THE EFFECT OF SOIL TEMPERATURE ON THE GROWTH OF GREENHOUSE ROSES

Thesis for the Degree of M. S.

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DAVID LEE SANFORD

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THESIS

ABSTRACT

The Effect Of Soil Temperature on
The Growth Of Greenhouse Roses

By

David Lee Sanford

A comparison was made of the root growth, shoot growth, and flowering of the rose cv. Bridal Pink at soil temperatures ranging from 5° to 35°C. Records included initial root and shoot growth of dormant plants in Study I and in Study II data included number of nodes per flowering stem, flower stem length, fresh weight of the flower, days required for a return of stems to flowering, and internal water stress on actively growing plants.

Results showed root regeneration increased as soil temperature was increased from 5° to 25°C with shoot growth increasing in a similar manner as soil temperature increased. Stem lengths of flowering shoots were significantly shorter at a soil temperature of 35°C than at the other soil temperatures. The number of nodes was significantly reduced at only the 5° and 10°C soil temperatures. Fresh weights did not differ statistically among the treatments. A soil temperature of 25°C produced 55.5% greater number of blooms than those grown at 10°C. A fewer number of days were required for return to flowering

as soil temperature increased from 5° to 30°C. Internal water stress was reduced at soil temperatures of 20° and 25°C when compared to higher and lower soil temperatures.

THE EFFECT OF SOIL TEMPERATURE ON

THE GROWTH OF GREENHOUSE ROSES

By

David Lee Sanford

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To Trish

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INTRODUCTION

Cut roses are one of the nation's leading commercially-grown cut flowers. The production of roses has become highly competitive in a changing business environment which requires the careful attention of the producer. This places the responsibility on the grower as to how resources will be used in the production of a crop. The environment under which a plant is placed will determine how much of the potential growth that can be achieved.

Comparatively little attention has been given to the importance of root temperature in the growth of the rose plant, as is true with most other crops. This study was undertaken to investigate the effect that various soil temperatures would have on the growth of rose plants.

REVIEW OF LITERATURE

Temperature and Root Growth. The growth of roots is influenced by soil temperature and carbohydrate supplies from the photosynthetic processes of the plant. Each genus and species seems to have its own optimum root temperature for growth. Darrow (23) found that the greatest root growth (rhizome production) in *Poa pratensis* (bluegrass) occurred at soil temperatures of 15° and 25°C and decreased at higher temperatures. Wort (72) working with Marquis wheat, found total root growth decreased with increasing temperatures from 22° to 42°C. Stuckey (65) and Brown (13) have also found the greatest root growth in forage crops occurs in the early spring and fall when soil temperatures are low.

Dickson (26) and Wort (72) working with wheat showed that greatest root growth occurred when soil temperatures were relatively low. They reported that corn roots made their greatest growth at higher soil temperatures than for most cereal crops studied.

Working with vegetable crops, Burkholder (14), Richards (54), and Bushnell (15) have reported growth responses to soil temperature also vary with species and environmental conditions. They showed that bean top growth and yield increased as the soil temperature was increased from 18° to 33°C, and that potato tops grew best as a soil temperature of 21° but tuber formation was optimum at 17°C.

Bates et.al. (7) compared root growth of woody plant species and found that soil temperature is the most important factor in controlling the growth of Englemann spruce. Barney (4) working with loblolly pine seedlings reported increased root growth as soil temperature was increased to 25°C then decreased at higher soil temperatures. Larson (43) reported that no optimum soil temperature was evident for root growth in Red Oak Seedlings, but that low temperatures severely retarded root regeneration. Toynette et.al. (67) studying five woody plant species noted differences in their tolerance to short periods of high soil temperatures. Rose and peach were the least tolerant to high soil temperatures of the five species studied.

Apple roots were found by Collison (20) to make some root growth at temperatures near 0°C. Nightingale (48) noted that less root growth occurred on dormant plants placed at 7°C than on actively growing plants that were placed at this low temperature. He found the optimum soil temperature for apple and peach roots at approximately 18° with poorer root growth at extremes of 7° and 35°C. Batjer et.al. (8) obtained similar results using dormant apple trees. Rogers (56) and Proebsting (52) reported apple trees develop more roots as the temperature was raised from 7° to 21°C. Nelson and Tukey (47) found that new roots of E. Malling rootstocks were initiated significantly earlier at soil temperatures of 18.8° and 25.0°C than at 12.7° and 6.6°C.

Woodruff and Woodruff (71) studied the effect of root temperatures on pecans; Girton (29) and Hass (31) citrus;

Gray (30) and Roberts (55) strawberry; Woodham and Alexander (70) and Skene and Kerridge (61) grapes, and Pearson et.al. (49) cotton; all reported a close relationship between temperature and root growth.

Bateman and Dimock (6) observed that the rate of root development of poinsettia was greatest at soil temperatures near 26°C, with no root growth occurring below 13°C and a progressive reduction in growth at soil temperatures above 30°C.

Working with greenhouse roses, Shanks and Laurie (60) reported a progressive decrease in the fresh weight of roots as the temperature increased from 13° to 22°C.

Hansen (32) found while working with the propagation of Yew, Poinsettia, and English Ivy that root initiation and elongation were optimum at 25°C, while Geranium had the greatest root initiation and elongation at 30°C than at higher or lower medium temperatures.

<u>Temperature and Shoot Growth</u>. Cannon (17) found shoot growth could be increased under unfavorable atmospheric conditions by maintaining favorable root temperatures for growth. Barr and Pellett (5) reported that the soil temperature for greatest shoot growth was generally higher than the soil temperature for greatest root growth.

The effects of root temperature on shoot growth of forage crops has been reported by Jones and Tisdale (34), Darrow (23), Studkey (65), Earley and Catter (27), Maderski and Jones (46), and Knoll et.al. (38). Even though there were differences between the species studied, top growth was generally reduced at excessively low and excessively high root zone temperatures.

Dickson (26) and Wort (72) found that the optimum root temperature for maximum shoot growth for wheat varied with age of the plant. Higher temperatures were optimum during early stages of growth while lower root temperatures were optimum for later stages. Dickson (26) found the response of corn to be the opposite that observed for wheat.

Working with peas, Brenckley and Singh (11), found that root temperature appears to be of greater importance than air temperature, since good growth can be produced under high air temperatures provided the roots are kept relatively cool. Lingle and Davis (44) working with tomato seedlings, showed shoot growth increased with root temperature from 10° to 25°C. When the root temperature was at 10°C, the growth ratio of the shoots to roots approached zero. Tew, et.al. (66) reported that sunflower plants grown at a 10°C soil temperature had only 10% the leaf area as at 25° and 40°C.

Nightingale (48), Batjer et.al. (8), Proebsting (52), Rogers (57), and Nelson and Tukey (47) found the top growth of apple trees to be closely associated with root growth. Bailey and Jones (3) reported that blueberry height and linear growth increased with increasing root temperatures from 13° to 32°C. Stephens (64) has reported similar results on Yellow-Poplar seedlings. Larson (43) reported reduced shoot growth of Red Oak seedlings at low soil temperatures and favorable air temperatures.

Jones (35) reported *Gardenia veitchii* size of leaf and rate of growth are related to soil temperature. Leaf size increased with increased temperature to 32°C. Woodham and Alexander (70), observed increased grape shoot growth as the soil temperature increased from 10° to 30°C.

Allen (1) reported a reduction in the flowering of several greenhouse crops grown at excessively low and excessively high temperatures. Seeley (59) found heating snapdragon soil to a minimum of 21°C produced more flowering stems and earlier flowering, but the differences were non-significant. Seeley (59) also found no advantage in heating carnation soils. Carpenter and Rasmussen (19) reported chrysanthemum plant heights and fresh weights decreased as irrigation water temperatures decreased from 18° to 2°C.

Pfahl et.al. (50) and Kohl et.al. (39) observed a reduction in the flowering of roses grown at excessively low and excessively high soil temperatures. Carpenter and Rasmussen (19) using cold irrigation water on roses found no difference in numbers of flowers, but stem lengths, and fresh weights were reduced significantly. Shanks and Laurie (60) found the fresh and dry weight of shoots of Better Times Roses increased directly with soil temperatures. It was determined that a root temperature of approximately 18°C was optimum for shoot growth where night air temperatures were maintained at 16°C.

