UNIT 1 THE EVOLUTION OF AGRICULTURE

Structure

1.1 INTRODUCTION

Agriculture as we understand today is the science and art of growing food, fibre, forage and energy crops and fruit and ornamental trees, raising of livestock for milk (dairying) and meat and rearing of sheep, goats and pigs. It also includes fisheries and poultry. Modern agriculture also includes issues and policies relating to its marketing including exports and imports, which has become very important globally after the World Trade Agreement. Thus agricultural products have to be produced at an international competitive price.

Modern agricultural practices are remarkably different from those of the pre-industrial era. The significant changes in agriculture in the post-industrial era can best be appreciated if we understand the evolution of agriculture in the pre-industrial era. Therefore, in the first unit of the course, you will study about how agriculture emerged in human societies and how it developed through the ages. The Industrial Revolution in Europe marks a distinct phase in the evolution of agriculture. With the development of science, population growth and shrinking of available land and resources, agriculture in modern times has undergone revolutionary changes. In the final section of the unit, we look at some features of modern agriculture. In the next unit, we introduce the concept of Agro-Ecosystem so that a sound foundation is built for understanding the environment-agriculture relationship.

Objectives

After studying this unit, you should be able to:

- enunciate the hypotheses regarding the evolution of agriculture;
- describe developments in agriculture through various periods in human history, viz. Neolithic age, Chalcolithic age, middle ages and industrial era;
- discuss the post-Neolithic development of agriculture in the Indian subcontinent;
- describe the main features of the Agricultural Revolution in England and the developments in USA; and
- discuss the main facets of modern agriculture.

1.2 AGRICULTURE IN THE PRE-INDUSTRIAL ERA

Evolution and development of agriculture especially during the pre-Christian era and before the Industrial Revolution, was very slow. Domestication of animals and plants moved at a snail's speed in the *Neolithic* (*New Stone Age*) and *Chalcolithic* (*Bronze*) *ages*. According to Sauer (1952), an American biographer, primitive agriculture began in forested uplands and not in the river valleys and the hearths of domestication are to be sought in marked diversity of plants and animals. A significant contribution to the present knowledge of the main centres of cultivated

plants has been made by the Russian biographer Vavilov (Fig.1.1). He suggested that agriculture evolved in several regions of the world at the same or different periods of time. He identified eight such **geocentres** (geographical locations of wild ancestors of modern cultivated plants). We list them in Table 1.1 along with the regions/countries covered, plants domesticated and the possible periods. It reveals that a number of crop plants were domesticated in more than one geocentre. However, opinions differ on the regions of domestication of several crop plants among biographers and biologists. This information should, therefore, be taken with caution and is subject to modification.

Fig.1.1: Nikolai Ivanovich Vavilov, born in 1887 was a Russian botanist and geneticist. In 1918 he discovered in Transcaucasia a variety of wheat that grows at an altitude of nearly 3,000 ft (914 m) and is resistant to rust and mildew. His genetic study of wheat variations led to an attempt to trace the locales of origin of various crops by determining the areas in which the greatest number and diversity of their species are to be found. In 1936 he reported that his studies indicated Ethiopia and Afghanistan as the birthplaces of agriculture and hence of civilization. Vavilov divided cultivated plants into those that were domesticated from wild forms, e.g., oats and rye, and those known only in the cultivated form, e.g., corn.

Table 1.1: Geocentres of the world

Sl. No.	Geocentre (Period)	Regions/Countries	Crop Plants Domesticated
1.	Southwest Asia (7500-1700 BC)	Asia Minor, Turkey, Iraq, Iran, Israel, Jordan, Syria, Lebanon, Cyprus, Crete, Greece, Arabian Peninsula, Afghanistan, Egypt	Wheat, barley, lentil, pea, chickpea, broad bean, flax melons, several vegetables
2.	Central Asia (4000-3000 BC)	Tajikistan, Kazakhstan, Kirigizistan, Turkmenistan & area lying to west of Tien Shan	Peas, flax, carrots, onion, garlic, radish, spinach, alfalfa, almond, walnut, Pistachio and grapes
3.	Southeast Asia (9000-1700 BC)	India, Pakistan, Bangladesh, Sri Lanka, Myanmar, Thailand, Cambodia, Vietnam and Philippines	Rice, sugarcane, legumes, coconut, bamboo, taro, yam, durian, mango and cucumber
4.	China-Japan (6000-5000 BC)	China and Japan	Soybean, sorghum, millet, corn, sweet potato, barley, peanuts, cotton, tobacco, tea, sericulture, several fruits and vegetables
5.	Mediterranean (By 4000 BC)	Iberian Peninsula, Coastal areas of Spain, France, Italy, Albania, Bosnia, Serbia, Croatia, Crete, Cyprus and coastal strips of Africa	Flax, olive, figs, vines, rutabagas, lupines, oak and lavender
6.	Africa (By 5000 BC)	Nile Valley and other parts of Africa	Wheat, cotton, oats, flax, African rice, castor beans, cowpea, coffee, oil-palm, kola nut
7.	South America (7000-3000 BC)	Peru, Brazil, Bolivia, Chile, Ecuador, Argentina	Manioc, arrowroots, water-nuts, sweet potato, pumpkin, potato, tomato, lima beans
8.	Central America (7000-3000 BC)	Mexico, Guatemala, Costa-Rica, Honduras, Nicaragua, Panama and El-Salvador	Corn, cacao, tomato, potato, kidney beans, pumpkin, sunflower, red pepper, tobacco and avocado

In addition to geocentres, which tell us about the domestication of cultivated plants that made the beginning of agriculture, there are a number of hypotheses regarding the evolution of agriculture mainly based on the archaeological findings including C^{14}

dating. On the basis of their findings and evidences, archaeologists tend to describe the life of the past societies within a temporal and spatial framework and attempt to explain the changes that occurred. These include the kinds of plants grown and the animals used for movement and transport. We give below five of the hypotheses related to the evolution of agriculture:

1. *South-East hearth hypothesis:* As cited by Bender (1975) South-East Asia was the ideal hearth for the evolution of agriculture because it had the ideal conditions for transition from hunting-gathering to farming. These conditions were:

    a) flourishing economy,

    b) orientation towards food-gathering rather than hunting,

    c) sedentary nature,

    d) living in forest areas,

    e) being away from large river valleys subject to frequent floods, and

    f) availability of a wide variety of plants and animals. This theory is closely linked to the existence of geocentres.

