SYMPOSIUM ORGANIZATION, PAPERS, AND AUTHORS

Presiding over the Symposium was Fred D. Cochran, North Carolina State University, Raleigh, Chairman of the Vegetable Crops Section of the American Society for Horticultural Science.

TROPICAL PRODUCTION OF VEGETABLE CROPS, by James E. Knott, University of California, Davis.

EVAPORATIVE COOLING TECHNIQUES FOR REGULATING PLANT WATER STRESS, by Robert L. Carolus, Michigan State University, East Lansing.

PLANT RESPONSES TO NEAR-ULTRAVIOLET LIGHT, by Karl N. Nilsen, Washington State University, Pullman.

AN INTEGRATED SYSTEM FOR PROVIDING POWER, WATER AND FOOD FOR DESERT COASTS by Carl N. Hodges and Carle O. Hodge, Environmental Research Laboratory, University of Arizona, Tucson.

USE OF CONTROLLED ENVIRONMENT FOR VEGETABLE PRODUCTION IN DESERT REGIONS OF THE WORLD, by Merle H. Jensen and Marco Antonio Teran R., Environmental Research Laboratory, University of Arizona, Tucson.

TROPICAL PRODUCTION OF VEGETABLE CROPS

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The Philippines have available more complete meteorological data than do many other tropical countries. Thus, the situation there can serve as a basis for the discussion of the aerial environment of the tropics and the way in which the environment influences the growing of vegetables.

There are 5 aspects of the aerial environment in the warm, humid tropics that have an important bearing on vegetable production. These are the occurrence of tropical storms and the patterns of rainfall, temperature, relative humidity, and length of day (3).

Tropical storms

Whether violent storms are called typhoons, hurricanes, tropical cyclones, or monsoons, they bring heavy rain and strong winds. These winds can flatten crops, especially if the crops are trellised. Stakes or trellises are in common use in the tropics to keep the plants off of the wet soil during the rainy season.

In the Philippines possibly as few as 1% of the storms strike the southern part of the Archipelago as far north as 8° latitude; this makes almost all of Mindanao valuable for crop production. The area from 8 to 11° N latitude receives about 7% of the severe storms which strike the islands. The zones from 11 to about 13° N latitude, and from there to about 15° N latitude, which includes Manila, are hit, respectively, by 19 and 16% of the storms. Then there is an area reaching to 19° N latitude in which typhoons are very frequent, 32% of the storms affecting this area. North of 19°, typhoons are almost as frequent, with about 25% affecting this area.

Typhoons have a bearing on rainfall distribution. A single storm in the fall of 1967 is reported to have dropped 48 inches of rain in 24 hr at Baguio in the mountains of Luzon. The western parts of the Archipelago are not protected by mountain ranges and receive the impact of the severe storms from the southwest between April and November. These same southwest monsoons bring the heavy rains to Indonesia, Malaysia, Thailand, and other parts of southeast Asia.

Rainfall

Topography and air stream direction affect rainfall. Based on their effects, 4 types of climate have been described for the Philippines (1). These are mainly longitudinal in character, whereas the typhoon frequency zones are rather latitudinal. Unfortunately, the regions in all 4 types of climate are exposed to typhoons in varying degree. Typical rainfall patterns for these types are shown in Fig. 1.

Type I: There are 2 pronounced seasons—a dry one from November to April and a wet one the remainder of the year. Irrigation is needed for vegetable production during the dry season. There is some furrow irrigation, but much of the water is applied by hand with two 5-gal cans on a shoulder yolk, often several times a day. Where vegetables are to be grown in the rainy season, rather high beds are needed for drainage. In some places where this type of climate prevails, sweetpotatoes are a primary crop during the typhoon season.

Type II: There is no dry season. A very pronounced maximum rainy period occurs from November to January. The eastern parts of the Archipelago have this type of rainfall.

Type III: The seasons are not very pronounced. It is relatively dry from November to April, and wet the remainder of the year. This pattern of rainfall exists in some of the central areas which are partially sheltered from the northerns and trade winds, but not from all of the typhoons.

Type IV: The rainfall is more or less evenly distributed throughout the year. This type provides a good supply of moisture for vegetable growth, but does present problems of pest control. Some growers find

Fig. 1. Examples of the 4 types of rainfall distribution. Data from Philippine Weather Bureau records for 1966 (2). The type I mountain data are the average of 1964 to 1966 inclusive.
it necessary to apply fungicides and insecticides almost every other day in order to protect the foliage of their crops.

The mountain valleys in which vegetables are grown may receive 160 to over 200 inches of rainfall annually. This may be double the amount that falls on areas nearer sea level.

**Temperature**

Temperatures prevailing in tropical areas are generally uniform throughout the year.

The annual monthly mean for the Philippines, as a whole, is 27°C, with a monthly mean minimum of 25.6°C in January and a monthly mean maximum of 28.2°C in May. Most weather stations report annual means just a few tenths of a degree above or below this 27°C figure.

