CONTAINER STYLE AND HYDROPHILIC GEL INFLUENCE ON BEDDING PLANT PRODUCTION AND POSTHARVEST QUALITY

by

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Introduction

Commercial growers and grounds maintenance managers are concerned with production of quantities of bedding plants while optimizing use of greenhouse bench space. Therefore, various sized containers, with a trend towards small individual cells, are being utilized. As well as quantity, quality is an important concern to growers. Bedding plants grown in small containers are susceptible to water stress which may greatly impair the quality of the marketable product and increase management costs. The effect of smaller container size on quality and growth parameters needs to be carefully evaluated.

The purpose of this research is twofold. First, to evaluate the effect of container style and size on plant growth. Second, to investigate the possible use of hydrophilic gels to extend postharvest life of bedding plants.

Brassica oleracea Italica c.v. 'Green Duke' and *Calendula officinalis* c.v. 'Lemon' have been selected as test crops for bedding plants. These cool season crops were selected since they can be grown under similar environmental conditions, are increasing in popularity in production and marketing, and are subject to stresses in the greenhouse and at the retail market or holding area. Production of a quality plant in minimum space would be of significant value to growers or retailers.

Literature Review

Greenhouse bedding plant production is steadily increasing. The approximate annual growth rate has been 20 percent, with an average wholesale value of $113 million in 1977 (27). This value has resulted primarily from an increased production in volume. The trend appears to be toward producing bedding plants in small containers optimizing the use of bench space. In addition to the advantage of more rapid turnover, growers are finding an advantage in the increasing consumer demand for less expensive, easy to carry small sizes (21). This is particularly the case in mass merchandising outlets.

Bedding plants are grown in various styles of containers, including peat pots, plastic pots, clay pots, fiber boxes, and plant paks. Annual flowers, herbs, perennial flowers, vegetables, and other plants sold for use in outdoor flower and vegetable gardens are included in today's bedding plant market. Vegetable crops are gaining in popularity and have contributed to the growth of bedding plant sales.

Research has dealt with the influence of container size and composition on the growth of vegetable transplants and yields. Growth and development of transplants were significantly influenced by pot size and/or spacing. The larger the container or spacing, the larger the plants (16, 29). In a comparison of 10 cm and 6.4 cm containers of various compositions, the 10 cm containers resulted in taller, bushier plants with greater dry weights than plants grown in 6.4 cm pots. Plants grown in the smaller container appeared elongated and less compact apparently due to limited amounts of nutrients and soil volume for root growth (29).

Tomato plants grown in 7.6 cm and 10 cm peat pots and planted in the field at 18 X 18 cm spacings produced highest total yields. The increased volume of soil per plant obtained by increasing container size and/or spacing distance between plants apparently contributed to increased plant growth and yields (16).

A container tends to influence plant development through the nature of its physical construction-water-soil interrelationship (16). Trials with vegetables grown in peat pots and placed in the field produced earlier and greater yields (2, 16). The plant is not shocked by root damage during transplanting and therefore produces an earlier crop. The peat pots are able to absorb moisture readily and remain pliable throughout the growing period. This allows for root penetration of the walls with little competition between the root and container for moisture (16).

In a study conducted to determine the effects of relative humidity and type of container on the seedling growth of three F_1 hybrid annuals, it was found that each species responded differently to the type (composition) of container used. Petunia, ageratum, and marigold seedlings were grown in 7.5 cm clay and plastic pots in a soilless mix of peat and vermiculite. The fresh and dry weights of petunia seedlings were significantly greater in plastic pots, while marigold seedlings were unaffected by the type of container. Ageratum seedlings, on the other hand, had significantly greater fresh and dry weights in clay pots (18).

The growth of vegetable transplants in clay and plastic pots depended upon the pot size and plant being grown (29). These results suggest that the growth of some plants is more sensitive to root temperatures than others.

Soil temperature in non-porous containers including plastic pots, are higher than those in clay pots and other porous containers (18).

The effects of the use of disposable containers on quality reduction in bedding plants have been studied. Bedding plants were grown in plastic containers, paper pots, and peat blocks. All plants grew satisfactorily in the various containers with no quality reduction (28).

Research suggests that improved plant production and development is affected most significantly by container size rather than composition (16, 29). The effect of container composition on growth appears to be dependent upon the plant species and its intended use. Most growers recognize the advantages of producing plants in the larger containers with large soil volumes. However, the trend is toward growing large volumes of plants in smaller containers. Smaller containers result in a lower unit cost with a higher return to the grower per square foot (3).

A recent study conducted by Klich revealed that consumer satisfaction was based on quality of plants sold (15). Bedding plants grown in small containers are susceptible to water stress which greatly impairs the quality of the marketable product. The problem is compounded by retail marketplace conditions where watering frequency is often a function of managerial convenience rather than plant demand (12). A quality plant often reaches the marketplace and quickly deteriorates due to moisture stress.

Research has been conducted in an attempt to extend the postharvest life of bedding plants. The use of hydrophilic gels has been used in numerous studies to increase survival, improve handling, conserve water, promote growth, and reduce maintenance of various crops, specifically for use in the bedding plant and nursery industries (23). These substances are capable of absorbing hundreds to thousands of times their dry weight in fluids for six months to a year (10). They have been found to expand to thirty times their size increasing aeration - a key factor in plant growth (10, 23).

The effects of Terra-Sorb on water retention have been studied by various individuals (23). Terra-Sorb is a starch based absorbent manufactured by Industrial Services International, Inc. The hydrogel is a gelatinized starch-hydrolyzed polyacrylonitrate graft copolymer using potassium hydroxide. This hydrophilic gel has been used on ferns, container grown nursery stock, and various bedding plants. It is normally mixed dry in the medium and has been found to absorb gravitational and capillary water. The structure of each molecule has two main parallel groups of atoms, periodically joined by connecting links. When water is added, an electrical repulsion exists causing the main branches of the molecule to repel each other, water then moves between the branches and the particles swell (23). Hydrophilic polymers act as rechargeable reservoirs holding many times their dry weight in water, most of which is held at -0.1 to -2.0 atm (12). This water can be readily extracted by the plant root, promoting ideal growing conditions. The use of Terra-Sorb resulted in a reduced crop time, reduced irrigation frequency, increased shelf life, and minimized transplant shock (23).

Munday evaluated Terra-Sorb for its effectiveness in increasing water holding capacity and for reducing the required watering of a soilless growing medium. The water holding capacity increased by 9, 18 and 36%, and 16, 22 and 38% as the rate of Terra-Sorb increased for 10 cm and 15 cm containers, respectively. Therefore, water requirements were reduced and plant stress minimized (20).

Another study evaluated the use of Terra-Sorb on a soilless medium and its ability to extend the shelf life through its water retention capabilities. Four rates, 1, 2, 3, and 4 lbs/cu. yd. were incorporated into 10 cm plastic containers containing a pine bark medium. Pots were fertilized at each irrigation. Water retention was determined by weight differences between dry pots and pots at field capacity. Results indicated that the use of Terra-Sorb increases the retention of soluble nutrients and reduces leaching of these nutrients by reducing watering intervals (22).

The use of hardwood bark as a growing media or substitution for peat moss has increased rapidly (26). Bark provides excellent aeration and drainage, but the mixes containing bark tend to dry faster. Still (26) conducted a study using Viterra amended medium (rates ranging from 57 to 454g/0.03 m^3) to extend shelf life of chrysanthemum. Viterra 2 is a granular, organic polymer (99.5 percent AI potassium propenoate-propenamide copolymer) manufactured by Nepera Chemical Co. Viterra at the recommended rate (3.2kg/m^3) reduced watering, increased shelf life and was not phytotoxic. Shelf life of plants grown in Viterra amended mixes was 11 to 33% longer than control plants.

Bearce and McCollum (4) studied the effects of Viterra 2 on the performance of pot plants and bedding plants, using a peat-lite and noncomposted hardwood-bark media. Viterra 2 was incorporated into the media and plants were grown to a salable size. Water was then withheld and days to wilting recorded. Root development of all treatments was examined and photos taken. From the data, Bearce and McCollum determined that Viterra 2 would increase shelf life by 57%. They also concluded that Viterra 2 improved available water capacity, drainage and aeration, plant quality, top growth, flowering, and root development.

Conover and Poole (8) grew Maranta and Pilea in soil incorporated with Viterra 2 at 3.2 kg/m^3 at pH levels of 5.5, 6.0, and 6.5 to determine if it would be effective within that pH range and be beneficial to growth and shelf life of these foliage plants. Viterra 2 improved growth and increased shelf life by approximately 10% for both species. However, the small growth increases and limited shelf life extension seemed insignificant when compared to the additional cost of $31.52 per cubic meter for Viterra 2 amended potting media.

In another study by Conover and Poole (9), the influence of Viterra on growth and wilting of three foliage plants schefflera, croton, and boston fern was examined. Plant growth and grade was improved and shelf life was extended an additional 15 to 30%.

Gehring and Lewis (12) studied the effect of Viterra 2 on wilting and moisture stress of marigold and zinnia. Viterra 2 was incorporated dry into a peat-lite medium (Jiffy Mix) at four rates, 0.5, 1, 1.5, 2 times the manufacturers' recommended rate. The plants were grown to a marketable size and then placed in a growth chamber at a temperature of 21.6 C and 60% relative humidity. They were watered thoroughly and then examined at four hour intervals until wilted. The number of hours for plants to exhibit this state were recorded, and a pressure bomb was used to quantitatively evaluate the plant moisture status. Results indicated that the hydrophilic gel incorporated at intermediate rates was most effective. They also found that hours to wilting of certain bedding plants can be increased and moisture stress reduced by incorporation of hydrophilic gels in the growing medium. This proves more economical than increases in container size. They did not simulate retail marketplace conditions. They stated that the magnitude of results obtained under actual growing or marketplace conditions would probably be less, and hours to wilting increases of an hour or less could be significant in reducing plant losses and extending market life.

Armitage and Kowalski (1) examined the effect of irrigation frequency on postharvest quality. 'Coral Sea' petunia was grown in plastic cell packs in 1 peat: 1 vermiculite using three irrigation frequencies: 1) media was allowed to dry out completely (soil moisture = -4 to -10 bars); 2) surface of media was allowed to dry out between waterings (soil moisture = -0.8 to -3 bars); and 3) media constantly wet (soil moisture = 0.6 bars). Dry weights and stem length were greater in plants from high moisture treatments compared with plants from other treatments. Once plants exhibited one open flower, they were then moved into post production environments: 1) 10°C constant temperature; 2) 20°C constant temperature; and 3) 20°C night temp., 30°C day temp. Frequency of irrigation did not influence plants placed in the cool environment. In the moderate and hot environments, plants irrigated with high frequency declined in quality most rapidly. Low moisture treated plants had slower flower development and senescence, greater dry weight, and better visual quality compared to plants from other moisture treatments. These results indicate that the low frequency plants were well toned, allowing more rapid adaptation to the warmer temperatures. Although, water frequency may actually harden off the plants and acclimate them to the marketplace conditions, plant growth may be sacrificed in the process.

Greenhouse plants are usually grown in small pots. When water is withheld, it takes only hours or days to reach the same water potentials that occur after days or weeks of drying in the field due to the reduced soil volume when container grown. If plants are severly stressed they usually have little economic value.

One of the earliest discernible effects of water stress is reduction in cell growth (17). Water stress directly reduces plant growth through a reduction in turgor potential, crucial in cell expansion and stomatal movement (13, 17, 30). Reduced cell turgor causes closure of stomata and reduction in cell enlargement, thereby reducing both the leaf surface area and the rate of photosynthesis per unit of leaf area (17). Almost any growth parameter is changed by water stress provided that the stress is strong and long enough, yet most changes in plant processes brought about by stress arise indirectly (13).

Various parameters may be used to indicate plant water status. Visual wilting is often used to indicate stress as wilting is dependent on turgor potential. The wilting response of leaves is an effective mechanism for shedding radiation and reducing the rate of development of severe water deficits (17). Yet, physiological processes are often affected before wilting becomes apparent (13).

Leaf water potential (Ψ) is the fundamental measure of plant water status. The pressure chamber technique determines the pressure necessary to force water (xylem sap) back to the cut surface of a severed petiole (13, 24, 30). Leaf water potentials were compared with those measured with a thermocouple psychrometer known to indicate accurate values of leaf water potentials. Determinations were within $\pm$ 2 bars of psychrometer measurements (6).

Lowered plant water potential leads to partial or complete stomatal closure (11). Large increases in leaf resistance may be taken as indicative of almost complete stomatal closure (13). Reducing leaf turgor directly reduces stomatal opening since opening is turgor dependent. Drought induced stomatal closure causes a repartitioning of the incident energy resulting in increased canopy temperature (24).

The use of canopy temperature to detect water stress in plants is based upon the assumption that transpired water evaporates and cools the leaves below the temperature of the surrounding air. As water becomes limiting, transpiration is reduced and leaf temperature increases. The infrared thermometer is a noncontact method for estimating surface temperature. The temperature is an integrated value over the field of view of the sensor (14).

Leaf water potential, canopy-air temperature differential, and leaf diffusion resistance indicate water deficits to some degree. When the leaf water potential decreases, leaf diffusion resistance increases because of loss of turgor in the guard cells, and then canopy air temperature differential increases because of the reduction in transpiration (7, 11, 20). Of these plant measurements, leaf diffusion resistance has been found to be the least responsive and leaf water potential the most responsive. Canopy temperature and leaf diffusion resistance appear to be more dependent on climatic conditions at the time of measurement than leaf water potential (7).

The purpose of this study is to measure the plant water status of two crops and to evaluate the effectiveness of hydrophilic gel amended media on the postharvest quality of these crops. The use of hydrophilic gels may prove beneficial, as they have been reported to extend postharvest life in various studies (4, 10, 12, 21, 22, 23, 25). Their use results in less shrinkage in the marketing channel, especially in the mass-market retail outlets, because the plants do not wilt as rapidly as plants grown in media lacking hydrophilic gel (27).

Methods and Materials

The purpose of this study was:

a) to evaluate container style and size on the growth and development of bedding plants

b) to evaluate the use of hydrophilic gels and their rates in bedding plant production and postharvest quality

c) to simulate a stressful environment and evaluate the effectiveness of the hydrophilic gels in extending hours to wilt (shelf life)

I. Container Study - Direct Seeding

Three styles of containers of two sizes each were compared. Containers and their volumes were: seedling cavity trays (27 cm^3, 110 cm^3), styrofoam todd planter flats (25 cm^3, 75 cm^3), and square peat containers (50 cm^3, 105 cm^3). A uniform peat-vermiculite (1:1) soilless growing medium (Redi-EarthR) was used in all containers. Broccoli (Brassica oleracea Italica c.v. 'Green Duke') and calendula (Calendula officinalis c.v. 'Lemon') were seeded in thirty containers of each style and size (two seeds per container). A randomized complete block expermimental design with three replications was used. Research was conducted at the Kansas State University research greenhouses in Manhattan, Ks. Crops were seeded Oct. 29, 1982 and grown for six weeks in the greenhouse at 24°C day and 18°C night temperatures. Plants received fertilized irrigations of soluble 20-20-20 fertilizer with alternate waterings.

The following data were collected. Days to first emergence of the hypocotyl were recorded as they emerged. Plant height (mm) from the media surface to the top leaf was recorded weekly on twenty plants per experimental unit. Stem diameter (mm) taken between the third and fourth nodes, and leaf length (mm) and leaf width (mm) taken on a leaf at the fourth node, were measured on ten plants per experimental unit after six weeks. A visual rating of the overall appearance and marketability of the plants was made after 6 weeks using a rating scale of 1 = superior to 5 = undesirable. Ten plants were dried at 65°C for 24 hours and dry weights recorded for shoot and root portions. The roots were separated from the media by a flow of water through a breaker and then soaked in water to remove the remaining media from the roots.

II. Container Study - Direct Seeding and Transplants

On Dec. 20, 1982 and Jan. 21, 1983, an additional study evaluated these same containers using direct seeding and transplanted seedlings. Media, fertilization, and other growing procedures were identical to the first study. Seedlings were germinated in vermiculite (24°C) and transplanted into the containers two weeks after emergence. The same data were taken except root weight determinations. Roots grew into the peat containers making it impossible to separate the roots for evaluation.

III. Hydrophilic Gels - Type and Rate

On Feb. 6, 1983, 27 cm^3 and 110 cm^3 seedling cavity trays were filled with media containing Viterra (3.2 kg/m^3), an acrylic compound manufactured by Nepera Chemical Co., and Terra-Sorb (1.2 kg/m^3), a starch polymer, manufactured by Industrial Services International, Inc. Hydrophilic gels were incorporated dry into the soilless peat-vermiculite medium. Three rates of hydrophilic gels, 0.5, 1, 1.5 times the manufacturers'recommended rate (see above) were used. An additional treatment, media with no hydrophilic gel, was included for each container size. Broccoli (Brassica oleracea Italica c.v. 'Green Duke') was direct seeded on Feb. 6 and grown at 24°C day and 18°C night temperatures for five weeks. A randomized complete block experimental design with three replications was used. Plant height was recorded weekly. Stem diameter, leaf dimensions, and shoot dry weights were also recorded.

The plants were then thoroughly watered and placed in a growth chamber at 21.6°C. Lights were on 12 hours daily (8am to 8pm). Water was withheld and hours to wilting recorded. Wilting was determined when one half of the plants in a treatment were severely wilted and rendered marketably unacceptable.

