed to germinate require soil contact to absorb moisture, optimum soil temperature, soil aeration and pest free soil environment. The tillage practices basically aim to provide favourable seed bed through the favourable changes in soil-air-water-temperature relationships. The preceding section on tillage effects on soil properties explained the influence of tillage practices on soil physical, chemical and biological properties. Another function of tillage is to remove mechanical impedance to the root growth. The root growth and density of rooting are very important from the perspective of crop establishment. It is the roots that absorb water and nutrients. Tillage ensures creation of porosity which aids in the root growth. The conservation tillage systems were found to produce higher root densities in case of maize crop as compared to the conventional tillage practices (Hilfiker and Lowery, 1988).

4.9.2 Crop Yield

Tillage practices influence the crop yield by influencing the seed germination, crop growth, weed free environment, soil biology (micro fauna and macro fauna), soil conditions favouring moisture retention, moisture conservation, water stable aggregates, organic matter accumulation and favourable thermal regime of the soil.

4.10 LET US SUM UP

Tillage is one of the fundamental practices of agricultural management. Tillage is the physical manipulation of the soil with the aim to improve the soil condition for crop production. Nevertheless, the tillage practice is not without its problems. The adverse impact due to repeated tillage includes soil compaction, soil loss and declining soil fertility. The increasing cost of energy (fuel) questions the economic and ecological feasibility of conventional tillage. As a result, alternative techniques in tillage practices like various forms of conservation tillage and Best Management Practices have been evolved to maintain the integrity of soil ecosystem and sustainability of agroecosystem. Conservation agriculture is “an agricultural technology and a suite of land management principles, based on the agricultural practice like no-tillage, continuous organic soil cover, and crop rotations”. We have studied in this unit about conservation agriculture, conservation tillage, and influence of tillage on soil properties and crop growth and development. This can be summarised in the following points:

- Principles of conservation agriculture
- Types of conservation tillage
- Influence of tillage on soil properties, crop growth, and productivity.

4.11 KEY WORDS

Soil Aggregates: Soil aggregates is defined as secondary units or granules comprising many primary soil particles (sand, silt and clay) cemented together by various binding agents like organic substances, iron oxides, clay, carbonates, etc.

Bulk density of soil: Bulk density is the ratio of the mass of oven dried soil solid particles to the total volume of the soil. It is expressed as g/cm^3 or Mgm^{-3}.

Clay: it is a finer fraction of soil separate comprising particles of 0.002 mm diameter. The presence of such particles in a soil in different proportion relative to sand and silt particles determines soil textural classes.

Clay minerals: Naturally occurring inorganic materials (usually crystalline) found in soils. These are mostly formed from the soluble products of the primary minerals and may be considered as secondary minerals having a significant surface area.

Conservation tillage: It is defined as the tillage and planting system in which at least 30% of the soil surface is covered by the plant residue after planting to reduce soil erosion.

Crumb structure: Crumb structure is considered good for crop cultivation and it is made of soft porous, more or less rounded granules. This type of structure occurs in the surface soil rich in organic matter. The crumb structure is formed due to the adoption of good farming practices.

Soil separate: Soil separates are one of the individual sized groups of mineral soil particles namely sand, silt and clay.

Soil Structure: Soil structure is defined as the arrangement of soil particles and their aggregates into a certain structural unit. Soil structure can be changed or modified by farm operations.

Soil Texture: Soil texture is defined as the relative proportion of sand, silt and clay particles in a soil mass. It is a basic property of soil and cannot be changed or modified.

Tillage: Tillage is defined as mechanical manipulation of soil aimed at improving the soil condition for crop production. Tillage provides soil conditions favourable for rapid water intake and temporary storage of water, conserve nutrients, and incorporate basal doses of fertilizers. Tillage also destroys the weeds, and removes crop stubbles.

Tilth: Soil tilth is defined as the physical condition of the soil with respect to its ease of tillage, fitness as a seed bed and its impedance to seedling emergence and root penetration. Tilth is the product of tillage.

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4.13 ANSWERS TO CHECK YOUR PROGRESS

Answers to Check Your Progress 1

Your answers should include the following points:

1. Conservation agriculture is defined as a "resource-efficient agriculture crop production based on integrated management of soil, water, biological resources combined with external inputs".
2. Conservation agriculture is based on the "principles of continuous residue cover, minimum soil disturbance, and diverse crop rotation".
3. Tillage is defined as the physical manipulation of soil to provide favourable soil environment for the growth and production of crop plants. The basic aim of tillage is to obtain a desirable soil tilth.