Vegetables requiring warm temperatures do well up to altitudes of about 1,000 m. Above that, vegetables that grow best at cool temperatures are usually produced. Therefore, the mountains in tropical areas are important sites for vegetable growing. The drop in temperature of about 6°C for each 1,000-m rise in altitude brings the temperature into a range suitable for cool-season vegetables. For example, Baguio at 1,500 m has an annual mean of 18.2°C. Thus one finds cabbage, potato, carrot, and other cool-season crops growing in the Mountain Province in the Philippines, in Bagor and Bandung in Indonesia, in Dalat in Vietnam, in the Cameron Highlands in Malaysia, and at the higher altitudes in other tropical countries. It is possible sometimes, by choosing the proper variety, to grow a cool-season vegetable at lower elevations during the cooler part of the year. In Liberia, at about 7° N latitude, the ‘Minnetto’ variety of lettuce from New York heads fairly well. Similarly, the Indian varieties of cauliflower, such as ‘Early Patna’, ‘Early Market’, and ‘Pusa Kathi’, have done well at many locations in the tropics of both hemispheres (3, 4).

**Humidity**

The high humidity of tropical areas is well known. In the Philippines the monthly means of relative humidity in most places are commonly in the high 80’s. The high humidity, combined with warm temperature, is conducive to serious fungal and bacterial disease problems. One of the critical needs in tropical areas is the development of vegetable varieties with resistance to such diseases.

**Light of day**

In the tropics there is little difference in day length between the longest and the shortest day. There is no problem in the production of day-neutral or short-day vegetables, or short-day varieties of vegetables. Crops which require a long day for the productive stage are not adapted.

Vegetables such as the yam bean, *Pachyrhizus erosus* (L.) Urban; winged bean, *Tetragonolobus purpureus* Moench; pigeon pea, *Caianus Cajan* Millsp.; and chayote, *Sechiium edule* (Jacq.) Sw. are examples of short-day vegetables which do well in the tropics.

**Literature Cited**


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**EVAPORATIVE COOLING TECHNIQUES FOR REGULATING PLANT WATER STRESS**

Robert L. Carolus

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The water stress or “potential” (6) of a plant is dependent on both the level of available soil moisture and the atmospheric stress. Atmospheric stress increases with increase in air temperature, in radiant energy which influences plant temperature, and in air movement which influences plant temperature and relative humidity near the stomatal openings on leaf surfaces. Atmospheric stress decreases with an increase in relative humidity. Under satisfactory light and nutrient conditions, the level of water stress in a plant is the dominant factor controlling growth and many aspects of plant development. The optimum level of available soil moisture for the most satisfactory growth, development, and quality of a crop is not a fixed value but varies with and is dependent on the climatic parameters that influence water stress.

With a high available soil moisture and a low atmospheric stress, growth is vigorous and vegetative, and the fruit is soft, succulent and low in soluble solids. Tomatoes show “blotchy ripening” when the plant is under minimum water stress (4). With a low available soil moisture and high atmospheric stress, growth is restricted, plants are hardened, flowers and small fruits frequently drop, some leaves show insolation, and fruits are firm and high in soluble solids. Tomato fruits tend to lose water to the foliage to maintain their increased transpirational losses and in so doing develop blossom-end rot, due to the withdrawal of water from low osmotic areas of the fruit (4, 5).

Regulation of the internal water stress of a crop to insure optimum production of high quality is difficult to achieve by adjusting soil moisture under seasonal variations in climate, particularly in the more humid areas of the world. In practice, irrigation is frequently delayed in humid areas in hope of rain which frequently fails to materialize. If the crop is subject to a severe atmospheric stress, it may be irreversibly injured. On the other hand, if a heavy irrigation is followed shortly by heavy rainfall and low atmospheric stress conditions, plants become excessively succulent, subject to many diseases and to quality deterioration. In arid areas, the maintenance of available soil moisture at near field capacity to supply water for transpirational losses into a high atmospheric stress environment would probably optimize growth. However, frequent irrigation is required to maintain a high soil moisture, which consequently restricts soil aeration and prevents rooting into the sub-surface and sub-soil. Maintaining an optimum water balance in the plant at critical stages of development should be accomplished by regulating transpirational losses rather than by applying water to the soil.

**Influence of meteorological factors on transpiration**

Relative to transpiration at 80°F and 50% relative humidity, the theoretical changes in the magnitudes of water losses due to either increases in air or plant temperature and/or relative humidity are shown in Table 1. With an increase in relative humidity from 50 to 90%, the rate of water loss is reduced 80%; with a decrease in humidity to 10%, the rate is increased 73%. An increase in air temperature from 80° to 100°F at 50% relative humidity increases the potential rate of water loss 88%, while an increase in leaf temperature from 80° to 90° increases the rate of loss 76%; and the potential loss is increased by 174% if the leaf is 20°F above the ambient air temperature.

Even at high humidity, radiant heating to 10° above 80°F air temperature results in about a 5-fold increase in the potential rate of evapotranspiration.

**Table 1. Theoretical relative transpiration rates at different humidities at different plant and air temperatures.**

<table>
<thead>
<tr>
<th>Plant temp.</th>
<th>Air temp.</th>
<th>Relative transpiration at different air relative humiditiesa</th>
</tr>
</thead>
<tbody>
<tr>
<td>80°F</td>
<td>80°F</td>
<td>90% 50% 10%</td>
</tr>
<tr>
<td>90°F</td>
<td>90°F</td>
<td>100 139 250</td>
</tr>
<tr>
<td>100°F</td>
<td>100°F</td>
<td>188 340</td>
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<tr>
<td>90°F</td>
<td>80°F</td>
<td>96 176 257</td>
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<tr>
<td>100°F</td>
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<tr>
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<td>90°F</td>
<td>177 331 465</td>
</tr>
<tr>
<td>110°F</td>
<td>90°F</td>
<td>355 510 664</td>
</tr>
</tbody>
</table>

*Relative to rate with both plant and air at 80°F at 50% relative humidity.