Chapter 1

Horticulture: An Overview

Muhammad Jafar Jaskani and Iqrar Ahmad Khan♦

Abstract

Horticulture is a sub-sector of agriculture which plays significant role in economy, human nutrition, gender mainstreaming and employment. Horticultural commodities include fruits, vegetables, flowers, spices and condiments, which have grown steadily and turn into a major segment in agricultural trade. Pakistan's climate favors production of a range of horticultural crops. The country has production rankings worldwide for citrus, mango, apricot, dates, potato, dry chilies and peppers, okra, onion, spinach, cauliflower and green peas. Despite a significant growth, the productivity of fruits and vegetables in Pakistan is low. The reasons are numerous, including poor seed and nursery, obsolete production practices, pests and diseases, and market failures. Application of advanced technologies, farm mechanization, and capacity building of growers and stakeholders are needed to improve productivity. National and global horticultural scenario and important technologies practiced in horticulture sector are discussed in this chapter.

Keywords: Automation, biotechnology, food security, hydroponics, nursery plugs, olericulture, organic horticulture, pomology, productivity, protected horticulture, vegetable grafting.

1.1. Introduction

Horticulture is the science and art of cultivating high value plants including fruits, vegetables, ornamentals (flowers, trees and shrubs), herbs and medicinal plants. Horticulture has a significant share in the global food value chain for the ever-

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♦Muhammad Jafar Jaskani* and Iqrar Ahmad Khan
Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.
*Corresponding author's e-mail: jjaskani@uaf.edu.pk

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University of Agriculture, Faisalabad, Pakistan.

increasing world population. Its prospects are preferable for a sustainable and environment friendly ecosystem. Ornamental plants are grown for aesthetic value that plays a vital role in the lives of people.

Horticultural crops/produce quality and safety are a matter of concern. Regulation of flowering and fruit set together with plants architecture are as important as plant nutrition and protection. The growth and development of plants is structured by diverse procedures, such as pruning and training for improving plant canopy features, which can influence the biomass, yield, insect-pest and disease prevalence.

Latin words, *Hortus* and *Cultura*, which means garden and cultivation, respectively, constitute the term 'Horticulture' (Malik et al. 1994). Horticulture is a branch of plant science which deals with wide range of crops. There are different definitions of horticulture found in the literature and slightly changed with the passage of time as its aims and scope broadened. Initially, horticulture was defined as "the production of crops within an enclosure" (Bailey 1939). In ancient times, the horticultural crops were grown in enclosures surrounded by boundary walls, which was known as garden. With the passage of time, the need for food has increased and horticultural production expanded into the open fields without boundaries and for commercial purposes (Denisen 1979). Janick (1986) explained the term horticulture as "the branch of agriculture concerned with intensively cultured plants used for food, medicinal purposes or aesthetic gratification". Modern horticulture includes cultivating, processing, and marketing of fruits, vegetables and ornamental plants (Acquaah 2005).

There are three major divisions of horticulture, *i.e.* pomology, olericulture and floriculture (Edmond et al. 1975). Pomology is the production of fruit crops, including the growing, harvesting and postharvest handling practices. Botanically, fruit is a ripened ovary. Horticulturally, fruit is not always an ovary alone. Horticultural fruit is the edible, fleshy or dry portion of a plant whose development is closely associated with the floral parts. Fruits are classified into different categories based on their development. Pomes are false fruits in which edible portion is thalamus and ovary, *e.g.,* apple, pear and quince. Stone fruits or drupes are identified as true fruits whose development is associated with the ovary wall with a hard stone/seed inside, as in case of peach, apricot, plum and cherry. Berry is another category of true fruits which have fleshy skin and inner walls, for example citrus and cucurbits. Aggregate fruit is developed from flower having multiple pistils on a common receptacle as blackberry, and strawberry. Multiple fruit is developed from many but closely clustered flowers such as pineapple, fig and mulberry. Fruit trees are perennials in nature and utilize more space as compared to seasonal crops. They also have good impact on the environment to control air pollution and heat.

Olericulture is the branch of horticulture which deals with the production of vegetables. The vegetables are further categorized into sub-groups based on their edible portion including leaves (spinach, fenugreek, amaranth, cabbage and lettuce), fruits (tomato, chillies, okra, cucurbits and brinjal), pods (peas, cowpea and cluster bean), roots (radish, carrot, turnip and beet) and tubers (potato, a stem and sweet potato, a root). The vegetables are rich source of vitamins (A, B and C), minerals (calcium, phosphorus and iron), carbohydrates and protein rich legumes which affect the human health positively.

Ornamental horticulture deals with the production and use of ornamental plants according to their aesthetic value. The ornamental plants are divided into sub-groups based on their usage; a) ornamental foliage plants, which are grown for the beauty of their leaves, and b) flowering plants which are grown for their flowers. The production of flowering plants is the prominent division of ornamental horticulture and known as floriculture. The ornamental plants can be grown in the fields/parks/lawns and called outdoors, while there are certain plants which can be grown in containers and kept indoors, and so termed as indoor plants. The production of ornamental tree plants is called as arboriculture (Reiley and Shry 2004). Landscaping is also part of ornamental horticulture which deals with the dressing of specified land with turfs and ornamental plants to enhance aesthetics.

