

MODULE - 6

Sustainable
Development



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CONCEPT OF SUSTAINABLE AGRICULTURE

Agriculture is the process of producing food, feed, fibre and other desired products by cultivation of certain plants and raising of domesticated animals. Agriculture has changed dramatically, especially since the end of World War II. Food and fibre productivity has increased by using new technologies, mechanization, increased use of fertilizers and pesticides and expansion of irrigation facilities. These changes allowed farmers with reduced labour demands to produce the majority of the food and fibre. Although these changes have had the positive effect of these practices have also caused some serious environmental and social problems such as erosion of top soil depletion and pollution of groundwater contamination, unemployment of farm labourers due to their replacement by increasing use of farm machinery in agriculture operations.

A growing movement has emerged during the past two decades to question the role of the agricultural establishment in promoting practices that contribute to these social problems. In view of the growing negative consequences of modern agriculture there is growing demand to promote “sustainable agriculture”. Sustainable agriculture incorporates address many environmentally safe agricultural practices and offers innovative and economically viable opportunities for farmers, labourers, consumers etc., policymakers and many others in the entire food system.



OBJECTIVES

After completing this lesson, you will be able to:

- *relate changing human needs with over use of environment;*
- *need for enhancing quality of environment;*
- *define sustainable agriculture and justify its need;*
- *describe concepts and methods of sustainable agriculture;*
- *explain about organic farming and its benefit;*



- *describe the method of preparing vermicompost;*
- *explain biofertilizers and their use in agriculture;*
- *explain Integrated Pest Management (IPM);*
- *explain GMOs and its related issues.*

21.1 HUMAN NEEDS AND OVER USE OF ENVIRONMENT

Urban populations are growing rapidly throughout the world and many cities in developing countries have become centres of poverty. Almost half of the world's people live in densely populated urban areas. Rural people migrate to urban areas in search of jobs, food, housing, a better life style, entertainment etc. Others move to cities because of poverty, lack of land to grow food and declining agricultural jobs etc. The proportion of global population living in urban areas is increasing and urban population is increasing rapidly in developing countries and poverty is becoming one of the major problem in urban areas as more poor people migrate to cities from villages. Biggest human need is, need for survival.

21.2 NEED FOR ENHANCING QUALITY OF ENVIRONMENT

The huge population puts a tremendous pressure on resources. The high rate of consumption of resources and high waste output. Large areas of forests and agricultural land are disturbed and degraded to provide urban dwellers with houses, food, water, energy for transport, minerals and other resources. As cities expand, they destroy rural crop land, fertile soil, forests, wet land and wild life habitats. At the same time, they provide little of the food they use. From the point of view of environment, the cities are like giant vacuum cleaners, sucking up all the resources and giving out pollution, wastes and heat.

There is great need to improve the situation so that human beings enjoy a good quality environment. We do deserve a healthy environment to survive and lead a good life.

21.3 SUSTAINABLE AGRICULTURE

Sustainable agriculture is that form of agriculture which attempts to produce sufficient food to meet the needs of present day population without exhausting soil fertility and irreversibly damaging the environment. Sustainable farming systems are those that are least toxic and least energy intensive and yet maintain productivity and profitability i.e. low input agriculture or organic farming.



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Thus, sustainable agriculture is one that,

- supports profitable production;
- protects environmental quality;
- uses natural resources efficiently;
- provides consumers with affordable, high-quality products;
- decreases dependency on non-renewable resources;
- enhances the quality of life for farmers and rural communities;
- and will last for generations to come.



INTEXT QUESTIONS 21.1

1. Define sustainable agriculture.

2. Mention three advantages of sustainable agriculture.

21.4 METHODS OF SUSTAINABLE AGRICULTURE

Sustainable production practices involve a variety of approaches. At the planning level one must take into account the local geography (topography), soil condition and nature, local climate, pests, local inputs and the farmer’s goals. The grower (farmer) must then select appropriate practices. Several methods adopted in sustainable agriculture are:

- cultivation practices to increase biological and economic stability.
- selection of improved varieties to suit the need.
- soil management by proper method of tillage.