Answers to Check Your Progress 2

Your answers should include the following points:

1. Conservation tillage is defined as tillage and planting system in which at least 30% of soil surface is covered by plant residue after planting to reduce erosion by water.
2. No-tillage method of conservation tillage conserves soil moisture by improving soil physical properties and drastically reducing the evaporation losses. Since the soil is covered with the residues, the soil erosion by wind and water is reduced as compared to conventional tillage. Further, no-tillage system saves the energy, labour and time. Due to the increased activity of beneficial soil micro-organism and earthworms, soil productivity is improved.

UNIT 5 ORGANIC FARMING FOR ENVIRONMENTAL HEALTH

Structure

5.0 INTRODUCTION

We often come across with different organic products, both food and non food, which are available in the market including online business portals. The organic products are produced (cultivated) as the conventional products are produced but certain standards, prescriptions and precautions are built in the production system to make them safe. No synthetic chemical is used in organic farming. Thus, the products obtained under organic farming do not contain any chemical or its form (residue) and are safe for consumption. They are equally safe for the environment where either their wastages or by-products are released. Presently, under organic farming almost every food items are being produced. Day by day, several food and non food items are being added in the list. India is the largest producer of organic cotton in the world. It is picking up across the world. Many countries are converting their major chunk of agricultural land under organic farming due to environmental safety. Several studies across the world have indicated that crop productivity under organic farming is not lesser compared to that of conventional farming. Besides, the organic products have superior quality (nutritional and keeping) compared to that of conventional products. Many studies have also indicated that the quality of environment is healthy under organic farming. organic farmers consider the farm as an organism.

Under the organic farming, the soil is enriched with microbes which work tirelessly towards improving the nutrient supplying capacity of the soil. Thus, the principle behind organic farming is not to feed the plant but to feed the soil. It also helps to build sufficient humus in the soil. Due to sufficient amount of humus, the soil is capable of sequestering carbon dioxide from atmosphere. This results in lowering the Green House Gas effect. Further, we shall comprehend about the benefits of organic farming in managing the environmental health besides performing production.

5.1 OBJECTIVES

After going through this unit, you would be able to:

- Comprehend the concept of organic farming,
- Assess the benefits of organic products and deleterious effects of conventional farming,
- Visualize the scope of organic farming, and
- Comprehend about the role of organic farming in improving the environmental and occupational health.

5.2 WHAT IS ORGANIC FARMING?

As discussed above, the farming done without use of chemical following certain prescribed standards is the organic farming. In order to comprehend it in scientific explanations, the definition of organic farming is given.

5.2.1 Definition

Organic farming according to Henning *et al.* (1991) is both a philosophy and a system of farming, grounded in values that reflect an awareness of ecological and social realities and the ability of the individual to take effective actions. In practice, it is designed to work with natural processes to conserve resources, encourage self-regulation through diversity, to minimize waste and environmental impacts, while preserving farm profitability.

According to Lampkin (1994, 1997), the aim of organic farming is: "to create integrated, humane, environmentally and economically sustainable production systems, which maximize reliance on farm-derived renewable resources and the management of ecological and biological processes and interactions, so as to provide acceptable levels of crop, livestock and human nutrition, protection from pests and disease, and an appropriate return to the human and other resources".

Organic agriculture is defined by IFOAM as: "a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved."

If we analyse these definitions, it clearly indicates to the relevance of organic farming towards the safety of health of ecology or environment. The first definition also highlights the social relationship between the farming and environment. No doubt, injudicious use of chemicals in farming has led several health and environmental complications over the period of time. The present situation is grim. The soil fertility and crop production are not sustainable. One of the most valuable benefits of organic farming is the improvement in soil quality, which can be expressed in terms of chemical, physical and biological properties and their interactions (Ortiz Escobar and Hue 2007).

