



Pearson New International Edition

Hartmann & Kester's Plant Propagation
Principles and Practices

Hartmann Kester Davies Geneve
Eighth Edition

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PEARSON

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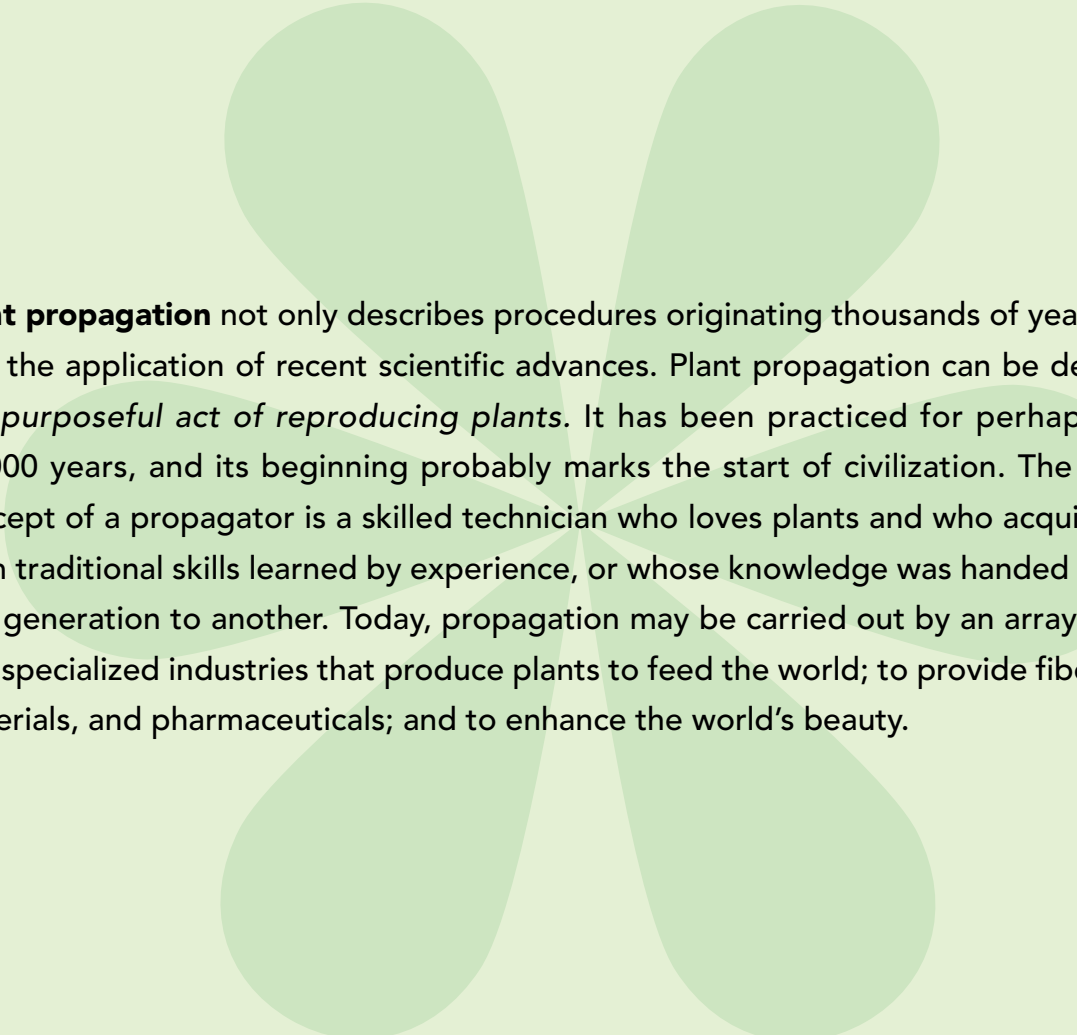
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General Aspects of Propagation



Plant propagation not only describes procedures originating thousands of years ago, but also the application of recent scientific advances. Plant propagation can be described as *the purposeful act of reproducing plants*. It has been practiced for perhaps the past 10,000 years, and its beginning probably marks the start of civilization. The traditional concept of a propagator is a skilled technician who loves plants and who acquired the art from traditional skills learned by experience, or whose knowledge was handed down from one generation to another. Today, propagation may be carried out by an array of general and specialized industries that produce plants to feed the world; to provide fiber, building materials, and pharmaceuticals; and to enhance the world's beauty.

