THESIS

COMPARISONS OF THREE POPULAR ROSE (*ROSA HYBRIDA* L.) CULTIVARS

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY VIRGINIA S. STORY ENTITLED "COMPARISONS OF THREE POPULAR ROSE (*ROSA HYBRIDA* L.) CULTIVARS" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

COMPARISONS OF THREE POPULAR ROSE
(*ROSA HYBRIDA* L.) CULTIVARS

Two-year-old *Rosa hybrida* L. 'Royalty', 'Emblem', and 'Samantha' plants were pinched on 20 October 1992 for a Christmas crop and on 28 December 1992 for a Valentine's Day crop. All temperature set points were 22C/17C day/night. At 10 and 25 days after pinch, and at flowering, 5 shoots from each bench location were destructively sampled for leaf (node) number, stem length, stem diameter, and fresh and dry weights of stem, leaves, flower bud, and total. Time to visible bud, to color, and to flower from pinch were recorded as were number of flowers and blind shoots produced. Results were tabulated; an analysis of variance showed that the three rose cultivars produced flowers that were not significantly different but did vary as far as numbers of flowers produced and stem length. Seasonality also produced some differences.

Based upon an analysis of variance on the 1992 Christmas crop, the study found no significant differences for flowering times, but found differences in numbers of both flowers and blind shoots produced.

Based upon an analysis of variance for the 1993 Valentine's Day crop, the study also found no significant differences for flowering times, but found differences in number of flowers, but not number of blind shoots, produced and in stem length.

Based upon an analysis of variance comparing the three cultivars, with the Christmas and Valentine's Day crops combined, the study showed differences in number of flowers produced and stem length.

Based upon an analysis of variance comparing the Christmas and Valentine's Day crops (all three cultivars combined), the study showed no difference in number of flowers produced, more blind shoots at Christmas, and a longer and heavier Valentine's Day flower, although flowers took longer to reach maturity.

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"Sure, and may there be a road before you and it bordered with roses, the likes of which have ne'er been smelt or seen before, for the warm fine color and the great sweetness that is on them."

An Irish Blessing

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The United States is a rose-loving country. In fact, the rose is the national flower (Macoboy, 1993) and was on one of the first self-stick U.S. postage stamps (although the leaves were chlorotic!) (Amer. Philatelic Soc., 1993) Roses are the number one cut flower in sales in the United States. Red roses may send a special message of love, especially at Valentine's Day, or otherwise as one company specializes in "revenge" bouquets of 13 dead roses (Driscoll, 1989). These "messages" resulted in an estimated almost 80 million roses being sold in the United States for Valentine's Day, 1994 (Roses Inc., 1994a).

'Royalty' is a very popular red cultivar (DeVor, 1990). It generally has a longer post harvest life, a higher yield, more resistance to disease, and a longer stem than most other red cultivars. 'Kardinal', a more recent cultivar with a brighter red color, is gaining in popularity even though it has somewhat shorter stems than 'Royalty' (Jackson and Perkins, 1990).

Roses come in every color except blue, although attempts are being made to change this. An Australian company, Calgene Pacific, is working at developing a blue rose. The company has isolated the gene from petunias that causes blue pigment in plants, which is called delphinidin. The gene can be transferred to roses but it has yet to produce a blue rose. Depending on the pH of the environment, delphinidin produces either a red or a blue flower. The company is now at work on the genes that control pH, seeking the optimum conditions that control for blueness in a rose (Johnstone, 1992).

Linnaeus first used the Roman name *Rosa* rather than the Greek name *Rhodon* for rose. Roses have their center of origin in Central Asia, including Afghanistan, Iran, the far western provinces of China, and the southern republics of the former Soviet Union. Roses have been found in excavations at Pompeii and Egypt, and appear in Greek and Roman literature. The term *sub rosa*, which means "under the rose", originates in Roman mythology. Cupid presented a rose to Harpocrates, the God of Silence, in exchange for a favor. Harpocrates was so pleased with the rose that he promised confidentiality of conversations that took place *sub rosa*, under the traditional "ceiling rose". The prickly stems of rose composed Jesus' crown of thorns. The rose plays an important role in many religions, including Christianity, Hindu, and Islam. Rose lovers value the fragrance. Tea roses get their name because of the resemblance to the fragrance of China tea. Fragrance usually comes from the petals, except for musk roses whose fragrance comes from the stamens. The important gene that allows for repeat-flowering came from China through the empire building of the Renaissance period (Macoboy, 1993).

Cut roses come from both domestic production and imported plant material. U.S. cut rose consumption has more than doubled from 430 million stems in 1971 to 1.11 billion stems in 1992 (Table 1). Domestic production of roses has exceeded 500 million stems since 1987, making it a very significant floriculture crop, peaking in 1990 decreasing since that time. Imports are overtaking domestic production, with the percent domestic market share decreasing since 1971, dropping to less than 50% in 1992. This meant that in 1992 rose imports accounted for more than half (51.8%) of the U.S.

market, up from 47.7% in 1991 (Voight, 1993).

Cut rose imports for 1993 were 690 million, up 115 million from 575 million for 1992 (Roses Inc., 1994b). This is an increase of 20% over 1992. Individual prices of imported 65 cm stems in 1993 ranged from a low of $0.07 (Visa cultivar) the week of February 26 to a high of $1.10 (Madame del Bard cultivar) the week of February 5 (Ornamental Crops, 1993b).

Cut rose imports are also increasing, both as to absolute numbers of stems (Table 2) and as a percent of total sales (Table 1). Domestic per capita consumption is rising more rapidly for roses than for any other cut flower (Voight, 1993) but the increased sales are coming more from imported rather than domestic roses. Most imported roses come from South America. Historically, Columbia has been the main non-domestic source of cut roses, with a market share of 398 out of 574 million imported stems in 1992 and 490 out of 694 million imported stems in 1993 (Table 2). Columbia is beginning to lose its competitive edge by not keeping up with research, marketing, and new and more efficient distribution systems. Because of this, it has not been able to keep up with countries with similar conditions and its market share is eroding. (Economist, 1993). Ecuador's market share is increasing as Columbia's is decreasing. In 1988, Ecuador provided 17 million out of 289 million imported stems, or less than 6%. In 1992 this increased to 84 million out of 574 million imported stems or almost 15% of the total imports for the year. During this same period Columbia's market share dropped from 74% to 69%, showing that other countries besides Columbia are becoming a definitive market force (Floral Marketing Assoc., 1993). This is an example of the speed at which market share and sources can change in the global economy.

The North Atlantic Free Trade Agreement (NAFTA) may change the face of the industry by allowing easier access of foreign goods into domestic markets, driving up imports and driving down prices. Currently the number of roses available exceeds the demand. This has resulted in lower prices and translated into lower grower income. Growers have been unable to reduce costs or improve production enough to overcome this and have been closing businesses or reducing/eliminating rose production. The industry has requested either an exemption for roses from the trade agreement or the maximum phaseout period of 15 years of the current eight percent duty on roses from Mexico (Roses Inc., 1993a).

The greenhouse rose, *Rosa hybrida* L., is the leading cut flower produced in the United States (U.S. Dept. of Agriculture, 1993). Production peaks are timed for three major holidays which are Valentine's Day, Mother's Day, and Christmas. Improved cultural techniques that would reduce production costs, increase production numbers, and reduce customer cost would benefit both producers and consumers.

A high quality cut rose has a flower head set squarely on the stem, petals free from damage, form and petalage typical for the cultivar, color that is fresh and clear, a stem that is long and strong, a tight bud that will open, and fresh and unblemished foliage (Pi Alpha Xi, 1987).

A single rose plant grown in a greenhouse for cut flowers normally produces for 5-10 years, and sometimes longer. Decreased yield due to plant age may compel replacement with a more vigorous, younger plant. New cultivars with improved yields and quality, that may have been patented to preserve the rights of the breeder, may replace the older plants. Winter, with its lower light levels, is a difficult time to grow roses. Yield has been observed to decrease as a result of decreased bud break as well as increased time necessary for development of an axillary bud to flower during the lower light winter season (Zieslin et al., 1973). The increased time for production and decreased yield overall in winter make it difficult for growers to maintain the high yields necessary for profit maximization during the major holidays which all occur in this low light period. Methods for accelerating development, increasing stem strength, and enlarging total flower size during the winter growing period would be especially beneficial to growers for improving production and profits during the holidays.

General cultural practices aim at timing high yields for winter holiday periods. New plantings may be made in the spring in greenhouse ground beds or raised beds at a spacing of 30 x 30 cm (Laurie et al., 1979). Young shoots are pinched to eliminate early blooming while building the size and strength of the plant (a building pinch). When harvesting roses, two 5-leaflet leaves are left on the plant to encourage bud growth and flowering in the subsequent crop that ensues from the same shoot. This harvesting practice increases plant height and carbohydrate reserves and fosters better winter production. Established plants are pruned in early summer to reduce height and encourage new, strong shoots to sprout near the base of the plant (bottom breaks). This vigorously growing plant tissue encourages increased overall winter yields. Temperature also plays a role in production. Temperatures may be regulated to hasten or delay the rate of flower growth and development, encouraging flowers to bloom for critical holiday sales times. Greenhouses for growing roses are covered (glazed) with glass, diffuse fiberglass, or clear acrylic plastic to allow maximum transmittance of solar radiation for enhanced photosynthesis and growth.

Production varies with the seasons as light levels change. For the holidays of Christmas and Valentine's Day, light is limiting, but demand for roses is high.

Seasonal fluctuations in rose production have been attributed to changes in solar photosynthetically active radiation (PAR) often measured as photosynthetic photon flux (PPF) (Mattson and Widmer, 1971; Armitage and Tsujita, 1979). This is light energy in the wave band 400-700 nm (Taiz and Zeiger, 1991). Studies have supported methods for increasing PAR to enhance production. Supplemental lighting may be provided using high intensity discharge (HID) lamps which promote increased growth and yield during low-light periods (Armitage and Tsujita, 1979; Carpenter and Anderson, 1972). High pressure sodium (HPS) lamps have been shown to be most efficient in promoting plant growth when used as a supplement to sunlight (Cathey and Campbell, 1980; Clark and Devine, 1984). Supplemental PAR during the winter months increased rose yield of four cultivars ('Forever Yours', 'Shocking Pink', 'Red American Beauty', and 'Electra') by stimulating growth in four ways: 1) added axillary bud development resulting in improved branching, 2) increased bottom break, 3) reduced time to flower, and 4) reduced number of blind shoots (aborted flower buds) (Carpenter and Anderson, 1972). The excessive branching, though, decreased quality for these four cultivars by reducing stem length, node number, and fresh weight of blooms.

Light or PPF is important in rose development as is temperature, and the interaction between light and temperature may also be very important. High PPF has been shown necessary for basal bud sprouting, while one week of cooling at 4C also promoted this sprouting (Khayat and Zieslin, 1982). High temperatures (27-38C) prior to forcing have been shown to decrease plant growth, produce shorter potted rose plants, and delay flowering, while cool temperatures (2-10C) up to 6 weeks prior to forcing reduced flowering time (Asaoka and Heins, 1982).

No differences in production of three different rose cultivars were observed in one study during ambient light conditions in January and March (Carpenter and Anderson, 1972). All three cultivars had different increases in fresh weights in response to supplemental lighting. In contrast, another study found decreases in fresh weights and in stem lengths with supplemental lighting (Armitage and Tsujita, 1979).

Commercial rose response to off-peak supplemental HPS lighting (Hopper, 1992) has shown increases in number of flower stems produced under supplemental HPS lighting conditions for 'Royalty', 'Samantha', 'Sonia', and 'Gabriella'. No significant change in stem length was noted for any of the four cultivars studied although fresh weights were significantly increased for 'Royalty' and 'Sonia'. The number of flowers increased significantly for all four cultivars.

Light supplementation studies are hard to compare because of varying compositions of the light spectrum in the supplemental lighting as well as different geographical locations, different horticultural practices, and different cultivars grown (Zieslin and Yoram, 1990). In general, supplemental lighting reduced the time to harvest. Conflicting information about the effect of supplemental lighting may result from differences in harvesting, pruning, and general plant management methods. Increasing the number of flowers may result in shorter stems (Carpenter and Rodriguez, 1971) and lower weights. Productivity depends on various factors such as lateral bud release, flower bud abortion, renewal shoots, growth rate of flower stems (Zieslin et al., 1973) and all of which are influenced by PPF. It has been suggested (Zieslin, 1992) that flowering is the result of the 'escape' of the apical meristem from inhibition rather than as a result of a flowering stimulus. Apical inhibition maintains the plant in a vegetative state while removal of this inhibition results in flower differentiation.

A description of flower growth and development of 'Royalty' (Hopper and Hammer, 1991) and carbon partitioning for 'Samantha' (Jiao et al., 1989) have been developed. These provide base line comparisons for other studies.

Although studies have shown increased yield under supplemental lighting conditions (Armitage and Tsujita, 1979; Menard and Dansereau, 1992) limiting factors such as nitrogen and carbon dioxide levels may be involved. Carbon dioxide enrichment has been shown to increase the number of 'Royalty' roses of superior classes. Supplementary lighting may require the adjustment of carbon dioxide levels and fertilization regimes in order to meet the needs of the plants.

Quantification of plant growth must account for the influence of various environmental factors such as PPF, temperature, water availability, and CO_2 on photosynthesis. It has been contended that variations in 'Samantha' rose photosynthesis is 70% due to PPF level, 20% due to CO_2 concentration, and 5% due to temperature over a specific range of conditions (Jiao et al., 1991b). In a related study, changes in net carbon exchange rate (NCER) over a range of 300 to 1200 ppm CO_2, were quantified; general increases in NCER occurred as the CO_2 concentration increased (Jiao et al., 1991a). There is a linear relationship between increasing CO_2 concentration (ranging from ambient to about 1000 ppm) and the internal leaf CO_2 concentration (Coker and Hanan, 1988). A review of CO_2 enrichment studies found that the average transpiration rate for 18 different species may be reduced 34% when CO_2 is supplemented (Kimball, 1986). It was unknown if high CO_2, which would cause stomatal closure, might actually increase the growth of water-stressed plants. It is probably due to CO_2 enriched plants using less water because of stomatal closure, and experiencing fewer negative effects under environmental conditions that could precipitate water stress (Kimball, 1986). However, closed stomates may cause leaf temperatures to rise and induce additional transpiration for overcoming the effects of the heat. In a reverse manner, increasing water stress was observed (Aikin, 1974) to decrease the rate of CO_2 uptake by roses. If water was not limiting, CO_2 uptake (a measurement of photosynthesis) was seen to increase as light increased from 0 to around 1500 footcandles (fc), and uptake was fairly flat between 1500 and 5000 fc (Aikin and Hanan, 1975). Under water stress conditions of -10 bars, the CO_2 uptake was reduced as compared with that under -4 or -6 bars over a wide range of light levels from 1000 to 6000 fc. Relationships between environmental factors appears relatively complex, and studies have not been completed that measure actual water use of roses under different CO_2 concentrations. Further work is necessary to combine these relationships into a coherent model structure.

