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ENVIRONMENTAL EFFECTS ON GERANIUM DEVELOPMENT

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I. Introduction:

Although the geranium is a major floriculture crop, relatively little is known quantitatively about how light and temperature effect geranium growth. Most geranium growers rely on personal experience and a limited amount of research which has been done conducted on the effects of light and temperature on seed geranium growth.

Both seed and zonal geraniums are grown. Although the method of production differs between seed and zonal geranium, they are both classified taxonomically as *Pelargonium* x *hortorum* Bailey. The relative popularity of zonal geraniums decreased somewhat during the late 1970's and early 1980's when the popularity of seed geraniums increased substancially. The increase in seed geranium popularity was due to several factors including low cost of production, the ability to uniformly flower large quantities of plants and their ability to tolerate adverse environmental conditions. In particular, the seed geranium was more tolerant of high temperatures and drought stress. New zonal geraniums were introduced during the late 1980's which were more tolerant of adverse environmental conditions.

This chapter will concentrate on how light and temperature effect geranium growth. Research will be presented on environmental studies conducted on both seed and zonal geraniums. Some of the research on seed geranium was conducted by Allen Armitage and Douglas Hopper while at Michigan State University and John White and I. Warrington while at Pennsylvania State University. Recent research results from the University of Minnesota and the University of Hanover on the effects of the environment on zonal geranium growth are also presented.

Geraniums are day-neutral. In other words, photoperiod length has no effect on flower initiation.

Although photoperiod length does not affect geranium flower initiation, light quantity does.

In general, flower initiation occurs earlier as the amount of light which seedlings receive each day increases.

'Red Elite' flower initaition occurred earlier as total light per day increased from 3.3 to 17 moles of light per square meter.

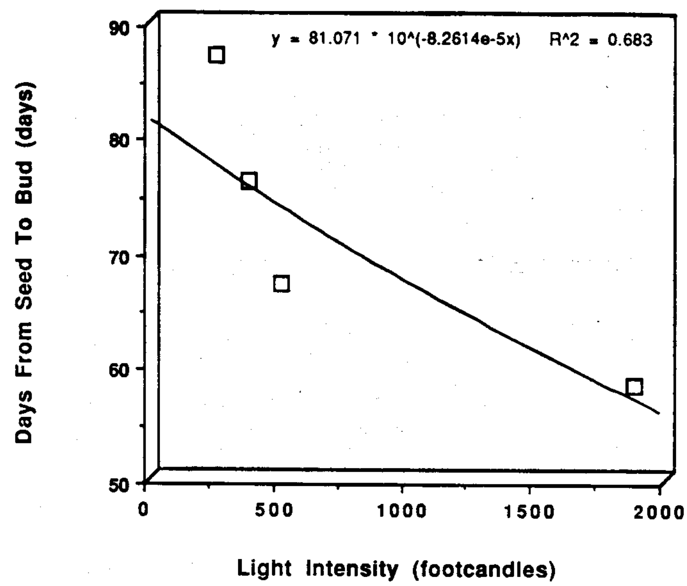

Figure 1. The effect of light intensity on the time from germination until anthesis of hybrid seed geranium 'Red Elite' (Armitage et al, 1984).

Geraniums are day-neutral. In other words, photoperiod length has no effect on flower initiation. Although photoperiod length does not affect geranium flower initiation, light quantity does (Craig and Walker, 1963; Armitage et al, 1984; Erickson et al, 1980; White and Warrington, 1988). In general, flower initiation occurs earlier as the amount of light which seedlings receive each day increases (Figure 1). For instance, flower initiation was hastened in 'Red Elite' hybrid seed geranium as the daily light integral which plants were grown under increased from 3.3 to 13 moles day^{-1} m^{-2}. Flower initation did not occur at daily light integrals below 3.3 moles day^{-1} m^{-2}. Increasing the daily light integral above 17 moles day^{-1} m^{-2}

II. Light:

Light Quantity: Light is the energy which drives plant growth through photosynthesis. Insufficient light or excessive light can limit plant growth.

Light can be limited through either low light intensity and/ or a short photoperiod. In contrast, supra-optimal light levels, i.e. > 600 *u*mol s^{-1} m^{-2} for 16 hours can be detrimental to geranium growth (White, personal communication). The importance of light quantity to geranium growth is dependent on the stage of plant development. In general, light quantity is more important in hastening geranium flower initiation than flower development.

