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# RELATIONSHIPS OF LIGHT INTENSITY AND TEMPERATURE WITH GROWTH AND DEVELOPMENT OF PRECONDITIONED AND SHADED RANUNCULUS PLANTS UNDER HIGH ALTITUDE TROPICAL CONDITIONS

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**ABSTRACT**
A study was conducted to determine how shade (0%, 40%, 80%) reduces high light intensity and temperature to optimize growth of ranunculus (*Ranunculus asiaticus* L.) under high altitude tropical conditions. The study was set up in a split plot design, replicated three times and repeated once. Ranunculus tuberous roots were preconditioned at 30$^o$C, 20$^o$C, 10$^o$C or 2$^o$C for two weeks and thereafter grown under the four shade levels. The relationships of sprouting with light intensity were negative and positive quadratic in seasons 1 and 2, respectively, and with soil temperature negative quadratic. The relationships of light intensity and air temperature were correspondingly negative and positive linear in seasons 1 and 2, respectively, with flowering time; negative linear with flower stem length; negative quadratic with flower buds and flower head diameter; positive and negative quadratic in seasons 1 and 2, respectively, with flower stem diameter; and positive quadratic with tuberous root fresh biomass. Thus, shade modifies light intensity and temperature that then interact to influence growth and development of ranunculus in diverse ways. Moderate seasonal temperatures and 40,000 lux light intensity, prevailing under 40% shade are ideal for best top growth of ranunculus. High air temperature and light intensity, prevailing under 0% shade in a cool season and low air temperature and light intensity, prevailing under 80% shade in a hot season are the best for growth of heavy tuberous roots of ranunculus.

**KEY WORDS:** Bulbous, Dormancy, Cut flower, Productivity, *Ranunculus asiaticus*, Vernalisation.

## INTRODUCTION

The floricultural subsector worldwide faces major limitations, including lack of new and improved flower varieties to satisfy changing consumer preferences (Lapade, et al., 2002). Consequently, growers are introducing exotic flowers and forcing them in new environments through manipulation of climatic growth conditions. Light influences plant photomorphogenesis by altering plant height, lateral branching and flowering (Heins et al., 1982a, Heins et al., 1982b). Light retards stem elongation by reducing effective gibberellin supply in growing regions (Salisbury and Ross, 1991). Leaves normally supply a gibberellin precursor to the stem and light blocks the precursor's conversion to active gibberellin, thus preventing synthesis of this hormone from increase stem elongation. Shading is an effective practice for reducing irradiance. Low irradiance has been shown to increase internodal elongation in many ornamentals (Armitage and Wetzstein, 1994). Plants need an adequate level of shade for optimum growth and yield, particularly under high solar radiation (DeHertogh, 1996). High irradiance is associated with increased flower production in most self-inductive plants (Halevy, 1984). In areas where sunlight is low during the winter season and where prevailing temperatures are low, direct sunshine is preferred by most bulbous plants. Later in the season and in areas where sunlight is very intense, bulbous plants should be shaded (DeHertogh, 1996).

Ranunculus (*Ranunculus asiaticus* L.) is a bulbous plant that fits the category of a new and exciting flower, much sought after by modern consumers. Growth and development of bulbous plants are mainly affected by seasonal thermoperiodicity, constituting the basis of the techniques used to control flowering during forcing (Rees, 1992). In some bulbous species daily thermoperiodic changes are required to induce flowering and temperatures favourable to flower differentiation generally inhibit root initiation and differentiation (Halevy, 1990). In *Oenothera biennis*, variation in temperature, light, nutrients and other environmental factors affect production time (Reekie, 1997).