Soil Temperature and Water Stress. Plant growth is influenced by the internal water stress of a plant. Limiting water restricts plant growth by reducing the physiological processes within the plant. Crafts (21) gives an excellent discussion on how water deficits influence physiological processes. Kramer (40, 41) has shown that root zone temperature affects the water absorption capacity of roots which can cause plant water stress.

It has been shown by several workers (10,25,36,37,58,68) that the pressure bomb could be used to evaluate the status of water within a plant. The water column within a plant is generally under tension which results from the demand of the leaves for replacement of water lost through transpiration. When a stem is cut, the water column withdraws into the stem. To measure the original tension, the cut stem is placed, with the cut end protruding through a seal, in a pressure chamber. Pressure is applied to the leafy stem and forces the water column back to the cut surface. When this water is observed the pressure is assumed to be the tension on the water column before it was cut.

Waring and Cleary (68) have shown the importance of standardizing the testing procedure. If the pressure is increased very slowly or very rapidly higher readings may be recorded, therefore, standardizing the rate of increase is essential for comparing treatments. This rate will vary with plant species, for example, Waring et.al. has shown for Douglas fir a rate of increase at about 10 psi per second to be satisfactory whereas 2.5 psi per second pressure increase with more herbaceous materials may be necessary.

MATERIALS AND METHODS

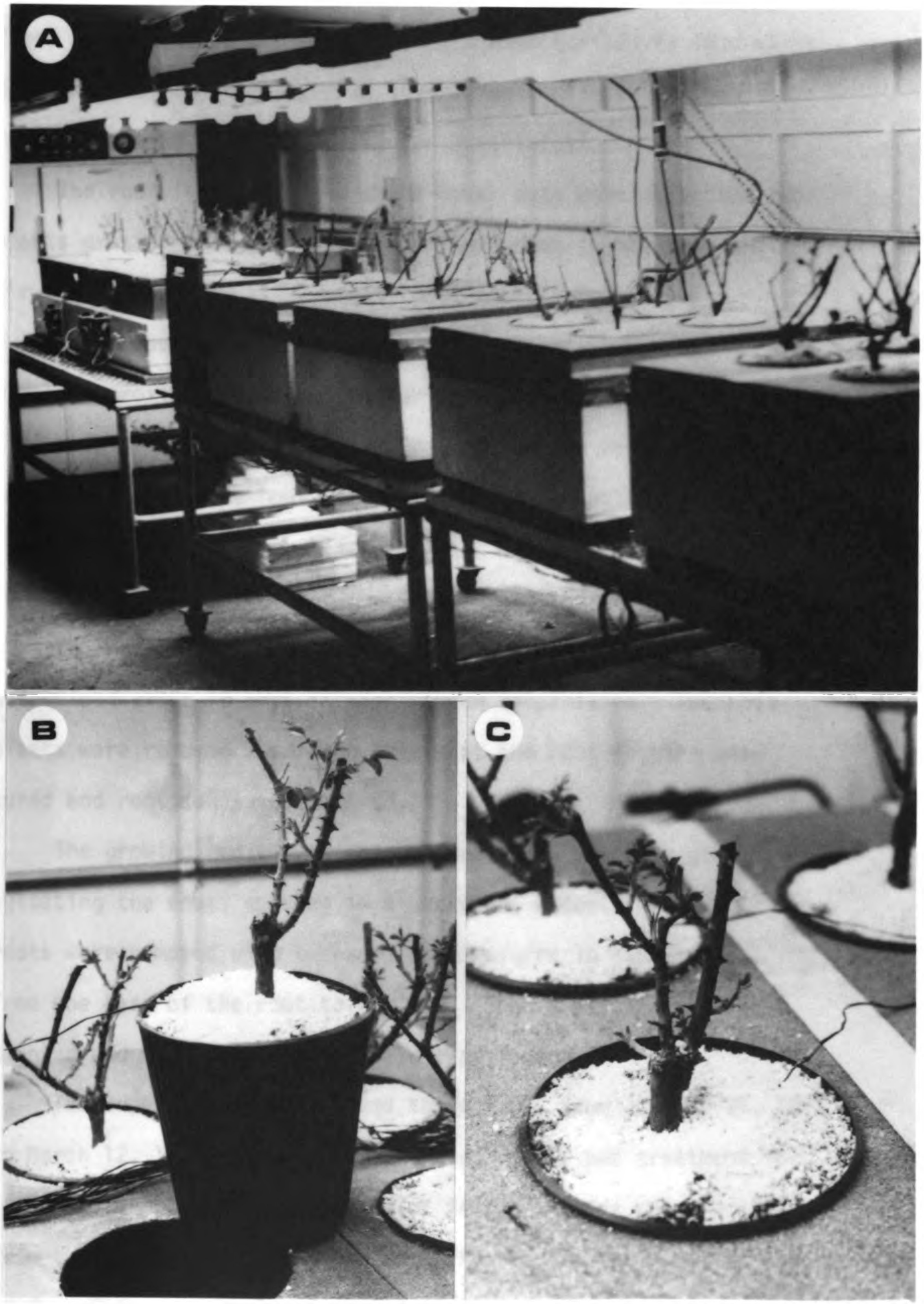
Study I. Dormant plants of rose cv. Bridal Pink were planted in a medium consisting of a 1:1 mixture of peat and perlite in 17.5 cm plastic pots. The pots were placed in experimental chambers for refrigeration or heating to maintain constant medium temperatures of 5°, 10°, 15°, 20°, 25°, 30°, or 35°C (Figure 1).

The refrigeration system consisted of four refrigerated units 60 x 60 cm with a 30 cm depth with tubes containing circulating freon around the inside perimeter to maintain the desired air temperature. The top of each unit was 5 cm thick styrafoam with holes 17.5 cm diameter to suspend four pots in each unit. By controlling the temperature of the air surrounding the pots, the desired medium temperature was maintained at 5°, 10°, 15°, and 20°C. Perlite was placed over the medium in the pots to insulate it from the constant room temperature of 21°C.

To maintain the warm medium temperature of 25°, 30°, and 35°C, three styrafoam units each of similar size (70 x 52 x 30 cm) were constructed. Each chamber was heated by two 60 watt incandescent light bulbs connected to individual thermostats. Four pots were suspended in each chamber through the lid made of 5 cm thick styrafoam.

Rose plants were lighted 16 hours daily beginning after planting the dormant plant, using Wide Spectrum Gro Lux fluorescent tubes mounted 4 inches apart in 4-foot by 8-foot fixtures.

Figure 1. Experimental equipment for maintaining medium temperatures: (A) shows the systems for maintaining the warm and cool medium temperatures, (B) shows the chamber top with hole cut for insertion of container, (C) shows the container inserted in the chamber. Note the perlite on soil surface for insulation from air temperature and the thermocouple inserted into growing medium.


A
B
C

There were 12 tubes per fixture. Each tube emitted 73 lamp watts, totaling 876 lamp watts per 32 square feet. The tubes when lighted emitted 27.4 lamp watts per square foot.

The root initiation and shoot break data were collected from plants growing in a constant temperature room to maintain a 21°C air temperature for all 7 media temperature treatments.

Thermocouples of 24-gauge copper-constantan wire were placed approximately in the center of each pot during all studies. A 24-point recording potentiometer was used for recording soil temperatures for one hour at 6 hour intervals during the day.

The plants were fertilized at each irrigation with a 200 ppm NPK solution throughout the duration of the study.

The root and shoot development from dormant rose plants was determined after 10 days at each medium temperature. The rose plants were removed from each treatment and root lengths measured and root counts determined.

The growing medium was removed from each plant by gently agitating the roots soaking in a bucket of water. Individual roots were removed with tweezers and measured in centimeters from the base of the root to the tip. Shoots also were counted and the length measured in centimeters.

The experiment was repeated three times from January 31, 1971 to March 12, 1971, using 4 dormant rose plants per treatment for each trial. Dormant rose plants of Triple X grade were received from the propagator and stored at 35°F prior to their use in the study. Data were analyzed statistically using Tukey's test at the 5% level.