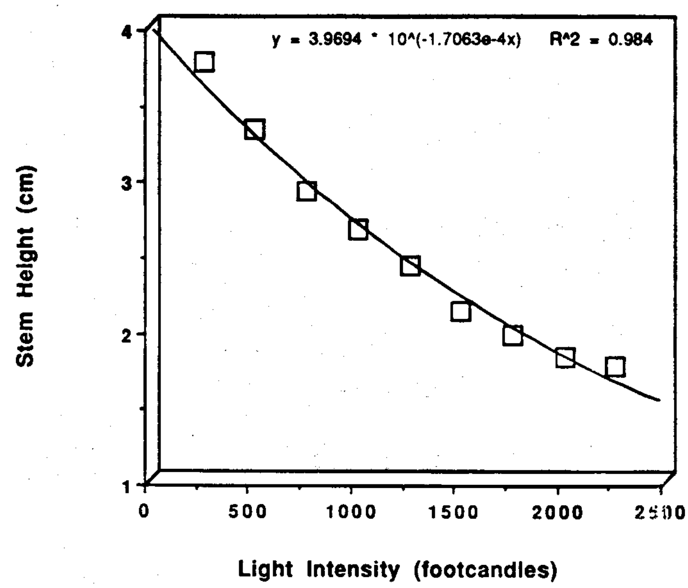

Figure 2. The effect of irradiance on stem height at flower of hybrid seed geranium 'Red Elite' (Hopper, 1986).

did not significantly hasten flower initiation (White and Warrington, 1988).

After flower initiation, light quantity has little effect on the rate of flower development (Erickson et al, 1980; Armitage et al, 1984; White and Warrington, 1984a; White and Warrington, 1984b). In addition, light quantity has little affect on the rate of geranium leaf unfolding (White and Warrington, 1988).

In contrast to light quantity affects on development rate, light intensity or irradiance does affect geranium morphological development. For example, hybrid seed geranium cv 'Red Elite' plant height decreased as irradiance increases up to 600 $u$mol s^{-1} m^{-2} (3000 footcandles for 12 hours) (Hopper, 1986). Further increasing light intensity above 600 $u$mol s^{-1} m^{-2} generally will not result in shorter plants (Figure 2).

Geranium stem calibre and branching increase as irradiance increase up to 600 $u$mol s^{-1} m^{-2} (3000 footcandles for 12 hours) (Hopper, 1986). Conversely, low irradiance levels, i.e. <100 $u$mol s^{-1} m^{-2} (<500 footcandles), can reduce branching. It is, therefore, critical to maintain stock plants and cuttings under light intensities sufficient to insure compact, stocky growth (>1000 footcandles).

Other morphological characteristics which are affected by irradiance are petiole length, pedicel length, leaf size, leaf thickness, flower number and flower size (White and Warrington, 1984; Hopper, 1986). The petiole is the section of stem connecting the leaf blade to the stem. The peduncle is the stem section connecting the inflorescence to the stem. As light intensity increases, petiole and peduncle length decrease. Similarly, leaf expansion and flower number and size decrease as light intensity increases (Figure 3).

Plant color is also affected by light intensity. Leaf zonation, leaf color, and flower color are more intense, or darker, at higher light intensities.

Zonal geranium fresh weight can be a determinant of both cutting and plant quality. In general, cutting and plant dry weight increase as irradiance levels increase from 4 to 26 moles day^{-1} m^{-2} (Pytlinski and Krug, 1988).