Diffusion resistance (scm^{-1}), leaf temperature (°C), and quantum ($uEm^{-2}sec^{-1}$) were measured daily on three plants per experimental unit at 9 am using a Licor Li-1600 steady state porometer. Pressure bomb readings, using the technique described by Scholander (24), were used to determine the leaf water potential (bars) for each treatment. Canopy temperatures were recorded using an Everest model 110 infrared thermometer. Water retention curves were run on media treatments to determine water holding capacity and water availability of the media using a procedure described by Richards (5).

IV. Plant Quality Under Stress Conditions

Viterra 2 was incorporated into peat-vermiculite ($Redi\text{-}Earth_R$) medium at the manufacturers' recommended rate ($3.2\ kg/m^3$). The control consisted of media with no hydrophilic gel. Broccoli and calendula were direct seeded Apr. 24, 1983 into 27 cm^3 and 110 cm^3 seedling cavity trays. Plants were arranged in a randomized complete block design with three replications. Data collected included weekly plant heights, stem diameter, and leaf dimensions. In addition, leaf areas (sq. cent.) and leaf numbers were recorded using a Licor model 3100 leaf area meter.

At the end of five weeks, one group of plants were moved to an outdoor environment with conditions that tend to shorten the postharvest life of bedding plants. The remaining plants were kept in the greenhouse environment.

Water was withheld from one half of the plants (stressed), while the other half continued to receive water as needed (well-watered) in both locations.

Temperature (°C), relative humidity (%), and wind speed (mph) were monitored hourly from 7 am until 7 pm daily at both locations using hydrothermographs, sling psychrometer, and a hot wire anemometer, respectively. Canopy temperature was also recorded hourly using the infrared thermometer previously described. Diffusion resistance, leaf temperature, and quantum were measured on three plants per experimental unit at 9 am and 5 pm using a Licor Li-1600 steady state porometer. Leaf water potential was determined at 9 am and 5 pm on one plant per experimental unit for both crops. A PMS pressure bomb was used to determine the leaf water potential of broccoli. Due to the shape and size of the petiole of calendula, a Campbell's Scientific Model J14 leaf press was used to determine the leaf water potential. The leaf press recorded pressure in lbs/sq. in. Three readings were taken for each leaf sample:

a) when moisture was first observed at the edge of the leaf

b) when the leaf collapsed revealing a darker green color

c) when complete collapse occured resulting in a blackening of the leaf.

The readings were averaged according to the formula x = (a.b.c)1/3 and computed to atmospheres by the equation: MPa = 0.27 + 0.0155 · X .

The measurements described above were taken twice daily until the plants severely wilted at which time hours to wilt were recorded. Plants were then removed and shoot dry weights taken.

Results of all studies were analyzed using analysis of variance and means separated by Duncan's Multiple Range Test. A significance level of .05 was used to test hypotheses.

Results and Discussion

Study I. The influence of container style and size on broccoli plants - directly seeded. Since results of this study were identical to a subsequent study comparing direct seeded & transplanted broccoli, results of Study II are presented.

Study II. The influence of container style and size on broccoli plants -- direct seeded and transplanted.

There was little influence on germination rate or percentage in container styles or sizes tested. All seeds germinated within a day of each other approximately two days after planting. There was greater initial germination in seedling cavity trays after day 1, but by day 2 all treatments had germinated equally.

The height of broccoli direct seeded plants and transplants varied by container style and size. Heights of broccoli plants in the larger containers were significantly greater than those in the small volume containers. Height differences became significantly greater on week 4 through week 6. (Figure 1) Plants grown in the small containers exhibited etiolation, with elongated, spindly growth. Stem diameter and shoot dry weight were significantly greater in the large containers where plants were stocky with thick stems and large leaf surfaces. (Table 1 & 2)

If we compare both sizes tested in peat, seedling cavity, and speedling containers, seedling cavity plant heights were initially taller (wk 1 and wk 2). In the following weeks peat and seedling cavity's heights were similar until week five when peat heights exceeded seedling cavity's. Speedlings were shorter throughout. (Figure 2)

The above comparison included different sized containers for each style. If we compare each style and size, the following results were measured. The large peat containers (105 cm^3) resulted in greater plant heights, stem diameters, leaf dimensions, and shoot dry weights. Plants exhibited lush growth with the roots penetrating the moistened peat containers. The large volume seedling cavity tray (110 cm^3) and small volume peat container (50 cm^3) produced comparable plants with less plant height, stem diameter, leaf dimensions, and shoot dry weight. The small volume seedling cavity tray (27 cm^3) and large volume speedling flat (75 cm^3) produced smaller plants with the small volume speedlings (25 cm^3) producing the least amount of growth. The small volume seedling cavity tray and speedling flat produced small, spindly plants with small leaf surfaces and elongated stems. The same pattern of growth was observed for transplants except for the large volume peat container which exhibited poor growth throughout. (Table 2, Figure 3)

When comparing direct seeded and transplanted broccoli plants the following was observed. Heights of direct seeded plants exceeded transplants by approximately one weeks growth. This probably due to a set back in growth due to "transplanting shock". Overall, plant height, stem diameter, leaf dimensions, and shoot dry weights were greater for direct seeded plants. Shoot dry weights were 43% greater for direct seeded plants. (Table 3)

Calendula germinated slower than broccoli. By day 1 approximately 20% had germinated. Germination continued to occur until day 6 when germination was nearly complete. As with broccoli, seedling cavity trays germinated more rapidly initially than peat or speedling flats; however germination differences influenced by container style or size was not considered to be an important factor in influencing overall crop performance.

The height of calendula direct seeded and transplants varied by container style and size similar to broccoli. The large volume containers exceeded the small volume containers in plant height, stem diameter, leaf dimensions, and shoot dry weight. (Figure 4)

For container styles, peat exceeded seedling cavity and speedling flats in height, stem diameter, leaf dimensions and shoot dry weights. Speedling flats resulted in the least significant increases in all parameters measured. Seedling cavity trays resulted in intermediate values. (Figure 5)

In considering individual styles and sizes, the large peat container surpassed the other styles and sizes in plant heights, stem diameter, leaf dimension, and shoot dry weight. The large cavity and small peat containers produced quality plants with less growth. Large speedling flats were next to follow in all parameters measured. Small seedling cavity and "speedling" flats resulted in substantial reductions in height, stem diameter, leaf dimension, and shoot dry weights in comparison with the other containers. Similar results were observed with transplants. In all containers tested, the heights of the plants increased until week 4 when they reached a plateau and ceased to increase in height. They did increase in the number of whorls of foliage produced at the crown of the plant. (Table 4 & 5, Figure 6)

Direct seeded calendula performed better in all parameters measured than transplants. The differences were not as great as observed with broccoli. Although shoot dry weights of direct seeded plants did exceed transplants by approximately 36%. (Table 3)

From the results for both broccoli and calendula, it was observed that there is no advantage in transplanting seedlings for these particular crops.

It was also observed that peat containers (50 cm^3, 105 cm^3) and large volume seedling cavity trays (110 cm^3) produced quality plants with increased growth in all parameters measured. Plant quality appeared to decline for both crops as container volume declined. It is apparent from all parameters measured that soil volumes have a direct influence on plant growth and quality with reductions as volumes decrease. This is in agreement with Vandemark who concluded that the reduction in growth was due to limited amounts of nutrients and soil volumes for root and plant growth (29). The small volume containers allow for production of four times as many plants per unit area. It becomes a matter of sacrificing quality and growth for higher productivity and utilization of bench space.

Study III. The evaluation of hydrophilic gels and their rates.

In comparing high, medium and low rates of Viterra and Terra-Sorb there were some differences among treatments on germination rate and percentage of broccoli until day 4 when all treatments had germinated equally. Control and Viterra treatments had greater initial germination than Terra-Sorb treatments. On Day 1, control and Viterra treatments exceeded Terra-Sorb treatments in germination percentage by nearly 67% and day 2 by approximately 30%. By day 4 the control and Viterra treatments had approached 100% germination. Container size influenced germination percentage with the small volume containers exceeding the large volume containers up until day 4. However, in considering overall plant growth and development germination influences were considered to be a minor factor and data on germination are not presented.

The growth of broccoli plants was influenced by treatments and container size. The large volume seedling cavity trays (110 cm^3) exceeded the 27 cm^3 seedling cavity trays in plant heights, stem diameter, leaf dimensions, and shoot dry weights throughout the study. This was apparently due to the increased volume of soil and availability of nutrients for growth.

Comparison of both sizes tested in each treatment, reveal Viterra incorporated at the recommended rate (3.2 kg/m^3) to exceed the other treatments in plant heights, stem diameter, leaf dimensions, and shoot dry weights. The difference among the other rates compared was minimal. Terra-Sorb incorporated at the high rate did result in smaller plant heights and overall growth parameters measured. (Table 6)

In addition to evaluating the hydrophilic gels influence on growth parameters, the influence of these substances on the extension of shelf life (hours to wilt) was also examined. Various methods of indicating stress were used to determine apparent plant responses to drought and the hydrophilic gels effectiveness in prolonging shelf life.

The broccoli plants were placed in the growth chamber and monitored daily at 9 am. Canopy temperature, diffusion resistance, and plant water potential were measured at this time. Plants remained in the growth chamber until day 9 when all treatments had wilted and were determined marketably unacceptable. Viterra treatments appeared to have a slight advantage in extending postharvest quality when compared to Terra-Sorb treatments. Viterra treatments had lower canopy temperatures, lower diffusion resistance, and slightly higher plant water potentials. This data is not reported since results were identical to Study IV when indoor and outdoor marketplace conditions were used.

When comparing container size, the small volume containers began to exhibit signs of stress on day 3 as determined by visual wilting and parameters measured indicating stress. Day 4 control plants in the small volume containers were determined to be marketably unacceptable. The plants were extremely wilted and there was an increase in canopy temperature, diffusion resistance, and a decrease in plant water potential. Other treatments began to decline in quality showing similar increases in stress. All treatments in the small volume containers were determined to be marketably unacceptable by day 5 and large volume by day 9. Viterra incorporated at the medium and high rates extended shelf life by a few hours over other treatments. Again data is not reported since Study IV represents the differences observed under marketplace conditions. Since growth increases were the largest in Viterra at the medium rate this material and rate was used in the subsequent study to evaluate the hydrophilic gels influence on postharvest quality under marketplace conditions.

Study IV. The evaluation of Viterra at the recommended rate on extending postharvest quality in a marketplace environment.

On April 26, 1983, broccoli seed was sown in cavity seedling trays (27 cm^3, 110 cm^3) with Viterra amended (3.2 kg/m^3) media or media with no hydrogel. The germination percentage was slightly greater by day 2 with Viterra, but overall there was little difference in germination percentage or rate.

Various growth parameters were measured to determine the influence of Viterra on plant growth and postharvest quality. Plants in the large volume seedling cavity trays were taller than plants in the small volume containers as before. Viterra amended media did not differ significantly in plant heights or leaf dimensions but there was a trend for Viterra treatments to be slightly larger in growth. Stem diameters and leaf weights (fresh) were significantly greater for Viterra treatments. Overall we observed a slight increase in overall plant size due to Viterra as observed by all parameters considered collectively. (Table 7)

On May 27, treatments were begun. Stress treatments received their last irrigation and outdoor treatments were moved into the outdoor environment. The day was sunny and warm.

Diffusion resistance was one parameter measured to determine the degree of stress that the plants were undergoing. Indoors, diffusion resistance of plants in the small volume containers increased by the afternoon of day 1 and continued to increase the following morning when they were determined unmarketable. Diffusion resistance of plants in the large volume containers increased slightly day 1, stabilized that evening and then increased rapidly by the afternoon of day 2. Some recovery was reported day 3, but plants were determined unmarketable later that morning. (Figure 7)

Viterra lowered the diffusion resistance in comparison to the control stressed. Plants did not remain marketable past the morning of day 2 for the control stressed. By the afternoon of day 2 the diffusion resistance of Viterra stressed treatments had increased greatly and plants were no longer marketable. By watering, we were able to eliminate increases in diffusion resistance throughout the study. (Figure 8)

Canopy-air temperature differentials were a second parameter measured. The small volume containers had more positive canopy-air temperature differentials than the large volume containers throughout the study. By 9 am day 2, plants in the small volume containers became unmarketable, while plants in the large volume containers remained marketable through 12 pm day 3. (Figure 9)

On Day 1, control plants had higher canopy-air temperature differentials than both well watered and stressed Viterra treatments. Not until 5 pm day 2 did Viterra leaf temperatures of stressed treatments exceed control watered treatments. By day 3, both watered treatments were similar. The canopy-air temperature differentials of Viterra stressed plants remained lower than control stressed until 11 am day 3. (Figure 10)

Conditions were more stressful outdoors. Diffusion resistance increased rapidly by the afternoon of day 1 and decreased slightly by the morning of day 2, with little difference between container size. Plants in the small volume containers were quickly rendered unmarketable the morning of the second day. (Figure 11)

Watered and stressed plants showed increased diffusion resistance the afternoon of day 1. Stress resulted despite watering. The morning of day 2 the watered plants had recovered and had substantially lower diffusion resistance. On the other hand, the diffusion resistance of stressed plants continued to increase. Viterra stressed plants had lower diffusion resistance the afternoon of day 1 than both stressed and watered control treatments. But by the following day the diffusion resistance for the stressed Viterra and control plants had markedly increased. The diffusion resistance of watered treatments increased the afternoon of day 1 but was reduced the following day. (Figure 12)

Canopy-air temperature differentials outdoors were similar to results for indoor treatments. Small volume containers had higher canopy-air temperature differentials than the large volume containers. (Figure 13)

On Day 1, canopy-air temperature differentials of Viterra stressed and watered treatments were lower than both control treatments. The morning of day 2, the canopy-air temperature differential for all treatments was similar until 11 am. By the afternoon of day 2, the control stressed treatments had higher canopy temperatures than the other treatments. Viterra watered treatments showed the coolest canopy temperatures. (Figure 14)

Pressure bomb readings were the third parameter measured. Similar results were obtained for indoor and outdoor treatments, although outdoor treatments resulted in more rapid stress. Results related to diffusion resistance and canopy-air temperature differential in that the leaf water potentials of the large volume containers exceeded the small volume containers. (Figure 15 & 16) In the small containers both indoors and outdoors, Viterra treatments had higher leaf water potentials than control treatments by 5 pm day 1. Stressed treatments also had lower leaf water potentials than watered treatments. Control stressed plants had lower leaf water potentials by the morning of day 2 than other treatments. Viterra stressed plants had somewhat higher leaf water potentials. Watered treatments for both control and Viterra treatments were substantially higher than stressed treatments, but little difference was found among watered treatments. (Figure 17 & 19)

A similar trend was found with both the indoor and outdoor leaf water potentials of the large containers. (Figure 18 & 20)

From the data, small volume containers and control treatments showed earlier and more severe signs of stress than the large volume containers and Viterra treatments. Leaf water potentials, canopy-air temperature differentials, and leaf diffusion resistance indicated water stress. As stated earlier and confirmed in other studies, when leaf water potential decreases, leaf diffusion resistance increases because of loss of turgor in guard cells, resulting in increased canopy-air temperature differentials due to reduced transpiration (7, 11, 20). In addition to reduced stress resulting from the use of Viterra, hours to wilt were extended. Viterra treatments in the large volume containers increased hours to wilt by 8.3 and 6.4 hours indoors and outdoors, respectively. Increases of 2.6 and 1.6 hours for the small volume containers were also shown. (Table 8 & 9) These increases in shelf life and marketability must be weighed against the additional cost of Viterra amended media.

Calendula seed was sown April 24, 1983, in Viterra amended and non-amended media as with the broccoli. There was no difference in germination percentage or days to germination for either treatments. Calendula were grown for six weeks and heights were measured weekly. Plant heights of the large volume containers exceeded the small volume containers throughout the study. Viterra treatments were slightly greater than control treatments in all growth parameters, plant heights, stem diameter, leaf dimensions and fresh leaf and shoot weights. The results were similar to those reported with broccoli. (Table 7)

On June 4, water was withheld from stressed treatments and the outdoor treatments were moved into the outdoor environment. Diffusion resistance was monitored twice daily at 9 am and 5 pm. Indoors, diffusion resistance for the small volume containers rose rapidly the afternoon of day 1 and then leveled the following morning but rose again by afternoon when plants were determined to be unmarketable. Diffusion resistance of the large volume containers rose slightly but was significantly lower than the small volume containers until the morning of day 3. At this time the diffusion resistance rose rapidly and plants were no longer marketable. (Figure 21)

Viterra and control stressed treatments showed increased diffusion resistance by the afternoon of day 2, but Viterra treatments were slightly lower. By the morning of day 2, plants had recovered slightly but diffusion resistance increased that afternoon for both treatments.

