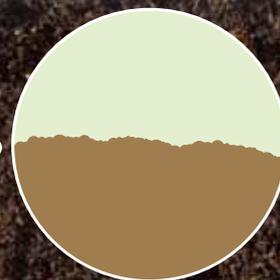




# Harvesting the Sun

A Profile of World  
Horticulture



## About this Publication

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From the 7,500 science-focussed members who between them present a huge amount of technical data and learning at ISHS symposia somewhere in the world almost every month, relatively few outcomes are shared with the public – who are the consumers of food and the beneficiaries of the knowledge and the wellbeing environment that are the rewards from horticulture.

Our objective for this publication was defined by this observation and by recognising that most people hold a narrow perspective of horticulture.

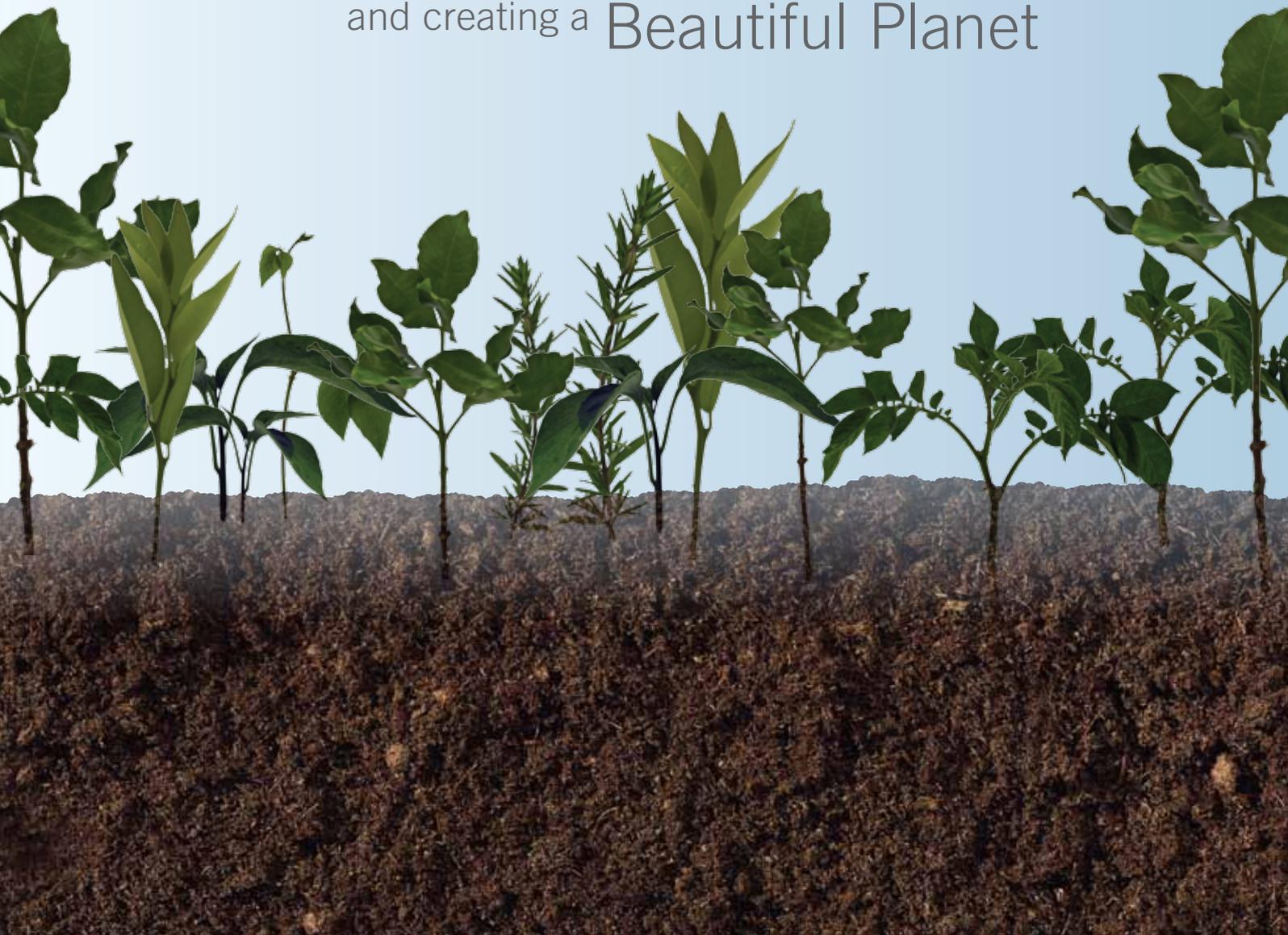
Many people could therefore benefit from information that could be used by the general public, policy makers, politicians and the general press to showcase the importance of horticulture and research in horticulture. We hope that the material that has been assembled goes some way towards answering the question '*What is Horticulture all about?*'

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# Harvesting the Sun

## A Profile of World Horticulture

Fruit, Vegetables, Flowers,  
and Ornamental Garden Plants  
supporting Life, providing Food,  
bringing Health and Wealth,  
and creating a Beautiful Planet



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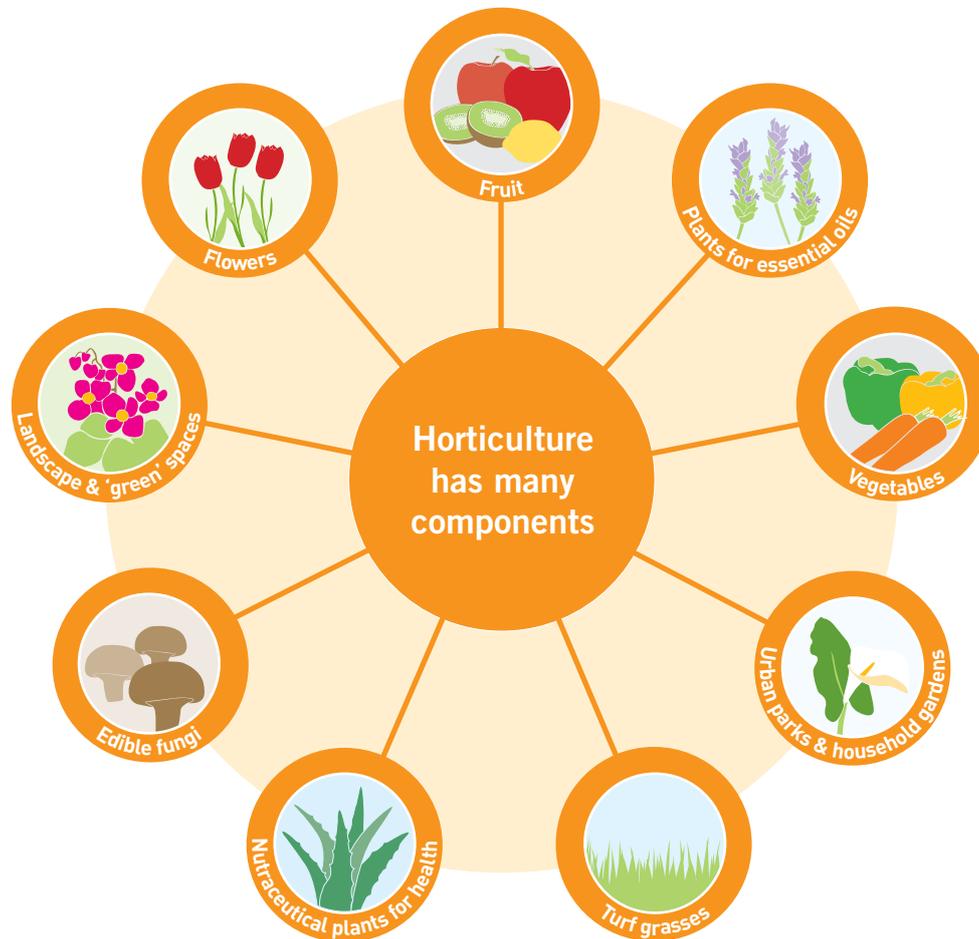
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## CHAPTER ONE

# The Big Picture



Horticulturalists provide food to feed the world, beautify our neighbourhoods, decorate our gardens and give ambience and wellbeing by combining the energy of the sun with soil, seeds, water, and ingenuity.

Their enterprises range in size from the subsistence micro gardens of villages to huge commercial enterprises with large holdings of greenhouse and field crops and extensive orchards. They supply world markets through sophisticated supply chains delivering fruit and vegetables to your supermarket with FAO calculating this to be in excess of 2.4 billion tonnes (2009).

Horticulture is also parks, public gardens and reserves, sports fields and golf courses, trees, vegetables and flowers in urban and peri-urban communities, home gardens for food and beauty. Such facilities have aesthetic, sociological and psychological benefits for human kind. For many

people, flowers, bulbs, foliage and ornamental live plants are their picture of horticulture – so it should not be a surprise that global export trade in these exceeds US\$17 billion annually.

In the same region less sophisticated production with tiny, well tended plots of produce can be found alongside more elaborate businesses involving global scale investments in land and capital assets. Horticulture is conducted in diverse locations covering both tropical and temperate zones. Every day in every location horticulturalists face challenges with seed production, weather conditions, soil and fertiliser management, disease and pest control, product quality, packaging and storage, product traceability and the vagaries of promotion and marketing. With a mix of courage, enterprise and skill, horticulturalists deliver fruit, vegetables, plants and flowers to a demanding world.

Horticulture has exotic vibrant sub-cultures. Innovative thinking has led to new developments in production methods such as soilless hydroponic growing. Creativity has led to urban lifestyle gardens that show flair and originality – and add significant value to our world. New ideas continually inspire industry to meet future challenges and customer demands.

Horticulture is a growing economic powerhouse with a large economic footprint globally. It provides livelihoods and employment, increased incomes, and enhanced wellbeing and satisfaction to populations of virtually all countries.

It provides vital food for humanity bringing both health and nutritional benefits. In developing countries, most horticultural products are sold fresh with limited packaging and storage. In these countries it is increasingly being recognised that higher returns per unit effort and unit area from horticultural activities create jobs, especially for

women and youth, bring incomes to pay for education and for building sustainable communities. Given that the world population will reach nine billion by year 2045, it follows that food production and distribution must become more effective, more efficient and more sustainable.

Horticultural producers and the scientists who advise them, work with many other skilled people in the supply chain to get high-quality, perishable produce to markets for us all to enjoy and appreciate.

The satisfaction of producing quality produce is shared by those who produce the products, and the packing, sorting, and transport groups who get them safely to market, and by those who sell them typically in attractive presentations.

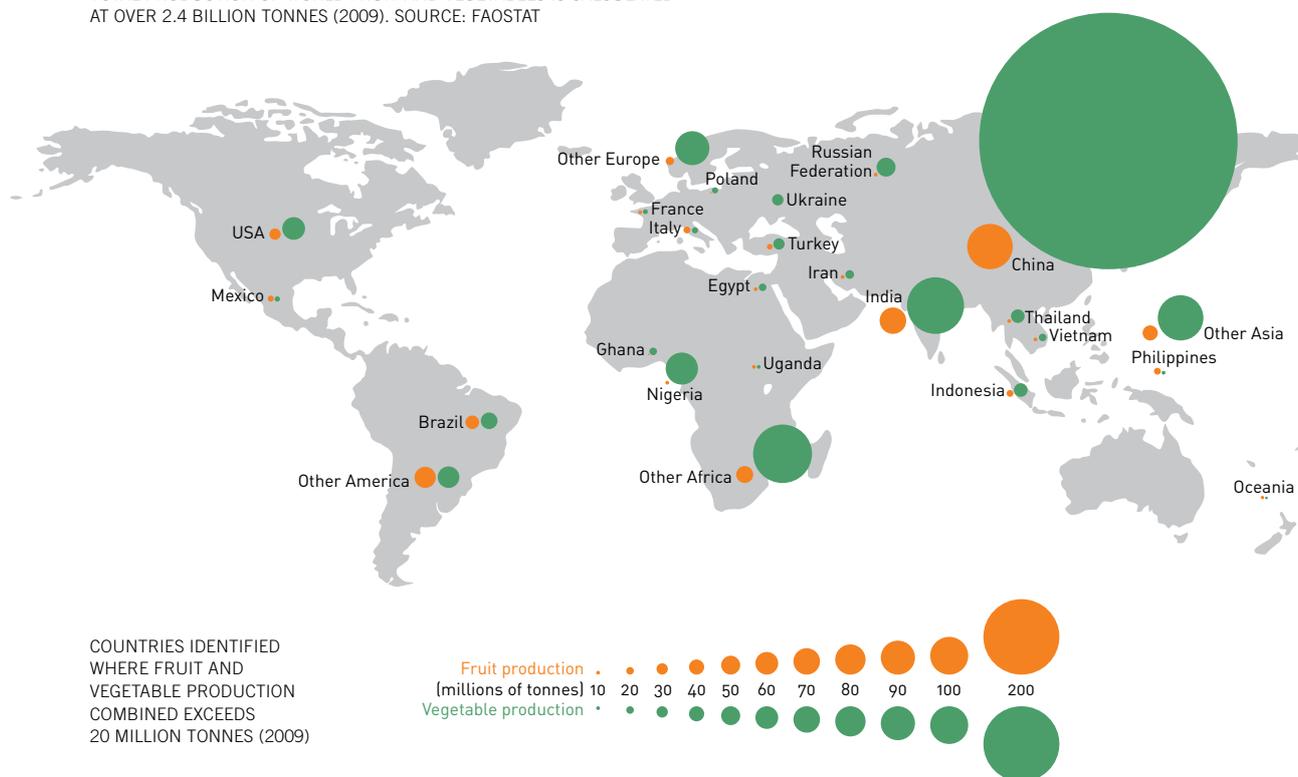
The benefits are to those who use and consume the wide diversity of horticultural products that are available year-round in many of the world's markets. Fruit, vegetables, flowers and 'green spaces' impact our lives in many ways.



Fruit, vegetables, flowers, gardens and landscape: the rich diversity of horticulture.

## World production of fruit and vegetables

TOTAL PRODUCTION OF WORLD FRUIT AND VEGETABLES IS CALCULATED AT OVER 2.4 BILLION TONNES (2009). SOURCE: FAOSTAT



Of the world's production of fruit and vegetables, 42% is grown in China and India – more than one billion tonnes out of the total of 2.4 billion tonnes. China alone grows 38% of the vegetables and 19% of the fruit produced globally (tonnes measure).

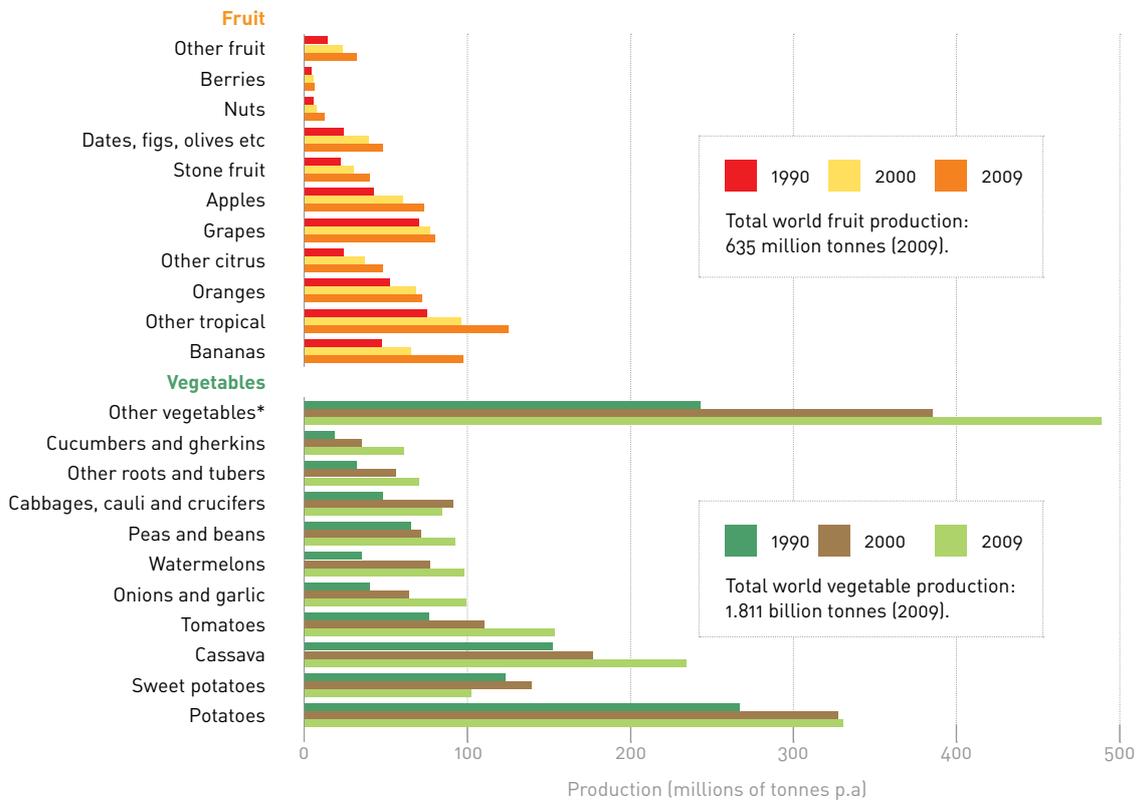
China produces 44% of the world's apple crop and 50% of the world's peaches and nectarines. India's largest volume fruit crop is bananas (27 million tonnes). This is 28% of global production.

| Production in millions of tonnes (2009) | Fruit | Vegetables | Total |
|---|-------|------------|-------|
| China                                   | 118   | 683        | 801   |
| India                                   | 71    | 152        | 223   |
| Nigeria                                 | 10    | 85         | 95    |
| USA                                     | 29    | 61         | 90    |
| Brazil                                  | 37    | 43         | 80    |
| Indonesia                               | 17    | 35         | 52    |
| Russian Federation                      | 3     | 48         | 51    |
| Turkey                                  | 15    | 32         | 47    |
| Thailand                                | 9     | 34         | 43    |

The above nine countries between them produce 51% of the world's fruit and 65% of the world's vegetable crops.

## World fruit and vegetable production (1990, 2000, 2009)

SOURCE: FAOSTAT



\* Other vegetables include carrots, chillies, eggplant, lettuce, pumpkins and others.

## The scale of world horticulture

World production of fruit and vegetables in 2009 was 2.446 billion tonnes (source: FAOSTAT).

### Fruit

World production of fruit in 2009 was 635 million tonnes, an increase of 256 million tonnes (68%) in the 29 years since 1990.

The most remarkable increases have been in tropical fruit ('Bananas' and 'Other tropical fruit' in the graph), which increased from 122 million tonnes in 1990 to 222 million tonnes in 2009, an increase of 82%.

### Vegetables

The shift from staple crops to leafy and other vegetables reflects a move towards more nutritious and balanced diets, bringing total world vegetable production in 2009 to an estimated 1.811 billion tonnes, a 65% rise since 1990.

In 1990, production of potatoes and sweet potatoes was estimated at 389 million tonnes and at 432

million tonnes in 2009, an increase of only 11%. In those 19 years there was a large increase in the diversity and an increase of 94% in volume of vegetables, excluding potatoes and sweet potatoes, from 710 million tonnes to 1.379 billion tonnes.



Vegetable market, Chile.

## Fruit and vegetable production is often on a very large scale

The majority of modern horticulture production is done in large scale enterprises focussed on high volume output requiring a large amount of capital investment, large areas of land under cultivation, sophisticated methods of production and a high degree of management expertise. These large scale vegetable farms, extensive fruit orchards and mega-scale greenhouses often cover many hectares.

Large scale production is the only practical and economic system to reliably produce consistent levels of quality and volume for the year-round production that markets demand.

Generally more than one species of plants are grown to establish crop rotations, generate alternative sources of income, and provide year-round employment for the full supply chain involving a continuous sequence of expert skills. Some activities are contracted to other parties, for example specialist cool store operators and fruit packers, graders and marketers.

These large scale production units are vertically integrated, often having their own plant nurseries, crop cultivation and management machinery, harvest, grading and storage facilities, and options for freighting and marketing their own produce.

Growers receive only a small portion of the retail value of a crop from which they must manage all of the resources required for quality production. To manage these costs sophisticated tools are used to manage fertiliser and water inputs and target and minimise the use of herbicides and pesticides. With fewer and fewer people in the global work-

force being prepared to engage in land-based manual labour, producers are increasingly using highly specialised machinery and robotics.

To meet the high standards expected with any food-related activity considerable attention is paid to human hygiene and removing contamination from chemicals, dust and dirt, and unwanted debris. High-speed harvesting machinery, with GPS guidance and on-board quality tracking, delivering to post-harvest washing and preparation machinery are now standard requirements for most large-scale producers supplying the big metropolitan markets. Gains continue to be made in production efficiency. In fruit production, the ease of tree management has reduced labour inputs and better tree structures have reduced the incidence of pests and diseases. Nursery plant quality has improved through the use of compost growing media and environmental controls for optimising plant growth, and the use of vigour-controlling rootstocks. Enhanced yields and improved fruit quality have followed from higher tree densities and new pruning strategies that have shortened time to production.

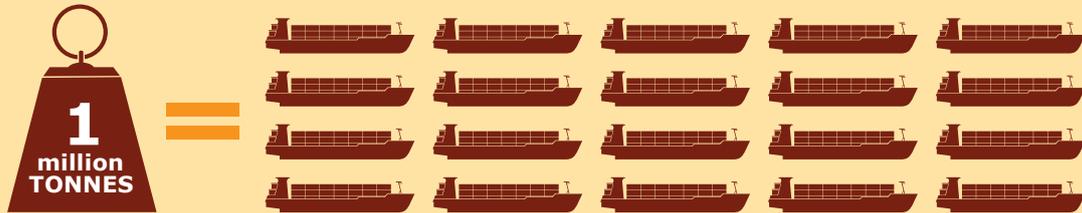
Vegetable growers aided by plant breeders have achieved advances in plant yields by selecting varieties with improved pest and disease resistance. Together with precision planting machinery, specific seed planting arrangements, precise positioning of fertiliser, and computer controlled irrigation management that is driven by environmental demand, the result has been increasingly optimised yields while efficiently using input resources.