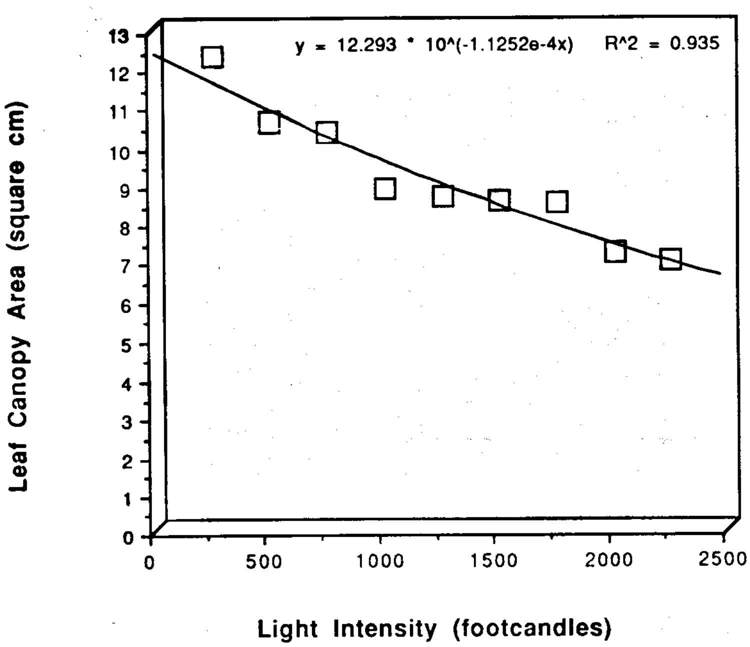

Figure 3. The effect of increasing irradiance on hybrid seed geranium 'Red Elite' leaf canopy area at flower (Hopper, 1986).

Light quality: Plant appearance is greatly affected by light quality or color (Smith, 1986). Red and far red light have a great effect on plant growth. Red and far red light affect the 'state' of phytochrome (a bluish pigment in plant leaves that perceives photoperiod and light quality). In general, plant quality decreases as the proportion of far red versus red light which a plant is exposed to increases. Far red light: 1) increases stem elongation, 2) increases leaf size, 3) decreases leaf thick-

After flower initiation, light quantity has little effect on the rate of flower development.

Light intensity affects geranium morphological development.

For example, 'Red Elite' plant height decreased as irradiance increased up to 600 $u$mol s^{-1} m^{-2}.

In contrast, geranium stem calibre and branching increased as irradiance increased up to 600 $u$mol s^{-1} m^{-2}.

Leaf zonation, leaf color, and flower color are more intense, or darker, at higher light intensities.

Plant appearance is greatly affected by light quality or color.

A plant leaf acts as a light filter - the leaf absorbs red light but lets far red light pass through.

Therefore, leaves below a canopy are exposed to more far red light than red light. This shading results in stretching and poor breaking in the lower leaf axils.

The developmental responses of plants to temperature follow a similar pattern.

ness, 4) increases pedicel, petiole, and peduncle length, 5) decreases branching, and 6) reduces the color intensity of leaves and flowers (Smith, 1986).

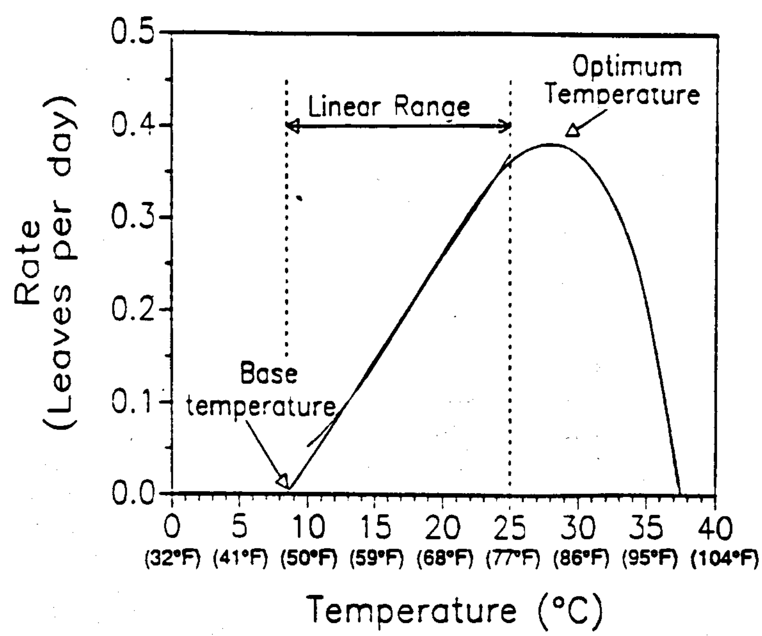

Figure 4. Typical response curve of how the rate of plant development is influenced by temperature (aquired from R. Heins, Michigan State University).

The phytochrome state in a plant is artificially altered when supplemental lighting is used. Incandescent light is high in far red light. Fluorescent light is high in red light. This is the basis for the shorter, darker green, well branched growth habit of plants grown under fluorescent lights and taller, lighter green, sparsely branched growth habit of plants grown under incandescent lamps or on plants exposed to a short term incandescent light exposure during the night.