5.2.2 Scope

The scope of organic farming is immense due to its varied advantage over modern practice of chemical farming. The environmental pollution and health hazards besides loss in soil fertility are some of the important attributes of chemical farming. Several stretches of land have become infertile. The ground water has become unsuitable for drinking purpose. The people are forced to migrate to different places. You will find such reports across the states where the agriculture is advanced. The farmer's suicide is also attributed to the indirect effect of chemical farming. The farmers commit suicide when they fail to repay their debt which they have taken for purchase of chemicals for their farming. In event of crop failure, such events occur.

Besides these the organic farming offers great scope to improve the crop yield over a period of time.

One of such reports is reproduced here (**Noémi Nemes, 2009, FAO**)

Examples of Cotton Yield Increase in India

A study conducted by IWMI in 2003 in India showed that organic cotton yields were somewhat higher than in conventional farms (Shah *et al.*, 2005). A 13 percent increase of yield was found in another organic cotton project in Andhra Pradesh by Raj *et al.* in 2005. Similarly, the Central Institute of Cotton Research in Nagpur found that organic treatment resulted in 11-21 percent higher yields (Eyhorn *et al.*, 2005).

Another study by Jackson (2005) found that organic cotton yields in Kutch were on average 2.5- 2.75 t/ha, similar to or even in excess of those obtained under non-organic systems, and much more than irrigated conventional hybrid cotton yields in other states, such as Punjab and Andhra Pradesh. Factors explaining these differences lie in low pest populations due to dry climate, the widespread use of *Desi* varieties and greater attention paid to soil fertility.

It is very much suitable under dry land condition which occupied more than 60 percent of cultivable land.

Conventional farmers are usually more indebted

Most studies did not evaluate the debt issue and thus did not take previous investments in agriculture into account. Some authors, however, noted that conventional farmers were significantly more indebted, especially in developing countries (Eyhorn et al., 2005; Shah et al., 2005; Jalees, 2008). Eyhorn et al. (2005) noted that most conventional cotton farmers in Central India bought inputs on loan, at annual interest rates between 10-15 percent (from cooperative societies) to over 30 percent (from private money lenders). Since production costs were usually lower, the necessity in organic agriculture to take up loans was far less. As Jalees (2008) indicated, the main cause for India's extremely high farmers' suicide rate is debt servicing for start-up costs, mainly GM seeds and chemical inputs.

(Reproduced from **Noémi Nemes, 2009, FAO**)

The animals reared under organic farming are health and do not suffer with contagious diseases. Their products are chemical free and high nutritive. Thus, from the above references, it can be inferred that organic farming offers great scope in food production and conservation of natural resources.

5.2.3 Status

Due to consistent awareness about the safety of food and environment under organic farming, there is expansion in its area in almost all the countries of world. The expansion in area under cultivation is leading expansion in business in organic products.

5.2.4 World

Every year FiBL and IFAOM carry out survey to take stock of organic farming in terms of production, area and marketing of its products world wise. During year 2016, both have published "The World of Organic Agriculture-Statistics & Emerging Trend 2106". This is an exhaustive compilation of information on various aspects of organic agriculture. The present information has been shared from this publication. A glimpse of the organic agriculture is given below:

Table 5.1: Organic Agriculture Worldwide

Indicator	World	Top countries
Countries with organic activities	2014: 172 countries	New Countries : Kiribati, Puerto Rico, Surinam, United States Virgin Island
Organic Agricultural land	2014: 43.7 Million Hectare(mha)	Australia (17.2 mha:2013), Argentina (3.1 mha) US(2.2 mha: 2011)
Organic Share of total agricultural land	2014:0.99%	Falkland Islands (Malvinas) (36.3%) Liechtenstein (30.9%) Austria (19.4%)
Wild collection, and further non agricultural areas	2014:37.6 mha	Finland (9.3 mha) Zambia (6.8 mha) India (4 mha)

Producers	2014: 2.3 million	India (6,50,000:2013) Uganda (190552) Mexico (169,703:2013)
Organic Market Size	2014: 80 billion US dollars	US(35.9 billion USD) Germany(10.5 Billion USD) France(6.8 billion USD)
Per capita Consumption	2014: 11 USD(14 euros)	Switzerland(221 euros) Luxemburg(164 euos) Denmark(162 euros)
Number of countries with organic regulations	2015: 87 countries	
Number of IFOAM affiliates	2015:784 from 117 countries	Germany :91 affiliates China : 57 affiliates India :44 affiliates USA:40 affiliates

Source: Willer, Helga and Julia Lernoud(2016).