Many farmers in India and other developing countries follow the traditional practice of mixed cropping or diverse cropping and crop rotation.

(a) Mixed cropping or diverse cropping

It is an old practice in our country. Two or more crops are grown all at the same time in a field. If by chance one crop fails, the others crops cover the risk of total crop failure. Usually a long duration crop is grown with a short duration one so that both get sufficient nutrition at the time of maturity. Then water and nutrient requirement are also different.



Generally a leguminous crop is grown along with the main crop. Legumes help to increase soil fertility by fixing atmospheric nitrogen. This saves the cost of chemical fertilizers.

The various plans followed in diverse or mixed cropping practices are-

- polyvarietal cultivation where several genetic varieties of the same crop are planted.
- intercropping where two or more different crops are grown at the same time on a plot like carbohydrate rich cereal that uses soil nitrogen and nitrogen fixing legume that puts back the nitrogen in the soil.
- polyculture, in which different plants maturing at various times are planted together. This practice has many advantages because fertilizer and water requirements of plants are different so there is less need of these inputs. Pests are controlled naturally because their natural predators find multiple habitats to survive. It has been found that this practice produces much higher yield per hectare compared to monoculture.

Large scale mechanization led to the spread of *monoculture* i.e. only one crop variety is sown in the entire area when only one cultivator is planted in a large area. This system uses a lot of fertilizer, pesticide, water. This practice may be productive for sometime but causes environmental and economic problems.

(b) Crop rotation

It is the practice of growing different crops in regular succession in the same field. This practice controls insects and diseases, increases soil fertility and decreases soil erosion. Generally soil cannot sustain continuous cropping with high yielding single crop because certain nutrients required by the crop get exhausted totally while others remain unutilized leading to serious nutrient imbalance in soil and encouraging certain diseases and pests. Sowing a leguminous crop (eg. green gram) as a rotational crop is very useful because legumes enhance nitrogen level in the soil due to their ability to fix atmospheric nitrogen, reduces the need for chemical nitrogen fertilizer. Thereby cutting the cost and saving the soil from the harmful effects of using high yielding varieties along with the application of large amount of fertilizer, pesticides and water. It is possible to grow two or sometimes three different crops in succession on the same land within a year is known as **multiple cropping**. This practice can go on for sometime but the land cannot maintain high yield in the long run.

Crop rotation takes into account the following factors:

- (i) Leguminous crop should be grown after non-leguminous crop.
- (ii) Crops requiring less water (irrigation) should be grown after one – that requires more water.
- (iii) Crops requiring less manure should be sown after one that requires more manure.



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Important crop patterns of crop rotation

1. Green gram - Wheat – Moong
2. Ground nut – Wheat – Moong
3. Arhar – Sugarcane – Wheat – Moong
4. Paddy – Wheat – Moong

Optimum diversity may be obtained by integrating both crops and livestock in the same farming operation. Mixed crop alongwith livestock operations have several advantages. First, growing crops only on more level land and pastures or forages on steeper slopes will reduce soil erosion. Second, pasture and leguminous forage crops in rotation enhance soil quality and reduce erosion; livestock manure, in turn, contributes to soil fertility. Third, livestock can buffer the negative impacts of low rainfall periods by consuming crop residue that in “plant only” systems would have been considered crop failures. Finally, feeding and marketing are flexible in animal production systems. This can help cushion farmers against price fluctuations and, make more efficient use of farm labour.

Soil Management: A healthy soil is a key component of sustainable agriculture. That is healthy soil along with water and nutrients produces healthy crop plants that are less susceptible to pests and diseases. Accordingly, soil must be protected and nurtured to ensure long term productivity and stability. Methods of protection include using cover crops, compost, reducing tillage, conserving soil moisture by dead mulches, this increases water hold capacity of the soil.