2. *Migration hypothesis:* According to this theory, when life became harsh in places of their origin and enough food was not available, people moved to newer areas taking with them already developed agricultural practices and tools. Various combinations of crops that originated in the Southwest Asia formed the basis of agricultural systems in Europe, the Nile valley, Central Asia, the Indus valley and the Gangetic plains of India mainly due to migration.

3. *Climatic hypothesis:* Nomadic hunters and gatherers migrated from relatively cold and warm and wet regions to the areas of mild temperatures and temperate climates, where there was great diversity of plants and they camped for longer times and for their sustenance they developed agriculture.

4. *Rubbish heap theory:* This hypothesis was suggested by Hawkes and Woolley (1963) based on the symbiosis between plants, animals and people. The rubbish heaps made of animal droppings and house wastage were spots richer in plant nutrients and allowed a variety of plants to grow from which a selection of useful plants suitable for cultivation was made.

5. *City theory:* According to Jacobs, an economist (cited by Bender, 1975), the evolution of agriculture began in the trade centres (cities) that provided a place of exchange of information and produce of animal and plant origin. This was transmitted to smaller settlements (villages) around which agriculture evolved.

We now describe the emergence and evolution of agriculture through the ages, from prehistoric times. However, you may like to fix the concepts discussed so far in your mind. Attempt the following SAQ.

Radio-carbon or C^{14} dating is a method of obtaining age estimates on organic materials such as wood, charcoal, marine and fresh-water shells, bone and antler, peat and organic-bearing sediments and dissolved carbon dioxide and carbonates in ocean, lake and ground-water sources. It has been used to date samples as old as 50,000 years.

Radioactive carbon, produced when nitrogen 14 is bombarded by cosmic rays in the atmosphere, drifts down to earth and is absorbed from the air by plants. Animals eat the plants and take C^{14} into their bodies. Humans in turn take carbon 14 into their bodies by eating both plants and animals. When a living organism dies, it stops absorbing C^{14} and the C^{14} that is already in the object begins to disintegrate. Scientists can use this fact to measure how much C^{14} has disintegrated and how much is left in the object. Carbon 14 decays at a slow but steady rate and reverts to nitrogen 14. The rate at which Carbon decays (Half-life) is known: C^{14} has a half-life of 5730 years. Basically this means that half of the original amount of C^{14} in organic matter will have disintegrated 5730 years after the organism's death; half of the remaining C^{14} will have disintegrated after another 5730 years and so forth. After about 50,000 years, the amount of C^{14} remaining will be so small that the fossil can't be dated reliably.

SAQ 1

a) What do you understand by a geocentre?
b) Which crop plants were domesticated in ancient times in India?
c) Complete the table given below:

Sl. No.	Hypothesis	Main Feature
1.	Migration hypothesis	
2.		Agriculture evolved in areas of mild temperatures and temperate climates.
3.	Rubbish heap theory	
4.	City theory	
5.		Agriculture evolved in South-east Asia as it had the ideal conditions for farming.

1.2.1 Emergence of Agriculture

It is by and large agreed that modern man (*Homo sapiens*) first appeared about 30000 to 40000 years ago. The most famous sites of *Homo sapiens* are Cro-Magnon and Combe Capelle in France, Oberkassel in Germany and Predmosti, Mladec and Dolni Vestonica in Moravia (Randhawa, 1980).

With the arrival of modern man began the Mesolithic age about 10000 BC and ended by 7500 BC, when the Neolithic (New stone) age began. In the Mesolithic age, man was a hunter and gatherer of food. He mostly used tools made of stone for hunting, such as spears made of wooden sticks having a sharp stone head. Stones were also used in slings. Fire had been discovered by then and was used to cook the meat. The domestication of dog was the major achievement of Mesolithic hunters. Once the dog had become the member of the human society, control and domestication of small ruminants became possible. Sheepherders even today keep dogs for controlling their herds.

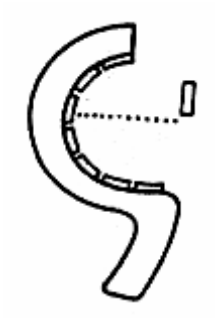


Fig.1.2: Microliths were hafted in a bone or a wooden piece to make a compound tool, like a sickle.

Neolithic or New Stone Age (7500-6500 BC)

Agriculture emerged between 7500-6500 BC in West Asian hilly regions embracing Israel, Jordan, Iraq, the Caspian basin and the adjoining Iranian Plateau (Braidwood, 1960). The Natufians named after a campsite in Wadi-el-Natuf in Jordan used sickles of small flint blades set with gum into the grooved shafts of bone. The blades were finely notched and set in a line to make a continuous saw edge. Continuous cutting of grass or corn stalks polished the edges of the flints into a bright lustre (see Fig.1.2).

It is in this Western Asian region that the wild ancestors of barley and wheat and of domesticated animals like goat, sheep, pig and cattle are found. Thus, apart from a fertile soil all other essentials of mixed farming (crop production and stock raising) were present in this region.

