INFLUENCE OF NIGHT AIR TEMPERATURE, IRRIGATION WATER TEMPERATURE AND SOIL TEMPERATURE ON FOUR BEDDING PLANT SPECIES

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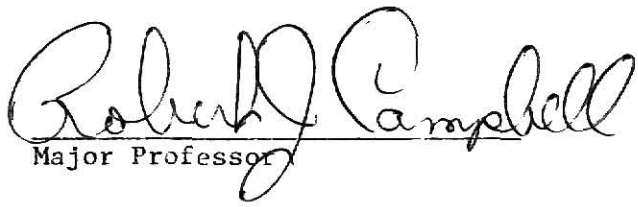

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INTRODUCTORY STATEMENT

This thesis has been written in manuscript form to be submitted for publication in the Journal of the American Society for Horticultural Science. The research for this manuscript was conducted in the spring of 1976 in the Department of Horticulture and Forestry research greenhouses and laboratories at Kansas State University, Manhattan, Kansas.

Influence of Night Air Temperature, Irrigation Water Temperature and Soil Temperature on Four Bedding Plant Species.[1]

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Abstract. Seedlings of petunia, marigold, coleus and pepper were grown 8-11 weeks at 4.4, 10 or 15.6°C night air temperatures and irrigated with 10, 25 or 40°C water. Plants at 15.6°C flowered earlier and, except for root dry weight of marigold, yielded more total dry weight, shoot dry weight and root dry weight. Irrigation with 25 or 40°C water did not overcome growth delays of bedding plants grown at 4.4 or 10°C night air temperature. Marigolds irrigated with 10°C water had lower bud and flower counts and yielded less shoot fresh weight, total dry weight and shoot dry weight. Soil temperature response to irrigation water temperature was immediate but temporary. Since warm irrigation water was not beneficial to plant growth, it's use would not be advised until optimum irrigation temperatures are determined. Cold water

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irrigation of plants growing at 4.4 or 10°C night air temperature would not appear to be harmful. However, growth of marigolds at 15.6°C was limited by 10°C irrigation water.

The high cost of fuel and its decreasing availability has forced many bedding plant growers to lower their night-time greenhouse temperatures. Depending upon the prevailing outside temp, significant amounts of fuel can be saved (6). However, growth and particulary flowering are delayed in many bedding plant species when they are grown from 4.4 to 10°C night air temp (1,2).

Low soil temp, a result of the cooler night air, contributes to delays in growth and flowering. Kramer (10) reported that cold soil lowered root absorption by decreasing root-membrane permeability and by increasing water viscosity. Hori et al. (7) reported the response of cucumber, tomato, turnip and snapbean to various combinations of root and air temp. Root temp below 13°C were unfavorable, regardless of the air temp. Above 13°C root temp, growth was influenced exclusively by air temp in tomato and snapbean. Cucumber and turnip growth were influenced more by root temp than air temp. It appeared that if either the roots or the shoots were grown at suboptimum temp, growth was delayed and plant growth was unfavorable.

If cool air temp cannot be avoided, the resulting cold soil temp can be eliminated by artificially raising the soil temp to a constant level using various kinds of heating cables placed under the soil surface or by circulating heated water through pipes buried in the soil root zone. Rykbost et al. (13) reported

that 13 field and greenhouse crops responded to soil warming by maturing earlier. However, yield response varied from no-increase to more than double-the-normal yield. Greenhouse crops such as roses, carnations and Asparagus plumosus derived no benefit from soil heating to 22°C (8,9,14,15). Cooper (4) reported the responses of numerous other plants to cold soil and to soil warming.

Irrigation with cold water contributes to the problem of cold soil. After the initial sharp decline of soil temp, recovery to normal temp has been found to take approximately 2 hr for pots, 8 hr for ground benches and up to 24 hr in field plots (3,12,16). Plant response to cold irrigation water varies from species to species. Plant height and fresh wt at flowering in certain Chrysanthemum cultivars and flower stem lengths and fresh wt in roses were significantly reduced when the plants were irrigated with cold water. A sudden loss in relative turgidity and the partial to complete closing of stomata was also reported (3).

Warm water irrigation can be used to raise soil temp, but soil temp response has proved to be temporary. After irrigation with warm water, soil temp returned to normal after 2 hr in 10 cm plastic and 15 cm clay pots (5) and after 8 hr in raised and ground benches (12).

Nave (11) reported an optimum irrigation water temp of 32.2°C for carnation, geranium, foliage plants and stocks. 'Sim' carnations and greenhouse roses did not show beneficial effects after irrigation with 21 to 65°C water (12,14). Gibbons (5) found that the response of 3 geranium cultivars to

irrigation water temp of 21, 31 and 48°C was cultivar dependent, each cultivar appearing to have its own optimum irrigation water temp. Gibbons' results suggested a relationship between growth, nutrient uptake and water temp that is genetically controlled.