<u>Study II</u>. In a second study, four dormant plants of rose cv. Bridal Pink were planted in a soil medium consisting of a 1:1:1 mixture of soil, peat, and perlite at each of seven soil-medium temperatures used in Study I. The chambers were moved into a greenhouse at recommended day and night air temperatures and at the seasonal solar radiation for the duration of this experiment (April 1971 through May 1972). Similar air temperatures were maintained at 21° to 23°C days and 18°C nights for all treatments during the period when flowering data was being collected (February, March, April, and May 1972), while treatment soil medium temperatures were 5°, 10°, 15°, 20°, 25°, 30°, and 35°C. After flower buds had developed in the initial stems; each stem was pinched once removing the bud and the stem to below the first 5-leaflet rose leaf. The shoots developing from the auxillary buds were allowed to flower. Commercially recommended environmental and cultural recommendations were followed during the study (45).

After February 8, 1972 all canes were tagged and dated after each flower was cut. The flowers were cut at their usual commercially recommended stage, leaving one 5-leaflet on the new rose canes. When canes flowered again, a new tag was dated and attached to the cane.

Data collected immediately after cutting included date cut, number of nodes per flowering stem, length of stem in centimeters from the base of the bud to the point where the stem originated, the fresh weight of the flower in grams.

Growth and flowering data collections were terminated May 9, 1972.

Pressure Bomb Data Collection. The pressure bomb equipment consisted of a pressure chamber, a source of pressure (compressed nitrogen), and a method of measuring the applied pressures (pressure gauge). Figure 2. The procedure followed was as described by Scholander et.al.(58) and Waring and Cleary (68).

Data were collected on cloudy as well as sunny days with air temperatures ranging from 25° to 32°C. Samples were cut beginning at 2:00 pm. each day and immediately (less than 60 seconds) placed into the pressure chamber and a reading taken before proceeding to the next sample.

The sample, consisting of a leafy shoot 10-12 cm long, was inserted through a rubber stopper with a hole which allowed the cut end of the sample to protrude 0.5 cm through the stopper. The stopper was then firmly pressed into the chamber cover and the cover installed into the chamber body. Pressure was then applied at 2.5 psi per second by adjusting the rate control valve. Close observation of the cut stem surface showed a film of water appearing, at which time the chamber shut-off valve was closed. The plant moisture stress was then read from the pressure gauge. This procedure required less than 60 seconds per sample.

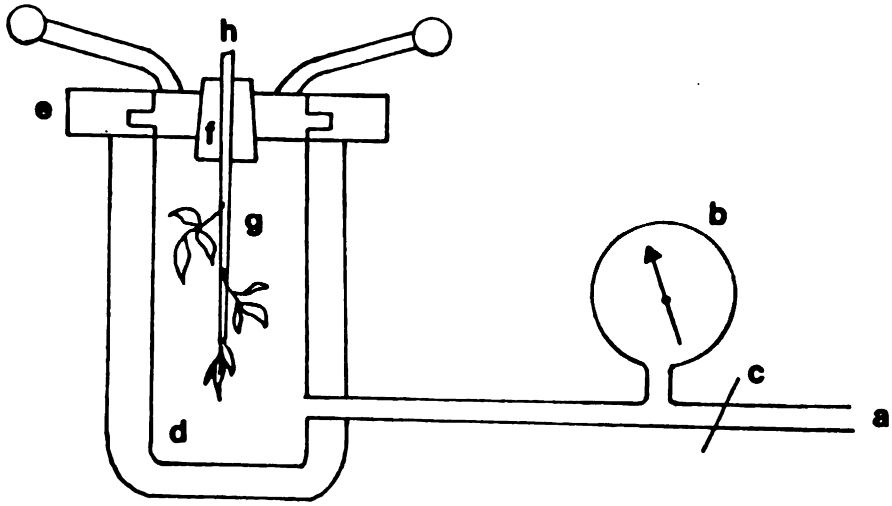


Figure 2.--Pressure Bomb

a. Compressed gas pressure source
b. Pressure gauge
c. Valve
d. Stainless steel pressure chamber
e. Screw cap
f. Rubber stopper
g. Leafy shoot
h. Sample cut end

RESULTS

The growth and flowering of rose cv. Bridal Pink was significantly altered when grown at low and high soil temperatures. Variables compared in Study I were initial root and shoot growth of dormant plants and in Study II vegetative stem growth and flower development, which included the number of nodes per flowering stem, flower stem length, fresh weight of the flower, timing in days from cut-to-cut, and internal water stress on actively growing plants.

Study I. The temperature of the growing medium influenced the initial growth of dormant Triple X rose plants of cv. Bridal Pink. In general, both root growth and shoot growth were affected in a similar manner. The photographs (Figures 3 and 4) clearly illustrate the differences observed in both shoot growth and root growth at the various medium temperatures.

Root growth increased as medium temperature was increased from 5° to 25°C (Figure 5). The plants growing at a medium temperature of 5°C produced the fewest number of roots; however, this treatment did not differ significantly statistically from the 10°, 15°, and 35°C medium temperatures (Table 1). The greatest root growth occurred at a medium temperature of 25°C but this did not differ significantly from the 30°C media temperature.

Root length was significantly reduced at 5°C when compared to all other treatments (Table 1). A 25°C media temperature produced

Figure 3. The effect of soil temperature on the growth of roots and shoots 10 days after planting dormant Triple X rose cv. 'Bridal Pink'. Plants were grown at: (A) 5°C; (B) 10°C; (C) 15°C; (D) 20°C soil temperatures.

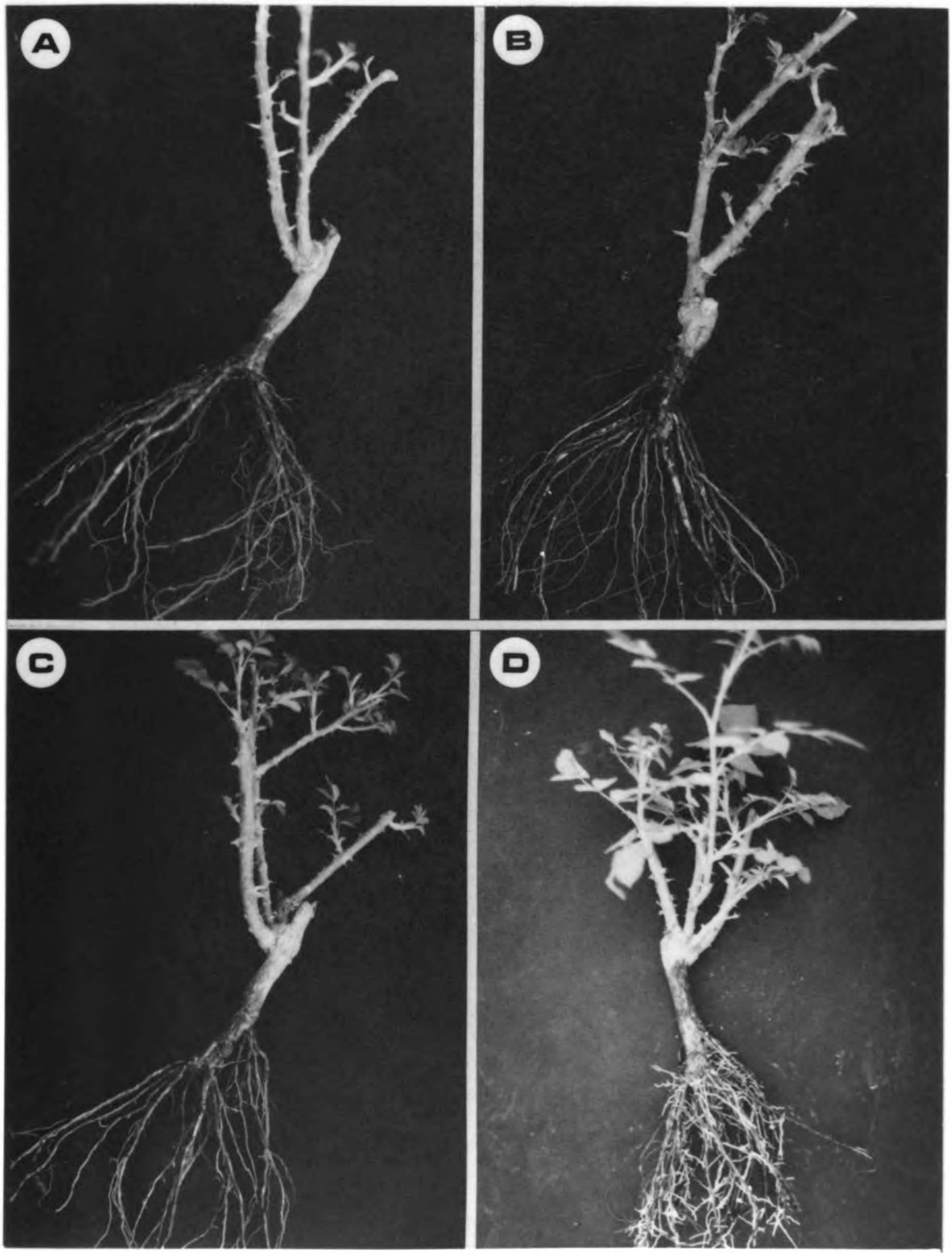

A
B
C
D

Figure 4. The effect of soil temperature on the growth of roots and shoots 10 days after planting dormant Triple X rose cv. 'Bridal Pink'. Plants were grown at: (A) 25°C; (B) 30°C; and (C) 35°C soil temperatures.