The oldest Neolithic settlement sites known are Ali Kosh, Bus Mordeh phase in Iran (7500 BC), Jericho in Jordan (7000 BC), Jarmo in Iraq (6750 BC) and Belt Cave below the Caspian (6500 BC) in northern Iraq (Randhawa, 1980).

The important achievements of Neolithic agriculture are:

- *Growing of cereals*: Wheat, barley, corn (maize), millets, and rice.
- *Domestication of animals*: a) goat and sheep b) cattle and pigs
  c) horse and ass (in that order).
- *Housing*: Houses were made of sun-dried bricks and stone. Lime plastering of walls was also done.
- *Pottery*: Baking of pots was done.
- *Basket making*: Baskets of tree branches, straw and other materials were made.
- *Spinning and Weaving*: Flax and wool.

Fig. 1.3 shows some implements used towards the end of Stone Age.

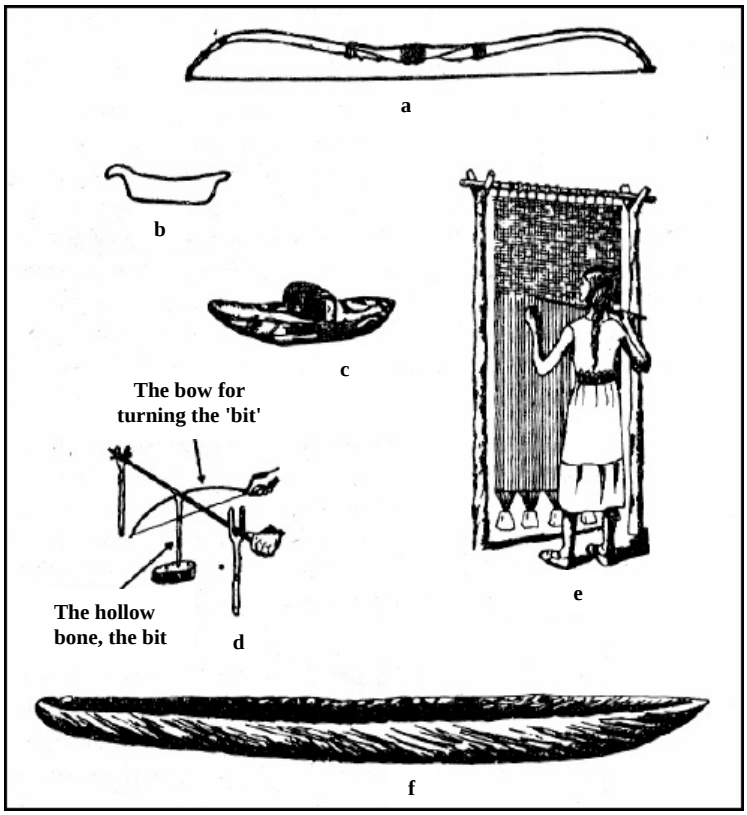


Fig.1.3: Implements used towards the end of the Stone Age: a) composite bow; b) skin boat, outline from Norway; c) grain milling stone; d) bow drill for boring stone; e) weaving loom, reconstructed according to available remains and descriptions; f) boat made out of a tree trunk.

1.2.2 Development of Agriculture up to the Middle Ages

The emergence of agriculture in the Neolithic age gave rise to tiny settlements. The discovery of copper in the later period changed the way agriculture was practiced. This period is known as the Chalocolithic age.

Chalcolithic or Bronze Age (3000 BC-1700 BC)

The term Chalcolithic is applied to communities using stone implements along with copper or bronze implements. This occurred mostly between 3000 BC and 1700 BC. The Chalcolithic revolution began in Mesopotamia (The valleys of Tigris and Euphrates rivers, now Iraq) and from there it spread to Egypt and subsequently to the Indus valley. The people who settled in Mesopotamia were Sumerians, who had just emerged from the Neolithic stage. By 3000 BC, Sumerian civilization was fully developed. Copper in Mesopotamia was imported from Oman or the Persian Gulf. Sumerians developed the technique of making bronze. In this period the basic agricultural techniques, which were developed in hilly uplands shifted to river

valleys. The nomadic shifting cultivation gave way to the *cereal-fallow system*. The main achievements of the Chalcolithic period in relation to agriculture were:

Cereal-fallow system is a system of growing crops in which the land is left fallow after growing a cereal crop.

- *Invention of the plough* – The Sumerians developed the plough by 2900 BC. In other parts of the world, cultivation of small plots with hoes was a common practice.

- *Invention of the bullock cart* – Development of wheel was a great achievement of pre-historic carpentry. Wheeled vehicles are represented in Sumerian art as early as 3500 BC. In the Indus valley wheeled carts were in use in 2300 BC.

- *Development of sailing boats* – It helped in transporting agricultural produce to far off markets.

- *Development of irrigation.*

- *Discovery of chemical processes* involving smelting of copper ore and study of the physical properties of metals.

- *Working out an accurate solar calendar*.

- *Art of growing of additional crops* viz. melons, forage crops of Lucerne and Egyptian clover, flax, beans (vicia), Kabli chickpea and fruit crops such as grapevines, fig, date palm and citrus.

The above achievements changed the tiny villages of the Neolithic period into populous cities with some industry and foreign trade. According to Braidwood (1960) the life of human beings during the Chalcolithic or Bronze Age changed more radically than in all preceding years. Before the emergence and evolution of agriculture, most human beings spent their waking moments seeking their next meal except when they had a great kill.

The first environmental hazard encountered at that time was water logging and salinity due to long period of irrigation without adequate drainage. According to Whyte (1960) salinity caused by 1000 to 1500 years of agriculture was the cause of the decline of the Sumerian civilization. By 1700 BC, wheat had completely disappeared from Mesopotamia and barley which is more salinity tolerant survived but gave lower yields.