A review of the literature found no studies of the response of bedding plants, other than geranium, to warm water irrigation. Therefore, a study was undertaken on 4 bedding plant species to determine if warm water irrigation would: 1) be beneficial over cold water irrigation, and 2) overcome the growth delays in plants grown at suboptimum night air temp.

Materials and Methods

Limited research space and time restricted our study to 4 bedding plant species. The 4 species that were selected were Petunia X hybrida Hort. Vilm. Sndr. cv. Tango, petunia; Tagetes patula L. cv. Sparky, marigold; Coleus X hybridus Voss cv. Red Rainbow Improved, coleus: and Capsicum annuum L. cv. California Wonder, pepper. Petunia and marigold are not harmed by cool growing temp, but coleus and pepper are. The selected cultivars are commonly grown in the Midwest. Petunia, coleus and pepper seed were sown on 5 February 1976 in vermiculite and sand (1:1, v/v). Marigold seeds were sown 10 days later. Two 1.8 by 2.4 m plexiglass greenhouses were maintained at night air temp of 4.4 and 10°C. A section of a larger glass greenhouse was maintained at 15.6°C. Steam heat was used in all 3 greenhouses. Daytime temperatures ranged from 21 to 32°C. Irrigation water temp were: 25 and 40°C, the water heated in 20 l plastic containers by

100-watt aquarium heaters; and 10°C, the water chilled in a refrigerator. Before each irrigation, the water was adjusted to the exact temp required and poured into a pre-cooled or pre-warmed 5.7 l insulated container. The water was then siphoned out with rubber tubing into the pots. Seedlings were transplanted at the 2 leaf stage between 23 February and 1 March into a soil: moss peat:perlite (1:1:1) mix in 8.9 cm standard plastic pots. The first watering was with normal temp tap water after which the pots were immediately placed into the greenhouses. Each greenhouse was divided into 4 blocks with 3 replications of each irrigation water treatment per block for each of bedding plant species. There were 36 plants of each species in each greenhouse or 432 total plants in the study. The irrigation water treatments began on 5 March and the plants were watered thereafter when needed. On 15 March all plants were fertilized with Peters 20-20-20 (3.9 g/l) and Peters soluble trace element mix (1.3 g/l). All plants were again fertilized 6 April, but only with 20-20-20. The fertilizer was incorporated into the irrigation water treatments. The plexiglass greenhouses were sprayed with a shading compound 23 March and were later partially shaded by tall trees in mid-April. Insects and red spider mites were controlled with sprays of nicotine sulfate (2.6 g/l) on 15 April and Pentac (0.65 g/l) on 20 April.

One-third of the plants were randomly selected after 8 weeks of growth and measured for height, shoot fresh wt, shoot dry wt and root dry wt. Three weeks later the remaining plants were measured for height and number of buds and flowers; first-

flower dates were recorded on the petunias and marigolds; and half were harvested for shoot dry wt determinations. On the remaining petunias, peppers and coleus, stomatal-diffusive-resistance readings were taken once for each of the species from 3 May through 18 May with a stomatal-diffusion porometer, constructed by the Kansas State University Evapotranspiration Laboratory.

A 24-point potentiometer was used continuously 9 April to 26 April to monitor changes in air and soil temp of plants in the 4.4 and 10°C greenhouses. Thermocouples were positioned either at plant height or buried in the soil at a depth of 3 cm. The potentiometer ran for 24-hr cycles.

Analysis of variance on data was made using the AARDVARK program developed by the Kansas State University Statistics Department. Temperatures recorded on the potentiometer were converted to Celsius and plotted using the PLOTTER program also developed by the Statistics Department.

Results

Night air temp had a greater effect on plant growth than irrigation water temp. Bedding plants grown at the 15.6°C night air temp yielded more total dry wt, shoot dry wt and root dry wt than bedding plants grown at 4.4 and 10°C (Table 1). The root dry wt of marigolds was the only exception, with significantly less root dry wt at the 15.6°C night air temp. The root/shoot ratios of petunia and marigold were significantly smaller at the 15.6°C night air temp; but the root/shoot ratios of pepper and

Table 1. Growth responses of 4 bedding plant species to night air temperature.[z]