1.2. World Horticulture Scenario

The projection of world population by 2025 is 8 billion people (Gelsdorf 2010). There is a challenge of feeding this growing population which is suffering from hunger (<1 billion) and malnutrition (>3 billion). The horticulture industry is one of the most considerable sectors that can improve food security, provide employment and contribute towards economic growth.

Global fruit production in 2012 was 636 million tons, an increase of 160 million tons (33%) occured in 12 years since the year 2000. The most remarkable fruit has been banana (101 million tons) followed by apples (76 million tons). During 2012, the world vegetable production remained 1106 million tons, a 41% rise in nutritious and balanced diet since 2000. Potato is the leading vegetable with total world production of 365 million tons in 2012 followed by sugar beet, cassava, tomatoes, sweet potato and watermelon. Asia contributes 52% fruits and 76.9% vegetables of the total world production. China and India are the world's leading producers of fruits and vegetables (Table 1.1). Vietnam and South Africa are top fruits and vegetables, exporting countries, respectively (Table 1.2), while China and USA are major fruits and vegetables importing countries, respectively (Table 1.3).

The volume of the world's floriculture business is about US$ 100 billion. The demand for horticultural produce (fruits, vegetables and flowers) has always been on the rise. Currently, floriculture production is concentrated in a few countries. More than 70% of the world's cut flowers are grown by the Netherlands, Columbia, Ecuador and Kenya. The major consumers of these crops are United States, France Germany, United Kingdom and the Netherlands. During 2013, the Netherlands share was 52% in export of cut flowers, bulbs and foliage plants (van Rijswick 2015). However, countries like South Africa, South Korea, India, Malaysia, China, Malawi, Mexico, Peru and Zambia have entered in the global flower trade. These countries have good climate for ornamental horticulture but bear high freight charges because of distant export markets. Floriculture is a capital intensive business that requires sizable investment for greenhouses, infrastructure and working capital.

Table 1.1 Top fruits and vegetables producing countries in the world.

Fruits		Vegetables	
Country	Production (000' tons)	Country	Production (000' tons)
China	151838	China	583321
India	82632	India	121015
Brazil	37774	USA	34269
USA	26985	Turkey	28281
Spain	17699	Iran	23652
Mexico	17553	Egypt	19591
Italy	16371	Russia	15485
Indonesia	16003	Mexico	13238
Philippines	15886	Italy	13049
Turkey	15341	Spain	12701

Source: FAOSTAT (2013)

Table 1.2 Top fruits and vegetables exporting countries in the world.

Fruits		Vegetables	
Country	(US$ '000)	Country	(US$ '000)
Vietnam	498579	South Africa	33210
Thailand	344901	Turkey	27233
China	331970	Germany	25654
Netherlands	146742	Egypt	24904
Turkey	112021	Nigeria	8507
Spain	90575	Vanuatu	8500
USA	77653	Netherlands	8331
Uzbekistan	66000	Sudan	6040
Israel	44977	USA	5661
Azerbaijan	10648	UAE	141
Pakistan	4429	Pakistan	92

Source: FAOSTAT (2013)

Table 1.3 Top fruits and vegetables importing countries in the world.

Fruits		Vegetables	
Country	(US$ '000)	Country	(US$ '000)
China	1075096	USA	88487
Netherlands	160340	Germany	84467
Russia	158640	Japan	45920
USA	135513	Saudi Arabia	27578
Germany	114123	Italy	26524
France	80526	UAE	16813
Indonesia	78402	Netherlands	13553
Canada	54415	United Kingdom	11344
Italy	49644	Egypt	9244
United Kingdom	41075	Syria	7239
Pakistan	4917	Pakistan	152

Source: FAOSTAT (2013)

1.3. Horticulture in Pakistan

Horticulture sector in Pakistan occupies fairly significant share in agricultural GDP and employment. The varied environments of Pakistan are favorable for cultivation of a large variety of horticultural crops. The Government of Pakistan has accepted horticulture and dairy sectors as a source of diversification in agriculture. Horticulture creates plenty of opportunities for employment, particularly for jobless youth and the women. Pakistan has made a place on the world's horticulture map with an annual production of 12.3 million tons of fruits and vegetables during 2013-14 (GOP 2013-14).

The fruits production in Pakistan has made notable growth during the last four decades and reached to about 6.1 million tons during 2013-14 (GOP 2013-14) (Table 1.4). The main fruit crops of the country are citrus (Kinnow mandarin the leading cultivar, 70% of total citrus production), mango (Sindhri and Summar Bahist Chaunsa are prominent cultivars), date palm (Asil, Begum Jungi, Dhaki, Hillawi), apples, pomegranates, guava, apricots, peaches, plums, almonds, banana, papaya, ber, coconut, jaman, pear, falsa, walnut, mulberry, cheku, litchi, loquat etc. Similarly, Pakistan grows several vegetables of temperate, tropical and sub-tropical groups and produced about 6.2 million tons during 2013-14 (Table 1.5). Potato, onion, tomato, cabbage, chili, cauliflower, garlic, turnip, ginger, radish, carrot, peas, okra, pumpkin, cucumber, watermelon, muskmelon, bitter gourd, squash, brinjal, sweet pepper, spinach, sugar beet, sweet potato, lettuce, mint, fenugreek and coriander are the important vegetables grown in the country.

Table 1.4 Area and production of major fruits in Pakistan during year 2013-14.