There is an increasing trend in the expansion of area under organic farming in almost all the countries of the world. Worldwide, 2.3 trillion farmers are engaged in organic production.

5.2.5 India

Due to awareness about the organic food products, the demand for it is increasing. The area under organic farming is not increasing impressively but the export and domestic consumption are increasing to the tune of 25-30 and 40 per cent, respectively. Overall, the Indian organic industry has sustained an annual growth rate of 50-60% in production. Almost every state in the country produces organic products. Some of the states have been trying to convert their full agriculture into organic farming. Recently, Sikkim state has declared itself as an organic state. Maximum area under organic farming is in Madhya Pradesh (52%) followed by Maharashtra and Orissa. An account of area expansion under organic farming in India from 2005-2014 is presented below:

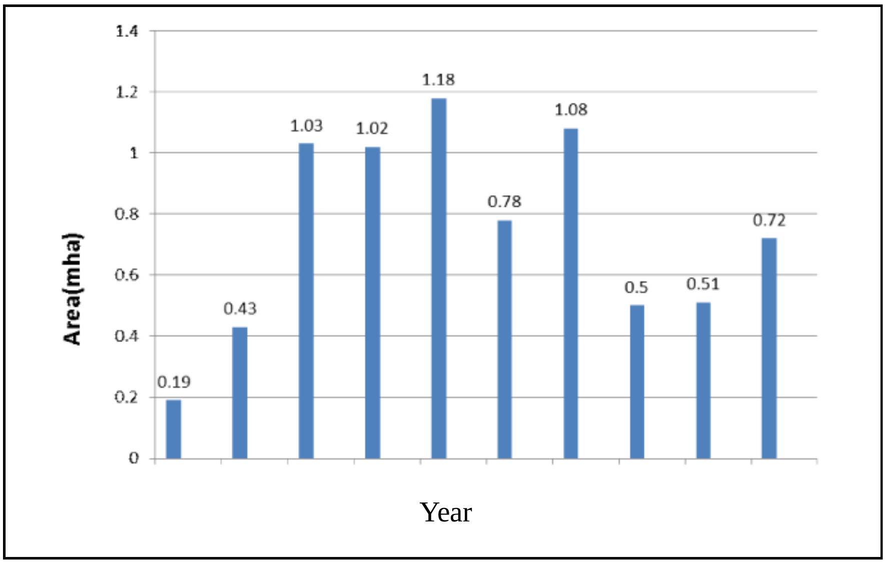

Figure 5.2 b Area expansion under organic farming in India from 2005-2014

Source: APEDA (2016) (from Willer, Helga and Julia Lernoud (2016).

There are 6, 50,000 farmers registered as organic farmers in our country, the highest number in the world. India is the largest organic cotton (74.2 %) in the world followed by China (10.5%). India Ranks 33rd in terms of total land under organic cultivation and 88th in terms of the ratio of agricultural land organic crops to the total farming area.

Contribution in the National Economy

The country is earning good amount of money by exporting organic food products to different countries in the world. During 2012, 130 million Euros were earned by exporting the organic food products (APEDA, 2016).

5.3 CHEMICAL *VS* ORGANIC FARMING

As such we should not compare the chemical and organic farming with respect to the practices, because both have distinct features. The ecosystem under both the practices differs significantly. Right from crop sowing to storage, both of them differ. Now let us comprehend the differences in these two forms of cultivation.

Table 5.3: Chemical Vs Organic Farming

Parameters	Chemical Farming	Organic Farming
Fertilizer	Artificially synthesized	Organic manure such as composts, vermicompost, Bio-fertilizers, etc.
Animal husbandry	Given antibiotics and artificial rearing conditions	Mostly given medicine from plants and other traditional sources, given natural conditions for growth and development
Seed	Any seed, GMO or Hybrid	No GMO, seeds only from traditional sources
Environment	Chemical and their residues prevail in the environment including groundwater	No chemical or residues of chemicals. Few traces may be observed due to contamination
Soil fertility	Mostly short term due to no perpetuation of any biological cycle	Long term soil fertility due to presence of abundant soil flora and fauna
Carbon sequestration	Very less carbon sequestration due to poor humus (carbon content)	High carbon sequestration due to high carbon content and equally presence of high microbial population
Pest control	Through synthetic pesticides	Use of plant based pesticides, bio-control agents including microbial , parasites, trap crops, alternate plant, physical measures such as light trap, pheromone trap etc. and predators
Plant immune system	Low due to high dose of synthetic nutrients and faster growth. These lead to dilution effect	High due to presence of more flavinoids. the growth of plant is optimum and
Cropping system	Monocropping or monoculture	Mixed cropping

Check Your Progress 1

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. What do you mean by organic farming?