With this brief overview of developments in agriculture in the rest of the world, we now turn our attention to the Indian subcontinent. But before studying the next section you may like to reinforce what you have studied so far by trying the following SAQ.

SAQ 2

a) List the crops (cereals, fruits and vegetables) grown in:

   New Stone Age
   Bronze Age

b) What agricultural implements were used in these eras?

Development of Agriculture in the Indian Subcontinent in the Pre-Christian Era

The great cities of Harappa and Mohen-jo-daro, now in Pakistan, were discovered in the 1920s. They were the first evidence of a fairly advanced river valley civilisation in the Indian Subcontinent (Fig. 1.4). It is known as the Indus Valley or Harappan Civilisation.

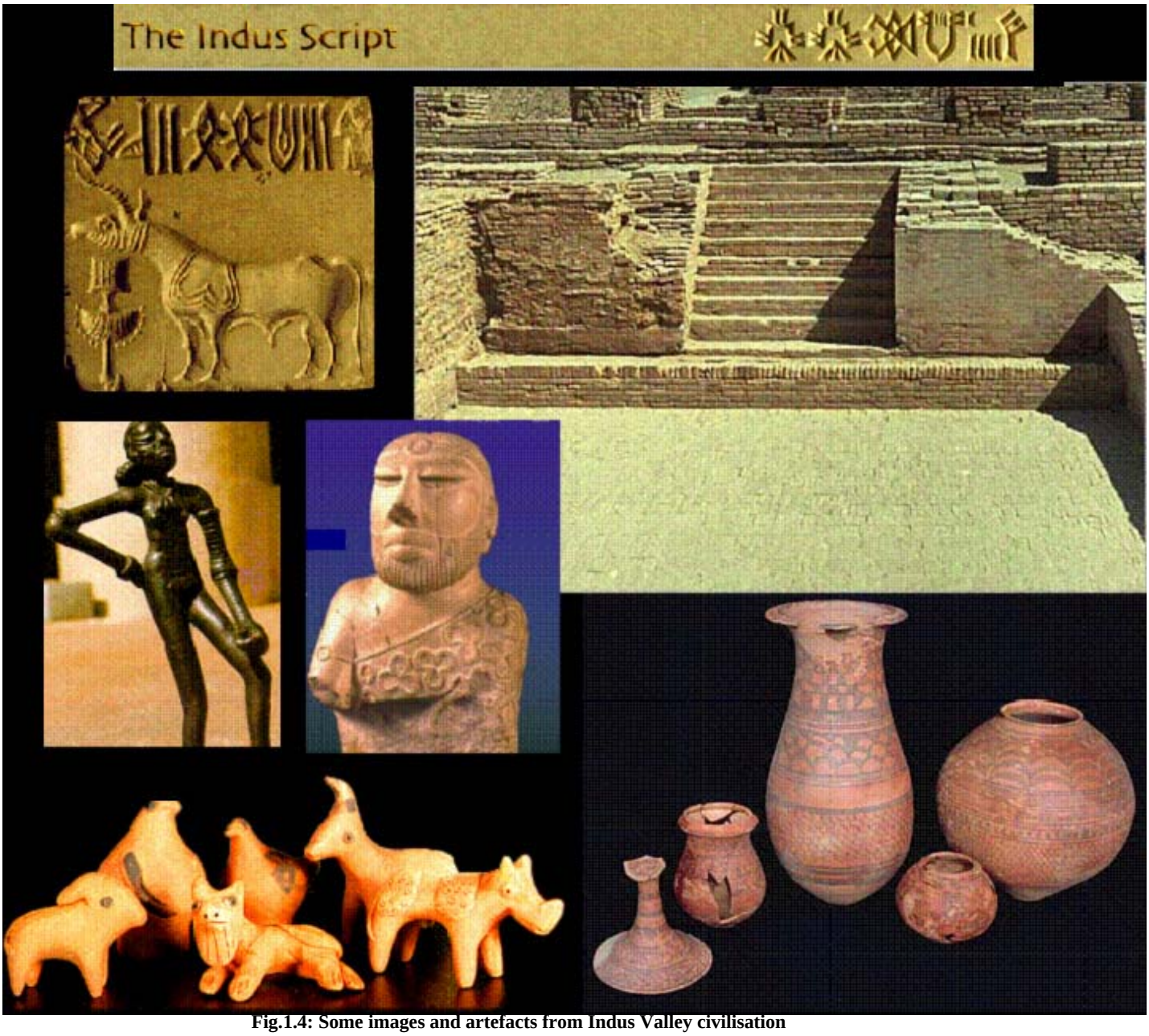


Fig.1.4: Some images and artefacts from Indus Valley civilisation

Harappan agriculture was Chalcolithic in nature and from Harappa it spread to neighbouring parts of India such as Punjab, Haryana, Jammu and western Uttar Pradesh. The crops grown were wheat, barley, gram, sesame, peas, rapeseed-mustard, and cotton. Fruit crops grown were date-palm, pomegranate, lemon and plough was used for land cultivation and bullock carts for transporting goods. The excavations in Mohen-jo-daro show that the harvested grain was stored in special granaries.

The Aryans (1500-600 BC)

The home of Aryans is believed to be South Russia. They left their homeland about 1800-1600 BC perhaps due to drought and famine and dispersed east and westwards in large groups. One group conquered and occupied northern Iran, the other Asia Minor and the third entered the Indian subcontinent through Afghanistan and Baluchistan. As quoted by Randhawa (1980), Sanskrit, Greek, Latin and Zend are sister languages derived from a common ancestral language, which was spoken by

Aryans in their homeland. Vedas were composed by Indo-Aryans during 1500 to 1200 BC and were handed over orally from father to son. The deities invoked for good crops and betterment were *Agni*, *Surya*, *Marut*, *Prithvi*, *Varun* and *Indra*.