Fruits	Area (000' ha)	Production (000' Tons)
Citrus	194.5	1982.2
Mango	172.0	1888.4
Apple	110.5	525.9
Dates	90.1	524.6
Guava	64.0	546.6
Banana	29.6	139.1
Apricot	29.6	190.2
Grapes	15.3	64.4
Peach	15.1	52.6
Pomegranate	12.9	50.0
Almonds	10.8	21.5
Plum	6.7	56.2

Source: GOP (2013-14)

Table 1.5 Area and production of major vegetables in Pakistan during year 2013-14.

Vegetables	Area (000' ha)	Production (000' tons)
Potato	159.1	3491.4
Onion	147.6	1939.6
Chilies	63.6	171.8
Tomato	52.2	529.6
Okra	14.1	108.4
Garlic	6.6	55.3
Turmeric	4.4	48.5

Source: GOP (2013-14)

Pakistan has sustained the production of many products like Kinnow, dates, mango, apricot, chilies and peppers, okra, dry onions, spinach, cauliflower etc. Presently, Pakistan occupies 1st position in the production of Kinnow mandarin, 2nd in guava, 5th in dry chilies and peppers, 6th in mango, apricot, dates and okra, 9th in spinach and cauliflower, 10th in green peas, 11th in citrus and 14th in pistachio, 17th in almond and 18th in pumpkins, squashes and gourds in the world (Table 1.6). No doubt, Pakistan's ranking in world fruit and vegetable production is significant but the productivity in the country is low as compared to the developed countries (Table 1.7 and 1.8). The availability of flowers and ornamental plants has recently increased with change in crop production priorities and rise in living standards. Red roses (Surkha, Gruss-en-teplitz) and Marigold have been in use since ages for garlands but the demand for long stem flowers like roses, tuberoses, gladiolus and lilies have tremendously increased by the local consumer. The medicinal and aromatic plants sector is insignificant and in the development phase. A large variety of herbal plants are produced in National Parks of northern areas of Pakistan (Shinwari 2010).

The high postharvest losses in horticultural produce result in low income to the growers and merchandizers, besides restricting the exports. Hence, the enhancement of pre- and post-harvest management technologies is needed to minimize postharvest losses and develop horticulture as an industry in Pakistan.

Table 1.6 Ranking of Pakistan in the world with respect to fruits and vegetables production.

Fruits	Ranking	Vegetables	Ranking
Mango	6	Dry chilies and peppers	5
Apricot	6	Okra	6
Dates	6	Dry onions	7
Oranges	11	Spinach	9
Pistachio	14	Cauliflower and broccoli	9
Almond	17	Green peas	10
Lemons and Limes	20	Pumpkins, Squashes, Gourds	18

Source: FAOSTAT (2013)

Table 1.7 Difference in yield of fruits among different countries (t ha^{-1}).

Fruits	1st Position		2nd Position		3rd Position		Pakistan
	Country	Yield	Country	Yield	Country	Yield	Yield
Mango and Guava	Samoa	36.27	Israel	22.22	Mali	19.20	9.68
Apricot	Austria	15.88	Egypt	15.24	Ukraine	14.51	6.22
Dates	Egypt	32.73	China	12.50	Syria	10.98	5.88
Pistachio	Pakistan	3.41	China	2.96	Jordan	2.52	3.41
Oranges	Ghana	39.01	South Africa	38.02	Albania	36.91	11.00
Almond	Jordan	6.94	Lebanon	6.12	Australia	5.59	2.11
Lemons and limes	Israel	39.66	USA	37.17	Lebanon	28.25	10.89

Source: FAOSTAT (2013)

Table 1.8 Difference in yield of vegetables among different countries (t ha^{-1}).

Vegetables	1st Position		2nd Position		3rd Position		Pakistan
	Country	Yield	Country	Yield	Country	Yield	Yield
Dry chillies and peppers	Morocco	18.87	Jamaica	14.50	Cabo Verde	12.22	2.31
Okra	Bahrain	25.39	Senegal	24.70	Bahamas	24.26	7.66
Dry onions	Ireland	68.75	Korea	64.58	Australia	54.79	13.19
Spinach	Kuwait	44.27	UAE	38.46	Jordan	35.36	12.04
Cauliflower and broccoli	Cyprus	75.00	Kuwait	53.02	Palestine	50.58	17.13
Green peas	Jordan	24.50	Kyrgyzstan	17.50	Luxembourg	15.11	6.45
Pumpkins, squashes, gourds	China	71.00	India	49.00	Russian Federation	11.28	9.76

Source: FAOSTAT (2013)

1.3.1. Prospects

More than sixty types of fruits belonging to temperate, subtropical and tropical climates are produced in Pakistan. About 35 vegetables are produced through out the year, beginning an early production from the Sindh province and out-of-season summer vegetables from the higher elevations. Mostly fresh fruits are consumed and only 16% of fruits are being processed into value added products (Parveen et al. 2014).

Horticulture sector provides possible opportunities to increase earning, alleviate poverty and reduce socio-economic disparities. Horticultural products have ability to add foreign exchange through agricultural export. An encouraging increase has been noticed in the export earnings from the horticultural crops during the recent years. Major horticultural exports from Pakistan are dates, citrus, mango, apricots and many vegetables. During 2011, 443 thousand tons (US$ 102 million) potato, 324 thousand tons (US$ 120 million) Kinnow mandarin, 173 thousand tons (US$ 39 million) dry onions, and 137 thousand tons (US$ 53 million) fresh vegetables were exported from Pakistan. Overall fruits, vegetables, juices and spices exports from Pakistan had a value of US$ 690 million, which contributes only 3% of the total exports. In view of the WTO standards, improvement in quality standards is essential to enhance our share in the international trade (FAO 1999a).