Crop	Night air (°C)	Height[y] (cm)	Fresh shoot wt (g)	Total dry wt (g)	Shoot dry wt (g)	Root dry wt (g)	Root/ shoot ratio	Bud and flower count	First flower (days)	Diffusive resistance (sec cm^{-1})
Petunia 'Tango'	4.4	6.8b[x]	19.9b	1.95b	1.75b	0.20b	0.11a	10.8b	70.4a	9.59ab
	10.0	7.0b	20.2b	1.89b	1.69b	0.20b	0.12a	9.3c	70.7a	11.01a
	15.6	11.2a	24.9a	3.40a	3.10a	0.30a	0.10b	15.5a	53.8b	7.49b
Marigold 'Sparky'	4.4	14.4b	16.0	2.83b	1.20b	0.83a	0.42a	10.0c	61.0a	-
	10.0	13.9b	16.6	2.79b	1.98b	0.81a	0.41a	11.5b	59.8a	-
	15.6	16.6a	16.5	3.26a	2.70a	0.56b	0.21b	15.6a	50.4b	-
Coleus 'Red Rainbow Imp.'	4.4	5.0b	4.2b	0.32b	0.25b	0.07b	0.281b	-	-	8.97a
	10.0	4.5b	4.4b	0.34b	0.27b	0.07b	0.26b	-	-	7.03ab
	15.6	9.2a	15.3a	1.41a	1.06a	0.35a	0.33a	-	-	5.21b
Pepper 'California Wonder'	4.4	10.9b	6.5b	1.31b	0.83b	0.48b	0.56b	-	-	5.47
	10.0	10.5b	6.2b	1.25b	0.79b	0.46b	0.58b	-	-	6.00
	15.6	12.7a	9.3a	2.44a	1.38a	1.06a	0.77a	-	-	6.13

[z]Data for bud and flower counts and diffusive resistance were taken after 77 days. All other data were taken after 56 days.

[y]Data are averages of 12 plants per treatment for petunia, marigold and pepper; 6 plants per treatment for coleus. Bud and flower counts and first flower are averages of 24 plants per treatment.

[x]Mean separation by Duncan's multiple range test, 5% level.

coleus were significantly smaller at 4.4 and 10°C than at the 15.6°C night air temp. The 4.4 and 10°C night air temp delayed first flower by approximately 17 days in petunia and 10 days in marigold. Bud and flower counts for petunia and marigold were significantly greater at the 15.6°C night air temp.

Warm (25 and 40°C) irrigation water did not overcome delays in growth of bedding plants grown at cooler night air temp. Marigolds were the only plants in this study to show a significant response to irrigation water temp (Table 2). The shoot fresh wt and bud and flower counts were significantly greater for marigolds irrigated with 40°C water. The total plant dry wt and shoot dry wt were significantly greater for marigolds irrigated with 25 and 40°C water than for marigolds irrigated with 10°C water.

The root/shoot ratios of marigolds in Table 3 show that the marigolds responded differently to the irrigation water treatments at each night air temp. Although not statistically different, the root/shoot ratios of marigolds irrigated with 10°C water at the 4.4°C night air temp were larger than the root/shoot ratios of marigolds irrigated with 25 and 40°C water. Marigolds irrigated with 25°C water at the 10°C night air temp had a significantly larger root/shoot ratio than the marigolds irrigated with 10°C water. Although not statistically different, the root/shoot ratios of marigolds irrigated with 40°C water at the 15.6°C night air temp were larger than the root/shoot ratios of marigolds irrigated with 10 and 25°C water.

Stomatal-diffusive-resistance measurements taken on petunias, peppers and coleus did not differ significantly between irrigation

Table 2. Growth responses of 4 bedding plant species to irrigation water temperature.[z]

Crop	Irrig. water (°C)	Height[y] (cm)	Fresh shoot wt (g)	Total dry wt (g)	Shoot dry wt (g)	Root dry wt (g)	Root/ shoot ratio	Bud and flower count	First flower (days)	Diffusive resistance (sec cm^{-1})
Petunia 'Tango'	10	7.5	20.5	2.23	2.00	0.23	0.12	11.5	65.2	9.26
	25	8.6	22.3	2.55	2.31	0.24	0.11	12.3	64.8	10.35
	40	8.9	22.2	2.46	2.23	0.23	0.10	11.8	64.8	8.48
Marigold 'Sparky'	10	14.2	15.4b[x]	2.75b	2.06b	0.69	0.35	11.5b	58.1	-
	25	15.1	16.4ab	3.00a	2.26a	0.74	0.36	12.6ab	56.6	-
	40	15.4	17.3a	3.14a	3.37a	0.77	0.34	13.0a	56.5	-
Coleus 'Red Rainbow Imp.'	10	6.1	8.5	0.75	0.57	0.18	0.29	-	-	6.84
	25	6.4	8.6	0.73	0.56	0.18	0.30	-	-	7.70
	40	6.2	6.8	0.59	0.45	0.14	0.28	-	-	6.66
Pepper 'California Wonder'	10	11.7	6.9	1.57	0.95	0.63	0.63	-	-	6.26
	25	11.3	7.6	1.75	1.06	0.69	0.64	-	-	5.77
	40	11.1	7.4	1.68	1.00	0.68	0.65	-	-	5.57

[z]Data for bud and flower counts and diffusive resistance were taken after 77 days. All other data were taken after 56 days.

[y]Data are averages of 12 plants per treatment for petunia, marigold and pepper; 6 plants per treatment for coleus. Bud and flower counts and first flower are averages of 24 plants per treatment.

[x]Mean separation by Duncan's multiple range test, 5% level.

