COLORADO FLOWER GROWERS ASSOCIATION

Bulletin 328 | Edited by David E. Hartley | October 1977

EFFECTS OF HEATED SOIL ON PLANT GROWTH[1]

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Many researchers throughout the world have been evaluating the feasibility of indirectly warming plant growing media with thermal discharge water associated with the water cooling cycle of industrial and/or electrical generating equipment. North Carolina researchers (4) found that cabbage plants grew faster and larger in heated plots and strawberry harvesting was hastened by 10 days. University of Minnesota researchers (1) grew potatoes as a test crop and found that heated soils speeded maturity. Boersma and Rybost (2) simulated a warm water subsoil heating system by burying electrical heating cables. They observed both positive and negative results depending on the plant species grown.

In September, 1975, preliminary experiments were started at the Department of Horticulture Plant Environmental Research Center to study the effects of soil temperature on the growth and yield of numerous plant species.

Methods and Materials

Construction. A quonset greenhouse was remodeled and ground bed benches installed. The house was covered with a double layer, Monsanto "602" polyethylene, air inflated cover. It was cooled by a thermostatically controlled 30 inch, Acme non-loading fan and manually controlled ventilators for the main air source and automatic louvers for the 1st stage cooling. The heating system consisted of a pneumatically controlled perimeter steam line (1st stage heat) and a gas fired unit heater for the 2nd stage. The environment was controlled at the following temperatures:

Heat: 52°F day and night   Cool: 65°F day.

Solar input was the controlling factor for daytime temperatures, which "drifted" between 52 and 65°F. Two benches 42″ × 30′ were constructed at ground level with wooden side walls around the perimeter (Figure 1 upper) and a heating mat installed at an 8″ depth in one bench (Figure 1 lower) to simulate a bench heated with "warm water".

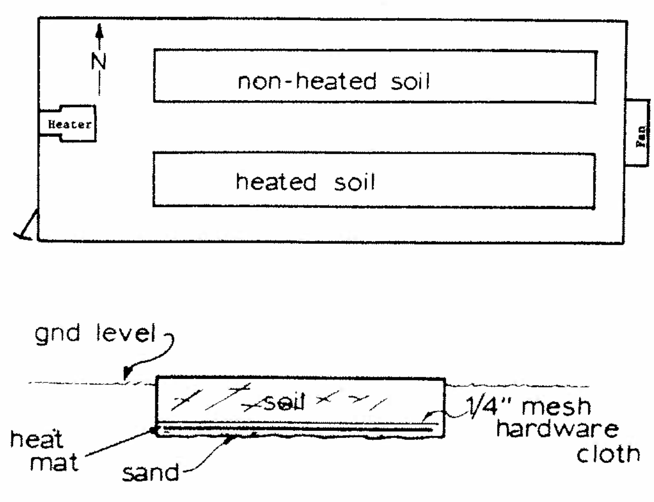

Figure 1: (Upper) Orientation of air inflated greenhouse, Colorado State University.
(Lower) Cross section of heated soil bench.

[1] *A portion of the results obtained in Demonstration Project FCRC N 252-336-083, Four Corners Regional Commission, Suite 238 Petroleum Plaza Building, 3535 East 30th Street, Farmington, New Mexico 87401.*

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The soil temperature varied from 44-55°F in the nonheated ground bed and 58-61°F in the heated bench from January 8, 1976, through May 8, 1976. The heated soil was only mildly affected by the 40°F water used for irrigation and it temporarily lowered the soil temperature in the nonheated bench 6-8°F.

The same nutrient treated water used in the floriculture research range for cut flower and pot plant production was used. Nutrients were supplied each time the plants were watered.

Radishes

Three crops of three radish varieties were grown between November 15, 1975, and April 23, 1976. (Table 1) They were directly seeded, replicated 3 times, in both the heated and nonheated benches.

Table 1: Varieties of radishes grown to evaluate their responses to heated and nonheated soil conditions.

	Variety	Sown	Harvested	Days to Harvest
Crop I:	'Early Scarlet Globe'	11/15	1/7	53
Crop II:	'Early Scarlet Globe'	2/2	3/4	31
	'Sparkler White Tip'	2/2	3/4	31
	'Cherry Belle'	2/2	3/17	44
Crop III:	'Sparkler White Tip'	3/17	4/23	37
	'Cherry Belle'	3/17	4/23	37

Crop I results. Fresh weight of 'Scarlet Globe' harvested from the heated soil treatment was significantly greater (14.3 percent) and the overall length, root to leaf tip, was 17.2 percent greater than those grown in the nonheated treatment (Fig. 2). There were no differences in the diameter of radishes harvested from each treatment. Plants were harvested 53 days after seeding.