Some horticultural units extend “as far as the eye can see”. Citrus (left) and berryfruit (right), California. PHOTOS: D. KARP

**How much is a million tonnes? It's the capacity of about 20 typical large container ships.**

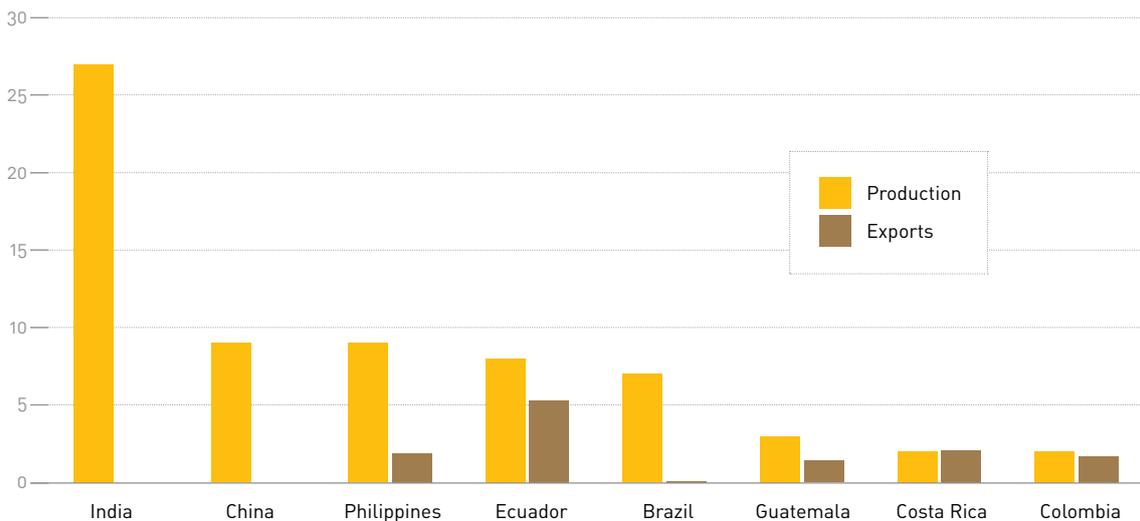
If you lined up, end-to-end, the container ships needed to carry the combined 2.4 billion tonnes of world production of fruit and vegetables, they would stretch from Brisbane, Australia continuously to Los Angeles, California (about 11,500 km).



**Bananas: Top 5 producing countries compared with Top 5 exporting countries**

SOURCE: FAOSTAT

Production (millions of tonnes p.a.)



The countries that produce the most fruit and vegetables are not necessarily the biggest exporters. Production and exports statistics can have quite different profiles.

The graph above compares the top five banana producing countries (61% of world production) with the top five banana exporting countries that between them produce only 13% of global banana production.

The differences are more reflective of the demands for self-sufficiency. In contrast, the opportunities to develop more diverse markets would require investment in infrastructure and the support for dealing with issues as diverse as sophisticated storage, packaging and freight considerations, through to meeting stringent market access requirements.

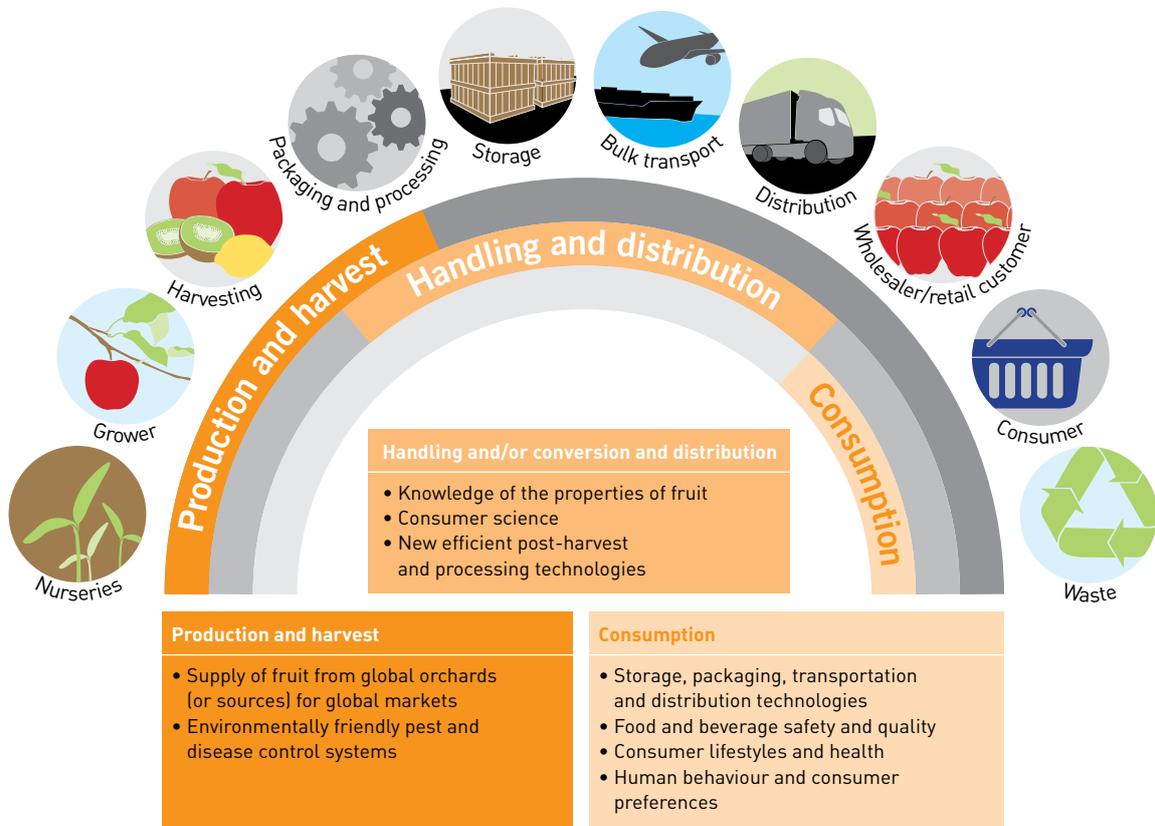
**Thought Challenge #1**

More than at any previous time in history, consumers in developed countries have a greater choice from a wider range of affordable fresh and processed fruit and vegetables.

*Q. Are consumers aware, or care, that horticulture is undergoing a shift in the production of fruit, vegetables and flowers from countries with high-energy inputs and high labour costs to those with lower energy inputs and lower labour costs?*

# Horticulture supply chain – the many steps

Using fruit as the example



Production, processing and sales are each critical stages in the supply chain. Upper left: peaches, Cape Region, South Africa. Above right: citrus sorting, Thailand. Lower left: fresh fruit and vegetable retail, Venice, Italy. Lower right: transporting apples, Guangzhou, Guangdong Province, China.

## CHAPTER TWO

# From Small Shoots

*Can you find another market like this?*

*Where, with your one rose you can buy hundreds of rose gardens?*

*Where, for one seed you get a whole wilderness?*

RUMI (B.1207) 'THE SEED MARKET', TRANSLATED BY COLEMAN BARKS

Horticultural plants start as seeds, cuttings, spores, or bulbs. In the nurseries they become fragile shoots and careful tending prepares them for the fields. Add sun, soil, fertiliser and water, together with professional expertise, and the fields of horticultural plenty ripen ready for the harvest. It is intense, sophisticated and hard work. Breeding and selection of the most desired plants makes sure that they are robust and most suited to the environment and to specific production methods. Cultivation techniques are adapted to suit local soil types, weather conditions, pest and disease risks, market standards and opportunities.

Having successfully reached harvest, there are then the challenges of sorting, packing and presentation to ensure that customers get the product in a condition that is fresh, safe, ripe and clean and to the quality specifications promised.

In addition, the product must meet the requirements of border security, trade regulations and retail requirements. Producers must use all the appropriate facilities of well managed transportation, storage and packaging to ensure that the product succeeds in meeting consumer expectations.

Horticulturalists and those who get their crops to you are highly skilled, professional and resilient people.

## Plant breeding

The modern science of molecular biology is exciting as genomics and knowledge of the genetic structure of DNA is allowing development of molecular markers that breeders can use for determining if desirable and selected attributes/traits are present in breeding populations.

Increasingly there are new types and varieties of vegetables, an array of many different fruit, and a wonderful range of new flowers.

Scientifically managed plant breeding programmes can improve all crops, even ancient and traditional ones such as hops.

Hops have been used in beer since ancient Egyptian times. Higher yielding USA varieties were introduced to the world in the 1920s but became severely infected with root rot during the 1940s.

A science-based hop-breeding programme began in 1950 and decades later is now widely recognised for its innovation. Varieties resistant to root rot



Modern breeding programmes select apples with natural multiple resistance to a number of pests and diseases and with enhanced fruit quality.  
PHOTO: NZ INSTITUTE FOR PLANT & FOOD RESEARCH LTD

were released to industry in the 1960s. The world's first triploid (seedless) hops with up to 50% more alpha acid (the bittering pre-cursor in beer) were released during the 1970s.

At present, research and development in hops is focused on flavour and aroma characteristics, and this has been reflected in a dazzling variety of boutique, local and international brand beers.

Provision of high-quality plants from tissue culture and other nursery techniques is essential for premium production – orchids in Thailand.



## Nursery production and tissue culture

Horticultural producers employ a number of different methods to propagate the plant material used for specific fruit and vegetable crops and for ornamentals. Many crops are established from seeds – often as hybrids. Some are established from rooted vegetative cuttings. Others rely upon the desirable variety being grafted onto a selected rootstock – as occurs with many fruit trees – where the rootstock itself can control the vigour of the tree or provide resistance to soil-borne diseases.

Plant tissue culture is a specific technique that is used for vegetative propagation. It relies on starting with a very small part of plant tissue that is then grown up and multiplied under sterile conditions. All of the minerals and nutrients required for growth are provided and the hormonal balance in the growing medium can be adjusted to promote shoot and root growth independently. The plant shoots grow by being supported on an agar-based

gel that also contains the mixture of compounds that are required to nurture growth.

The sterile conditions for plant tissue culture production ensure freedom from competing pests and diseases. This method is used to generate very large numbers of plantlets in a short time, especially where plants are difficult to grow from seeds or cuttings. It can also be used in laboratories to help in eliminating viruses from plants, to ‘rescue’ desirable plants from breeding programmes which would not survive under natural conditions, and even to store elite plants for long periods of time.

There are many different forms of tissue culture which range from using mini-cuttings, to growing tips, to even cell suspensions.

Many different crops can be grown using tissue culture including a wide range of orchid species and varieties.

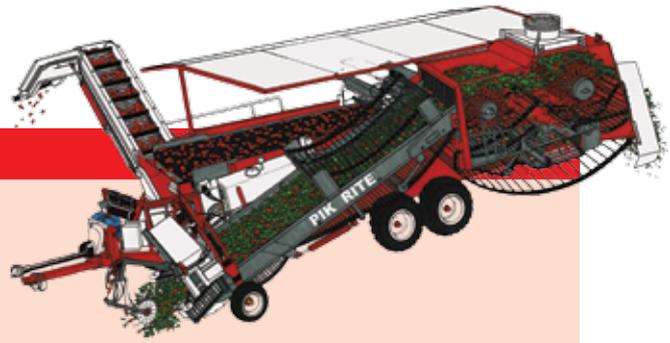
## A bottle of ketchup

Fifty years ago, tomato varieties destined for processing were the same as those sold in the markets. To ensure a full yield from the plants they were picked at least three times by hand over a number of days. Crop losses were high. Labour shortages made it difficult sometimes to secure crops for processing. One efficient worker could harvest approximately 1.5 tonnes in an 8-hour day.

In the 1950s and 1960s a revolution occurred based on science-led activities at the University of California in Davis. Scientists used diversity within the tomato family to breed a new type of tomato – one that ripened evenly, stayed on the vine for a good period of time, contained a high soluble solids concentration (making them well suited for processing), and with a thick skin and a special shape that was well-adapted to mechanical harvesting.

In close symmetry with these advances in conventional plant breeding, horticultural engineers developed the first mechanical tomato harvesting machine.

Subsequent continuous improvements in both breeding and horticultural engineering have



seen these developments change the nature of process tomato cultivation world-wide.

Modern harvesters harvest the crop once, not three times, and some have on-board sorting sensors that automatically discard green and poorly-coloured fruit and wastage is minimised. An output in excess of 1.25 tonnes per minute (75 tonnes per hour) is typical.

This means that the harvesting rate with such machines is about 400-times higher than that per worker without harvesting machinery. Harvest costs are now about 12% of the grower's total costs. In California alone, more than 10 million tonnes of tomatoes from over 100,000 hectares are harvested each year for processing.

These very significant developments have meant that production has kept up with global demand and that this processed product remains affordable to many.

**A 40 tonnes per hour tomato harvester as in the cut-away illustration above. Some models can harvest up to 80 tonnes per hour. PHOTOS: WWW.PIKRITE.COM**



## Thought Challenge #2

In 2011 the world's population reached 7 billion. By year 2045, world population is projected to reach 9 billion. At the present rate of production and supply chain efficiencies, this will require an increase in production from the present annual 2.4 billion tonnes of fruit and vegetables to over 3.1 billion tonnes.

*Q. Where will that increased production of food come from?*

## Sack farms

In the poor villages around Nairobi there is simply no land for gardens. The ingenious response has been to grow plants in tall, recycled sacks filled with soil. Women make 'vertical farms' by poking holes in the sacks and putting seeds and seedlings at different levels. The usual crops are spinach, kale, sweet pepper and spring onions. The owners of these unassuming sack gardens enjoy fresh food and better nutrition. Any surplus produced is sold to friends and neighbours who can also enjoy the benefit of fresh produce.

At the edges of the villages micro-gardens produce seed for traditional African vegetables.

Small plots (about 50 sq m) with double beds raise seeds faster. Fast-growing African varieties like amaranth and spider plant are raised from seed to seed in as little as three months. Using the top and slots in the sides, up to 60 seedlings can be grown in one sack.

It is a struggle fraught with peril. They have no tenure to the land. It can be taken from them at any time. Drought and the loss of access to wastewater (used also as fertiliser) can bring disaster.



Sack farming, Nakuru, Kenya.

## Other initiatives by low-income households

Other examples of urban horticulture abound. FAO assistance has helped a municipality in Bolivia train some 1,500 low-income households in organic cultivation of fruit, vegetables and herbs in small greenhouses. In Burundi it has improved access to credit, inputs and training for 7,500 to 10,000 residents who practice urban horticulture. In Columbia 50,000 residents of Bogota, Medellin and Cartagena have now got garden plots and micro-gardens on terraces and rooftops.

## Smart technologies for the control of pests

Crawling, flying and windblown pests and diseases can cost millions of dollars in lost production. Pests and diseases can spoil produce and waste wealth, and infestations can lead to loss of production, hence hunger and starvation.

Smart integrated technologies using both basic and applied scientific research aids in the control of pests and diseases and improves the environment. Scientific management of pests and diseases before and after harvest can lower the use of chemicals yet still maintain high levels of production and give higher levels of consumer acceptance and lower production costs.

In the 1970s, growers and scientists observed that pests could develop resistance to a number of different pesticides.

In response, the knowledge workers got to work. The lifecycles of pests were studied and factors identified that determine pest numbers on target crops. Alternatives were sought to the current pesticides that were less persistent in the environment and more specific for particular pests.

This information became key to the 'Integrated Pest Management' (IPM) methods now used to control pests on vegetables such as brassicas (cabbages, cauliflowers and broccoli), process tomatoes, sweetcorn, potatoes, squash, lettuce and onions.



Monitoring crops at different development stages can ensure targeted and efficient use of pesticides and the protection of beneficial predators. PHOTOS: NZ INSTITUTE FOR PLANT & FOOD RESEARCH LTD

IPM programmes are dependent on crop monitoring of pest numbers on each vegetable crop by growers and trained crop scout specialists. From that information, growers can reduce pesticide use, avoid the use of broad-spectrum control chemicals, lower costs and adopt practices that will not harm natural predators.

The development and rapid adoption of IPM systems and practices was only possible because of the interpretation and application of science-based knowledge that horticultural scientists had accumulated over the previous 40 or more years.

The holistic 'all of everything' approach also led scientists to develop Integrated Fruit Production (IFP) systems. These were initially developed and adopted, for example, in the apple industry as a step toward ensuring the continued entry of apples onto global markets. IFP is now applied to a wide variety of fruit crops, for example, stone fruit in California and kiwifruit in virtually every country where kiwifruit are grown in large commercial quantities.

The core aim of IFP was to reduce the use of agrichemicals to control pests and diseases. It takes account of orchard location, rootstocks, varieties, soils and nutrition, water management, weed management, tree management, pests, and diseases.

IFP results in lower use of both insecticide and fungicide sprays and has eliminated the use of the most persistent and toxic pest control chemicals.

In one study, (the 'KiwiGreen' programme for kiwifruit in New Zealand), the internal rate of return (IRR) on R&D costs for development and implementation of the programme was calculated at between 31% and 79% depending upon the assumptions of how much world prices would have been depressed had that programme not succeeded. In 2004, the net present value (NPV) calculation for the programme was over US\$250 million.

In 2000, the successful 'KiwiGreen' programme was expanded to include integration of environmental factors, ethical trading practices and hygiene, to become an environmental management system that maps, measures and monitors the entire progress of fruit from orchard to retail outlet and can trace product all the way back to a particular grower and orchard site.

Integrated Pest Management (IPM) and Integrated Fruit Production (IFP) systems now provide knowledge-based practices that use sustainable technologies that are safe in both environmental and human health terms.

### Thought Challenge #3

Advanced horticultural systems with Integrated Pest Management (IPM) techniques and other improvements are now often close to organic system practices. Pesticide applications have been minimised over the past 30 years but some are still necessary in both advanced production systems, and contrary to commonly held perceptions, also in organics.

*Q. Are consumers generally aware of the huge improvements that have been made in production systems for fruit and vegetables?*

## Decision support systems

The fast moving dynamism of horticulture requires decisions to be made successfully at the optimum point in time. Scientifically designed decision support systems allow better management decisions that enhance production efficiencies, shift harvest times and even extend the productive life of a crop. This systematised knowledge is transferable across the world.

### Decision support systems – the example of asparagus

The yields and market returns from growing asparagus can be very cyclical. Scientists found that non-irrigated asparagus crops consistently out-yielded the irrigated crop. 'Curious', they said. Tackling the matter with research, they observed that extra water and fertiliser increased the above-ground fern growth but this could reduce the accumulation of energy reserves.

As a result of the research and the design of a decision support system, growers can now measure and monitor these energy reserves throughout the year. The data from the field is sent via the internet to a research unit that formulates real-time interpretations and sends the resultant information back to growers. Armed with real-time information, growers can then make decisions on harvest timing, the length of harvest season, irrigation management and disease control practices.

By knowing what is happening in the soil, below ground, growers can more than double the outputs of an asparagus crop. Having online access to the technology and to the scientific knowledge that backs it up, means growers can extend the life of an asparagus plant from three to up to seven years.

Decision support systems are also being developed for other crops so that productivity and quality are optimised.

### Scarce water resources

World fresh water (and indeed fertiliser) resources are limited. Consequently, it is vital to develop systems that optimise the use of water and the other critical inputs that are used in food production.

Knowledge technologies and skills that preserve, find and use water effectively for food production are essential. Hydroponics is one approach that horticultural producers have used to control the volume of water that is used in a production system together with closely regulating the amount of fertiliser applied and, in some approaches, removing the need for soil (and hence the need for cultivation, weed control and even sterilisation).

The increasing scarcity of water has led to improved irrigation scheduling and to new research that seeks ways of achieving more efficient resource use. Open irrigation systems are frequently being replaced by more efficient trickle systems. PHOTOS: (LEFT) UNIVERSITY OF CALIFORNIA, DAVIS, (RIGHT) D. KARP





Modern glasshouses are highly complex but very efficient in producing many different crop types; The Netherlands.  
PHOTO: WAGENINGEN UR GREENHOUSE HORTICULTURE, THE NETHERLANDS

## The greenhouse industry

Growing plants in environmentally controlled areas is not new. In the time of the Roman Emperor Tiberius (42BC - AD37), a greenhouse had thinly sliced selenite (*Lapis specularis*), a type of gypsum that forms crystal sheets that are nearly as clear as glass, that captured the warmth from the sun for the Emperor to have a cucumber-like vegetable year round. In the 13th century, The Vatican in Rome had a glasshouse for new species of plants brought back to Italy by traders. By 1825 greenhouses, first known as ‘orangeries’ for the propagation of orange trees, were heated by furnaces or built into earthen pits with windows facing the sun – a practical design still used.

In all greenhouses, crop yields and product quality typically exceed that of outdoor-grown crops. Furthermore, close control of the environment can markedly reduce the need for pesticides and enhance the efficient use of water and fertilisers. Design features optimise energy usage and the capture of rainwater can reduce demands on water supply.

Effective use of more complex structures requires the integration of plant science, plant pathology, entomology, plant nutrition, electronics, structural and ventilation engineering, lighting technologies, and computer control system programming and management.

The Netherlands alone has around 9,000 greenhouse enterprises that operate over 10,000 hectares of greenhouses and employ some 150,000 workers, efficiently producing US\$4.5 billion worth of fruit, vegetables, plants, and flowers, some 80% of which is exported.

One of the largest greenhouse complexes in the world is in Almeria, Spain, where greenhouses cover almost 50,000 acres (200 km<sup>2</sup>) and is sometimes referred to as the ‘sea of plastics’.