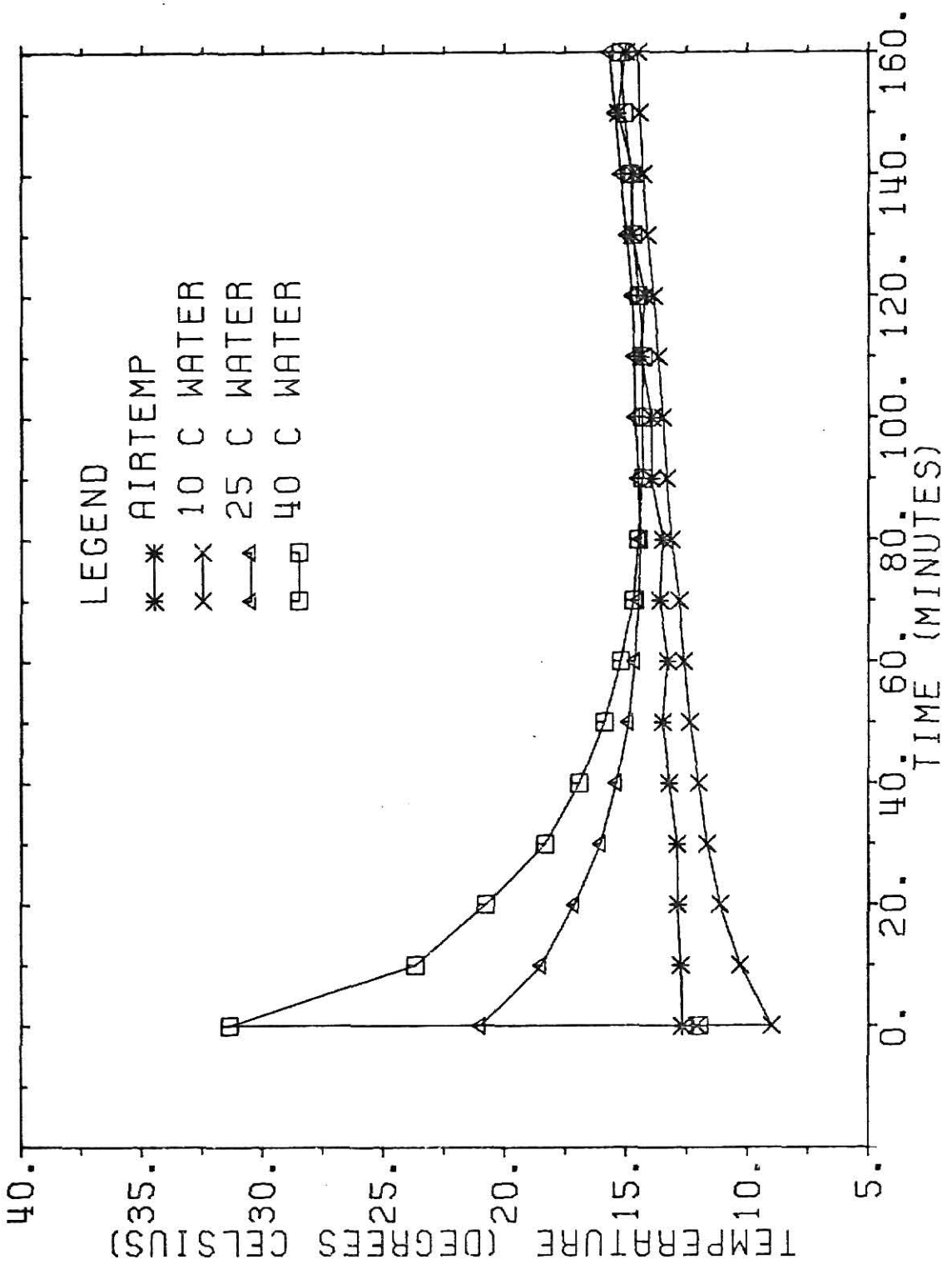
Table 3. Growth response of marigold to the interaction of irrigation water temperature and night temperature 56 days after transplanting.[z]

Night air (°C)	Irrigation water (°C)	Shoot dry wt (g)	Root dry wt (g)	Root/ shoot ratio
4.4	10	1.86c[y]	0.88	0.48a
	25	2.02bc	0.82	0.41ab
	40	2.11bc	0.80	0.38ab
10.0	10	2.02bc	0.71	0.35b
	25	1.84c	0.88	0.48a
	40	2.08bc	0.83	0.40ab
15.6	10	2.31b	0.48	0.21c
	25	2.91a	0.51	0.18c
	40	2.90a	0.69	0.24c

[z]Data are averages of four plants per treatment.

[y]Mean separation by Duncan's multiple range test, 5% level.

Fig. 1. Soil temperature changes in 8.9 cm stantard plastic pots as caused by irrigation water temperature.