Varietal improvement with limited land at our disposal, we have to increase production of food grains, fodder, sugar, oil, fibers, fruits and vegetables. One of the most important method to do that is to improve the existing varieties of plants by the application of genetics and plant breeding and related sciences. Significant improvement in crop production has been achieved by using the conventional methods of selection and plant breeding.

Some of the objectives of varietal improvement are:

- (i) development of high yielding varieties of crop plants.
- (ii) food crops developed for better and higher nutritional quality like protein quality in pulses, baking quality in wheat, preserving quality in fruits and vegetables, oil quality in oil seed producing plants.
- (iii) development of crop varieties resistance to diseases and pests.
- (iv) improving varieties for resistance against heat, cold, frost, draught and water logging.

21.5 BIO-FERTILIZERS AND THEIR USE IN AGRICULTURE

For a sustainable agriculture system, it is essential to use renewable inputs (fertilizer, pesticides, water etc.) which can benefit the plant and cause no or minimal damage to the environment. One possible way is to reduce the use of chemical fertilizers and pesticides.



One of the energy efficient and pollution free method is to exploit the ability of certain microorganisms like bacteria, algae and fungi to fix atmospheric nitrogen, solubilize phosphorus, decompose organic material or oxidize sulphur in the soil. When they are applied in the soil, they enhance growth and yield of crops, improve soil fertility and reduces pollution. They are known as “bio fertilizers”. Thus bio-fertilizers are living or biologically active products or microbial inoculants of bacteria, algae and fungi (separately or in combination) which are able to enrich the soil with nitrogen, phosphorus, organic matter etc.

21.5.1 Important bio fertilizers

Following are some of the important types of bio fertilizers which can be considered for agro based industries.

- **Rhizobium biofertilizer:** *Rhizobium* is a symbiotic bacteria forming root nodules in legume plants. These nodules act as miniature nitrogen production factories in the fields. The nodule bacteria fix more nitrogen (N_2) than needed by legume plant and the bacteria. The surplus fixed nitrogen is then secreted and fertilizes the soil. Rhizobium is more efficient than-free living nitrogen-fixing bacteria and can fix upto 200 kg N/ha/yr.
- **Azotobacter biofertilizer:** Azobacter are aerobic free living nitrogen fixers. They grow in the rhizosphere (around the roots) and fix atmospheric nitrogen non-symbiotically and make it available to the particular cereals. These bacteria produce growth promoting hormones which helps in enhancing growth and yield of the plant.
- **Azospirillum biofertilizer:** These are aerobic free living nitrogen fixers which live in associative symbiosis. In this type of association bacteria live on the root surface of the host plant and do not form any nodule with roots of grasses. It increases crop yield and its inoculation benefits crop. They also benefit the host plants by supplying growth hormones and vitamins. These bacteria are commonly used for the preparation of commercial inoculants.
- **Blue green algae:** Blue green algae (BGA or cyanobacteria) like *Nostoc* and *Anabaena* are free living photosynthetic organisms also capable of fixing atmospheric nitrogen. In the flooded rice fields blue green algae serves as a nitrogen biofertilizer.
- **Azolla biofertilizers:** *Azolla* is a water fern inside which grows the nitrogen fixing blue green algae *Anabaena*. It contains 2-3% nitrogen when wet and also produces organic matter in the soil. The *Azolla-Anabaena* combination type biofertilizer is used all over the world. This can be grown in a cooler regions. But there is a need to develop a strain that can tolerant to high temperature, salinity and resistant to pests and diseases. Production technology is very easy and can be adopted by rice farmers. The only constraint in *Azolla* is that it is an aquatic plant and water becomes limiting factor in growing it particularly in summer.
- **Phosphorus solubilising biofertilizer:** Phosphorus is an important element required for plant growth. This element is also needed for nodulation by rhizobium. Some



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microorganisms are capable of solubilizing immobilized phosphorus making it available to plants for absorption.