Measuring of the dry matter accumulated over time is a simple long-term measure of net photosynthesis. Additional photosynthesis and dry matter accumulation may not increase the harvestable yield for use in practical production, such as by increasing rose leaf size only, which is not important for marketing purposes (Hicklenton, 1988). Quality of the product may be increased, in larger flowers or longer stems, if more carbon is partitioned to those structures. Additional carbon availability within the plant has increased the number of flowers produced, possibly by partitioning the carbon to dormant bud tissue (Thompson and Hanan, 1976). The partitioning of any dry matter formed during CO_2 enrichment must be better understood so that real economic benefits may be achieved (Hicklenton, 1988). Such partitioning of fresh and dry matter has been measured.

Flower growth and development is a very complex process. Scientists attempt to hold all but one factor constant in order to measure that one variable, although unknown factors inevitably creep in. Results are reported accordingly and assumptions are made which may or may not be correct. Procedures are followed that may be consistent in the research greenhouse and are necessary for the results obtained but may have no relationship to commercial production. The attempt is made to mimic commercial production in research, but businesses are run differently from academic institutions. Also, the effects of cropping, whether staggered or timed for significant flushes, may make a difference in results.

Cut roses are sold based on stem length, with longer stems commanding significantly higher prices. "Long-stemmed" roses are usually over 45 cm, with long-stemmed sweetheart roses over 35 cm. Prices vary accordingly. Other factors affecting the price of a cut rose stem are size of bloom, straightness and strength of stem, and lack of damage to either the flower or foliage (Roses Inc., 1993b).

Many different cultivars are in domestic production. The objective of this study was to compare three popular cultivars as to flower production, number of blind shoots, and as to the difference between the Christmas and the Valentine's Day crops.

This experiment assessed individual cut rose quality for three different rose cultivars, 'Royalty', 'Emblem', and 'Samantha', (Fig. 1) as reflected in stem size, fresh and dry weights, developmental time to visible bud, color, and final harvest, and total production. It was done as an adjunct to computer modeling studies (Hopper, Meinke, and Story, 1993a and 1993b).

MATERIALS AND METHODS

A study was undertaken in the winter of 1992 and the spring of 1993 on cut rose crops scheduled for the Christmas and Valentine's Day holiday sales, two traditionally economically important periods for greenhouse rose growers. Pinch dates (dates when significant plant material was removed to encourage bud break or new shoot growth) were planned so that the harvests would coincide with the Christmas and Valentine's Day sales dates for holiday flowers. Since it takes about 7 weeks or 50 days for a flower to grow from a cut or a pinch, the pinch date was determined by counting backwards this amount of time from the time of expected harvest and sale.

Three hybrid tea or large-flowered modern garden rose (Appendix B) cultivars were chosen, 'Royalty', 'Emblem', and 'Samantha' (Fig. 1). 'Royalty' is a very popular long-stemmed red rose that is lightly fragrant and has a long vase life (DeVor, 1990). 'Emblem' is a long-stemmed yellow rose with outstanding flower and stem quality, very good vase life, and mildew resistance. 'Samantha' is a long-stemmed red rose that is resistant to blueing, holds well in cold storage, and has a good vase life (Jackson and Perkins, 1990).

Plant shoot characteristics measured included node number (NN), stem length (SL), stem diameter parent shoot (SDP), stem diameter new shoot (SDN), fresh weights of stem (FWS), leaves (FWL), flower bud (FWF), and total (FWT), and dry weights of stem (DWS), leaves (DWL), flower bud (DWF), and total (DWT). Flower development was measured for each stem by tagging each and recording days from pinch until visible bud (DVB), first bud color (CLR), and flowering or harvest (FLR). The number of flowers (NF) and the number of blind shoots (NBS) was also recorded.

Greenhouses. Four similar, unconnected, quonset-type greenhouses (Heat Houses 1-4) covered with fiberglass reinforced panels (FRP) were used for this study. Each house measured 6.1 m by 15 m and was oriented with the longer dimension north-south. Each house had five benches labeled A (closest to the door) to E (Fig. 2). Of the five benches, two (B and C) were used for this project. This made a total of eight benches used for the research, two in each of the four greenhouses.

Benches. The three rose cultivars were grown on east-west oriented benches measuring 1.2 by 3.6 m (lettered B and C in Fig. 2). Fifteen plants of each cultivar were planted in randomized blocks in each bench (three rows across). Benches A, D, and E were used as buffer benches on the north and south sides of the experimental benches. Each bench measured 120 cm by 360 cm, and contained 100% rockwool media (ParGro, medium grade, Partek, Englewood, CO) to a depth of approximately 18 - 20 cm. All benches were equipped with solenoid-controlled, twin-wall drip irrigation systems (Chapin Watermatics, Watertown, NY). Benches were irrigated at least once daily with the Colorado State University nutrient solution (Appendix A) for 2 minutes.

Plants. Each bench was planted with fifteen plants of each of the three cultivars, for a total of 45 plants per bench. The plants were hybrid tea roses (*Rosa hybrida* L.): 'Royalty' (XXX grade; Devor Nurseries, Inc., Chico, California), 'Emblem' (XX grade; Jackson and Perkins Roses, Medford, Oregon), and 'Samantha' (XX grade; Jackson and Perkins Roses, Medford, Oregon) (Appendix B). At the beginning of this study the plants were two years old.

The original planting of the benches took place 12 August 1991. Each rose plant was pruned of any dead tissue, dipped in an antifungal agent, and planted directly in the bench. Each bench was watered to saturation and tented with 6-mil white plastic (Denver Wholesale Florists, Denver, CO) to increase the relative humidity surrounding the plants and to reduce the incident radiation on the plants. The plastic reduced solar radiation levels to 30% of the radiation in the rest of the house (as determined by a LI-COR LI-185 quantum sensor and meter (Lincoln, Nebraska). Plants were watered to saturation daily to ensure adequate water availability during rooting and bud break. When plants began to break bud, tents were gradually opened over the course of a week, allowing the plants to acclimate to the lower relative humidity levels and higher radiation levels in the greenhouses, after which plastic tents were removed completely.

Conditions. Similar conditions were used in all 4 greenhouses. Temperature set points were 22C/17C day/night. Computerized monitoring of these day/night temperatures provided records of the actual environments for the plants (Fig. 3-6). The same ambient photosynthetically active radiation (PAR) measured as PPF (Fig. 7-10), fertilizer solution (Appendix A), and water pressure were available in all houses. All benches in all houses were watered at least once daily for 2 minutes.

Care was taken to provide clean and sanitary conditions so as to prevent plant disease. Rose diseases come under two classifications: infectious (fungi, bacteria, viruses, and nematodes) and noninfectious (excess, deficiency or imbalance of nutrients, water, pH; environmental extremes; air pollutants; pesticides; and injuries). These diseases are controlled through various combinations of exclusion, eradication, protection, resistance, and therapy (Horst, 1983). Red spider mites and powdery mildew are two very important pests of roses (Ball, 1991).

Methods. The two-year-old plants were initially cut back in September 1992 to bring them into the same developmental stage. All plants were hard-pinched, leaving two 5-leaflet leaves on each shoot, 20 October 1992 (day 294) for the Christmas crop and 28 December 1992 (day 363) for the Valentine's Day crop. Fifteen average-sized pinched shoots were randomly selected and tagged for study from among each cultivar on each bench, giving a total of 360 shoots to be studied across all treatment locations. This early tagging prevented including a shoot that might grow up from below, one not originating from the hard pinch. Harvesting random shoots at 50 days would include harvesting shoots of variable and indeterminate age. The tags on each shoot were marked with the day of the year when visible bud, first color, and harvest occurred. To examine treatment effects, one tagged bloom from each plant of each cultivar (= 15 blooms/cultivar = 45 blooms/bench) was destructively sampled. At 10 and 25 days after pinch, and at flowering, 5 shoots of each cultivar from each bench location were destructively sampled for plant response characteristics listed above. Plant material was then dried and dry weights were taken. Days from pinch until visible bud, first bud color, and flowering (harvest) were recorded. Harvested shoots were placed in warm (>40C) tap water before storage in a 5C cooler for a maximum of 7 days until final data were recorded. Shoots were harvested below the knuckle (point of stem attachment to parent shoot) in order to measure the entire stem length and weight; measurements of stem length were taken from the point of attachment to parent shoot to just below the bud where the stem begins to widen. At flowering, all blooms were harvested and counted, whether or not they were tagged for data analysis. To examine the treatment effect on total production over time, the untagged blooms were cut and daily numbers for each cultivar recorded. Blind shoots were counted at the end of the harvest periods.

Computerized control. Computerized control and measurement of the greenhouses was provided by a Hewlett-Packard 9920S Computer Control System (Hanan et al., 1987). The computer code is written in HP BASIC. Raw voltages from environmental sensors and control signals sent to equipment are handled by a digital acquisition/control (DAQ) board, relaying the voltages to and from the HP9920S system upon execution (once per minute).

Experimental design. The location of each cultivar in the study benches was randomly designated (Fig. 2). The randomized complete block experimental design underwent analysis of variance (ANOVA) in the SAS statistical package (SAS, 1990) for each of the plant characteristics measured, both between cultivars, within crops, and between crops. Each pair of houses was considered a block, and each cultivar was considered a treatment. In case individual bench performance was considered significant, data recorded from each bench was indicated by labeling, so that each block could be considered split by each bench. Each cultivar was forced to occur in each bench. Significant differences among means were determined with the Student-Newman-Keuls test (SAS). The Student-Newman-Keuls test was used with $\alpha = 0.05$.

RESULTS AND DISCUSSION

For three rose cultivars, comparisons were made for numbers of nodes per stem, flowers produced per group of 15 plants, and blind shoots produced per group of 15 plants (Fig. 11). For the Christmas crop, 'Samantha' produced more nodes per stem than 'Emblem'; 'Royalty' node numbers were not significantly different from the other two. For the Valentine's Day crop, 'Samantha' produced more nodes per stem than either 'Royalty' or 'Emblem'. Combined crops showed similar results to Valentine's Day in that 'Samantha' produced more nodes per stem than either 'Royalty' or 'Emblem' (Table 3). 'Royalty's' flower yield was greater than either that of 'Emblem' or 'Samantha' in the Christmas crop; the flower yields of 'Royalty' and 'Samantha' were greater than that of 'Emblem' in the Valentine's Day crop (Table 3). In the combined crops, 'Royalty' produced more flowers than either 'Emblem' or 'Samantha'. Research has suggested that a high red to far red ratio may substantially affect the number of buds that break (Roberts et al, 1993), and that the total number of shoots produced may be increased with supplemental lighting (Bredmose, 1993). Cultivars were randomly blocked in each greenhouse, holding the amount of light constant so as not to affect the number of flowers produced. One study showed increased yield (as well as stem length and quality) in a humidity-controlled environment as opposed to a non-controlled environment (Darlington and Dixon, 1991). The humidity was controlled (humidity is used for cooling) and warm summer temperatures were moderated using a high pressure, high efficiency fog system on 'Royalty' and 'Samantha' roses. Another study suggested that the number of flowers produced could be the result of the 'escape' of the apical meristem from inhibition rather than the result of a flowering stimulus, with the apical inhibition preventing flowering and the removal of this inhibition allowing flower induction to occur (Zieslin, 1992). The study was not clear on how this removal of inhibition takes place. 'Royalty' produced more blind shoots than either 'Emblem' or 'Samantha' at Christmas, but there were no significant differences among the three cultivars at Valentine's Day. Combined crops also did not show any statistical differences in numbers of blind shoots produced. Blind shoots as a percent of blind shoots plus flowers produced was not found to be different among the three cultivars. Inconsistent blind shoot production has been reported in light studies comparing red to far red light ratios, with no apparent relationship between light source or quality and blind shoot production (Roberts et al, 1993). Although light was measured in this study, red to far red ratios were not measured.

'Royalty' and 'Samantha' stems were longer than 'Emblem' stems in the Valentine's Day crop, but there were no significant differences in the Christmas crop (Fig. 12). Similarly, stems of 'Royalty' and 'Samantha' in the combined crops were longer than those of 'Emblem' (Table 4).

Stem diameters of both the parent shoot and the new shoot (Fig. 13) were not significantly different both within the individual crops (the three cultivars were not significantly different) and in the combined crops (Christmas and Valentine's Day crops merged showed no significant differences) (Table 4).

Days to visible bud, first color, and harvestable flower were measured (Fig. 14).

In the Christmas crop, 'Royalty' was first to show visible bud, then 'Samantha', followed by 'Emblem'. In the Valentine's Day crop, 'Royalty' was also first to show visible bud with 'Emblem' and 'Samantha' not significantly different from each other. The combined crops showed days to visible bud in the same order as Christmas: 'Royalty' first, 'Samantha' second, and 'Emblem' third. Days to first color were not significantly different within cultivars at Christmas (Table 5). At Valentine's Day, 'Emblem' was first to show color, with 'Royalty' and 'Samantha' next but not significantly different from each other. Combined crops had 'Emblem' showing color before 'Samantha', and 'Royalty' was not significantly different from either 'Emblem' or 'Samantha'. All of these differences disappeared at Christmas, Valentine's Day, and for the combined crops when looking at days to harvestable flower. There were no significant differences in days to flower either within crops or between crops as all cultivars flowered at about the same time. Variations in days to visible bud and first color are irrelevant to the grower if they do not translate into decreased days to a harvestable flower.

Fresh weights of stem, leaves, flower, and total were measured. The Christmas crop showed no significant differences for the fresh weights of either stem, leaves, flower, or total flowering stem (Fig. 15). The Valentine's Day crop showed a significant difference only for leaves, with 'Royalty' weighing more than 'Emblem' or 'Samantha', but this difference disappeared in total fresh weights, there being no significant differences among cultivars. With the combined crops, 'Royalty' and 'Emblem' leaves were heavier than those of 'Samantha', but all differences again disappeared in total fresh weights (Table 6).

Dry weights of stem, leaves, flower, and total were measured. The Christmas crop showed no significant differences for the dry weights of either stem, leaves, flower, or total flowering stem (Fig. 16). The Valentine's Day crop showed a significant difference in both leaves and total, with 'Royalty' being heavier than 'Emblem' or 'Samantha'. Combined crop dry weights showed stem weights of 'Royalty' and 'Samantha' to be heavier than those of 'Emblem' (Table 7). 'Royalty' leaves weighed more than either 'Emblem' or 'Samantha'. Combined crop total dry weights were not significantly different.