LEGEND
AIRTEMP
10 C WATER
25 C WATER
40 C WATER
TEMPERATURE (DEGREES CELSIUS)
40.
35.
30.
25.
20.
15.
10.
5.
0.
20.
40.
60.
80.
100.
120.
140.
160.
TIME (MINUTES)

water treatments. Measurements taken on petunia and coleus were significantly lower at the 15.6°C night air temp than at 4.4 and 10°C.

Soil temperature response to the irrigation water temp was immediate, but temporary (Fig. 1). The soil and air temp recorded from the 4.4 and 10°C night air temp greenhouses did not differ significantly; therefore, the data from the 2 greenhouses were pooled. The 10, 25 and 40°C irrigation water treatments immediately changed the current soil temp, 12.2°C, to approximately 9, 21 and 31°C. Soil temp returned to the current air temp, 12.9°C, within 1-10 min for the 10°C irrigation water treatment, 30-40 min for the 25°C treatment and 40-50 min for the 40°C treatment. The small vol of soil in each pot allowed soil temp to fluctuate rapidly and match the prevailing air temp throughout the day and night.

Discussion

Any sudden change in soil or air temp may result in a possible slowing down of photosynthesis, respiration, water absorption, mineral absorption, water movement and transpiration (4). In our study, the soil temp in the pots was the same as the prevailing air temp. Therefore, for plants grown at 4.4 or 10°C night air temp and irrigated with 10°C water, the soil temp was not changed enough to shock the plant. Thus, there was no additional delay in plant growth or drop in dry wt yields of these plants. Irrigation with warm water may have warmed the root systems of the bedding plants grown at 4.4 and

10°C sufficiently to temporarily speed up various plant processes. However, the short interval of time that soil temp remained higher was not enough to help the plant. Since irrigation was not needed as often at the lower night air temp, the soil temp remained at the current air temp for longer uninterrupted time periods.

Growth of marigolds at the 15.6°C night air temp and irrigated with 10°C water was significantly less than the growth of plants irrigated with 25 and 40°C water for 2 possible reasons. First, the soil temp was never lower than 15.6°C except when watered with 10°C water. The cold water may have shocked the roots and the plant. Carpenter and Rasmussen (3) reported that 1.7 and 7.2°C irrigation water caused a sudden drop in turgidity of Chrysanthemum grown at 18°C. Secondly, irrigation was more frequent at the 15.6°C night air temp due to the rapid drying out of the soil. Repeated shocking of the plant over an extended time period could delay plant growth and result in lower dry wt.

The data from this study indicate very few differences between the plants grown at the 4.4 and 10°C night air temp. Towards the end of the study, outside night air temp no longer averaged below 4.4°C; therefore the 4.4°C plants were not grown as cool as they were earlier in the study. If plant growth in the 4.4°C greenhouse had been delayed by the low temp, it may have caught up with the plant growth in the 10°C greenhouse before the study was terminated. The significant decrease in petunia buds and flowers at the 10°C night air temp was probably caused by severe early morning shading by trees around the greenhouse

that leafed out later in the spring.

The low root/shoot ratios of petunia and marigold (Table 1) at the 15.6°C night air temp may indicate that roots are more efficient at warmer soil temp, thus requiring less root tissue to support each unit of shoot tissue. However, the data from coleus and pepper does not support this as their root/shoot ratios were highest at 15.6°C.

The lower stomatal diffusive resistance in petunia and coleus at the 15.6°C night air temp would indicate larger stomata and/or stomata that were more open at the time the reading was taken. Carpenter and Rasmussen (3) reported that stomata closed when plants were irrigated with cold water. The data for this study were taken approximately 3.5 hr after irrigation and would indicate that, if stomata had closed immediately after irrigation with 10°C water, they had opened again before we measured the diffusive resistance.

Different plant species appear to have different optimum irrigation water temp requirements. Using cold water on plants growing at 4.4 or 10°C night air temp would not appear to result in less growth. However, the use of warm irrigation water would not be advised unless it was proven beneficial to growth. Frequent irrigations with warm irrigation water would probably be more advantageous to plant growth. More work needs to be done to determine the optimum irrigation water temp requirements of each species of bedding plants. The possibility of repeated shocking of bedding plants grown at 15.6°C night air temp and irrigated with 10°C water would warrant the avoidance of the use of cold irrigation water on bedding plants if at all possible.

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A P P E N D I X

Table A-1. Analysis of variance for various growth parameters on petunia.

Source of variance	Degrees of Freedom	Mean Squares								
		Height (cm)	Fresh shoot wt (g)	Total dry wt (g)	Shoot dry wt (g)	Root dry wt (g)	Root/ shoot ratio	Bud and flower count	First flower (days)	Diffusive resistance (sec cm-1)
Night temp (N)	2	74.06*	94.83*	8.81*	7.70*	0.04*	0.002*	258.10*	2256.05*	37.65*
Water temp (W)	2	6.95	13.02	0.32	0.31	0.00	0.00	4.68	1.26	10.64
N x W	4	3.45	5.17	0.09	0.07	0.00	0.00	0.64	5.97	3.59
Blocking	3	8.58	12.45	0.16	0.14	0.00	0.00	24.61*	128.41*	12.01
Error	24/60[z]	7.00	6.41	0.14	0.12	0.00	0.00	5.78	11.30	10.53
Total	35/71									

*Significant at .05 level.