- **Mycorrhizal** fungi acts as biofertilizer are known to occur naturally on roots of forest trees and crop plants. In soils low in available nutrients there is an increased absorption of nutrients by plants infected with Mycorrhiza. The fungus has the ability to dissolve and absorb phosphorus that plant roots can not readily absorb.

A wise way will be to develop an integrated nutrient supply system involving the combination of chemical fertilizers and biofertilizers.



INTEXT QUESTIONS 21.2

1. How does crop rotation practice improve soil quality?

2. What is the difference between polyculture and multiple cropping?

3. Define biofertilizers and give two important advantages of using it.

4. What roles do Rhizobium and blue green algae play in agriculture?

21.6 ORGANIC FARMING AND ITS BENEFITS

Organic farming is a type of agriculture or farming which avoids the use of synthetic fertilizers, pesticides, growth regulators, and livestock feed additives. Organic farming systems rely on crop rotation, crop residues, animal manures, legumes, green manure, off-farm organic wastes and biofertilizers, mechanical cultivation, mineral bearing rocks. To maintain soil productivity to supply plant nutrients and biological pest control, controlling weeds, insects and other pests. All kinds of agricultural products can be produced organically, including grains, meat, dairy, eggs, fibres such as cotton, jute, flowers etc. Thus organic farming creates a sustainable lifestyle for generations to come.

Organic farmers build healthy soils by nourishing the living component of the soil, the microbial inhabitants that release, transform, and transfer nutrients. Soil organic matter contributes to good soil structure and water-holding capacity. Organic farmers feed soil biota and build soil organic matter with cover crops, compost, and biologically based soil amendments. These produce healthy plants that are better able to resist disease and insect predation. Organic farmers’ primary strategy in controlling pests and diseases is prevention through good plant nutrition and management. Organic farmers use cover crops and sophisticated crop rotations to change the field ecology, effectively disrupting habitat for



weeds, insects, and disease organisms. Weeds are controlled through crop rotation, mechanical tillage, and hand-weeding, as well as through cover crops, mulches, flame weeding, and other management methods. Organic farmers rely on a diverse population of soil organisms, beneficial insects, and birds to keep pests in check. When pest populations get out of balance, growers implement a variety of strategies such as the use of insect predators, mating disruption, traps and barriers.

Some important benefits for organic farming and organic foods:

- Organic farming is a science in itself which can be learnt easily by any conventional farmer.
- It has been found that by switching to organic farming, conventional farmer can actually reduce its production cost by over 25% as compared to the cost of conventional farming. This is eliminate the use of expensive synthetic fertilizers and pesticides, minimizing soil erosion by up to 50% and increasing crop yields up to five-folds.
- A well planned transition strategy may allow conventional farmers to adopt new, more effective organic farming practices easily.
- Organic farms can support substantially higher levels of wildlife especially in low lands and where animals can roam in pastures or graze on grassland. Not only does wildlife benefit, but entire ecosystems and ground water are improved by simply following organic farming methods.
- Organic farming practices not only benefit farmers and consumers; but the dairies can benefit. When dairies feed their cows organic feed and graze them on organic fields, the cows experience better health, less sickness, diseases and ultimately produce better tasting milk for consumers.
- Organic farming promotes healthy soils that are teaming with life and rich in micro nutrients and which can be used for decades to grow crops without getting exhausted.
- Consumers purchasing organically grown foods are tastier. Regardless of minimal price differences, consumers can smell, taste and see the difference in the quality of organically grown food products.
- Organically grown products are free from harmful chemicals, artificial flavors and preservatives that ultimately cost consumers more money than non-organically grown products. You can always taste the difference between organically grown and conventionally grown products.

21.7 VERMICOMPOST

Vermicomposting is an appropriate technique for efficient recycling of animal wastes, crop residues and agro-industrial wastes. The process of conversion of organic materials into manure is chiefly microbiological. Earthworms are important for producing vermicompost from organic wastes.