A plant leaf acts as a light filter - the leaf absorbs red light but lets far red light pass through (Smith and Morgan, 1983). Therefore, leaves below a canopy are exposed to more far red light than red light. This leaf shading results in stretching and poor breaking in the lower internodes and leaf axils. Stock plants should, therefore, be spaced to avoid shading among plants.

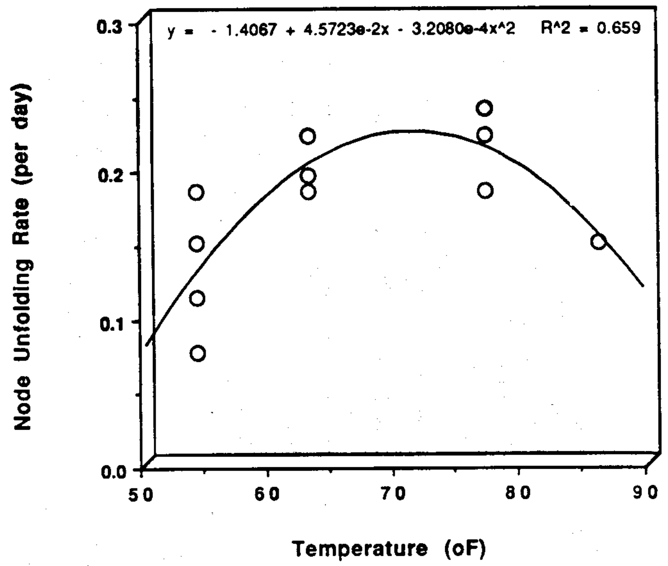

Figure 5. The effect of average daily temperature on zonal geranium cv 'Veronica' node unfolding rate when grown under temperatures ranging from 54 to 86°F (Erwin, unpublished data).

III. Temperature:

Temperature affects plant development rate, appearance and quality. The average daily temperature (24 hour) and the way in which temperatures are delivered during a 24 hour period affects plant development.

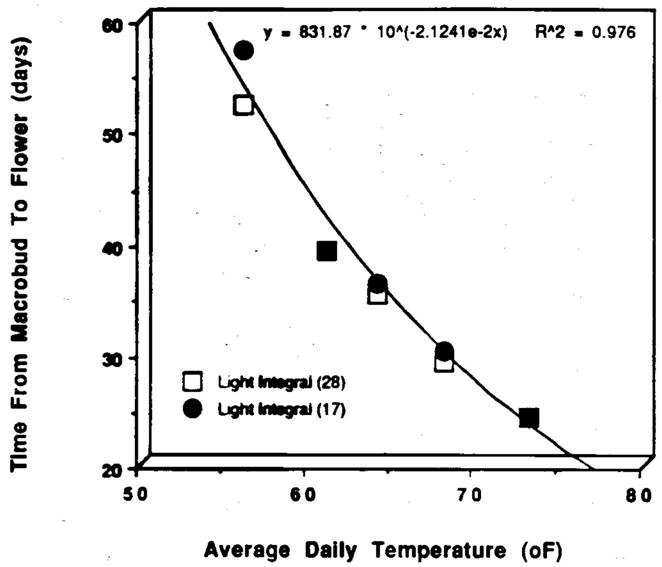

Figure 6. The effect of average daily temperature on the time from macrobud to flower on the hybrid seed geranium cv 'Red Elite' (White and Warrington, 1988b).

Plant development rate: The developmental responses of plants to temperature follow a similar pattern. There is a base temperature below which there is no growth. As temperature increases above the base temperature, the rate of plant development increases, almost linearly, to some maximum rate. As temperature increases above this point, the rate of plant development decreases (Figure 4).

The rate of plant development is dependent on the temperature which it is exposed at any given moment. In general, we grow geraniums at temperatures in the 'linear range' of the temperature growth response curve. In this range, the rate of plant development is strongly correlated with the average daily temperature which a plant is exposed to during a 24-hour period.

Leaf Unfolding Rate: Hybrid seed geranium 'Red Elite' leaf unfolding rate increases almost linearly as average daily temperature increases from 48 to 81°F (White and Warrington, 1988). Similarly, the leaf unfolding rate of the zonal geranium cv 'Veronica' increases as average daily temperature increases from 54 to 76°F (Figure 5; Erwin, unpublished data).