The diffusion resistance of watered treatments remained significantly lower throughout the study. (Figure 22)

Canopy-air temperature differential was recorded hourly until plants were determined unmarketable. Day 1, all treatments were similar. From 8 am to 10 am of day 2, the small volume containers had significantly higher (more positive) canopy-air temperature differential than the large volume containers. At approximately 10 am extreme cloud cover moved in and then cleared by about 4 pm. From 4 pm until marketability declined, small volume containers had significantly higher canopy-air temperature differentials throughout the indoor study. (Figure 23)

Little difference was reported for canopy-air temperature differentials between Viterra and control treatments. Canopy-air temperature differentials of stressed treatments were similar to watered treatments until on the afternoon of day 3 when stressed treatments had higher canopy temperatures than watered treatments. Day 1 and 2 canopy-air temperature differentials for all treatments were similar. At 1 pm day 3, control stressed treatments increased rapidly above the other treatments. The Viterra stressed had lower canopy-air temperature differentials until 5 pm. The watered treatments continued to have cooler leaf temperatures than stressed treatments. (Figure 24)

Outdoor treatment results were similar to indoor results but more pronounced as was true in the study on broccoli. The diffusion resistance of plants in small volume containers rapidly increased and marketability declined by the afternoon of day 1. The large volume containers showed a gradual increase in diffusion resistance until the afternoon of day 2 when they were determined unmarketable. (Figure 25)

The diffusion resistance of control stressed treatments rapidly increased on day 2. The Viterra stressed treatments did not increase drastically until the morning of day 3. The watered treatments of both Viterra and control had reduced diffusion resistance throughout the study. (Figure 26)

Canopy-air temperature differentials of the outdoor treatments were similar, to results reported with broccoli. The small volume containers had significantly higher temperature differentials than large volume containers. Small volume containers were determined unmarketable by 5 pm day 1. (Figure 27)

Canopy-air temperature differentials showed little difference among treatments day 1 and 2. Day 3, the canopy-air temperature differential of control stressed treatments was slightly greater than the other treatments. These plants were determined unmarketable by 9 am day 3. The Viterra stressed treatments increased rapidly at 11 am day 3 and continued to have higher canopy-air temperature differentials until determined unmarketable at 5 pm. The watered treatments once again had the lowest temperature differentials with control watered treatments slightly greater than Viterra. (Figure 28)

A leaf press was used to determine the leaf water potential of the treatments. Indoors the large volume containers were significantly greater than the small volume containers. The watered treatments had higher leaf water potentials throughout the study, with little difference between control and Viterra treatments. Overall leaf water potential for calendula followed similar patterns as observed on broccoli plants, therefore only canopy-air temperature differential and diffusion resistance data are presented for calendula.

Indoors and outdoors, control stressed plants, especially those in the small volume containers, showed signs of stress somewhat earlier than Viterra treatments. This was apparent from the increased diffusion resistance, increased leaf-air temperature differentials, and reduced leaf water potential of the control treatments.

Indoors Viterra media extended hours to wilt 2.4 and 8.0 hours for the large and small volume containers, respectively. Outdoors, increases of 12.6 and 6.7 hours for large and small volume containers were recorded. (Table 10 & 11)

Summary

In studies with broccoli and calendula, plant growth and quality was shown to be greatly influenced by container style and size. As the volume of soil for root development increases so does plant growth. This is in agreement with Vandemark, Knavel, and Martin (16, 19, 29). Martin found that with increasing pot size, size and quality of plants increased. Plants grown in the smallest pots were inferior in quality due to crowding and or insufficient nutrient supply (19). Similar results were found in the container studies with broccoli and calendula. Peat containers and large volume seedling cavity trays produced quality plants with greater plant heights, stem diameters, leaf dimensions, and shoot and dry weights. Plant quality declined for both crops as container volume decreased.

Hydrophilic gel amendments, Viterra and Terra-Sorb, were found to increase plant growth slightly and to extend shelf life by as much as eight hours over controls. These substances reduced moisture stress and aided in maintaining postharvest quality. Viterra at the manufacturers' recommended rate appeared most effective in increasing plant growth and extending postharvest quality. Leaf water potentials were higher, leaf diffusion resistance lower, and canopy-air temperature differentials less negative for Viterra amended treatments. Bearce and McCollum, Conover and Poole, and Gehring and Lewis, have reported similar findings (4, 8,9, 12). Hydrophilic gels may have a place in large commercial mass market channels but due to the additional expense of the substances, it is doubtful whether they will ever gain acceptance by small growers and grounds maintenance managers.

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FIGURE 1. Broccoli height as influenced by container size

*Differences significant at .05 level

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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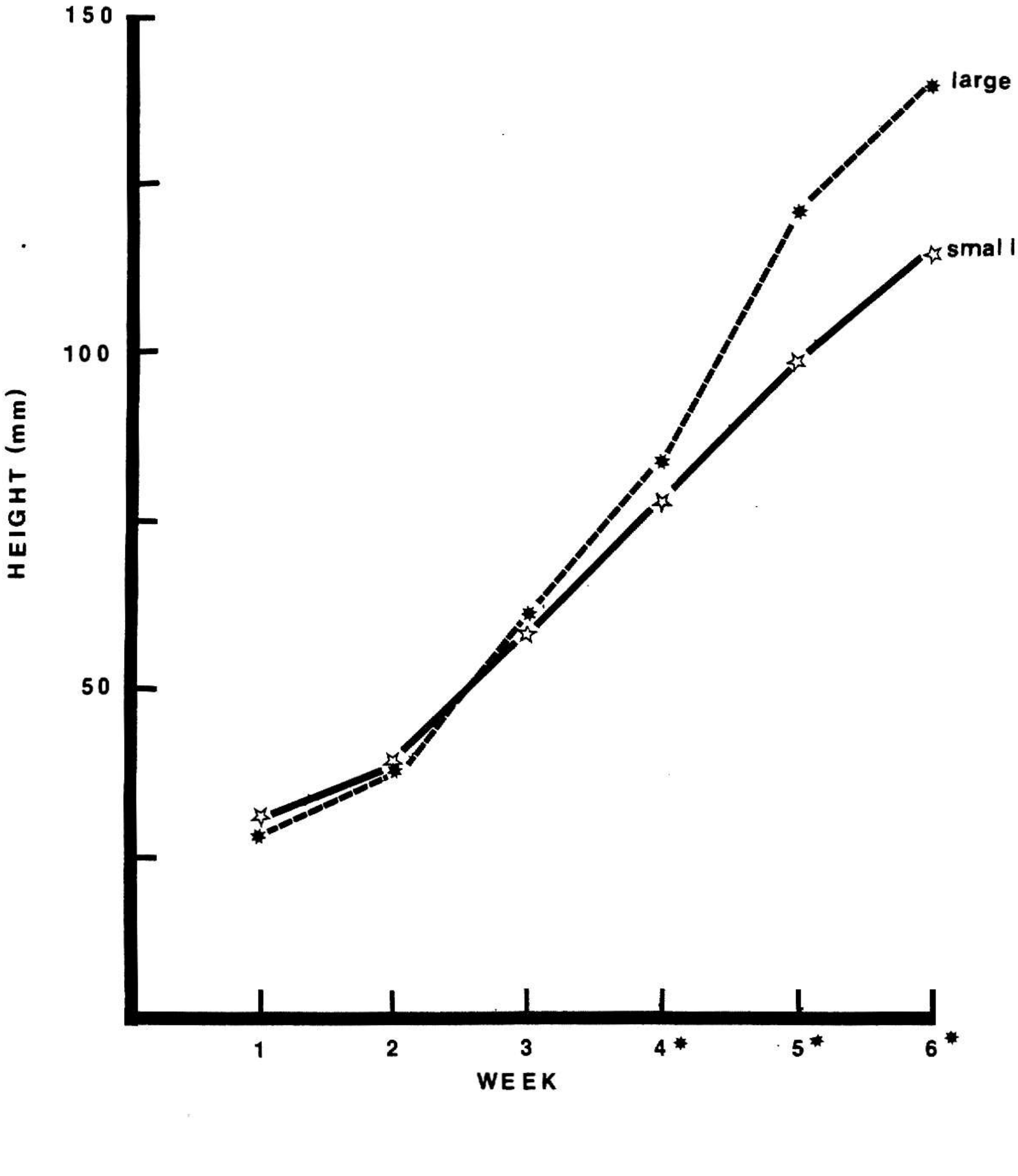
150
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50
HEIGHT (mm)
large
small
1
2
3
4 *
5 *
6 *
WEEK

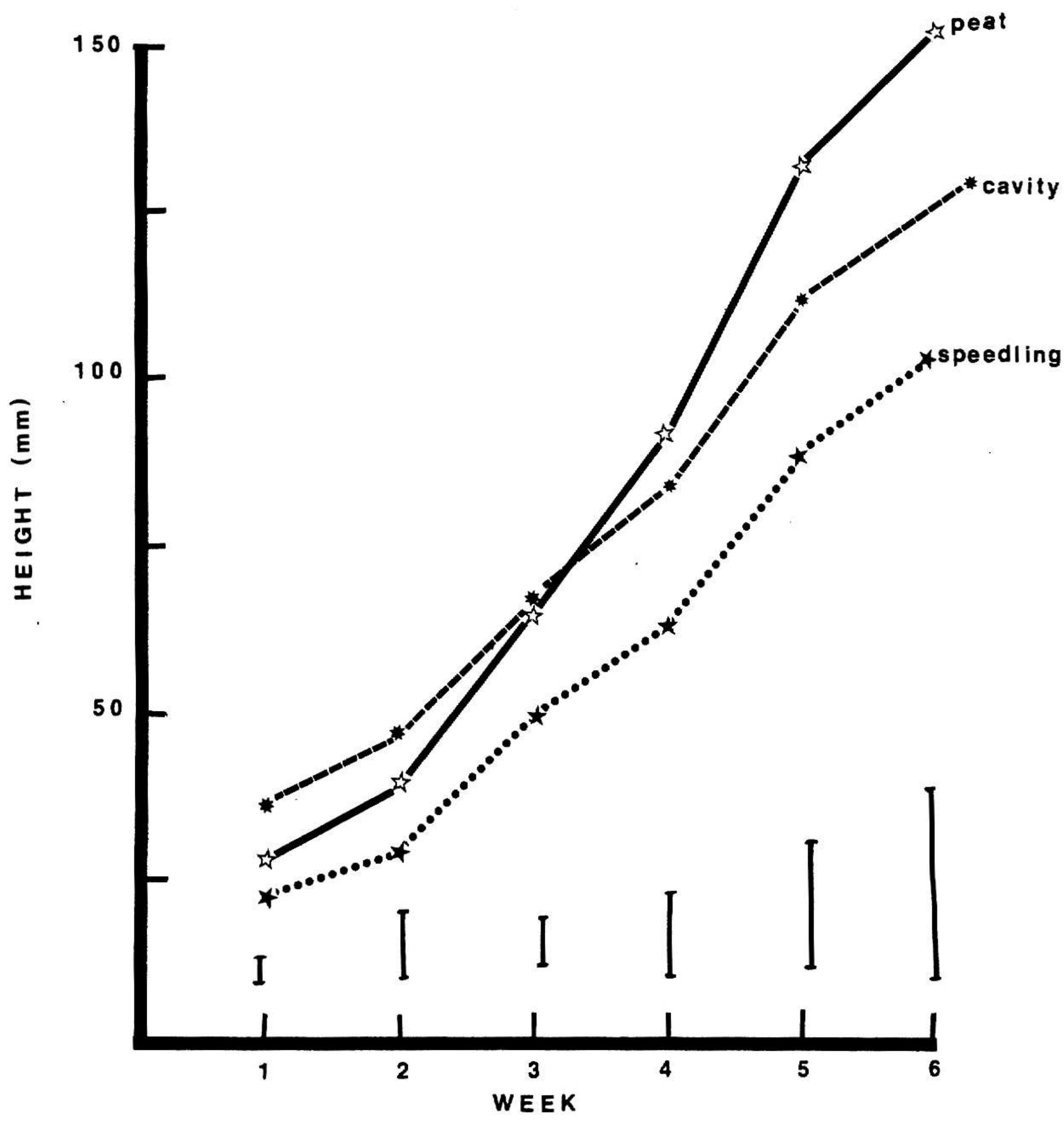
TABLE 1 & 2. Container style and size influence on broccoli plant growth - direct seeded and transplants

	Small Containers				Large Containers				Mean			
	Leaf Dim. (mm) Width	Leaf Dim. (mm) Length	Stem Diam (mm)	Shoot Dry Wt.(g)	Leaf Dim. (mm) Width	Leaf Dim. (mm) Length	Stem Diam (mm)	Shoot Dry Wt.(g)	Leaf Dim. (mm) Width	Leaf Dim. (mm) Length	Stem Diam (mm)	Shoot Dry Wt.(g)
Direct Seeded												
Peat	58.0 b	68.2 b	4.7 b	5.4 b	72.3 a	86.0 a	5.9 a	9.5 a	65.2 a	77.1 a	5.3 a	7.4 a
Cavity	36.4 e	42.8 d	3.0 d	2.3 d	56.1 c	67.2 b	4.7 b	5.7 b	46.3 b	55.0 b	3.8 b	3.9 b
Speedling	32.2 f	38.0 e	2.9 d	1.9 d	51.2 d	58.8 c	4.0 c	4.1 c	41.7 c	48.4 c	3.5 c	2.9 c
	42.2	49.7	3.5	3.2	59.9*	70.7*	4.9*	6.4*				
Transplants												
Peat	60.6 a	69.5 a	4.3 a	4.0 a	38.2 c	43.9 c	2.6 b	1.3 c	49.4 a	56.7 a	3.4	2.6 ab
Cavity	37.9 c	43.4 c	2.9 b	1.6 c	58.9 a	65.5 a	4.2 a	4.1 a	48.4 a	54.5 a	3.5	2.9 a
Speedling	34.2 d	40.4 c	2.8 b	1.6 c	49.2 b	55.8 b	4.0 a	3.7 b	41.7 b	48.1 b	3.4	2.6 b
	44.2	51.1	3.3	2.4	48.8*	55.1*	3.6*	3.0*				

(means sharing common letters not significantly different at 5% level or for two mean comparisons
*indicates significance)

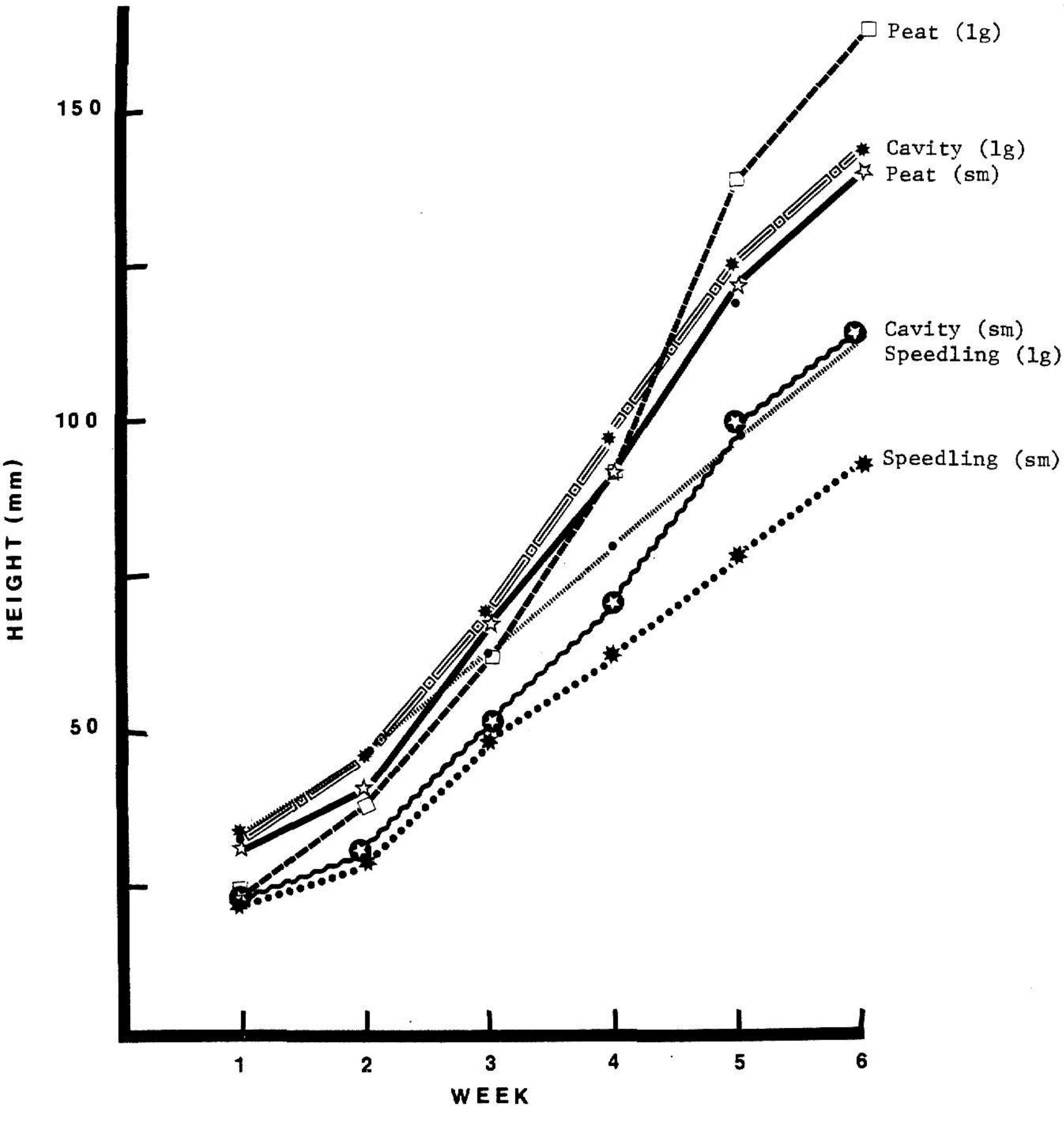
FIGURE 2. Broccoli height as influenced by container style

Length of bar equals standard error



peat
cavity
speedling
150
100
50
HEIGHT (mm)
1
2
3
4
5
6
WEEK

FIGURE 3. Broccoli height as influenced by container style and size



Peat (lg)
Cavity (lg)
Peat (sm)
Cavity (sm)
Speedling (lg)
Speedling (sm)
150
100
50
HEIGHT (mm)
1
2
3
4
5
6
WEEK