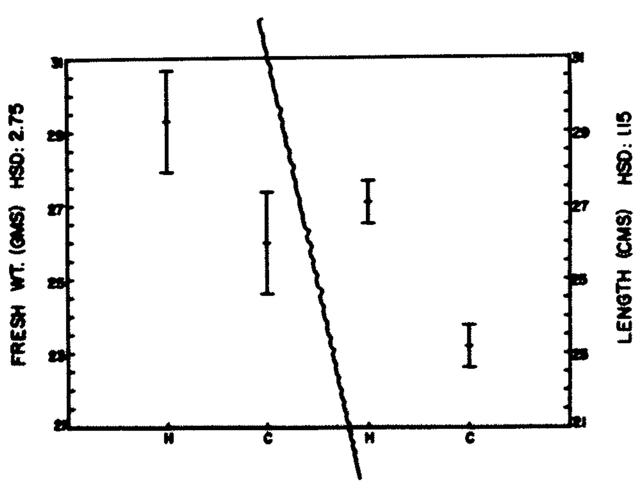

Figure 2: Left: Fresh weight of 'scarlet globe' radishes grown in heated (H) and unheated (C) soil.

Right: The length of 'scarlet globe' radishes from leaf to root tips, grown in heated (H) and unheated (C) soil.

Crop II results. The second crop involved 3 radish varieties (Table 2). The fresh weights of all varieties of radishes harvested from the heated treatment were significantly greater than the plants grown in nonheated soil. Varietal response to the treatments was also evident. There was no significant differences in the root diameter of the varieties.

Table 2: The percent increase in fresh weight of radishes harvested from the heated soil in relation to the weight obtained from the nonheated treatment.

Variety	% Increase in Weight	Time to Maturity
'Early Scarlet Globe'	53.7	31 days
'Sparkler White Tip'	81.6	31 days
'Cherry Belle'	57.1	44 days

Crop III results. The results obtained from the third crop of radishes was comparable to the two previous evaluations. The mean fresh weight of the roots was somewhat lower, which was attributed to noncontrolled moisture levels in both soil temperature treatments. The length of time required to generate a sizable radish, 37 days when compared to 31 days for the same varieties in Crop II, could also have been caused by decreased moisture availability. The longer photoperiods, warmer temperatures and ultimately increased photosyntheses, all contributed to greater water requirements, probably causing stress in the third crop of radishes.

Lettuce

Crop I results. Seed of 'Grand Rapids H-54', leaf lettuce, were sown in 3 random block locations in both soil temperature treatments on November 26, 1975. At harvest time, 83 days later, the average weight of the heads grown in the heated treatment was 20% greater than those produced in the nonheated soil.

Crop II results. Seed for the second lettuce planting were germinated under mist and transplanted, replicated three times, in each of the two temperature treatments on March 12, 1976. The plants were harvested 77 days after transplanting. The total production (fresh weight) of the heated treatment was only 7.7% greater than the nonheated treatment. There were no significant differences in the dry weights for the second planting. The lack of significant difference may have been caused by the increased positive effects of solar energy on the nonheated soil temperature.

Swiss Chard

Seed of the swiss chard variety, 'Large White Ribbed', were sown on February 2, 1976. On March 5, 1976, the young plants were transplanted into three replicated blocks within each soil temperature treatment. Plants from each replication were harvested on April 23 and May 2; 82 and 91 days respectively, after the sowing date. The plants were cut at the soil line and fresh and dry weights taken (Figure 3). The plant material from the first harvest in the heated soil treatment had 44.8% greater fresh weight than the material harvested from the nonheated treatment, but the difference decreased to 24.0% for the second harvest. Throughout the growing period there was a marked visual difference between the growth rates of plants in the heated and nonheated treatments; plants in the heated soil treatment developed faster. Data indicated that almost one half of the fresh weight was obtained during the last nine days of growth.