1.3.2. Limitations

The production of fruits, vegetables, flowers, medicinal and aromatic plants is constrained by several factors:

- Insufficient availability of quality seed and planting materials.
- Imbalanced use of inputs such as fertilizer, irrigation, plant protection.
- Significant losses caused by biotic and abiotic stresses.
- Non-availability of proper services for harvest and postharvest management and supply chains.
- Inadequate storage and processing/packaging facilities.
- Poor market infrastructure and access to information.
- Insufficient infrastructure to support technology development research, education and training.

The low productivity, high cost of production, poor quality of produce and high postharvest losses make us uncompetitive in the global markets. The advantage needs to be taken of precision horticulture, hybrid seeds, protected cultivation, biotechnology, bio-fertilizers and integrated nutrient use, disease and pest management. There is a need to change the content and strategies of research in consultation and partnership with the private sector. The expansion of horticulture sector in future will largely depend on innovative and competitive technologies.

1.4. Horticulture and Food Security

The world produces adequate food for everyone, but unequal distribution has created a gap between the countries that produce more food than they consume and those countries with production deficits. The developing world is facing the overwhelming challenge of increasing population. About 815 million people suffer from hunger and malnutrition, mostly in the developing world. The developing countries will also face serious challenges of migration of population from rural to urban areas. About 52% of the people will live in megacities—all asking for more food, land, and infrastructure. According to the World Health Organization (WHO), an estimated 334 million children in the developing countries are malnourished (FAOSTAT 2013). In 2020, one out of every four children in these countries will still be malnourished. It is recognized that modern agriculture must diversify production and achieve sustainable higher output to supplement food and nutritional security.

The WHO states that Food Security is achieved "when all people, at all times have physical and economic access to adequate/sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". Food accessibility, availability and consumption/nutrition are the three dimensions of food security, and horticulture offers the best for increased food self-sufficiency, improved nutrition and ensures increased incomes and employment. Horticultural products, which include fruits, vegetables and nuts, are vital for the daily diet as they contain micronutrients, fibers, vegetable proteins and bio-functional components. Vegetables, especially leafy, have significant amounts of vitamins A and C, iron, calcium and some other minerals. In addition, fruits and vegetables have importance in prevention of non-infectious diseases. Dietary diversification through horticultural food intake can be seen as a sustainable approach to fight against nutrients malnutrition.

Communities with poor resources are increasingly using their skills in horticulture as a means to increase cash income and more broadly to improve their livelihoods by supplying fruits and vegetables, fresh or processed, to high-value local, urban and international markets. The rising demand for horticultural produce creates opportunities for income generating activities for small-scale farmers and entrepreneurs in rural, peri-urban and urban settings. Horticultural production not only improves food and nutrition security, but also provides livelihoods to producers and all parties involved in the associated value chains, contributing towards economic growth and development.

Horticultural interventions to enhance food safety at farm level, combined with extensive nutrition and food safety education, can offer a long-term food-based strategy to control and eliminate nutrient malnutrition in the people with poor resources. Horticultural production is relatively easy and it can play an important role in poverty alleviation programs and food security initiatives by providing work and income opportunities.

1.5. Modern Day Horticulture

1.5.1. Protected Horticulture

Horticultural production is climate and weather dependent. Conventionally, horticultural production is confined to outdoors. Among the greatest constraints in horticultural crop production are a lack of sun light (not in Pakistan), temperatures that are either too hot or too cold, moisture deficiencies or excesses, weed growth, deficiencies in soil nutrients, excessive wind velocity and atmospheric carbon dioxide. Many of these constraints have been alleviated or lessened by protected cultivation of horticultural crops.

Protected cultivation is a unique and specialized form of agriculture, which enables some control of wind velocity, moisture, temperature, mineral nutrients, light intensity and atmospheric composition. It has been made possible by a better understanding of growth factor requirements for crop productivity. Devices or technologies for protection (windbreaks, irrigation, soil mulches) or structure (green houses, tunnels, row covers) are used with or without heat. The main objective is to grow crops where otherwise they could not survive due to heat or frost injury by modifying the natural environment to alter the harvest period, often with earlier maturity to increase yields, improve quality, enhance the stability of production and make commodities available when there is no outdoor production.

Attempts to adapt crop production to the environment with protective devices or practices dates back to ancient times. Structures for crop protection began in the early part of the Roman Empire to accommodate the Emperor Tiberius Caesar (14-37 AD). They constructed movable beds of cucumber and perhaps other crops to place outside on favorable days and inside during inclement weather. Transparent slate like plates or sheets of mica or alabaster was used as covers. Such culture methods ceased with the decline of the Roman Empire. It was not until the late 15th to 18th centuries that the greenhouses appeared, primarily in England, Netherlands, France, Japan, and China. They were crude square or rectangular wooden or bamboo frames or structure covered with panes of glass, oiled paper or glass bells to cover hotbeds. During the late 1600s to 1700s, use of stoves and heating flues began in first glass greenhouses. They had glass on one side only in the form of a sloping roof. Later in the 18th century, glass was used for the front and on both ends of lean to houses. Then the development of forcing frames and greenhouses spread from Europe to America and elsewhere. These houses were devoted to produce cucumbers, tomatoes, eggplant and beans.