TABLE 3. Comparison of direct seeded with transplanted plants

Broccoli Seedlings

	Height (mm)	Leaf Dim. (mm) Width	Length	Stem Diam (mm)	Shoot Dry Wt. (g)
Peat - Direct	151.2	65.2	77.1	5.3	7.4
Transplant	93.6	49.4	56.7	3.4	2.6
Cavity - Direct	128.1	46.3	55.0	3.8	3.9
Transplant	118.8	48.4	54.5	3.5	2.9
Speedling - Direct	102.3	41.7	48.4	3.5	2.9
Transplant	99.9	41.7	48.1	3.4	2.6
Mean - Direct	127.2	51.1	60.2	4.2	4.7
Transplant	104.1	46.5	53.1	3.4	2.7

Calendula Seedlings

	Height (mm)	Leaf Dim. (mm) Width	Length	Stem Diam (mm)	Shoot Dry Wt. (g)
Peat - Direct	143.1	123.6	34.5	9.7	7.7
Transplant	129.7	118.4	27.6	7.6	3.8
Cavity - Direct	109.2	92.4	24.2	6.3	3.5
Transplant	103.0	91.5	22.2	5.8	2.6
Speedling - Direct	86.6	79.2	19.7	5.5	2.1
Transplant	88.6	80.3	19.8	5.2	2.0
Mean - Direct	112.9	98.4	26.1	7.2	4.4
Transplant	107.1	96.7	23.2	6.2	2.8

FIGURE 4. Calendula height as influenced by container size

*Differences significant at .05 level

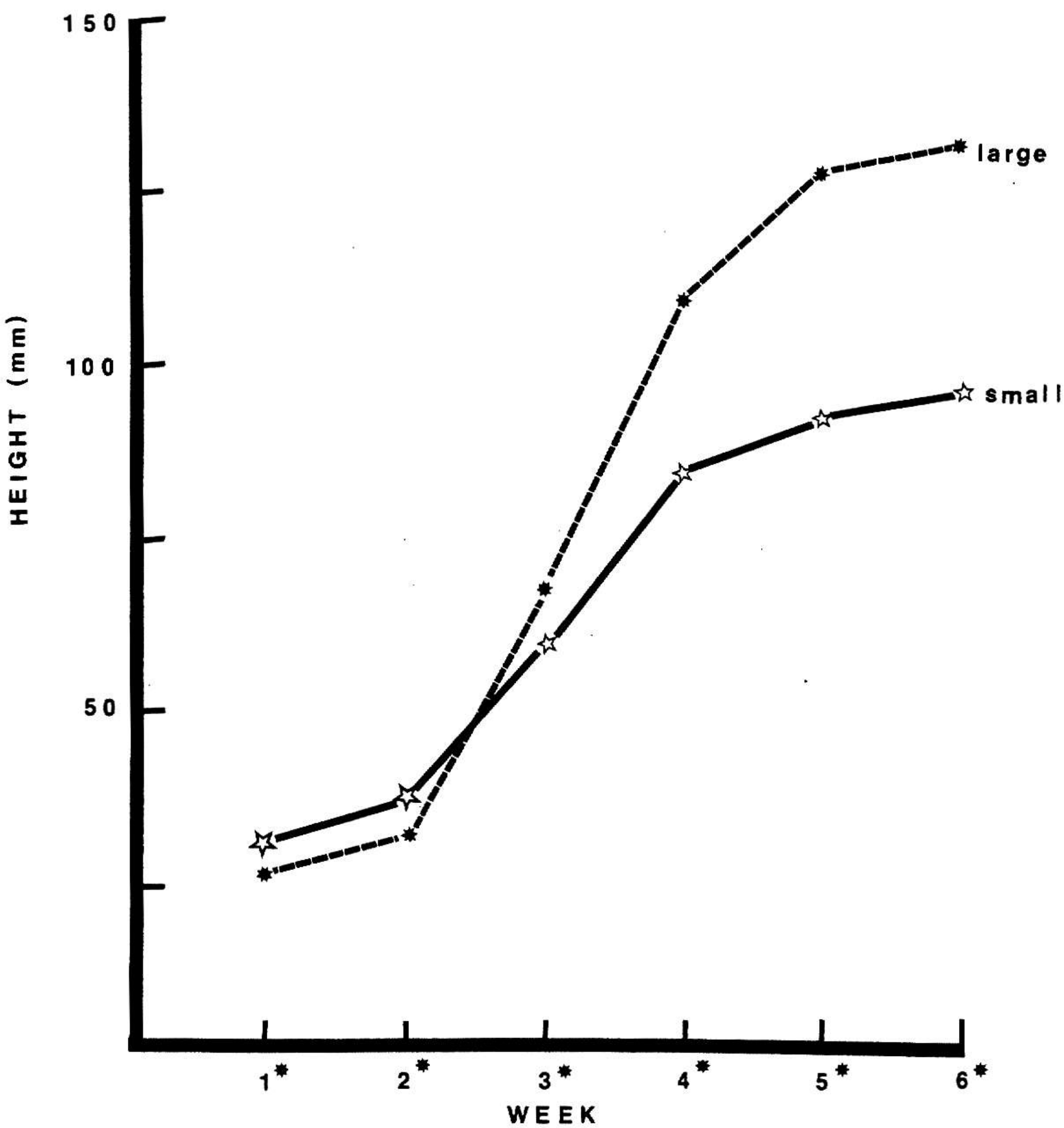

150
100
50
HEIGHT (mm)
large
small
1*
2*
3*
4*
5*
6*
WEEK

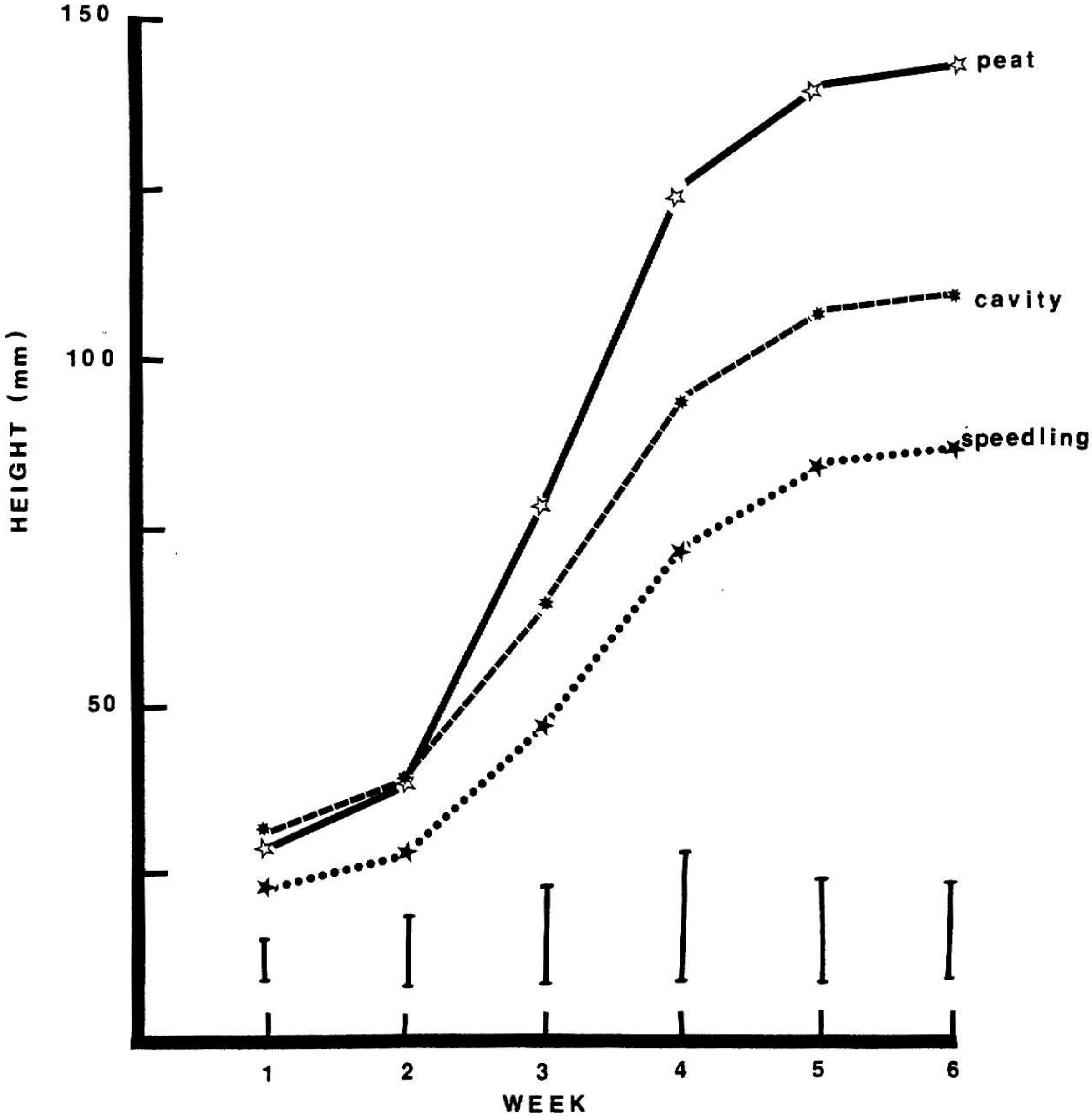
TABLE 4 & 5. Container style and size influence on calendula plant growth - direct seeded and transplants

	Small Containers				Large Containers				Mean			
	Leaf Dim. (mm) Width	Leaf Dim. (mm) Length	Stem Diam (mm)	Shoot Dry Wt.(g)	Leaf Dim. (mm) Width	Leaf Dim. (mm) Length	Stem Diam (mm)	Shoot Dry Wt.(g)	Leaf Dim. (mm) Width	Leaf Dim. (mm) Length	Stem Diam (mm)	Shoot Dry Wt.(g)
Direct Seeded												
Peat	30.4 b	110.9 b	7.6 b	5.2 b	38.6 a	136.3 a	11.7 a	10.2 a	34.5 a	123.6 a	9.7 a	7.7 a
Cavity	17.5 d	68.0 c	4.2 c	1.5 c	30.9 b	116.7 b	8.3 ab	5.4 b	24.2 b	92.4 b	6.3 b	3.5 b
Speedling	15.6 d	62.4 c	3.9 c	1.3 c	23.9 c	96.1 bc	7.1 b	2.9 c	19.7 c	79.2 c	5.5 c	2.1 c
	21.2	80.4	5.2	2.3	31.1*	116.4*	9.0*	6.2*				
Transplants												
Peat	23.8 c	109.7 c	6.8 c	3.2 b	31.4 a	127.1 a	8.5 a	4.5 a	27.6 a	118.4 a	7.6 a	3.8 a
Cavity	16.2 d	69.1 e	4.0 d	1.3 d	28.1 b	113.8 b	7.4 b	4.0 a	22.2 b	91.5 b	5.8 b	2.6 b
Speedling	14.6 e	63.8 f	3.7 e	1.0 d	24.9 c	96.9 d	6.7 c	2.9 c	19.8 c	80.3 c	5.2 c	2.0 c
	18.2	80.9	4.8	1.8	28.1*	112.6*	7.6*	3.8*				

(means sharing common letters not significantly different at 5% level or for two mean comparisons
* indicates significance)

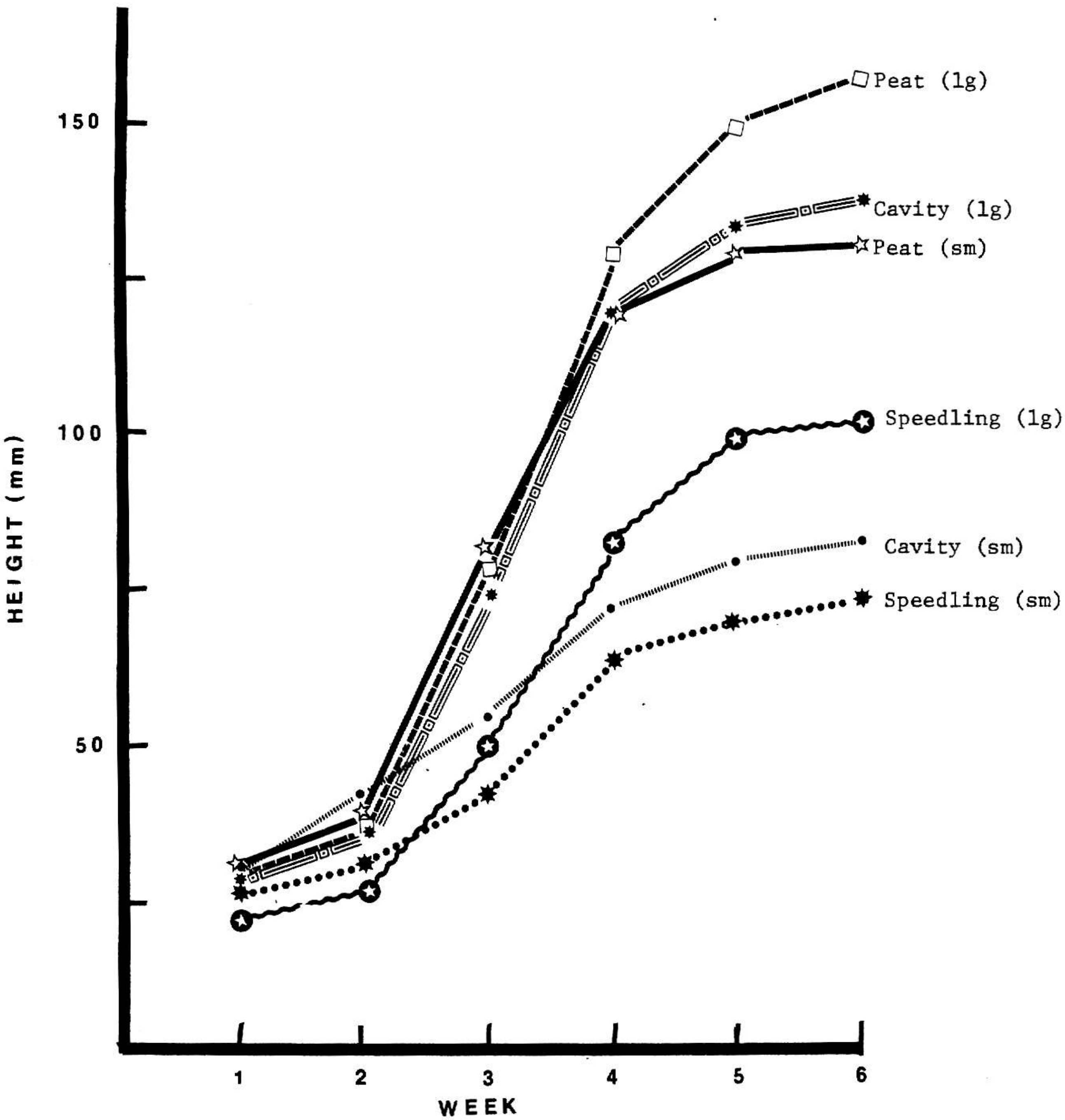
FIGURE 5. Calendula height as influenced by container style

*Length of bar equals standard error



150
100
50
HEIGHT (mm)
peat
cavity
speedling
1
2
3
4
5
6
WEEK

FIGURE 6. Calendula height as influenced by container size and style



Peat (lg)
Cavity (lg)
Peat (sm)
Speedling (lg)
Cavity (sm)
Speedling (sm)
150
100
50
HEIGHT (mm)
1
2
3
4
5
6
WEEK

TABLE 6. Broccoli plant growth (direct seeded)

	Plant Height (mm)	Stem Diam (mm)	Leaf Dim. (mm) Width	Length	Shoot Dry Wt. (g)
Control	102.2 ab	2.6 b	42.5 b	38.0 b	2.5 ab
VITERRA					
High	101.4 ab	2.8 b	43.2 ab	37.4 b	2.8 ab
Medium	108.1 a	3.2 a	47.9 a	43.1 a	3.4 a
Low	99.4 ab	2.6 b	41.2 b	36.8 b	2.5 ab
TERRA-SORB					
High	93.6 b	2.6 b	40.6 b	36.1 b	2.3 b
Medium	101.9 ab	2.8 b	43.2 ab	38.7 b	2.6 ab
Low	100.4 ab	2.6 b	42.1 b	37.3 b	2.6 ab

(means sharing common letters not significantly different at 5% level)

TABLE 7. Plant growth parameters

Broccoli

	Plant Height (mm)	Stem Diam (mm)	Leaf Dim. (mm) Width	Leaf Dim. (mm) Length	Leaf Area	Leaf Wt (g)	Shoot Wt (g)
Viterra	157.4	4.5*	59.5	66.3	107.5*	8.8*	7.0
Control	155.6	4.3	58.1	64.5	99.9	7.5	6.2