Leaf unfolding rate decrease as temperatures increase above 76 to 81°F on hybrid seed and zonal geraniums. Therefore, increasing temperature above 76°F will not hasten geranium flowering but will probably delay flowering and/or leaf unfolding rate (Armitage et al., 1981; Erwin, unpublished data).

The concept or understanding of how geranium leaf unfolding is affected by average daily temperature is an important tool to produce geraniums of a given size: every leaf that unfolds represents a potential branch or inflorescence.

Seed Geranium:

Leaf unfolding/day = .0071 * (Average temperature (°F))- 0.279

Zonal geranium:

Leaf unfolding/day = -1.4067 + (.045723 * Temperature (°F)) - (.0003208 * Temperature $(°F)^2$)

Leaf unfolding models have been developed for the hybrid seed geranium and the zonal geranium. Two representative leaf unfolding models for each type of model are shown above:

The rate of plant development is dependent on the temperature which it is exposed to at any given moment.

In most cases, the rate of geranium development, or leaf unfolding rate, is dependent on the average daily temperature which a plant is grown under over a 24 hour period.

The rate of leaf unfolding generally increases as temperature increases from 48 to 76°F. Increasing temperature above 76°F can decrease leaf unfolding rate.

Geranium stem elongation as the day temperature plants are grown under increases relative to the night temperature.

Geranium stem elongation increases as the DIFference between the day and night temperature plants are grown under increases.

Geranium stem elongation is very sensitive to cool temperatures during the first 3 hours of the morning. Elongation can be dramatically reduced by dropping the temperature during the first 3 hours of the morning to below the previous night temperature.

Flower number, and size are affected by the average daily temperature plants are grown under.

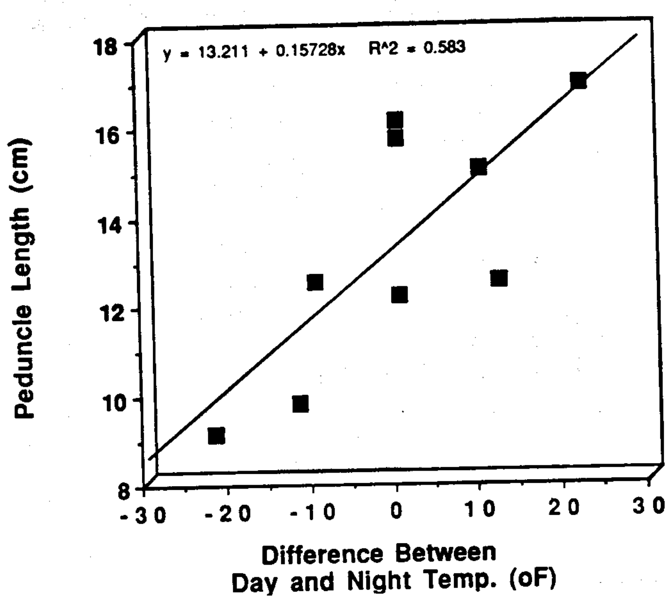

Figure 7. The effect of the difference between day and night temperature (DIF) on geranium peduncle length at flower.

Flower Development Rate: Geranium flower bud development rate appears to have a lower maximum temperature than that of leaf unfolding. Flower bud development rate increases as temperature increases from 50 to 72°F (Figure 6). Increasing temperature above 72°F does not increase the rate of flower bud development (White and Warrington, 1988; Pytlinski and Krug, 1988). In fact, increasing temperatures much over 72°F probably slows flower bud development rate.

Plant appearance: Plant appearance is effected by how temperatures are delivered during a 24 hour period as in the case of stem elongation or by average daily temperature as in the case of flower number per inflorescence, flower size, and inflorescence and flower dry weight.

Plant height: Geranium stem elongation increases as the day temperature plants are grown under increases (Erwin, 1991). Conversely, geranium stem elongation decreases as night temperature increases (Erwin, 1991). Recent research on a number of plant species has shown that the effects of day and night temperature on stem elongation can be best described by the difference (DIF) between day and night temperature rather than actual day and/or night temperatures within the 50 to 80°F temperature range (Heins, et al, 1988; Erwin et al, 1989a; Erwin et al, 1989b; Erwin and Schwarze, 1991; Moe et al, 1991). As with other plant species, geranium plant height and internode length increase as the DIFference between day and night temperature (day temperature - night temperature) increase (Erwin, 1989; Heins et al, 1988). As long as the difference between the day and night temperature is the same between 2 plants, the internode lengths will be the same regardless of the absolute temperatures the plants were grown under.

