Protected Cultivation of Horticultural Crops Worldwide

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Protected cultivation, which enables some control of wind velocity, moisture, temperature, mineral nutrients, light intensity, and atmospheric composition, has contributed and will continue to contribute much to a better understanding of growth factor requirements and inputs for improving crop productivity in open fields. Protected cultivation is a unique and specialized form of agriculture. Devices or technologies for protection (windbreaks, irrigation, soil mulches) or structures (greenhouses, tunnels, rowcovers) may be used with or without heat. The intent is to grow crops where otherwise they could not survive by modifying the natural environment to prolong the harvest period, often with earlier maturity, to increase yields, improve quality, enhance the stability of production, and make commodities available when there is no outdoor production. The primary emphasis is on producing high-value horticultural crops (vegetables, fruit, flowers, woody ornamental, and bedding plants).

Production areas, structures, and crops have been expanding rapidly during the past century (see Sidebar). From the beginning, agricultural production has been primarily outdoors. It is a major industry that is primarily climate- and weather-dependent. In fact, the most determinate factor in horticultural crop production is the climate.
The magnitude of the impact of climate and weather agriculture productivity and quality of the product even now is appreciated only by farmers and a small segment of the scientific community, namely horticulturists, and hardly at all by the general population.

For example, the perceptive document *Agriculture: Toward the Year 2001* (FAO, 1979) makes no mention of climate. Farmers appreciate and fear the impacts of weather. Climate remains the primary factor as to where food and fiber are produced and which crops are grown (Dalrymple, 1973).

Among the greatest constraints in horticultural crop production are a lack of sunlight, temperatures that are either too hot or too cold, moisture deficiencies or excesses, weed growth, deficiencies in soil nutrients, excessive wind velocity, and atmospheric carbon dioxide. Most of these are climatic factors or directly related to them. Many of these constraints have been alleviated or lessened by protected cultivation or controlled environments.

The lack of water is the single most important environmental impediment to plant growth and global food production. Water is our most precious and most wasted resource. The greatest crop losses in the United States from 1930-78 were caused by drought. Losses from drought were almost equal to all other climate-induced losses, including excess water, floods, cold, hail, and wind (Boyer, 1982).

By far, the most intensive and ancient means of protected cultivation of crops is irrigation. Windbreaks, the magnitude of which is not known, provide a second means. By irrigation, crop production has been extended to deserts and semi-arid lands that otherwise would be nonproductive. Many of the hazards of drought have been overcome.

The recent rate of increase of irrigated land has been precipitous. From 1950 to the early 1980s, the crop area irrigated in the world increased from 94 to 250 million ha (Postel, 1989). This increase accounted for 40% to 50% of the increase in agricultural output. While the expansion of irrigation in the late 1980s and early 1990s has slowed dramatically in the United States and elsewhere, some nations, such as China, anticipate further expansion. Today, 17% of the world’s cropland that is irrigated produces a third of the agricultural output. Four countries-China, India, the United States, and Pakistan-contain half the world’s irrigated land. More than two-thirds of all the food in China is produced on land that is irrigated, and more than half of the land in India, Indonesia, and Japan is irrigated. Irrigation technologies for China date back more than 2200 years to the construction of the Du Jiang Weir in what is now Sichuan Province.

World-wide agriculture claims two-thirds of all the fresh water removed from rivers, lakes, streams, and aquifers (Postel, 1993). Further expansion of irrigation is now limited by short water supplies in much of the United States, Russia, China, India, Pakistan, Spain, Italy, Mexico, Chile, and Australia and almost all Mediterranean, Arabian Gulf, and African countries. The high agricultural use of water is increasingly under challenge, from the standpoint of rising food costs and other competitive options such as recreation, municipalities, industry, energy generators, and the current low efficiency (35% to 40%) for agricultural use. Coupled with irrigation of high-value crops has been the rise in the use of the highly efficient drip or trickle systems, which, at the global level, now comprise between 1.5 and 2.0 million ha. Drip irrigation systems are frequently an important component of other structures designed for protected cultivation of horticultural crops.

Controlled-environment agriculture or protected cultivation has now extended far beyond the realms of crop irrigation and water management. The focus of this paper is mostly on structures and technologies, other than irrigation, that have emerged largely during the past century.

### Types of plant protection

All plant species have an optimal range for each environmental factor. Installing a screen or shelter alters the energy and other exchanges between the whole plant (or apart of it) and the environment. The position of the screen or shelter, relative to the plant, determines the kind of protection. In mulches, the screen is located below the above-ground parts of the plant, over the soil. Greenhouses, tunnels, and direct covers are other types of protection, where the screen is placed over the plants as a cover. Windbreaks are placed laterally to the crop (CPA, 1992).

**Windbreaks.** Windbreaks are used for mechanical protection, particularly for vine crops, as protection against the whipping of the wind, which reduces evapotranspiration. Windbreaks enhance early maturity, improve growth, increase production, and result in a better-quality product. The action of wind on crops is direct and indirect. It induces morphological and anatomical changes, similar to those produced by drought; reduces photosynthetic activity, and increases evapotranspiration (FAO, 1986). On bare soils, wind erosion can be very destructive, especially in arid regions and deserts. The main advantage of windbreaks is to reduce crop damage either from breaking and drying, particularly of the stems and leaves of vine crops, or blowing particles that affect the

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