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2. How plant is healthier under organic farming compared to that of chemical farming?

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3. Why chemical farming is harmful?

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4. Why we should promote organic farming?

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5.4 PRINCIPLES OF ORGANIC FARMING

The organic farming relies on the on-farm resources and devoid any synthetic chemical in it. Maintaining ecosystem healthy and conserving resources with inculcation of ethics in the operators are the important principles of the organic farming. Under organic farming, the farm is considered as an organism. Now, you can visualise that if you consider something as an organism, means live entity, then your actions should always be humane. However, the principles of organic farming have been scientifically formulated by International Federation of Organic Agriculture Movements (IFOAM).

a. The Principle of Health

Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.

b. The Principle of Ecology

Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

c. The Principle of Fairness

Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

d. The Principle of Care

Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.

All the above principles simply explains that organic farming considers the entire planet as one and indivisible. Thus, its actions shall be in consonance with the requirement of a healthy ecosystem where present generation can live and provide ample space for the generations to come. We all know that ethics play an important role in harmonizing various factors of cultivation and environmental protection.

5.5 NATIONAL STANDARDS FOR ORGANIC FARMING (NSOF)

You may be aware that the Government of India through its Ministry of Commerce has developed National Programme of Organic Production (NPOP) in the year 2000. It is being implemented through Agricultural and processed Food Products Export Development Agency (APEDA), a statutory body under the Ministry of Commerce, GOI. The standards for the organic products have been listed in the NPOP. The chapter 3C of NPOP lists the national standards for organic production (NSOP). The NSOP is actually the standards which have to be followed by an organic operator. The NSOP is available for the following product categories:

(i) Crop production

(ii) Livestock, Poultry and Products

(iii) Beekeeping /Apiculture

(iv) Aquaculture Production

(v) Food Processing & Handling

(vi) Any other category of products that the National Accreditation Body (NAB) may include from time to time

You can retrieve the updated version of NPOP by visiting the website of APEDA *i.e.* www.apeda.gov.in. Like India, several other countries have developed their own organic standards. Let us discuss few of them.

5.6.1 Important Standards for Organic Certification

Broadly, all standards can be categorized into two classes *viz.*, National and International standards. The national standards are those which have been formulated by a particular country for their domestic organic production system. For example, NPOP, USA's NOP (National Organic programme) etc. The International Standards are those which are accepted by all the organic production countries. These are IFOAM and Codex organic standards. Different countries have formulated their standards adopting these internationally accepted norms. Now let us examine some of the important standards.

NOP (National Organic Programme): It is the organic standards of United States of America, regulated by USDA.

JAS (Japanese Agriculture Standards): It is also known as

Japanese Agricultural Organic Standard (JAS). The organic JAS system has been further developed with the addition of the JAS Standards for organic livestock products, organic processed foods of animal origin and organic feeds which took effect in November 2005.

Bio Suisse (Association of Swiss Organic Agriculture Organizations) Standards: This standard is applicable for the farmers of Switzerland.

Likewise, there are many countries that have already developed standards in organic farming for their domestic regulations. A number of African countries such as Uganda, Ghana etc. have also devised their organic regulations.

5.6.2 India Organic Logo

As name appears, the India Organic Logo is hallmark of organic products produced as per NPOP in India. As a consumer when you visit any market, you must look for this logo on the packet of the products. Presence of this logo legally establishes the fact that a product is organic. If you refer NPOP document, you may also learn the colours of this logo and their significance to the nature and environment. All the colors composed in the logo signify the role of organic farming in preserving the nature and natural resources.

5.6.3 Critical Control Points (CCPs)

Actually, these are the possible threats to the integrity of the production or processing system for the organic products. These are also called Organic Critical Points (OCPs). Organic Control Points (OCPs) are any point or procedure in an organic system where loss of organic integrity may occur through commingling with nonorganic product or contamination with prohibited substances.