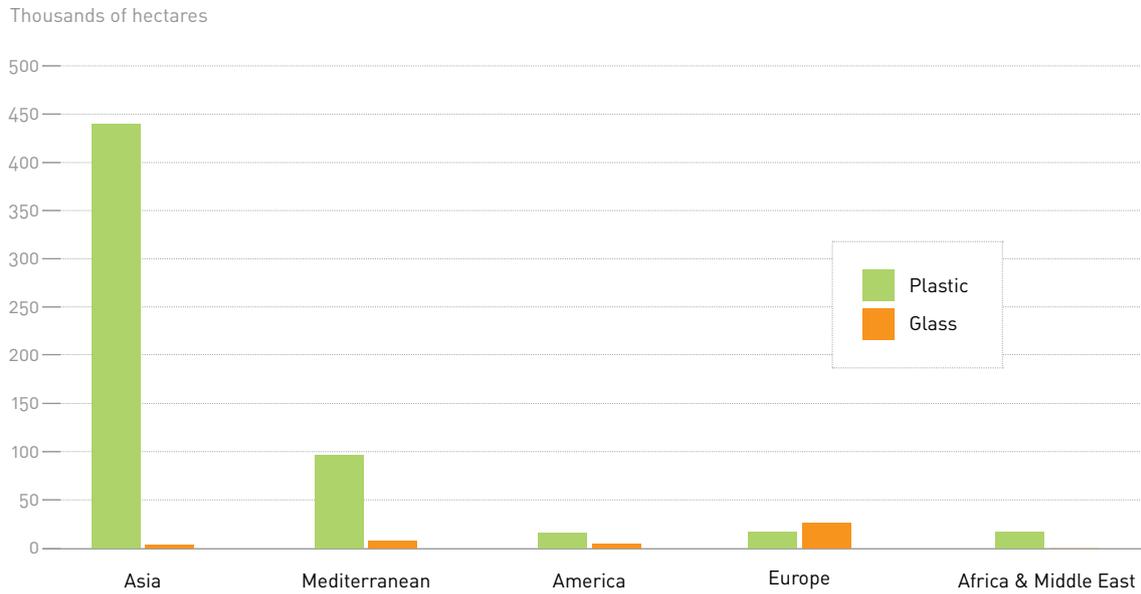
Nonetheless, the greatest expanse of protected cropping occurs in Asia, especially in China, South Korea, Chinese Taipei and Japan.

Extensive use is made of plastic greenhouses to modify winter conditions, achieve early and longer production seasons and to provide protection from adverse environmental conditions such as rain. Crops that are produced are most typically vegetables such as tomatoes and capsicums; flower crops such as roses, carnations and cymbidium orchids; and fruit crops as diverse as bananas and table grapes.

### Protected crop areas in greenhouses and tunnels

(estimated areas under plastic and glass, thousands of hectares, year 2000)

SOURCE: 'GREENHOUSE HORTICULTURE.' *ENCYCLOPEDIA OF FOOD & CULTURE*. ED. SOLOMON H KATZ. VOL 2. GALE CENGAGE, 2003. ENOTES.COM. 2006. 18 SEP, 2011. [HTTP://ENOTES.COM/FOOD-ENCYCLOPEDIA/GREENHOUSE-HORTICULTURE](http://enotes.com/food-encyclopedia/greenhouse-horticulture)



Plasticulture is used in many forms to produce fruit, vegetable and flower crops over extensive areas – (upper photos) strawberries in Mexico; (lower left) flowers in Thailand; (lower right) extensive greenhouses, Granada Coast, Spain.

## Flowers, foliage, bulbs and live plants are big business

For centuries, flowers have been a strong influence on our living environment. First century Romans had a highly developed flower trade. They manipulated flowers to bloom out of season and used hot water generated in a central location to heat baths and greenhouses.

Modern production is currently concentrated in a few countries: 77% of the world's cut flowers are grown by The Netherlands, Columbia, Ecuador and Kenya (2009). The major consumers of these crops are in Germany, United Kingdom, United States, The Netherlands and France.

The general trends are for newly developing countries to gain market share at the expense of the established producers. Newly emerging players in the international flower trade are India, China, South Korea, Malaysia, Malawi, Mexico, Palestine, Peru, South Africa and Zambia. Ethiopia is developing rapidly with flower exports increasing five-fold between 2006 and 2008. China intends to be a significant player and there has been a very large investment of local government funds into the flower industry.

These countries have good climatic conditions but

face long transport distances to markets. Israel has a long-standing investment in flower production and as with The Netherlands has faced competition from the newly-emerging countries.

Despite many new entrant exporting countries, in 2009, 48% of exports of cut flowers, bulbs, foliage and live plants were from The Netherlands. In 2009, The Netherlands imported US\$1.8 billion in these categories and exported US\$8.3 billion. The total world exports for these categories exceeded US\$17 billion, with the mix being:

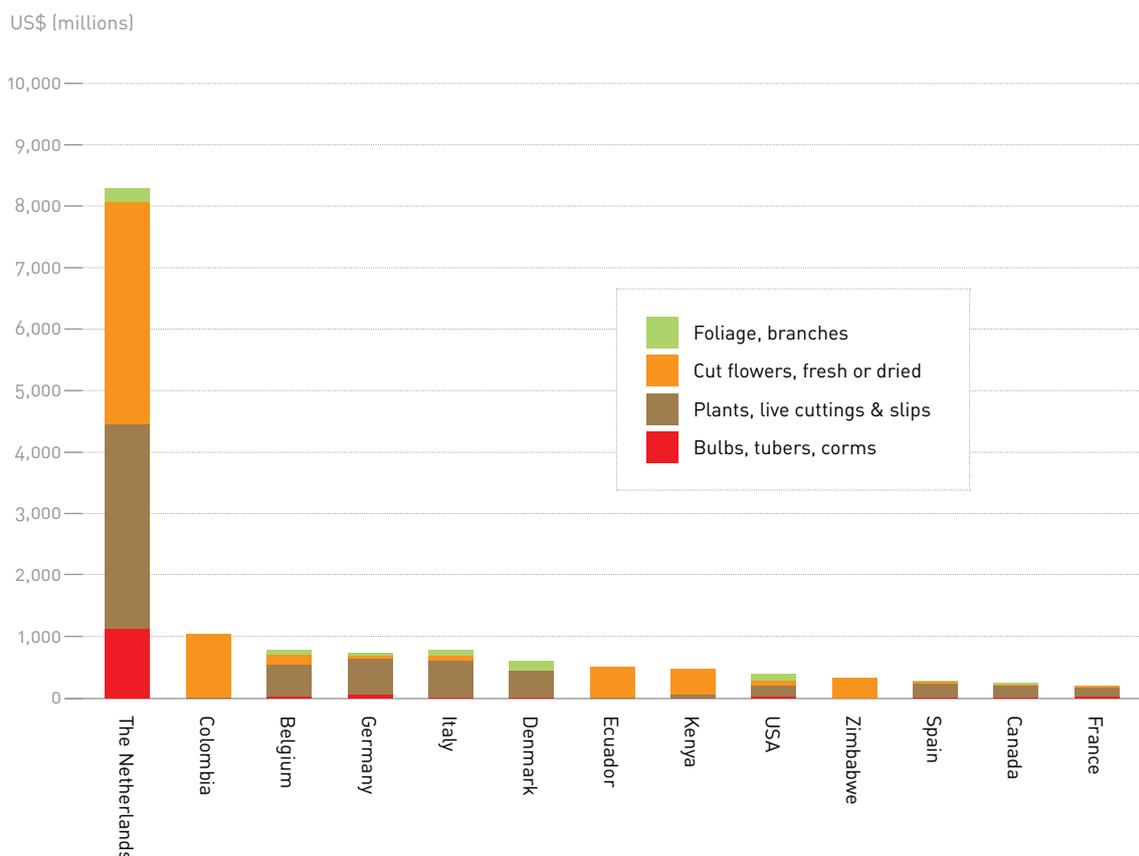
- Cut flowers (fresh or dried) US\$7.3 billion
- Live plants and cuttings US\$7.3 billion
- Bulbs, tubers and corms US\$1.5 billion
- Foliage US\$1.2 billion

Flowers are hard to transport over long distances. Countries distant from markets face expensive airfreight costs to get the flowers to consumers. For example, the cost of airfreight, marketing, handling in Europe and packaging make up 50% of all costs for Kenya and 62% for Uganda.

The reliability of air connections is an additional risk factor for exporters located far from their main markets.

### Exports of cut flowers, foliage, bulbs and live plants: 2009

Total world exports of these categories: US\$17.2 billion SOURCE: ITC CALCULATIONS BASED ON COMTRADE STATISTICS  
(Countries cited where combined export value in 2009 exceeded US\$200 million)





Orchids being prepared for market, Thailand.

Flowers are very sensitive to the treatment they receive once they are cut. They need strict temperature and humidity control, and good air quality to deliver an attractive product to market. The time to market is short. Organisation is the key to the success of the flower industry.

To grow flowers successfully you need the right seeds and planting material, excellent physical factors such as abundant water, clean soil (excepting hydroponics), good climate and high light intensity. The industry is capital intensive with high costs for greenhouses and infrastructure and a need for high levels of working capital. Flowers need productive labour, a lot of expertise in growing techniques, very good management and a first class infrastructure including controlled temperature freight systems and cool stores.

There is also the need for pesticides and some special chemicals to maintain condition and to

meet cross-border requirements, plus costly energy for heating and a high level of quality consciousness all along the production and postharvest chain.

All this calls for good management and organization. The response of growers in established producing countries to challenges from the developing countries has been more extensive use of technology and science. Hand grading has been replaced with mechanical grading; digital computers control light, temperature and water use; natural gas has replaced coal and oil; new varieties that grow in winter conditions are being grown.

An example is rose growing in The Netherlands that has become a highly sophisticated, increasingly computerized, capital-intensive activity that requires sizeable investments, placing it increasingly beyond the capability of smaller growers.

Live plants and fresh cut flowers – Chelsea Flower Show displays.



### The influence of supermarkets on selling channels for flowers

Flowers are still being sold through the traditional outlets: supermarkets, market and street vendors, florists and garden centres – but in some countries supermarkets already dominate the trade. Examples are in Switzerland where the two major supermarket chains together account for 60 to 70% of all sales, and in the United Kingdom where the market share of supermarkets is approaching 40%.

What is certain is that from Israel to the United Kingdom and from The Netherlands to the United States, supermarkets are targeting the flower trade as an area for expansion.

Supermarkets prefer to buy large quantities of cut flowers through long-term contracts and directly from known producers. Buying directly is the shortest route from grower to retailer to consumer, and buying directly allows supermarkets to have certainty about the conditions under which the flowers that they sell are being produced.

African producers are capable of producing large volumes and are willing to sell directly at an agreed price, making them attractive to supermarkets.

African producers appear to be the main beneficiaries of this change in purchasing habits. Supermarkets are interested in African flowers because they are inexpensive and because growers are willing to accept a set price.

To the growers, the arrangement is attractive because supermarkets buy large quantities at pre-arranged prices. But in order to live up to their side of the bargain, African growers must invest in optimal production methods. Often this includes investments in greenhouses, forced ventilation and heating and, in all cases, greater attention to quality.

### Hydroponics

In its simplest definition, hydroponics is gardening without soil. Its earliest recorded use goes back to the Pharaohs of Egypt and the Hanging Gardens of Babylon that are believed to have used hydroponics.

#### Some points about hydroponics:

- hydroponic systems have some clear environmental benefits with the most significant being that they use 70 to 90% less water compared with many forms of conventional production
- there should be no nutrient run off – and hence reduced concerns about contamination of groundwater, rivers and streams
- systems can range from drip or trickle emitters with soil-grown plants through to aerated nutrient solutions for trough or tank-grown plants

- systems can succeed in places where the soil is poor or depleted or where water is very limited (such as in desert locations)
- hydroponics can be used both outdoors in field production and indoors in modern greenhouses.

By controlling the plant's growing environment, inclusive of the use of hydroponics, some impressive yield gains have been measured. In one study identical cucumber plants produced 3 tonnes per hectare in the field in soil but close to 13 tonnes per hectare when grown hydroponically. Tomato yields that ranged from 5 to 10 tonnes per hectare in soil produced 60 to 300 tonnes per hydroponic hectare.

Covered crops, Granada Coast, Spain.



**Hydroponics**

There are many variations of hydroponic systems, but all are variations or combinations of the six basic types in the table below:

| Hydroponic system type  | Drawback  |
|---|---|
| Wick system. A passive system, which means there are no moving parts. It is the simplest type of hydroponic system where the nutrient solution is drawn into the growing medium with a wick from the reservoir.   | Plants that are large or use large amounts of water may use up the nutrient solution faster than the wick(s) can supply.  |
| Water culture system. The simplest of all active hydroponic systems where a platform, typically made of closed-cell extruded polystyrene foam, holds the plants and floats directly on an aerated nutrient solution. This is often the system of choice for fast growing leaf lettuce.  | It doesn't work well with large plants or with long-term plants. Very few plants other than lettuce do well in this type of system.                                       |
| Ebb and Flow system. Works by temporarily flooding the growing tray with nutrient solution and then draining the solution back into the reservoir, in a cycle that repeats several times a day.   | As the roots can dry out quickly when the watering cycles are interrupted, the system is vulnerable to power outages as well as pump and timer failures.                  |
| Drip systems. The most widely used type of hydroponic system where a timer controls a nutrient solution to drip onto the base of each plant from a small drip line. Some include a recovery system where the excess nutrient solution that runs off is collected back to a reservoir for re-use.                                | A recovery system can have large shifts in pH and nutrient strength levels that require periodic checking and adjusting. A non-recovery system requires less maintenance. |
| Nutrient Film Technique (NFT) systems. A constant flow of nutrient solution is pumped into the growing tray (usually a tube) and flows over the roots of the plants, and then drains back into a reservoir. Typically the plant is supported in a small mesh or rigid basket with the roots hanging into the nutrient solution. | NFT systems are susceptible to power outages and pump failures and the roots dry out rapidly when the flow of nutrient solution is interrupted.                           |
| Aeroponic system. The most high-tech type of hydroponic production where the roots hang in the air and are misted with nutrient solution every few minutes.   | The roots will dry out rapidly if the misting cycles are interrupted.   |

**Hydroponic growing of tomatoes in The Netherlands. Note the detailed attention given to crop hygiene and the pest-free nature of the closed, computer controlled growing environment.**  
 PHOTO: WAGENINGEN UR GREENHOUSE HORTICULTURE, THE NETHERLANDS.



## Pollinators

Bees are the smallest workers on the land. They are the pollinators of many horticultural crops. One of 20,000 known bee species, the Western honey bee (*Apis mellifera* L.) is the most common pollinator and the iconic provider of honey. Between 15% and 30% of food consumed by humans in developed countries requires an animal pollinator. As a general rule, the fact it does not need expensive hand pollination makes food more affordable.

Pip fruit (eg. apples) and stone fruit (eg. apricots) rely heavily on insect pollination as do many berry and vegetable crops such as watermelon, cucumber, pumpkin and raspberries, and also many spices.

It is in the world's best interest to ensure the conservation of pollinators, but there has been a recent decline in pollinators in a number



Apple blossom

of countries. This decline includes the threat called Colony Collapse Disorder (CCD) that has been linked to many factors including parasites, climate change, habitat loss, availability of food, pollution, pesticides, alien invasive species, diseases and possibly other influences.

## Production standards worldwide

GlobalGAP is a European-based private sector body that sets voluntary standards for the establishment of a single standard for Good Agricultural Practice (GAP) during production and postharvest of fruit and vegetables.

The scheme started as EUREPGAP in 1997 largely as a reaction to consumers having increasing concerns about product safety, environmental issues and labour standards.

At the time, producers supplying to multiple retailers had to undergo multiple audits every year against different criteria to meet the market standards.

Early steps highlighted the importance of Integrated Crop Management (inclusive of IPM and IFP) and a responsible approach to worker welfare. Over the next ten years and with the emerging pattern of globalised trading, EUREPGAP gained in global significance. To prevent confusion, in 2007 EUREPGAP was re-branded to become GlobalGAP.

The scheme now has over 93,000 certified producers in more than 100 countries, including all of North America, all of continental Europe and Scandinavia, most of South America, a number of African countries, major producing countries within Asia and South-East Asia (including Japan,

China, India, Indonesia and others) and Oceania. As an interim step some countries develop localized GAP programmes.

The scheme is controlled by more than 1,400 inspectors/auditors of the 130 GlobalGAP approved Certification Bodies.

GlobalGAP provides a pre-farm-gate standard for certification of farm inputs and covers all activities until the product leaves the farm. It is a business-to-business label and is therefore not directly visible to consumers. It incorporates different product applications capable of fitting to the whole of global agriculture.

GlobalGAP benefits include the promotion of sustainable production, on-farm management improvement, value addition of products, a global accreditation system that has integrity, market access qualification for small holders, and harmonized buyer requirements.

Beyond the farm, the scheme provides other benefits such as increased export yields and prices. A 2005 case study by USAid in Kenya attributed GlobalGAP as enabling farmers to achieve their highest ever income recorded for smallholders and up to 40% savings on pesticide costs.

## CHAPTER THREE

# The Journey to You

Horticultural products are living things. Immediately after harvest, senescence is underway in plant tissue that starts to break down and begins to deteriorate. The journey of horticultural products from where they are grown to where they are used is a struggle against this natural process.

This deterioration occurs faster at warm than at cool temperatures. The most effective way to prolong shelf life is to remove the product from direct sunlight after harvest and then reduce to optimal storage temperature as soon as possible after harvest.

Most crops grown in temperate parts of the world can be kept at 0-1°C while those grown in tropical or subtropical zones can be stored at 10-12°C. Product quality is best maintained in refrigerated cool stores where temperatures are monitored and controlled accurately by computers.

Harvested horticultural crops are very perishable and can be damaged if handled in a rough manner during harvesting, sorting or transporting. Products damaged physically by pests or diseases deteriorate faster than non-damaged products and thus have a much shorter shelf life. Gentle handling and good packaging will reduce such damage.

A wide range of packaging is used in preparing and sending crops to market. Packaging serves three major functions: to preserve, protect and promote.

Preserve by extending shelf life. Protect by preventing physical and disease damage during handling and transport. Promote by having labels, brands, logos, country of origin, details of variety, weight, size and grower number printed and displayed on the package. In the current environment where sustainability is important, most packaging for export is recyclable, hence use of technologically advanced cardboard products and the increasing use of biodegradable films.

Postharvest life of some fruit and vegetables can be further extended by changing the atmosphere around the product, either in a sealed gas-tight cool store or in a polymeric film package that is differentially permeable to gases. The normal atmosphere of 79% nitrogen [N], 20% oxygen [O<sub>2</sub>] and 0.04% carbon dioxide [CO<sub>2</sub>] plus some other inert gases is changed to 1-5% [O<sub>2</sub>], 1-10% [CO<sub>2</sub>] with the remainder N. This reduced O<sub>2</sub> environment (controlled [CA] or modified atmosphere [MA] storage) slows metabolism, reduces ethylene production and action, delays deterioration and hence extends shelf life, especially for apples, pears, avocado, kiwifruit, mangoes, plums, cabbages, sweet onions and broccoli. Ethylene is a simple naturally occurring ripening gas produced by many fruit, vegetables and flowers. It has both positive and negative effects. It is necessary for normal ripening to occur but it can cause premature ripening, induce senescence and reduce shelf life.



Packaging methods can be very sophisticated for fresh export products or very simple for local market sales. (Left) sugar peas, Nairobi; (right) produce market, Seoul, South Korea.

Preparation for sale and display is meticulous and highly technical to ensure product safety and retention of quality. (Left) apples, New Zealand and (right) grapes, South Korea.



Commercially ethylene is used for ripening tomatoes, avocados, kiwifruit and bananas.

Low temperature and CA storage cause a reduction in naturally occurring ethylene production and action, and so delay ripening and deterioration.

What consumers desire most in horticultural products is freshness. But maintaining quality from farm to plate is only one of the many challenges facing those who manage the dynamic horticultural industry.

Like all customers in the modern world, consumers of horticultural products need and demand consistent quality, appearance, good presentation, taste, nutrition, health benefits and strict conformance with health and safety standards.

And just when horticulturalists meet these high standards there is the possibility they will all change. Consumers change their tastes and wants. New trends towards vegetables such as capsicums, broccoli and the convenience of bananas come along.

Consumers expect a year-round supply of many fruit and vegetables such as bananas, tomatoes, lettuces, apples, and oranges. Products are sourced globally to satisfy this consumer need, so effective, efficient supply chains are essential. Many consumers now recognise that most fruit and vegetables have health conferring attributes as a result of the '5 + a DAY' programme\*.

Growers have to be able to respond quickly to market opportunities. Information on what is wanted and where it is required has to be transmitted back along the value chain to the growers.

Mastering the intricacies of marketing and positioning the product in retail selling points requires infrastructure and support services (such as refrigeration systems, cool store design, packaging, ICT inputs, transportation, reliable electricity supply, communication systems). To make sure all these tasks are completed well calls for the knowledge and expertise of scientists and technical experts.

\*Please see page 56.



(Left) Packing avocado for export, Chile and (right), grading and packing asparagus, Thailand.

Fast, efficient, cost-effective preparation and sorting of produce is important to growers of horticultural crops. To obtain premium returns, it is vital that crops go to the best markets and that the highest quality produce can achieve the best price in the markets. Lesser quality can be profitably sold to consumers in lower grade markets or be directed to processing options such as freezing or canning. Good sorting enhances customer satisfaction, provides a higher average price for the

crop and heightens the chances of return sales. Consumers appraise fruit and vegetables by colour, size, firmness and sweetness and are not impressed with blemishes. Repeat purchases will occur if taste, juiciness and sweetness appeal to the consumer. The response of the horticultural industry to achieve product segregation for particular markets needs has been to design clever, innovative, highly sophisticated grading and sorting equipment.

## Hi-speed accurate grading of fruit and vegetables

### Fruit graders

Early fruit graders were adapted from other industries, such as egg graders that sorted fruit into categories according to approximate weight or size. Others followed a series of mechanical clockwork based devices, such as the Orbit grader designed by John Hancock in New Zealand in 1964, that literally lobbed fruit that according to weight fell into one of seven canvas chutes. That machine was used in the kiwifruit industry for a number of years but was

replaced by modified machines from the apple industry.