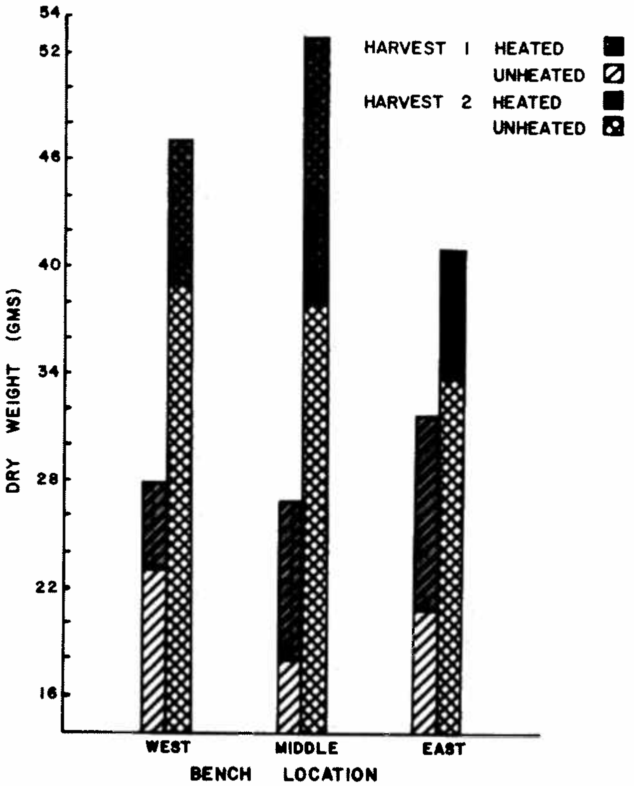

Figure 3: Fresh weight of Swiss chard sown February 2, 1976, and harvested 83 (harvest 1) and 91 (harvest 2) days after sowing in heated and unheated soil beds. Significant at 5% level.

Cauliflower

Seeds of a new greenhouse cauliflower variety, 'Self Blanche', were sown on October 18, 1975, and transplanted into three replicated blocks in each soil temperature treatment on November 24. The plants were harvested 98 days after transplanting and total plant weight, diameter of the head and its fresh weight recorded.

The cauliflower plants in the heated treatment reached maturity sooner than the plants grown in the nonheated soil treatment. At harvest a few of the heads from the heated ground bed were flowering (Figure 4). Heads from the heated treatment were 149.0 percent heavier than those from the unheated treatment (Figure 5). The diameter of the heads produced in the heated soil was 80 percent greater than cauliflower heads harvested from the unheated treatment.

The cauliflower on the south side of the plots in both heated and unheated soil treatments developed heads faster than those on the north side. It is conjectured that the response to temperatures created by solar radiation plus high light intensities contributed to increased growth of the "south side" plants.

Carnations

Cuttings of the carnation cultivar 'White Sim' were rooted under intermittent mist, and upon planting, November 18, 1975, were replicated three times in both the heated and nonheated soil treatments. The complete plants were harvested approximately 183 days (26 weeks) after they were transplanted. A bench position effect was noted and the data obtained indicated plants grown in the west end of the benches responded the least. (Figure 6). However, the fresh weight of the plant materials harvested from the heated ground bed was greater than the nonheated treatment by 10.96, 10.69, and 7.8 percent in the east, middle and west plots respectively, but not significant. The length of time required for the carnation plants in each plot to produce flower buds showing color ranged from 1.5 to 11 days earlier in the heated soil plots. The maximum difference in production time between the fastest heated and slowest nonheated plot was 23 days (Figure 7). The carnations in the heated bench reached all stages of development before the plants in the nonheated treatment. The results of this evaluation are not in exact agreement with those obtained by Holley in 1954, although differences in maturity due to soil temperature were indicated.

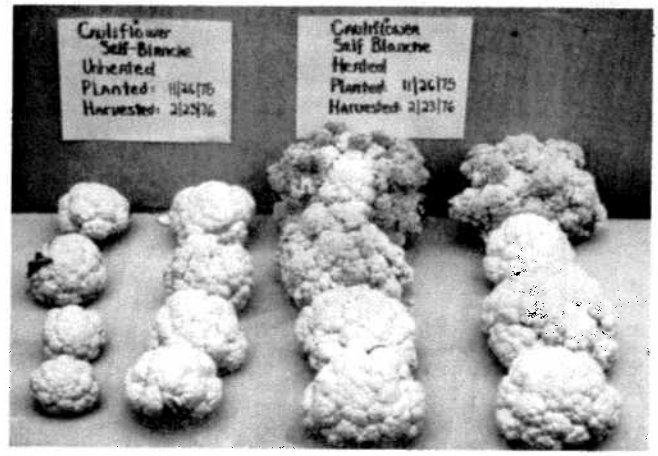

Figure 4: Cauliflower heads harvested 98 days after transplanting, November 24, 1975, in heated and unheated soil beds.

