UNIQUE BENEFITS OF GREENHOUSES FOR VEGETABLE PRODUCTION IN HAWAII

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Unheated greenhouses in Hawaii allow production of warm season crops like tomatoes in the cool upper elevations by raising air temperatures. Greenhouses also act as rainshelters and increase the predictability of harvest. In one area, they eliminated a tomato disease caused by rain which collected impurities from volcanic air pollution. Increased soil aeration and workability is gained when rainshelters are built in high rainfall areas where highly hydrated soils with irreversibly drying properties exist.

A casual observer may question the need for greenhouses in Hawaii since the state is acclaimed for its mild climate. The vegetable greenhouse in Hawaii generally consists of a wood or steel supported plastic or fiberglass covered structure which neither utilizes heating nor cooling devices. Usage of these structures for vegetable production has risen from less than 2 ha in 1971 to around 7 ha in 1975 and it has now expanded to around 10 ha (6). The intent of the following discussion is to focus on four benefits which are largely responsible for this increased use of greenhouses in Hawaii's vegetable industry.

Increased Air Temperatures

A portion of Hawaii's vegetable industry lies in the upper elevations (1,200 m) where temperatures are considered too cool for warm season crops such as tomatoes (Figure 1). As a result, field tomatoes are not raised in these cool and often wet conditions. However, unheated greenhouses with the sides mostly covered have produced satisfactory yields of up to 6 kg/plant in a 6-month time period in the greenhouse. This profitable level of tomato production is largely due to both the increased air temperature and the duration of the higher temperature caused by the greenhouse effect.

Data collected from a recording thermograph in May on both a low light (160g cal/cm^2) and a high light (344g cal/cm^2) day indicate that outside air temperatures exceeded the generally considered minimum temperature for tomato growth (13^{o}C) for only 5 hours with a maximum temperature of only 17^{o}C for the low light day and 15^{o}C for the high light day (Figure 2). However, the temperature exceeded 13^{o}C for 12 hours in the enclosed plastic greenhouse and reached a daily maximum of 25 to 27^{o}C. In the same study, a clear polyethylene mulch also increased the soil temperature and the highest yield recorded was 120,000 kg/ha (1).

Growers in temperate areas where fuel is a critical item may note with interest that tomato production of 3 to 6 kg/plant is possible where the

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greenhouse air temperatures may be below 13°C for 12 hours per day (Figure 2) and where the daily minimum approaches the minimums in Figure 1 for 2 to 4 hrs/day. Furthermore, tomatoes produced at the 1,200 m elevation are very firm and the overall quality is considered to be excellent.

Protection From Rain

A substantial portion of Hawaii's vegetable production area lies in the less than 100 cm rainfall belt. However, some of the present and much of the available land for the future is located in rainfall belts of 200 to 500 cm/year. In these high rainfall areas, the greenhouses act as rainshelters.

Rainshelters allow predictable production in areas which would be otherwise very dependent upon the rain patterns. Worker efficiency and comfort is maximized in rainshelters. Radial cracking, a physiological problem associated with excessive rains in a short period of time, can also be avoided by rainshelters. Disease incidence is reduced since fungicides are not washed from the plants; fertilizer efficiency is greater since the leaching of mobile nutrients like N and K can be controlled by the irrigation program. In the event that an excessive salt accumulation occurs in the soil, the polyethylene roofs of the rainshelters in these high rainfall areas could be removed for several months and the natural rainfall could solve the problem by leaching the salts away.

Eliminated a Volcano Related Tomato Disease

Rainshelters provided the solution to a most unique field tomato disease (2). Symptoms included blossom drop, poor fruit set, hollow, small and almost seedless fruits and a less luxuriant appearance. Soil and tissue tests revealed no abnormalities. Insect injury was not apparent and disease producing organisms could not be isolated from the plants or the soil in which they were growing.

Coincident with the disease occurred a definite haze over the affected area which was apparently caused by fumes from active and degassing vents associated with Kilauea volcano located about 75 km away.