The advent of the personal computer (costing \$3,000 in 1980 and replacing the typically \$50,000 main-frame machines of the time) allowed the affordable processing of algorithms in real-time, which meant that individual fruit could be assessed at blinding speed. Hence the evolution of the remarkable fruit and vegetable grading and sorting machines of today.

### Clever high speed fruit graders

Modern equipment can now sort fruit by weighing and scanning individual units multiple times within milliseconds measuring weight, diameter, colour, shape, density, internal sugar content and blemishes. Using sophisticated technologies, including Near Infra Red (NIR) cameras, there is guaranteed accurate pack weights. Furthermore, the 20 to 30 images of each fruit that are captured can be used to produce an integrated image, recognise whether a small blemish is present or not (while recognising that both the stem and calyx are not blemishes) and sort the fruit by colour grade – all at the rate of 10 or more fruit per second, and then deliver each fruit to one of 50 predestined drop points on the packing line. In California, USA, a single facility uses 40 such lanes to grade and sort Clementine oranges at a rate of 240 orchard bins per hour. This equates to 1.2 million pieces of fruit accurately sorted and graded per hour!



(Upper photo) In California a bank of high speed grading machines micro weigh and photo stitch analyse mandarins for blemishes across 40 lanes at 10 fruit per second per lane, and (lower photo) travel at high speed to assigned packing stations. PHOTO: WWW.COMPACSORT.COM



High speed grading and sorting of kiwifruit, New Zealand.  
PHOTO: ZESPRI INTERNATIONAL LTD

### Berryfruit graders

Small berryfruit, such as blueberries, have historically been sorted and packed by hand, with workers selecting out only 'good looking' fruit with above-average keeping qualities.

The advent of grading machines that could rapidly recognise different fruit qualities by colour was an innovation of huge benefit to high volume packers of berryfruit.

### Soft berryfruits

A machine for sorting soft berryfruits had long been a dream for many fruit packers. The softness of fruit cannot be reliably detected by colour. It seemed that softness was a quality that could only be detected by the touch of a human hand and hand grading was slow and potentially damaging to fruit.

The solution was the development of a sensor technology which generated a sine wave from the contact that a berry makes as it falls from an angle

### Colour sensing technology



High speed berryfruit grader uses colour sensing technology to identify and air jets to remove non-conforming berries. PHOTO: WWW.BBCTECHNOLOGIES.COM

Colour sensing technology can be used to sort combinations of colours on individual fruit as small as 2 gm in weight. For example, it can sort blueberries at a rate of 100 kg per hour. A single 72 lane/1.2 metre wide machine can process 7,200 kg per hour.

Larger fruit (eg. 8 gm each) can be sorted at 200 kg per lane per hour – or over 14.4 tonnes per hour for the 72 lane model. These machines successfully process a wide variety of fruit and nuts, including: blueberries, cranberries, olives, strawberries, cherries, cherry and grape tomatoes, peanuts, almonds and pistachios.

onto a small sensor. There is a strong correlation between the shape of the sine wave that is generated and the softness of the fruit. Following detection, soft fruit are removed from the grading line by air jets.

Individually wrapped and protected fruit in a supermarket, Beijing.





Beetroot: before and after washing in a high speed 'polisher'.



Washed and 'polished' potatoes exit this machine at the rate of 15 tonnes per hour.  
PHOTO: WWW.WYMASOLUTIONS.COM

### Vegetable graders

Vegetables need to be cleaned, washed and graded for premium presentation – and in large quantities.

In the 1970s a company that was repairing farm implements and mechanical grading machines, started developing machinery for preparing fresh carrots, potatoes and parsnips and have now developed a 'Polisher' with a rotary barrel or drum and 14 brushes that rotate independently.

These machines, that can process 12 tonnes of carrots or 15 tonnes of potatoes per hour, have been installed in countries as far apart as Australia, Canada, Switzerland, Poland and Mexico.

## Packaging

Effective packaging is paramount to horticultural products. It serves to protect the produce in transit, keeps it from contamination, reduces dehydration and if possible retains its freshness. Sub-standard packaging not only presents the product poorly, but may also indicate to the customer that the product is of poor quality and even that it is unsafe. If a consequent purchase is not made then growers, suppliers, and indeed all the people in the supply chain, suffer financially and socially.

Plastic or moulded cardboard retail packs might seem simple items at first glance. However, such packages can in fact be a guard and defender of the contents. Good packaging can save waste, reduce shrivel through control of humidity, and be a physical barrier to pests and reduce bruising. Well designed, effective packaging, therefore, gives the consumer a guarantee of freshness, vitality and safety.

If transport conditions and packaging are optimum, then the ageing of fruit and vegetables can be slowed down by as much as 800%.

### An example of 'intelligent' packaging

Knowing when fruit is ripe and at its optimum state for eating is a vital matter to growers and to discerning customers. Fruit lovers like to enjoy fruit when it is 'just right' and may hesitate over buying excellent produce if they are not quite sure that it is indeed 'ripe'.

Without the touch of human hand, a new horticultural technology RipeSense™ eliminates this problem by using a sensor label that reacts to the aromas released by fruit as it ripens.

The sensor is initially red and graduates to orange and finally to yellow. By matching the colour to the sensor, consumers choose fruit to the ripeness they prefer.



It's such a clever innovation that TIME magazine recognised it as being one of the world's most amazing inventions of 2004. PHOTO: RIPESENSE.COM

## The 'fresh-cut' answer

The consumer's desire for pre-sliced or diced fresh fruits or vegetables with freshness, quality, convenience and low waste has led to the development of the 'fresh-cut' sector in the market. The successful development and sale of fresh-cut products in permeable polymeric film bags, is the most rapidly growing food sector in both North America and Europe.

Consumers are finding that fresh-cut fruit or vegetables that have been trimmed, and/or peeled and/or sliced, diced and cut and packaged as a 100% usable product, offer high nutrition, convenience and flavour while maintaining freshness and minimising waste.

The fresh-cut horticultural segment supplies both the food service industry with large-scale volumes and retail outlets with specialist packs that are suitable for either families or for individual consumers. Salad vegetables make up more than 60% of fresh-cut produce sales.

The most popularly used packaging format is propylene film for bags (or 'pillows') in either 250 and 500 gm packs. Extensible, plasticized PVC is used for tray wrapping. The pillow system is less expensive than other packaging systems having lower labour costs through the use of highly automated filling and weighing processes.



Fresh-cut fruit in a supermarket.

## The modified atmosphere solution

The search for better retention of quality led horticultural scientists to the modified atmosphere solution as a means of extending the shelf life of a wide range of fresh products.

This technology substitutes the air inside a package with a protective gas mix. The gas in the packaging (normally a 'pillow') helps to ensure that the product will stay fresh for as long as possible. The modified atmosphere process frequently decreases the oxygen in the package from 20% to less than 5% in order to slow down product metabolism, reduce ethylene production and restrict the growth of fungal rots and the rate of ripening deterioration.

The removed oxygen can also be replaced with enhanced levels of carbon dioxide, which can lower the pH and inhibit the growth of bacteria. Modified atmosphere conditions within food packages are very effective in prolonging the life and quality of products but it is rarely commercially applied at its maximum potential.

All perishable horticultural products should be stored at optimal temperatures so as to maximise shelf life.

Picked, graded, packed and presented, the crop begins its journey to your door.

## Supply chains and cold chains

A supply chain management system is the integration of organization, people, technology, activities, information and resources required to move a product efficiently from a supplier to a customer.

Since most fresh foods are perishable and often require a long process of transport and storage, a special cold chain system is vital.

The infrastructure of a cold chain logistical system generally consists of: pre-cooling facilities, cold storage facilities, refrigerated carriers, packaging, warehousing and information management systems incorporating traceability and tracking.

The best way to maintain quality after harvest is to make sure that food in the supply chain is kept at appropriate low temperatures to reduce spoilage losses and prevent contamination. For most crops grown in temperate climates, product temperatures should be maintained at 0-1°C for maximum shelf life; for most tropical and subtropical crops temperatures should be above 10°C to avoid chilling injury. Scientists have established optimal storage conditions for most fruit, vegetables and flowers.

## Examples of ideal storage conditions for fruit and vegetables

| FRUIT          | Temperature range (°C) | Relative humidity range (%) | Storage time |
|----------------|------------------------|-----------------------------|--------------|
| Apple          | -1 to 4.5              | 90 – 95                     | 4 – 32 wks   |
| Banana – ripe  | 13.5 to 15             | 85 – 90                     | 2 – 5 days   |
| Banana – green | 12.5 to 21             | 85 – 95                     | 4 – 21 days  |
| Grapes         | -1 to 0                | 85 – 95                     | 12 – 24 wks  |
| Kiwifruit      | -0.5 to 0              | 90 – 95                     | 8 – 16 wks   |
| Mango          | 10 to 13               | 85 – 90                     | 2 – 3 wks    |
| Orange         | 0 to 9                 | 85 – 90                     | 3 – 16 wks   |
| Pear           | -2 to 0                | 90 – 95                     | 8 – 28 wks   |
| Pineapple      | 5 to 7                 | 85 – 90                     | 2 – 4 wks    |
| Strawberry     | -0.5 to 0              | 85 – 100                    | 5 – 14 days  |
| Dried fruit    | 0 to 7                 | 55 – 80                     | 48 wks       |

| VEGETABLES         | Temperature range (°C) | Relative humidity range (%) | Storage time |
|--------------------|------------------------|-----------------------------|--------------|
| Asparagus          | 0 to 2.5               | 85 – 100                    | 2 – 4 wks    |
| Broccoli           | 0                      | 90 – 100                    | 1 – 2 wks    |
| Celery             | -0.5 to 0              | 90 – 100                    | 3 – 10 days  |
| Lettuce            | 0                      | 90 – 100                    | 4 – 16 wks   |
| Mushroom           | 0                      | 85 – 100                    | 1 – 2 wks    |
| Onion – dry        | 0                      | 65 – 75                     | 4 – 32 wks   |
| Pea – green        | -0.5 to 0              | 65 – 100                    | 1 – 3 wks    |
| Potato – eating    | 7 to 12                | 85 – 100                    | 8 – 32 wks   |
| Pumpkin            | 10 to 12               | 70 – 90                     | 8 – 24 wks   |
| Tomato – green     | 12 to 16               | 85 – 95                     | 1 – 3 wks    |
| Tomato – firm ripe | 6 to 8                 | 85 – 95                     | 3 – 7 days   |

### The cost of not having an effective cold chain is huge – end-to-end

The cost of not getting this right is huge. Because of inefficient cold chain stages during food transport, China incurs losses of 40 billion yuan (US\$6 billion) a year from food spoilage.

Pakistan has a fruit and vegetable crop area of 1.4 million hectares and the horticulture sector contributes about 12% to national agricultural GDP. Postharvest losses range between 20% to 40% for horticultural produce and that loss has an estimated value of US\$900 million.

Recognising the loss has been the incentive for a US\$150 million cold chain system along Pakistan's National Trade corridor involving 23 cold stores, 39 pack houses and 2 reefer (container) yards.

In addition to reducing spoilage losses these improvements are expected to improve shelf life and quality of fresh produce, stabilise prices in domestic markets, increase production surpluses and increase export opportunities.

Other countries are increasingly recognising the scale of fresh food losses that amount to 1.3 billion tonnes worldwide.

In India, where only 2% of products that should be temperature controlled are handled that way, about 30% of the fruit and vegetables grown annually are wasted.

This is due to a lack of awareness about proper handling and storage requirements as well as poor infrastructure, inconsistent electricity supply, insufficient cold storage capacity in close proximity to farms and poor transportation infrastructure.

In China only about 15% of products that should be temperature controlled are handled that way and in the Asia Pacific region only about 8%. This compares with about 85% compliance with good cold chain practices found in Europe and North America.



Avocado exports, Chile.

Cold chains need to start at the farm with attention to harvest methods, removal from direct sunlight and pre-cooling, and extend right through the chain to the retail and consumer level.

A well organized cold chain reduces spoilage, retains quality of harvested products and guarantees a cost efficient delivery to the consumer, bringing quality and profit benefits to all those linked in the supply chain.

It is an end-to-end process and if any of the links is missing or are weak, the whole system can fail.



Cold chain storage, Africa.

### Standards for cool chains

In 2003, the Cool Chain Association (CCA), a non-profit organisation, was set up and an industry standard and yardstick for reliability, quality and proficiency in perishable and temperature-sensitive products was established.

The result is an open and auditable industry standard incorporating benchmarking to establish transparent and comparable quality measures for carriers (airlines, road hauliers), handling agents, forwarders, perishable centers, airports and warehouses with long and short-term cold stores.

To be effective and successful, cold chain management systems must have continual monitoring of product temperature throughout distribution and, where there is a problem, there have to be appropriate corrective action plans in place.

## Traceability

When there is a breakdown in a supply chain and food or plants degrade, or become contaminated with other substances or carry undesirable insects, then the point of failure must be traced as fast as possible. This is easier to accomplish if the product carries with it a record of the location of harvest, storage and transport history.

New solutions to supply chain traceability are moving from sophisticated bar code systems to new technology such as Radio Frequency Identification.

A Radio Frequency Identifier (RFID) is an electronic tag placed in the product which is 'asked' electronically on a truck, train, ship or plane, in a warehouse, or in

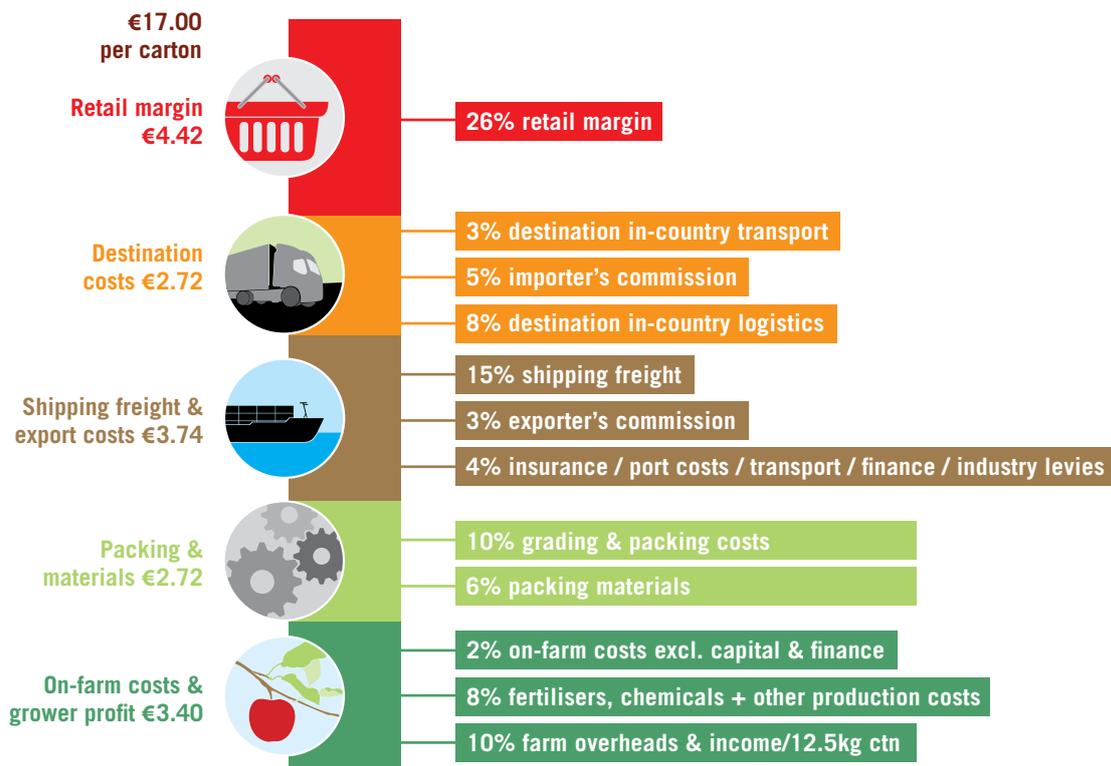
a storage facility to identify itself and deliver the data it has been programmed to collect.

RFID units embedded with products can provide a real time record of current location, distance travelled, location of origin and information on environmental factors such as temperature, relative humidity and vibration.

In 2009 the Spanish supermarket chain Mercadona with 1,236 supermarkets installed RFID tag readers within the dry, fresh and frozen goods sectors at its centre near Madrid. Wal-Mart the world's largest retailer required all incoming goods to store to have RFIDs by 2010.

## Supply chain cost structure

Example based upon apples from Southern Hemisphere retailed for €17.00 per carton (12.5kg) in a European market in 2008 (duty costs excluded)



As shown in the cost structure diagram above, the profit that the grower of the produce receives may only be a small portion (~10%) of the cost that consumers pay at retail. SOURCE: M. DODD, 2008

### Thought Challenge #4

The producers of export fruit and vegetables currently receive typically less than 20% of the retail value – an amount less than the retail margin.

*Q. What might happen if, through the inadequacy of their incomes, producers cease production?*



Fruit and vegetables sold in many different types of markets around the world.

## Food safety and biosecurity

Before and throughout their journey to market, horticultural produce may be exposed to microbial and other contamination. Food safety is a major issue for the industry and international trading often requires horticultural growers and exporters to call upon scientific expertise to deal with quarantine and market access issues concerning unwanted pests and diseases.

Border protection and biosecurity authorities using sophisticated systems, set policy and design protocols and use technology to detect residual agri-chemical traces and identify problems of pests and diseases.

### Biosecurity postharvest technologies

With few exceptions all produce must use some form of biosecurity technology. A number of technologies have been developed for treatment of fruit after harvest to destroy any unwanted contaminating pests. Of particular concern are the fruit flies that lay their eggs in many varieties of tropical fruit.

Low temperatures for long periods can kill tropical fruit flies, especially if combined with changed

atmospheres. The atmosphere surrounding the fruit can be modified either by reducing oxygen or increasing carbon dioxide concentrations (referred to as modified atmosphere, MA, or controlled atmosphere, CA).

Other treatments developed include using heated air, water or steam with temperatures ranging from 45-55°C for 5-110 minutes depending on product, variety and size. Extreme care must be taken to monitor product temperature continuously during treatment to avoid tissue damage.

Such treatments include: hot water treatment, vapour heat or forced-hot air, vapour heat treatment (VHT) and forced hot-air heating treatment (FHAT).

Mangos and papayas are good examples of fruit grown in areas where fruit fly is established. Export of mangos or papayas to another country that does not have such pests, usually requires a quarantine treatment as a phytosanitary measure to ensure that no live fruit fly larvae or insects are present in imported fruit.

## Irradiation

Food irradiation is a process where products are exposed to ionizing radiation to sterilize or kill insects and microbial pests by damaging their DNA.

While much of the focus of irradiation use on fruits and vegetables has been for extending shelf-life and reducing decay, irradiation is effective at sterilizing or preventing further development of a range of insect pests on perishable fruits and vegetables.

Irradiation is a capital-intensive technology requiring a substantial initial investment, ranging from US\$ 3 million to US\$13 million. Radiation plants are costly and would be more economical if used essentially year-round. However, fresh fruit and vegetable production is regional and seasonal.

While studies have shown consumer acceptance of irradiated produce in the USA is increasing, serious public concerns remain about safety of food in other countries where irradiated products are not accepted by consumers.

### Handle me with care

From seed to table the efforts of a multitude of individuals and businesses are involved in the safe and presentable delivery of horticultural products to your door to satisfy your requirements. It is a triumph of care and attention, sound and innovative science and the dedication of growers and deliverers alike.



Post-harvest sorting, grading and storage require sophisticated, highly technical facilities to manage large volumes of produce and to meet safety and quality standards. (Left) avocados, Chile and (right) apples, New Zealand.

## Ultra high pressure (UHP) technology

Ultra high pressure (UHP) technology is a non-thermal cold pasteurization technique using pressures up to 87,000 psi to shock and kill bacteria in food products.

The process is said to have the same inactivating effect on micro-organisms as heat or chemicals, but with no effect on taste, texture, colour, nutritional value or the vitamin content of the food.

When used on avocados, UHP extends the product life from 30 days to 60 days and the resulting paste is suitable for spreads and guacamole. UHP can also modify physical and rheological properties of proteins, which could lead to the development of new pressurised products with applications in food technology and as an ingredient in other food presentations.

### Thought Challenge #5

Governments are reducing and in some countries are terminating information transfer services for technical and production knowledge available to farmers (with examples being New Zealand and the United Kingdom).

*Q. Might there be increased risk of food safety crises and major plant disease outbreaks as a result of the near total absence of expertise in such technical transfer services?*

## CHAPTER FOUR

# The People

A growing world population and the increase in wealth by many will increase the demand for horticultural produce to unprecedented levels. To meet this demand, modern horticultural production

is critically dependent on knowledge. It needs technically-competent, skilled people in all parts of the industry who can respond quickly to market opportunities and the vagaries of production.

### The journey-to-you for vast volumes of horticultural products requires many skills



#### SUPPLY CHAIN STAKEHOLDERS



#### CROSS DISCIPLINARY STAKEHOLDERS

- Research & development and tertiary education
- Horticultural engineering & consultancy services
- Goods & services suppliers including financial services
- Beneficial participants, community activities, real estate, sports & recreation, regional authorities

## Horticulture is a dynamic industry

People in horticulture have to adapt their local knowledge to changing factors in production, to advances in technologies such as disease management and to cope with changing climate and local and international economic conditions. Not only that, but they also need to adapt outside knowledge to their local conditions and have the flexibility to develop and adopt increasingly efficient production systems as market conditions change. Changing demands will require future professionals in horticulture to have the capacity to conduct both original and adaptive research in all aspects of what are often complex production and distribution systems.

These increasingly demanding skills have to be applied by all workers at all levels in horticulture, from growers with small units to those with large and sophisticated production operations, the technically complex packaging and sorting machine operations, and to those operating fast and efficient cool chains to end markets.

Specialised knowledge is required but application and implementation need multidisciplinary approaches.

Horticulture has long-term needs for investment in training institutes, schools, technical institutes, and universities that can deliver this specialised knowledge with formal technical training programmes, practical skill courses and professional tertiary degrees developed to the highest levels, including PhD.