Growth and development of some plant species is regulated more by synergism of temperature and light (White and Warrington, 1988). *Liatris* inflorescences are normally ready for cutting 90 days after planting, but increasing temperature shortens flowering duration (Wanjao, 1981). Soils at 5$^o$C completely inhibit *Liatris* sprouting and corms sprout within 8 days upon transfer to soil at 20$^o$C (Espinosa, et al., 1991). *Allium moly* stopped root growth when soil temperatures dropped to 3$^o$C, but growth resumed when temperatures were raised above 4$^o$C (Wilson and Peterson, 1982). Temperature after planting has a marked effect on root dry matter content of *Allium aflatunese* and *A. christophii* that exhibited an optimal of 5$^o$C and 14$^o$C, respectively (Funnell, 1993). In *Dahlia,* soil temperature interacts with photoperiod in controlling root tuberization, shoot growth rate and flowering (Moser and Hess, 1968). Soil temperature is the main factor controlling flowering of *Alstroemeria* in that when rhizome temperature is between 5$^o$C and 15$^o$C flowering continues indefinitely and when it ranges from 20$^o$C to 25$^o$C flowering of previously cooled rhizomes ceases in about 14 weeks (Healy and Wilkins, 1982). Growth degree days indicate that temperature is the major factor influencing flowering duration, when light conditions are relatively constant (Noto and Romano, 1986). When shoots remain underground, soil temperature is critical, and once above the soil level, air temperature has the greatest effect on flowering duration (Cohat, 1993). Dutch irises do not grow when air temperature is lower than 6$^o$C (Fortanier and Zevenbergen, 1973).

Growth rate, flowering and quality of many bulbous plants are affected by light and temperature integrals. Although tropics experience high light intensity necessary for production of high quality flowers, forced shading to lower temperature can result in poor sprouting, slow growth rate, and short stems. The present study determined effective forcing regimes that promote optimal growth of ranunculus in tropical climates.

## MATERIALS AND METHODS

The present research was conducted at 0$^o$10' South, 36$^o$40' East and 2100 m above sea level. The experimental site receives average annual rainfall of 950 mm and average temperature of 17$^o$C and has well-drained, red to dark-reddish brown, friable clay soils (Jaetzold and Schmidt, 1983). Dormant tuberous roots of ranunculus cultivar Elegance were bought from Biancheri Creations in Italy. The 'Elegance' series can tolerate high light intensity conditions prevalent in the tropics and is made up exclusively of double-flowered ranunculus with plump buds and strong stems like those of a large-flowered rose. The experimental design consisted of split plots in randomized complete blocks, with 0%, 40% and 80% shade levels assigned to main plots and preconditioning temperatures of 30$^o$C, 20$^o$C, 10$^o$C and 2$^o$C for two weeks assigned to subplots. Each main plot, measuring 0.75 m x 3 m, was subdivided into 0.75 m x 0.75 m subplots. A 1.5-m path separated blocks as well as main plots within a block.

Ranunculus tuberous roots were placed in perforated polythene bags and preconditioned in incubators for two weeks. The tuberous roots were dipped in 1 g/L benomyl followed by planting in fine tilth soil at a depth of 0.5 cm to 1 cm, with the vegetative bud facing upwards. The spacing and density used were 10 cm between tuberous roots and 5 tuberous roots per experimental unit in a single row, respectively. Shade was then applied by stretching the shade net at approximately 1.5 m above the soil level, supporting it with poles, extending it to encompass the sides and the end of each covered main plot, and leaving room only for ventilation. Water was applied to all the plots to field capacity using a hosepipe before planting. After planting, the soil was kept moist by irrigating continuously for 10 to 14 days. Thereafter, soil was irrigated regularly to maintain it at field capacity. When plants started developing, 40 kg/ha 17N:17P:17K was applied to soil on a weekly basis. The soil was analysed and found to have 1.2% and 1.3% N, 37.5 ppm and 31.3 ppm P, 320 ppm and 250 ppm K, in seasons 1 and 2, respectively, which was used to determine the amount of potassium nitrate to apply to maintain the recommended optimal ratio of 20N:10P:30K. Weeding was done when needed.

Variables measured were: time taken to sprouting and full flower formation, flower stem length, total floral buds initiated on each stem, flower head and stem diameters, tuberous root fresh weight, light intensity (LI), and air and soil temperatures. Light intensity was measured at 9:00 am and 3:00 pm using a light meter (ST-85 Auto-range illuminance meter, Beijing, China). Soil temperature was measured using a soil thermometer at a depth of 10 cm from planting time until sprouting. Air temperature (AT) was measured using a minimum and maximum thermometer from sprouting to flowering stage, at 9:00 am and 3:00 pm daily. Data were subjected to regression analysis to establish the relationships between light intensity, soil temperature, air temperature, and ranunculus tuberous root growth responses.