When the three cultivars were merged so as to compare all of the Christmas with all of the Valentine's Day crop (all cultivars combined) (Table 8), similarities and differences were identified. Numbers of nodes and numbers of flowers were similar, and the Christmas crop produced almost twice the number of blind shoots as did the Valentine's Day crop. The Valentine's Day crop had longer and larger stems than did the Christmas crop. Days to color were not significantly different between crops, but Christmas showed fewer days to visible bud and to flower. Valentine's Day showed heavier fresh and dry weights of stem, leaves, flower, and total flowering stem.

The Hewlett-Packard 9920 computer controller collected data on specific daily environmental conditions [day and night temperatures (Fig. 3-6) and photosynthetically active radiation (PAR) measured as photosynthetic photon flux (PPF) (Fig. 7-10)] for the two cropping periods (Tables 9 and 10). Temperature set points were the same for all 4 houses (22C/17C day/night) but daily fluctuations did occur between the houses, with wide day to day fluctuations between sunny and cloudy days (Fig. 3 - 6). These figures show how close the controls were in maintaining the temperature set points and where equipment malfunctions may have taken place. Temperatures fluctuate with the weather. The heating systems controlled the temperature as needed, mostly at night. All four houses had forced air overhead heating systems. Houses 3 and 4 also had ground-level heating systems which worked concurrently with the forced air systems. Fluctuations occurred as outside temperatures fluctuated. Variations occur in all greenhouse environments. The fluctuations were tracked, recorded, and responded to. The overriding assumption was that the equipment always works properly, when that assumption may be incorrect. Commercial growers have similar difficulties in maintaining consistent temperature control. Commercial environments mandate a close relationship with temperature information and a quick response to changes.

PPF levels change with the seasons (Fig. 7-10). PPF was higher at the Christmas pinch (day 294) than at the Valentine's Day pinch (day 363). The Christmas crop began growing when the light levels were highest and the Valentine's Day crop began growing when the light levels were lowest. This might account for some of the results. The heavier Valentine's Day crop may be a result of higher PPF at the end of the growing cycle whereas the Christmas crop had higher PPF when the buds were initiating.

The rose plants were two years old at the initiation of this study, so they were already in place and producing. This allowed a continuing study under conditions similar to those experienced by a commercial grower.

The results given above may appear important to a researcher, but often the grower is left wondering how to implement this information in a practical manner. It has been hypothesized that for some cut flower qualities that are significantly different, the differences may not be economically important to growers because the flowers were visually similar (Roberts et al., 1993).

Growers are interested in traits which will bring a higher price. Stem length is the main criteria in sorting roses, with minimum stem lengths (in cm) of 30, 35, 40, 45, 50, 55, 60, 65, and 70. Growers don't always offer all of the grades, but may offer every other one (Roses Inc., 1993b). If the extra stem length from the treatment in question moves a rose into the next category, the research will translate into more dollars for the grower. One more node per stem, with no increase in stem length, or heavier leaves will not increase income for the grower unless overall quality is affected.

Increasing the number of flower stems produced, and most especially the number produced in the sales period before a major holiday, is very important to growers. Even if the total number of stems remains the same but production can be moved from a non-holiday period when prices are low to a holiday period when prices are high, the grower's income would increase. Decreasing the number of blind shoots should also benefit the grower by increasing the number of flowers produced.

Increased stem diameter plays a marginal role in direct benefit to the grower, as long as minimum strength is present. The stem must meet minimum requirements of strength and straightness to bring in a good price, but beyond a certain level there is no direct benefit to the grower. In fact, some stems grow overly thick, which detracts from the quality of the rose and uses rose plant reserves that would be better spent on an additional flower or in increased stem length.

The days to visible bud and to color are only relevant if they also translate into an earlier harvest. In theory, when a grower observes a visible bud, temperature or other environmental factors may be altered to control flowering time. The days that count to a grower are the days until the flower can be harvested and sold. Reducing the number of days to a saleable rose directly translates into increased profit, since another cropping may be produced over a year's time. Sales occur more often, cash turns more quickly, and the plants can grow more flowers.

Fresh and dry weights indicate overall flower quality but, again, do not translate into a direct benefit to the grower except within a very broad range. Too low a weight (either fresh or dry) or too high a weight could translate into poor quality or too small a flower, but in general, are the types of measurements that scientists and the grower finds of little use.

CONCLUSIONS

Colorado agriculture, and more specifically Colorado horticulture, has a sizeable investment in the cut rose industry. Production of cut roses is decreasing in the United States, and in Colorado, in a large part due to inexpensive imports, mostly from South America. The domestic rose industry needs help in order to compete in the market. The American public loves cut roses and also loves an inexpensive price. Aid in raising a higher quality rose for a lower price is important to growers. This study looked at three popular rose cultivars, as to their differences and similarities in producing high quality cut flowers for the domestic market in two different holiday seasons.

The three cultivars studied were 'Royalty' (red), 'Emblem' (yellow), and 'Samantha' (red) (Fig. 1). There were some differences in node numbers (which translates into numbers of leaves) but there was no relationship between this and the variation in stem length. The number of flowers produced varied between cultivars but the relationship between the cultivars was different for Christmas and Valentine's Day. There were more blind shoots produced, though, at Christmas than at Valentine's Day. Stem length again varied in the Valentine's Day crop, but not for the Christmas crop. Stem diameters, fresh weights, and dry weights varied only for Valentine's Day dry weights. There were no significant differences in days to harvestable flower between cultivars for either crop.

More variation appeared when the cultivars were combined so as to compare crops. The number of nodes and flowers produced were not significantly different although the Christmas crop produced more blind shoots. Stem length, stem diameter (parent and new shoots), days to visible bud, color, and flower, and all fresh and dry weights were greater for the Valentine's crop over the Christmas crop. This may have been due to higher PPF when the heavier growth took place.

Flowers produced in the Christmas crop were not significantly different from each other except that 'Royalty' produced more flowers and more blind shoots. The flowers themselves, though, were not significantly different from each other.

Flowers produced in the Valentine's Day crop showed a similar pattern to Christmas except that both 'Royalty' and 'Samantha' produced more flowers and had longer stems than 'Emblem', and 'Royalty' had a heavier dry weight than either 'Emblem' or 'Samantha'.

The crops were combined within cultivars and compared. The only differences were that 'Royalty' produced more flowers and 'Royalty' and 'Samantha' produced longer stems.

The greatest differences were between the Christmas and Valentine's Day crops when all cultivars were combined. These differences were greater than those shown between cultivars for either Christmas, Valentine's Day, or combined.

In summary, the variation between the Christmas and Valentine's Day crops, cultivars are not differentiated, may be due to the variation in PPF received. The variation in yield within cultivars and crops may be due to the large flush of 'Royalty' in the Christmas crop depleting the reserves of the plants before the Valentine's Day crop began to grow.

Additional studies are needed to determine why 'Royalty' produced such a flush of flower production for the Christmas crop. Repetition of this flush at will would be most beneficial to the grower.

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Table 1. Roses: Imported, domestic, and per capita (x1000.)

Year	Imported		Domestic		Total	Per capita
	# of Stems	(% Share)	# of Stems	(% Share)[y]		
1971	1,038	(0.2%)	428,815	(99.8%)	429,853	2.08
1979	35,325	(7.4%)	444,620	(92.6%)	479,945	2.14
1980	44,497	(9.5%)	425,667	(90.5%)	470,164	2.07
1981	71,870	(14.6%)	421,639	(85.4%)	493,509	2.15
1982	90,111	NA	NA	NA	NA	NA
1983	120,305	NA	NA	NA	NA	NA
1984	129,113	(21.8%)	462,439	(78.2%)	591,552	2.50
1985	173,151	(26.6%)	477,026	(73.4%)	650,177	2.73
1986	217,022	(32.0%)	462,177	(68.0%)	679,199	2.82
1987	263,849	(31.8%)	564,621	(68.2%)	828,470	3.40
1988	288,795	(33.8%)	565,440	(66.2%)	854,235	3.48
1989	314,195	(34.9%)	587,483	(65.1%)	901,678	3.64
1990	427,002	(41.7%)	596,648	(58.3%)	1,023,650	4.10
1990[z]	--	(42.4%)	581,262	(57.6%)	1,008,264	4.04
1991	504,142	(47.7%)	552,638	(52.3%)	1,056,780	4.19
1992	574,567	(51.8%)	533,652	(48.2%)	1,108,219	4.35

Sources: Ornamental Crops National Market Trends and Floriculture Crops, USDA (Voight, 1993).

[z]Beginning with 1990, domestic data were revised and include information from growers with $100,000 or more in sales . . . as opposed to $10,000 or more sales in previous years. Furthermore, 1991 domestic data are from 28 states' growers while 1992 data are from 36 states' growers. Data comparability prior to 1990 also presented with difficulty.

[y]Calculated by author from information supplied from this table.

Table 2. Cut rose imports (Ornamental Crops National Market Trends, Feb 25, 1994, Oct. 22, 1993, Dec. 4, 1992).

Country	1993 Quantity[z]	1992 Quantity	1991 Quantity
Bolivia	2,199	3,024	3,350
Colombia	490,192	398,486	350,796
Costa Rica	6,325	7,348	7,604
Dominican Republic	3,168	3,618	3,459
Ecuador	113,097	83,614	58,442
Guatemela	29,935	27,907	23,536
Mexico	35,420	36,539	43,779
Netherlands	11,240	12,387	10,656
Others	3,007	1,644	2,520
Total	694,583	574,567	504,142

[z]Units of 1,000 stems.

Table 3. Numerical growth response of three rose cultivars grown for the Christmas 1992 and Valentine's Day 1993 crops.

		Cultivar		
Characteristic	Crop period	Royalty	Emblem	Samantha
No. of nodes[z]	Christmas	11.8 ab	11.1 b	12.7 a
	Valentine's Day	11.4 b	11.4 b	13.3 a
	Combined	11.6 b	11.3 b	13.0 a
No. of flowers	Christmas	44.8 a	21.5 b	25.0 b
	Valentine's Day	26.9 a	20.3 b	27.9 a
	Combined	35.8 a	20.9 b	26.4 b
No. of blind shoots	Christmas	20.4 a	15.1 b	13.8 b
	Valentine's Day	9.00 a	9.25 a	8.00 a
	Combined	14.7 a	12.2 a	10.9 a

[z]Means within a row followed by different letters indicate significant differences among treatments at P=0.05, Student-Newman-Keuls test.

Table 4. Growth responses of three rose cultivars grown for the Christmas 1992 and Valentine's Day 1993 crops.

		Cultivar		
Characteristic	Crop period	Royalty	Emblem	Samantha
Stem length (cm)	Christmas	68.2 a	62.6 a	68.2 a
	Valentine's Day	74.0 a	62.8 b	72.4 a
	Combined	71.1 a	62.7 b	70.3 a
Stem diameter (cm) (parent shoot)	Christmas	0.778 a	0.742 a	0.775 a
	Valentine's Day	0.800 a	0.855 a	0.853 a
	Combined	0.789 a	0.798 a	0.814 a
Stem diameter (cm) (new shoot)	Christmas	0.696 a	0.652 a	0.688 a
	Valentine's Day	0.784 a	0.748 a	0.768 a
	Combined	0.740 a	0.700 a	0.728 a

[z]Means within a row followed by different letters indicate significant differences among treatments at P=0.05, Student-Newman-Keuls test.

Table 5. Developmental responses of three rose cultivars grown for the Christmas 1992 and Valentine's Day 1993 crops.

		Cultivar		
Days to	Crop period	Royalty	Emblem	Samantha
Visible bud[z]	Christmas	25.8 c	31.3 a	28.6 b
	Valentine's Day	28.2 b	31.9 a	30.9 a
	Combined	27.0 c	31.6 a	29.7 b
Color	Christmas	42.5 a	41.3 a	44.2 a
	Valentine's Day	44.4 a	41.9 b	45.1 a
	Combined	43.4 ab	41.6 b	44.6 a
Flower	Christmas	51.3 a	52.3 a	54.0 a
	Valentine's Day	53.8 a	53.9 a	54.9 a
	Combined	52.5 a	53.1 a	54.4 a

[z]Means within a row followed by different letters indicate significant differences among treatments at P=0.05, Student-Newman-Keuls test.

Table 6. Fresh weights (wt) of three rose cultivars grown for the Christmas 1992 and Valentine's Day 1993 crops.

		Cultivar		
Fresh wt of	Crop period	Royalty	Emblem	Samantha
Stem (g)[z]	Christmas	12.4 a	12.5 a	12.9 a
	Valentine's Day	18.2 a	14.7 a	17.5 a
	Combined	15.3 a	13.6 a	15.2 a
Leaves (g)	Christmas	12.9 a	13.8 a	12.2 a
	Valentine's Day	20.6 a	17.7 b	15.8 b
	Combined	16.8 a	15.7 a	14.0 b
Flower (g)	Christmas	10.3 a	11.4 a	10.6 a
	Valentine's Day	14.1 a	14.4 a	14.3 a
	Combined	12.2 a	12.9 a	12.4 a
Total (g)	Christmas	35.7 a	37.7 a	35.7 a
	Valentine's Day	52.8 a	46.8 a	47.5 a
	Combined	44.3 a	42.3 a	41.6 a

[z]Means within a row followed by different letters indicate significant differences among treatments at P=0.05, Student-Newman-Keuls test.

Table 7. Dry weights (wt) of three rose cultivars grown for the Christmas 1992 and Valentine's Day 1993 crops.

		Cultivar		
Dry wt of	Crop period	Royalty	Emblem	Samantha
Stem (g)[z]	Christmas	3.94 a	3.62 a	4.36 a
	Valentine's Day	6.42 a	4.56 a	6.17 a
	Combined	5.18 a	4.09 b	5.26 a
Leaves (g)	Christmas	3.87 a	3.78 a	3.72 a
	Valentine's Day	7.13 a	5.43 b	4.86 b
	Combined	5.50 a	4.61 b	4.29 b
Flower (g)	Christmas	1.90 a	2.06 a	1.96 a
	Valentine's Day	2.71 a	2.76 a	2.52 a
	Combined	2.30 a	2.41 a	2.24 a
Total (g)	Christmas	9.71 a	9.47 a	10.04 a
	Valentine's Day	16.3 a	12.8 b	13.5 b
	Combined	13.0 a	11.1 a	11.8 a

[z]Means within a row followed by different letters indicate significant differences among treatments at P=0.05, Student-Newman-Keuls test.