In addition to these specialised horticultural knowledge fields, world horticulture needs many people in the ancillary support areas of trade expertise, computing, engineering, law, statistics and others. There is a real need for increased emphasis on horticulture as a career opportunity. Entrants to horticulture can expect rewarding careers and a deep satisfaction in the importance of their work in growing food, flowers and plants for the world.

## Horticulture requires many skills at all levels to ensure success:

### Successful horticulture production requires specialist knowledge in many disciplines

- seed production and nursery management
- crop management, including tree training and pruning
- plant physiology
- plant pathology and disease control
- entomology and pest control
- harvest management, including mechanical harvest options
- plant breeding
- soil and fertiliser management
- irrigation management
- weed control
- computing and software applications
- project management
- budgeting and financial management

### Postharvest horticulture needs specialist skills

- postharvest management, including quality assurance and product quality assessment
- packaging technology
- sorting technology
- information technology, including product traceability
- engineering, including specialised knowledge applicable to harvesting, storage and transport
- market research
- processing technologies
- shipping knowledge
- specialised promotion and marketing intelligence
- storage technologies (cool and controlled atmosphere)
- supply chain logistics
- sales and marketing

## Entrants to the knowledge world of horticulture can seek careers as:

- Teachers at all levels – school, tertiary, training
- Information/technical transfer specialists
- Marketing and sales personnel
- Specialist engineers
- IT specialists
- Economists
- Trade negotiators
- International marketing and promotion experts
- Financial management and investment professionals
- Expert growers
- Scientists
  - o soil scientists
  - o plant physiologists
  - o environmental scientists
  - o crop management specialists
  - o postharvest specialists
  - o pest and disease specialists
  - o molecular biologists, sensory scientists, nanotechnologists and others
  - o plant breeders



Improved cultivars, sophisticated production methods, and enhanced storage and packaging will need the input of highly-skilled professional growers, scientists, technicians and engineers who are proficient in horticulture and the related fields. Left: apple breeding, NZ INSTITUTE FOR PLANT & FOOD RESEARCH LTD. Right: packaged vegetables, supermarket, Beijing, China

## Training

Horticulture is taught at most levels of education in many countries. This includes majors at high schools, special programmes within technical institutes and polytechnics, and degree programmes to PhD level at universities. Horticultural science is taught primarily at universities.

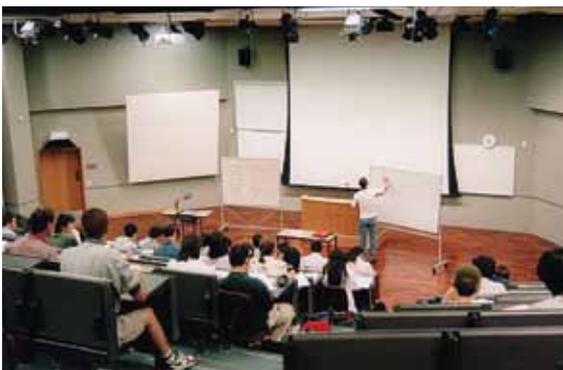
Within universities, special departments often deal separately with vegetables, fruit and viticulture, and may further separate into departments focussed on specialties such as production, postharvest, entomology, plant pathology, botany/plant physiology, soil science, engineering and economics. Clearly the amount of specialisation depends largely on the size of the tertiary institute and the numbers of students seeking enrolment. In general, degree programmes in both horticulture and horticultural science are increasing in enrolments in developing countries as the potential of horticulture to increase wealth, improve health and provide export opportunities is being realised.

In contrast, in developed countries, horticulture degree programmes are rapidly being amalgamated into general plant science departments as food supply, food security and low food prices are taken for granted after several decades of 'plenty'. Urbanisation of societies is also impacting as increasing numbers of young people have little knowledge or interest in rural employment in horticulture or in horticultural science.

The overall decline in horticulture enrolments in the developed world is increasingly creating tensions in relation to the failure of universities to graduate sufficient people to replace those who are retiring or to provide the basic support skills that are needed by industry. Significantly, government-supported farmer extension programmes, which are provided entirely by university trained personnel, are also being reduced in many countries including New Zealand, the United Kingdom and the USA as ongoing budget cuts take effect and urban-based priorities capture political agendas.

Further, the growing complexity of food production in the face of factors such as demands for sustainability, the impacts of climate change, 'buy local' campaigns, and the global spread of serious crop pests and diseases, means that greater rather than fewer numbers of highly skilled university graduates are needed than ever before. Rapidly escalating food prices, and even food shortages, are an inevitable consequence of short-sighted and short-term policies of governments and university administrations in developed countries who are allowing the demise of these degree programmes.

On average, horticulture provides twice the amount of employment per hectare of production as cereal crop production. Horticultural crop production is job rich and the options are very diverse.



Modern horticultural production requires the training of technical and professional people to the highest levels of tertiary education. PHOTOS: MASSEY UNIVERSITY

### Thought Challenge #6

Universities in developed countries such as the USA, the United Kingdom, Germany, and The Netherlands have closed down many horticultural science departments over the past 30 years.

*Q. In the future, where will the highly skilled, technically competent professionals come from to provide certainty to the supply of sustainably produced safe food, and to identify and manage cross-border incursions that can occur?*

## Viable communities need horticulture's employment opportunities



## Developing countries

The horticultural industries within countries of the developing world need to achieve the level of sophisticated production that guarantees food safety and quality standards, and the economies of scale for viable export opportunities.

The initial benefits from increased horticultural investment and production are often replacing the gathering of food from the wild and moving to managed cropping.

The move from cereal production to high-value horticulture crops increases employment opportunities

in developing countries. The prosperity that flows from more effective use of land provides the surplus wealth required to maintain a sustainable population. Retaining the population preserves local services such as schools and hospitals that would otherwise be lost when land is depopulated. Horticultural production in developing countries is characterised by relatively low use of technologies and lower cost structures. Together with low cost labour, this actually makes developing countries internationally competitive.

### Thought Challenge #7

The average age of farmers in Japan is now 66 years, reflecting the unwillingness of young people to become involved with farming. This ageing trend of farmers is also apparent in other countries, especially in advanced economies.

*Q. Who will be the future food producers in Japan and other countries where young people are increasingly attracted to urban lifestyles and not to farming?*

## Women in horticulture

In today's horticultural industries, particularly in developing countries, women play significant roles as farmers, agricultural business leaders, labourers, entrepreneurs, and customers. These opportunities provide employment, enhance financial independence and raise living standards.

In fact, women comprise a majority (50% to 91%) of the horticultural labour supply in most developing countries. For example, in Mexico, 80% to 90% of people involved in sorting, grading and packaging of horticultural produce are women. However women face unique constraints in horticultural production systems including inadequate or unequal access

to land, credit, technology and information, and the difficulties associated with poor working conditions.

Horticulturalists are business people and entrepreneurs. There is a heavy reliance on women to ensure that all opportunities to enhance living standards through higher value horticultural crops are maximised.

Increasingly women are emerging as top educationalists and science leaders within research institutions focussed on the challenges that face horticulture across the world.

### Lifelong learning for farmers – the COL solution

The impact of globalization has suddenly required millions of poorly trained farmers in developing countries to face new challenges and opportunities.

Agriculture in general and horticulture in particular has become more volatile, competitive, knowledge-led and market-oriented. The complexities of marketing perishable produce, minimizing storage and transport losses and complying with strict sanitary and phytosanitary standards are beyond the capacity of most smallholders.

One promising possibility for the up-skilling and knowledge transfer needed to address this challenge comes from the Commonwealth of Learning (COL), an inter-governmental organisation established by Commonwealth governments headquartered in Vancouver, Canada.

It has developed a learning process that is both an alternative and an adjunct to traditional transfers of knowledge. The Commonwealth of Learning approach takes up the practical and current knowledge of successful farmers and links it with sound research and the current knowledge already existing in a traditional and unsystematic form in the industry.

COL links farmers with various stakeholders in the industry allowing each party to benefit from each other's knowledge and to enhance their ability to negotiate with other stakeholders.

The emphasis in the Commonwealth of Learning model is on Open and Distance Learning (ODL) making extensive use of electronic, internet, digital and the latest ICT technologies.



The emergence of low-cost computers is transforming knowledge transfer in all countries.  
PHOTO: WWW.COL.ORG

For instance, advantage has been taken of the boom and accessibility of mobile phones in the developing world.

Using voicemail, farmers, brokers, suppliers and women members of the learning chains can share quality learning conversations where members make their learning experience available to others.

The conversations are codified. Self-help groups form a strong active user constituency. The focus has been on strengthening the codified learning and tacit learning in the informal knowledge environment and linking it with formal knowledge resources to generate an upward spiral of learning networks.



Mobile phones are enhancing communication and providing an effective means of transferring knowledge about crops, production and marketing. PHOTO: WWW.COL.ORG

The community, instead of being a passive consumer of information, becomes a partner in knowledge management. Learning becomes self-directed.

In India indirect investment of US\$50,000 organized by COL has helped generate assets worth US\$1.3 million in 400 households in one year.

## Changing times require advancements in education and research

We live in changing times with increasing urbanisation of populations, increases in living standards, growth in the power of multinational supermarkets, decreasing numbers of food producing farmers (but aggregation of land and operations), governments having fewer rural MPs to represent the farming sector (less political focus on farming), and a decline in agricultural services to farming communities over time (more user-pays cost-recovery). Additionally, postharvest food losses remain unac-

ceptably high despite international efforts to achieve Millennium Development Goals. The recent global economic crisis has caused major setbacks in achieving some MDG goals, and government and donor finances have been severely curtailed, especially in R&D and extension work. Education and training in horticulture requires graduates who will become advisors and trainers to ensure that existing and proven farming information is fully utilised.

### Training organisations

Many institutions and NGOs are involved in training farmers with seminars, workshops and other techniques. Among the higher profile organisations are:

- FAO [Food and Agriculture Organization of the United Nations]
- CIRDAP [Centre on Integrated Rural Development for Asia and Pacific, based in Sri Lanka]
- APO [Agricultural Productivity Organisation, based in Japan]
- World Vegetable Centre [AVRDC, based in Chinese Taipei and Tanzania]
- Australian Centre for International Agricultural Research [ACIAR]
- International Fund for Agricultural Development [IFAD, based in Rome]
- The Global Horticultural Initiative [GlobalHort]
- US Agency for International Development [USAID]
- European Union [EU] – multiple programmes from member countries and from EU per se [eg. CTA]
- International Tropical and Subtropical Fruit Network [TFNET, based in Malaysia]
- USAID Horticulture Collaborative Research Support Programme [HortCRSP, based at University of California, Davis]
- Commonwealth of Learning [COL, based in Vancouver] – specialises in distance education and training.
- CIRAD [Centre de coopération internationale en recherche agronomique pour le développement, based in France]

There are also many other institutions including universities and independents that run specialist programmes.

## CHAPTER FIVE

# Growing Economically

### Investment

The capital investment needed on-farm is determined by the commitment that producers must make to planting stock, tractors and related cultivation and harvest equipment, irrigation machinery, and buildings. What is often not so apparent is the off-farm investment in packing and grading equipment, packaging supplies, storage facilities, processing plants, and specialised transport.

Where horticultural product is processed, such as with wine grapes or frozen and canned vegetables, the off-farm investment can be considerably higher than the on-farm investment. For wine production, an estimate of off-vineyard investment is three times on-vineyard investment.

In most other fruit and vegetable operations, investment off-farm closely matches that on-farm. This has led to specialised provision of high investment facilities such as packing houses and coolstores that may be owned and operated as cooperatives in order to achieve economies of scale.

Viable horticultural production, especially at large scale, can therefore have very large impacts on local economies from the need for large capital investment; the supply of goods such as fertilisers, fencing, and machinery; services such as financial, insurances, and information, the employment of people, all of which are needed both on- and off-farm. These activities are critical and are often

the basis for retaining essential infrastructure and services such as the provision of health services and schooling in rural locations.

In New Zealand, where horticultural industries occupy approximately 130,000 hectares, the on-farm investment is estimated to be NZ\$14.2 billion and the off-farm investment NZ\$24 billion.

During the last decades, economic growth in horticulture globally has far exceeded that of most agricultural commodities. Annual growth rates for vegetable supplies have surpassed cereals by 200% to 600%, with much of this acceleration occurring in the 1990s.

The growth rates for horticulture currently exceed all other major commodities. At a global level the value of all fruit and vegetables traded is more than double the value of all cereals traded.

Farmers engaged in high-value horticultural crop production can earn much higher net farm incomes than those growing staple crops.

Two examples are:

- Fruit and vegetable producers in India generate five to eight times more in profits than cereal farmers
- In Kenya, farmers producing fruit, vegetables or flowers for export can earn six to twenty times more than maize growers.



Investment in horticultural enterprises, both on- and off-farm, can be very considerable. Above: Grape growing and wine production. PHOTOS: UNIVERSITY OF CALIFORNIA, DAVIS

Developing nations, notably Chile, Mexico, Kenya and Egypt, have been able to maintain growth and profitability by developing the research, training, infrastructure and technologies critical to sustaining this success. Few low and middle-income countries have managed to sustain long-term growth in horticulture without such commitment in professional development and infrastructural support along the entire supply chain. Countries that failed to invest in research and human capacity building have experienced short-term growth or growth in a limited number of highly targeted crops, but have not achieved sustained growth and development in this sector.

## Wealth generation

Horticultural industries generate considerable wealth for producers, suppliers, local communities and countries. In many countries, horticultural production can define whole regions that become internationally renowned for the quality and value of the products that are produced and sold. Examples include the Salinas Valley in California for vegetable production, the Hood River and Yakama regions in the USA for pears and apples, New Zealand for kiwifruit, Bordeaux for wines, Turkey for dried fruit products such as apricots, Ecuador for bananas, the Philippines for pineapples, and Queensland for macadamia nuts.

In each of these cases, the scale and complexity of the industries is enormous. The wealth generation is such that these horticultural activities have significant impacts on the gross domestic product of the country concerned, having significant export volumes and values. For example, of all fresh and processed vegetables produced in the USA, California produces 44% of the harvested area, 49% of the production and 52% of the value. From Spain, around 10 million tonnes of fruit and vegetables are exported annually (primarily to other European countries) with a total value of about Euro 8 billion. The top categories are tomatoes (900,000 tonnes), lettuces (500,000 tonnes), cucumbers (450,000 tonnes), citrus (3.8 million tonnes), stone fruit (600,000 tonnes) and melons (380,000 tonnes).

Horticultural crops are invaluable for agricultural development in the developing world. They have high economic and nutritive value. They offer opportunities for agricultural and economic diversification especially for smallholders who

Despite the clear benefits of horticultural crop production for developing nations, horticulture has received vastly less development and research investment than cereal grains. Between 1968 and 1996 for instance USAID, a major provider of funds for agricultural research, focused on cereal crops such as rice, wheat and maize. Tropical fruit and vegetables received less than one-tenth of the amount invested in the staple crop centres. Investment in the sector is still inadequate if its full potential is to be realised.

Nevertheless, horticulture has recently become an explicit priority in the development agendas of many donor, research and implementing agencies.



Horticultural crops can provide higher incomes and generate higher employment than staple crops. Export activities, however, require investment in appropriate infrastructure.

can gear production to specific local, regional or export markets.

Initially the focus for developing countries was geared towards feeding the local population. In recent years it has become increasingly important for wealth creation with increasing emphasis on exporting horticultural products to sophisticated consumers in developed countries.

For example, Kenyan producers of green beans for the European export market benefit from a favourable confluence of ideal growing conditions, technically supported growers, excellent infrastructure and strong export market demand.

There are many opportunities for improvements in infrastructure and service provision, and the development and promotion of international markets, supply chain systems and supporting technologies. Horticulture has the proven potential to stimulate economic growth, reduce poverty, enhance health and address issues of inequity and environmental degradation in developing countries.



Successful exporting requires close attention to product handling, cool chain management and traceability.  
PHOTOS: ZESPRI INTERNATIONAL LTD

## Critical success factors for horticulture

### Good governance

Knowledge-based horticulture needs good governance to ensure oversight of capital investment, company operations, market development and market access.

### Intellectual property protection

Those who design, develop and provide better cultivars, better packaging, better sorting technology and other improvements, need development, application and enforcement of intellectual property rights agreements.

### Land tenure and credit provision

All horticulturists, ranging from small producers

to giant agribusinesses, need secure land tenure and regulated credit markets.

### Good agricultural practice

Horticultural standards have to be set and enforced to meet the stringent requirements of importers.

### Research and development

While there is significant potential for horticulture to contribute to a variety of development goals, the conditions for success and sustainable growth are complex and not well articulated, underscoring the need for research investment.

## The Eden Project

Located in Cornwall, England and described as the world's largest greenhouse, plants from around the world are grown inside two huge biomes constructed in a reclaimed quarry pit and prove that given an appropriate growing environment, virtually any plant can be grown away from its natural environment. One biome is for tropical plants (1.56 hectares) with fruiting trees such as banana and coffee and the second biome (0.65 hectares) creates a Mediterranean warm temperate environment that has plants including olives and grapes. Other plants are grown outside the two biomes.



The Eden Project's biomes, Cornwall, UK.

## Thought Challenge #8

Only 10% of people in the United Kingdom and 18% in the USA live in rural communities. Nowadays, worldwide less than 50% of people live in rural communities. Rural votes mean less and less to elected officials.

*Q. Who will represent the minority who are critical for production and security of food supplies to modern communities?*





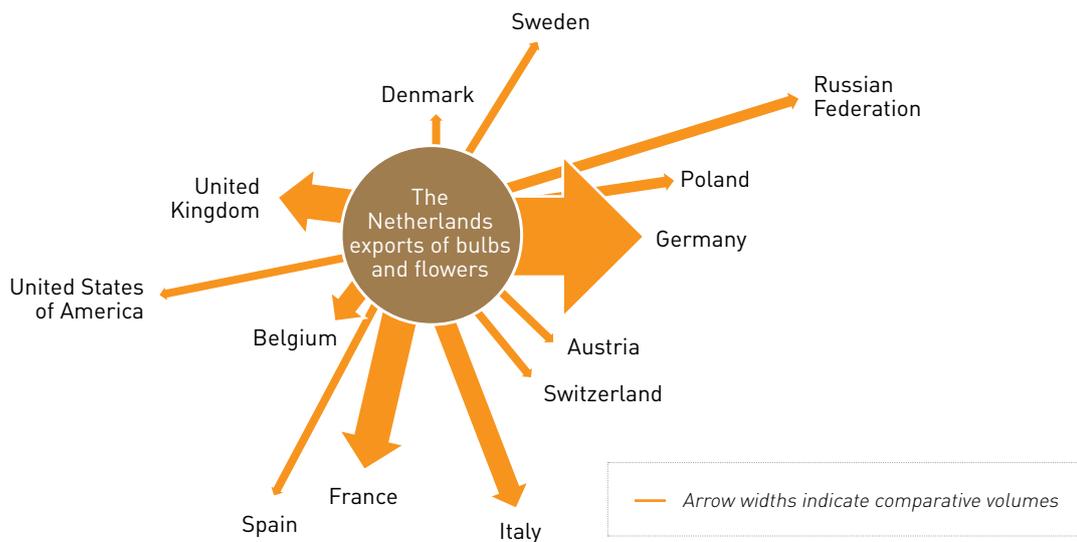
Tropical crops, such as bananas, are exported to consumers in colder climates; many other crops are produced globally for supply to countries where land and labour for horticulture are limited.

Some countries such as Japan, the Russian Federation, the United Kingdom, Germany and France are strongly dependent upon imports of fruit and vegetables for food supply, food security and variation within their diets. Others such as Chile, Spain, Italy, China and The Netherlands are strong net exporters of these products. In other instances, such as the USA and Argentina, imports approximately balance exports but the range of products in each category allow a much more diverse diet for local consumers, such as the import of tropical fruit into the USA.

The following diagrams show examples of large scale horticultural product exports that are important food and onamental plant supply sources for many countries and which deliver significant economic benefits to exporting countries.

**Trade flows: THE NETHERLANDS exported over US\$10 billion in live plants, bulbs, cut flowers in 2010**

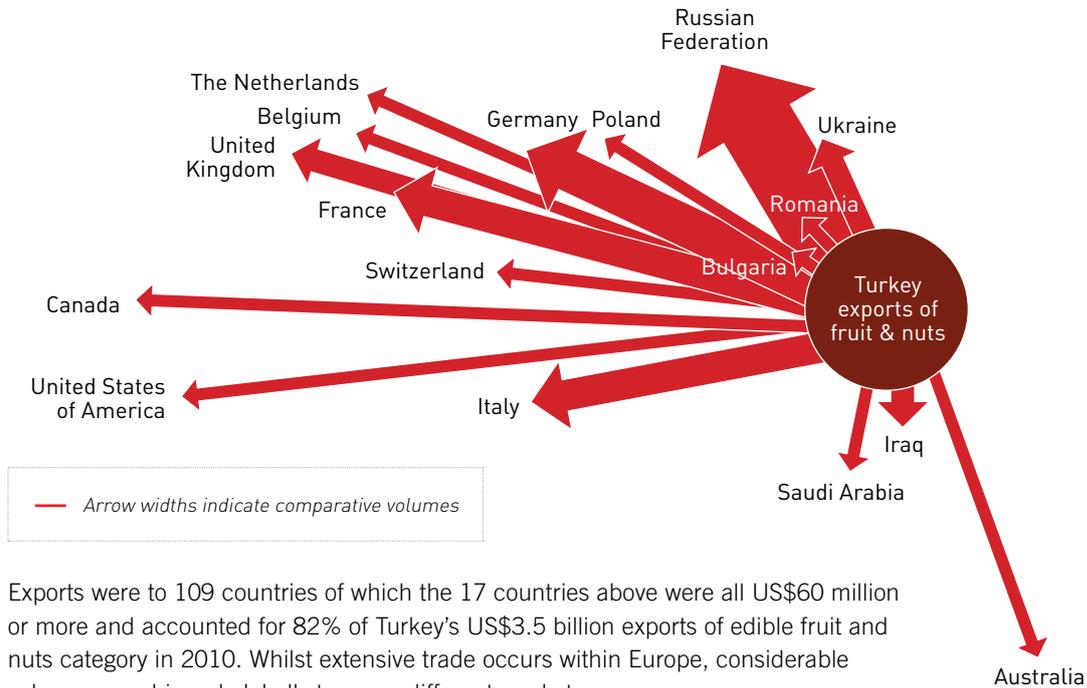
SOURCES : ITC CALCULATIONS BASED ON COMTRADE STATISTICS



Exports were to 148 countries of which the 13 countries above were all US\$200 million or more and accounted for 85% of The Netherlands US\$10.6 billion exports of flowers and bulbs category in 2010. The majority of this trade is in Europe.