Geranium stem elongation is sensitive to cool temperatures during the first 3 hours of the morning (Erwin et al, 1989). Dropping the plant temperature during the first 3 hours of the morning to below the night temperature will reduce stem elongation substantially (Erwin, 1989). Using the 'morning drop' in temperature technique decreases stem elongation almost as much as growing plants with a cooler day than night temperature all day. This technique is most useful in greenhouses with poor temperature control and/or southern growers who cannot grow plants with an equal or cooler day temperature than night temperature.

Pedicel, petiole and peduncle elongation are also strongly influenced by DIF (Figure 7) (Erwin, 1991; Erwin and Schwarze, 1991). As with stem elongation, petiole, peduncle and pedicel elongation increase as DIF increases.

In contrast to stem elongation, flower number and size are affected by the average daily temperature which geraniums are grown under (Erwin, 1991). For instance, zonal geranium cv 'Veronica' flower number per inflorescence decreased from 52 to 15 flowers as the average daily temperature plants were grown under increased from 54 to 86°F (Erwin, 1991) (Figure 8). Although the relationship is not strong, flower diameter decreases slightly as the average daily temperature plants are grown under increases from 54 to 86°F (Erwin, 1991) (Figure 9).

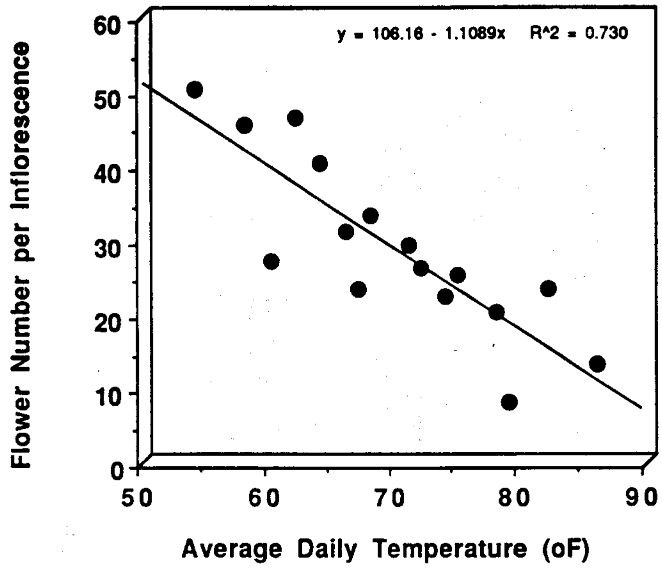

Figure 8. The effect of average daily temperature on the number of flowers per inflorescence on zonal geranium cv 'Veronica' at anthesis (Erwin, 1991).

There is no effect of average daily temperature or DIF on individual flower dry weight at flower with temperatures between 54 and 86°F (Figure 10)(Erwin, 1991).

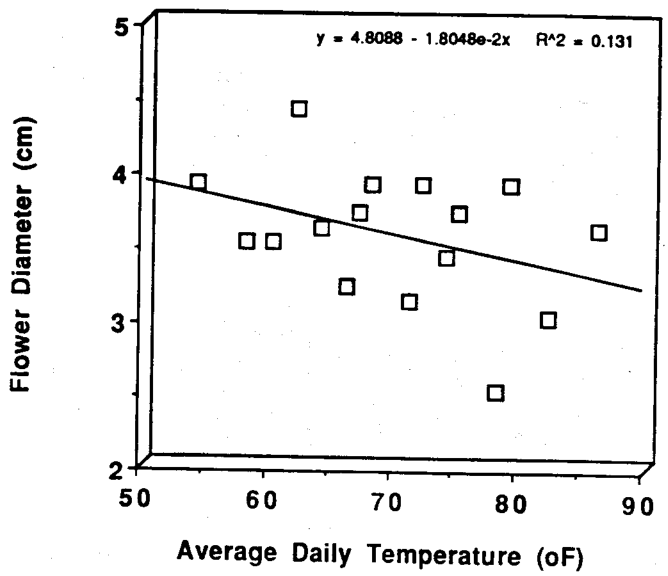

Figure 9. The effect of average daily temperature on zonal geranium cv 'Veronica' flower diamter at anthesis (Erwin, 1991).

Temperature also affects leaf and flower color. In general, as day and night temperature decrease, leaf and flower color intensity increase.