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Vermicompost can be prepared from all sorts of organic residues. Examples:

- Agricultural residues
 - dry organic wastes (like sorghum straw, rice straw after feeding cattle, dry leaves, pigeon pea residues, groundnut husk and wheat husk)
 - waste vegetables
 - soybean residues
 - weeds (particularly *Parthenium hysterophorus*, also called Vayyaribhama or Pander full or Congress weed, before flowering)
 - sugarcane trash
- Sericultural residues from silk production
- Animal manures
- Dairy and poultry wastes
- Food industry wastes
- Municipal solid wastes
- Biogas sludge
- Bagasse from sugarcane factories

21.7.1 Steps in Making Vermicompost

Step 1:	Cover the bottom of the cement ring with a polythene sheet. (Or use the sheet to cover the ground of the area you're using).
Step 2:	Spread a layer (15-20 cm) of organic waste on top of the sheet.
Step 3:	Sprinkle rock phosphate on top of the organic material (2kg).
Step 4:	Prepare cow dung slurry (15kg) and add the slurry as a layer on top of the mixture.
Step 5:	Fill the ring completely and evenly with the layered material.
Step 6:	Paste cow dung or soil over the top of the material.
Step 7:	Allow the material to decompose for 20 days. After 20 days, put the earthworms on top. They will find the cracks and enter the material.
Step 8:	Cover the ring with wire mesh or gunny bags to prevent birds from eating the worms.
Step 9:	Sprinkle water over the whole mixture at 3-day intervals for 2 months, to maintain adequate moisture and body temperature of the worms. <i>Note: when the compost is ready, it is black, quite lightweight and has a pleasant, earthy smell.</i>
Step 10:	After 2 months, (or when the compost is ready), remove the ring and heap the material in a cone shape on the floor. Leave the heap undisturbed for 2-3 hours, to let the worms move slowly to the bottom.
Step 11:	Separate the upper portion of the heap.
Step 12:	Sieve the lower portion of the heap to separate the worms. They can be used again for preparation of more vermicompost.
Step 13:	Pack the compost in bags and store them in a cool place.



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21.8 INTEGRATED PEST MANAGEMENT (IPM)

The most sustainable way to control pests is a carefully designed integrated pest management (IPM) program. In this approach, each crop and its pests are evaluated as parts of an ecological system. Then farmers develop a control program that includes cultivation, biological and chemical methods applied in proper sequence and with the proper timing.

The aim of IPM is not to eradicate the pest population completely but to keep the crop damage to economically tolerable level.

Farmers monitor the field and when they find the pest level to be high enough, they first use biological methods and cultivation practices to control and then use small amounts of insecticides mostly insecticides derived from plants as a last resort.

(a) Biological control includes

Natural predators, parasites and pathogens of the pests are used. Examples are:

- Pest on cucumber plant called red spider mite is controlled by using a predatory mite that feed on red spider mite.
- Citrus fruits in California heavily damaged by scale insects which were controlled by Australian ladybird which ate away the insects.
- Mealy bug pest of Cassava plant were controlled by a parasitoid wasp which was its natural enemy.
- Hormones are used that disrupt the insects normal life cycle, thereby preventing it from reaching maturity and reproducing and multiplying.

(b) Cultivation practices

A variety of cultivation practices like crop rotation, polyculture and inter cropping etc. can be used to get rid of the pests. This has been discussed in details earlier in this lesson.

(c) Some amounts of insecticides, mostly of plant origin (e.g. Pyrethrum and Rotenone neem product) are applied as a last resort.

(d) Pest and disease resistant crop plants can be produced by genetic engineering. Example is B_t cotton, insecticidal for bacterial gene (*Bacillus thuringiensis*) introduced into cotton plant making cotton plant resistant to pest.

Like any other form of pest control method has some disadvantages:

- Farmer should have an expert knowledge about each pest.



- It acts more slowly than conventional pesticides.
- Methods developed for a crop in one area might not apply to areas with even slightest different growing conditions.
- Initial cost may be higher but in the long-term cost become very low.