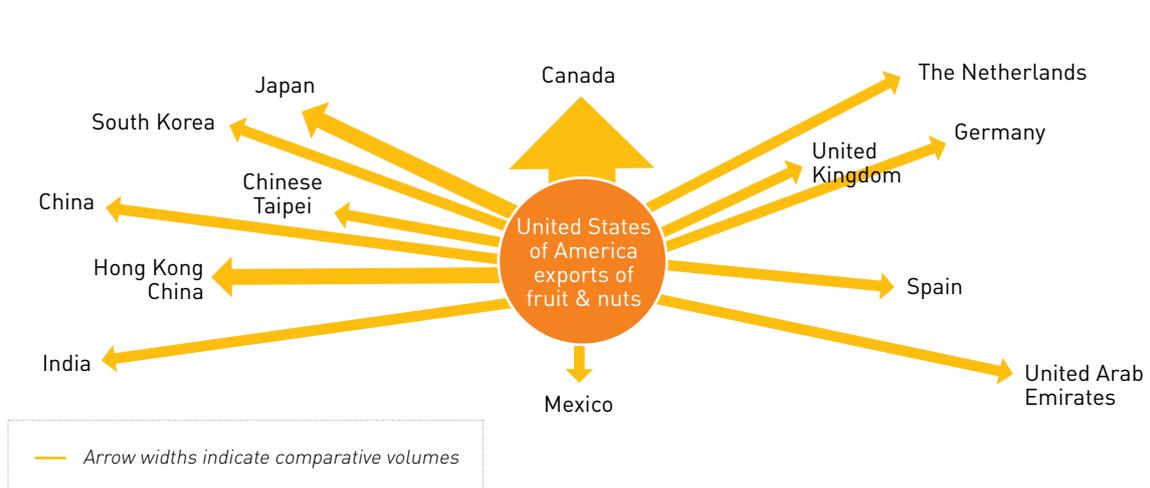
### Trade flows: TURKEY exported US\$3.5 billion in fruit & nuts in 2010

SOURCES : ITC CALCULATIONS BASED ON COMTRADE STATISTICS



### Trade flows: UNITED STATES OF AMERICA exported over US\$10 billion in fruit & nuts in 2010

SOURCES : ITC CALCULATIONS BASED ON COMTRADE STATISTICS



#### Thought Challenge #9

Buying locally grown food is very commendable.

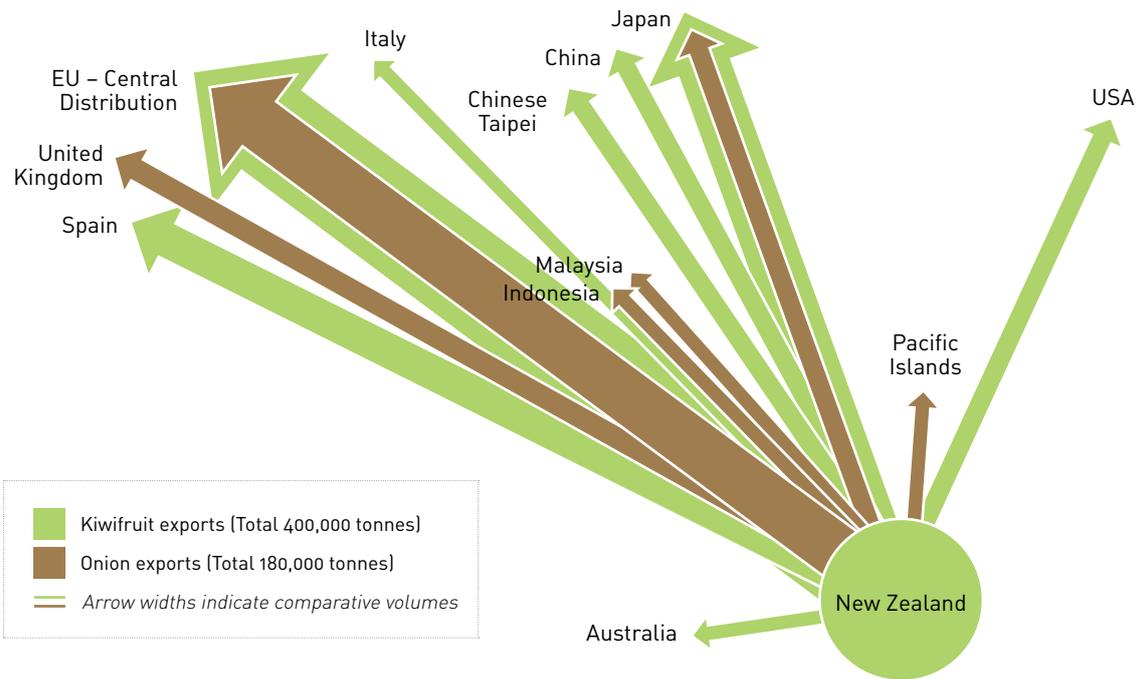
*Q. Some commentators believe that we should all grow food locally – but how far are you prepared to go? For example, are you prepared to stop drinking coffee – or stop eating bananas and other tropical fruit – and not have rice?*

The diagram below is an illustration of export trade flows of horticulture from a predominantly agricultural exporting country. In this example, New Zealand exported 400,000 tonnes of kiwifruit in 2010 to 59 countries of which 92% are represented

by the green arrows in the diagram. In the same year, New Zealand also exported 180,000 tonnes of onions to 47 countries, 85% of which are indicated by the brown arrows. In both examples the destinations are global.

**Example of trade flows of an exporting country distant from its end markets: Kiwifruit and onions exported from NEW ZEALAND (year to 30 June 2010)**

SOURCES : ITC CALCULATIONS BASED ON COMTRADE STATISTICS



Nut crops (left), bulb (right), flower, fruit and vegetable crops are traded globally in very large quantities. PHOTO (RIGHT): THE INTERNATIONAL BULB CENTRE



Attention to food-grade standards and cool-chain management are critical to ensuring food safety and the attainment of premium quality. Photos: (upper) bean packing, Morocco, (lower) packing for export, Kenya.

## Impacts on crop viability

The strong growth in global markets for horticultural products in both the developed and developing world over the past 30 years has occurred during a period of rising land and labour costs.

The expanded presence of women in the workforce of the developed world has influenced the increase in demand for convenience foods such as prepared salads, fresh-cut fruits, and the increase in food consumed in restaurants. These trends are playing significant roles in future demands for high-value products.

Local and regional markets for horticultural products in the developing world can be expected to increase for many of the same reasons that they have burgeoned in the developed world; namely, education and recognition of health benefits, increased urbanization, improved production technologies and market capacity, and more sophisticated retailing.

### The impact of labour costs

In the developed world increasing labour costs and scarcity of farm labour have significantly impacted the economic viability of some horticultural crops with the following being examples:

- o white asparagus in Germany
- o stone fruit in south-east Australia
- o fresh tomatoes and citrus in the USA
- o apples in the United Kingdom.

Escalating environmental constraints and competition for and from urban expansion are also constraining factors.

### New exporting countries for horticultural crops

A consequence of changing labour costs has been the transfer of much horticultural production from the developed world to the developing world, resulting in a ten-fold net increase in imports of horticultural products into the developed world's markets.

The traditional pattern of production and trade is being challenged by new producers, such as cut flowers from Kenya, apples from China, and processed tomatoes from India. In some tropical countries, temperate crops are being grown at high altitudes – growing strawberries in Thailand is one such example.

The wide diversity within and between species grown in developing countries presents an opportunity for the export of indigenous vegetables to ex-patriots living overseas and for increased novelty and diversity in restaurants and food outlets in international markets.

## Food losses and food waste

About one-third of the food produced in the world for human consumption every year, approximately 1.3 billion tonnes, is either not fit for consumption, or is wasted.

Industrialized and developing countries waste approximately the same quantities of food; 670 and 630 million tonnes, respectively. The amount of food lost or wasted every year is equivalent to more than half of the world's annual cereal crop (2.3 billion tonnes in 2009/2010). It is important to distinguish between loss and waste.

### Food loss

Food loss occurs at the production stage of horticulture and happens mostly in developing countries. This loss results from a lack of infrastructure such as sealed roads, port facilities, coolstores and refrigerated trucks, as well as low investment in food production systems and often from a lack of basic food handling knowledge.

Food losses during harvest and in storage mean lost income for small farmers and leads to higher prices for low income consumers. Appropriate training and the application of scientific knowledge could reduce this loss and have an immediate and significant impact on livelihoods and food security.

### Food waste

Food waste is more a problem in industrialized countries. Consumers in rich countries waste almost as much food (222 million tonnes per annum) as the entire net food production of sub-Saharan Africa (230 million tonnes). Per capita food wasted by consumers in Europe and North-America is 95-115 kg/year, while this figure in sub-Saharan Africa and South/Southeast Asia is only 6-11 kg/year.

At retail level, large quantities of food are also wasted due to quality standards that over-emphasize appearance. Additionally, most retailers have staff that are poorly trained and lack facilities to appropriately manage perishable produce.

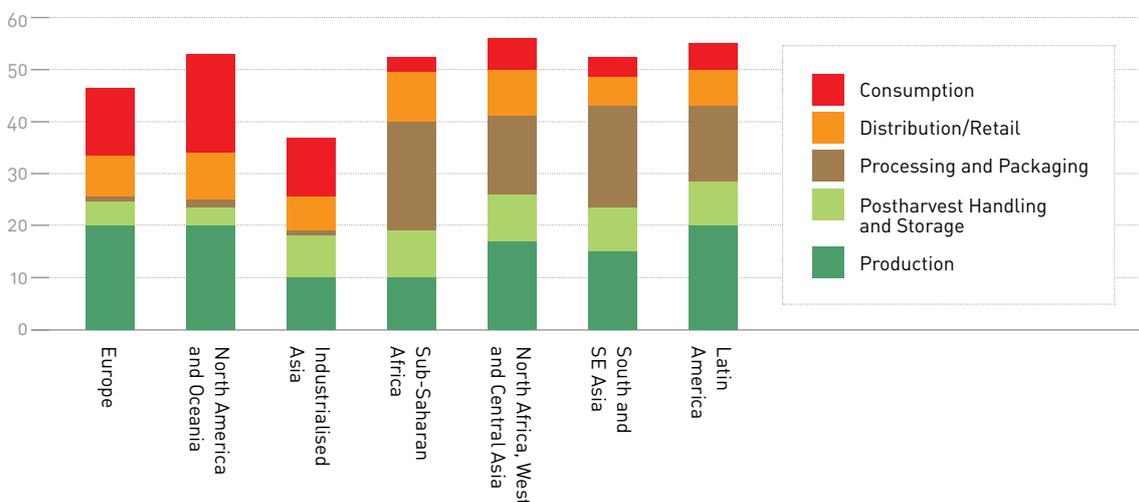
Consumers in rich countries are generally encouraged to buy more food than they need. 'Buy three, pay two' promotions are one example, while the oversized ready-to-eat meals produced by the food industry are another. Restaurants frequently offer fixed-price buffets that encourage customers to heap their plates with the result that the customer does not eat all of what is taken – and the excess goes to waste.

Consumers also often fail to plan their food purchases properly leading them to throw food away when 'best-before' dates have expired.

## Food losses and food waste – fruit & vegetables

SOURCE: DERIVED FROM GLOBAL FOOD LOSSES AND FOOD WASTE  
ROBERT VAN OTTERDIJK AND ALEXANDRE MEYBECK. FAO ROME 2011

% of total production and imports



## CHAPTER SIX

# Health and Wellbeing

Horticultural products are essential for human life and fundamental to the wellbeing of communities. Without horticultural products human life would cease. The human body is designed to utilise the energy stored in plants and nutrients that are not available from any other source.

Good health stems from wellbeing and horticulture contributes to wellbeing in a number of ways, not all of them apparent at first glance.

### Horticulture is all around us

They could be called segments or subsets of the horticulture industry. They are in reality the 'cradles of creation' where the wants and horticultural needs of communities are satisfied by horticulture and the ingenuity of its entrepreneurs and farmers.

These cradles of creation range from large turf farms to gardening centres and from plant and landscape growers to botanic gardens. They include small holdings next to cities, major large-

scale vegetable and fruit farms and orchards, hydroponic growers of tomatoes and flowers, and the sack gardens of high density towns in poor communities.

Many people take the benefits of amenity and ornamental horticulture for granted, but the benefits can be seen in office blocks and holiday resorts, zoos, urban buildings and offices. In every part of the world the harvest of horticulture is on display in the home gardens of those who understand and value the beautifying aspects of growing things. Even the rooftops in some cities have sprouted the greenness of gardens. The beautification of parks and streets, the green foliage on freeways and the ornamental plants that are the essence of urban landscapes are all part of horticulture's bounty.

This huge diversity is collectively the mosaic of the world of horticulture.

## Lifestyle/Amenity horticulture

Lifestyle horticulture, sometimes called environmental, amenity or urban horticulture, largely involves public and commercial entities involved in the production, management and servicing of urban green spaces for environmental, social, economic and health benefits.

The lifestyle horticulture sector includes products, commodities and services that range from ornamental

plants, fruit and forestry plants to cut flowers and the design and maintenance associated with arboriculture, parks, gardens, golf courses, sports grounds and indoor plantings.

It includes turf grass production, nursery and landscape establishment and the services provided by those that supply technical horticultural advice, information dissemination and project management.

### Queensland turf growers

Turf farming makes a significant contribution to the Queensland, Australia state economy. The gross value of production of lifestyle horticulture in Queensland (pop. 4.4 million) from nursery, turf and cut flowers has been forecast at AU\$898 million for 2009/2010. The return per hectare ranges from AU\$30,000 to AU\$60,000.

In 2007 it was estimated that Queensland had 217 turf farms producing just under 5,000 hectares of sod. Farm gate sales had increased to AU\$235.7 million per annum employing 857 full-time, 348 part-time and 116 seasonal workers with total wages and benefits paid to workers amounting to AU\$108.4 million. Most turf farms

in Queensland operate as vertically integrated operations with larger businesses contracting out various processes.

The largest sales segments are homeowners (35%), landscape installation and maintenance firms (20%), commercial or residential developers (18%), with the retail sales via garden centres, golf and sports field venues and brokers making up the balance.

Sales are usually made close to producers, with only 22% of growers selling product out-of-state or to international markets. Export sales only accounted for 11% of total sales value.

## Pennsylvania

Lifestyle/amenity horticulture such as the provision of parks, plants and open green spaces sometimes looks like it is all cost, and a luxury exercise to provide a more visually pleasing environment. Tangible economic benefits are not immediately apparent.

In the south-eastern region of the State of Pennsylvania, amenity landscape has been shown to account for millions of dollars each year in value-adding improvements, in savings, in earnings and in avoided costs.

Homes in the region are on average each worth US\$10,000 more because of access to open space or other horticultural enhancements. This adds a gain of more than US\$16.3 billion to the capital values of property in the State.

Protected open space generates US\$240 million annually in property tax in addition to US\$30 million per year in state and local tax revenue.

If the trees, fields, and forests that filter the water, clean the air, control flooding, and provide other environmental services were to be developed afresh, it would cost more than US\$132.5 million

per year to do what preserved lands already do. The health-related cost savings resulting from physical activity on protected open space amount to US\$1.3 billion per year including avoided workers' compensation costs and avoided productivity losses and reduced risks of cardiovascular disease, diabetes, certain cancers, and obesity. Direct medical costs saved were US\$795 million.

Nearly US\$577 million in benefits accrued annually to residents who participate in recreational activities on protected open space within south-eastern Pennsylvania.

Parks, trails and farms are destinations that attracted visitors who spent millions of dollars in the regional economy that helped to create and sustain jobs in both the public and private sectors.

Regionally, preserved open space accounted for approximately 6,900 jobs annually in industries including agriculture, tourism, hospitality, recreation, and open space management and preservation.



Green spaces enrich our lives in many diverse ways. (Upper left) rugby, New Zealand, (upper right) tennis, Wimbledon, UK. Lower photos: private and public landscaping, New Zealand.

## Quality-of-life interactions with plants

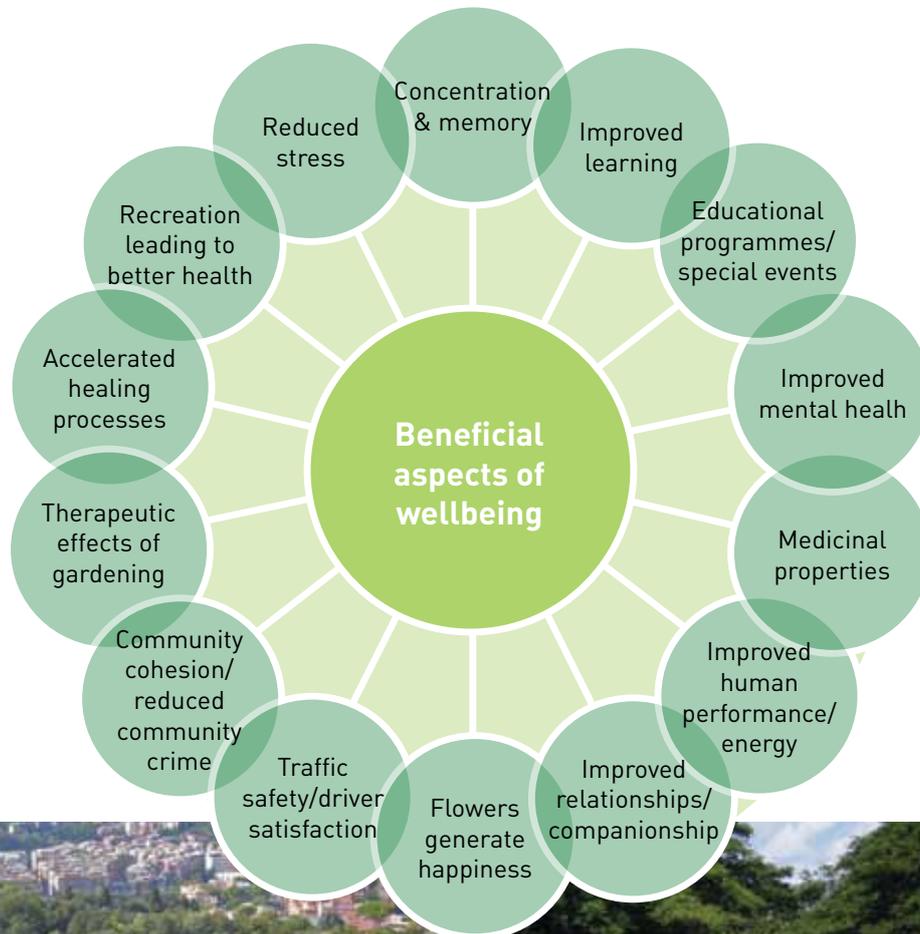
Scientists have developed an integrated model of quality of life and wellbeing, consisting of six major life domains:

- social wellbeing
- physical wellbeing
- psychological wellbeing
- cognitive wellbeing
- spiritual wellbeing
- environmental wellbeing.

The interactions between people and plants intersect each of the six quality-of-life domains.

Who benefits economically?

- Nursery plant and turf growers
- Horticultural service firms providing landscape and urban forestry
- Wholesale distribution firms including importers
- Services such as landscape design, installation, and maintenance
- Home improvement centres and mass merchandisers or other chain stores
- Brokers, transporters and retail operations
- Florists and independent garden centres.

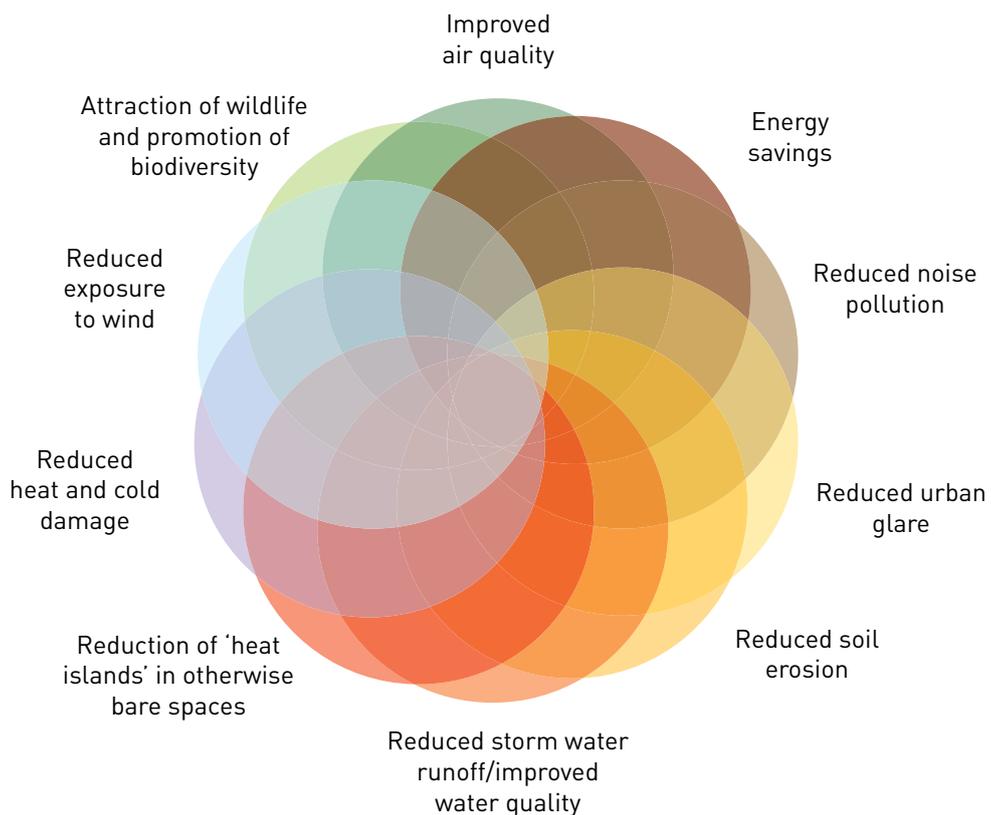


(Left) Papal Gardens, The Vatican, Rome, Italy; (right) Golf course, Apia, Samoa.