## RESULTS AND DISCUSSION

### Sprouting versus light intensity

A positive quadratic relationship between sprouting and light intensity resulted in season 1 (Fig. 1). In season 2, the relationship was negative quadratic. In season 1, sprouting was not affected much by light intensity since small differences resulted under a wide range of light intensities. In season 2, high light intensity under 0% shade inhibited sprouting indirectly through elevation of air temperatures (Meynet, 1993), which evaporated and reduced soil moisture content.

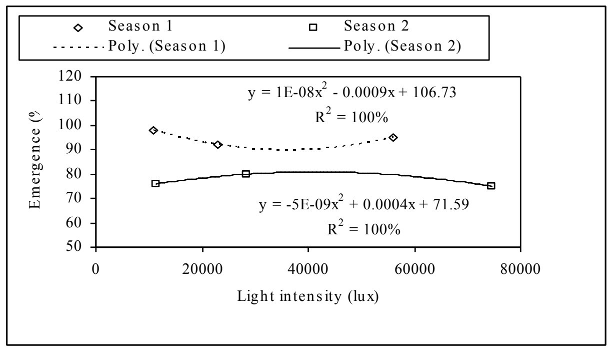


**FIGURE 1**. Sprouting versus light intensity. First, second and third values for each season correspond to 80%, 40% and 0% shade, respectively.

### Flowering duration versus light intensity

Negative and positive linear relationships between flowering duration and light intensity resulted in seasons 1 and 2, respectively (Fig. 2). Early growth capacity of inflorescences is associated with early differentiation (DeHertogh and LeNard, 1993). In season 1, high light intensity reduced time to flowering probably through interaction with other environmental factors such as the cool temperatures to cause early differentiation and subsequent early flowering (White and Warrington, 1988). Contrastingly in season 2, high light intensity and high temperatures interacted negatively to delay flowering (DeHertogh, 1996).

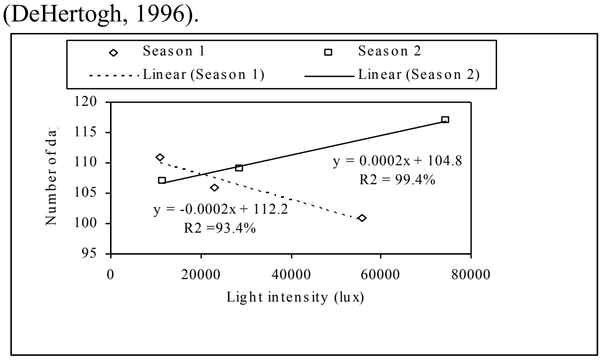

**FIGURE 2.** Days to flowering versus light intensity. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Flower stem length versus light intensity**

Negative linear relationship between flower stem length and light intensity resulted (Fig. 3). Increasing light intensity resulted in production of short flower stems probably through faster maturation of elongating cells, premature anthesis and destruction of gibberellins in ranunculus (Salisbury and Ross, 1991). Low light intensity on the other hand resulted in long flower stems of better quality through reversal of these mechanisms.

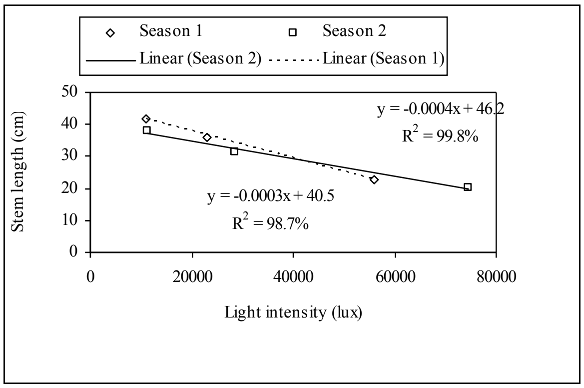


**FIGURE 3**. Stem length versus light intensity. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Flower buds versus light intensity**

Negative quadratic relationships between flower buds and light intensity resulted (Fig. 4). Increasing light intensity did not result in big differences in flower buds formed probably because flower buds are initiated very early either during storage or immediately after planting (DeHertogh and LeNard, 1993). Flower buds decreased as light intensity increased probably indirectly through elevation of air temperatures that negated the beneficial effect of prolonged induction of many tertiary flowers.