[z]Bud and flower counts and first flower are based on 2 plants per block, giving error = 60 and total = 71. All other data based on 1 plant per block.

Table A-2. Analysis of variance for various growth parameters on marigold.

Source of variance	Degrees of Freedom	Mean Squares							
		Height (cm)	Fresh shoot wt (g)	Total dry wt (g)	Shoot dry wt (g)	Root dry wt (g)	Root/ shoot ratio	Bud and flower count	First flower (days)
Night temp (N)	2	25.14*	1.37	0.83*	2.04*	0.27*	0.17*	203.63*	816.05*
Water temp (W)	2	3.20	10.56*	0.45*	0.28*	0.02	0.00	16.17*	20.10
N x W	4	0.23	3.28	0.17	0.16*	0.03	0.02*	6.04	41.81
Blocking	3	2.93	4.11	0.14	0.06	0.02	0.00	12.05	4.90
Error	24/60[z]	2.34	2.10	0.06	0.04	0.02	0.01	4.42	30.36
Total	35/71								

*Significant at .05 level.

[z]Bud and flower counts and first flower are based on 2 plants per block, giving error = 60 and total = 71. All other data based on 1 plant per block.

Table A-3. Analysis of variance for various growth parameters on coleus.

Source of variance	Degrees of Freedom	Mean Squares						
		Height (cm)	Fresh shoot wt (g)	Total dry wt (g)	Shoot dry wt (g)	Root dry wt (g)	Root/ shoot ratio	Diffusive resistance (sec cm-1)
Night temp (N)	2	39.30*	240.19*	2.32*	1.27*	0.16*	0.01*	21.20*
Water temp (W)	2	0.08	6.06	0.05	0.03	0.00	0.00	1.86
N x W	4	1.28	1.04	0.01	0.01	0.00	0.00	0.47
Blocking	1	0.02	0.59	0.00	0.00	0.00	0.00	1.08
Error	8	2.00	6.22	0.07	0.04	0.00	0.00	3.52
Total	17							

*Significant at .05 level.

Table A-4. Analysis of variance for various growth parameters on pepper.

Source of variance	Degrees of Freedom	Mean Squares						
		Height (cm)	Fresh shoot wt (g)	Total dry wt (g)	Shoot dry wt (g)	Root dry wt (g)	Root/ shoot ratio	Diffusive resistance (sec cm-1)
Night temp (N)	2	15.95*	35.01*	5.37*	1.27*	1.41*	0.16*	1.46
Water temp (W)	2	1.09	1.61	0.10	0.04	0.01	0.00	1.53
N x W	4	0.87	1.05	0.04	0.03	0.00	0.01	3.66
Blocking	3	20.93*	8.03*	0.40*	0.19*	0.04	0.00	2.81
Error	24	1.79	1.06	0.10	0.03	0.02	0.009	1.90
Total								

*Significant at .05 level.

Table A-5. Response of 4 bedding plant species to the interaction of irrigation water temp and night air temp.[y]

Crop	Night air (°C)	Irrig. water (°C)	Height (cm)	Fresh shoot wt (g)	Total dry wt (g)	Shoot dry wt (g)	Root dry wt (g)	Root/ shoot ratio	Bud and[z] flower count	First flower (days)	Diffusive[z] resistance (sec cm-1)
		10	6.2	19.3	1.87	1.67	0.20	0.12	10.3	70.1	8.51
	4.4	25	6.4	19.8	2.04	1.83	0.21	0.12	11.1	70.0	10.59
		40	7.8	20.7	1.93	1.75	0.18	0.11	11.0	71.1	9.68
Petunia											
		10	6.7	18.4	1.69	1.49	0.20	0.13	8.9	71.3	11.56
	10.0	25	6.7	20.4	1.91	1.71	0.20	0.12	9.6	71.3	12.33
		40	7.5	21.7	2.07	1.85	0.22	0.12	9.3	69.5	9.15
'Tango'											
		10	9.5	23.7	3.12	2.84	0.30	0.11	15.1	54.3	7.71
	15.6	25	12.6	26.8	3.70	3.38	0.32	0.10	16.3	53.3	8.15
		40	11.4	24.3	3.38	3.10	0.29	0.09	15.1	53.8	6.61
		10	14.0	15.1	2.75	1.86c[x]	0.88	0.48a	9.5	61.4	-
	4.4	25	14.6	16.0	2,84	2.02bc	0.82	0.41ab	9.5	62.3	-
		40	14.7	16.8	2.91	2.11bc	0.80	0.38ab	11.0	59.5	-
Marigold											
		10	13.2	16.5	2.72	2.02bc	0.71	0.35b	10.6	63.3	-
	10.0	25	14.2	15.9	2.72	1.84c	0.88	0.48a	11.4	56.8	-
		40	14.3	17.4	2.92	2.08bc	0.83	0.40ab	12.5	59.4	-
'Sparky'											
		10	16.1	14.5	2.79	2.31b	0.48	0.21c	14.3	49.8	-
	15.6	25	16.5	17.4	3.42	2.91a	0.51	0.18c	17.0	50.8	-
		40	17.3	17.7	3.58	2.90a	0.69	0.24c	15.6	50.6	-