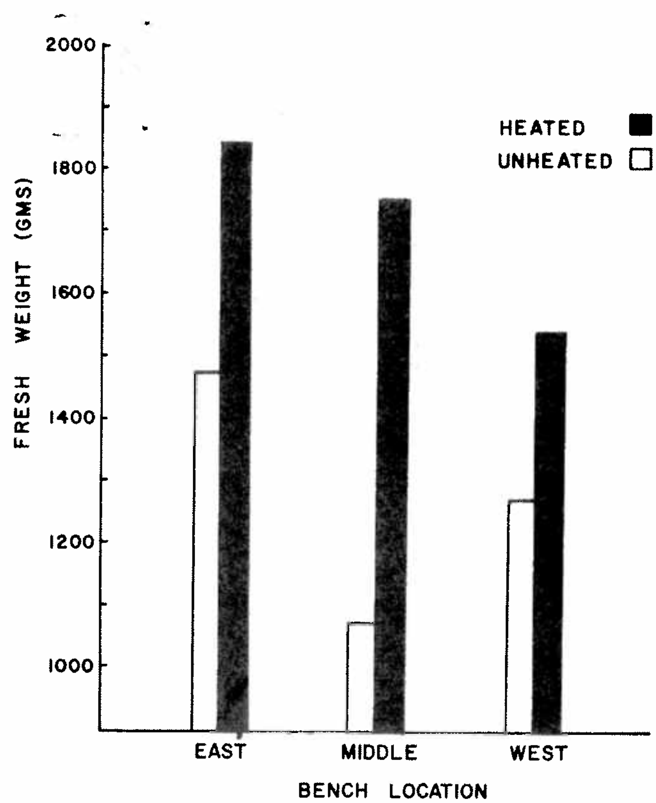

Figure 5: Total fresh weight of cauliflower heads harvested 98 days after transplanting in heated and unheated soil beds. Significant 1% level.

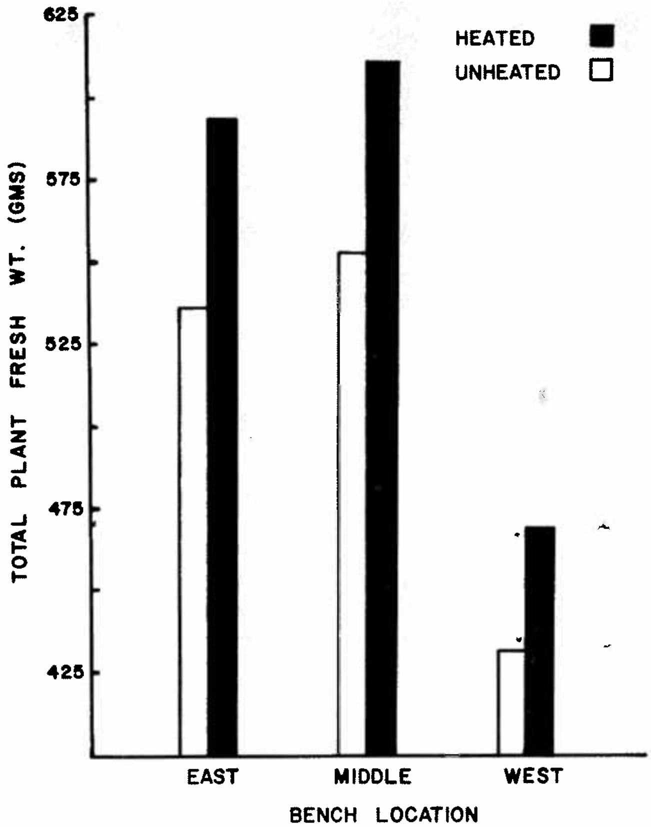

Figure 6: Total fresh weight of 'White Sim' carnation plants harvested 26 weeks after a November 18, 1975, planting. No significant difference at 5% level.