Aryans are credited for domestication of horse, which took place in the region now occupied by Ukraine, Kazakhstan and Turkmenistan. They used a horse chariot, which made the movement of people and agricultural goods much faster than bullock cart.

The Vedic Aryans were primarily pastoral. When they settled in Punjab, they cut the forests and built their villages. They grazed their cattle and grew barley. The land was ploughed by bullocks and fields were irrigated when required. Milk formed an important part of their diet and *ghee* (clarified butter) was also prepared.

The Aryans developed the art of smelting iron and made ploughshares and other tools from it. The iron ploughshares permitted cultivation of heavier soils found in Uttar Pradesh in India. Cow dung was used as manure for enriching the soil. In addition to barley they grew wheat, pearl millet, small millets, rice and linseed.

The Buddhist and Later Periods (500 to 200 BC)

In the sixth century BC four great religions of the world were born. These were Confucianism in China, Zoroastrianism in Iran, and Buddhism and Jainism in India. Of these Buddhism had a universal appeal. The Vedic practice of animal sacrifices was given up under the influence of Buddhism and the bullocks became companions of man in the conquest of virgin lands. Iron Age was well established and in addition to ploughshares and sickles, iron was used for making spearheads, arrowheads, axes, daggers and knives.

Buddhism adopted the cult of tree-worship from the older religions and this helped in increasing vegetation. Stories abound that Gautama Buddha was born under an *asoka* (*Saraca asoka*) tree, received enlightenment under a *pipal* (*Ficus religiosa*) tree, preached his new gospel in mango (*Mangifera indica*) groves and under shady banyan (*Ficus benghalensis*) tree and died under a *sal* (*Shorea robusta*) tree. Emperor Asoka, whose reign extended up to regions of Afghanistan, adopted Buddhism after the Kalinga war and promoted growing of trees for fruits and decoration. The fruit trees encouraged included mango, banana, jackfruit and grapevines.

During the Mauryan rule (322 BC-232 BC) in India, agriculture received considerable importance. Animal husbandry was developed and the importance of feed and fodder was recognized. Pastures were developed and veterinary service was established.

Thus, at the beginning of the Christian era there had been considerable interchange of plants between South Asia, Southwest Asia, Europe, Africa, India and China due to significant trade and interaction between these regions.

Crop production and domestication of animals were well established in Western Europe by Roman times. Crop-fallow was the common practice. Wheat and barley were sown in autumn and harvested in spring. Legumes (pulses) were also grown. Soil fertility was judged by colour, taste and smell. Crops were grown on the basis of soil fertility. We will now discuss how agriculture developed during medieval times. But before that, you may like to attempt the following SAQ.

SAQ 3

Compare the level of development of agriculture in the Indus Valley civilization and the Vedic times in the Indian subcontinent pointing out the similarities and differences.

Development of Agriculture in the Medieval Period

The Arab traders played an important role in spreading crops during the medieval times. They carried wheat, barley, rice, cotton, sugarcane, flax, peas and beans from Mesopotamia to Portugal and Spain, North and West Africa and even to China and its neighbouring countries. They introduced rice, citrus fruits, mango, coconut and banana from Southeast Asia to East African countries in eighth and ninth centuries. Traders from Southeast Asia (Indonesia, Malaysia and Thailand) crossed the Indian Ocean and carried rice, banana and yam to Madagascar from where it spread to other neighbouring mainland countries.

The European navigators especially those from Spain, Portugal, Italy, Netherlands (Holland), Britain and Scandinavian countries discovered sea routes to Southeast Asia and the Far-east. They also discovered the New World (North and South America). Columbus discovered America in 1492, Vasco de Gama reached India via Cape of Good Hope in 1498 and Magellan circumvented the world in 1521. These navigators took European and Asian crops to Americas and American crops such as corn (maize) and potatoes to Europe, Asia and Africa.

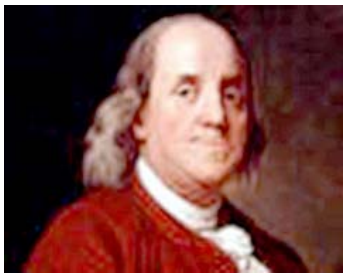
1.3 AGRICULTURE IN THE POST- INDUSTRIAL ERA

During the eighteenth century, a number of scientific discoveries were made and the stage was set for the Industrial Revolution in England. The scientific discoveries and the Industrial Revolution had far reaching influences on the evolution of agriculture and paved the way for modern agriculture. Therefore, we discuss them briefly.

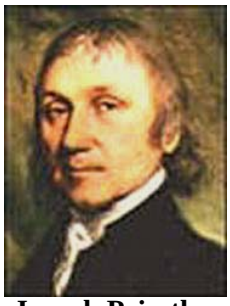
The Great Age of Discovery

James Hutton (1785) in his ‘Principles of Earth’ systemized the knowledge of geology, which brought out the importance of fossils and rock strata in interpreting the origin and development of earth. Benjamin Franklin (1706-1790), an American genius proved that lightning in the clouds is due to electricity. Volta (1745-1827) constructed the first electric battery. Joseph Priestley (1733-1786) and Scheele (1742-1786) independently discovered oxygen and Cavendish (1731-1810) discovered the chemical composition of water. Lavoisier showed that oxygen was involved in the burning of a material and that breathing in animals is an oxidation process. Edward Jenner (1749-1823) invented the process of vaccination. These are only a few of the important discoveries made in the eighteenth century (Randhawa, 1980).

As regards plants and animals, which form the basis of agriculture, Carlos Linnaeus (1707-1778) invented the bionomical nomenclature, the modern system of naming plants and animals. He used *Latin* for this purpose. According to this system each plant or animal species has two words to describe it; the first word refers to genus while the second word refers to the species. For example, in *Homo sapiens*, *Homo* is the genus, while s*apiens* is the species. Similarly, for mango the biological nomenclature is *Mangifera indica*. Here *Mangifera* is the genus and *indica* is the species name; *indica* indicates its linkage to India.