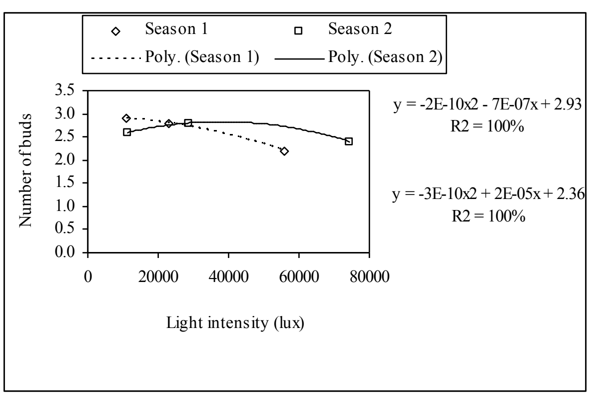


**FIGURE 4**. Flower buds versus light intensity. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Flower stem diameter versus light intensity**

Positive and negative quadratic relationships between stem diameter and light intensity resulted in seasons 1 and 2, respectively (Fig. 5). The response in season 1 was attributed to the interaction of light intensity and cool temperatures to produce xylem cells with bigger diameters (Salisbury and Ross, 1991). The response in season 2 was attributed to the interaction of light intensity and air temperature in which when both are high, production of xylem cells with smaller diameters is enhanced (Salisbury and Ross, 1991).

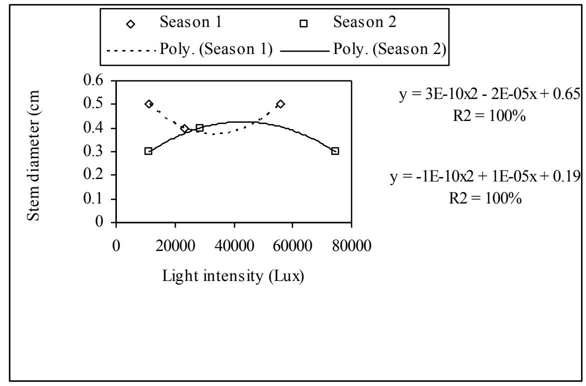


**FIGURE 5**. Stem diameter versus light intensity. First, 2nd and 3rd values for each season correspond to 80%, 40% and 0% shade, respectively.

**Flower head diameter versus light intensity**

The relationship between flower head diameter and light intensity was negative quadratic (Fig. 6). The flower head diameter increased with increasing light intensity up to an optimal level and then sharply decreased. Uninterrupted strong light causes exhaustion of plants (Leopold and Kriedemann, 1975). High light intensity in the present study seemed to have exhausted plant food reserves and hence the smaller flower head diameters observed under it.

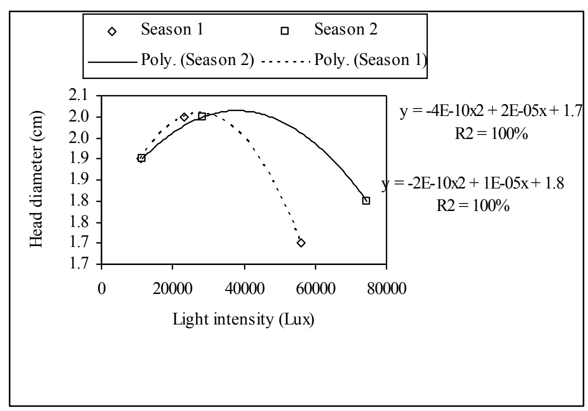


**FIGURE 6.** Flower head diameter versus light intensity. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Tuberous root weight versus light intensity**

Positive quadratic relationship between tuberous root fresh weight and light intensity resulted (Fig. 7). Tuberous root fresh weight decreased with increasing light intensity up to a point which probably coincided with high photosynthetic rate that replenished the reserves. This clearly shows the synergism between anabolic processes and tuberization in this species (Meynet, 1993). Tuberous root fresh weight decrease under moderate light intensity may be due to food reserve depletion, normally associated with high respiration rates.