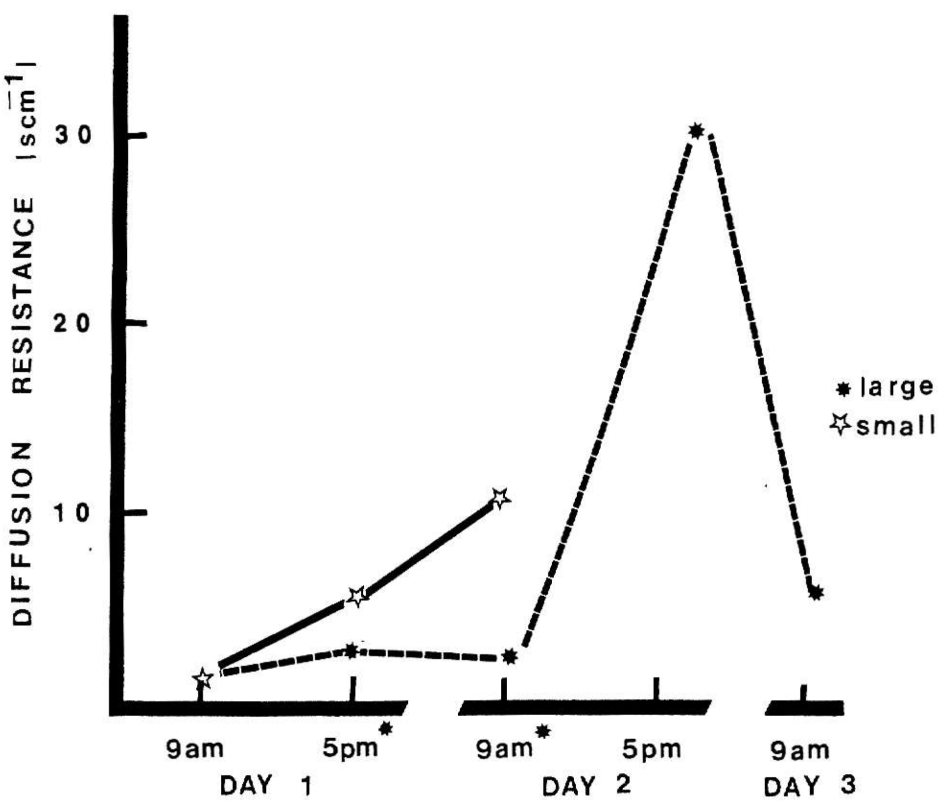
Calendula

	Plant Height (mm)	Stem Diam (mm)	Leaf Dim. (mm) Width	Leaf Dim. (mm) Length	Leaf Area	Leaf Wt (g)	Shoot Wt (g)
Viterra	147.0	7.8	33.2	124.9*	148.5*	17.4	5.3
Control	138.3	7.4	33.2	118.4	128.8	15.1	4.7

*Differences significant at .05 level

FIGURE 7. Diffusion resistance of broccoli plants as influenced by container size indoors

*Differences significant at .05 level

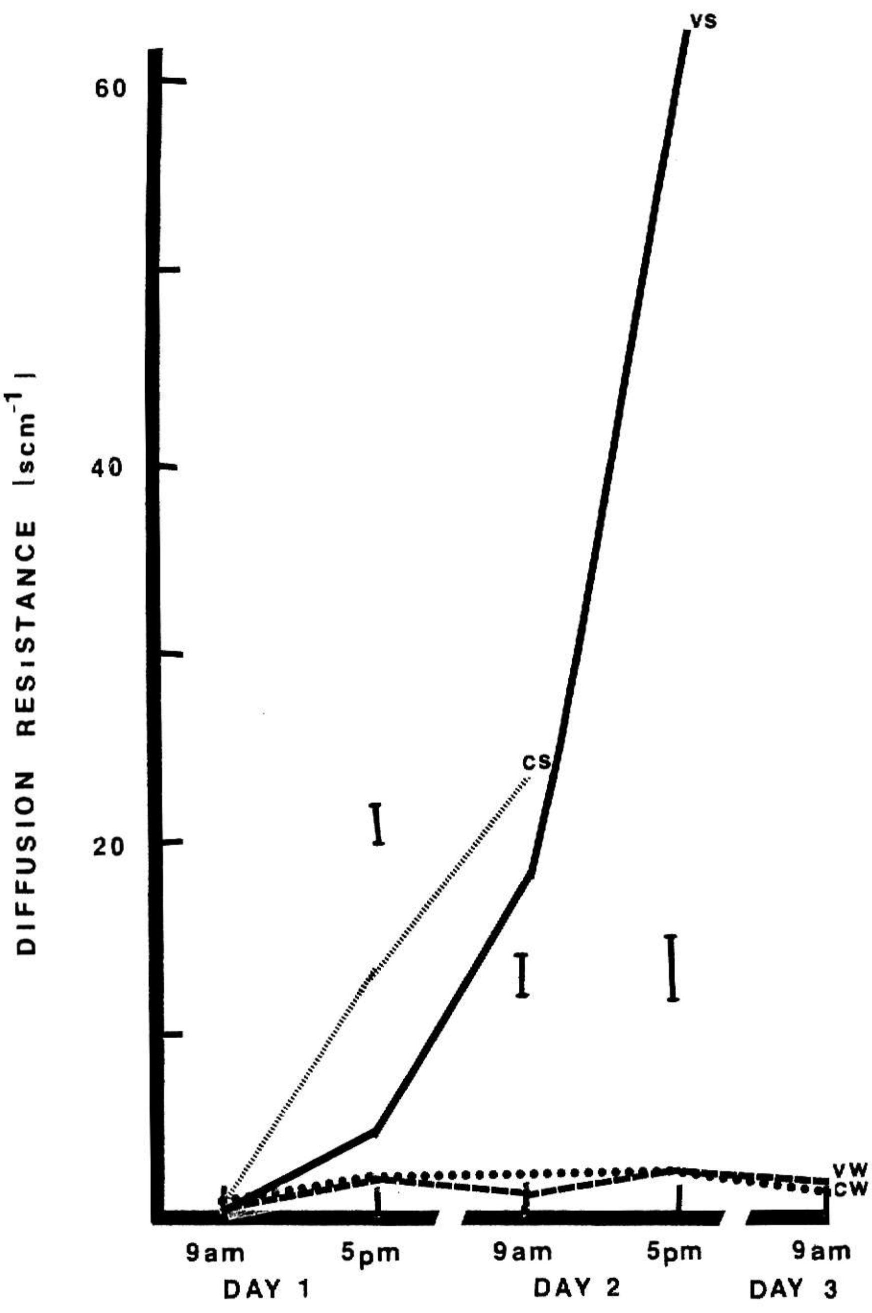


DIFFUSION RESISTANCE (scm⁻¹)
30
20
10
large
small
9am
5pm
9am
5pm
9am
DAY 1
DAY 2
DAY 3

FIGURE 8. Diffusion resistance of broccoli plants indoors

cs = control stress   vs = Viterra stress
cw = control watered   vw = Viterra watered

*Length of bar equals standard error



DIFFUSION RESISTANCE (scm^{-1})
60
40
20
VS
CS
VW
CW
9am
5pm
9am
5pm
9am
DAY 1
DAY 2
DAY 3

FIGURE 9. Temperature differential of broccoli plants as influenced by container size indoors

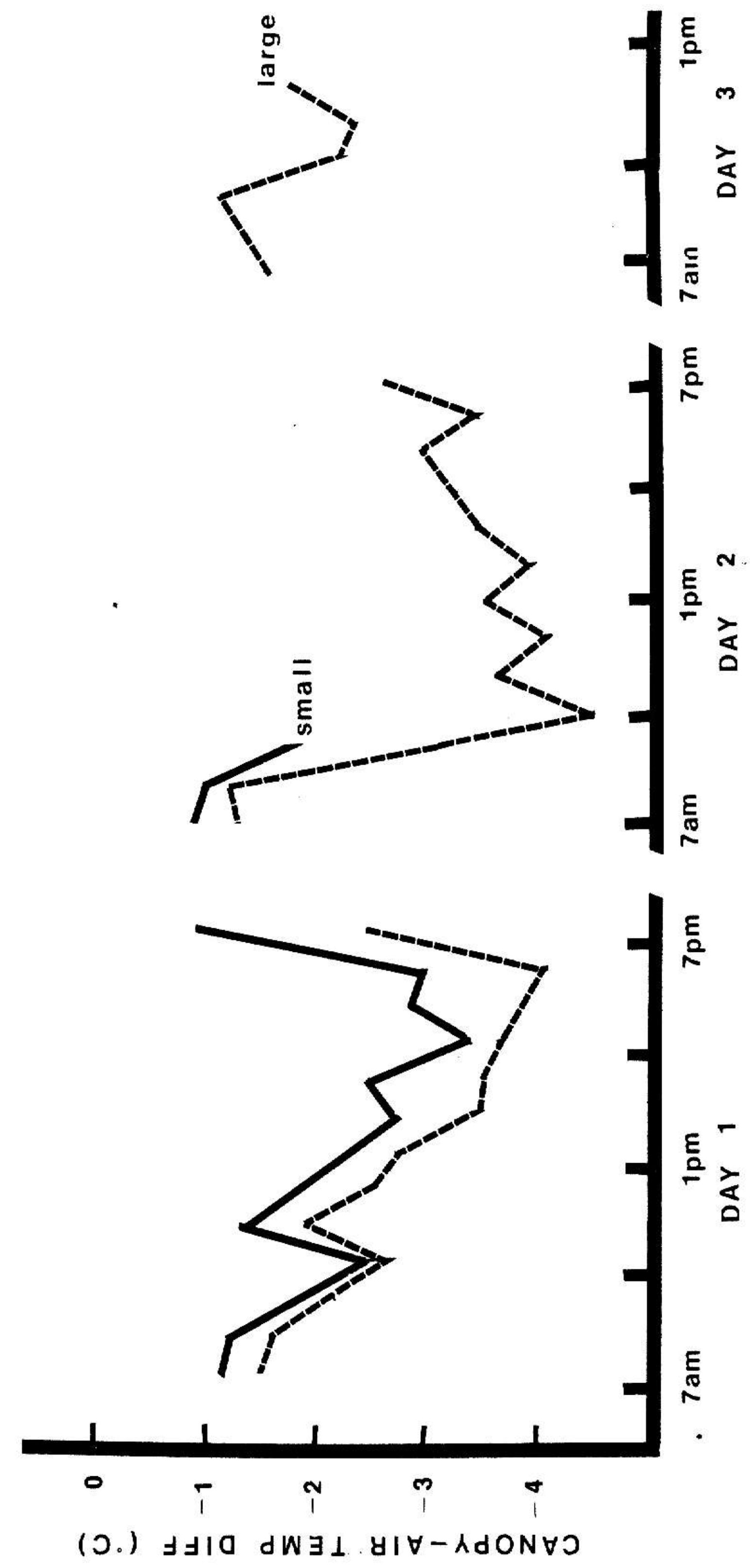

CANOPY-AIR TEMP DIFF (°C)
0
-1
-2
-3
-4
7am
1pm
7pm
DAY 1
7am
1pm
7pm
DAY 2
7am
1pm
DAY 3
small
large

FIGURE 10. Temperature differential of broccoli plants indoors

cs = control stress   vs = Viterra stress
cw = control watered   vw = Viterra watered

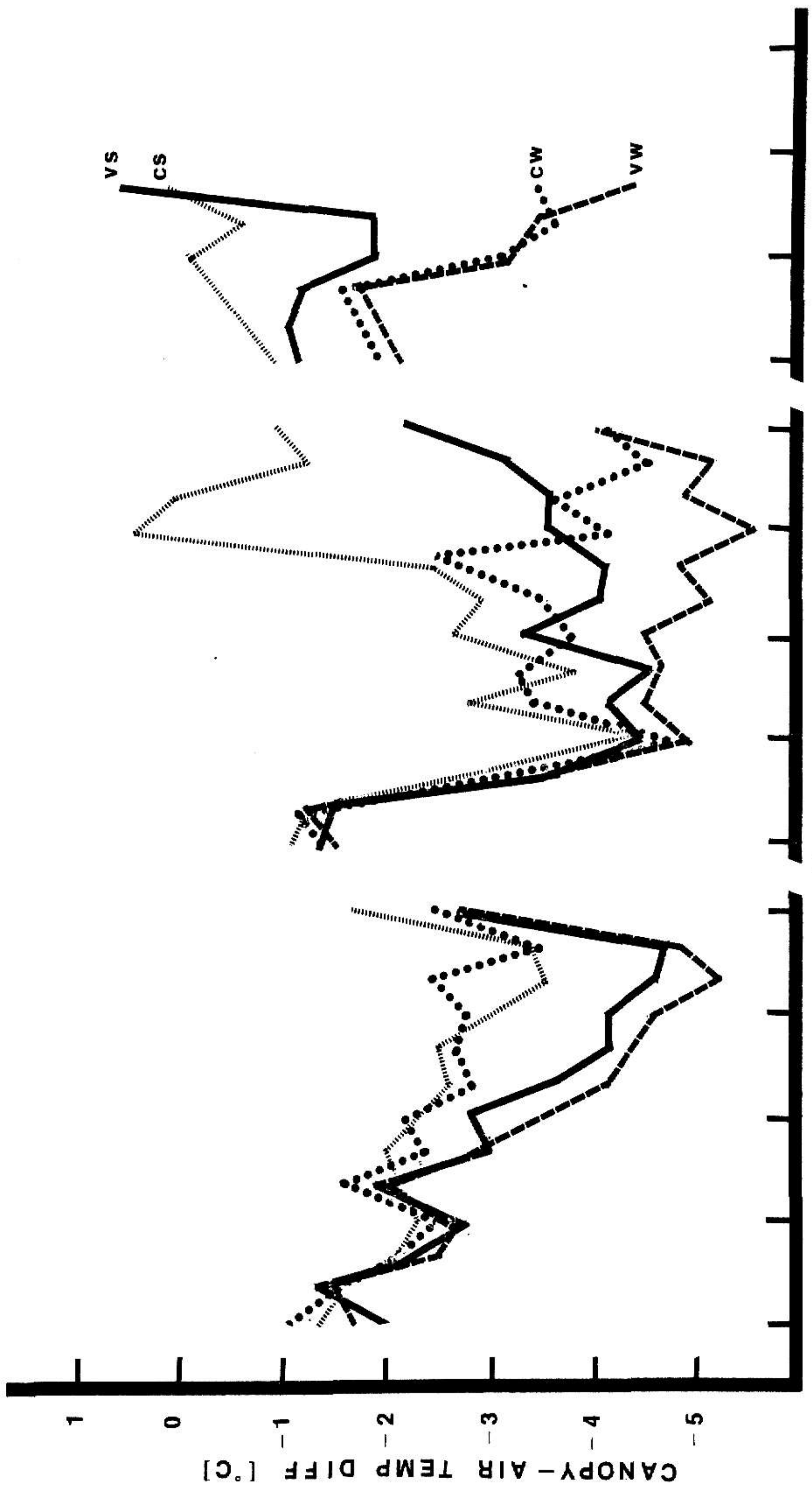
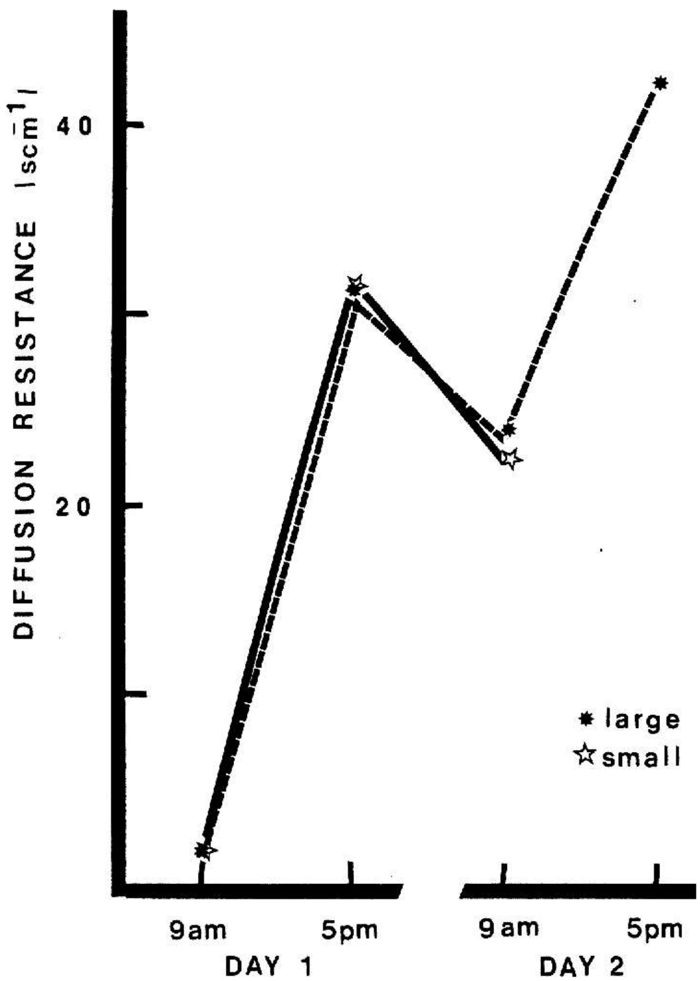

CANOPY — AIR TEMP DIFF [°C]
1
0
−1
−2
−3
−4
−5
7am
1pm
DAY 1
7pm
7am
1pm
DAY 2
7pm
7am
1pm
DAY 3
VS
CS
CW
VW

FIGURE 11. Diffusion resistance of broccoli plants as influenced by container size outdoors