In the Westland's and elsewhere in the Netherlands, where much of the exploratory work on protected horticulture had its origin more than two centuries ago, more than 10,000 ha is covered by glass greenhouses with area increasing each year, devoted to the year-round production of high quality vegetables (tomato, pepper, eggplant, cucumber and lettuce), cut flowers (rose, chrysanthemum, carnation, tulip and lily), and potted plants (Ficus, Dracaena, Kalanchoe, Begonia and Azalea).

Farmers of Pakistan are increasingly adopting state-of-the-art tunnel technology that offers comparatively more profit and productivity against traditional methods of farming. The area of growing off-season vegetables under tunnel farming is about 55,000 acres across the country, out of which 30,000 is in the Punjab province. Three types of poly tunnels, *i.e.,* low tunnel, walk in tunnel and high tunnel are used for vegetable production. Generally, bell peppers, green chilies, bitter gourd, cucumber, brinjal, tomato, and gourds are produced under vegetable forcing system.

1.5.2. Precision Horticulture

Application of precision technologies to orchards and high value agriculture is growing. Precision agriculture addresses the causes of inefficient agricultural production practices: the soil, the weather and environment, plant genetics and their interaction, and the labour. This fundamental knowledge is then complemented with the information on machinery performance, and all physical, chemical and biological inputs used in the crop production (Gemtos et al. 2011). In this perspective, 'precision' denotes to the quality or state of being exact. Precision horticulture thus becomes an approach of production management where precise inputs and practices are applied at exact places within a field or specific sites, with the objective to do 'the right thing', at the 'right time', and in the 'right way'.

Precision competence is quickly developing in Pakistan. The goal is to enhance the effectiveness of management practices such as yield mapping or irrigation applications, pest management by measuring and managing the chronological differences in crop productivity. Considering these differences allows management to be connected to explicit crop needs at each site in the orchards, hence enhancing production. The recording of objective crop development information is not a common practice in many horticultural crops. High productivity results from the combination of several components and are applied at different timings: (a) primary selections which govern the structure of the orchard during its lifespan: rootstocks, cultivars, tree planting geometry; and (b) yearly events that are closely linked to the trees training methods but progresses yearly as pruning, training and thinning practices. Precision horticulture relies heavily on modern technologies such as computer programs to achieve and evaluate the information flow in an orchard. Also research into the yield variation and fruit quality parameters are undertaken. Watching crop growth and development, and other factors is certainly important for taking concurrent management decisions, particularly for fruit thinning and harvest. Remote sensing is one of the effective methods of collecting information within season on horticultural crops (Pinter et al. 2003).

The potential applications of precision technologies include the use of EM38, an electromagnetic-induction apparatus that measures soil conductivity, which is associated with salinity, clay content and moisture. Similarly, visible-near-infrared spectroscopy can show minerals and organic matter content in soil. Satellite imagery, based on the amount of light absorbed, can show up dry or stressed areas in the orchards because of improper irrigation or disease. Lidar is remote-sensing technology and has potential to map fruit on the trees (Buchanan 2016). Terrain modeling is based on open-source software that can produce insulation maps, indicates sun exposure and solar energy in each part of the orchard and this information could be valuable for estimation of fruit maturity in orchards and vineyards.

1.5.3. Hydroponics/Aeroponics Production

As the available area for agriculture is decreasing, it is imperative that alternative methods should be developed for the cultivation of crops. The utilization of alternative growth mediums may allow for increased yields by shifting the burden of production from soil-based agriculture to hydroponic and aeroponic systems. Aeroponic and hydroponic systems have shown great promise as environmentally sound methods for the cultivation of plants and to recycle water, a way to preserve water, which is becoming increasingly scarce.

Hydroponics is gardening by using water without soil. Some important points about hydroponics are that they use 70% to 90% less water, no nutrient run off, successful in poor soils or limited irrigation water, and can be established in outdoor fields or greenhouses (Anonymous 2008).

Aeroponics is a system of hydroponics where the roots of the plants are suspended in a chamber and a nutrient solution is sprayed. A distribution system consisting of, pump, timer, pipes and nozzles, sprays the nutrients from a solution storage tank. Aeroponic systems are recognized as commercially successful for plant propagation, germination of seeds, production of potato tubers and leafy vegetables. Any species of plants can be grown in a true aeroponic system because the micro environment of an aeroponic can be finely controlled. Suspended aeroponic plants receive 100% of the available oxygen and carbon dioxide to the roots zone, stems, and leaves, thus accelerating biomass growth and reducing rooting times. NASA research has shown that aeroponically grown plants have an 80% increase in dry weight biomass (essential minerals). Aeroponics systems use 98% less water than a comparable system utilizing soil as the substrate. Aeroponically grown plants do not face transplant shock and reduce the spread of diseases, and this technology is equally practicable to study the plant physiology and pathology.

Several formulae for hydroponic solutions are available and use different combinations of chemicals to reach compatible compositions and concentrations. Generally, the macronutrients like calcium nitrate, potassium nitrate, magnesium sulfate and potassium phosphate, and micronutrients like Fe, Mn, Cu, Zn, B, Cl and Ni are used in hydroponics. Occasionally chelating agents and humic acid are added to increase Fe solubility and nutrient uptake, respectively.