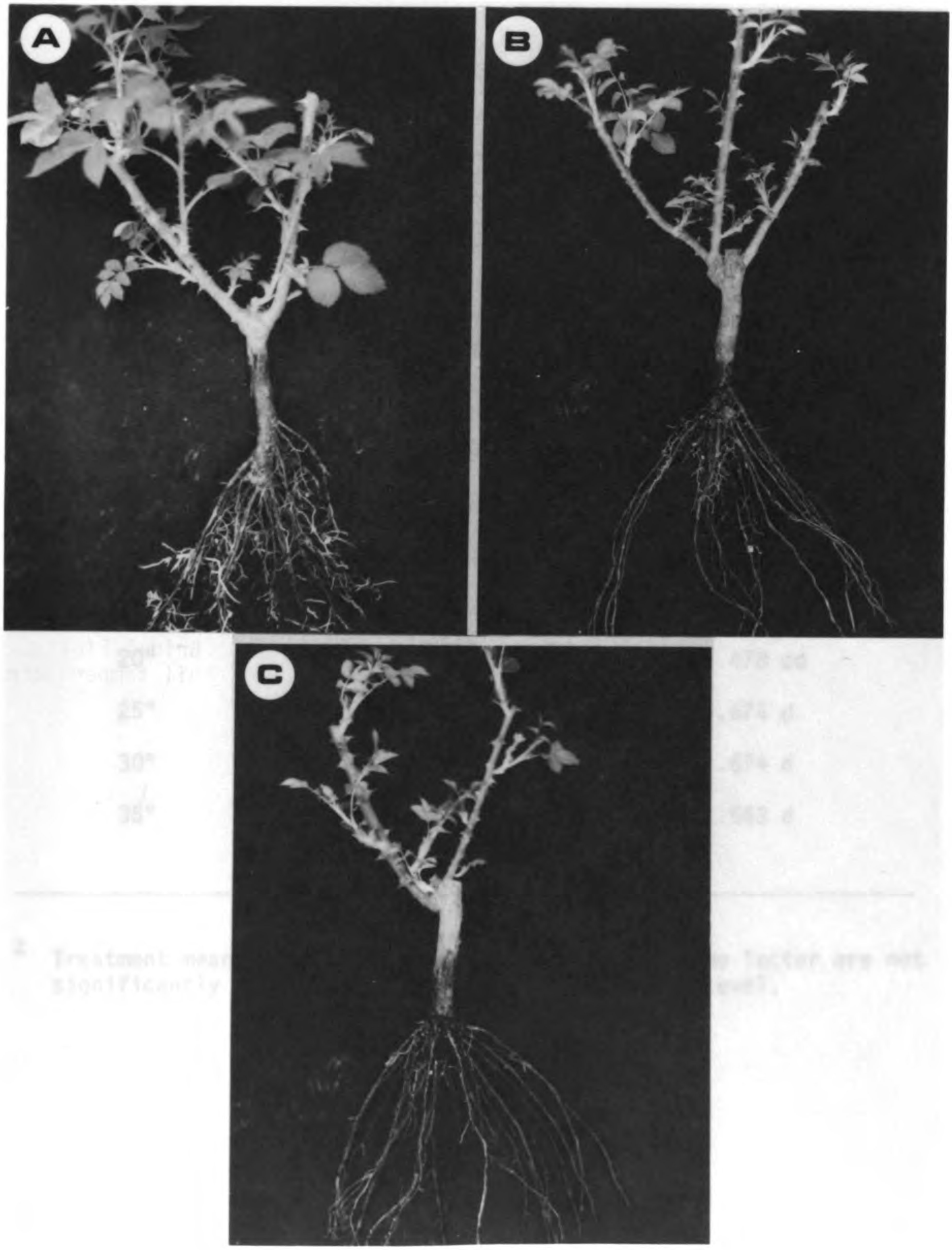
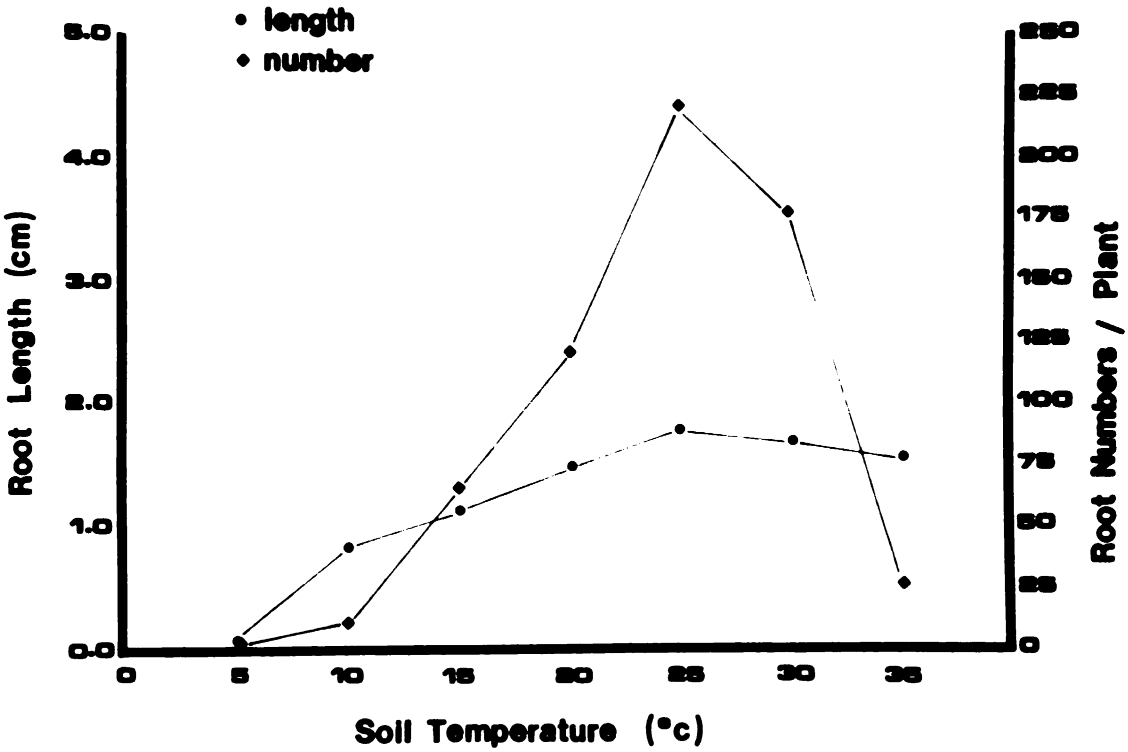

A
B
C

Table 1. The effect of soil temperature on root growth 10 days after planting dormant plants of rose cv. 'Bridal Pink'.

Treatment (°C)	Root Number	Root Length (cm)
5°	0.111 a[z]	0.056 a
10°	10.556 a	0.818 b
15°	64.333 ab	1.032 bc
20°	121.111 bc	1.478 cd
25°	222.667 d	1.674 d
30°	178.444 cd	1.674 d
35°	25.667 a	1.543 d

[z] Treatment means within the same column with the same letter are not significantly different by Tukey's test at the 5% level.

Figure 5. Effect of soil temperature on root count and length 10 days after planting dormant plants of rose cv. 'Bridal Pink'.