Under NPOP (Chapter 5), the following Critical Control Points **(CCPs)** are listed for the risk assessment:

- Measures taken by the farmers to deal with part conversion (if farmers still grow some non-organic crops).
- Conversion period
- Production rules for the whole production unit, e.g., seeds, fertilization and soil management, pest management, approved inputs, prevention of drifts, animal husbandry.
- Harvest and post harvest procedures.
- Processing and handling procedures

As an organic operator, you may not use any chemical or pollutant but you do not have control on your neighbours. Their actions are equally hazardous for your safety of your farm or product. These possible threats are called CCPs. Different organic standards have listed measures to contain these CCPs effectively under varied circumstances. The OCPs or CCPs are given for all kinds of products/actions such as livestock, crop production, processing, transportation etc.

5.6.4 Contamination Control

In a very simple term, we may refer contamination as rendering the product useless or dangerous by comingling of some toxic materials. Under organic farming, the measures to control the contamination form an integral component of the products system. Contamination through air, water, soil, chemicals and sharing of implements in an organic production system is common. It has been noticed that when a chemical is sprayed or applied in the field, it blows with air and reaches to other destinations. This process is called as drift. The drift is major threat to organic farming if in its vicinity, any chemical is used. The NPOP has laid measures to prohibit any chance of contamination to the organic farming.

5.6.5 Safety of Organic Foods

Organic foods are supposed to be safer compared to their counterparts of conventional production system where chemical are recommended for use. Since no chemical and GMO are allowed in organic farming, the chances of residual contamination of environment through the escape of organic food is minimal. Similarly, if any organism consumes any organic food product, there is remotest chance of any metabolic hazardous due to food.

Under conventional animal husbandry, the animal are fed with antibiotics and other chemicals. They persist in the animal body and it has been seen that metabolites sometimes are more radical than the original chemical. The organic animal husbandry prohibits use of any form of chemical for the animal rearing.

The pollen grains of crop plants are safe for the working peoples in the farm. It is equally safer for the bees and other beneficial insects who visit the farms and crop plants for their different needs.

Check Your Progress 2

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. What do you mean OCPs ?

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2. How drift of chemicals affects the safety of an organic farm?

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3. Why contamination control is essential in organic farming?

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4. What are the measures to prevent the contamination control?

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5.7 ORGANIC FARMING AND HEALTH OF ENVIRONMENT

Before reaching to this sub-section of the unit, you could have comprehended the concept and philosophy of organic farming. Now, we should correlate the features of organic farming with respect to its being safe for itself and for the surroundings where it is performed. The use of chemicals and Genetically Modified Seeds of any crop variety are prohibited in the organic farming. Besides these, long term soil fertility built up and natural insect pest control/ management are other aspects of organic farming. We all know that soil organic carbon is essential component for the soil fertility. The growth of soil microbes is directly proportional to the organic carbon content of the soil. The humus is the source for the organic carbon content in the soil. We get humus from organic manures which are applied in the soil only. Therefore, building healthy soil is the crucial function of organic farming.

Now let us go through to other aspects of organic farming which ensures healthy environment.

5.7.1 Agriculture and Environmental Safety including Global Warming

Agriculture as we know include both crop production and animal rearing. These are done to obtain food, fibre and fuel. Later, we also extracted several other products by domesticating several new species of plants. Over the period of time, the agriculture received several interventions by the men to boost its productivity. During pre-Green Revolution period (prior 1966-67), mostly organic manures were used to improve the soil fertility and natural processes were adopted to protect the crop against pest and disease infections. Most of the crops were grown using the traditional varieties available with the farmers. During Green Revolution, High Yielding crop varieties were introduced in Indian agriculture. These crop varieties needed good fertile soil with assured irrigation, pesticides for their health management. This led increased use of chemicals in agriculture. Due to injudicious use of chemicals over a period of time in farming, the agriculture became a potential source of GHG (Green House Gas) in the atmosphere. It contributes around 17 percent GHGs directly and additional 7 to 14 percent through change in land use (OECD, 2014). Thus, it is a source as well as victim also. Simultaneously, agriculture also acts as sink for GHGs, for example plants absorb CO_2 for their photosynthesis. These GHGs cause global warming, a result of climate change. The earth climate is bound to change due to change in actions and reactions on the earth. But once it become harsh due to sudden shift in its parameters, the tolerance of lives to the changes is narrowed down. This is the present scenario. There are several reports which indicate that productivity of certain crops is severely affected due to climate change. The chemicals used in agriculture release toxic residues in the environment due to their persistency. These residues not only affect the human health but also the health of soil microbes and other lives in the environment. The entire Biodiversity is adversely affected due to these chemicals. Off course the pollutants released from the industries add more toxicity in the environment.