With reduced pest problems, and nutrients constantly fed to the roots, productivity in hydroponics is high, although plant growth can be limited by the low levels of carbon dioxide in the atmosphere, or limited light exposure. To increase yield further, some sealed greenhouses inject carbon dioxide into their environment (carbon dioxide enrichment) to help growth, add lights to lengthen the day, or control vegetative growth.

1.5.4. Organic Horticulture

The use of organic methods of growing, soil management, disease and pest management, water and nutrient management for horticultural crops is known as organic horticulture. The basic aim is to reduce the use of synthetic pesticides and fertilizers. The horticultural crops have diverse use in our daily life including food, medicine and for aesthetic value. The organically produced horticultural crops have positive effect on the human health and for the surrounding environment. Generally, the organic production involves the processes close to nature and has sustainability. Organic production basically focuses on the soil health/fertility (organic soil amendments, compost and mulches, crop rotation), plant health, (management of diseases and pests, companion planting), storage and marketing of produce.

Organic production has been practiced since the prehistoric times. At that time, this system was adopted based on availability of resources as there were no synthetic chemicals available. Now, organic production is based on the knowledge which leads to the induction of modern techniques in this system. Currently, organic production is designed to work with the ecological systems with minimum disturbance in the earth natural balance as organic farming lead to the use of natural resources for production of crops. Organic fertilizer production from city wastes can be a good alternative to synthetic fertilizers and a possible organic resource for production of horticultural crops organically (Cofie et al. 2006). The other possible sources of organic fertilizers can be organic household garbage, organic waste collected from public markets, slaughterhouses and farmers' fields.

Worldwide about 37.6 million ha of land is under organic agriculture; out of which 17.3 million ha is in Oceania (39.7%), 11.6 million ha in Europe (26.6%), 6.8 million ha in Latin America (15.5%), 3.6 million ha in Asia (8.2%), 3.1 million ha in North America (7.1%) and 1.3 million ha in Africa (2.9%) (FiBL and IFOAM 2016). Pakistan has 23.8 thousand ha of land under organic production, which is 0.1% of total agriculture land of Pakistan. There is linear increase in production of tropical and subtropical organic fruits (banana, mango, coconut, papaya and pineapple), *i.e.* 37.9 thousand ha in 2004 to 233.1 thousand ha in 2014. Pakistan contributes only 0.2% (878 ha) of world's organic tropical and subtropical fruits. Permanent crops have significant organic land including coffee (0.7 m ha), olives (0.6 m ha), nuts and grapes (0.3 m ha) and cocoa (0.2 m ha) on the globe (Table 1.9). The countries with the largest organic vegetables production share are Denmark (25.3%), Austria (21.3%), Poland (19.8%) and Switzerland (14.8%). The number of countries with organic legislation is increasing and many still are in the process of drafting legislation including Pakistan. Worldwide, the market values of organic produce sales are about US$ 3 billion. Australia and New Zealand are large organic producer and exporter of organic kiwi fruit, apples, pears and vegetables. Asian countries like China, India, Thailand, Indonesia and Sri Lanka also have export oriented organic sectors (FiBL and IFOAM 2016).

Table 1.9 Horticultural crop categories in organic agriculture worldwide in 2014.

Crops	Area (ha)
Strawberries	4065
Flowers and ornaments plants	9578
Berries	45160
Tea/mate	69025
Citrus fruits	75215
Medicinal and aromatic plants	118254
Coconut	156373
Temperate fruits	188168
Tropical and subtropical fruits	233143
Cocoa	249194
Nuts	286109
Vegetables	290137
Grapes	315979
Olives	627478
Coffee	762916

Source: FiBL and IFOAM (2016)

The production and marketing of organically produced horticultural crops are two important aspects. After their sufficient production, the marketing plays an important role to attract more farmers towards organic production as organic food fetch more prices in the market, subject to certification and meeting the compliance requirements. Hence, organic production of fruits and vegetables can play substantial role in uplifting the living standards of farming community of developing countries.

1.5.5. Peri-Urban Horticulture

Peri-urban horticulture involves the growing of horticultural crops in the immediate surroundings of cities. Normally, short life cycle crops (annuals) are grown in the cities but biennials and perennials can be grown in the surroundings of the city, which are helpful to fulfill the local demands. Cultivation of horticultural crops in the peri-urban areas not only makes availability of fruits and vegetables at affordable price but also a fresh source of providing minerals and vitamins to the local community (Midmore and Jansen 2003). The agricultural land near the cities has been decreased due to its conversion into non-arable land by human activities. Per-urban system includes solid waste, nigh soil and reuse of water, which is an opportunity as well as a challenge.

The increasing urbanization due to migration from rural areas presents an opportunity for the migrants to settle in the peri-urban areas and search for livelihoods. Else, the rapid urbanization will lead to urban poverty and urban food insecurity. The role of peri-urban horticulture has become a key component of the survival strategies of poorer sections of the population while also contributing significantly to the urban fresh food supply chain (Midmore and Jansen 2003).

Peri-urban horticulture approach is gaining popularity in the developing countries to meet the food needs with limited sources and have positive effect on the environment and nutrient recycling. It is important to officially recognize the positive role of peri-urban horticulture in urban planning and development, nutrition and livelihood. The FAO has been assisting governments in framing measures to promote peri-urban horticulture as a part of national food security strategies and development of urban master plans (FAO 1999b).