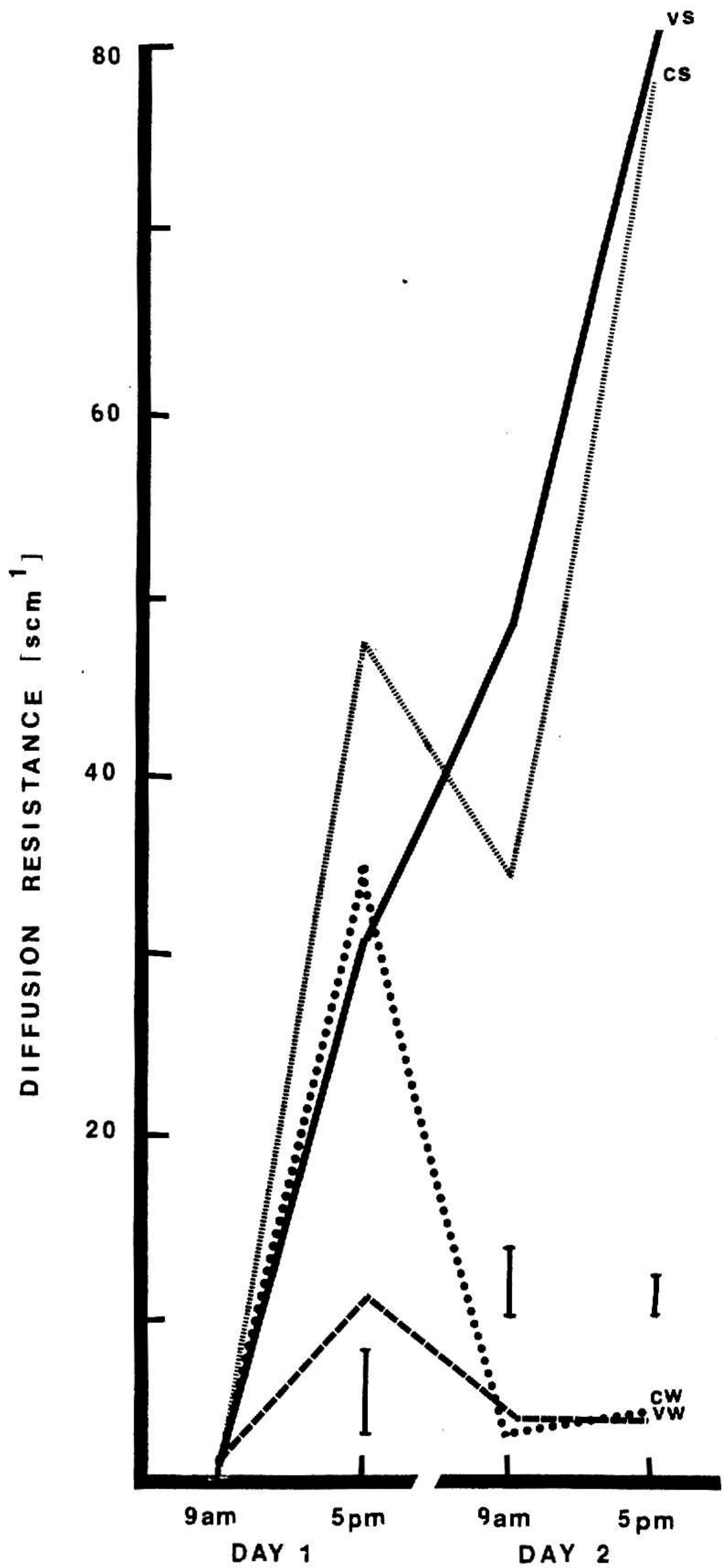


DIFFUSION RESISTANCE (s cm^{-1})
40
20
large
small
9am
5pm
DAY 1
9 am
5pm
DAY 2

FIGURE 12. Diffusion resistance of broccoli plants outdoors

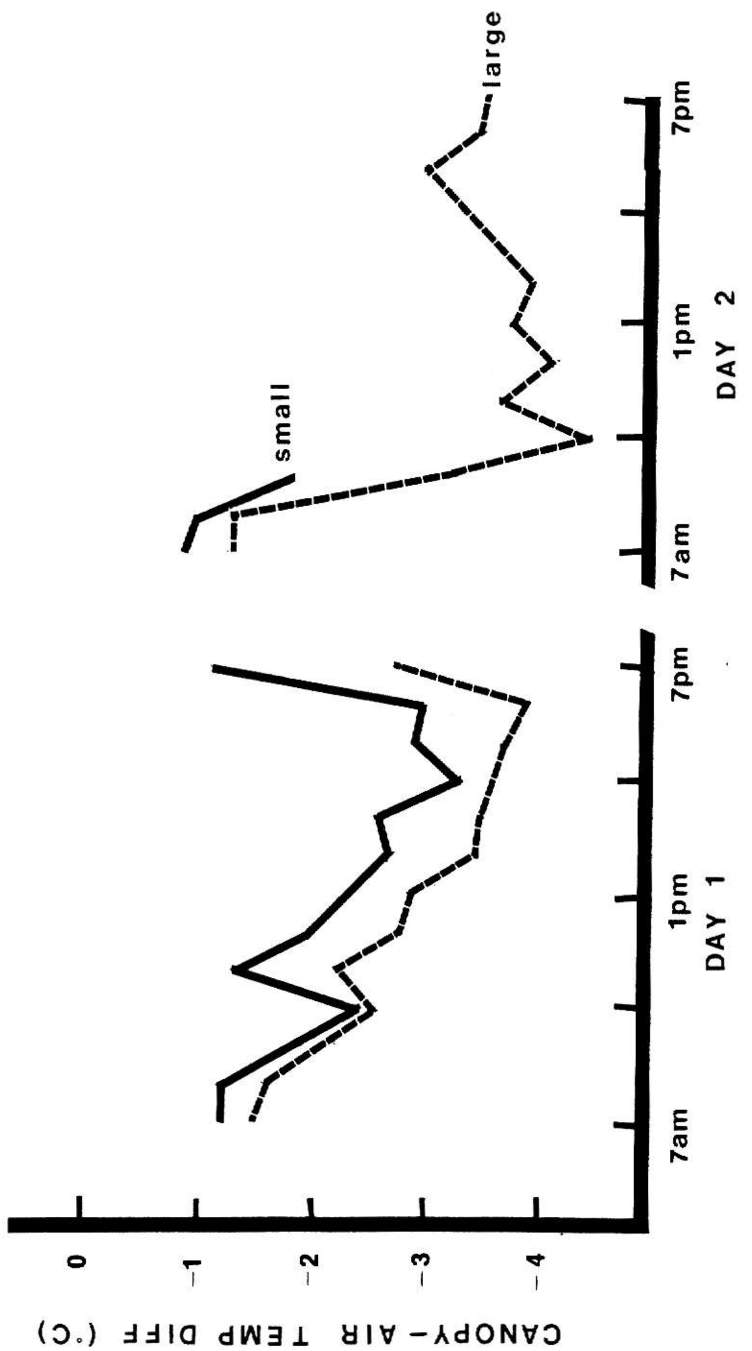
cs = control stress   vs = Viterra stress
cw = control watered   vw = Viterra watered

*Length of bar equals standard error



80
60
40
20
DIFFUSION RESISTANCE [scm⁻¹]
VS
CS
CW
VW
9am
5pm
9am
5pm
DAY 1
DAY 2

FIGURE 13. Temperature differential of broccoli plants as influenced by container size outdoors



CANOPY-AIR TEMP DIFF (°C)
0
-1
-2
-3
-4
7am
1pm
7pm
DAY 1
7am
1pm
7pm
DAY 2
small
large

FIGURE 14. Temperature differential of broccoli plants outdoors

cs = control stress vs = Viterra stress
cw = control watered vw = Viterra watered

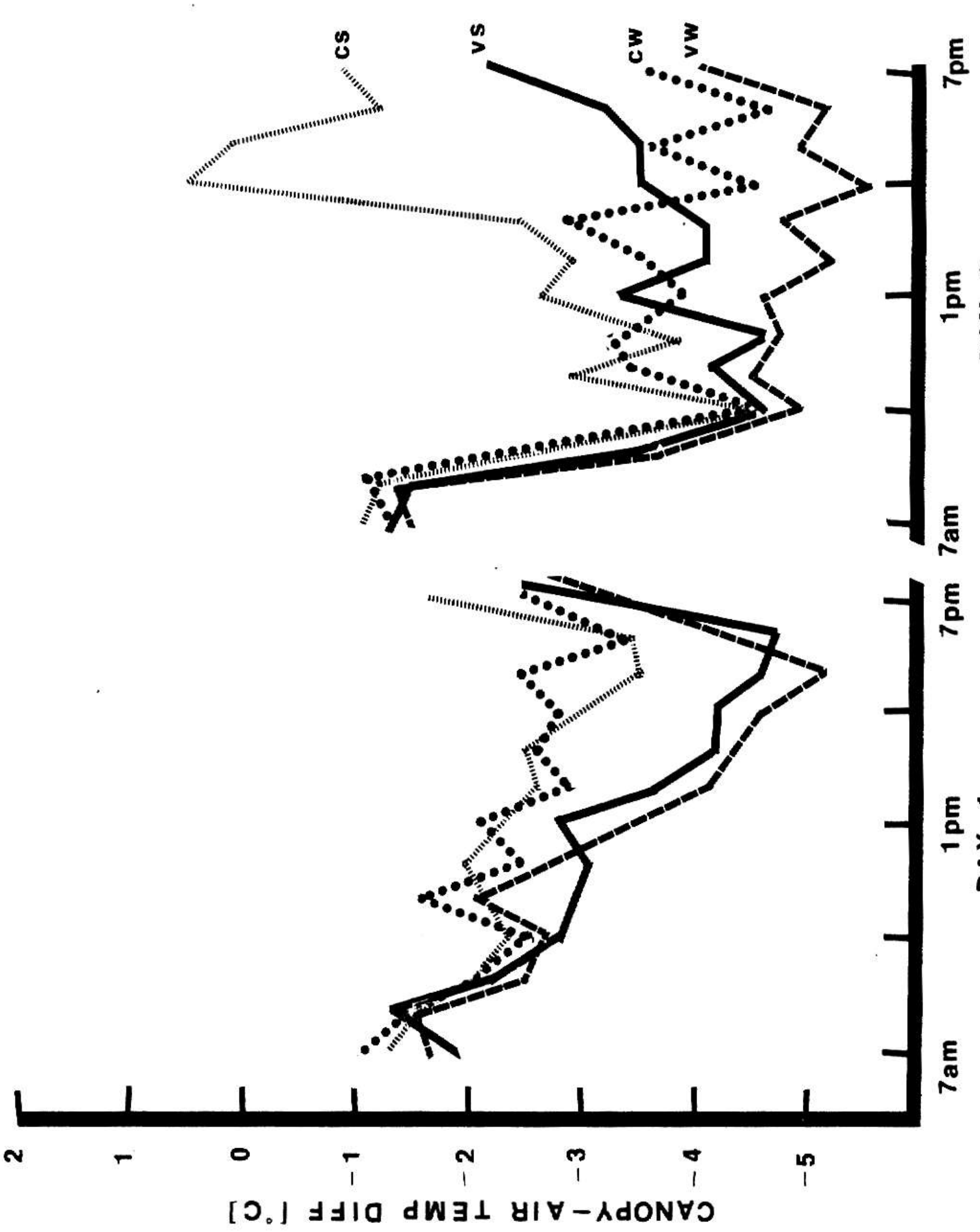
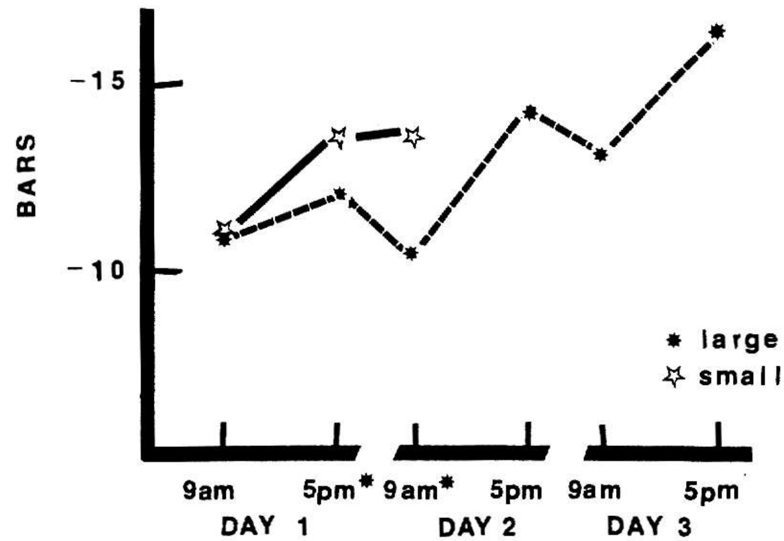

CANOPY-AIR TEMP DIFF [°C]
2
1
0
-1
-2
-3
-4
-5
7am
1pm
7pm
DAY 1
7am
1pm
7pm
DAY 2
CS
VS
CW
VW

FIGURE 15. Pressure bomb readings of broccoli plants as influenced by container size indoors

*Differences significant at .05 level

FIGURE 16. Pressure bomb readings of broccoli plants as influenced by container size outdoors

*Differences significant at .05 level


-15
-10
BARS
large
small
9am
5pm*
9am*
5pm
9am
5pm
DAY 1
DAY 2
DAY 3

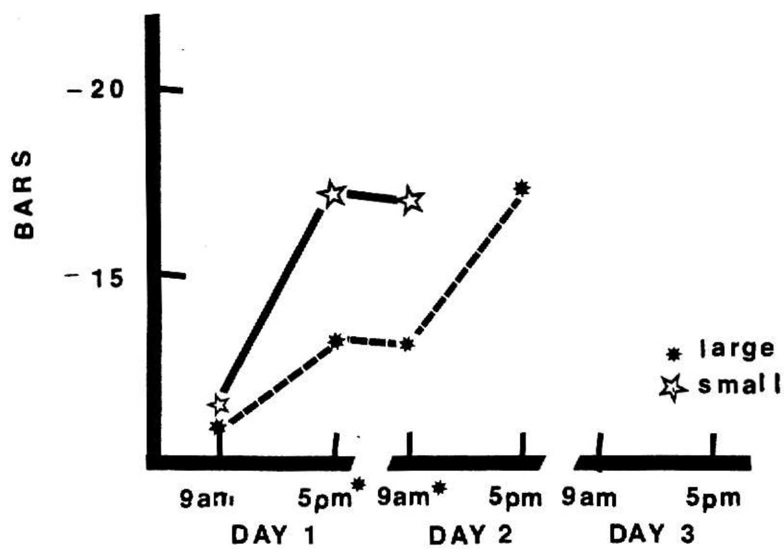
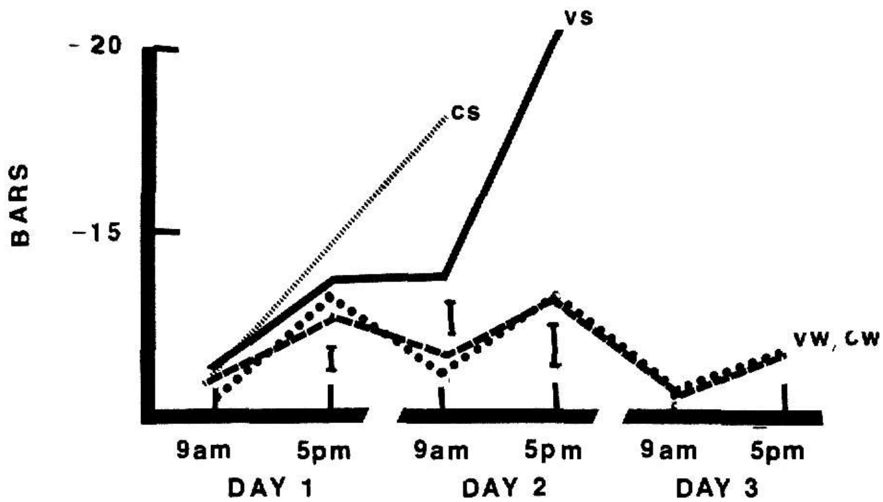

-20
-15
BARS
large
small
9am
5pm*
9am*
5pm
9am
5pm
DAY 1
DAY 2
DAY 3

FIGURE 17. Pressure bomb readings of broccoli plants indoors small containers

*Length of bar equals standard error

FIGURE 18. Pressure bomb readings of broccoli plants indoors large containers

*Length of bar equals standard error


VS
- 20
CS
BARS
-15
VW, CW
9am
5pm
9am
5pm
9am
5pm
DAY 1
DAY 2
DAY 3

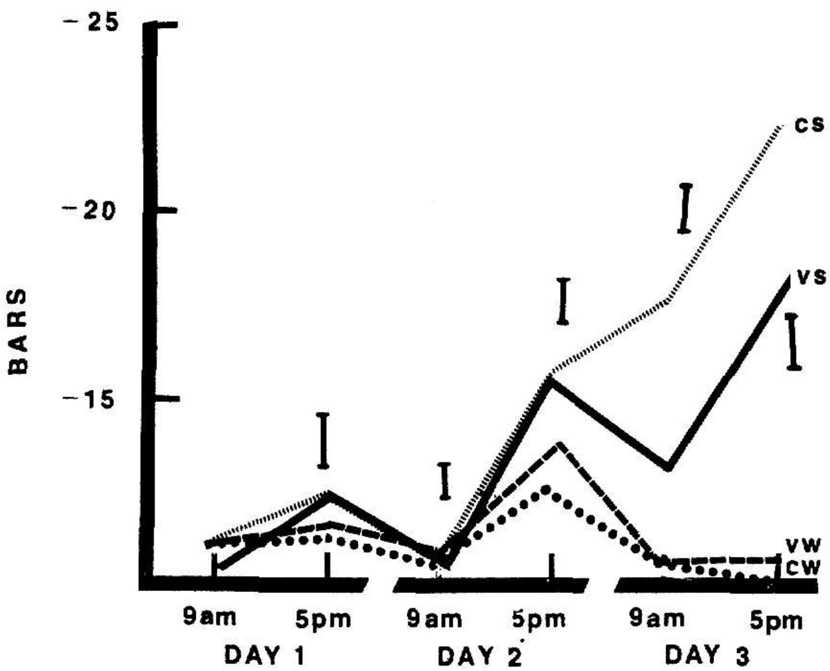
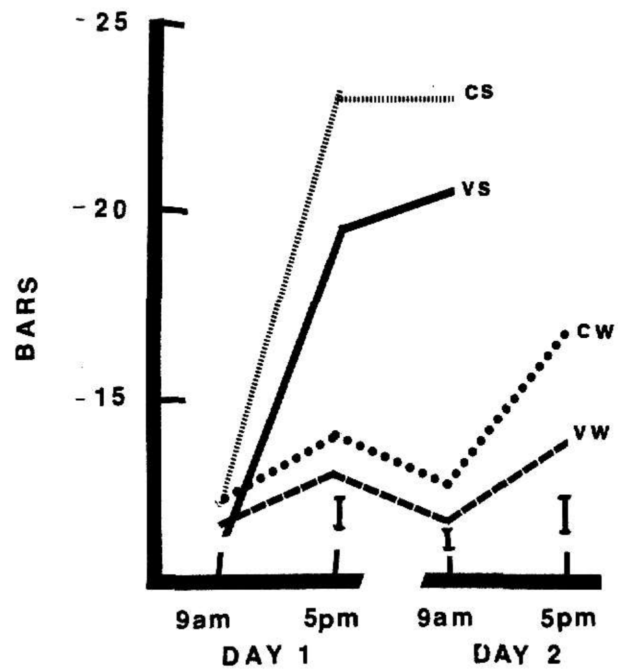