(continued next page)

Table A-5. Continued.

Crop	Night air (°C)	Irrig. water (°C)	Height (cm)	Fresh shoot wt (g)	Total dry wt (g)	Shoot dry wt (g)	Root dry wt (g)	Root/ shoot ratio	Bud and flower count[z]	First flower (days)	Diffusive resistance[z] (sec cm-1)
		10	5.5	4.7	0.37	0.29	0.08	0.29	-	-	8.60
	4.4	25	4.3	4.0	0.30	0.24	0.07	0.27	-	-	9.20
		40	5.2	3.9	0.31	0.24	0.07	0.29	-	-	9.10
Coleus 'Red											
		10	4.5	4.9	0.38	0.30	0.08	0.28	-	-	6.93
	10.0	25	5.3	5.5	0.42	0.33	0.09	0.27	-	-	7.60
		40	3.9	2.9	0.22	0.18	0.04	0.22	-	-	6.60
Rainbow Imp.'											
		10	8.4	15.8	1.50	1.13	0.37	0.32	-	-	5.00
	15.6	25	9.6	16.4	1.48	1.10	0.38	0.35	-	-	6.30
		40	9.6	13.6	1.25	0.94	0.31	0.33	-	-	4.33
		10	11.4	6.3	1.29	0.83	0.46	0.54	-	-	5.65
	4.4	25	11.0	6.7	1.39	0.88	0.52	0.59	-	-	5.46
		40	10.4	6.3	1.25	0.79	0.46	0.57	-	-	5.30
Pepper											
		10	10.4	5.3	1.06	0.66	0.40	0.60	-	-	5.48
	10.0	25	10.2	6.3	1.30	0.82	0.48	0.60	-	-	6.68
		40	10.8	6.9	1.39	0.90	0.49	0.55	-	-	5.85
'California Wonder'											
		10	13.2	9.0	2.37	1.34	1.03	0.76	-	-	7.66
	15.6	25	12.8	9.8	2.55	1.48	1.07	0.73	-	-	5.16
		40	12.0	8.9	2.40	1.31	1.09	0.83	-	-	5.56

[z]Data taken after 77 days. All other data were taken after 56 days.

[y]Data are averages of 4 plants per treatment for petunia, marigold and pepper; 2 plants per treatment for coleus. Bud and flower counts and first flower are averages of 8 plants per treatment.

[x]Mean separation by Duncan's multiple range test, 5% level.

Table A-6. Analysis of variance for height of 4 bedding plant species 77 days after transplanting.

Source of variance	Petunia 'Tango'		Marigold 'Sparky'		Coleus 'Red Rainbow Imp.'		Pepper 'California Wonder'	
	Degrees of Freedom	Mean square	Degrees of Freedom	Mean square	Degrees of Freedom	Mean square	Degrees of Freedom	Mean square
Night temp (N)	2	323.40*	2	0.53	2	164.45*	2	2.95
Water temp (W)	2	9.05	2	0.21	2	22.66	2	0.61
N x W	4	16.84	4	3.13	4	6.89	4	
Blocking	3	21.35	3	9.18*	1	0.00	3	12.03*
Error	60	10.91	60	2.32	26	7.81	24	3.52
Total	71		71		35		35	

*Significant at the .05 level.

Table A-7. Analysis of variance for shoot dry wt of 4 bedding plant species 77 days after transplanting.

Source of variance	Petunia 'Tango'		Marigold 'Sparky'		Coleus 'Red Rainbow Imp.'		Pepper 'California Wonder'	
	Degrees of Freedom	Mean square	Degrees of Freedom	Mean square	Degrees of Freedom	Mean square	Degrees of Freedom	Mean square
Night temp (N)	2	3.18*	2	0.19	2	6.57*	2	0.67*
Water temp (W)	2	0.60	2	0.12	2	0.04	2	0.01
N x W	4	0.40	4	0.02	4	0.09	4	0.02
Blocking	3	0.19	3	0.16	1	0.02	3	0.04
Error	24	0.22	24	0.12	8	0.21	24	0.07
Total	35		35		17		35	

*Significant at the .05 level.