There are several studies which indicate that change in climatic parameters result in unpredictable change in crops yield. Agriculture is inherently sensitive to climatic conditions and is among the most vulnerable sectors to the risks and impacts of global climate change (Parry and Carter 1989; Reilly 1995). In the absence of adaptation and CO_2 fertilization benefits, a 1°C increase in temperature alone could lead to a decrease of 6 million tonnes of wheat production. This loss is likely to increases to 27.5 million tonnes at 5°C increase in mean temperature. It was estimated that we could lose 3.9 Million Tonnes of wheat due to climate change by 2020, 11.7 million tonnes by 2050 and 23.5 Million Tonnes of heat by 2080 (results for the A2 scenario of HadCM3 model). Implementing adaptation strategies may, however, be difficult considering that wheat cannot be planted earlier in most of the Indo-Gangetic plains because of late availability of fields after rice harvest (Aggrawal, 2009). The affect of the changes in climatic parameters on agriculture also varies according to the places. At some place the affect could be different compared to another place. The soil microbial population equally get affected due to climate change and thus accordingly their functions. Heavy mechanization had been disastrous for agriculture. The machines open the soil deep and expose the thermo-sensitive microbes and insects which are killed due to intense heat of sunshine. These lives are good for the soil manipulations and sequestration of carbon.

5.7.2 Organic Farming and Carbon Sequestration

We have read above that agriculture in the present form is responsible for climate change and global warming. It is mostly due to the heavy mechanization and use of chemicals for various aspects of agriculture, including the animal rearing. Opposite to it, the organic farming devoid any chemical thus, contributes less in GHGs. The residues of the chemicals are not present in the soil and their emissions are also restricted.

In two long terms comparison experiments with arable rotations in Switzerland, the DOK trial (Mader *et. al*., 2002) and the Burgrain experiments the global warming potential of all crops was reduced by 18 percent in organic plots. This might be primarily due to absence of any synthetic chemical.

The organic oils are rich in microbial population due to abundance of organic carbon in the soil. We all are aware that the microbes consume the carbon for their energy requirements. When there are more microbes in the soil, there is more carbon sequestration from the atmosphere. If there is more carbon sequestration, the carbon dioxide load in the environment gets reduced and green house effect will also be mild. Thus, the carbon food print in the atmosphere is reduced under organic farming. Under organic farming, the plants receive balanced nutrition which results in their optimal growth. The healthy plant also utilises more CO_2 for their photosynthesis, thus reducing the load of GHGs in the environment.

5.7.3 Organic Farming for long term Soil Fertility and Natural Crop Insect Pest and Disease Management

Building long tern sustainable soil fertility is the prime objective of the organic farming. The soil is fed to feed the plants. We have learnt so far that only organic manures and other biological sources such as biofertlizers are used for building soil fertility under organic farming. The supply of nutrients from soil to plants should be optimum so that natural plant growth is achieved. The organic manures are endowed with multiple nutrients and help soil to supply the same to the plants growing in it. The organic manures also help in building a healthy microbial network in the soil. These microbes, be it bacteria, actinomycetes, fungus etc., work tirelessly towards simplifying the complex compounds into simpler compounds for their energy requirement. Under organic farming, no synthetic chemical is applied, thus, there is no imbalances in the nutrient composition of the soil. This help in building long term soil fertility. Due to healthy microbes, the decomposition process in the soil operates efficiently.

Also, natural and balanced population of enemy and friendly insects are maintained under organic farms. As we all know that chemicals applied to control pests and disease also kills friendly insects and microbes, besides emitting drift in the atmosphere. If these friendly microbes are not killed, they automatically maintain a balanced population of other (enemy) microbes and insects in the environment. Healthy ecosystem is essential for good quality food production. The food which contain less or non chemical residues, do not pollute the environment once it escapes in it.