In a field test, tomatoes growing outside grew poorly and produced no salable yield, whereas, those growing under a plastic rainshelter grew normally and produced 5 kg/plant.

Thus, it was evident that the components in the rain were responsible for the disease. Analysis of the rainwater revealed it to be acidic (pH 4.0 - 4.4) as the result of excessive $SO_4^=$ and Cl^- content; the rainwater also contained 27 organic compounds the sum of which were in the ppb range which was a thousand times more than in rainwater 350 km away. These impurities resulted in increased leaching of nutrients from the foliage and an inhibition of pollen germination. Consequently, seed development was impaired resulting in soft and hollow fruit. The volcano has since subsided and this problem does not presently exist, but on an island with occasional volcanic activity, one never knows when a similar problem will 'erupt.'

Improved Physical Conditions of Soil

A number of tropical soils (including some in Hawaii) undergo a more or less permanent physical change upon exposure to rather severe drying conditions (5,6). Prior to drying, these soils are highly hydrated, muddy, sticky, and somewhat hard to work. Upon drying, the soil forms relatively stable aggregates of a low bulk density.

The particle size distribution of an oven-dried soil belonging to the Akaka series (a hydrandept soil) was > 10 mesh = 60%, 10 - 20 mesh = 25%, and < 20 mesh = 15%; the bulk density was 0.6g/cc (3). When this soil was rewet, its field capacity water content decreased to only 58% as compared to over 300% in its natural state. The dried soil is no longer muddy or sticky; therefore, it is very easy to rototill and the porosity seems greatly increased.

A greenhouse environment promotes the drying of these soils, particularly the surface layer. When this is mixed into the undried soil, the physical condition of the soil greatly improves. In effect, a greenhouse grower in an area with an irreversibly dried soil finds that his soil conditions are much more desirable than the soils of an outside grower.

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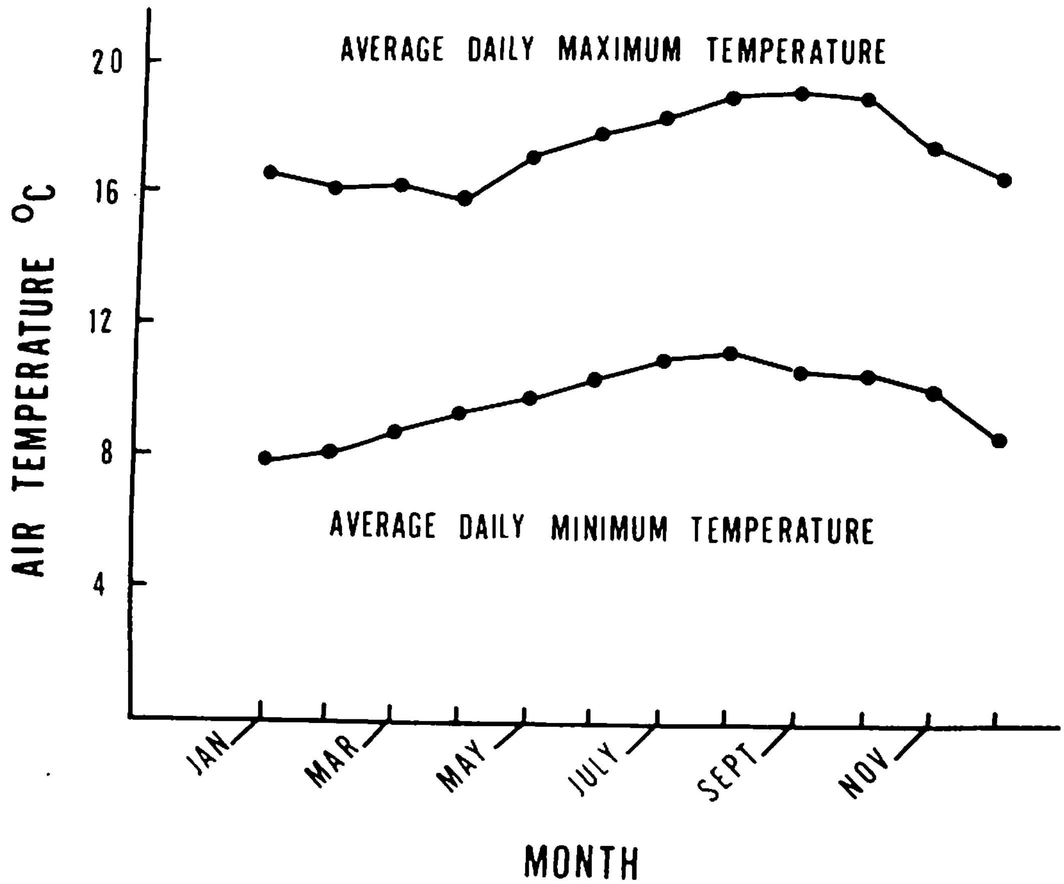