Benjamin Franklin



Joseph Priestley

Henry Cavendish

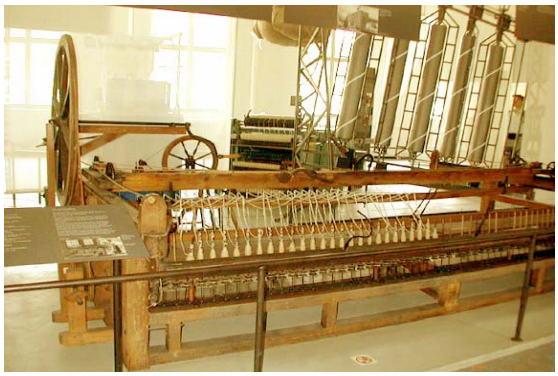
Carlos Linnaeus

Fig.1.5: Scientists of the Great Age of discovery

The Industrial Revolution

The Industrial Revolution in England began with the textile industry. Until 1764, spinning was done with the spinning wheel, where one person could take only one thread at a time. Three great inventions, Hargreaves' spinning-Jenny of 1764, Arkwright's water frame of 1769 and Crompton's mule of 1779 made the first real breach in the old hand techniques, first by multiplying the action of the hand and by using the power in the primary process of spinning. Thus, machinery substituted manual work in spinning and weaving leading to a manifold increase in production.

In 1784 Cartwright invented a new improved loom and by the end of the eighteenth century power driven machines had been invented, permitting the spinning of 200 threads at a time. The engineers who sparked off the Industrial Revolution in England were the lineal descendents of the millwrights and metal workers. They included men such as, James Watt (1736-1819), the discoverer of steam engine, Murdock (1754-1839), the inventor of coal gas lightening and Mathew Boulton (1728-1809), who became the first manufacturer of steam engine (Randhawa, 1980).



(a)

(b)

Fig.1.6: Inventions that set the stage for the Industrial Revolution; a) Hargreaves' spinning-Jenny, b) Arkwright's water frame

The Industrial Revolution had a harmful effect on rural artisans and craftsmen in England and adversely affected the cottage textile industry in India. Much of the

agricultural development in cotton production in India by the British was primarily directed towards providing adequate cotton to spinning mills in England. The large scale cultivation of indigo in the eastern states in India was also controlled by the British and was meant to supply indigo to cotton mills in England.

The Industrial Revolution caused profound social upheavals, but it also made England the workshop of the world. Apart from promoting its textile trade it provided British army with the artillery and other war materials that were superior to other countries in the world. It put many technologies and scientific knowledge at the disposal of human societies. When some of these were applied to agriculture, it underwent a significant transformation, which we take up in the next section.

1.4 MODERN AGRICULTURE

The agricultural revolution in England began in the early eighteenth century. Recognizing the soil fertility restoring value of legumes, the cereal-fallow cropping system was replaced by the cereal-legume rotation. Jethro Tull (1647-1741) invented a horse drawn hoe and a seed-drill with tines at right distance to sow the row crops.

(a) **(b)**

Fig.1.7: a) Seed drill; b) Horse Drawn Hoe

Winter crops of turnip and clover were introduced from Flemish agriculture. Before the introduction of these crops, lack of winter feed for the animals was a nightmare that returned every year and the farmers could keep only as many animals as their supply of grass, straw and hay would feed. The rest of the animals were slaughtered and their meat was salted and during the long winter months, farm families in England lived mostly on salted meat.

Robert Blackwell (1725-1795) brought about a revolutionary change in stock-breeding. He bred horses for draught purposes, cattle for beef and milk, and sheep for wool and mutton. The rise in prices of the agricultural products during the revolutionary and Napoleonic wars (1793-1815) gave stimulus to British agriculture and the use of new implements and farm machinery made progress. Societies for the improvement of agriculture were formed in Scotland in 1723 and a Professorship in agriculture was established at the University of Edinburgh in 1790. The Farmers Magazine, a monthly, was established in 1776.

The manufacture of chemical fertilizers started in the middle of the nineteenth century, when Lawes and Gilbert (1847) developed single super phosphate in England. The funds from the sale of this fertilizer were donated for establishing the Rothamsted Experimental Station in England.

SAQ 4

Describe the impact of Industrial Revolution on agriculture.

Many other developments in the New World were giving an impetus to farm mechanization, improved breeds of crops and animals, and synthetic fertilizers in agriculture. We describe now the development of agriculture in the United States of America.

Developments in Agriculture in the USA

American farmers had big farms and in the horse husbandry period needed many farm hands, which were difficult to get in the mid-west and northwest US. In 1890, a steam driven tractor was developed in the northwest US. This was followed by the development of a gasoline driven tractor by an Iowa (a state in US) farmer. The tractor with internal combustion engine was developed in 1910. The development of other tractor driven machines followed. Soon the tractors replaced horses and mules and crop harvesters replaced sickles in the US farms. These developments in farm machinery in the US soon reached Europe. Thus developed the modern mechanized agriculture. The increase in agricultural yields, however, was accompanied by environmental problems.

In order to get a soft seed bed and more and more nutrients released from the soil organic matter, farmers practiced repeated ploughing and over the years, the surface soil became too loose and this led to severe wind erosion popularly known as "the famous dust bowl" of the Great Plains of the 1930s. So damaging was the effect of this wide-spread wind erosion that the Soil Erosion Act of 1935 and Soil Conservation and Domestic Allotment Act of 1936 were passed by the US House of Representatives (Rasmussen, 1973).