Plant quality: Plant quality is judged in many ways. A common belief is that plant quality increases as plant fresh or dry weight increases. Zonal geranium fresh weight at flower decreases as temperature increases. Fresh weight is greatest when plants have been grown at 54°F. Day temperatures can have a det-

Flower number and size are affected by the average daily temperature which geraniums are grown under.

flower diameter decreases slightly as the average daily temperature plants are grown under increases from 54 to 86°F.

There is no effect of average daily temperature or DIF on individual flower dry weight at flower with temperatures between 54 and 86°F.

Zonal geranium fresh weight at flower decreases as temperature increases. Fresh weight is greatest when plants have been grown at 54°F.

Day temperatures over 82°F can dramatically reduce plant quality. Similar day and night temperature or a slightly cooler day than night tend to produce the highest quality plants.

Inflorescence dry weight decreases as the average daily temperature which plants are grown under increases

rimental effect on zonal geranium growth. In specific, day temperatures over 82°F can dramatically reduce plant quality. Similar day and night temperature or a slightly cooler day than night tend to produce the highest quality plants (Pytlinski and Krug 1988).

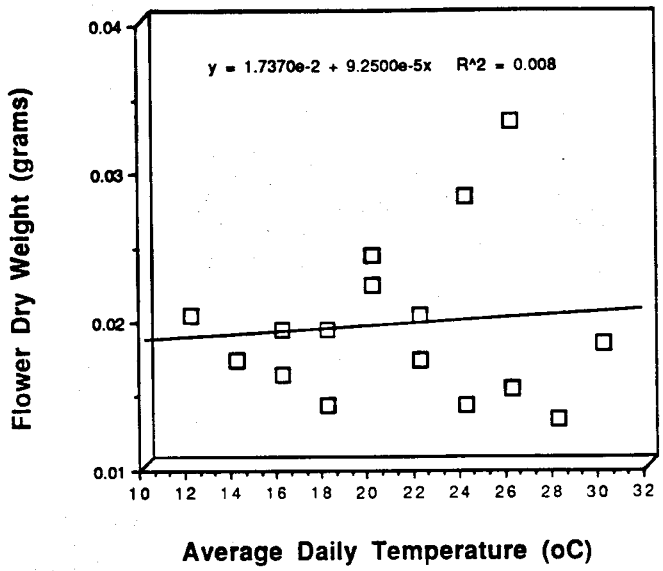

Figure 10. The effect of average daily temperature on individual flower dry weight at flower of zonal geranium cv 'Veronica' (Erwin and Schwarze, 1991).

Inflorescence dry weight decreases as the average daily temperature which plants are grown under increases (Erwin and Schwarze, 1991). For instance, zonal geranium cv 'Veronica' inflorescence dry weight decreased exponentially from approximately 1.1 grams to .2 grams per inflorescence as the average daily temperature plants were grown under increased from 54 to 86°F (Figure 11).

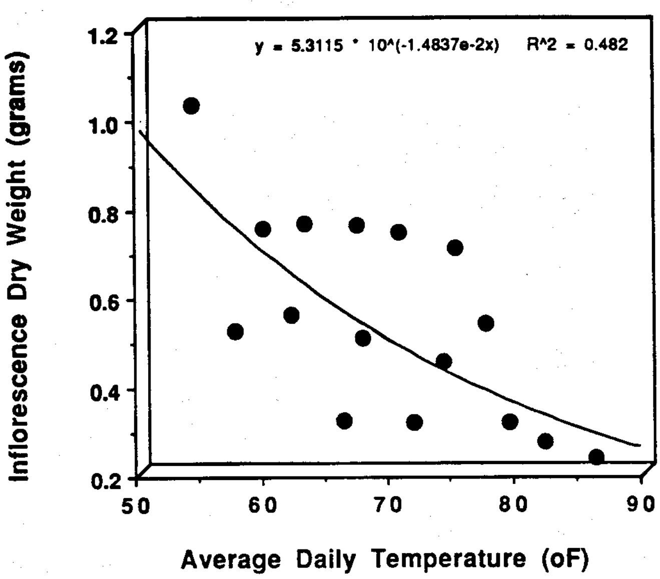

Figure 11. The effect of average daily temperature on total inflorescence dry weight of zonal geranium cv 'Veronica' at flower (Erwin and Schwarze, 1991).

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