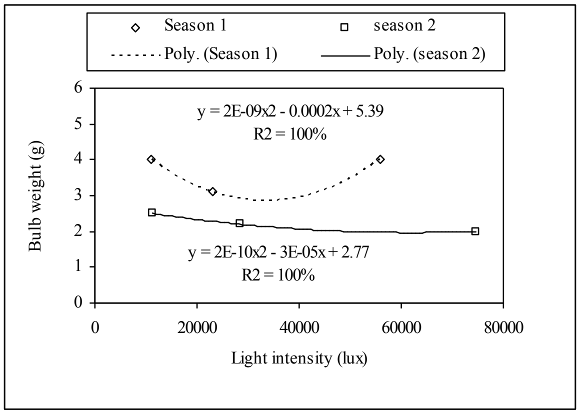


**FIGURE 7.** Root fresh weight versus light intensity. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Sprouting versus soil temperature**

Whereas no relationship resulted in season 1, a negative quadratic relationship between sprouting and soil temperature resulted in season 2 (Fig. 8). Slow growth rate resulted under high soil temperatures in season 2 probably due to drying up of soil, dehydration and incomplete rooting of ranunculus tuberous roots, as in tulips (Jennings and DeHertogh, 1977). In the case of tulips, the optimal temperature for root growth ranged from 13°C to 17°C. Temperatures over 21°C were inhibitory since tulip bulbs did not complete rooting.

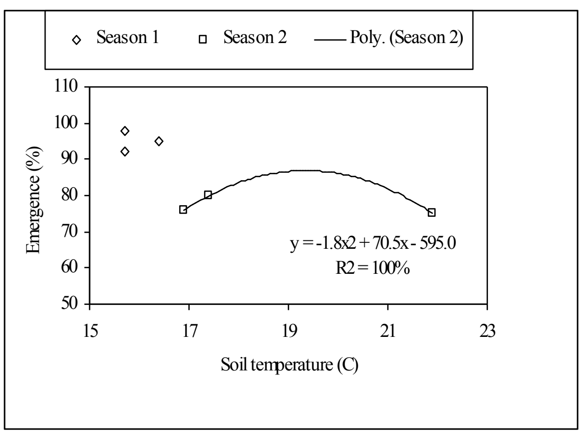


**FIGURE 8.** Sprouting versus soil temperature. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Flowering duration versus air temperature**

A negative linear relationship between flowering duration and air temperature resulted in season 1 (Fig. 9). Thus, increase in air temperature caused early flowering and this response concurred with other researchers (DeHertogh, 1996, Funnell, 1993), who reported that increasing temperatures accelerated plant growth and flower development until an optimum temperature was reached. On the contrary, a positive linear relationship between flowering duration and air temperature resulted in season 2, probably through high air temperature contributing to stunting growth and hence prolonging time to flowering (DeHertogh, 1996; Funnell, 1993; White and Warrington, 1988).

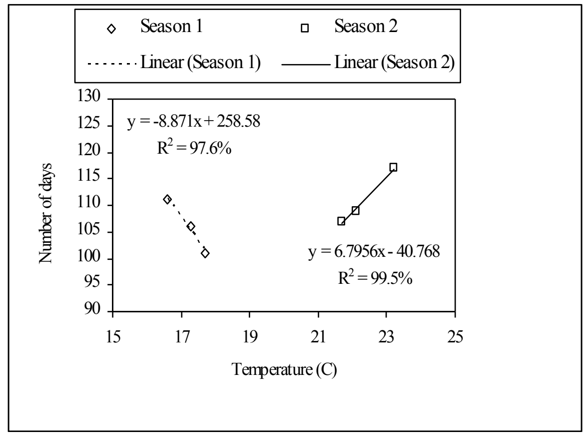


**FIGURE 9**. Flowering duration versus air temperature. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Flower stem length versus air temperature**