Table 8. Comparisons of three rose cultivars between the Christmas 1992 and Valentine's Day 1993 crops.

Characteristic	Crops: Christmas	Crops: Valentine's Day
No. of nodes[z]	11.9 a	12.0 a
No. of flowers[y]	30.4 a	25.0 a
No. of blind shoots[y]	16.42 a	8.75 b
Stem length (cm)	66.3 b	69.7 a
Stem diameter (cm) (parent shoot)	0.765 b	0.836 a
Stem diameter (cm) (new shoot)	0.679 b	0.767 a
Days to visible bud	28.6 b	30.3 a
Days to color	42.6 a	43.8 a
Days to flower	52.5 b	54.2 a
Fresh wt of stem (g)	12.6 b	16.8 a
Fresh wt of leaves (g)	13.0 b	18.0 a
Fresh wt of flower (g)	10.8 b	14.2 a
Fresh wt of total (g)	36.4 b	49.1 a
Dry wt of stem (g)	3.97 b	5.72 a
Dry wt of leaves (g)	3.79 b	5.80 a
Dry wt of flower (g)	1.97 b	2.66 a
Dry wt of total (g)	9.74 b	14.18 a

[z]Means within a row followed by different letters indicate significant differences among treatments at P=0.05, Student-Newman-Keuls test.

[y]Mean of production from 15 plants per section, three sections per bench, 2 benches per house, four houses; net 360 plants per crop.

Table 9. Mean values for environmental conditions in four greenhouses monitored 20 October to 12 December for the 1992 Christmas crop (Hopper et al, 1993a).

	Environmental parameter means				
	PPF[z]		Temperature (C)[y]		
House no.	Daily ($mol \cdot m^{-2} \cdot day^{-1}$)	Instantaneous ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	Day	Night	DIF[x]
1	9.34	216.2	21.2	16.8	4.4
2	8.94	206.9	21.6	16.9	4.7
3	7.50	173.6	20.9	15.8	5.1
4	8.65	200.2	21.7	16.7	5.0

[z]PPF = Photosynthetic photon flux. Daily value is the amount accumulated over the whole daytime measured in moles, and accounts for the total time over which light was measured. To calculate instantaneous values, divide the daily value by 0.0432 to translate to a continuous 12 hour value equivalent (measured each second).

[y]Day temperature and night temperature are averages based on temperatures recorded all day over the entire Oct.-Dec. period.

[x]DIF = day temperature - night temperature (C).

Table 10. Mean values for environmental conditions in four greenhouses monitored 20 December to 14 February for the 1993 Valentine's Day crop (Hopper et al., 1993b).

	Environmental parameter means				
	PPF[z]		Temperature (C)[y]		
House no.	Daily $(mol \cdot m^{-2} \cdot day^{-1})$	Instantaneous $(\mu mol \cdot m^{-2} \cdot s^{-1})$	Day	Night	DIF[x]
1	10.42	241.2	21.6	16.9	4.7
2	9.49	219.7	22.0	17.3	4.7
3	8.22	190.3	22.3	18.2	4.1
4	9.07	210.0	21.4	16.6	4.8

[z]PPF = Photosynthetic photon flux. Daily value is the amount accumulated over the whole daytime measured in moles, and accounts for the total time over which light was measured. To calculate instantaneous values, divide the daily value by 0.0432 to translate to a continuous 12 hour value equivalent (measured each second).

[y]Day temperature and night temperature are averages based on temperatures recorded all day over the entire Oct.-Dec. period.

[x]DIF = day temperature - night temperature (C).

Table 11. Coefficients for regressions fitting photosynthetic photon flux (PPF) in Heat Houses 1 - 4 to day of the year from Oct 20, 1992 (day 294) to Feb 19, 1993 (day 416), (n=123). All coefficients (b_0, b_1, and b_2) were significant at $p<0.0001$.

House	Intercept		Day		Day^2		Model	
no.	b_o	s_b	b_1	s_b	b_2	s_b	significance	R^2
1	216	28.1	-1.20	0.159	0.00172	0.000224	0.0001	0.374
2	171	23.7	-0.938	0.135	0.00134	0.000189	0.0001	0.321
3	156	25.2	-0.860	0.143	0.00123	0.000201	0.0001	0.265
4	181	26.5	-0.996	0.150	0.00142	0.000212	0.0001	0.290

Figure 1. Three rose cultivars, 'Royalty', 'Emblem', and 'Samantha' (left to right).

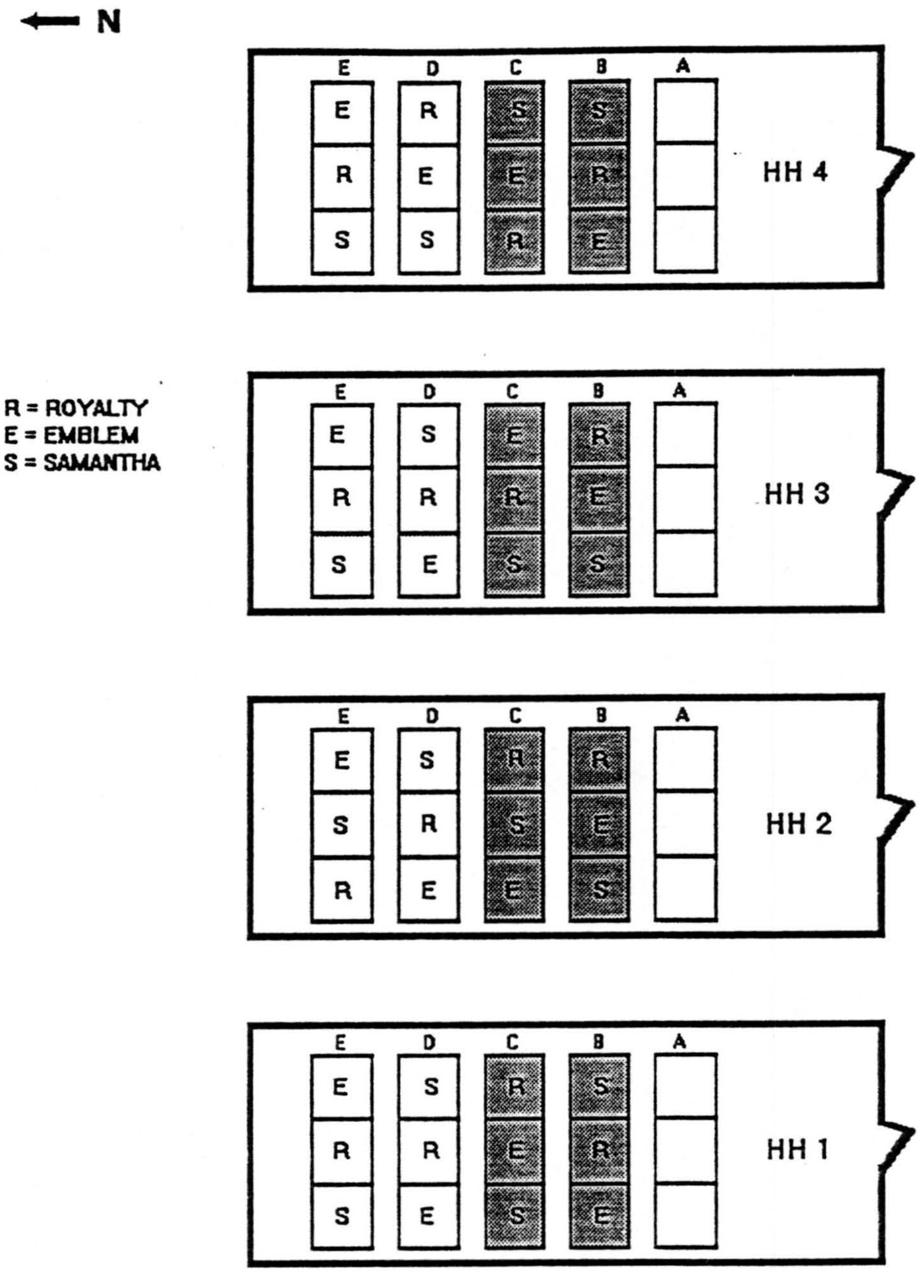

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Figure 2. Greenhouse layout. Study was conducted on benches B and C in each house. 'Royalty' (R), 'Emblem' (E), and 'Samantha' (S) cultivars were randomly assigned to a location in each bench.


ROYALTY
EMBLEM
SAMANTHA

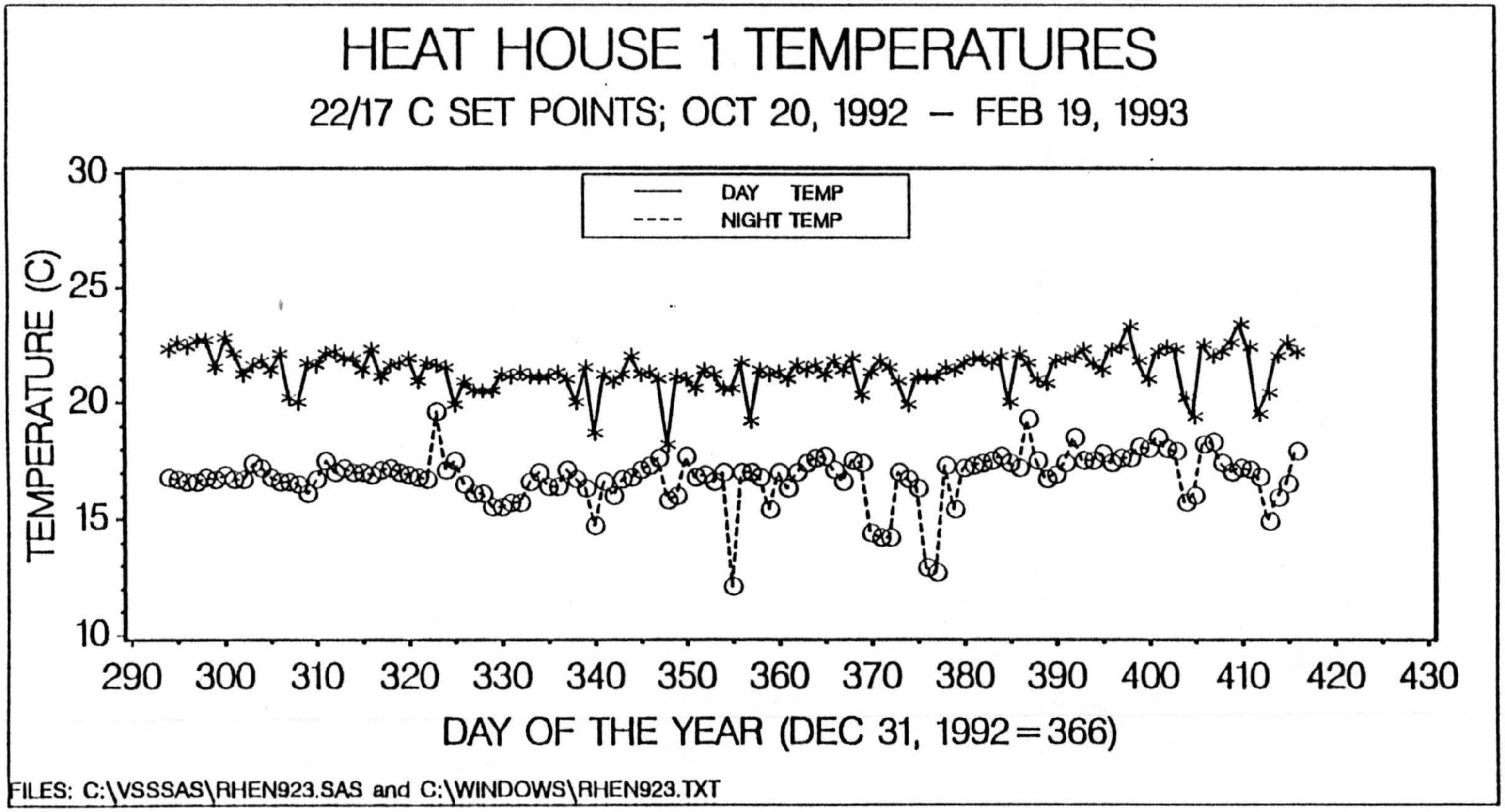

Figure 3. Average day (*) and night (○) temperatures in Heat House 1.

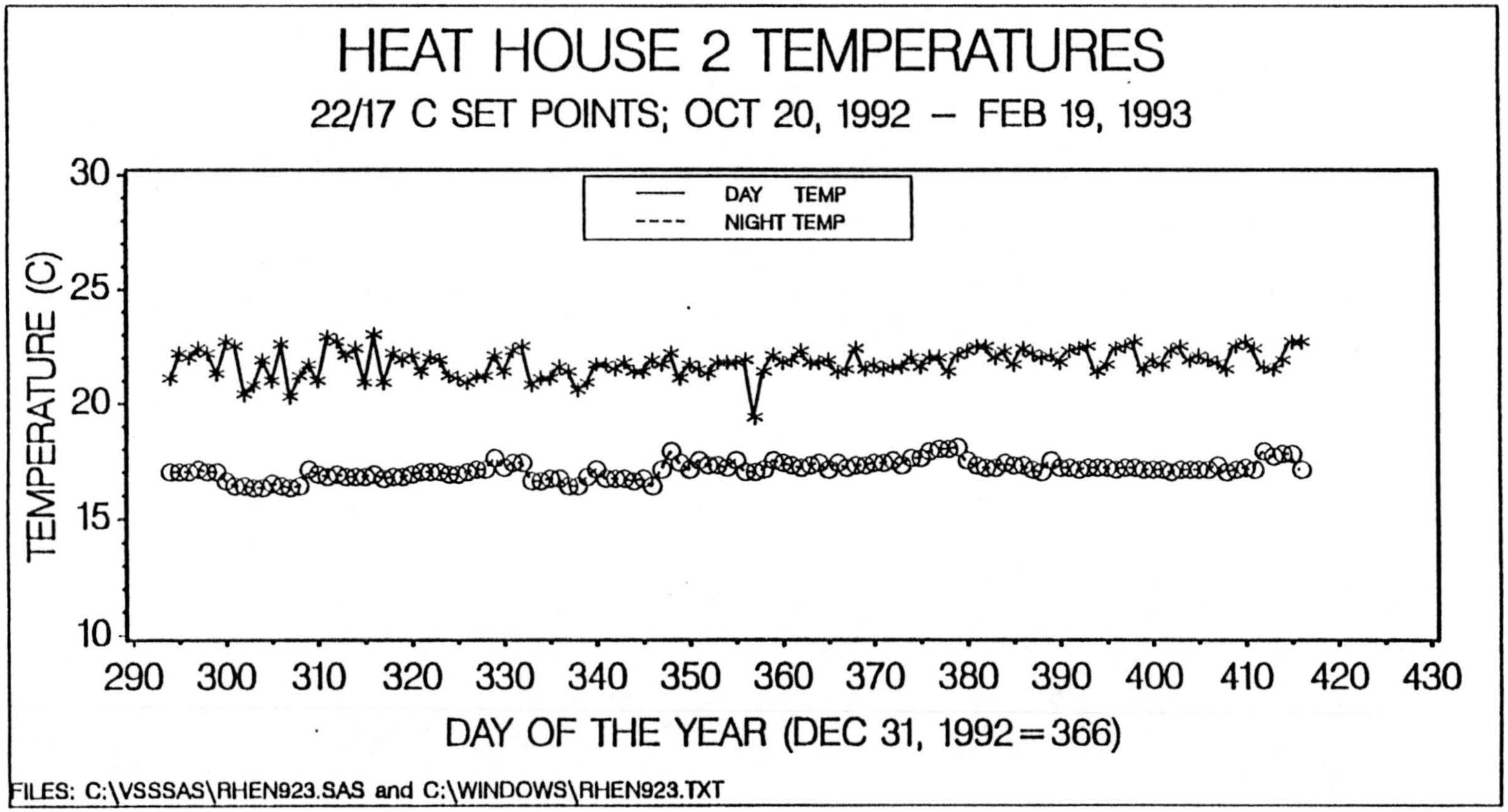

Figure 4. Average day (*) and night (○) temperatures in Heat House 2.