- 25
CS
-20
VS
BARS
-15
VW
CW
9am
5pm
9am
5pm
9am
5pm
DAY 1
DAY 2
DAY 3

FIGURE 19. Pressure bomb readings of broccoli plants outdoors small containers

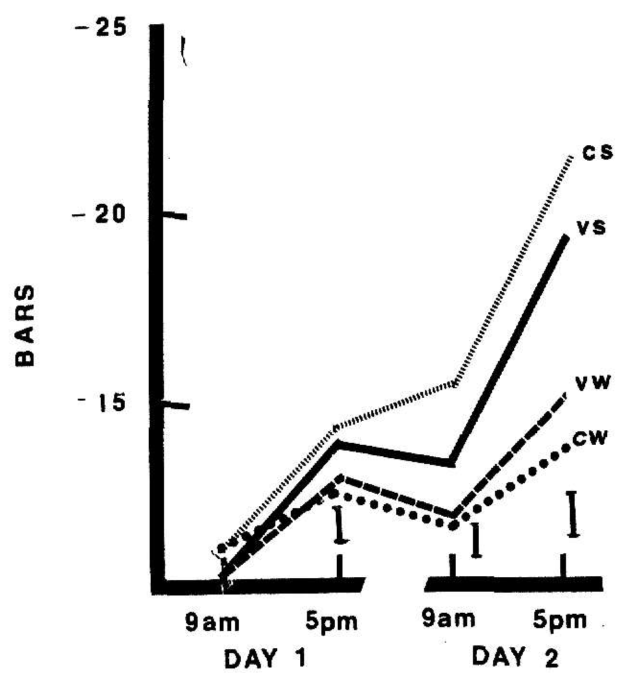
*Length of bar equals standard error

FIGURE 20. Pressure bomb readings of broccoli plants outdoors large containers

*Length of bar equals standard error



- 25
- 20
- 15
BARS
CS
VS
CW
VW
9am
5pm
9am
5pm
DAY 1
DAY 2



- 25
- 20
- 15
BARS
CS
VS
VW
CW
9am
5pm
9am
5pm
DAY 1
DAY 2

TABLE 8. Broccoli hours to wilt (indoor)

	Small	Large	
Control	34.7 c	41.7 b	38.2*
Viterra	37.3 cb	50.0 a	43.7
	36.0	45.8	

TABLE 9. Broccoli hours to wilt (outdoor)

	Small	Large	
Control	16.7 c	31.3 b	24.0*
Viterra	18.3 c	37.7 a	28.0
	17.5	34.5*	

*Differences significant at .05 level

FIGURE 21. Diffusion resistance of calendula plants as influenced by container size indoors

*Differences significant at .05 level

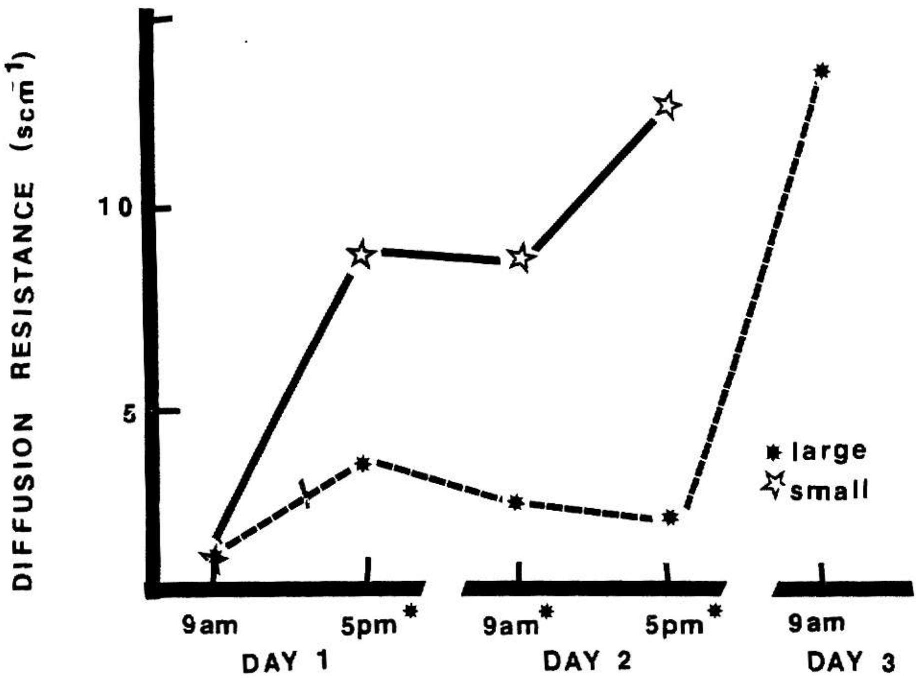
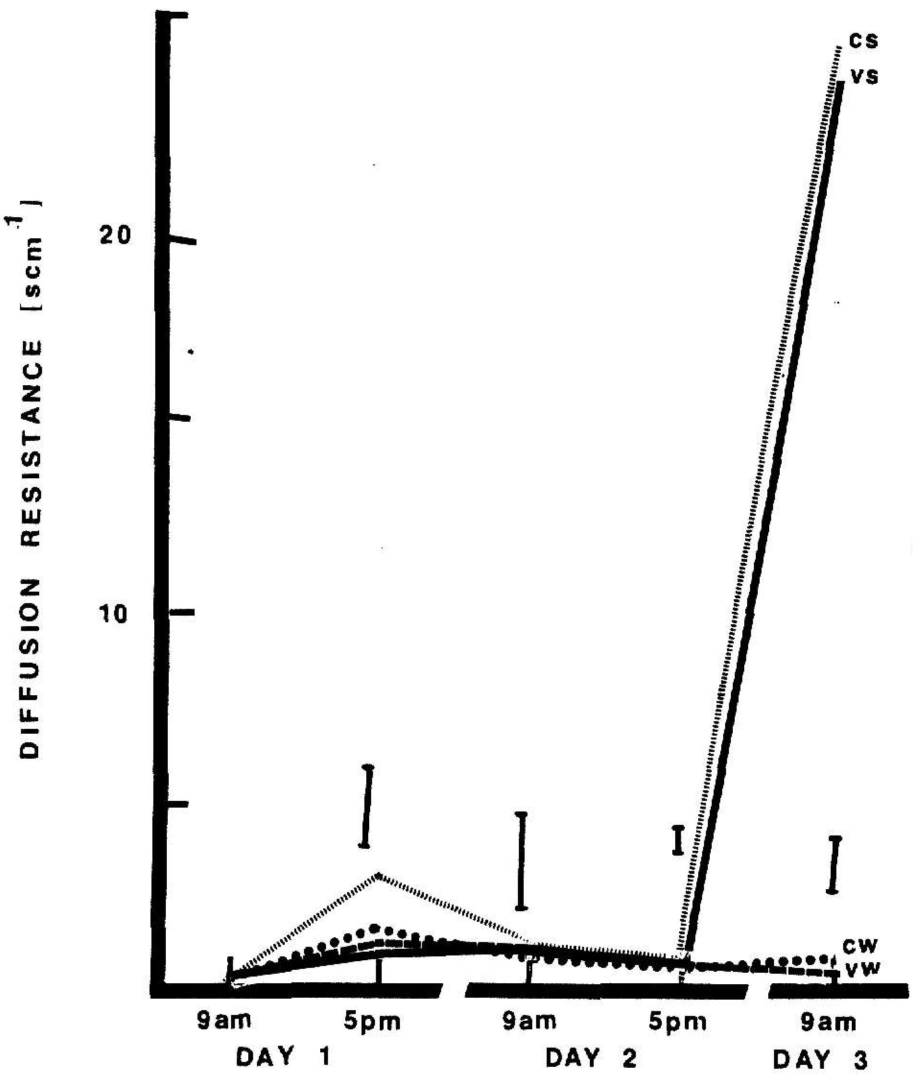

DIFFUSION RESISTANCE (scm⁻¹)
10
5
large
small
9am
5pm
9am
5pm
9am
DAY 1
DAY 2
DAY 3

FIGURE 22. Diffusion resistance of calendula plants indoors

cs = control stress   vs = Viterra stress
cw = control watered   vw = Viterra watered

*Length of bar equals standard error



DIFFUSION RESISTANCE [scm-1]
20
10
CS
VS
CW
VW
9am
5pm
9am
5pm
9am
DAY 1
DAY 2
DAY 3

FIGURE 23. Temperature differentials of calendula plants as influenced by container size indoors

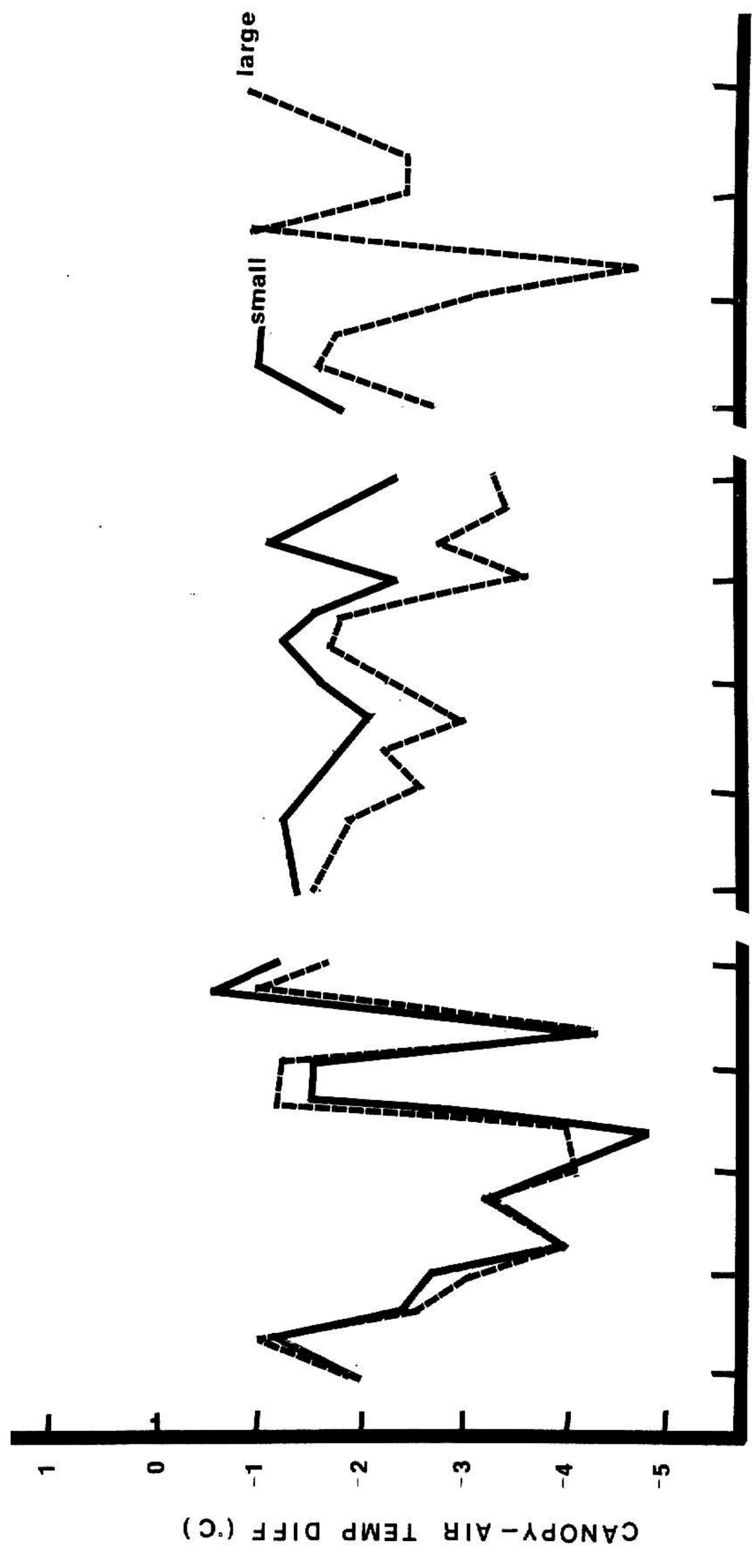

large
small
7am
1pm
7pm
DAY 1
DAY 2
DAY 3
1
0
-1
-2
-3
-4
-5
CANOPY—AIR TEMP DIFF (°C)

FIGURE 24. Temperature differentials of calendula plants indoors

cs = control stress	vs = Viterra stress
cw = control watered	vw = Viterra watered

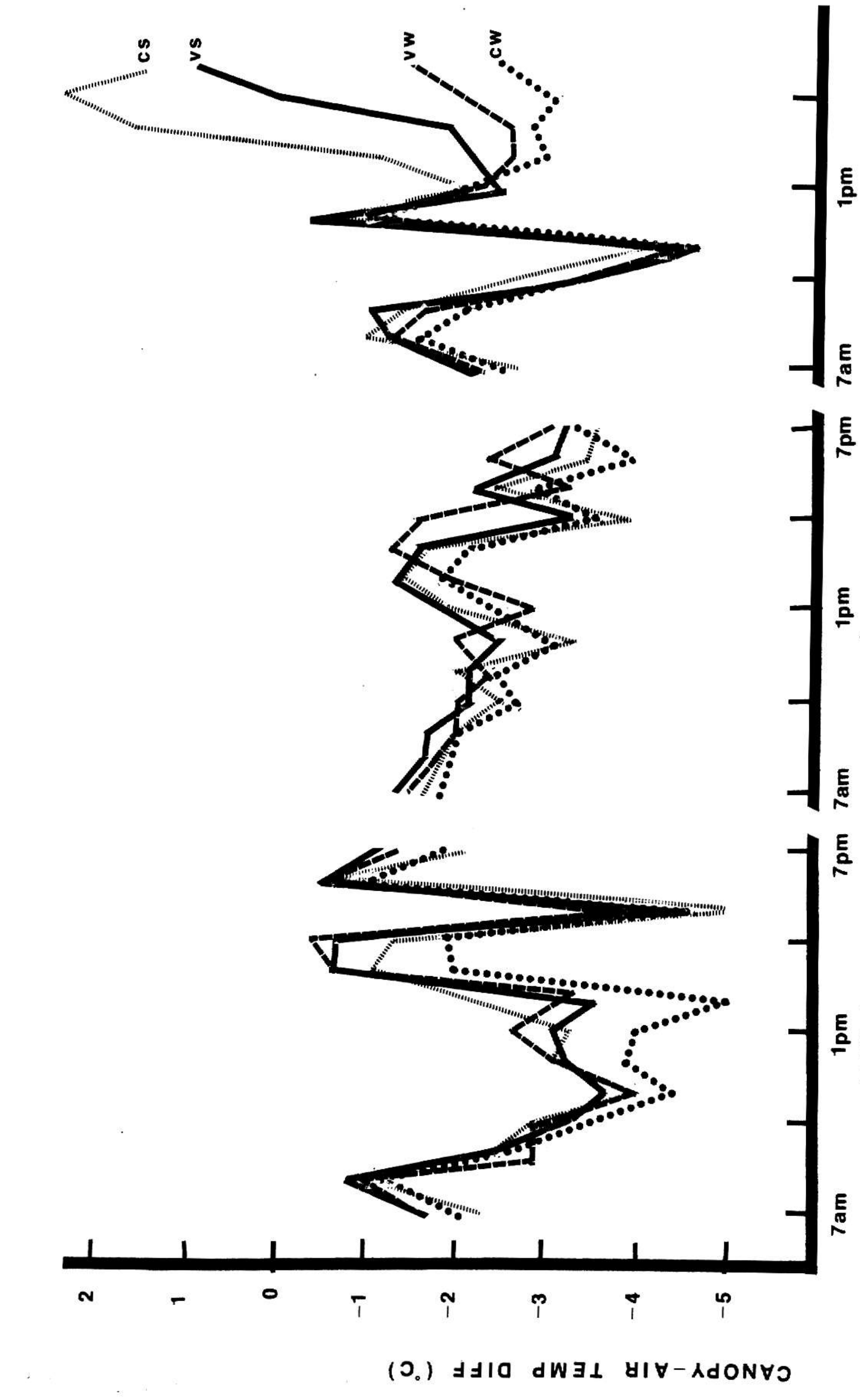

CANOPY-AIR TEMP DIFF (°C)
2
1
0
−1
−2
−3
−4
−5
7am
1pm
7pm
DAY 1
7am
1pm
7pm
DAY 2
7am
1pm
DAY 3
CS
VS
VW
CW

FIGURE 25. Diffusion resistance of calendula plants as influenced by container size outdoors