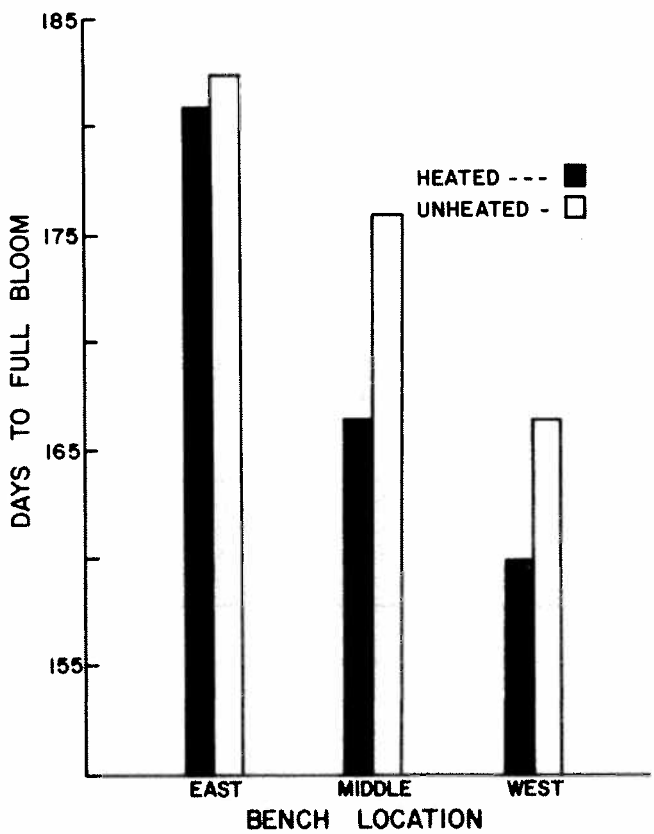

Figure 7: The number of days required for all breaks on 'White Sim' Carnation plants to show at least ½ inch of bud color from a November 18, 1975, planting.

Discussion of results

It appears that warmer soil temperatures can be substituted, to a degree, for air temperature within a greenhouse and positive responses of plant growth achieved. However, the heat given off by the soil may have created a warmer microclimate within the plant canopy, contributing positively to plant growth.

In this evaluation, bench position effects contributed to the responses of all species, although it was evident that soil temperature was directly related to the maturity of all plant species evaluated. The position effect (east to west) was apparently created by the design of the second stage heating system during heating periods and the differences in temperature from the air intake to the exhaust fan, during periods of ventilation. The east end of the greenhouse was apparently warmer during most of the evaluation than the west end, contributing to faster maturity in the east replications.

A second position effect was evident with some crops, especially cauliflower. Plants on the south sides of both heated and nonheated benches matured faster than those grown on the north. It is conjectured that the response to temperatures created by solar radiation, plus high light intensities contributed to increased growth of the "south side" plants.

Positive responses of plant growth of each species grown were obvious. Radish foliage was much larger in the heated treatment, but the diameter of the roots were similar. The Swiss chard grew faster and carnation plants flowered sooner in the heated benches.

The soil moisture level in the heated soil treatment was apparently adequate for good growth, during most of the experiment, but the frequency of application had to be increased as natural photoperiods and outside temperatures increased in early spring. If soil temperatures warmer than 60° are considered, soil moisture must be closely monitored. It is highly probable that the greatest benefits of soil heating will occur when air temperatures used in the culture of a particular crop, are somewhat lower than those recommended.

Future evaluations

Studies are now underway at CSU to evaluate the responses of carnations to a range of temperatures maintained in growing media with "standard" carnation greenhouse temperatures.

Further studies should be conducted to evaluate other plant responses on a larger scale, however, such research is not warrented at this time, unless industrial organizations desiring to put "waste heat" to work, all assist in a cooperative venture.

Future greenhouse construction should also be re-evaluated. In the 1950's, it was based primarily on an economy move by growers which included wooden superstructures, plastic covers and hanging gas fired unit heaters. Many of the "ole time" growers felt the elimination of heating pipes below and beside benches would interfere with cultural and timing programs. Based on the fact that many researchers throughout the world are recording positive results with soil heating, perhaps they were correct. Besides, there may have been the hidden benefits of providing heat for the plant microclimate and saving fuel — which would fit nicely in our era of energy conservation.

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