Figure 1. Average daily maximum and minimum air temperatures over a ten-year period (1967-76) at a 1,200 m elevation on the Island of Hawaii, State of Hawaii.

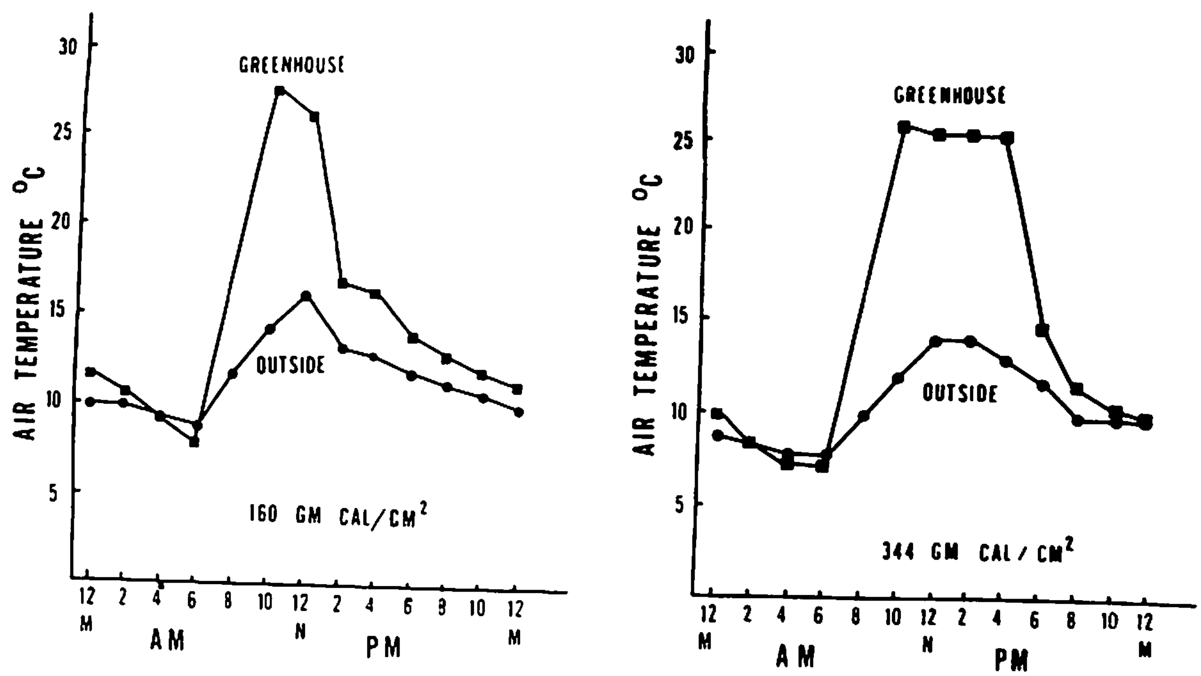

Figure 2. Air temperatures inside a greenhouse with covered sides and outside during a high and a low light day in May at a 1,200 m elevation on the Island of Hawaii, State of Hawaii.