*Differences significant at .05 level

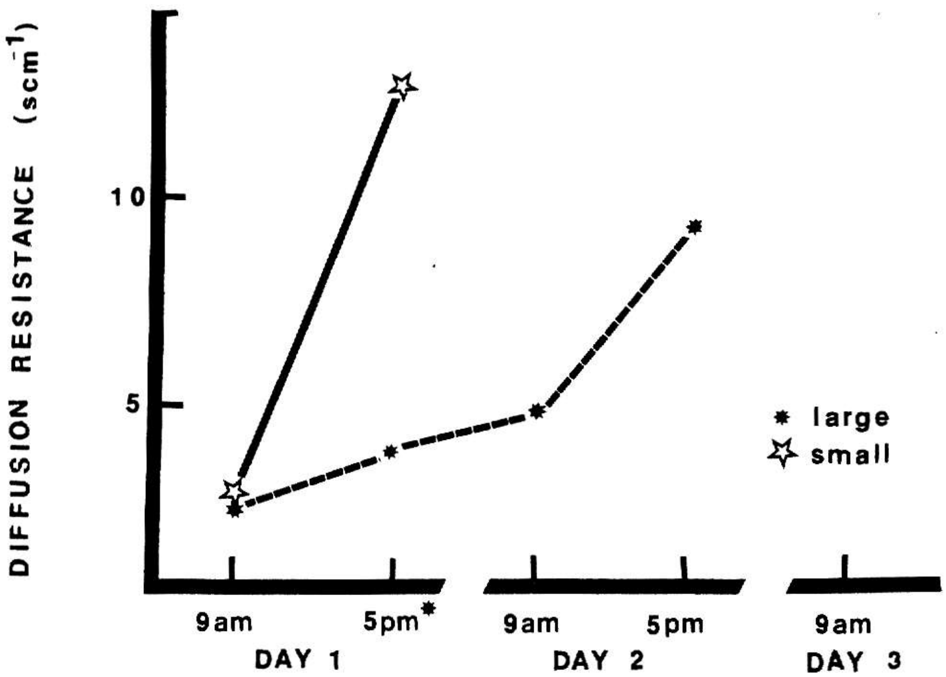

DIFFUSION RESISTANCE (scm-1)
10
5
large
small
9am
5pm*
9am
5pm
9am
DAY 1
DAY 2
DAY 3

FIGURE 26. Diffusion resistance of calendula plants outdoors

cs = control stress　　vs = Viterra stress
cw = control watered　　vw = Viterra watered

*Length of bar equals standard error

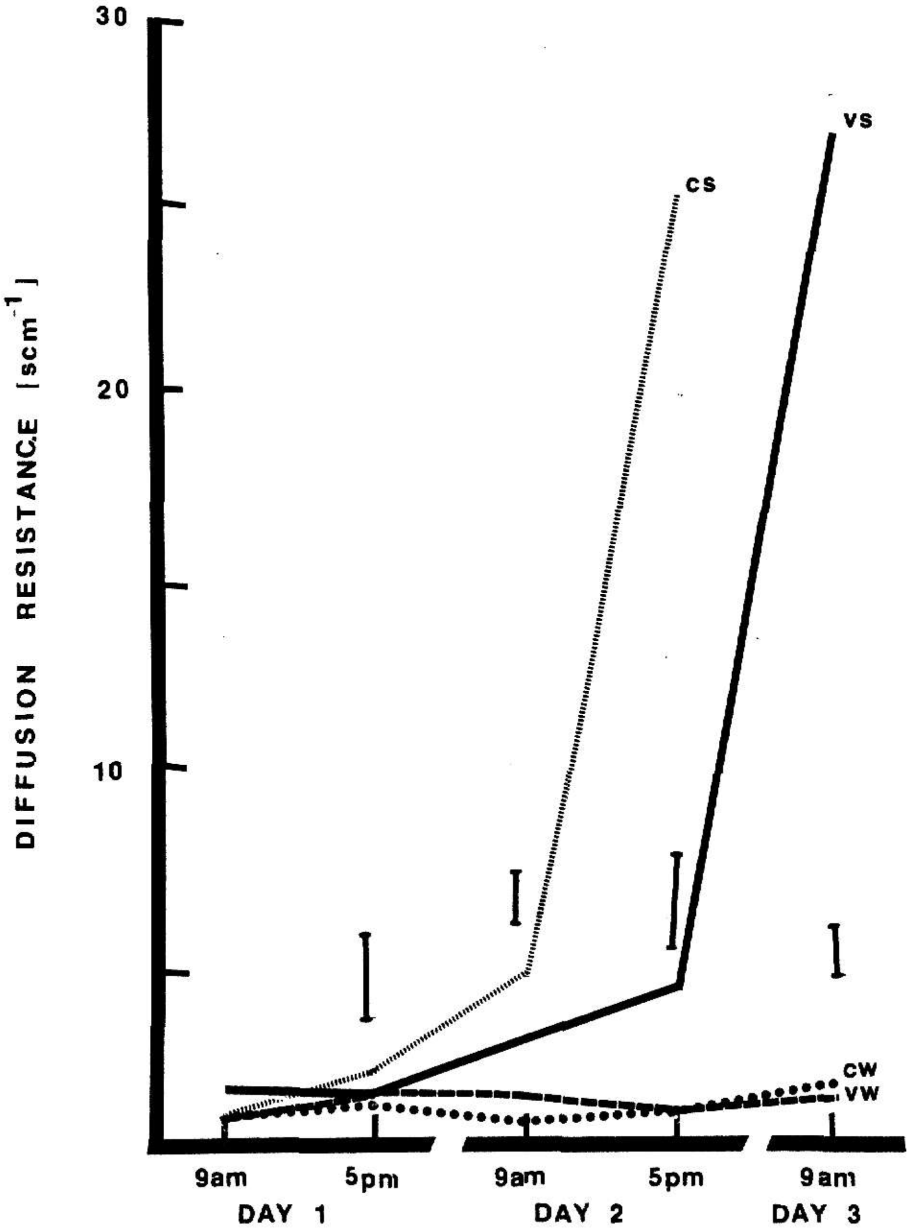

30
20
10
DIFFUSION RESISTANCE [scm-1]
cs
vs
cw
vw
9am
5pm
9am
5pm
9am
DAY 1
DAY 2
DAY 3

FIGURE 27. Temperature differentials of calendula plants as influenced by container size outdoors

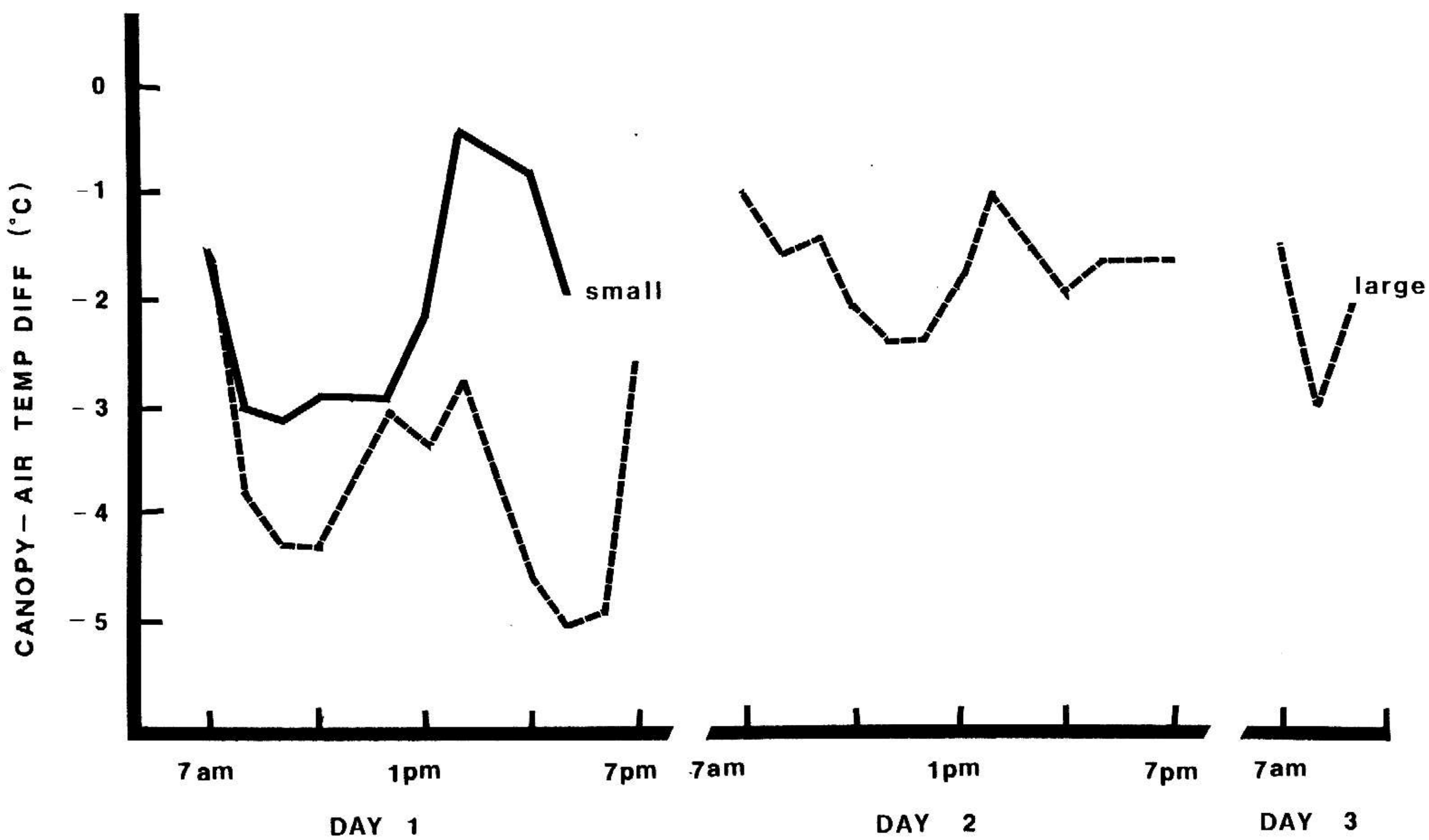

CANOPY – AIR TEMP DIFF (°C)
0
−1
−2
−3
−4
−5
small
large
7am
1pm
7pm
DAY 1
7am
1pm
7pm
DAY 2
7am
DAY 3

FIGURE 28. Temperature differentials of calendula plants outdoors

cs = control stress vs = Viterra stress
cw = control watered vw = Viterra watered

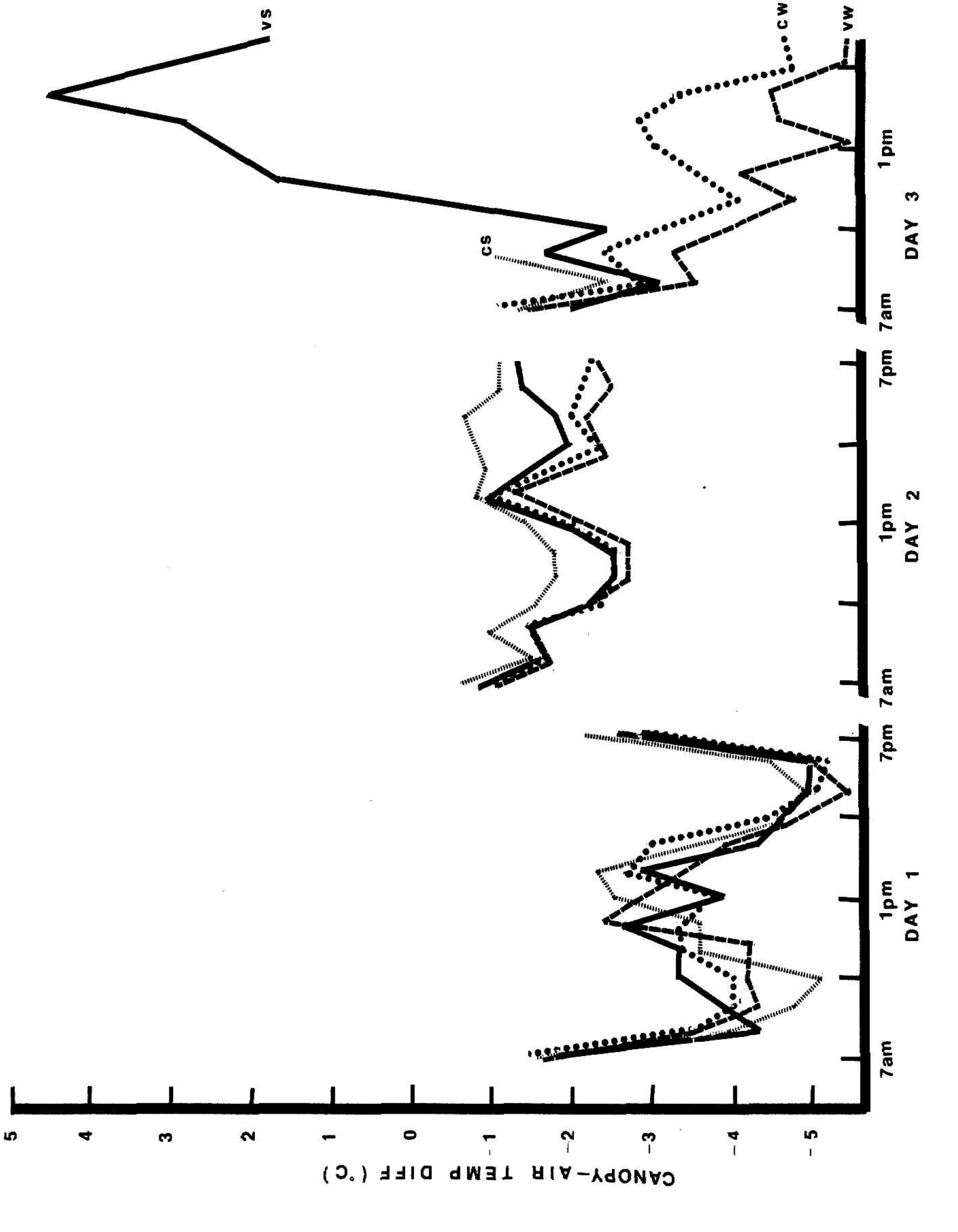

CANOPY-AIR TEMP DIFF (°C)
5
4
3
2
1
0
-1
-2
-3
-4
-5
7am
1pm
7pm
DAY 1
DAY 2
DAY 3
VS
CS
CW
VW

TABLE 10. Calendula hours to wilt (indoor)

	Small	Large	
Control	41.0 c	64.3 a	52.7
Viterra	49.0 b	66.7 a	57.8
	45.0	65.5*	

TABLE 11. Calendula hours to wilt (outdoor)

	Small	Large	
Control	20.0 d	43.7 b	31.8*
Viterra	26.7 c	56.3 a	41.5
	23.3	50.0*	

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I wish to thank Dr. Marr for his guidance and advice throughout my graduate study and for the many long hours spent in the greenhouse collecting data. Without his support and encouragement, the accomplishment of this degree could never have been attained.

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Last, but not least, my dad and friends provided the strength and words of encouragement for the success of receiving my Masters' Degree.

APPENDIX

TABLE A-1. Bulk density, aeration porosity and moisture retention measurements on media treatments

Soil Physical Property	Treatment						
	Control	Viterra			Terra-Sorb		
		High	Med	Low	High	Med	Low
Bulk Density (g/cm^3)	0.14	0.13	0.13	0.12	0.13	0.14	0.13
Aeration Porosity (%)							
-0.1 Bar	30.9	42.6	28.7	30.8	26.8	26.9	25.0
-0.33 Bar	28.9	36.1	26.9	25.6	25.0	25.9	23.1
Moisture Content by Volume (%)							
0 - Saturation	75.6	91.0	74.1	72.8	76.7	78.4	72.8
-0.10 Bar	43.4	59.8	40.3	43.2	40.3	40.6	37.7
-0.33 Bar	40.6	50.7	37.7	39.6	37.7	37.8	35.1
-0.6 Bar	35.0	45.5	33.8	36.0	35.1	36.4	32.5
-1.0 Bar	33.6	42.9	31.2	33.6	33.8	33.6	31.2
-2.0 Bar	32.2	41.6	29.9	32.4	33.8	33.6	29.9
-3.0 Bar	29.4	39.0	28.6	30.0	31.2	30.8	27.3

CONTAINER STYLE AND HYDROPHILIC GEL INFLUENCE
ON BEDDING PLANT PRODUCTION AND POSTHARVEST QUALITY

by

Lynn Loughary

B. A., Ottawa University, 1982

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1983

Broccoli (*Brassica oleracea italica* c.v. 'Green Duke') and calendula (*Calendula officinalis* c.v. 'Lemon') were grown in peat containers (50 cm^3 and 105 cm^3), styrofoam Todd planter flats (25 cm^3 and 75 cm^3), and plastic seedling cavity trays (27 cm^3 and 110 cm^3) for six weeks. A soilless medium (peat - vermiculite 1:1) was used in all studies. Peat containers produced greatest plant height, dry weight, and leaf length and width for both species. Broccoli plants were then grown in plastic seedling cavity trays (27 cm^3 and 110 cm^3) with Viterra$_R$ (3.2 kg/m^3) and Terra-Sorb$_R$ (1.2 kg/m^3) hydrogels incorporated into the medium using ½x, 1x, and 2x rates. Viterra (1x) resulted in greatest plant height, dry weight and leaf length and width. Larger containers produced increased plant growth regardless of hydrogel treatments. Viterra (2x) and Terra-Sorb (2x) extended shelf life 24 hours in a growth chamber (24 $^{\circ}C$). In a subsequent study, broccoli and calendula were grown in seedling cavity trays with Viterra (3.2 kg/m^3) and exposed to the outdoor environment. Viterra increased plant growth, reduced moisture stress, and increased postharvest quality for both crops.