21.9 BIOTECHNOLOGY AND MODERN AGRICULTURE

With conventional breeding practices reached their saturation point, the “gene revolution” seems to hold lot of potential. Agricultural biotechnology or gene technology or genetic engineering may act as the second “green revolution” that can be used to create high-yielding crop varieties that are: (i) herbicide tolerant, (ii) insect resistant, (iii) resistant to pathogens like virus, bacteria and fungi (iv) have better nutritional value and other commercial properties. The crop plants produced by these techniques are called “transgenics” or genetically modified (GM) plants or genetically modified organisms (GMOs).

By using the technique of genetic engineering it has been possible to genetically transform large number of agricultural and ornamental crops. Transgenics have been produced with the following aims:

- Crop resistance to herbicides.
- Crop resistance to insects and diseases.
- Atmospheric nitrogen fixation by cereal crops.
- Tolerance to high salt soils and to flooding in crops.
- Drought resistance in crops.
- Improving nutritional quality of crops.
- Prolonging shelf life of fruits and vegetables.

Some important examples of transgenics or GMOs are:

1. B_t cotton produced by incorporating B_t gene which encodes for BT toxin (insecticidal protein in *Bacillus thuringiensis*) in the cotton plant. The plant becomes insect resistant and this gene has been incorporated in corn, potato, tomato, tobacco etc. making them insect resistant (bio pesticides). Such plants can reduce our dependence on chemical pesticides which will save us money and our environment.
2. “Golden Rice” a transgenic with enhanced vitamin A content producing nutritionally rich rice to save many lives. Salt and flood tolerance genes have been incorporated in rice so that B_t rice in China shows higher yield and a huge reduction in pesticide use. Such rice can be grown on saline soil.
3. By slowing down and controlling ripening in tomato by introducing a bacterial gene that prevents ethylene formation thus delaying ripening. Such tomatoes are easy to handle during transportation and remains on the shelf for a long time.



4. Cold damage to crop plants can be minimized by introducing genes for antifreeze proteins (AFPs) found in the blood of arctic fishes. Frost resistant tomatoes have been produced by introducing gene for antifreeze proteins from polar fish living in ice water.

Plant biotechnology can help to make intensive agriculture less damaging to the environment as well as help the country to spend less money on fertilizers, pesticides, herbicides etc.

21.9.1 Benefits and controversies on GM products

(a) Benefits

(i) Crops

- Enhanced taste and quality.
- Reduced maturation time.
- Increased nutrients, yields, and stress tolerance.
- Improved resistance to disease, pests, and herbicides.
- New products and growing techniques.

(ii) Animals

- Increased resistance, productivity, hardness, and feed efficiency.
- Better yields of meat, eggs, and milk.
- Improved animal health and diagnostic methods.

(iii) Environment

- “Friendly” bioherbicides and bioinsecticides.
- Conservation of soil, water and energy.
- Bioprocessing for forestry products.
- Better natural waste management.
- More efficient processing.

(iv) Society

- Increased food security for growing populations.

(b) Controversies

(i) Safety

- Potential human health impact: allergens, transfer of antibiotic resistance markers, unknown effects.
- Potential environmental impact: unintended transfer of transgenes through cross-pollination, unknown effects on other organisms (e.g., soil microbes) and loss of flora and fauna biodiversity



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(ii) Access and intellectual property

- Domination of world food production by a few companies.
- Increasing dependence on industrialized nations by developing countries.
- Biopiracy—foreign exploitation of natural resources.

(iii) Ethics

- Violation of natural organisms’ intrinsic values.
- Tampering with nature by mixing genes among species.
- Objections to transferring animal genes in plants and vice versa.
- Stress for animal.

(iv) Labeling

- Not mandatory in some countries (e.g. United States).
- Mixing GM crops with non-GM confounds labeling attempts.

(v) Society

- New advances may be skewed to interests of rich countries.