Negative linear relationship between flower stem length and air temperature resulted (Fig. 10). Elongation rate of the inflorescence and anthesis is affected by interaction of light intensity and temperature (DeHertogh and LeNard, 1993). In the present study, short flower stems were attributed to premature anthesis of ranunculus and destruction of gibberellins under high temperature. On the other hand, long flower stems of better quality under low temperature, were largely attributed to preservation of gibberellins (Salisbury and Ross, 1991).

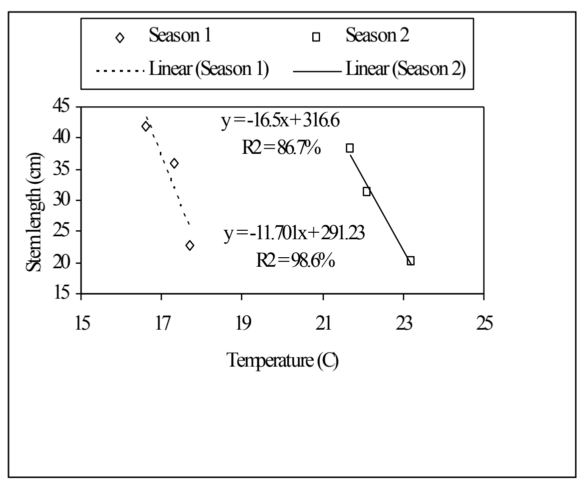


**FIGURE 10.** Flower stem length versus air temperature. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Flower buds versus air temperature**

Negative quadratic relationship between the number of flower buds and temperature resulted (Fig. 11). The response was attributed mostly to adverse air temperature, which when it was below or above optimum level the number of ranunculus flower buds decreased (Salisbury and Ross, 1991).

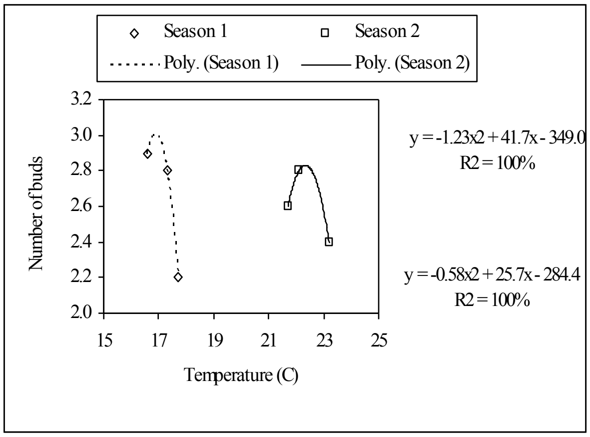


**FIGURE 11.** Flower buds versus air temperature. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Flower stem diameter versus air temperature**

Positive and negative quadratic relationships between flower stem diameter and temperature resulted in seasons 1 and 2, respectively (Fig. 12). The reason for the response in season 1 was attributed to preservation of photosynthates under low temperature and enhanced manufacture of photosynthates under elevated temperatures. In between the low and elevated temperatures none of these two promotive processes took place. In season 2, the small flower stem diameter for mild temperatures was attributed to insufficient photosynthate manufacture. The decline under high temperatures was attributed to enhanced catabolic processes (Salisbury and Ross, 1991).

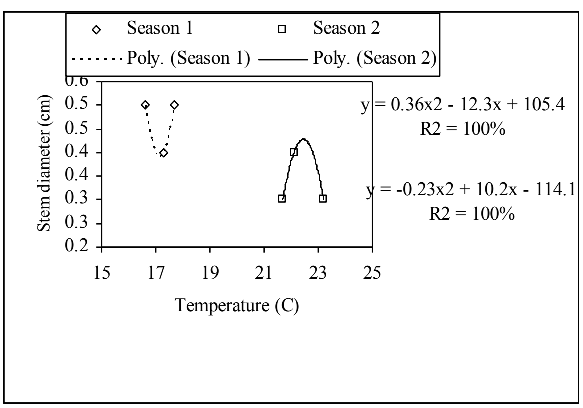


**FIGURE 12.** Flower stem diameter versus air temperature. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Flower head diameter versus air temperature**

Negative quadratic relationship between flower head diameter and temperature resulted in seasons 1 and 2 (Fig. 13). The responses in both seasons were attributed mostly to non-conducive temperature, which when it was below or above optimum, ranunculus flower buds decreased drastically (Salisbury and Ross, 1991).