1.5.6. Vegetable Grafting

Grafting is a technique in which true plant tissues are joined to develop vascular connection. One plant part makes root system and is known as rootstock, while the other is responsible for production of aerial parts of plant, including shoots, leaves, flowers and fruits, and is known as scion.

The rootstocks are tolerant to adverse environmental conditions and soil borne diseases, thus help to protect the scion. Grafting is helpful to manage various production issues like plant vigour, diseases, soil pests, and environmental effects. This technique is generally used for asexual propagation of fruit plants. Grafting was not a regular practice in vegetables as most of the vegetables are propagated through seeds/nurseries. But, now it is gaining popularity in some vegetables and their commercial adaptation is well established in different countries of the world including Japan, China, Korea, Middle East, Western Europe and USA (Lee 1994). The Asian countries, Japan, China and Korea are considered pioneer in this technique. Korea produces 95% of its watermelon through grafting technique on bottle gourd rootstock. Spain, Italy and France are leading users of grafted vegetables with estimated consumption of 129, 47 and 28 million plants annually. In Japan, grafting accounts for about 97% of watermelons, cucumbers, and eggplants, which are grown in greenhouses.

Grafting in vegetables has certain advantages over the conventional growing methods. The management of soil-borne pathogens is easy as rootstocks of some vegetables have tolerance/resistance to soil-borne pathogens like *Verticillium, Fusarium, Phytophthora*, and nematodes. Some rootstocks have also shown protection against viruses. As for example, muskmelon 'Olympic Gold' grafted onto 'Tetsukabuto' an interspecific squash hybrid, is chilling tolerant, resistant to root knot nematodes and *Pythium* (Justus and Kubota 2010; Al-Debei et al. 2012). A complete control of bacterial wilt was observed when tomatoes were grafted on 'CRA 66' and 'Hawaii 7996' rootstocks (Rivard and Louws 2008). In Korea, watermelons are grafted on bottle gourd to avoid *Fusarium* and chilling injury. The advantage of disease and pest tolerant/resistant stocks is very high under protected vegetable production (tunnels, hydroponics, organic farming). Besides the resistance capability of rootstock to biotic and abiotic factors, another important benefit is the increased vigour, early production and increased yield in certain vegetables. Japanese and Koreans have reported increased productivity (25-50%) in grafted eggplant, watermelon, tomato, melons and peppers compared to non-grafted plants.

Different grafting techniques have been introduced which are affected by different factors. Seedling quality is important to increase the success rate of grafting and primed seeds produce vigorous seedlings. Commercial nurseries produce grafted seedlings preferably by splice or tongue or cleft grafting. As grafting is done manually on small scale but for commercial production of grafted plant for large areas needs large number of skilled persons. A skilled person can graft 1000 watermelon plants per day in Korea. However, vegetables are grown 2-3 times in a year, so to fulfill the demand robotic system is an efficient alternate to manual method as is reported in Japan (Kobayashi 2005). The robot can graft 800 plants/h, about 4-5 times more than manual grafting, with a success rate of 95% and 99% for watermelon and cucumber, respectively.

1.5.7. Biotechnological Interventions

Biotechnology includes some techniques of biological processes to develop valuable products. Broadly, it is the use of microorganisms like bacteria, viruses, fungi, yeast, animal or plant cells to engineer products, plants or animals for specific uses.

The biotechnological tools are likely to have greater impacts in horticulture, where even minor changes such as colour, aroma, quality and postharvest behaviour would develop new cultivars and products of commercial importance. Some important areas in biotechnology of horticultural crops are genetic transformation, micropropagation, *in vitro* conservation of germplasm, synthetic seed technology, virus-cleaning, biofertilizers, biopesticides and postharvest biotechnology (Sengar et al. 1999).

The huge acreage under biotech crops especially soybeans, corn, cotton and canola indicates that the growers are getting benefits through biotechnology. However, the commercial use of biotechnology in horticultural crops (fruits, vegetables, flowers) is limited. Flavr Savr tomato was the first genetically modified crop to reach the market. Sweet corn, potato, squash and papaya varieties have been genetically engineered to resist insects and viruses. Transgenic papaya varieties have gained substantial market share. Application of biotechnology in horticulture has several technical, economic, regulatory and market hurdles, which are different than agronomic crops (Sengar et al. 1999). Hundreds of diverse plants are included in horticulture, the greater part of which has small acreage and low market demand. The patented genetic-engineering methods, regulations and registration of biotech horticultural products are substantially expensive.

Plant tissue culture is one of the widest applications of biotechnology. These are most widely used techniques for rapid asexual *in vitro* propagation, which provides disease free propagules, safer and quarantined movements of germplasm, embryo rescue in hybridization programs, haploid/double haploid production, genetic variability through somaclonal variation etc. Production of virus free plants, using meristem culture, is now possible in citrus, apple, banana and potato.

Genetically engineered applications are available for herbicide resistance (in tomato, potato, petunia), pathogen resistance (in *Brassica napus* against *Rhizoctonia solani*, papaya ringspot virus), improved fruit quality and shelf life (in tomatoes), pest resistance (in tomato, potato and brinjal), male sterility and fertility restoration (hybrid seed production in *Brassica napus*). Molecular makers like Restriction Fragment Length polymorphism (RFLP), Random Amplified Polymorphic DNA (RAPD), Amplified Fragment Length Polymorphism (AFLP), and Simple Sequence Repeats (SSR) are used for selecting agronomic traits and have made the breeder's job efficient. Molecular maps are now available for several horticultural crops including tomato, potato, and lettuce. In Pakistan, Bt cotton is the first biotech crop to reach the market (James 2010). There is room to bring insect and virus resistant biotech varieties of papaya, potato, squash and sweet corn.