• length
◆ number
Root Length (cm)
5.0
4.0
3.0
2.0
1.0
0.0
Root Numbers / Plant
250
225
200
175
150
125
100
75
50
25
0
0
5
10
15
20
25
30
35
Soil Temperature (°c)

plants with the greatest root length, although this was not different significantly from the 20°, 30°, and 35°C treatments.

Shoot numbers developing from dormant rose plants were largest for plants growing in a medium of 30°C, but did not significantly differ from plants grown at 15°, 20°, and 25°C soil temperatures (Talbe 2). At a 5°C media temperature, significantly fewer shoots developed than for the other treatments. An increase in medium temperatures to 30°C resulted in an increase in shoot numbers (Figure 6).

Shoot length was significantly reduced at 5°C media temperature when compared to the 20°, 25°, 30°, and 35°C medium temperatures, but the 10° and 15°C medium temperatures were not significantly different (Table 2). Similar to the regeneration of new roots, shoot length increased as the medium temperature was increased from 5° to 25°C (Figure 6).

Study II. Plant growth and flowering of the rose cv. Bridal Pink was significantly influenced by various soil medium temperatures.

Stem lengths of flowering shoots were significantly shorter at a soil medium temperature of 35°C than at the other soil medium temperatures (Table 3 and Figure 7). Stem length was not significantly different among the other soil medium temperature treatments.

The number of nodes per flowering stem were significantly reduced at the 30°C soil media temperature, but the node numbers did not statistically differ among treatments at 15°, 20°, 25°, and 35°C (Table 3 and Figure 8).

Fresh weights of the cut flowers were similar statistically among the soil-medium temperature treatments (Table 3 and Figure 9).

Table 2. The effect of soil temperature on shoot growth 10 days after planting dormant plants of rose cv. 'Bridal Pink'.

Treatment (°C)	Shoot Number	Shoot Length (cm)
5°	6.583 a[z]	1.90 a
10°	8.750 b	2.67 ab
15°	9.500 bc	3.00 bc
20°	9.500 bc	3.98 c
25°	9.833 c	4.34 c
30°	10.167 c	3.56 c
35°	8.917 b	3.09 c

[z] Treatment means within the same column with the same letter are not significantly different by Tukey's test at the 5% level.

Figure 6. Effect of soil temperature on shoot count and length 10 days after planting dormant plants of rose cv. 'Bridal Pink'.

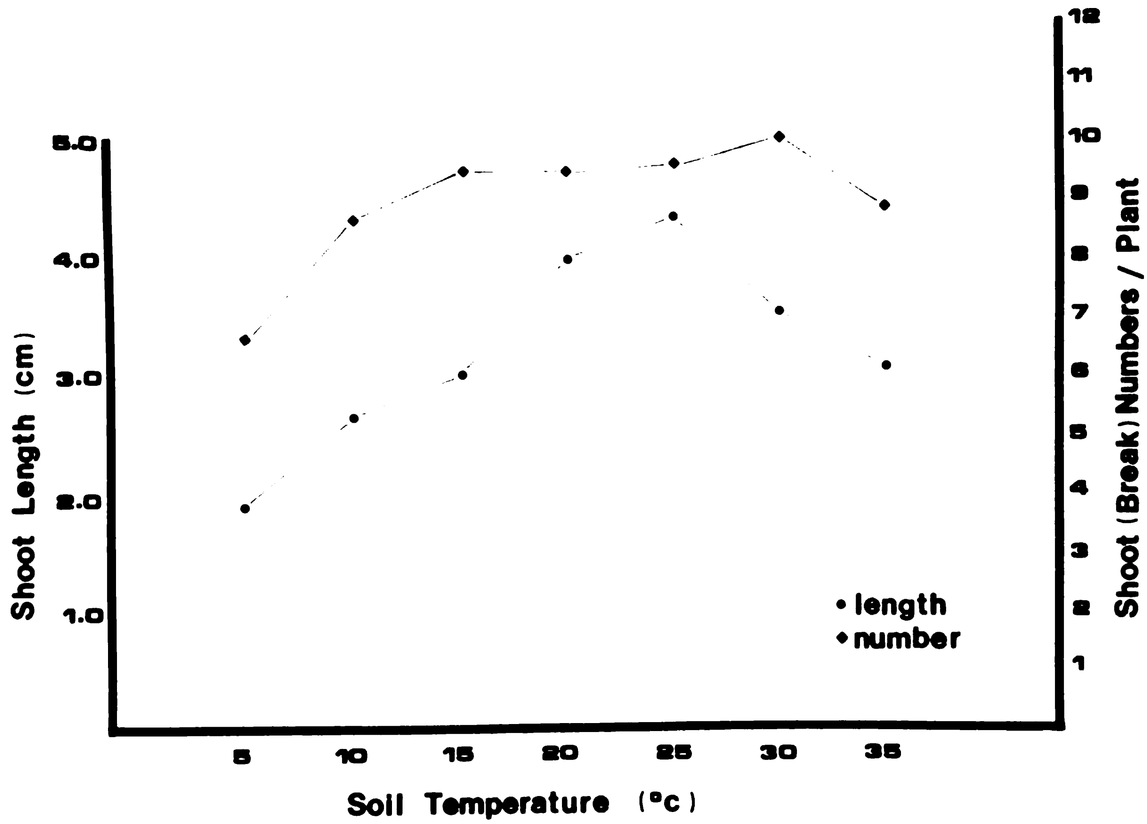

5.0
4.0
3.0
2.0
1.0
Shoot Length (cm)
12
11
10
9
8
7
6
5
4
3
2
1
Shoot (Break) Numbers / Plant
• length
• number
5
10
15
20
25
30
35
Soil Temperature (°c)

Table 3. The effect of soil temperature on flower production of rose cv. 'Bridal Pink'.

Treatment	Stem Length (cm)	Node Number	Fresh Weight (gm)	Pressure Bomb (ATM)
5°	30.851 b[z]	7.013 b	16.004 a	6.43 bc
10°	29.254 b	6.841 b	16.016 a	6.16 bc
15°	30.172 b	6.784 ab	15.093 a	5.80 ab
20°	29.819 b	6.638 ab	15.218 a	5.26 a
25°	30.137 b	6.663 ab	15.155 a	5.26 a
30°	27.985 b	6.219 a	14.875 a	6.04 bc
35°	24.893 a	6.677 ab	15.557 a	6.64 c

[z] Treatment means within the same column with the same letter are not significantly different by Tukey's test at the 5% level.

Figure 7. Effect of soil temperature on flowering stem length of rose cv. 'Bridal Pink'.