How Plant Propagation Evolved in Human Society

How Plant Propagation Evolved in Human Society

learning objectives

- Describe the evolution of plant propagation during human history.
- Describe aspects of modern plant propagation activities.

agriculture The deliberate practice of propagating and growing plants for human use.

“And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good.”

Genesis 1:12.

“Man has become so utterly dependent on the plants he grows for food that, in a sense, the plants have ‘domesticated him.’ A fully domesticated plant cannot survive without the aid of man, but only a minute fraction of the human population could survive without cultivated plants.”

from: J. R. Harlan, *Crops and Man*, 2nd edition.
Madison, WI: Amer. Soc. of Agron. 1992.

INTRODUCTION

The propagation of plants is a fundamental occupation of humankind. Its discovery began what we now refer to as civilization and initiated human dominion over the earth. Agriculture began some 10,000 years ago when ancient peoples, who lived by hunting and gathering, began to cultivate plants and domesticate animals. These activities led to stable communities where people began to select and propagate the kinds of plants that provided a greater and more convenient food supply, as well as other products for themselves and their animals (21, 35). Once this process began, humans could remain at the same site for long periods of time, thus creating centers of activity that eventually would become cities and countries.

Agriculture is the deliberate cultivation of crops and animals for use by humans and involves five fundamental activities:

1. Plant selection—selecting and (or) developing specific kinds of plants.
2. Plant propagation—multiplying plants and preserving their unique qualities.
3. Crop production—growing plants under more controlled conditions for maximum yield.
4. Crop handling and storage—preserving crop products for long-term usage and transport to other areas.
5. Food technology—transforming and preserving crop products for food or other uses (e.g., making bread, pressing oil, preparing wine, dehydration, etc.).



STAGES OF AGRICULTURAL DEVELOPMENT

The pivotal role of plant propagation in the evolution of human society can be seen in terms of particular stages of agricultural development.

Hunting and Gathering

Most of the millions of years of human existence as hunters and gatherers were related to the presence of specific food resources including seeds, fruits, roots, and tubers, as well as animals that fed on the plants. The distribution and the characteristics of plant species were determined by the environment; that is, both the physical world (climate, soil, topography) and the biological interactions of plant, animal, and human populations (21, 32, 35). Humans have existed for millions of years, spreading from their presumed place of origin in western Africa into Asia, Europe, and, eventually, into North and South America. Food supplies were abundant in the native vegetation, although quite variable in different parts of the world. Apparently, early humans were quite effective in searching out those that were useful, as well as in developing processes to utilize and preserve them.

What motivated humans to begin to propagate and grow specific kinds of plants near their homes has been the subject of much scientific debate (21, 35). It is clear that the development of agriculture forever changed the relationship between humans and their surrounding environment. This event occurred in separate areas of the world, more or less simultaneously within a relatively short period of a few thousand years nearly 10,000 years ago. These areas included the Near East fertile crescent of Southwest Asia and Northeast Africa, extending from the valley of the Euphrates and Tigris Rivers along the coasts of Syria, Turkey, and Israel to the Nile Valley of Egypt; China, including a northern and a tropical southern area; and Central and South America, including areas in Mexico, and the coastal lowlands and highlands of Peru (21, 23).

The key activity bringing about this change must have been the deliberate selection and propagation and cultivation of specific kinds of plants that were particularly useful to humans. As a result, a larger and more stable population could be supported, which evolved into cities and countries. Human organization changed from subsistence existence, where everyone participated in the production of food and other items, to a division of labor between agricultural and non-agricultural segments of the population, and even to specialization

within the agricultural segment. In this context, the plant propagator, who possessed specific knowledge and skills, had to assume a key role.

Domestication

Early civilization developed with relatively few domesticated plant species, determined both by their usefulness in the primitive economy and the ease with which they could be propagated.

domestication The process of selecting specific kinds of wild plants and adapting them to human use.