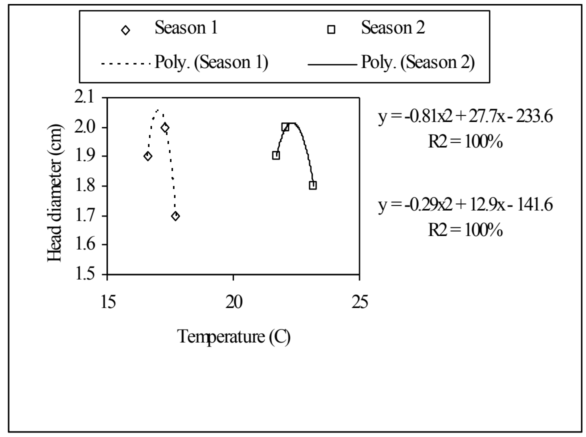


**FIGURE 13**. Flower head diameter versus air temperature. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**Tuberous root weight versus air temperature**

Positive quadratic relationship between tuberous root fresh weight and air temperature resulted (Fig. 14). The response was attributed to enhanced photosynthate preservation and tuber growth under low and high temperatures, respectively (Wilson and Peterson, 1982). Tuberous root weight was low in season 2 that was hot. It seems that high air temperatures during growth of ranunculus reduced available assimilates necessary for promotion of tuberous root growth (Wilson and Peterson, 1982) Initiation and subsequent rate of tuber growth is primarily related to availability of assimilates in excess of demands for shoot development (Leopold and Kriedemann, 1975).

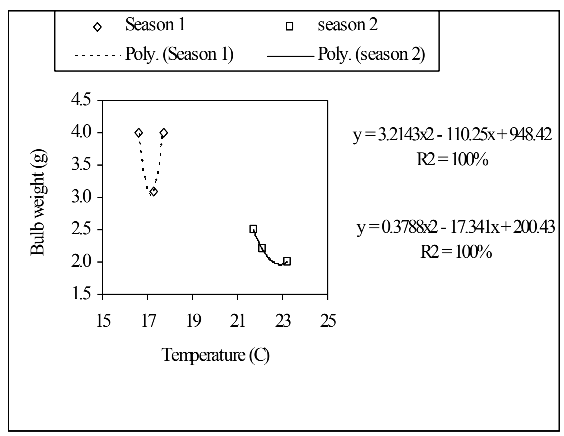


**FIGURE 14.** Root fresh biomass versus air temperature. First, second and third values for each season correspond to 80%, 40% and 0% shade.

**CONCLUSION AND RECOMMENDATIONS**

The relationships reveal that shade modifies both light intensity and soil and air temperatures, which then interact in influencing growth and development of ranunculus. The nature of ranunculus growth response varies, depending on the plant organ. Generally, 40000 lux and moderate seasonal temperatures under 40% shade are favourable for best top growth of ranunculus, irrespective of preconditioning temperature. However, lower light intensity plus lower temperature or higher light intensity plus higher temperature are the best for ranunculus tuberous root growth.

Therefore, 40% shade should be used in production of high quality ranunculus cutflowers. For production of heavy tuberous roots suitable for planting, ranunculus should be planted under low light intensity (80% shade) and low temperature for low photosynthate accumulation not to suffer heavy catabolic breakdown. Alternatively, ranunculus should be planted under high light intensity (0% shade) and high temperature because high photosynthesis would counteract high catabolic breakdown and still bring about biomass accumulation. Any of the tested temperatures is recommended for pre-conditioning of ranunculus tuberous roots before planting out.

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