1.5.8. High Health Nurseries

Healthy plants are the target of all nursery managers. The whole life of a plant depends upon the health of the tiny plantlet present at a nursery stage. There are two factors that affect the growth of the plants at the nursery stage, biotic and abiotic. Biotic factors consist of all biological agents *i.e.*, bacteria, viruses, fungi, insects, mites, nematodes, birds and mammals and their interaction with the growth of the plants. The abiotic factors include damage of plants due to ageing, chemical or physical injury, waterlogging and drought. By tradition the basic approaches to produce nursery are: i) the preventive measures *i.e.*, use of balanced fertilizers, resistant cultivars, cleanliness in the nursery, trained workers, and ii) the curative measures *i.e.*, use of pesticides and chemicals to cure the problem.

In recent years, containerized nursery plants have gained good market place because of the solution against soil-borne pathogens. Developed and healthy nurseries depend upon the production of plantlets in sanitated containers. Some advantages of containerized nursery are: (i) use of same site round the year by using sterilized potting mix, (ii) exclusion of soil-borne pathogens and noxious weeds, (iii) grown and operated in screen or greenhouses with partial management of microclimate, and (iv) grown rapidly after transplanting because of an undisturbed root system.

Management of high-quality container media is essential for the healthy and quality containerized nursery plants and hence heavy applications of organic matter are required. Potting media is a complex system of solid, liquid and gaseous materials, and their chemical and physical properties are affected by the composition and environmental factors. The qualitative characteristics of potting media are nutrient availability to plants, drainage and roots penetration (Khan et al. 2006). Further, optimum water holding capacity, electrical conductivity, pH, better aeration and organic matter of media helps in better seedling stand and growth of container grown nursery plants.

It is very important to keep the nursery area free of weeds and disease attack. Many plant species can be alternate hosts of important nursery pests. Cleanliness of nursery workers and budding tools is also very necessary. Propagation structures, tools, work surfaces and containers are kept possibly clean at all times. Different methods are applied effectively for the surface sterilization of the nursery plants and equipment. Hot water treatment at 40-55°C for about half an hour, depending upon the plant type and part of the plant to be used for the nursery propagation. Dipping the cuttings in 10% bleach solution, as well as dusting of fungicide powders on seeds and cuttings can also be used to disinfect them. Sometimes, fumigants play very effective role to disinfect the nursery environment. Meristem culture or micrografting techniques of plant tissue culture are effective to develop virus free plants (Naz et al. 2007). Therefore, different methods can be effectively used for the production of disease free high health nursery. With the development of science and technology, it is very important to produce healthy plants which themselves can resist all the diseases or external problems and survive successfully.

1.5.9. Automation/Robotics in Horticulture

Robots and automation processes are being used in horticulture, which minimize labour cost and reduce inconsistency in product quality during production and postharvest phases. Mechanical harvesting is mainly practiced in wine grapes, tomatoes, nuts, olives, citrus, sour cherries, almonds, prunes, and walnuts. Robots are also used in vegetable nurseries for grafting transplants, planting vegetable seeds and plantlets in greenhouses or fields (Kobayashi 2005).

Non-availability and high cost of labour pushed the developed world to exercise robots in horticulture. The picking, pruning, pest, disease and weed control tasks in horticulture are repetitive, laborious and expensive. The use of robots and automation can possibly reduce the cost of production. Remote sensing technologies are assisting in detection of pests and diseases, monitoring of plant health, assessing crop value, reducing the amount of sprays and nutrients, increase in the efficiency of labour (mechanical aids to humans), and reduction in crop damage at harvest (Pinter et al. 2003).

Fruit picking robots are used for oranges, apples, strawberries, kiwifruit etc. Microbots for pathogen control are developed which target viruses, fungi or bacteria.

Automatic cucurbit and tomato grafting machines are available which can graft about 800-1000 plants per hour with 95% success rate (Kobayashi 2005). Greenhouse robot sprayers ensure worker safety and precision application of pesticides. Octocopter (drones) carrying sensors and cameras for aerial surveillance are under use to monitor crop loads, stress conditions including water, nutrient, harvest maturity, pest and disease load (Chen et al. 2015). French scientists have developed ‘an instrumented glove’ as harvesting aid for measuring fruit quality (colour, sugars, and firmness). It is equipped with nondestructive miniature sensors and artificial intelligence and enables picker to make objective decisions. Similarly, modern packing houses have automatic washing, sorting, waxing machines and bin stackers. The shipment of horticultural crops is now safe using supply chain monitoring and traceability system which records temperature and relative humidity automatically at short intervals for precise monitoring (Amador et al. 2009).

In conclusion, there is a continued pressure for producers to reduce cost of production, harvesting and packing fruit and vegetables. Increasing labour cost drives mechanization, automation and robotics. Hence, a multidisciplinary research, involving plant scientists, engineers, food scientists, economists, and marketing expertise is needed to focus on designing new production systems for specific crops and machines.

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