## Economic benefits from amenity horticulture



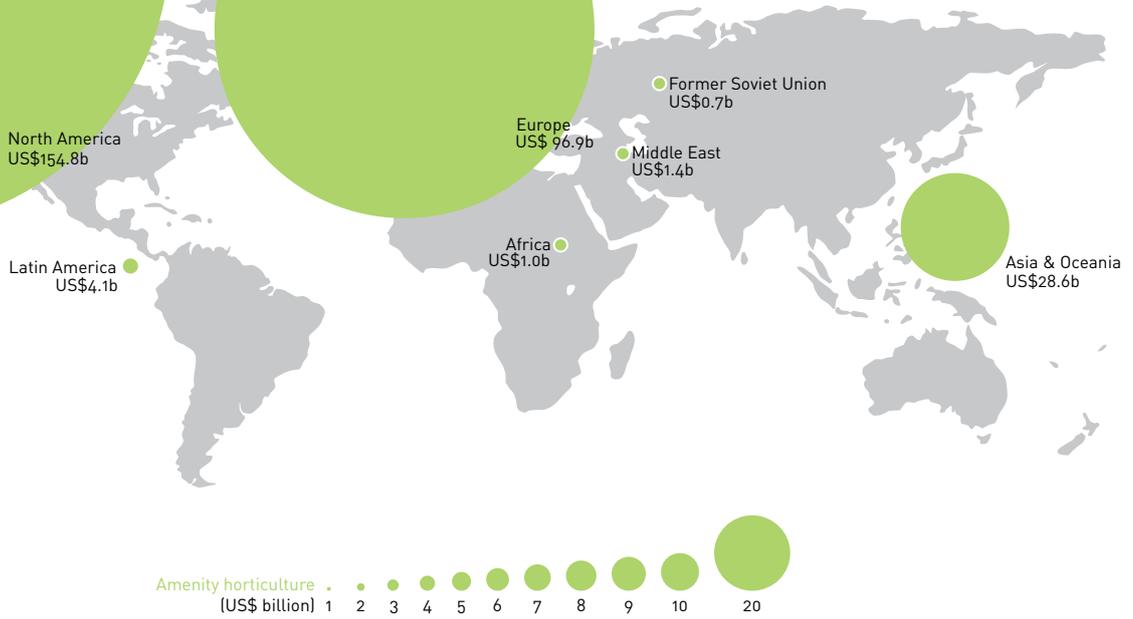
## Environmental benefits from amenity horticulture



### Lifestyle horticulture has significant economic value in developed countries

Total assessed value of regions identified is US\$287.7 billion

SOURCE: HYADU, HALL & HODGES, UNIVERSITY OF FLORIDA & TEXAS A&M, 2008



### World amenity horticulture assessed at almost US\$290 billion value

Parks and open spaces, the pot plants in your buildings and the turfed lawns of suburbia may look purely decorative but in reality they are lifestyle/amenity horticultural economic powerhouses and critical components of productive work environments and healthy communities.

Using a benchmark study as the start point, and adjusting the relative economic value of other

regions of the world, a 2008 study estimated that the economic impact of amenity/lifestyle horticulture was close to US\$290 billion. The study used reference points such as the value of a property beside or close to a park, versus a property that had no connection to a park or reserve. The world map above shows the makeup of the global estimate of the value of amenity horticulture.



Public parks and horticultural exhibitions enrich human lives and experiences.



Landscaping and the use of green spaces can enhance quality of life and human wellbeing.

## Horticulture for improved health

The World Health Organisation recommends a minimum of 400 grams of fruit and vegetables per day, excluding potatoes and other starchy tubers. This serves for the prevention of chronic diseases such as heart disease, cancer, diabetes and obesity, as well as for the prevention and alleviation of several micronutrient deficiencies.

Diets low in fruit and vegetables are typically deficient in a range of nutrients, vitamins and phytonutrients essential for human health.

It has been estimated that insufficient intake of fruit and vegetables around the world causes around 14% of gastrointestinal cancer deaths, about 11% of ischaemic heart disease deaths and about 9% of stroke deaths globally.

A measure of the potential life lost due to premature mortality and the years of productive life lost due to disability is known as a Disability Adjusted Life Year (DALY). By this measure approximately 16.0 million (1.0%) DALYs and 1.7 million (2.8%) of deaths worldwide are attributable to inadequate or low fruit and vegetable consumption.

Micronutrient deficiencies, which affect more than two billion people worldwide, increase disease susceptibility in all populations and compromise the development of cognitive capacity in children. It is well established that healthy diets improve the learning capacity of children and the productivity of workers.

Obesity, epidemic in the developed world and rapidly gaining in the developing world, is best combated by shifting consumption from processed starch-based foods towards consumption of fresh horticultural crops.

The recognition that greater consumption of fruit and vegetables has beneficial health outcomes is becoming increasingly widespread in the developed world and underscores the likelihood of increased demand.

In contrast, micronutrient-deficient diets lead to reduced mental and physical development, poor performance in school, loss of productivity in the workplace, and the likelihood of poverty in future generations.

### A mix of fruit and vegetables add value to daily health

A balanced diet that includes deeply coloured fruit and vegetables that provide vitamins, minerals, fibre and phytochemicals, is needed to maintain good health, protect against the effects of ageing and reduce the risks of cancer and heart disease.

Eating plenty of fruit and vegetables can help you ward off heart disease and stroke, control blood

pressure, reduce risks from some cancers, avoid a painful intestinal ailment called diverticulitis, and guard against cataract and macular degeneration, two common causes of vision loss.

The colour of fruit and vegetables is important.

## 5+ A DAY

'5+ A DAY' is the name of a number of programmes in countries such as Australia, France, Germany, United Kingdom, and the USA to encourage the consumption of at least five portions of fruit and vegetables each day. These programmes follow requests by the World Health Organization to consume at least 400 grams of vegetables daily.



### Red

Contain phytochemicals such as lycopene and anthocyanins with potential health-promoting properties.

*Includes:* red apples, cherries, cranberries, red grapes, pink/red grapefruit, red pears, raspberries, strawberries, watermelons, beets, red peppers, radishes, red onions, red potatoes, rhubarb, tomatoes.



### Orange and yellow



Contain varying amounts of antioxidants such as vitamin C as well as carotenoids and bioflavonoids, which have health promoting potential.

*Includes:* yellow apples, apricots, cantaloupes, grapefruit, gold kiwifruit, lemons, mangoes, nectarines, oranges, peaches, yellow pears, persimmons, pineapples, tangerines, melons, butternut squash, carrots, yellow peppers, potatoes (yellow fleshed), pumpkin, sweetcorn, sweet potatoes, yellow squash.

### White, tan, and brown

Contain varying amounts of phytochemicals, eg. allicin, found in the onion family.

*Includes:* bananas, brown pears, dates, white nectarines, white peaches, cauliflower, garlic, ginger, Jerusalem artichoke, kohlrabi, mushrooms, onions, parsnips, potatoes (white fleshed), shallots, turnips, white corn.



### Green



Contain phytochemicals such as lutein and indoles, which have potential antioxidant, and health-promoting benefits.

*Includes:* avocados, green apples, green grapes, honeydew melons, kiwifruit, green pears, artichokes, asparagus, broccoli, brussel sprouts, cabbage, beans, celery, cucumbers, endive, leafy greens, leeks, lettuce, green onions, okra, peas, green pepper, spinach, watercress, zucchini.

### Blue/purple

Contain phytochemicals such as anthocyanins and phenolics, which have potential antioxidant and anti-ageing benefits.

*Includes:* blackberries, blueberries, blackcurrants, purple grapes, plums, prunes, raisins, purple cabbage, eggplant, purple Belgian endive, purple peppers, potatoes (purple fleshed).



## Food and drug industries converge

Some horticultural crops are grown for their health benefits alone. This new genre of products are called 'Nutraceuticals'. These are aimed at slowing or preventing illnesses and include a number of foodstuffs recommended by doctors.

Nutraceuticals began with energy drinks and probiotic yoghurts and have now attracted the attention of food and beverage giants such as Nestlé, Danone and Pepsi. On the horizon is the research-backed development of plant-based health products to help combat diabetes, heart problems and Alzheimer's disease.

According to Euromonitor, the nutraceutical market is expected to be worth US\$175 billion worldwide. Their development has put products derived from horticulture in the same market as pharmaceuticals.

This will provide a different market channel for horticultural products with sales more often than not driven by a doctor's prescription. Nutraceuticals have better profit margins by about 20 to 25%. Sales to hospitals instead of retailers could mean that margins might be larger. In some health systems, insurers will reimburse payment for many products perhaps resulting in consumers being less conscious of the actual price of products marketed through the medical channel.

Food companies may prosper in the area of health plants when they are closer to the customer and understand their needs. Charles Mills, of Credit Suisse, said, "*The drug industry has very strong R&D but the food companies have the marketing skills.*"

## Science is targeting vegetables with high health benefits

Vital Vegetables® is a joint research programme between the New Zealand and Australian horticultural industries to develop new vegetable cultivars with increased levels of healthy compounds such as antioxidants.

The first of these products, Booster Broccoli™, contains significantly higher levels of the antioxidant sulforaphane (often abbreviated to SF) than other varieties of broccoli, giving it 40 percent more active antioxidants than regular broccoli varieties. SF is a long-lasting antioxidant that may enhance good health and wellbeing including protecting the body against DNA damage which may prevent tumour formation and development.

These vegetables are grown using traditional growing and farming techniques that employ sustainable farming practices, including minimal fertiliser and water use.

Research is continuing on other antioxidant-rich vegetables including tomatoes, corn, capsicum, cauliflower and lettuce. Genetic engineering has not been used in the development of these exciting new products.



Broccoli PHOTO: NZ INSTITUTE FOR PLANT & FOOD RESEARCH LTD

## Thought Challenge #10

Consumers have become dependent on the year-round supply of many fresh fruit and vegetables, for example lettuces, strawberries and pineapples.

*Q. Are consumers aware of the diverse origins of the fresh produce that they may be consuming?*

## CHAPTER SIX

# Outlook for World Horticulture

The choice of whether to plant a crop or not to plant, and what to plant, has faced farmers ever since crops were first planted.

In our present world, the task of feeding a hungry world stretches out far beyond the responsibilities of growers, but in the face of increasing demand and in spite of natural disasters of all kinds, farmers have risen to the challenge and enhanced the supply of food.

There are many parts of the world where production is below what could be achieved given the soils and the climatic conditions prevailing. Movement from this underperforming level to a 'normal' level of production in these regions will be an exciting part of the future of horticulture.

The adaptation of growers, supply chain operators, transporters and scientists in raising the levels of

quality and production in the last three decades has been huge. Production has been prodigious. Products are improving in quality and freshness.

Growers are providing many new cultivars to both northern and southern hemisphere markets to provide year-round supply and to be closer to major markets. Product diversity in world markets continues to increase with crops such as blueberries, mangoes, rocket lettuce, bok choy, and dragonfruit being readily available.

Biotic stresses such as pest and disease damage account for 10-30% of yield losses while abiotic stresses, such as nutrient and poor water management, account for 70-90% of yield reductions. Scientific knowledge is helping to provide answers to the difficult dilemmas facing all areas of the horticultural industry.

The rich diversity of horticulture provides opportunities to improve human health and wellbeing for all.



Elsewhere in this publication reference is made to the significant value that lifestyle and amenity horticulture adds to peoples' lives. The understanding and appreciation of this value is expected to increase as people recognise the importance of achieving a healthy lifestyle and a healthy environment. There

remain many parts of the world's cities and landscapes that can be transformed by the planting of amenity and lifestyle plants and flowers.

Whilst the foreseeable future has a number of challenges and opportunities, the future of horticulture is full of growth, potential and promise.

## Consumer behaviour and profiles

Many opportunities for horticulture arise from a number of the current challenges.

It is important that producers and marketers understand the basis upon which consumers buy food, as availability and price are not the only criteria as is demonstrated in the following two graphs from different markets.

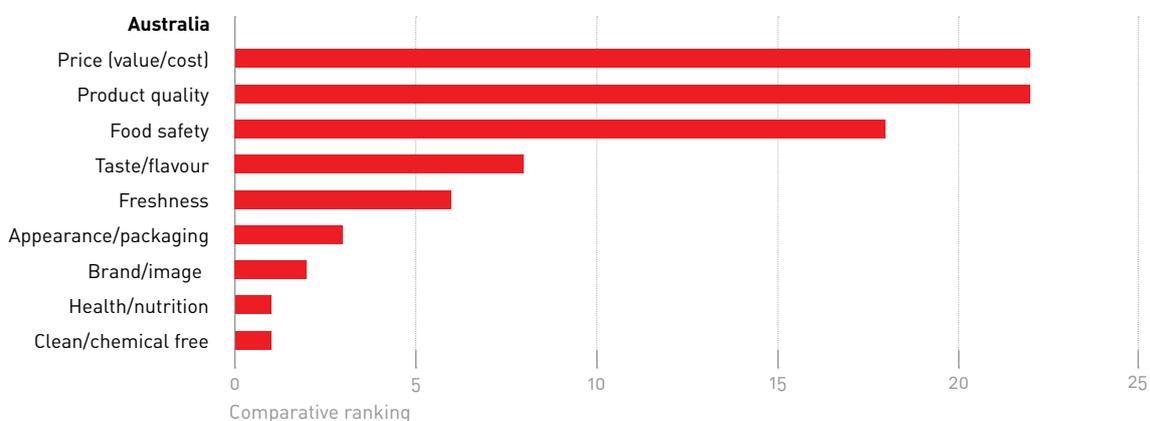
It is also important to realise that consumer behaviour changes over time as their knowledge and incomes increase and social influences change.



Modern consumers have a wide choice in what is available to them but are discerning in what they purchase. PHOTO: UNIVERSITY OF CALIFORNIA, DAVIS

### Food attributes influencing consumer purchase decisions (as nominated by market)

SOURCE: BEYOND PRICE AND QUALITY, DEPT OF RURAL AFFAIRS, VICTORIA, 2004



### Thought Challenge #11

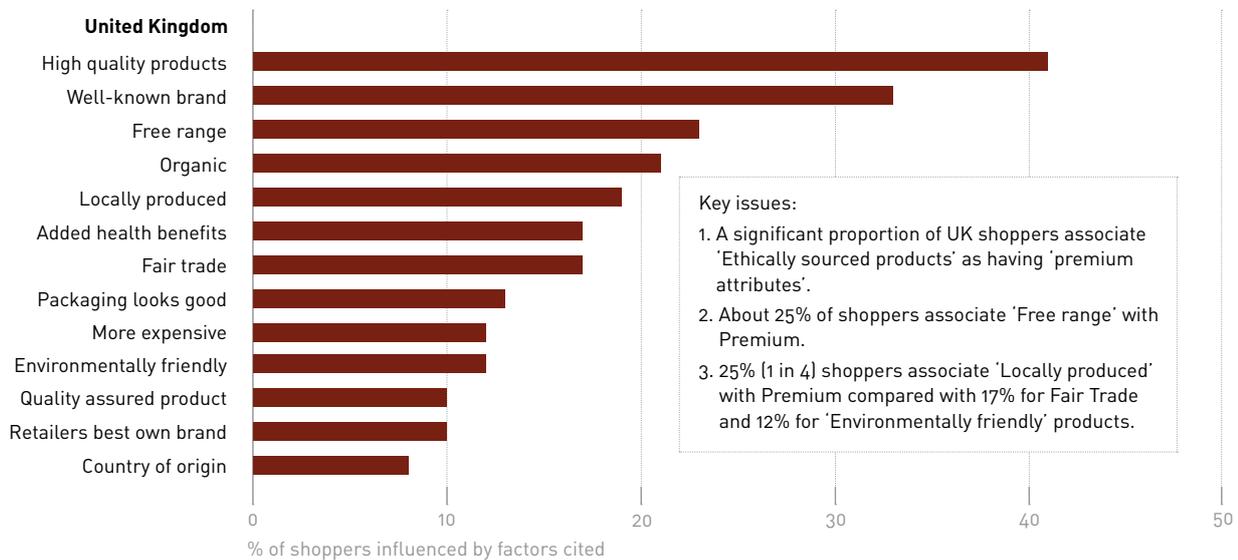
Much is made of the 'carbon footprints' that are generated as a consequence of shipping fresh produce from distant producers.

The reality is that sea freight is highly efficient and carbon footprints for many products can be predominantly from inefficient production practices, road transport through distribution chains and inefficient consumer behaviour. Fruit and vegetables shipped from the Southern Hemisphere to Europe often have smaller carbon footprints than similar produce grown and then carried by road transport within the EU. In some instances the consumer makes a larger carbon footprint after purchase, for example by driving to a supermarket to purchase a single product.

*Q. Are consumers aware of where carbon footprints occur – or do they solely think in terms of freight from another continent?*

### Food attributes influencing UK consumer purchasing

SOURCE: ADAPTED FROM IGD GROCERY AND SHOPPER SURVEY 2007: "WHAT NEXT FOR PREMIUM?" (N=1,017 UK SHOPPERS)



### Psychographics: consumer profiles

Psychographics, the study of shopper identification in relation to attitude to food, is a key part of the purchase equation. An IGD, Shopper Trends in Product and Store Choice, 2007 study offered the following profile:

*Foodies* – those who enjoy cooking, trying new things and cook meals from scratch (40%)

- Younger people, women, higher incomes.

*Traditionalists* – always eat the same thing, not adventurous with food choices (29%)

- Older shoppers, lower incomes.

*Economists* – shop to budget, interested in value for money (18%)

- More than 65 years young, limited incomes.

*Fuelies* – not interested in food, eat because they have to (13%)

- Males, low incomes.



Consumers vary widely in their purchasing behaviours. Above: apples and green beans. PHOTOS: UNIVERSITY OF CALIFORNIA, DAVIS. Left: Nuts & ginger, Borough Market, London, UK.

## Consumer trends

A consolidation of consumer trends identified from several sources leads to the following conclusions:

- Consumers will continue to seek products that are healthy, convenient, providing good value for money
- As incomes rise, consumers will look for excitement and difference in food experiences and will allow themselves to indulge in the tastes and flavours of new foods from different countries and regions of the world
- Consumers seek products that will aid them in disease prevention, self-treatment for health, appearance and general wellbeing, and risk prevention
- Purchasing decisions will be influenced by labels such as ‘SuperFoods’, ‘nutrient dense food’ or ‘high density foods’ all of which have a connotation of specific high concentration health-conferring beneficial attributes.



The range and diversity of fruit and vegetables available to consumers continues to increase. (Left) chirimoya (custard apple) and (right) jalapeno peppers. PHOTO: D. KARP (RIGHT)

### Consumer knowledge and demands – the future

Consumers of the future will be better informed and no less choosy than today. The internet will give them the opportunity to see what is available. Buyers of the future may survey a range of horticultural products on three dimensional screens and from those images decide to order produce to be delivered directly from wholesalers or growers.

The ability of enterprising growers to use technology and improved transport and presentation methods to access changing and faster channels to markets may change consumer preferences and lead to whole new industries.

More effective production methods in developing countries and the migration of peoples to the developed world may give growers new opportunities to produce horticultural products, first to ex-patriots and then to the wider public. What was once exotic to some is becoming commonplace to many consumers.

The onward progress of information and communication technologies will also lead to changes and new opportunities. Telephony, especially in the form of mobile phones and tablet computers, will deliver timely and effective science, education and knowledge to a wider range of growers (and indeed consumers) than at present.

The imperative for better information management, monitoring of produce volumes, prices and timely placement, and the opportunities for extension education will doubtless multiply.



Borough Market, London, UK.

## Food loss and food waste

Food loss and food waste amount to a major squandering of resources, including water, land, energy, labour, capital and infrastructure. Developing countries will come to recognise that, given the limited availability of natural resources, it is more effective to reduce food losses than increase food production to feed a growing world. This realisation will inevitably lead to a stronger commitment to improving food quality at the

production point, improving grading methods and standards, and improving cool-chain distribution facilities. The net gain of available food will be huge.

In developed countries where food waste is a high proportion of all food that progresses past retail, needlessly throwing food away will become increasingly unacceptable as resources in all forms become more valued.

## Technology and infrastructure

Much of the fruit and vegetables produced globally and sold locally is not sorted or graded. If more investment in technology was made in postharvest production many growers could achieve better prices, make better use of resources and be more profitable.

Increased emphasis and investment in complying with food safety standards, technology and knowledge would open wider market opportunities for smallholders especially. The gathering of small unit holders into cooperatives and/or the growth of independent, well financed contractors who could service a number of growers would also improve profitability for many growers.



Improving fruit and vegetable grading and storage in many markets will reduce wastage and enhance returns. Photos (left) Delhi fresh market, (right) Morocco fruit and vegetable market.

## Energy costs

The fuel component of production and transport costs is rising. It may pose an issue in relation to year-round provision of some crops. There could be an increased need to grow some products nearer to sites of consumption.

Rising fuel prices will be challenging. Whilst an estimated 93% of horticulture is consumed locally there is nevertheless a large volume that is exported to other countries. Where intensive

horticulture is practised in protected environments such as greenhouses, management of input costs such as energy, nutrients and fertilisers, is critical to maintaining viable quality outputs and viable enterprises.

In developing countries, energy for horticulture has traditionally come from labour, but there too the cost is rising and becoming an issue.