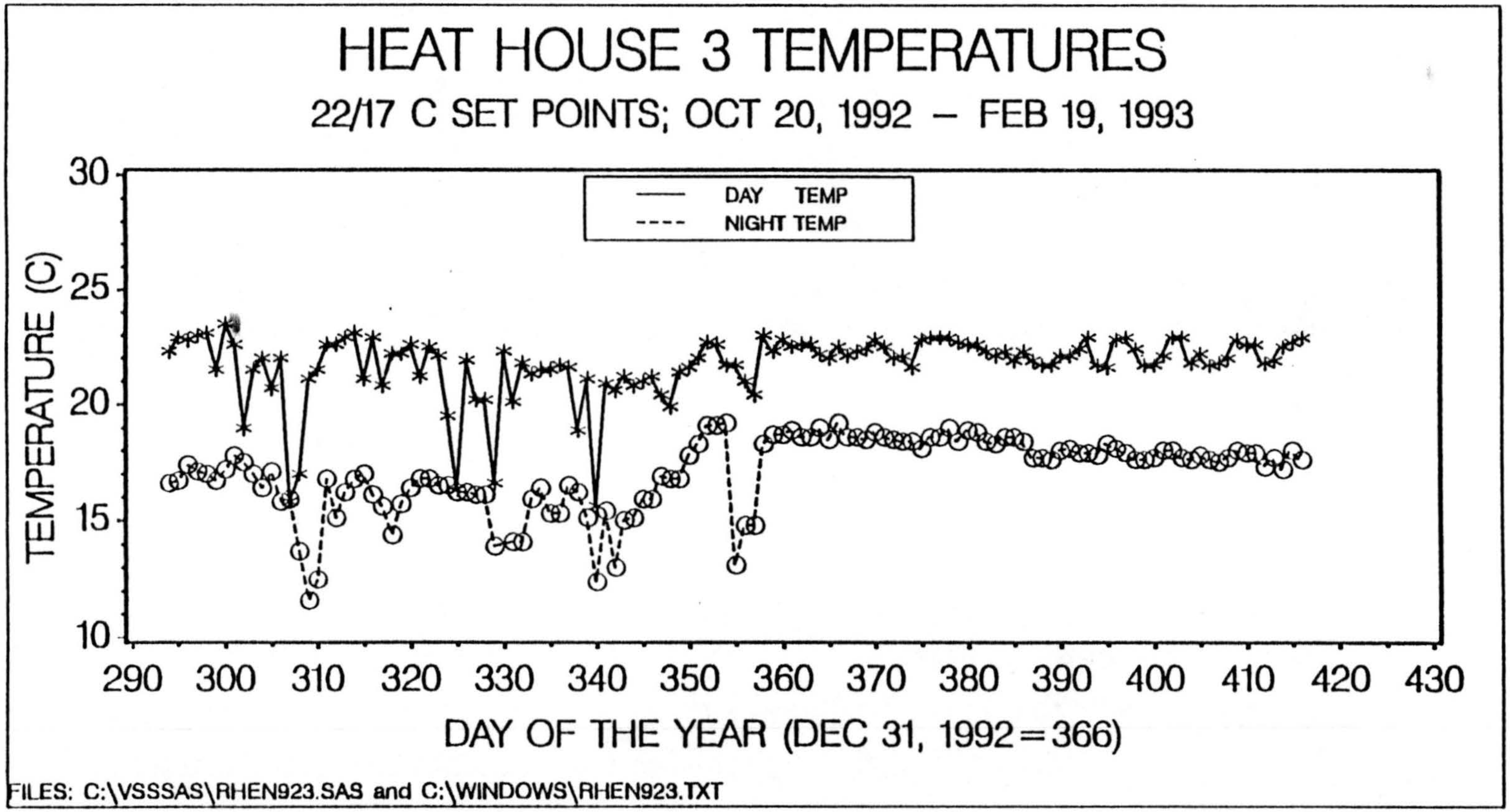

Figure 5. Average day (*) and night (○) temperatures in Heat House 3.

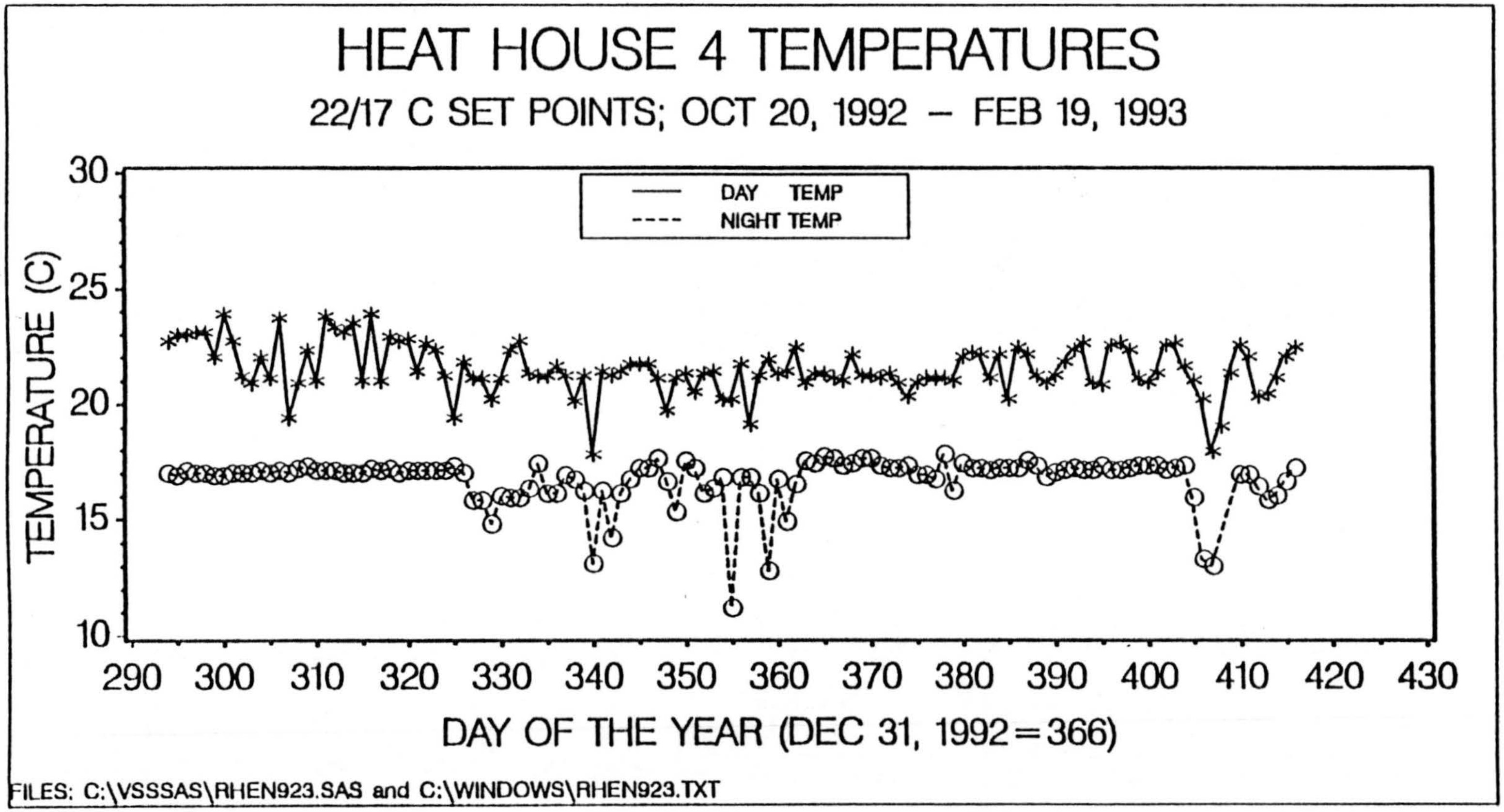

Figure 6. Average day (*) and night (○) temperatures in Heat House 4.

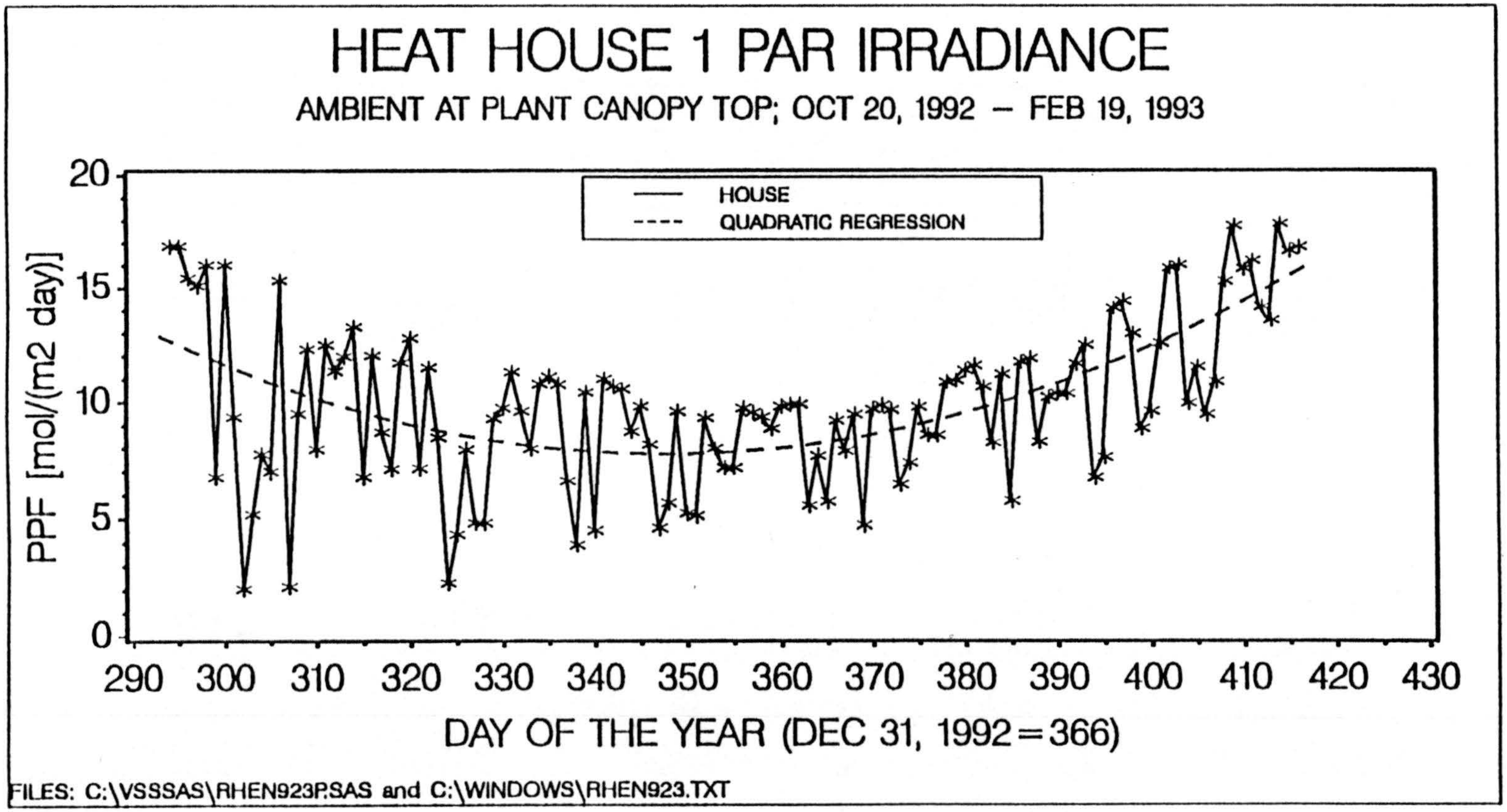

Figure 7. Average photosynthetically active radiation (PAR) measured as photosynthetic photon flux (PPF) in Heat House 1. (See Appendix C for regression analysis statistics.)