Table A-8. Growth response of 4 bedding plant species to the interaction of irrgation water temp and night temp 77 days after transplanting.

Night air (°C)	Irrig. water (°C)	Petunia 'Tango' Height[z] (cm)	Petunia 'Tango' Shoot dry wt[y] (g)	Marigold 'Sparky' Height[z] (cm)	Marigold 'Sparky' Shoot dry wt[y] (g)	Coleus 'Red Rainbow Imp.' Height[y] (cm)	Coleus 'Red Rainbow Imp.' Shoot dry wt[x] (g)	Pepper 'California Wonder' Height[y] (cm)	Pepper 'California Wonder' Shoot dry wt[y] (g)
4.4	10	21.8	5.67	16.7	3.41	10.4	1.60	15.6	1.76
	25	20.7	5.77	17.5	3.60	9.4	1.31	15.1	1.76
	40	21.8	5.59	17.6	3.59	14.2	1.39	16.2	1.87
10.0	10	24.0	4.50	17.7	3.25	15.4	1.44	16.0	1.54
	25	26.1	4.99	16.6	3.33	12.7	1.73	17.6	1.68
	40	25.2	5.60	17.0	3.51	14.3	1.19	15.9	1.62
15.6	10	18.1	5.84	16.9	3.57	19.2	3.35	16.2	2.11
	25	19.5	6.19	17.5	3.51	17.6	3.12	15.7	2.06
	40	15.6	6.11	16.5	3.72	19.3	3.31	14.9	2.07

[z]Data are averages of 8 plants per treatment

[y]Data are averages of 4 plants per treatment

[x]Data are averages of 2 plants per treatment

Table A-9. Growth response of 4 bedding plant species to night air temp 77 days after transplanting.

Night air (°C)	Petunia 'Tango' Height[z] (cm)	Petunia 'Tango' Shoot dry wt[y] (g)	Marigold 'Sparky' Height[z] (cm)	Marigold 'Sparky' Shoot dry wt[y] (g)	Coleus 'Red Rainbow Imp.' Height[y] (cm)	Coleus 'Red Rainbow Imp.' Shoot dry wt[x] (g)	Pepper 'California Wonder' Height[y] (cm)	Pepper 'California Wonder' Shoot dry wt[y] (g)
4.4	21.4b[w]	5.67a	17.3	3.53	11.4c	1.44b	15.6	1.80b
10.0	25.1a	5.03b	17.1	3.36	14.1b	1.45b	16.5	1.61b
15.6	17.8c	6.05a	17.0	3.60	18.7a	3.26a	15.6	2.08a

[z]Data are averages of 24 plants per treatment.

[y]Data are averages of 12 plants per treatment.

[x]Data are averages of 6 plants per treatment.

[w]Mean separation by Duncan's multiple range test, 5% level.

Table A-10. Growth response of 4 bedding plant species to irrigation water temp 77 days after transplanting.

Irrig. water (°C)	Petunia 'Tango' Height[z] (cm)	Petunia 'Tango' Shoot dry wt[y] (g)	Marigold 'Sparky' Height[z] (cm)	Marigold 'Sparky' Shoot dry wt[y] (g)	Coleus 'Red Rainbow Imp.' Height[y] (cm)	Coleus 'Red Rainbow Imp.' Shoot dry wt[x] (g)	Pepper 'California Wonder' Height[y] (cm)	Pepper 'California Wonder' Shoot dry wt[y] (g)
10	21.3	5.34	17.1	3.41	15.0	2.13	15.9	1.80
25	22.1	5.65	17.2	3.48	13.2	2.05	16.1	1.83
40	20.9	5.77	17.0	3.61	15.9	1.96	15.7	1.85

[z]Data are averages of 24 plants per treatment.

[y]Data are averages of 12 plants per treatment.

[x]Data are averages of 6 plants per treatment.

INFLUENCE OF NIGHT AIR TEMPERATURE, IRRIGATION WATER TEMPERATURE AND SOIL TEMPERATURE ON FOUR BEDDING PLANT SPECIES

by

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Seedlings of petunia, marigold, coleus and pepper were grown 8-11 weeks at 4.4, 10 or 15.6°C night air temperatures and irrigated with 10, 25 or 40°C water. Plants at 15.6°C flowered earlier and, except for root dry weight of marigold, yielded more total dry weight, shoot dry weight and root dry weight. Irrigation with 25 or 40°C water did not overcome growth delays of bedding plants grown at 4.4 or 10°C night air temperature. Marigolds irrigated with 10°C water had lower bud and flower counts and yield less shoot fresh weight, total dry weight and shoot dry weight. Soil temperature response to irrigation water temperature was immediate but temporary. Since warm irrigation water was not beneficial to plant growth, it's use would not be advised until optimum irrigation temperatures are determined. Cold water irrigation on plants growing at 4.4 or 10°C night air temperature would not appear to be harmful. However, growth of marigolds at 15.6°C was limited by 10°C irrigation water.