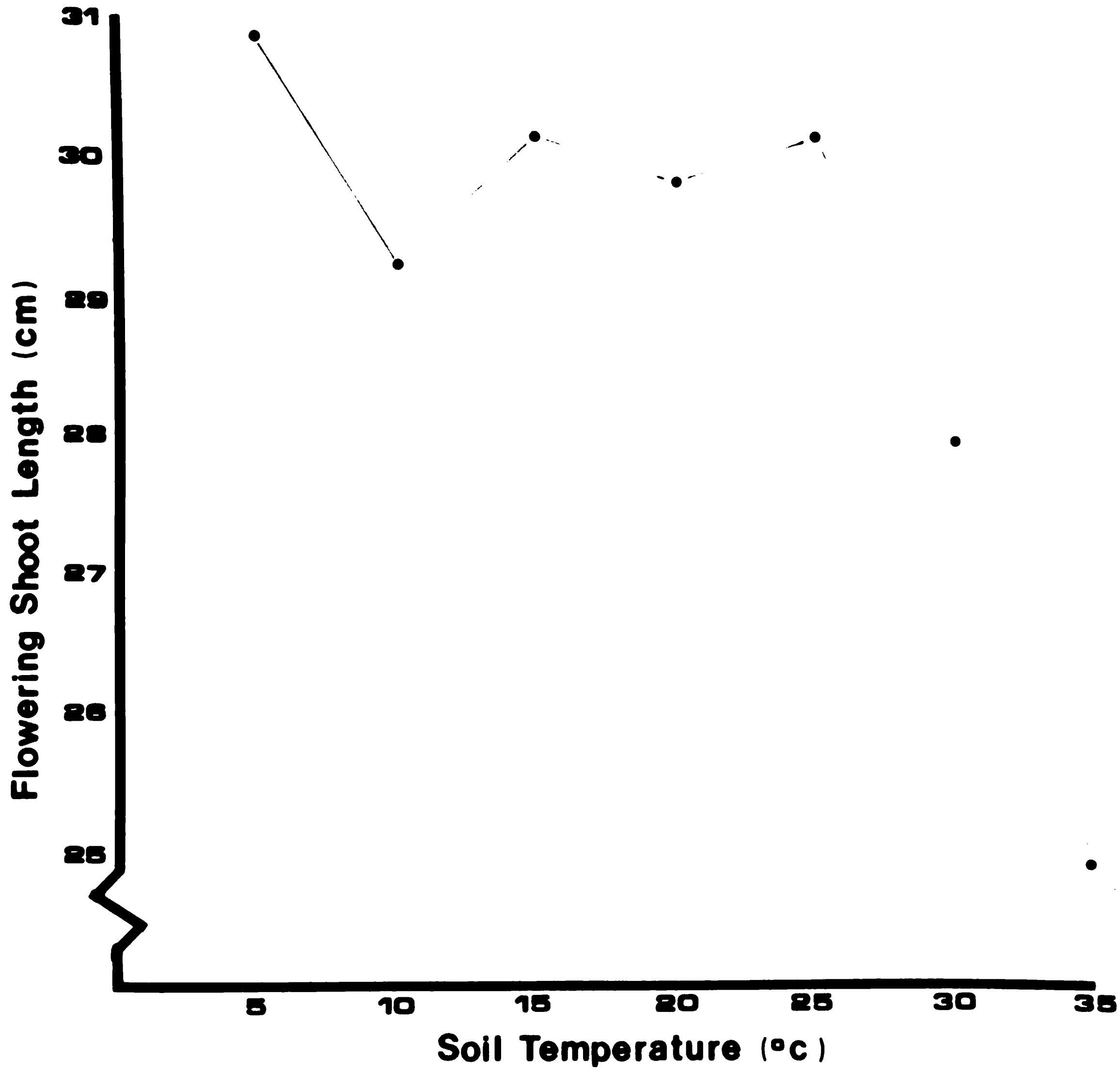

31
30
29
28
27
26
25
Flowering Shoot Length (cm)
5
10
15
20
25
30
35
Soil Temperature (°c)

Figure 8. Effect of soil temperature on node number per flowering stem of rose cv. 'Bridal Pink'.

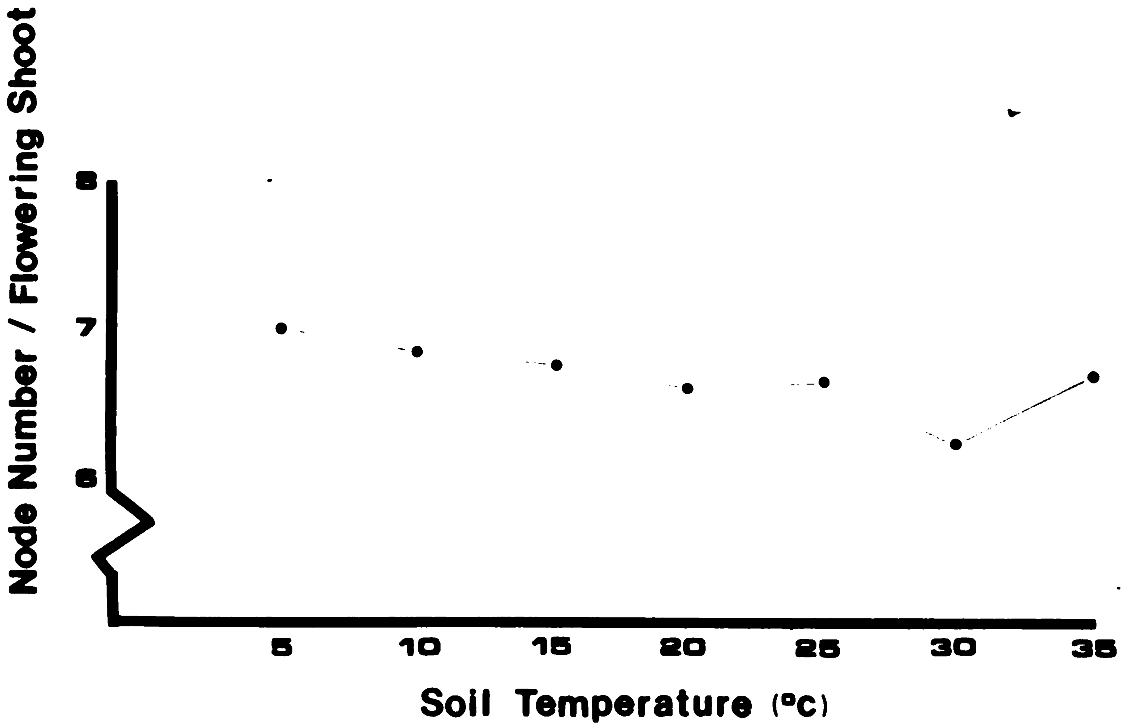
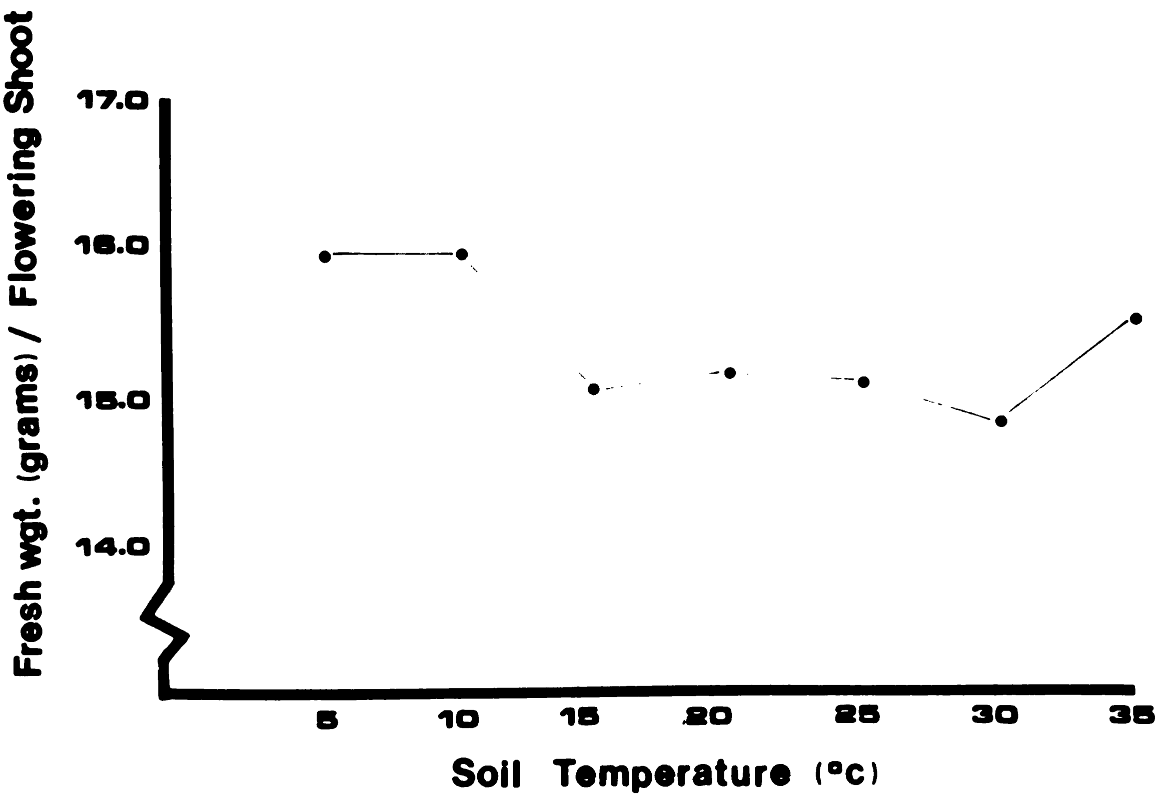

Node Number / Flowering Shoot
8
7
6
5
10
15
20
25
30
35
Soil Temperature (°C)

Figure 9. Effect of soil temperature on fresh weight of flowering stems of rose cv. 'Bridal Pink'.