The lists differed in the separate areas of the world where human societies evolved (21, 32, 34, 35). In the Near East, the earliest domesticated food crops included wheat, barley, peas, and lentil. In the Far East, millet appears to be the first domesticated crop, followed by rice. In Central and South America, the first food crops domesticated were apparently squash and avocado, followed by such important modern-day food crops as corn, bean, pepper, tomato, and potato. Many of the early food crops were seed plants (cereals, such as wheat, barley, rice), which provided carbohydrates, and legumes (beans, peas), which provided protein. These seed-propagated plants could be subjected to genetic selection in consecutive propagation cycles for such agricultural characteristics as high yield, “non-shattering,” large seed size, and reduced seed dormancy. These species were maintained more or less “fixed” because of their genetic tolerance to inbreeding. Highly desirable single plants of certain species, such as grape, fig, olive, pomegranate, potato, yam, banana, and pineapple (39) could be selected directly from wild populations and “fixed” through vegetative propagation. Domestication of fruit plants, such as apple, pear, peach, apricot, citrus, and others occurred with the discovery of grafting methods. By the time of recorded history (or that which can be reconstructed), most of the basic methods of propagation had been discovered. During domestication, crop plants had evolved beyond anything that existed in nature.

The establishment of specific crops and cropping systems resulted in some side effects that have continued to create problems (21). As the fields used to grow plants near human sites were disturbed and became depleted, certain aggressive plant species also were spontaneously established in these sites. These so-called weedy species have become a part of the agricultural system and more or less evolved along with cultivated plants.



Figure 1

Theophrastus (300 BC) was an important influence on Renaissance agriculture, as indicated by his being depicted and commemorated on the front page of John Gerard's influential herbal, published in 1597. His image is in the left panel opposite his Greek counterpart Dioscorides (1 AD), renowned as an authority on the medicinal use of plants.

ORGANIZATION OF HUMAN SOCIETIES

Ancient (7000 BC)

The initial phases of domestication probably involved plant selection, plant propagation, and plant production. With an increase in food supply, a larger population could be supported and division of labor began to occur. Classes of individuals may have included laborers, manufacturers, artisans, government bureaucrats associated with irrigation systems, religious groups, and soldiers, as well as farmers and herdsmen. Historical records of early civilizations in Egypt and the Middle East (as well as archaeological investigations) have shown that the agricultural sector was well organized to produce food (cereals, vegetables, fruits, dates), fiber (flax, cotton), and other items for the non-agricultural components of society (25). Early Chinese writings indicate the knowledge of grafting, layering, and other techniques, although rice and millet were the principal food sources. In the Americas, seed-propagated crops (maize, beans, cucurbits, squash), as well as vegetatively propagated crops (potato, cassava, sweet potato, pineapple), were developed and grown.

Greek and Roman (500 BC to AD 1000)

Early writings described the agricultural world in detail with accounts of propagation techniques much as we know them today. Control of land and agricultural surplus was the key to power and wealth (35). Small and large farms existed. Olive oil and wine were exported, and grains were imported. Vegetables were grown near the home as were many fruits (fig, apple, pear, cherry, plum). Not only were food plants essential, but Romans developed ornamental gardening to a high level (21).

Some of the earliest references to plant propagation come from Theophrastus, a Greek philosopher (circa 300 BC) and disciple of Aristotle (Fig. 1). He described many aspects of plant propagation including seeds, cuttings, layering, and grafting in his two books *Historia de Plantis* and *De Causis Plantarum* (36, 37). An example from the translation of *De Causis Plantarum* (37) illustrates his understanding of propagation: “while all the trees which are propagated by some kind of slip seem to be alike in their fruits to the original tree, those raised from the fruit . . . are nearly all inferior, while some quite lose the character of their kin, as vine, apple, fig, pomegranate, pear.”

Additional information on propagation can be seen in surviving works from Romans Pliny the Elder and Columella (circa 1 AD). For example, Pliny recommends that cabbage seeds be soaked in the juice of houseleek before being sown so that they will be “immune to all kinds of insects” (30), and Columella describes taking leafless, mallet stem cuttings in grape (12).