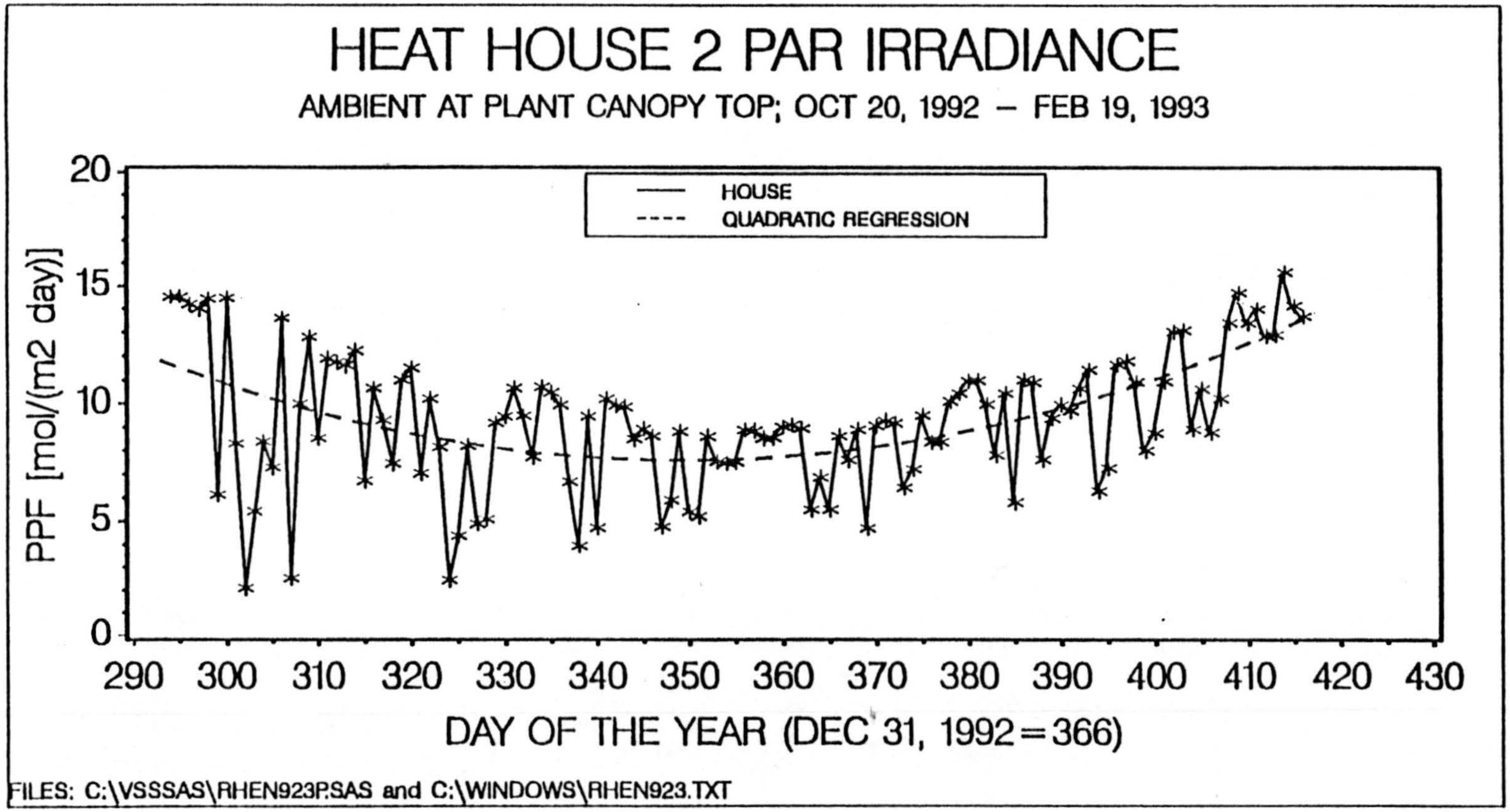

Figure 8. Average photosynthetically active radiation (PAR) measured as photosynthetic photon flux (PPF) in Heat House 2. (See Appendix C for regression analysis statistics.)

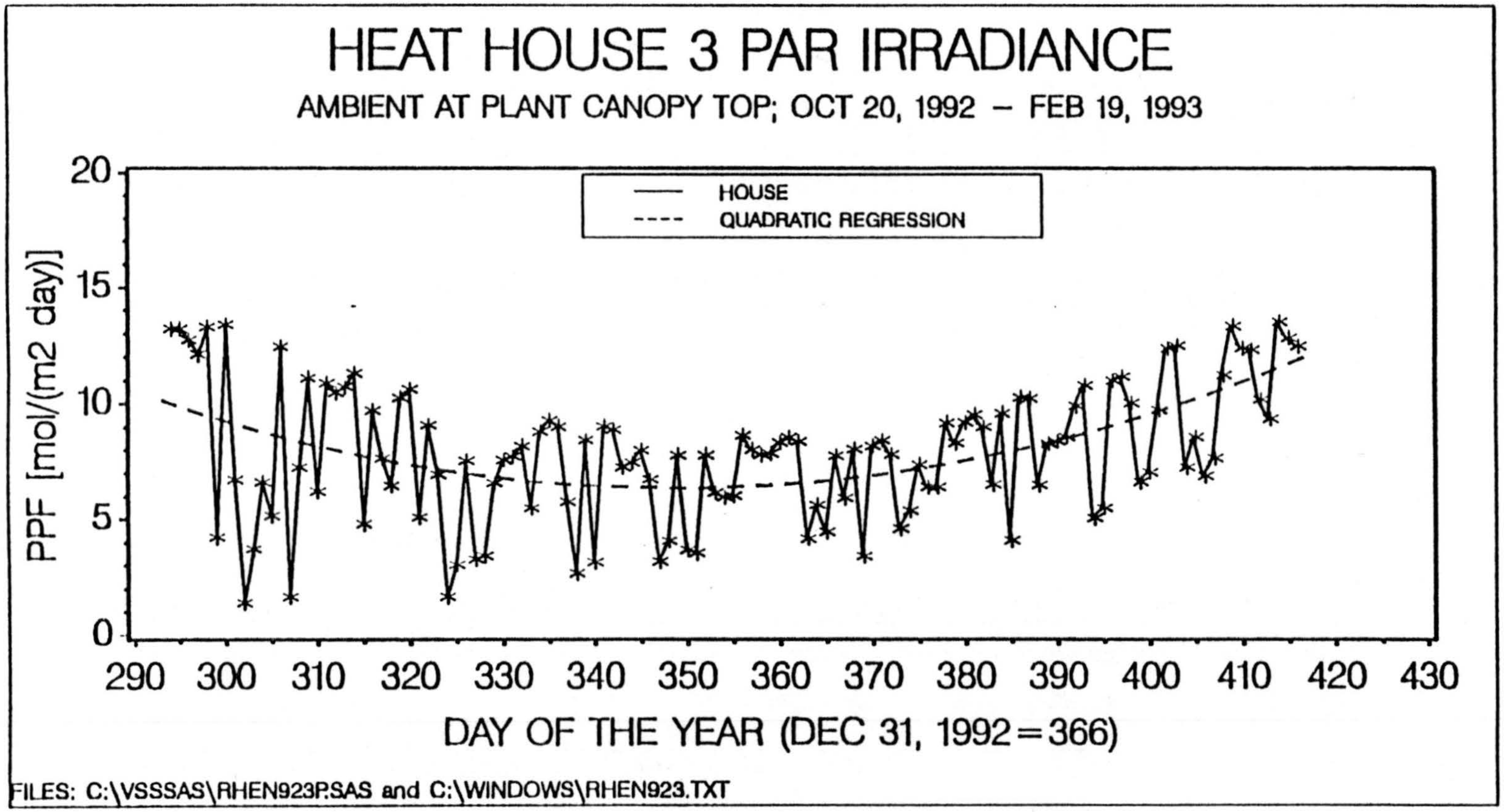

Figure 9. Average photosynthetically active radiation (PAR) measured as photosynthetic photon flux (PPF) in Heat House 3. (See Appendix C for regression analysis statistics.)

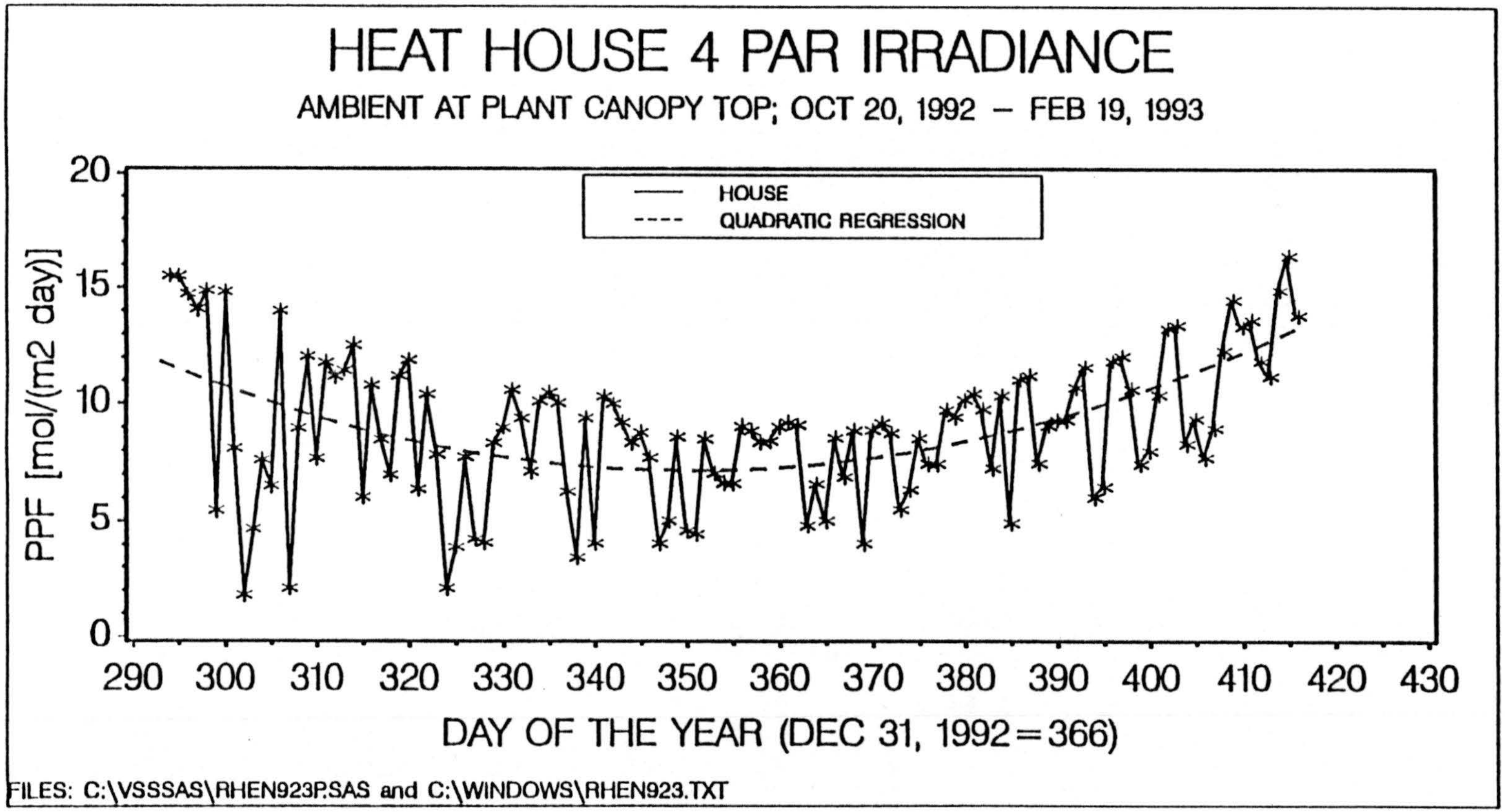

Figure 10. Average photosynthetically active radiation (PAR) measured as photosynthetic photon flux (PPF) in Heat House 4. (See Appendix C for regression analysis statistics.)

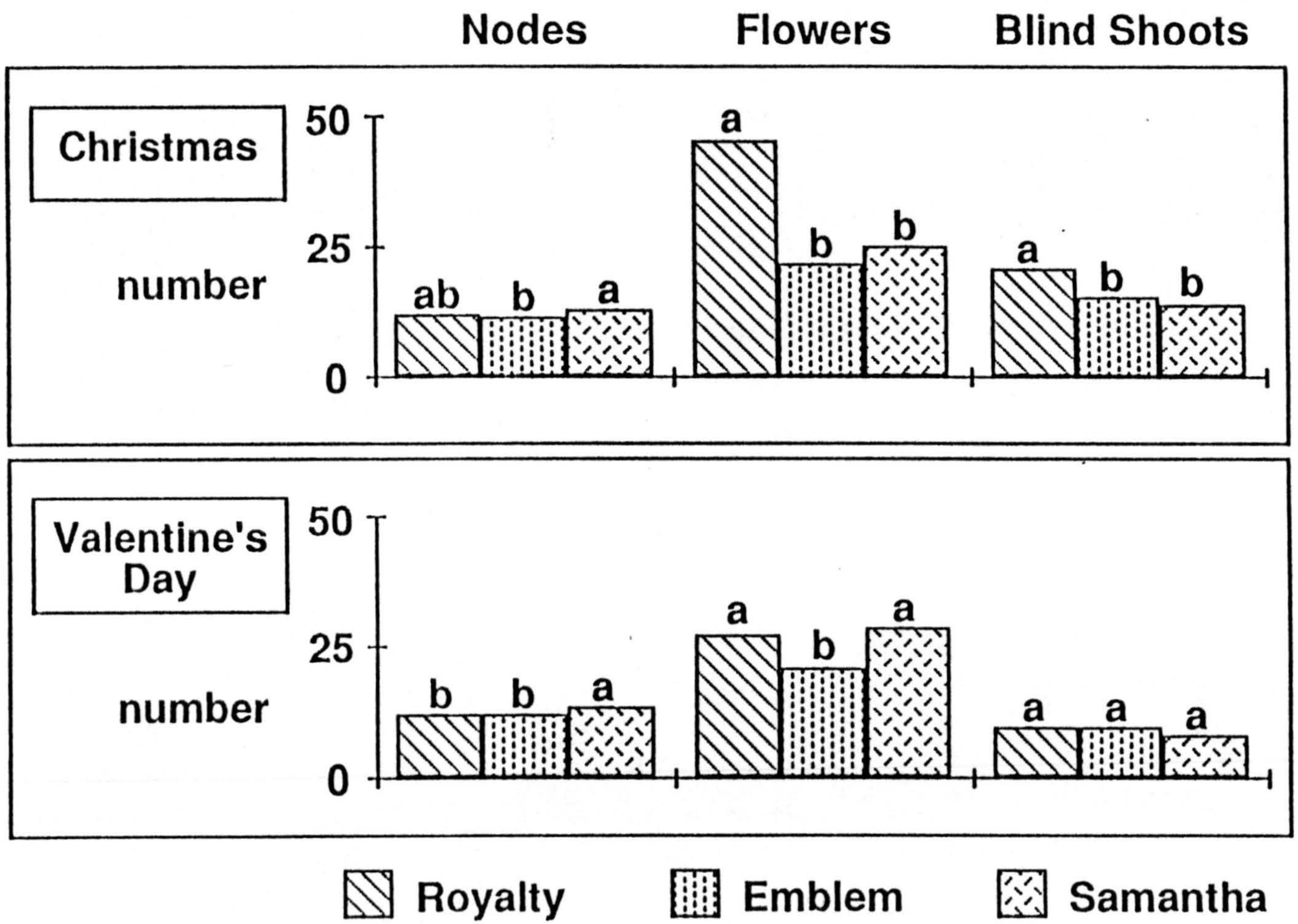

Figure 11. Numbers of nodes, flowers, and blind shoots from the Christmas and Valentine's Day crops.