Considerable research was done at the State Agricultural Experiment Stations in the US to develop what is now known as ‘Conservation tillage’ or ‘Stubble mulch farming’. In this kind of farming, sowing of crops is done in the field without land preparatory ploughing using special equipment which cuts the stubbles of maize, sorghum etc. at the soil surface and spreads them in the field, while a special tine makes a slit in the soil and sows the seed at the desired depth in a single operation. The stubbles left in the field accumulate at the soil surface and form a layer of undecomposed or partly decomposed organic matter mulch, which prevents soil erosion, conserves soil moisture and improves soil fertility (McCalla and Army, 1961 and Prasad and Powar, 1991).

Many changes in the world agriculture since 1914 are directly traceable to the World War I. The most important effect was the stimulation to agricultural production outside Europe to meet its food demands. The area devoted to cereals in Canada, USA, Argentina and Australia in 1921 was 19% more than the pre-war period. The production of pork in USA, beef in Argentina and butter and cheese in New Zealand and Argentina also increased (Rasmussen, 1973).

Another major contribution of American Agricultural Scientists was the development of hybrid corn during 1905-1920. The first corn hybrid to be produced commercially was ‘Burr-Learning’ double cross by the Connecticut Agricultural Experiment Station in 1917. Hybrid corn yields were very high and demanded heavy application of fertilizer, especially nitrogen. Although the first synthetic ammonia plant was built in Germany in 1910, a fertilizer plant was built by the US Govt. at Sheffield Alabama just prior to the close of the World War I to manufacture ammonium nitrate. It was followed by another fertilizer plant at Syracuse (New York state) in 1921 and yet another at Hopewell (Virginia state) in 1929. All these 3 fertilizer plants manufactured nitrogen fertilizers (ammonium nitrate/sodium nitrate).

In addition to encouraging the establishment of fertilizer plants, development of hybrid corn also led to the development of seed industry, because the farmers needed to buy hybrid seed each year. The first seed company for commercial production was established in 1926, but large-scale hybrid corn seed production was started in 1932.

These developments in agriculture in USA had an impact on global agriculture. Hybrid corn (maize) is now produced the world over including India. Furthermore the principle of hybridisation has been extended to other crops such as sorghum and pearl millet. China was the first to produce hybrid rice, which is now being produced in India also.

One of the latest advances made in agriculture is the development of genetically modified (GM) plants. In this case the crosses are made in laboratory across genomes to transfer a desired trait from one organism to another. GM maize and other food crops are being grown in US and some other countries. During the crop years 2002 and 2003 Gm Bt cotton was grown in India with only partial success against cotton boll worm. As yet there is no global acceptance of GM food plants. Nevertheless the GM technology offers a way for overcoming serious pest problems without the use of pesticides and may play an important role in modern agriculture.

The worldwide changes in agricultural techniques and practices were to impact South Asian countries in a significant manner. The Green Revolution in India is a good case study of how the developments in modern agriculture have proved to be a double-edged sword.

Green Revolution in India: A Case Study

After achieving independence, India's first priority was to achieve self-sufficiency in food. A number of programmes were initiated to improve the country's agricultural production but the real success came in mid 1960s when a large amount of the seed of high yielding varieties of wheat was imported from Mexico. They were sown on the farmers' fields in the crop year 1967-68 and that year wheat production in India showed a quantum jump; it increased from 11.4 million tonnes (one tonne – 1000 kg) in 1966-67 to 16.5 million tonnes in 1967-68. This ushered in what is called the *Green Revolution in India*.

Wheat production in India in the year 2002-03 was 78 million tonnes and per hectare yield increased from 887 kg/ha in 1966-67 to 2743 kg/ha in the year 2000-2001, a three-fold increase. India now ranks second in wheat production in the world. There has also been an increase in the productivity of other crops. The high yielding varieties of cereals (e.g., rice and the hybrids and synthetics of maize, sorghum, and pearl millet in India) give yields that are 2 to 3 times of those obtained with local tall varieties and therefore need heavy fertilization. The major problem with the local tall wheat and rice varieties was that when high amounts of fertilizer were applied they lodged and there was no yield increase, on the contrary lodging reduced yield. On the other hand, dwarf wheat and rice varieties did not lodge when heavily fertilized and this finally resulted in high yields.

The point to be noted is that modern agriculture is highly input intensive. For high yields, good quality seed is required, which in the case of hybrids has to be purchased each year from seed producing companies. Moreover, high yielding cereal varieties demand heavy fertilization and thus investment in fertilizer has increased. The consumption of chemical fertilizers in India increased from a mere 65 thousand tonnes of plant nutrients (N+P205+K20) in 1951-52 to 17.3 million tonnes in 2000-01 (FAI, 2002).

Since well fertilized crop plants remain greener and more succulent they invite more insect pests and thus with high yielding varieties the demand for pesticides (insecticides, fungicides, herbicides, rodenticides) increased from 24305 tonnes in 1971 to 85030 tonnes in 1994-95 (ICAR, 2001). Due to intensive agriculture (growing of 2 or more crops a year) the need for irrigation and farm mechanization has also increased. Due to heavy and over-irrigation, the water table particularly in the rice-wheat belt of north India has gone down to alarming levels. The number of tractors in India has increased from 1.5 lakhs in 1972 to 22.2 lakhs in 1998, while that of threshers has increased from 2 lakhs in 1972 to 32.3 lakhs in 1998 (ICAR, 2001).

Excessive use of chemical fertilizer leads to several environmental problems which include eutrophication of lakes, ponds and estuaries, nitrate enrichment of ground water, ammonia and nitrous oxide enrichment of the atmosphere, the latter is involved in depletion of ozone layer (Prasad, 1998). Similarly pesticides can persist in soil and edibles and are a health hazard (Edwards, 1973). Increased use of tractors on the farm leads to increased emission of smoke and CO_2. Thus modern agriculture creates several environmental problems and sustainability issues in agricultural production system. These are discussed in detail in later units.