Medieval Period (AD 750 to 1500)

Society was organized around large estates, manor houses, and castles with landlords providing protection. Large areas of forest were kept as game preserves. Equally important were the monasteries that acted as independent agricultural and industrial organizations and preserved a great deal of the written and unwritten knowledge (Fig. 2). In both kinds of institutions, a separation developed among those involved in the production of cereals, fibers, and forages grown extensively in large fields (agronomy); vegetables, fruits, herbs, and flowers grown in “kitchen gardens” and orchards near the home (horticulture); and woody plants grown for lumber, fuel, and game preserves (forestry) (25).



Figure 2
The monastic garden was an enclosed area of medicinal and edible plants. The Cloisters in New York has several representative enclosed period gardens.

The end of the medieval period and the beginnings of modern Europe brought a shift from a subsistence existence to a market economy and the emergence of land ownership (35). In Western Europe, both large landowners and owners of smaller individual plots emerged. In Eastern Europe, the shift was toward large wealthy estates with the populace being largely serfs.

Through these periods, the specific skills and knowledge of the plant propagator were possessed by specific individuals. These skills, considered “trade secrets,” were passed from father to son or to specific individuals. Often this knowledge was accompanied by superstition and, sometimes, attained religious significance.

EXPLORATION, SCIENCE, AND LEARNING

Plant Exchanges

The plant material exchange from the area of origin to other countries of the world has been one of the major aspects of human development. Not only did the range

plant exchange The movement of plants from their place of origin to their place of use.

of plants available for food, medicine, industrial uses, and gardening expand, but plant propagation methods to reproduce them were required. Early movement of useful plants often followed military expansion into different countries when the invading soldier brought plants from his home country into a new land. Conversely, returning soldiers introduced to their homelands new plants they found while on a military campaign. There are numerous examples of

this type of exchange taking place during the Roman conquests of northern Europe. Similarly, Islamic expansion in the 9th Century introduced citrus and rice to southern Europe, along with new concepts of cultivation and the use of irrigation. The voyages of Columbus opened the world to exploration and the interchange of plant materials from continent to continent. Such food staples as potatoes, tomatoes, beans, corn, squash and peppers all became available to Europe in the 16th and 17th centuries after voyages to the new world.

In addition to edible food crops, new and exotic plants were being sought out for introduction. Centers of learning in which scientific investigations began on all aspects of the biological and physical world were established in many countries. Linnaeus established the binomial system of nomenclature, and botanists began to catalog the plants of the world. Exploration trips were initiated where the primary mission was plant introduction, such as the voyages of Captain Cook in 1768, which included the plant explorers Sir Joseph Banks and Francis Masson who brought large numbers of exotic plants to England for the Royal Botanic Garden, established at Kew, outside of London (23, 31). Nathaniel Ward, a London physician and amateur horticulturist, invented the Wardian case early in the 1800s to help preserve plant material on these long expeditions (Fig. 3) (38).

Wardian case A glazed wooden cabinet designed to keep high humidity inside and salt water spray outside the case on long sea voyages.

Plant-collecting trips continued throughout the world: from Europe (David Douglas, Joseph D. Hooker,

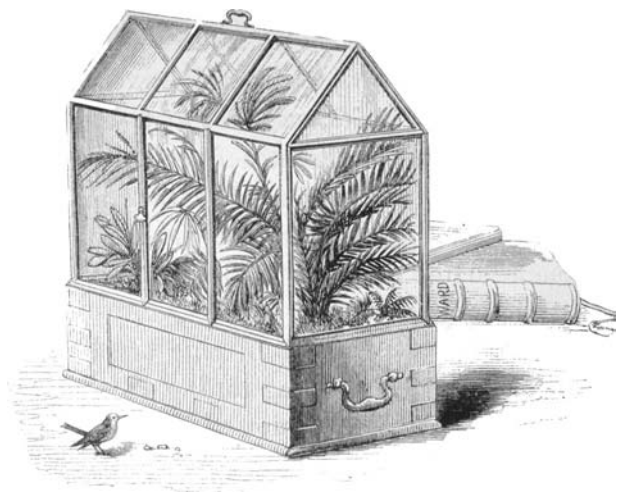


Figure 3
The Wardian case was invented by N. B. Ward in the early 19th Century to use when transporting plants over long ocean voyages.