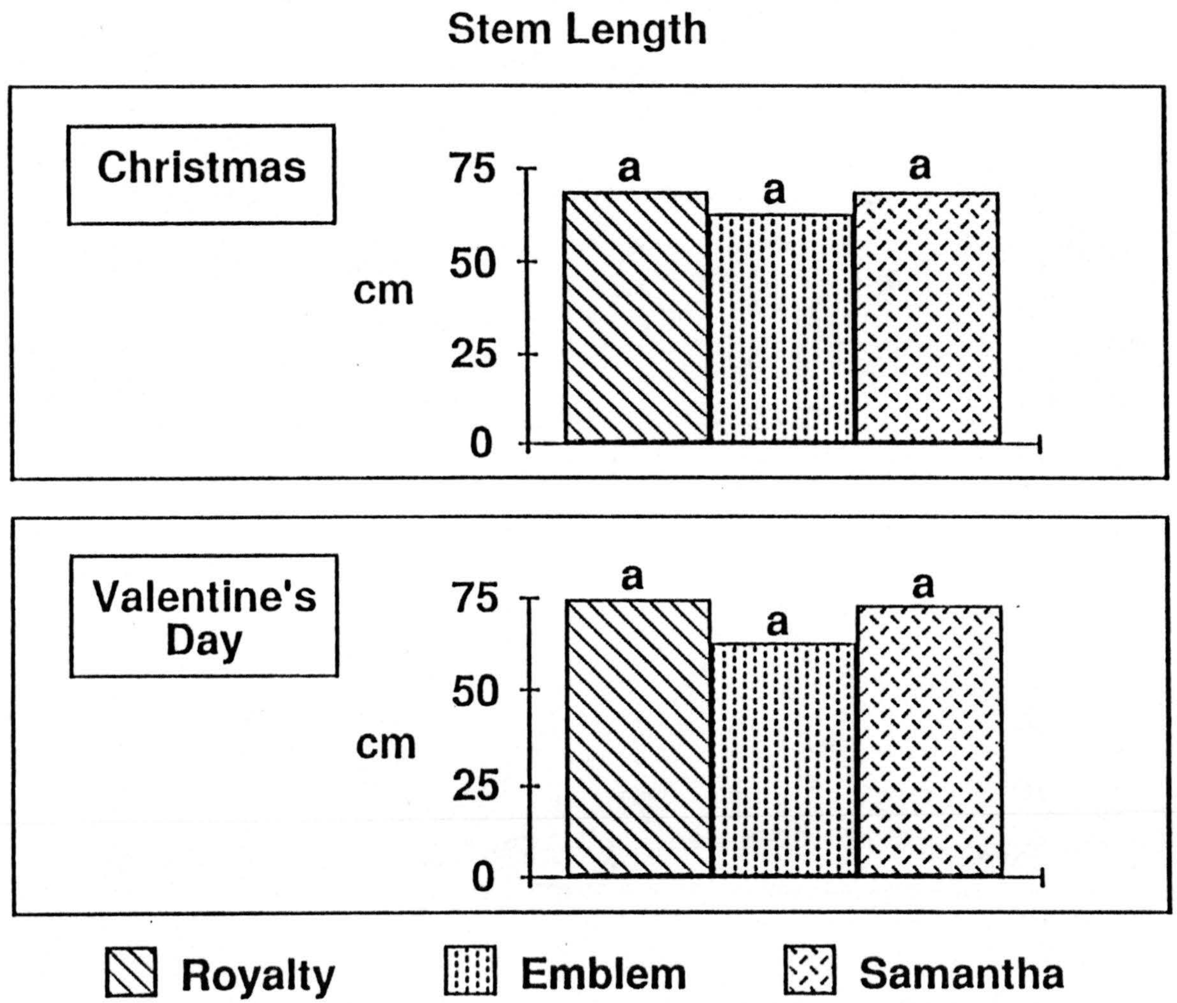

Figure 12. Stem length from the Christmas and Valentine's Day crops.

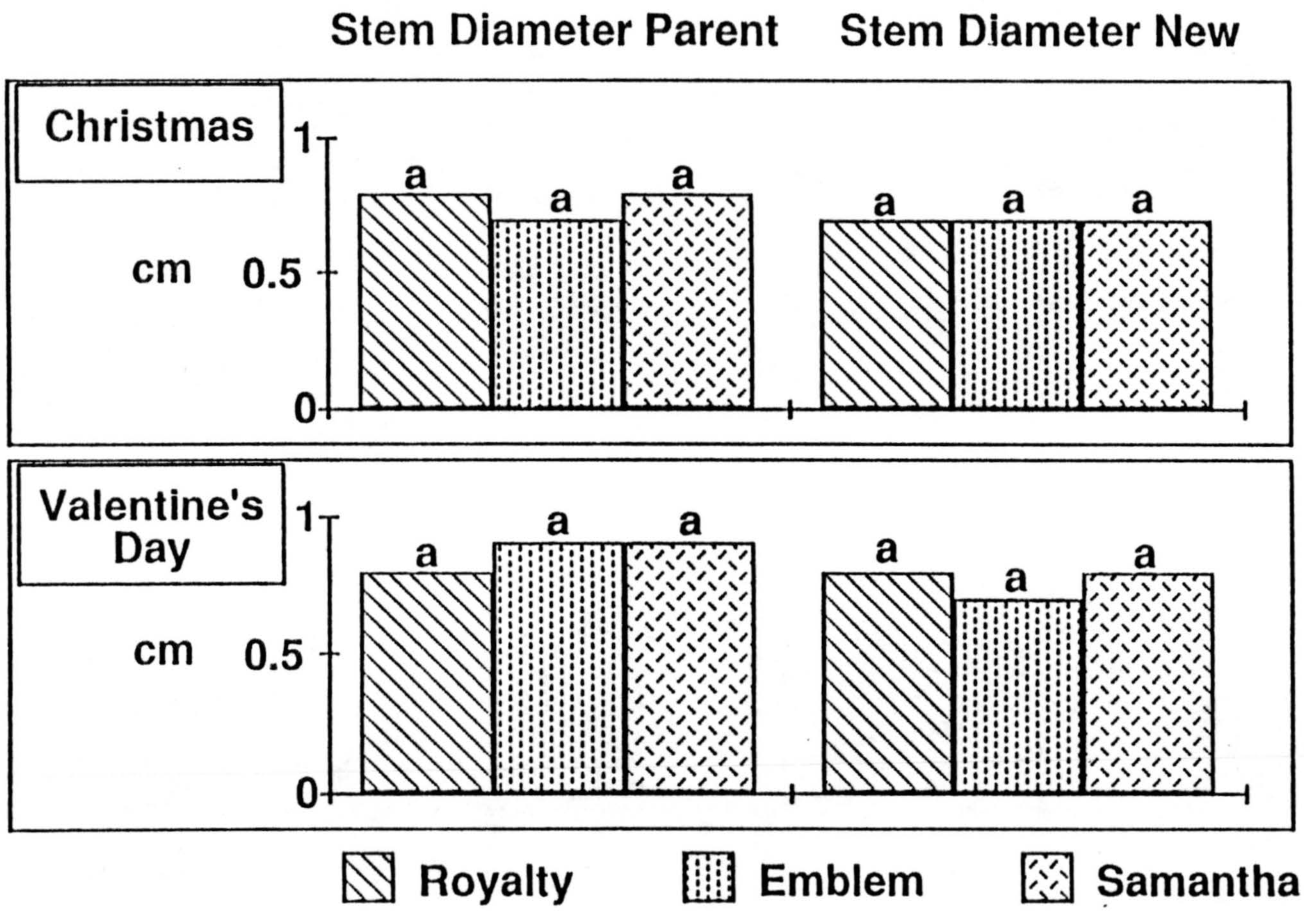

Figure 13. Stem diameters (parent and new shoots) from the Christmas and Valentine's Day crops.

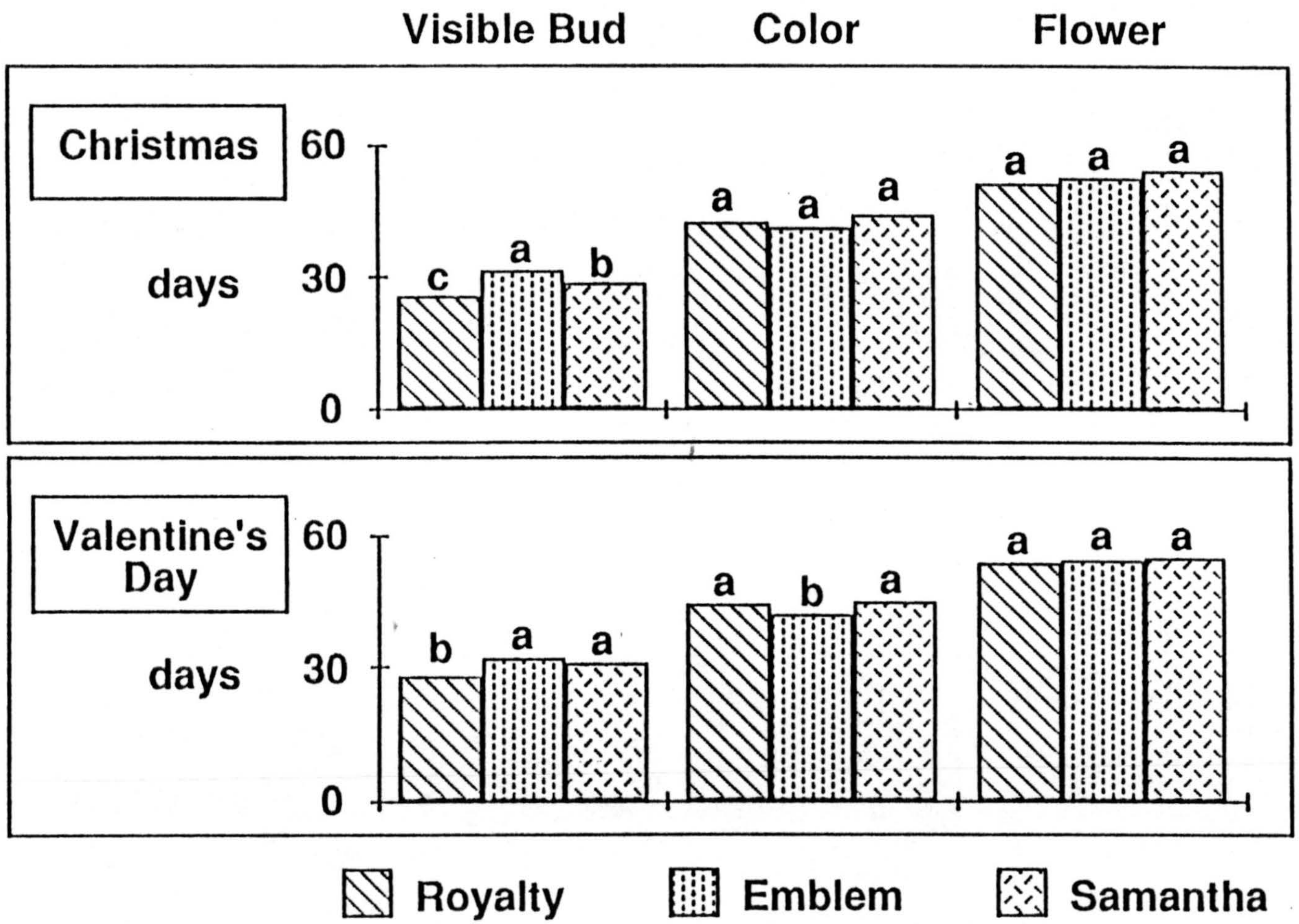

Figure 14. Days to visible bud, color, and flower from the Christmas and Valentine's Day crops.

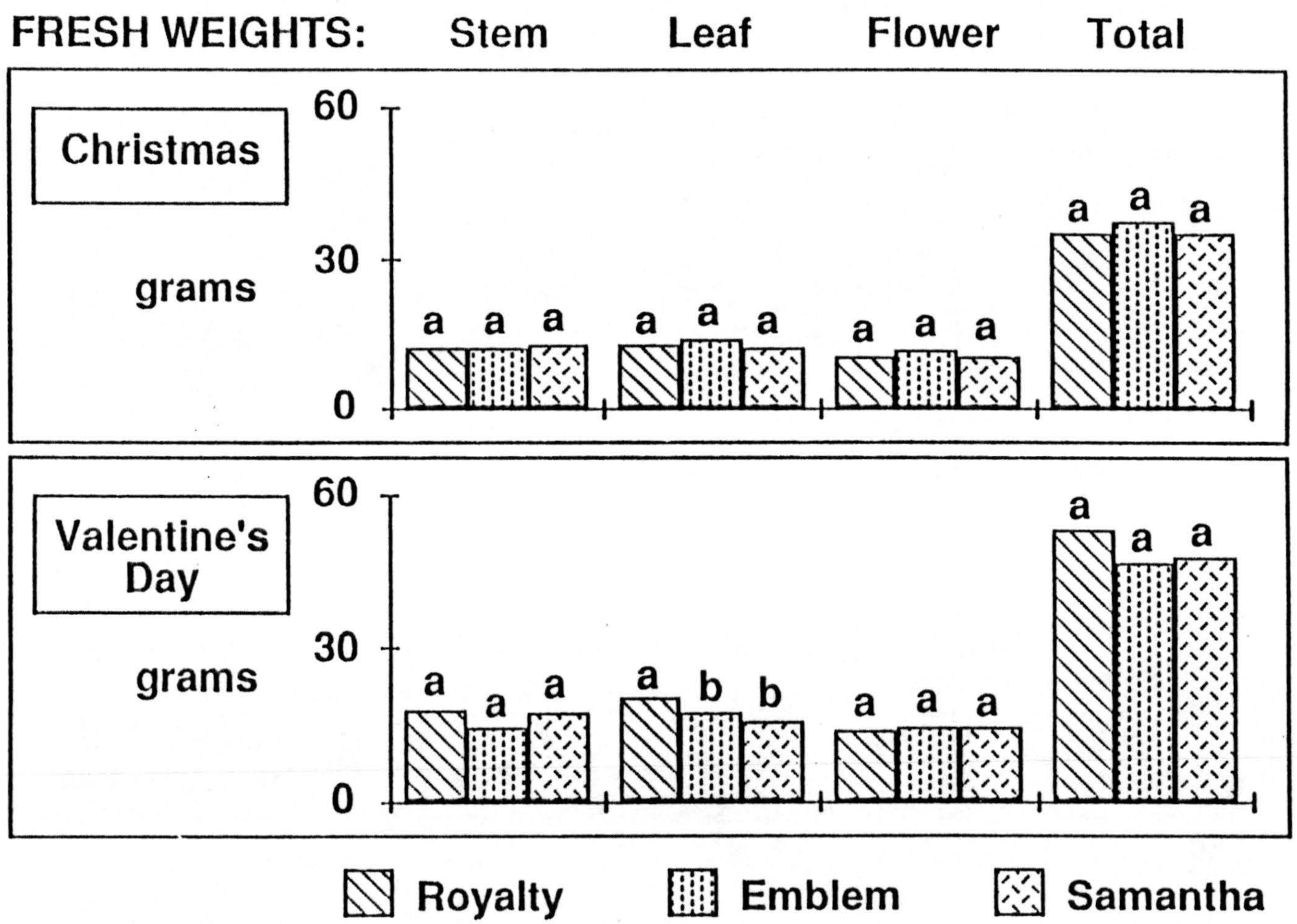

Figure 15. Fresh weights from the Christmas and Valentine's Day crops.