5.7.4 Occupational Health in Organic Farming

Like any other production system, agriculture itself is an important production system. It is the production system of raw products for many industries. Working in the filed under varied conditions also determines the health of the workers be it farmers, farmwomen or labourers. You might have seen masked labourers in field spraying pesticides or applying chemical fertilizers. Even after application of pesticides, sufficient residual impact in the field remains for more than week or so. Handling of chemical requires skill and awareness. Most of labourers in the agriculture are illiterate of untrained to handle these chemicals. In such event, their involvement in farming occupations results in health problems. Contrast to this, we can just visualize that under organic farming, since no synthetic chemical is used; there would always be good health of the famers and others. Above this, the system is able to provide safe food which will further add health to the associated farmers and others.

All types of inputs used in organic farming are environmentally safe and toxic free. There is no pollution by them either in environment or in groundwater. Safety measures are required in minimal (except for machines) under the organic farming.

Check Your Progress 3

Note: a) Write your answer in about 50 words.

b) Check your answer with those given at the end of the unit.

1. Why working in an organic farm is safe?

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2. Agriculture is a production system; give your opinion about it.

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3. Explain the characteristics of important occupations of agriculture?

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4. Do you think organic farming helps preserving environment, if yes how?

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5.8 LET US SUM UP

In this unit, we saw that organic farming is process of cultivation of crops of diverse nature. The present form of agriculture received several forms of synthetic chemicals during its various stages. For example, we used chemical fertilizers to supply plant nutrients and pesticides to protect our crop plants against the disease and pests. These chemicals and other practices of agriculture such as mechanization cause deterioration in the environmental health. It also poses health hazards in the people who work in the field. The emission of GHGs is major threat to the atmosphere and agriculture is a potential source of it. It also acts a sink of GHGs. But day by due to injudicious use of chemicals in agriculture, the problem is getting aggravated. Even the food item which we consume also contaminated with chemical residues and cause health hazards after consumption. They also degrade environment once thrown. Organic farming do not require any chemicals and also avoid largely nay input from outside. It help in curbing the emission of GHGs. Due to more addition of soil humus, it sequester carbon and cleans the environment. Also do not pose any health related issue for the workers.

5.9 KEY WORDS

Genetically Modified Organism (GMO): These are organisms created by transferring the desired characteristics through genetic manipulations. Bt cotton is one of the examples.

Monoculture: Repetitive growing of same crop on the same piece of land for more than two years.

Monocropping: Growing of only one crop on a piece of land in one season.

Bio-fertilizers: it is combination or single microorganism used for the supply of plant nutrients in the soil.

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5.11 ANSWERS TO CHECK YOUR PROGRESS

Answers to Check Your Progress 1

Your answers should include the following points:

1. You can define organic farming by simply looking at the point that it does not allow any chemicals (synthetic) and follows certain standards and norms. The products from organic farming devoid any chemical residues

2. As we all know that chemical supplied from outside promotes plant growth faster, more than the normal growth. This leads several issues with the plant growth and development. It also reflects on the productivity of the plant.

3. If the chemical are used in the desired amount, it helps the plant growth and development in balanced manner. Injudicious use of chemicals results in health and environmental consequences/hazards. There are several other complications associated with the chemical use in agriculture.

4. To save environment and health of the consumers, we should promote organic farming. It also offers good business and also avoids the occupational hazards.

Answers to Check Your Progress 2

Your answers should include the following points:

1. These are organic critical points are those which pose threat to the successful production system under the organic farming.

2. Actually in the field condition when a farmer sprays or broadcasts the chemical in his/her crop, due to wind velocity the chemical tend to carried with wind and contanm9inate the other field which in the vicinity.

3. Since contamination is a threat to the safety of food items, there must be strategies to avoid them.

4. There are several methods employed to prevent the contamination.

Answers to Check Your Progress 3

Your answers should include the following points:

1. Since no chemical is allowed in the organic farming, there is no threat to the health of the workers in the field.

2. You may visualize that like other production system, the agriculture is actually a production system which provides raw materials to many production system.

3. This is the most important aspect of agriculture. Many occupations such as ploughing to harvesting, the farmers and farm labourers as safe under organic farming as there is no chemical applied in the field .

4. Definitely, it help preserving environment**,.** You may visualise the impact of chemicals on the health of environment.