Figure 4

Herbals were produced soon after the invention of the printing press to describe the utility of local and introduced plants. Plants such as this pea in Matthioli's herbal (*Commentarii*, 1564) were depicted from woodcuts on blocks.

Robert Fortune, George Forrest, Frank Kingdon Ward) and from the United States (David Fairchild, Frank Meyer, Joseph Rock, Charles Sargent, Ernest Wilson) (13, 18, 23, 31). Significant ornamental species that are mainstays of modern gardens were collected: from the Orient (rhododendron, primula, lily, rose, chrysanthemum), Middle East (tulips, many bulb crops), and North America (evergreen and deciduous trees and shrubs). “Orangeries” and glasshouses (greenhouses) were expanded to grow the exotic species being collected from India, Africa, and South and Central America.

Scientific and Horticultural Literature

The first important written works on agriculture, plant medicinal uses, and propagation that shaped western society came from the early Greek, Roman, and Arab writers between 300 BC and AD 2. Although many works were undoubtedly lost, many survive today because they were preserved in Arab libraries and passed on through medieval monasteries. Following the invention of the printing press in 1436, there was resurgence in the production of books called herbals (Fig. 4) describing and illustrating plants with medicinal properties. Much of the information came from older first century Greek literature, especially Dioscorides (Fig. 2). These early works were written in Latin, but eventually works began to appear in local languages (2), making plant information available to a wider audience.

The Renaissance heralded the appearance of scientific enquiry that relied heavily on meticulous observation of plant morphology and behavior. This is wonderfully shown in the illustrations from Marcello Malpighi (29) on plant anatomy in 1675 (Fig. 5).

In the late 1800s, the concepts of natural selection and genetics made a big impact on scientific advancement. Charles Darwin and his *Origin of Species* (14) as well as its important contemporary *The Variation of Animals and Plants Under Domestication* (15) introduced the concept of evolution and set the stage for the genetic discoveries following the rediscovery of Mendel's papers in 1900. The subsequent explosion in knowledge and application provided the framework on which present-day plant propagation is based, as did the increase in knowledge of plant growth, anatomy, physiology, and other basics of biological science (31).

Books and articles on gardening and propagation began to appear (16). The first book on nurseries, *Seminarium*, was written by Charles Estienne in 1530. Later, Charles Baltet, a practical nurseryman, published a famous book, *The Art of Grafting and Budding*, in 1821, describing 180 methods of grafting (see Figs. 6 and 7) (11). A book by Andrew J. Fuller—*Propagation of Plants*—was published in 1885 (19).

The Morrill Act

The passage of the Morrill Act by the United States Congress in 1862 was a landmark event that established land-grant colleges and fostered the scientific investigation of agriculture and mechanical arts.

Departments of agronomy, horticulture, pomology, and related fields were established, which became centers of scientific investigation, teaching, and extension. Liberty Hyde Bailey (33), a product of this system, published his

Morrill Act An act of Congress in 1862 that established land-grant universities for scientific study and teaching of agriculture and mechanical arts.