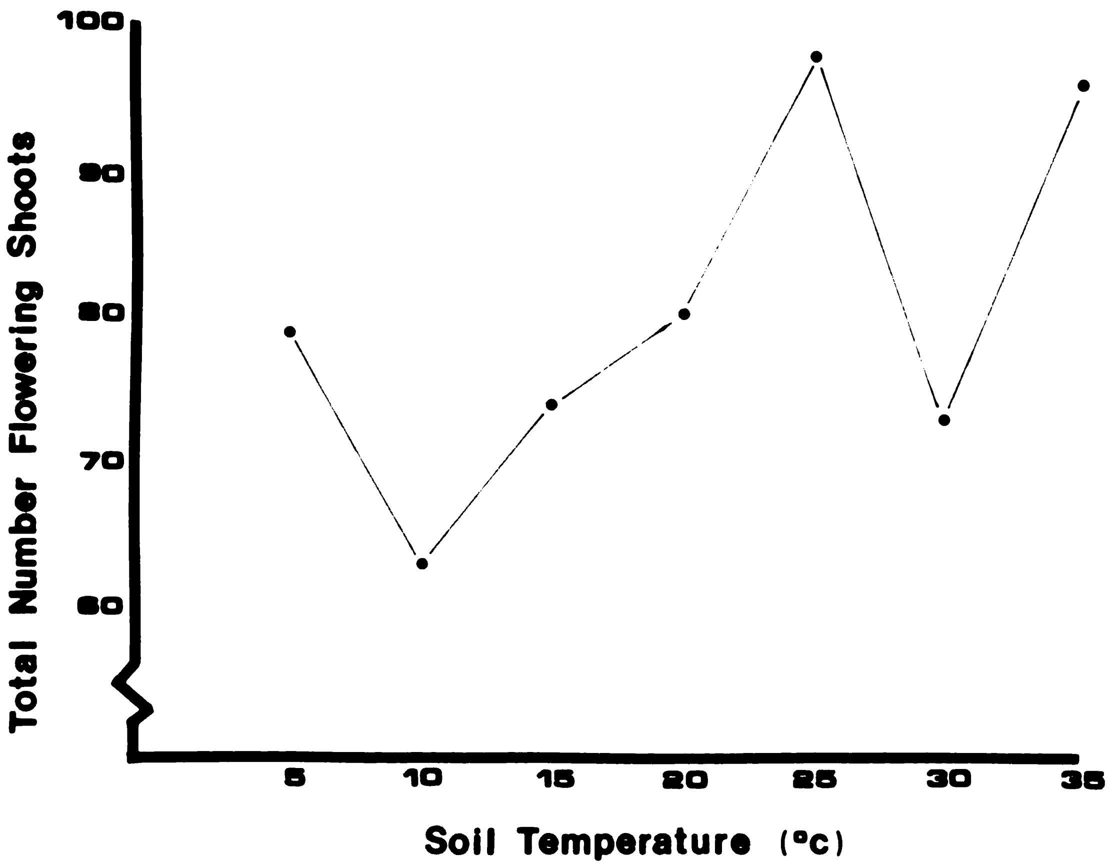

Fresh wgt. (grams) / Flowering Shoot
17.0
16.0
15.0
14.0
5
10
15
20
25
30
35
Soil Temperature (°c)

The largest number of cut rose flowers from February 8, 1972 to May 9, 1972 were from plants grown at 25°C soil-media temperatures, 55.5% greater than those grown at a 10°C soil-media temperature (Figure 10). The plants grown at 10°C soil-media temperature produced the fewest blooms. Plants growing at a soil-media temperature of 35°C produced 52.4% more blooms than those at a 10° soil-media temperature. Considerable treatment variability occurred in the number of cut flowers produced at the various soil-medium temperatures (Figure 10).

The number of days required from cutting a flower to flowering of the stem again was altered by the soil-medium temperature (Figure 11). A fewer number of days were required for return of stems of rose cv. Bridal Pink to flowering as the soil-medium temperature increased from 5° to 30°C. At a soil-media temperature of 5°C, 53.50 days were required for return of stems to flowering compared to 47.68 days at 30°C. This represents a 10.9% reduction in the number of days required from cutting a flower to flowering of the stem again. A soil-media temperature of 35°C resulted in an increase in the number of days required for the return of a flower when compared to the 30°C soil-media temperature.

The least amount of internal water stress occurred at soil-medium temperatures of 20° and 25°C when compared to higher and lower soil-medium temperatures (Figure 12). An increase in soil-media temperature of 10°C resulted in a significant increase in internal water stress while no significant difference occurred at the lower soil-medium temperatures.

Figure 10. Effect of soil temperature on flower production on rose cv. 'Bridal Pink' from February 8, 1972 to May 9, 1972.



100
90
80
70
60
Total Number Flowering Shoots
5
10
15
20
25
30
35
Soil Temperature (°c)

Figure 11. Effect of soil temperature on days to flower of flowers harvested from rose cv. 'Bridal Pink'.

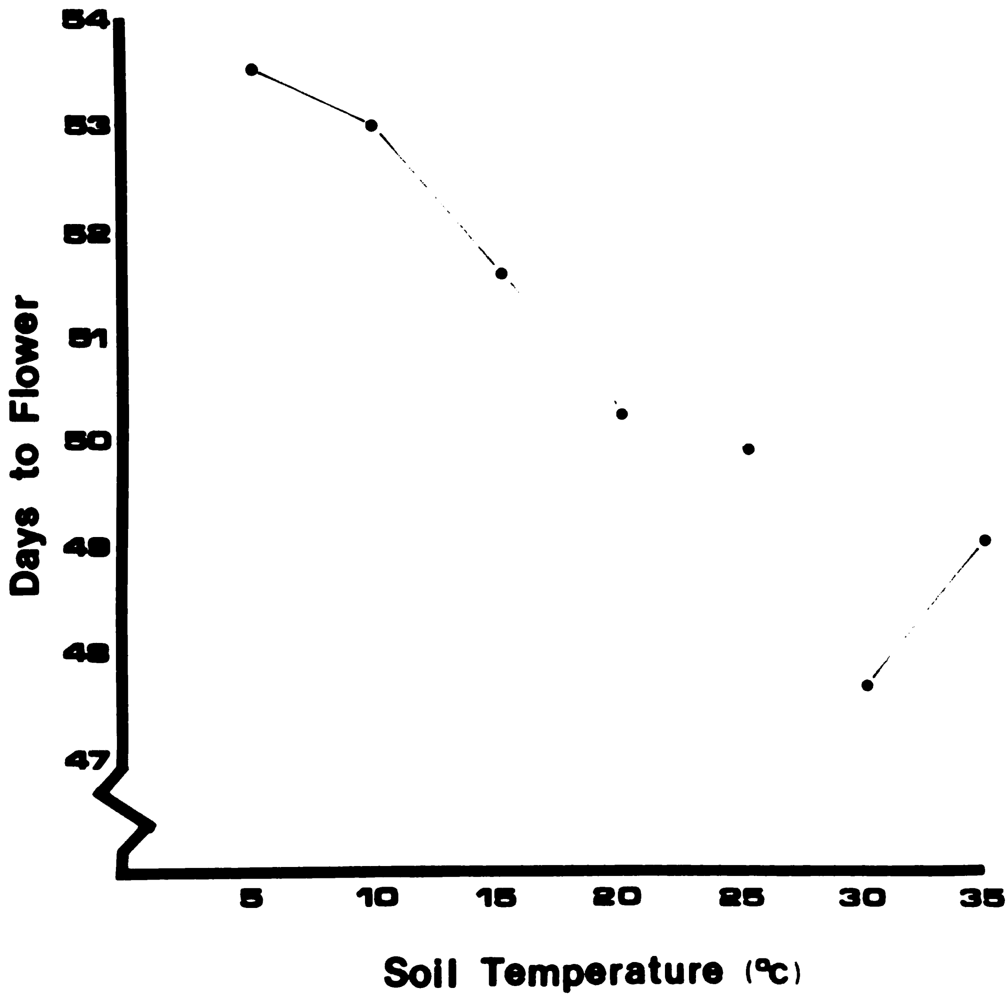
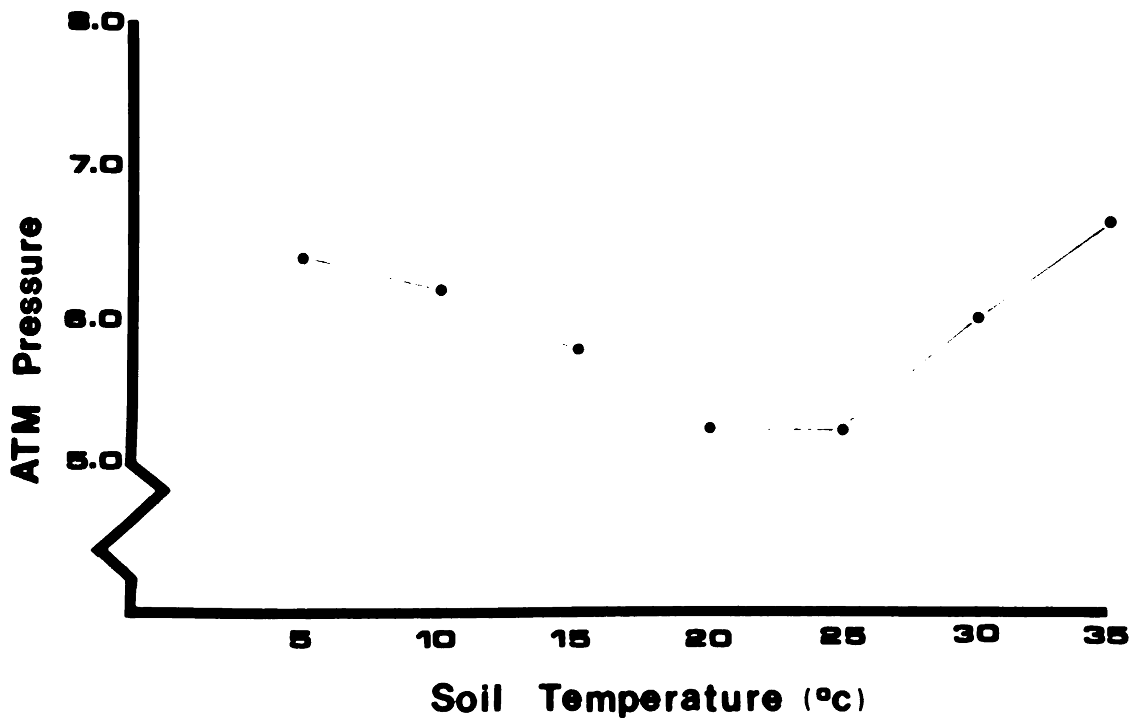