INTEXT QUESTIONS 21.4

1. Mention two important agricultural inputs which are avoided in organic farming?

2. What is IPM and what is its aim?

3. What types of improved crop varieties can be produced by gene transfer technology?

4. What is “Golden Rice”?



WHAT YOU HAVE LEARNT

- Sustainable agriculture systems are those that are least toxic and least energy consuming, yet maintain productivity and profitability.
- Agricultural practices like crop rotation, inter cropping, polyculture and proper soil management with mulches and cover crops to maintain soil moisture are integral part of sustainable agriculture.
- Biofertilizers are plant nutrients of biological origin like algae, bacteria, fungi which have no harmful effect on soil and environment.



Notes

- Organic farming is a type of agriculture which avoids synthetic inorganic fertilizers, pesticides, growth regulators and livestock feed additives.
- Organically grown food products are free from harmful chemicals, or typical flavours and preservatives.
- Vermicompost can be prepared at the backyard of your home, in one corner to your school field or may be public park which will produce manure as well as clean up the environment from garbage accumulation.
- Integrated Pest Management (IPM) is a grand idea to control pest and diseases. This increases production, saves the environment from pollution and harmful effects of pesticides and saves money which is usually spent on buying pesticides.
- Biotechnology technique is used to produce plants by gene transfer (transgenics) which can be a direct answer to grow plants resistant to diseases, pests, tolerant to cold draught and flooding etc. One can design a plant to suit this condition.



TERMINAL EXERCISE

1. Define sustainable agriculture and justify its need.
2. What are the two most important effects of increase in population in the cities?
3. Why do you need to improve the existing varieties of plants (give any three reasons)?
4. Mention any four types of crops that one can produce applying gene transfer technology.
5. Explain the aim and objectives of the process of IPM.
6. What are GMOs? Explain briefly giving any two examples.
7. What is biological control of pests?
8. Which are the two most important items which are applied generously in normal agriculture that are avoided in organic farming?
9. How do blue green algae help in agriculture?
10. Define biofertilizer and their uses in agriculture..



ANSWER TO INTEXT QUESTIONS

21.1

1. Sustainable agriculture and farming systems are those that are least toxic and least energy intensive and yet maintain productivity and profitability.
2. Sustainable agriculture is helpful to environment because (i) it protects environment quality, (ii) uses natural resources efficiently, (iii) decreases dependency on non-renewable resources.

**21.2**

1. Crop rotation practice increases soil fertility by growing legume as a rotational crop, decreases soil erosion, controls pests and diseases.
2. Polyculture is the practice of growing plants simultaneously on a piece of land which mature at various times.

Multiple cropping is growing two or sometimes three different crops in succession on the same land within a year.

3. Biofertilizers are plant nutrients of biological origin like algae, bacteria, fungi which have no harmful effect on soil and environment.

Advantages

A large amount of money can be saved by reduced the purchase and production of chemical fertilizers, human health can be saved from harmful effects of chemical fertilizers.

4. Rhizobium a symbiotic bacteria live in the root nodules of legume plants and fix atmospheric nitrogen and ultimately make the soil rich in nitrogen which is very essential for plant growth. Blue green algae (BGA) fix atmospheric nitrogen in their special cells called heterocysts and ultimately provide nitrogen to the soil. Both Rhizobium and BGA act as biofertilizers.

21.3

1. Two important agricultural inputs which are avoided in organic farming are Chemical fertilizers and pesticides.
2. IPM is Integrated Pest Management, which avoids harmful chemical pesticides and use biological methods and agricultural practices to get rid of the pests.

Its aim not to eradicate the pests completely but to keep them at economically tolerable level.

3. Gene transfer technology can produce crops:
 - Resistant to herbicides and pesticides.
 - Resistant to insects and diseases.
 - Tolerant to high salt in the soil.
 - With improved nutritional quality.
 - Prolonging shelf life.
4. “Golden Rice” is a transgenic rice with enhanced vitamin A content.