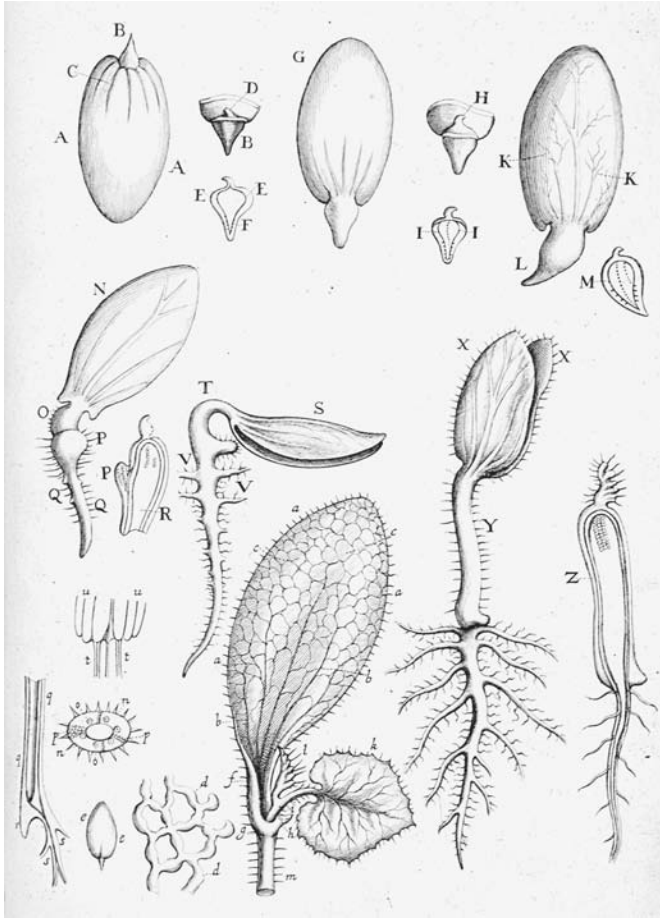


Figure 5
With the Renaissance, there was a resurgence in scientific inquiry. Malpighi was a keen observer of plants, as seen in his depiction of this germinating cucumber in his wonderfully illustrated *Anatome Plantarum*, 1675.

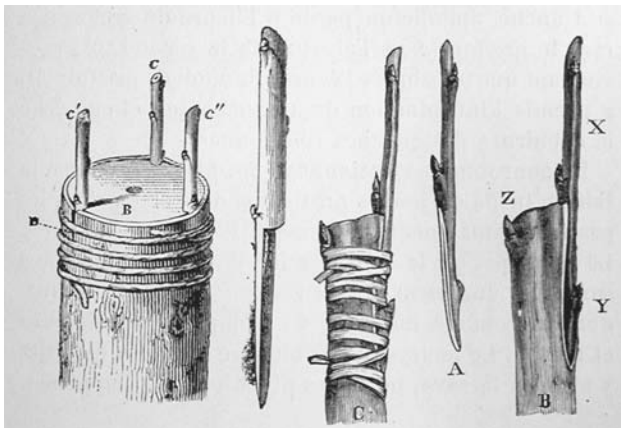


Figure 6
Bark grafting as illustrated in *The Art of Grafting and Budding* (1910) by Baltet.

first edition of *The Nursery Book* (3) later revised as the *Nursery Manual* in 1920 (6), which cataloged what was known about plant propagation and the production of plants in the nursery (Fig. 8). His *Cyclopedia of American Horticulture* (4) in 1900–1902, *Standard Cyclopedia of Horticulture* (5) in 1914–1917, *Hortus* (7) in 1930, *Hortus Second* (8) in 1941, and *Manual of*

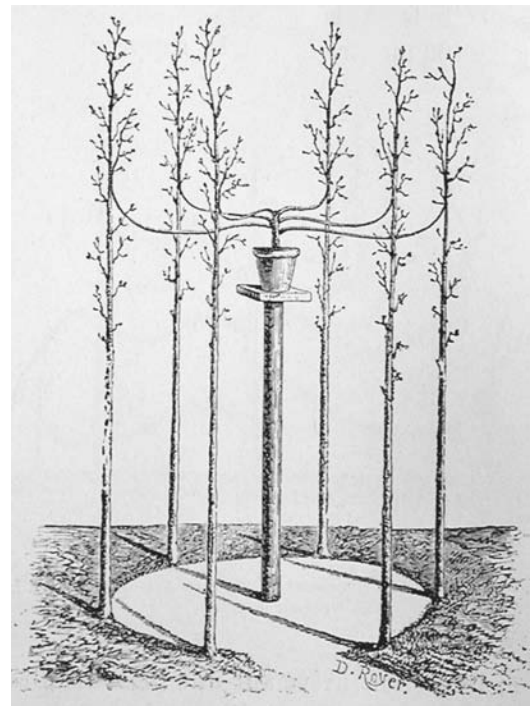


Figure 7
Approach grafting was a more important propagation technique before the introduction of mist propagation (11).