54
53
52
51
50
49
48
47
Days to Flower
5
10
15
20
25
30
35
Soil Temperature (°C)

Figure 12. Effect of soil temperature on internal water stress for rose cv. 'Bridal Pink'.


8.0
7.0
6.0
5.0
ATM Pressure
5
10
15
20
25
30
35
Soil Temperature (°c)

DISCUSSION

The results indicate that soil temperature influences both root growth, vegetative growth, and flowering of rose 'Bridal Pink'. Low root temperature inhibited both root and shoot growth. This is probably due to several factors such as reduced water uptake, decrease in translocation of growth substances, and the direct effect of temperature on root metabolism which subsequently reduced shoot growth.

Brower (12) attributed the reduction of both root and shoot growth at low and high soil temperatures to water stress caused by reduced absorption of water. Low temperature decreases the absorption of water in a number of ways. The viscosity of water itself is twice as great at 0° as at 25°C. The viscosity of the protoplasm must also be greatly increased, which decreases the permeability of the root tissue. Kramer (42) has shown that low temperature reduces the rate of water movement through a root at 5°C to be about 25% of the rate of 25°C under the same pressure gradient.

In this study internal water stress was measured using the pressure bomb. The results obtained in Figure 11 support the hypothesis that low and high soil temperatures increase the moisture stress within a plant.

Davis and Lingle (24) claimed the reduction in shoot growth of tomatoes at low soil temperatures was not caused by reduced absorption of water or mineral nutrients. They suggested that low temperatures decreased translocation from shoots to the roots. The result is accumulation of substances in the shoots which inhibit metabolic activity. Esau and co-workers (28) have reported that low temperatures may retard the rate at which materials are transported in the phloem. Therefore, low temperatures might reduce the root's effectiveness as a sink for phloem transported materials. Davis and Lingle (24) reasoned that a large number of growth substances that are produced in shoots have been shown to accumulate at girdles, should the shoot experience an alteration in the concentration of such compounds, due to an interruption or depression of phloem transport, a partial inhibition of shoot cell metabolism might result. The results in Figure 5 support these previous findings and correspond precisely with Hansen's (32) work on rooting.

It seems possible that the reduced growth of shoots as shown in Figures 5,6, and 7 which occur when roots are subjected to unfavorable environmental conditions may result from interference with their metabolic activities as well as from interference with absorption. Exudates from root systems of grapes grown at 30°C, where greater root and shoot elongation occurred, were shown by Skene and Kerridge (61) to contain more of certain cytokinins than exudates from those grown at 20°C. In addition to their action in stimulating cell divisions, cytokinins interact with auxin to induce organ initiation (62). They induced callus tissue to form roots, buds, or continue producing callus, or stop growing entirely depending on the amount of IAA and kinetin provided. Atkin et.al. (2) found increasing cytokinin in xylem exudate of corn as the soil temperature was increased from 8° to 28°C. It was their observation that with more branched root system at higher temperatures the increase in cytokinin level may be related to an increased number of sites of production, such as root apices. If cytokinin - auxin balance was influenced by the soil temperature to, in effect, cause an increase in the number of flowering shoots produced, this could possibly explain why, in this experiment, a high number of flowers were produced at the higher soil temperature of 35°C as shown in Figure 10.

The practice of covering a newly planted rose plant with polyetheyne has been used for years by commercial growers in increase the number of breaks (45). This microclimate creates an environment of high humidity while also increasing the temperature surrounding the plants adding further support to the findings in this study which showed an increased shoot number at the higher temperatures (Figure 10).

Other substances having shoot regulatory activity are claimed to be produced in roots (69,33). Although it has not been proved that the differences in growth are caused by differences in production of growth regulatory substances in roots, the possibility would justify further investigation.

Figure 7 shows a significant decrease in stem length as the temperature of the growing medium increases above 25°C to 35°C. This corresponds with the evidence previously sited in that roots, in addition to being organs of support and absorption, have the further role of supplying some growth substances to the shoot. There is evidence that gibberellins may be synthesized in roots and trans-

ported to the shoot (2,16,18,22,51,53). This export of gibberellins and other growth substances to the shoot are influenced by environmental factors. Thus, when the roots are subjected to stress, a decrease in translocation to the shoot would be expected to occur. A decrease in stem length could be expected to result with a decrease in gibberellin supplied to the shoots, as occurred in this experiment.

Relatively little data is available concerning the effect on growth and water absorption at high temperatures. Root temperatures above 30°C reduced water absorption in lemons, grapefruit, and oranges (9,31). Kramer (41) reported that exudation from detopped tomato root systems attained its maximum at 24°C and decreased at higher temperatures. The small number of roots in the top 30 cm of soil in warm climates is attributed to high summer soil temperatures (52). Several workers (4,48,56) have shown that root structure is modified at high soil temperatures by increased rate of maturation. The efficiency of roots as absorbing surfaces is greatly reduced because they become suberized almost to the tips.

SUMMARY

These studies show that prolonged root temperature treatments influence the growth of rose cv. 'Bridal Pink'. Temperature has a diverse and complicated impact on plant growth, for it influences the plant's water status and this must affect endogenous plant hormone production. One might also conclude that the growth and survival of the root system may depend on factors originating in the shoot, while the shoot may depend on factors originating in the root.

The data from these studies would tend to suggest that a higher soil temperature than commonly found in commercial rose ranges would be of some value. However, the effect of a higher soil temperature of 25°C was not significantly different from those of 10° to 15°C when comparing length, node number, and fresh weight of the flowering stems. It appears from the data that during the early stages of building the young plants, a soil temperature of 25°C might be most effective for both root and shoot growth. The vigor with which the crop starts is considered to be the most important and critical time in the life of a greenhouse rose.

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