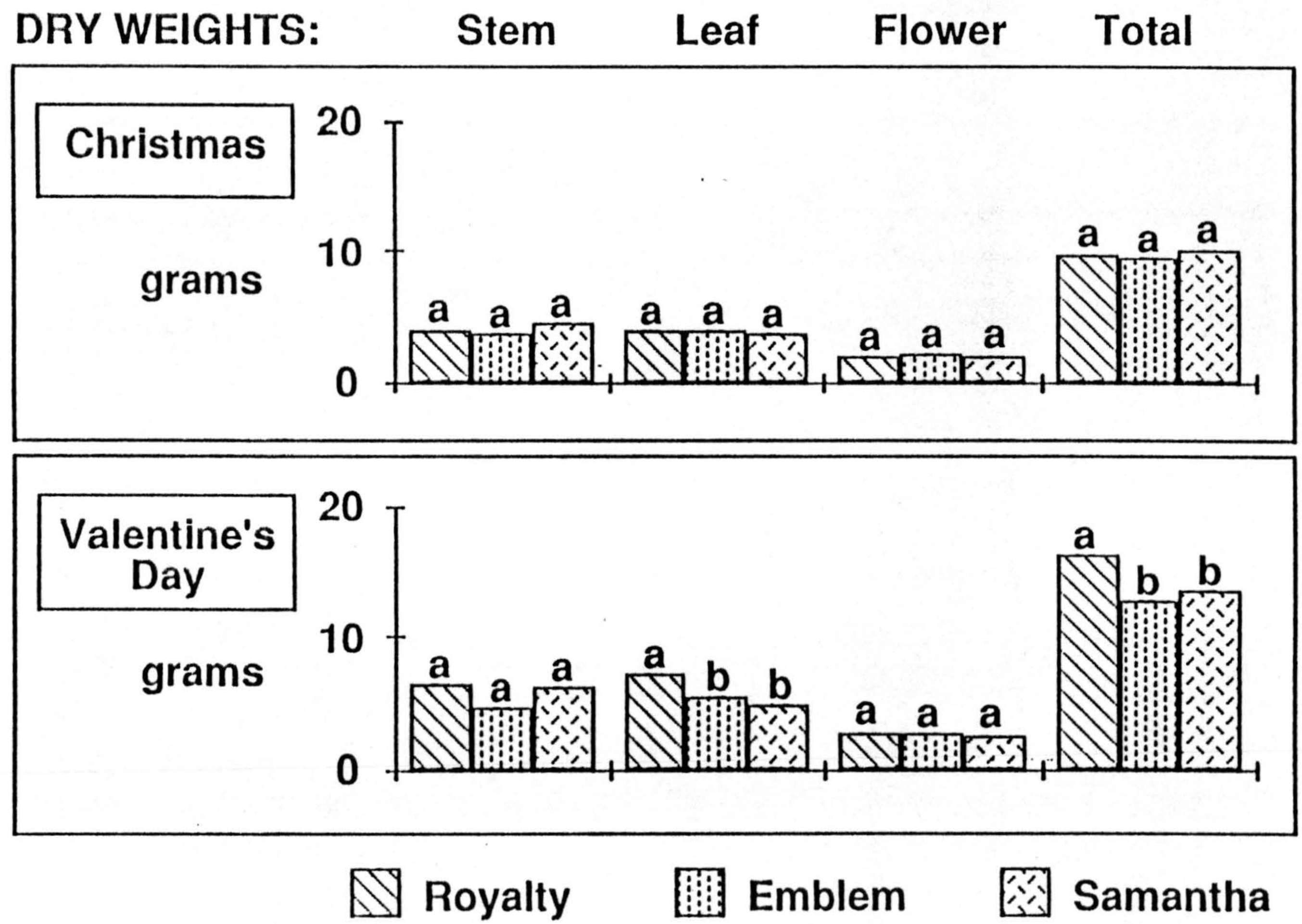

Figure 16. Dry weights from the Christmas and Valentine's Day crops.

APPENDICES

Appendix A. Colorado State University Plant Environmental Research Center (PERC) Nutrient Solution (D.A. Hopper, personal communication, revised April 8, 1992).

The fertilizer is mixed in two separate fifty gallon barrels which are rotated by interchanging the suction tubes each time the barrels are filled. The solution is diluted 1:200.

A. Barrel #1

1. Potassium nitrate (KNO_3) at 6 meq K^+/ℓ and 6 meq NO_3^-/l: 22.7 kg (50.0 lb)
   (One 50 lb. bag of KNO_3 is dissolved in the barrel)

2. Ammonium nitrate (NH_4NO_3) at 2 meq/l of each NH_4^+ and NO_3^-: 6.1 kg (13.4 lb)
   (6.1 kg of NH_4NO_3 are weighed and dissolved in the barrel)

3. Magnesium sulfate ($MgSO_4 \cdot 7H_2O$) at 1.3 meq Mg^+/l and 1.3 meq SO_4^{-2}/l: 6.2 kg (13.7 lb)
   (6.2 kg of Epsom salts is weighed and dissolved in the barrel)

4. Phosphoric acid (80% H_3PO_4) at 0.8 meq PO_4^{-3}/l: 2.0 l (2.12 qt)
   (2.0 liters of 80% H_3PO_4 is added to the barrel)

5. Borax ($Na_2B_4O_7 \cdot 10H_2O$) 11% B at .053 meq B/l: 95.0 g (3.35 oz)
   (Dissolved directly in the barrel; may need to boil)

6. STEM (Soluble Trace Element Mix) use 8 oz/100 pounds; for 113.8 pounds of other fertilizer, use 8 oz*1.138: 260.0 g (9.1 oz)
   (Note: This is 6.86 ppm of STEM in 10,000 gallons of final solution)

   This supplies:

Sulfur (S)	14.0 % of 260 g = 36.4 g	(0.96 ppm S)
Copper (Cu)	3.2 % of 260 g = 8.3 g	(0.22 ppm CU)
Iron (Fe)	7.5 % of 260 g = 19.5 g	(0.51 ppm FE)
Manganese (Mn)	8.0 % of 260 g = 20.8 g	(0.55 ppm Mn)
Molybdenum (Mo)	0.04 % of 260 g = 0.1 g	(0.0027 ppm Mo)
Zinc (Zn)	4.5 % of 260 g = 11.7 g	(0.31 ppm Zn)
Boron (B)	1.35 % of 260 g = 3.5 g	(0.093 ppm B)

7. Water to fill; approximately 190 liters.

B. Barrel #2

1. Calcium nitrate [$Ca(NO_3)_2 \cdot 4H_2O$] at 3.7 meq Ca^{+2}/l and 3.7 meq NO_3^-/l: 16.6 kg (36.6 lb)
   (16.6 kg of $Ca(NO_3)_2 \cdot 4H_2O$ are weighed and dissolved in the barrel)

2. Iron chelate (Sequestrene 138) Fe^{+2}/l: 32.0 g (1.13 oz)
   (63.0 g Sequestrene 138 are weighed and dissolved in the barrel)

3. Water to fill; approximately 190 liters.

Appendix B. Rose cultivar classification types and propagation methods .

CLASSIFICATION TYPES (traditional method, used in the greenhouse industry; D.A. Hopper, personal communication):

Hybrid tea: 'Traditional' long stem rose such as the cultivar 'Red american Beauty'. Exceptional range of color, fragrance, flower size, and shape. Cultivation dates back to 1867. Not much side shoot development; those present are disbudded.

Floribunda: Also called multiflora; product of the 20th century, resulting from mating of polyantha and hybrid teas; sweethearts also can fall into this category.

Intermediates: Generally the same as hybrid teas in flower size and shape, mainly characterized by a shorter stem length.

Grandifloras: Mainly used in gardens and not greenhouse production; these types have favorable Hybrid Tea characteristics, clusters of flowers, and large plant size (>180-250 cm).

Spray roses: Relatively new cultivars produced for clusters of flowers; these may have the center bud removed, or be left to flower as a cluster without any bud removal.

CLASSIFICATION TYPES (Modern method; Macoboy, 1993):

(In 1979 the World Federation of Rose societies adopted a simplified system.)

Wild Roses are the truly wild species and related garden forms for them, and are sub-divided into climbing and non-climbing roses.

Old Garden Roses were established prior to 1867, are of horticultural origin, and are sub-divided into climbing and non-climbing roses.

Modern Garden Roses are those most often seen, have been hybridized since 1867, and are sub-divided into:

Bush: Large-flowered (formerly Hybrid Tea)
Cluster-flowered (formerly Floribunda)
Polyantha

Shrub: English rose
Hybrid musk
Hybrid rugosa
Unclassified modern shrub

Ground cover

Climber: Large-flowered
Cluster-flowered

Miniature: Climbing miniature
Miniature

PROPAGATION METHODS (D.A. Hopper, personal communication):

Started eye rose plants have traditionally been used for cut flower production by the greenhouse industry. A single bud of the desired cultivar is budded (grafted) onto a favorable rootstock. Rootstocks may be different species, but the most widely used is *Rosa manetti* (*R. odorata, R. indica,* and *R. multiflora* are also used). Plant producers (Devor's Nursery, Jackson and Perkins, and Carlton Nurseries) do not have accepted grades or standards comparable to those established for garden cultivars and recognized by the American Association of Nurserymen (AAN). Each producer of greenhouse forcing plants has established criteria which has become a standard and generally accepted by customers. In general, a XXX (called 'triple X' or 'three X') plant can have one or more strong canes of a certain diameter and a well developed root system. A XX plant could have the same number of canes as the company's XXX plant but only be 60-70% of the XXX criteria. Started eye plants have 12 months of growth in the field.

Grafted plants use a scion (short piece of stem) of the cultivar grafted onto the rootstock of *R. odorata* or *R. indica*. These are smaller and younger (4-6 months) than the started eye plants, and are used for rock rockwool culture or hydroponic systems.

Appendix C. Regression analysis statistics for Tables 7 - 10.

REGRESSIONS FOR PPF1 to 4 FIT TO JDAY; QUADRATIC ;
13:30 Monday, March 14, 1994

Model: MODEL1
Dependent Variable: PPF1

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	562.42550	281.21275	35.867	0.0001
Error	120	940.84237	7.84035		
C Total	122	1503.26787			

Root MSE	2.80006	R-square	0.3741
Dep Mean	9.98488	Adj R-sq	0.3637
C.V.	28.04304		

FILES: C:\VSSSAS\RHEN923P.SAS and C:\WINDOWS\RHEN923.TXT

REGRESSIONS FOR PPF1 to 4 FIT TO JDAY; QUADRATIC ;
13:30 Monday, March 14, 1994

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	215.645459	28.05347051	7.687	0.0001
TIME	1	-1.196214	0.15914952	-7.516	0.0001
TIME2	1	0.001721	0.00022393	7.683	0.0001

FILES: C:\VSSSAS\RHEN923P.SAS and C:\WINDOWS\RHEN923.TXT

REGRESSIONS FOR PPF1 to 4 FIT TO JDAY; QUADRATIC ;
13:30 Monday, March 14, 1994

Dependent Variable: PPF2

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	318.72864	159.36432	28.394	0.0001
Error	120	673.51196	5.61260		
C Total	122	992.24061			

Root MSE	2.36909	R-square	0.3212
Dep Mean	9.29179	Adj R-sq	0.3099
C.V.	25.49663		

FILES: C:\VSSSAS\RHEN923P.SAS and C:\WINDOWS\RHEN923.TXT

REGRESSIONS FOR PPF1 to 4 FIT TO JDAY; QUADRATIC ;
13:30 Monday, March 14, 1994

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	171.456767	23.73563304	7.224	0.0001
TIME	1	-0.938497	0.13465409	-6.970	0.0001
TIME2	1	0.001343	0.00018946	7.091	0.0001

FILES: C:\VSSSAS\RHEN923P.SAS and C:\WINDOWS\RHEN923.TXT

REGRESSIONS FOR PPF1 to 4 FIT TO JDAY; QUADRATIC ;
13:30 Monday, March 14, 1994

Dependent Variable: PPF3

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	273.74137	136.87068	21.604	0.0001
Error	120	760.23828	6.33532		
C Total	122	1033.97965			

Root MSE	2.51701	R-square	0.2647
Dep Mean	7.91545	Adj R-sq	0.2525
C.V.	31.79866		

FILES: C:\VSSSAS\RHEN923P.SAS and C:\WINDOWS\RHEN923.TXT

REGRESSIONS FOR PPF1 to 4 FIT TO JDAY; QUADRATIC ;
13:30 Monday, March 14, 1994

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	156.249842	25.21755808	6.196	0.0001
TIME	1	-0.859731	0.14306117	-6.010	0.0001
TIME2	1	0.001232	0.00020129	6.123	0.0001

FILES: C:\VSSSAS\RHEN923P.SAS and C:\WINDOWS\RHEN923.TXT

REGRESSIONS FOR PPF1 to 4 FIT TO JDAY; QUADRATIC ;
13:30 Monday, March 14, 1994

Dependent Variable: PPF4

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	343.27735	171.63867	24.539	0.0001
Error	120	839.34727	6.99456		
C Total	122	1182.62461			

Root MSE	2.64472	R-square	0.2903
Dep Mean	8.93732	Adj R-sq	0.2784
C.V.	29.59191		

FILES: C:\VSSSAS\RHEN923P.SAS and C:\WINDOWS\RHEN923.TXT

REGRESSIONS FOR PPF1 to 4 FIT TO JDAY; QUADRATIC ;
13:30 Monday, March 14, 1994

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	181.690007	26.49714018	6.857	0.0001
TIME	1	-0.996558	0.15032033	-6.630	0.0001
TIME2	1	0.001422	0.00021151	6.724	0.0001

FILES: C:\VSSSAS\RHEN923P.SAS and C:\WINDOWS\RHEN923.TXT