A diverse range of fruit (left) and vegetables (right) is available to consumers.  
PHOTOS: NZ INSTITUTE FOR PLANT & FOOD RESEARCH LTD

## Climate variability

The current focus on climate variability will give horticultural scientists the opportunity to develop new cultivars and innovative growing systems through research and development. Climate changes will place more emphasis on the development of knowledge systems and technology to monitor water, nutrient, pest and disease factors and so lower plant stresses. New cultivars will have to be developed that adapt to changing temperature conditions. The opportunity will be available to evaluate plant genetic material stored in gene banks and with future climate variability in mind, to seek new varieties from the wild.

It is therefore essential to collect the seeds of wild relatives of fruit, vegetable, root and tuber crops and ornamental plants before they disappear. Some invaluable collections do exist and it is increasingly possible that these collections could make a contribution to maintaining sustainable and viable production in the face of climate variability.

It is also possible that changes in climate will reduce food production in some zones where temperature and radiant energy levels change and lead to an increase in food production in other zones where viable production becomes possible.

## Climate change impacts – grape wine production

A study in New Zealand considered the impacts that climate change might have on the growing of grapes for wine:

- Drier growing seasons – increased water demands
- Drier seasons – fewer fungicide sprays required
- Warmer growing seasons – earlier bud break and exposure to frost damage
- Warmer growing seasons – shift to new varieties
- Shorter vintages (the time between budbreak and harvest) and maybe lower yields
- Lower fruit acid concentration due to higher (night) temperatures
- Shift of production to growing areas that are currently marginal.

## Competition for water

With a growing world population and rising standards of living, water usage by urban populations will increase. This will include demands for recreation and concerns to protect water reserves for wild-life and conservation. Industries will also need more water. These and other segments of future societies will be competing with horticulture (ie. food production) for available water.

The intensive nature of horticultural crops requires reliable and consistent water supplies to optimise productivity and quality. Globally 70% of all water

used is in the many forms of agriculture.

In some regions of the world, water has been mined indiscriminately for many years by tapping into underground reservoirs formed during previous ice ages. In some places, the water being used is said to be 1,000 years old and is clearly not a renewable or sustainable resource.

It is indeed possible that shortages of water could limit production of fruit and vegetables if priority is not given to the use of this resource for food production.



Crop mulching can help to conserve water in the soil and efficient irrigation systems can enhance water use efficiency.

## Automated irrigation and nutrient management

The water needs of plants change day-by-day and season-by-season as plant needs for water depend on a number of environmental and plant development factors.

Wireless sensor networks have been developed enabling real time capture and collation of the information within the root zone of crops. This allows irrigation and nutrient application to be more precisely scheduled by accurately monitoring the real-time water use of plants with substrate moisture and temperature sensors.

Such methods assist to reduce water use, leaching of nutrients and overall runoff from intensive plant growing operations.

Other sensors that simultaneously measure air temperature, canopy relative humidity, leaf wetness, and photosynthetically active radiation will allow modelling to better predict plant stress and disease pressure.

These systems can all be monitored and managed via the internet.

## Thought Challenge #12

The global area of irrigated land doubled in the 30 years between 1950 and 1980 because of the construction of dams. Aside from construction in China, few dams have been developed since.

*Q. In the years ahead, where is irrigation water for increased crop production going to come from?*

## Water measurement

To ensure production remains viable and sustainable, measurement and management of water is crucial in all areas of horticultural activity including those associated with food production and also amenity and ornamental horticulture.

One key area requiring attention is improving the ability of countries to implement effective systems for 'water accounting' – the thorough measurement of water supplies, transfers, and transactions as the basis for informed decisions about how water resources can be managed and used.

Water accounting in most developing countries is very limited, and allocation procedures are non-existent, ad hoc, or poorly developed. Helping developing countries acquire good water accounting practices and developing robust and flexible water allocation systems is a major priority.

Horticultural scientists can provide underpinning information on a wide range of plants to help inform these important decisions

## Virtual water

The concepts of 'water footprints' and 'virtual water' can be helpful to understanding and optimising the use of water.

'Virtual water' is the volume of water used to make a product and is the sum of the water used in the various steps of the production chain. Virtual water consists of three components:

- (i) Green water being rainwater stored in soil and transpired by the plant
- (ii) Blue water which is water drawn from surface and groundwater reservoirs and irrigated onto soil
- (iii) Grey water which is water used during production and is of a lesser quality than Green or Blue water.

A virtual water calculation has been applied to the gross volume of water from all sources (average global virtual water content) that is needed to produce a single cup or glass of end-product. Such calculations gave the following results: 200 litres for milk, 140 litres for coffee and 120 litres for wine.

### Virtual water required varies with growing environments

A virtual water calculation was applied to a typical tonne of apples produced in three southern hemisphere production areas: if grown in Australia 735 cubic metres (m<sup>3</sup>) of water was required, if grown in Chile 245 m<sup>3</sup> was required and if grown in New Zealand, 141 m<sup>3</sup> was required. Virtual water calculations for kiwifruit were similar; it takes five times as much water to produce kiwifruit in Australia as compared to producing the same or similar crop in New Zealand.

This result is largely because of the more arid growing environment in Australia as compared to New Zealand.



Kiwifruit blossom

With better measurement of the water profile and footprint, consumers and growers may be able to make better choices in consumption which could lead to optimising water use. It is, for instance, possible to use a dwarf rootstock and improved canopy management to halve the water use per tonne of apples produced.

At the farm level, growers can change their cropping patterns to allow earlier or later planting, reducing their water use and optimising irrigation. Yields and productivity can be improved by shifting to soil moisture conservation practices, including zero- and minimum tillage. Planting deep-rooted crops would allow farmers to better exploit available soil moisture.

## Nanotechnology

Nanotechnology is the scientific term for the engineering and technology of the very, very small.

And the world of the very small is going to make a very big contribution to horticulture in the years ahead. Nanoscale science involves the understanding of the physical, chemical, and biological properties of matter at the length of scale of approximately 1 to 100 nanometres.

And a nanometre is really small. A sheet of paper is about 100,000 nanometres thick. A pin head is one million nanometres across. A human hair is approximately 50,000 to 100,000 nanometres in diameter.

In horticulture, nanotechnology has the potential to enhance the quality and value of food and non-food crops. It has a contribution to make in pest, disease and weed control and improvement of soil processes.

Preharvest nanotechnology could provide bio-sensors and diagnostic instruments for monitoring plant disease and environmental stresses enabling sustainable and precise production methods.

Other examples are micro sieves for separation and fractionation which can also improve emulsification processes in food processing. This would allow the use of drug delivery concepts for nutrient delivery and the enhancement of the nutritional quality of food products.

Postharvest technology improvements from nanotechnology could include better waste management and improved permeability characteristics in packaging materials. Such packaging could combine printable electronics and low cost sensors to inform the customer about the product and its quality.

These new instruments will enable much faster measurements in or near production lines by non-expert personnel. Nanotechnology will also result in new concepts for food production processes. It could even give rise to totally new products that at present we can only imagine.

## Automation and robotics in horticulture

Robots and automation processes are finding many uses in horticulture.

Automation and robotics reduce overall labour costs and increase the consistency of quality and safety during production and postharvest cycles. Mechanical harvesting is currently largely restricted to products destined for processing such as grapes for wine, olives, sour cherries, tomatoes and citrus. This is because of the physical damage that can occur during harvest.

Robots in horticulture are widely used in some nursery industries for producing transplants, especially with vegetable plants for grafting, and for planting vegetable seeds and plantlets in both greenhouses and open fields.

### Labour costs

Use of robots in the developed world is driven by the cost of labour and its availability. These two factors threaten to make many crops uneconomic. In the USA, labour costs have increased in the past decade from 38% of the net value of the farm economy to 58% currently. If the trends continue some farms will become uneconomic.

Many of the tasks associated with horticulture, such as picking, pruning, pest, disease and weed control, are repetitive and arduous. Such tasks seem ideally suited to robots.

The fruit industry in the USA is recognising that if it is to survive economically, it is fundamental that their costs are lowered significantly. Robotics and automation seem the only options to achieve this reduction in costs.

### What robots can do

Robots can contribute to the early detection of pests and diseases through the application of remote sensing technologies, in the monitoring of plant health, assessing crop value, reducing the amount (and cost) of sprays and nutrients (through the imaging of micro stresses caused by localised infections), increase in the efficiency of labour (by providing mechanical aids to humans) and to the reduction of damage to crops at harvest.

### Challenges of using robotics in horticulture

Designers of robots for fields and orchards face a daunting task. Robots have to 'see' the paths between the produce and they need to 'know' which areas have already been harvested. They need eyes to see the trunk of a tree and to separately identify fruit, flowers and leaves. Their arms need to be able to pluck, prune, spray and pollinate.

They have to be strong enough to handle rough terrain, sloping ground and mud. They must also be able to handle fragile fruits and berries which bruise easily. After avoiding all the people, poles, wires, stumps and rocks, robots need to be able to work near other robots without getting in their way.

Their economic use poses a number of problems. Some horticultural tasks such as fruit picking last for only a few months of the year. It simply is not profitable to use a robot for such a short period. Robots may have to be multifunctional and be able to pick, count buds, prune, and pollinate to ensure a reasonable return on their cost.

### Fruit picking robots

Examples of fruit picking robots in development and/or in early stages of use:

#### Oranges

*Italy:* System that uses GPS way points to navigate in the orchard; 8.7 second picking cycle, fills bin.

*USA:* A scout robot forms a 3-dimensional map of the location of fruit and an eight-arm picker robot gathers the fruit.

#### Apples

*Belgium:* Robots that pick 85% of crop at a 9 second cycle.

*USA:* Developing and testing technologies including navigation and augmented harvesting of fruit.

#### Strawberries

*Japan:* Operates in a greenhouse; 10 second cycle – provided fruit is trained to grow over the edge of the container.

#### Kiwifruit

*New Zealand:* autonomous visual navigation of orchard rows; pick rate 0.25 seconds (1 fruit per second for each of four 'hands'), gentle fruit handling and bin filling; automated bin replacement.



Top: Mechanical harvesting of cherries; experimental unit in Michigan, USA.  
Above: Automated tray transfer in greenhouses. PHOTO: WAGENINGEN UR GREENHOUSE HORTICULTURE, THE NETHERLANDS

## Superfoods

Although the term has no official definition, the term 'superfoods' has been widely promoted in marketing circles and applies to nutrient dense foods that are believed to have more significant health benefits than any other type of food because of their specific phytonutrient content.

There are five key criteria considered necessary for superfruit success namely novelty, health benefits, convenience, controlled supply and promotion.

From Goji berries to broccoli the amount of fresh produce claiming superfood status seems to be growing all the time. Trends in selected countries have seen a boom in superfoods and numerous superfood status products are enjoying buoyant sales, especially in the USA where the concept is more widely promoted.

In the United Kingdom the media have laid emphasis on the message that common diseases, such as heart failure, diabetes and cancer, can be prevented largely by eating a well-balanced diet. As a consequence the concept of superfruits and supervegetables – foods that contain high levels of disease-fighting nutritional compounds is having a huge impact on the United Kingdom fresh produce sector.

Superfoods span a vast array of foods, usually encompassing those with high antioxidant contents, including fruits and vegetables such as pomegranate, broccoli, blueberries, spinach, pumpkin (and even red wine and dark chocolate).

These intensely coloured, highly flavoured and attractive fruit and vegetables contain high concentrations of functional chemicals (bioactive compounds) including polyphenols, anthocyanins, carotenoids, vitamins (especially B, C and K), minerals, folic acid, fibre and a range of other components that are known to positively affect human health. Berries in particular have been the centre of increased research attention over the past few years because of their high antioxidant activity.

Red, orange, yellow and purple fleshed fruits and vegetables have greatest antioxidant activity plus an increasing number of health conferring attributes. For example, blueberries are considered a superfood because they contain significant amounts of antioxidants, phytoflavonoids, vitamin C, and potassium, all of which provide important health benefits.

Some consider the 'flagship' superfoods to be blueberries, spinach and salmon because of their particular nutrient attributes. Fruit and vegetables dominate listed 'superfoods'.

Note: the EU has banned use of the term 'superfruit' on labels unless specific nutritive and health attributes have been scientifically demonstrated; this is a consequence of there being too many spurious claims.



Many fruit and vegetables are very high in antioxidants. (Left) blueberries and (right) spinach.  
PHOTOS: NZ INSTITUTE FOR PLANT & FOOD RESEARCH LTD



A diet that is rich in fruit and vegetables can enhance human health. (Left) fresh peas and (right) blackberries.  
PHOTO (RIGHT): D. KARP

## What horticulture can expect

Some predictions for horticulture include:

- State-provided farm advisory services will decline further with time. An example comes from the Chilean horticultural sector where since 2000 there has been a marked increase in non-governmental extension services and industry-supported research programmes. Similar trends have occurred in New Zealand.
  - Farmers will organise into groups or associations to achieve collective power, and to advocate for the importance of their sector to urban populations and urban-based politicians.
  - ‘Champions’ will emerge who can provide local and/or regional leadership in key areas that will be essential to achieve much needed improvement in:
    - technical and marketing networks
    - information on postharvest technology
    - supply chain management concepts
    - marketing systems and channels.
  - Having too few advisory agents relative to the number of farmers needs to be addressed to optimize production, the use of scarce resources and to feed populations.
  - The creation of discussion groups and workshops to interact with advisors to provide the vital linkages between knowledge and practice.
  - The establishment of demonstration farms and postharvest facilities for development work and technical training that are vital for countries committed to developing their horticultural sectors – even without expanding farm resources.
- Increased utilisation of modern information transfer tools for information gathering and knowledge sharing and dissemination. The basic tools exist right now in the form of mobile phones, and increasingly cheaper internet-connected smartphones and computers. Access to these facilities and the infrastructure to populate, train and maintain systems need to be a funding commitment for many countries.
  - Governments will continue to provide vital infrastructure such as roads (to give access for cultivation, crop maintenance and harvested produce), plus the enabling resources of electricity, cool chains and port and quarantine standards that are beyond the scope of individual farmers.

Private-public cooperation may provide:

- Establishment of post-harvest facilities including packhouse, coolstores and processing factories.
- Specialised workshops covering topics such as: postharvest and supply chain management including product physiology (maturity, ethylene, temperature), coolstore design and operation, precooling, temperature and inventory management and food safety.
- Specific R&D projects are increasingly being enabled by the private sector participating in initiatives that also receive public funding.

## Commentary – Advocacy

By harvesting the sun in combination with the use of quality seeds, water, growing media and ingenuity, fruit, flowers, vegetables and ornamentals make horticulture a critical and vibrant part of our growing world.

International trade in fruit and vegetables is massive, but few people have an appreciation of the extent and complexity of horticulture. For many people horticulture is gardening, but the span of horticulture is very broad and its outputs are vital to the health and quality of life for virtually all people.

The value of fruit and vegetables in export trade is calculated to be US\$180 billion annually – but an estimated 93% of these crops are grown and consumed locally. Worldwide production of fruit and vegetables exceeds 2.4 billion tonnes. Amenity horticulture worldwide produces parks, gardens, sports fields, and many ornamental applications (such as indoor and office plants), and is calculated to add close to US\$290 billion in economic value to peoples' lives.

### Education and training

The capacity of horticulture to provide nutrition, health and wealth, will not be sustained without recognition of the complex factors that underpin the current production of fruit, vegetables, flowers, and ornamental plants.

New products and processes will require the continuing application of advanced scientific and technical knowledge, and skilled management by producers and others in the supply chain. Support for the sustainable growth of horticulture in all of its dimensions – physical, economic, environmental, and social – will require investment in education and training if vital information is to be available at the appropriate levels.

Educational resources in horticulture are being progressively reduced in developed countries where food supply is increasingly being taken for granted. These resources are increasing in developing countries where their value is being increasingly recognised.

### A shift in fruit and vegetable production focus

Horticultural crop production is increasingly shifting from countries with high land, labour and energy costs (as in the developed world), to other countries with lower input costs (such as Thailand, Vietnam, Kenya, Morocco and Mexico). This shift is markedly changing the patterns of world trade and in some places raising concerns about food safety and the environmental impact of 'fuel miles'.

### New jobs and economic opportunities

Horticultural crop production creates jobs – about twice the amount of employment per hectare compared to cereal production, and further jobs from horticulture's more complex and technically challenging supply chain. In developing countries, the move from animal grazing and staple crop production towards high-value horticulture crops is an important contributor to employment opportunities and income enhancement.

### Improved food security and nutrition

Fruit and vegetables are the most sustainable and affordable sources of micronutrients in diets, providing essential nutrition to those on marginal diets in developing countries and helping to combat the 'rich diseases' (heart disease, obesity) in developed countries.

### Increasing demand – but fewer additional resources

Consumer expectations for high quality, low cost and safe horticultural products are key factors in driving the horticultural industry. Challenging these ideals are access to suitable productive land, limited water supplies, the high costs of land and labour, and the increasing scarcity of fertilisers.

### The need for commitment

If increasing demand for horticultural products is to be met, substantial investment increases will be required in education and research with parallel investment in production, postharvest, processing, and other supply chain facilities and services.

More so than at any previous time in history, disruptions in food supply, crop failures, plant disease and pest outbreaks, and incidents of food contamination will increase. To ignore the increasing needs for training to reduce these hazards is to prejudice food security and the wellbeing of communities.

Maintaining and expanding the worldwide knowledge base in horticulture is critical for horticultural crops to continue to enhance human health, help sustain rural communities, generate wealth along complex supply chains, and enhance peoples' quality of life.



Fresh fruit display, Brazil.

## About this Publication

From the 7,500 science-focussed members who between them present a huge amount of technical data and learning at ISHS symposia somewhere in the world almost every month, relatively few outcomes are shared with the public – who are the consumers of food and the beneficiaries of the knowledge and the wellbeing environment that are the rewards from horticulture.

Our objective for this publication was defined by this observation and by recognising that most people hold a narrow perspective of horticulture.

Many people could therefore benefit from information that could be used by the general public, policy makers, politicians and the general press to showcase the importance of horticulture and research in horticulture. We hope that the material that has been assembled goes some way towards answering the question '*What is Horticulture all about?*'

### Source documents

To assemble this profile of world horticulture, information has been drawn from a wide spread of knowledge that in total would almost be a publication in itself. We apologise to any author who might feel that their information has been used without acknowledgement within the text – and they may well be correct. Our objective is

to share information as a sector-good benefit. To assist readers who may wish to explore the literature further, a list of sources is located on the ISHS website: [www.ishs.org](http://www.ishs.org). The ISHS Board and Executive may consider sequels to this publication and to that end constructive comments and advice will be welcomed.



Thousands of dedicated producers and sellers of fruit and vegetables worldwide take pride in the 2.4 billion tonnes produced annually for consumers to eat. Left: Apples fresh from the orchard, Albania. Right: Retail pride, Lisbon, Portugal.

Facilitated by ISHS, scientists and other professionals worldwide present, exchange and absorb a vast amount of knowledge about horticulture in all parts of the world.



• Top and second row: ISHS International Horticultural Congress, Lisbon, Portugal, 2010. • Middle row (PHOTO M. DOSSETT), above right: 9th Vaccinium Symposium, Oregon, USA, 2008 (Vaccinium: a genus of 450 species, many of which are important commercially and to health including cranberry and blueberry.) • Above left: ISHS International Loquat Symposium, Turkey, 2010. (Loquat: a fruit tree also known as Japanese plum and as Chinese plum.) • Bottom row: delegates at ISHS II International Symposium on Soilless Culture and Hydroponics, Puebla, Mexico, May 2011.

# International Society for Horticultural Science (ISHS)

The **International Society for Horticultural Science (ISHS)** is the world's leading independent organization of horticultural scientists. Dating from 1864, it was formally constituted in 1959 and now has more than 7,500 members representing 150 countries.

**The Structure of ISHS** is based on its 10 crop-related Sections and 14 discipline-related Commissions.

**Knowledge Base:** within ISHS there are more than 125 working groups who between them average one international symposium per week (45-50 symposia per year), with up to 80 scientific horticultural papers presented at a single symposium. Proceedings are published by ISHS: [www.ishs.org](http://www.ishs.org)

**Acta Horticulturae:** a series of scientific/technical publications, mainly devoted to the proceedings of the ISHS Symposia and the ISHS International Horticultural Congress covering the whole range of horticultural sciences. Since 1964 Acta Horticulturae has grown into one of the leading series in horticultural science with thousands of researchers all over the world using this resource to stay in touch with advances in their profession.

The over 49,000 full text articles organised into 900 volumes in Acta Horticulturae are indexed in all major databases including AGRICOLA and CAB abstracts and form the flagship serial publication of the International Society for Horticultural Science.

## ISHS International Board

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### CROP SECTIONS

|                                |                             |                     |                     |                                     |
|--------------------------------|-----------------------------|---------------------|---------------------|-------------------------------------|
| Citrus                         | Banana & Plantain           | Pome & Stone Fruits | Vine & Berry Fruits | Nuts & Mediterranean Climate Fruits |
| Tropical & Sub-tropical Fruits | Medicinal & Aromatic Plants | Ornamental Plants   | Root & Tuber Crops  | Vegetables                          |

### DISCIPLINE RELATED COMMISSIONS

|  |                                      |                                      |                                    |   |
|--|--------------------------------------|--------------------------------------|------------------------------------|---|
| Sustainability Through Integrated & Organic Horticulture | Fruit & Vegetables & Health          | Molecular Biology & In Vitro Culture | Economics & Management             | Education, Research, Training & Consultancy |
| Horticultural Engineering                                | Nomenclature & Cultivar Registration | Plant Protection                     | Irrigation & Plant Water Relations | Plant Substrates & Soilless Culture         |
| Quality & Post Harvest Horticulture                      | Protected Cultivation                | Landscape & Urban Horticulture       | Plant Genetic Resources            |   |

## Notes

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Fruit, Vegetables, Flowers,  
and Ornamental Garden Plants  
supporting Life, providing Food,  
bringing Health and Wealth,  
and creating a  
**Beautiful Planet**



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