Safety of natural resources is of prime concern so as to ensure productivity, profitability and sustainability of our major farming systems for the present and future. In this mission scientists are striving to strike a balance between the two diametrically opposite processes of exploitation and conservation. To achieve this, the extent of environmental protection, resource conservation and its rational utilization must form an integral part of agricultural research and developmental processes. Integrated farming systems have been considered a promising and potential pathway.

With this brief overview of the evolution of agriculture, and a discussion of various facets of modern agriculture, we would like to end the unit by summarizing its contents.

1.5 SUMMARY

- It is widely accepted that agriculture evolved in Southwest Asia during the Neolithic Age (7500-6500 BC).
- The important achievements related to agriculture during the Neolithic Age are:

  1) Growing of crops (wheat, barley, millets, maize); 2) Domestication of animals (goat, sheep, cattle, pig, ass); 3) Building of houses; 4) Pottery; 5) Basket weaving; and 6) Spinning and weaving.
- The important achievements of the Chalcolithic Age (3000-1700 BC) are: 1) Invention of the plough, 2) Invention of the bullock cart, 3) Development of irrigation, 4) Sailing boats, 5) Smelting of copper and making of bronze.
- A number of new agricultural developments in India (as well in Europe) were initiated by Aryans (1500-600 BC) who came from South Russia. They domesticated horses and used horse chariots that moved faster than the bullock carts. They cleared forests and established villages in Punjab and western U.P. and they grew wheat, barley, rice, millets and linseed. They perfected the art of smelting iron and made iron ploughshares, sickles, spearheads, arrowheads and swords.
- The Buddhist period (500-200 BC) in India is credited with the planting of shady roadside trees (banyan, *pipal*, and palm) and fruit trees (mango, jackfruit). They also grew banana and grapevines. In the Mauryan period (322-232 BC) in India, animal husbandry and veterinary science were developed.
- During the medieval period, considerable interchange of plants and animals took place all over the world in which Arab and South Asian traders and European navigators played the key role.
- Soon after the Industrial Revolution in England, modern agriculture started which ushered the agricultural revolution in England. A seed-drill was developed and stockbreeding was started. The first fertilizer plant was established for manufacturing single super phosphate.

- Heavy farm machinery, the foundation of modern mechanized farming was developed in USA, where the first tractor using internal combustion engine was developed in 1910. World War I provided the stimulus to the agriculture in US, Canada, Argentina and New Zealand because food had to be produced for Europe. Hybrid corn was developed in US during 1905-20. Due to its high yield it encouraged use of large amounts of fertilizer and pesticides. Hybrid corn also laid the foundation of seed industry. These new developments in agriculture soon reached Europe and other parts of the world.

- Green revolution in India occurred in mid 1960s due to large-scale import of high yielding varieties of wheat from Mexico. Though it made the country self-sufficient in food, it has thrown up several environmental issues that need to be addressed urgently.

- Modern agriculture is input intensive and needs good quality seeds, mechanization, large amounts of fertilizers, adequate irrigation and pesticides (insecticides, fungicides, herbicides, rodenticides) and thus demands heavy expenditure and raising the input efficiency. These inputs also create environmental problems and health hazards, which call for development of optimum, sustainable and eco-friendly production systems.

1.6 TERMINAL QUESTIONS

1. What role did the traders and navigators play in the evolution of agriculture in the medieval period?

2. What do you understand by Agricultural Revolution in England?

3. Briefly discuss the agricultural developments in USA.

4. What are the main inputs required in modern agriculture? Discuss briefly their impact on the environment.

5. Outline the current status of agricultural practices in India.

6. Briefly discuss why eco-friendly agricultural technology has become important today.

REFERENCES

1. Braidwood, R.J. (1960) The Agricultural Revolution. Scientific American 203(3): 130-152.

2. Bender, B. (1975) Farming in Pre-history – from hunter gatherer to food producer. Billing & Sons Ltd., pp.268, London.

3. Edwards, C.A. (1973) Resistant Pesticides in the Environment. 2nd ed. CRC Press, Boca Raton, pp.119, USA.

4. FAI (2002) Fertilizer Statistics 2001-2002. The Fertilizer Association of India, New Delhi.

5. Hawkes, J.J. and Wooley, L. (1963) Pre-history and the Beginnings of Civilization, Allen & Unwun, London (c.f. Randhawa, 1980).

6. ICAR (2001) Agricultural Research Data Book. ICAR, New Delhi.

7. Lawes, J.B. and Gilbert, J.H. (1847): Journal of Royal Agricultural Society. 9:226-232.

8. Prasad, R. (1998) Fertilizer urea, food security, health and environment. Current Science 75:677-683.

9. Prasad, R. and Power, J.F. (1991) Crop Residue Management. Advances in Soil Science 15:205-251.

10. Randhawa, M.S. (1980) A History of Agriculture in India. Vol. 1(pp. 541) and Vol. III (pp.422), ICAR, New Delhi.

11. Rasmussen, W.D. (ed.) (1973) Agriculture in the United States – A documentary History, Greenwood Press Inc., Westport, pp. 2913.

12. Sauer, C.O. (1952): Agricultural Origins and Dispersals. American Geographical Society, New York (c.f. Randhawa, 1980).

13. Unger, P.W. and McCalla, T.M. (1980) Conservation Tillage. Advances in Agronomy. 33:2-53.

14. Vavilov, N.I. (1949-50) The Origin, Variation, Immunity and Breeding of Cultivated Plants. Chronica Botanica 13:113-120.

15. Whyte, R.O. (1960) Evolution of Land Use in South-Western Asia, FAO, Rome.