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RESEARCH REPORT

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Factors Affecting Garden Performance of Flowering Plants in Hanging Baskets

Detailed Explanation of Experiments

William R. Argo and John A. Biernbaum
Department of Horticulture
Michigan State University East Lansing, MI 48824-1325

Note: Hangiing basket production recommendations for growers and home care recommendations for consumers are available separately from BPFI.

General Methodology

All root media were mixed in a small batch mixer with a volume of 0.09 m3 (3 ft3). Prior to planting, water was added to increase the moisture level of the root media to 40 - 50% of the container capacity in a 15 cm (6 inch) standard pot. Baskets were filled at a rate of 6 baskets/ 0.03 m3 (6 baskets/ft3).

The water used in all experiments (unless otherwise indicated) had an alkalinity of 320 mg liter^{-1} (ppm), a pH of 8.3 and electrical conductivity (EC) of 0.65 mS cm^{-1}. Irrigation water was applied without saturation for the first 2-3 weeks after planting. Watering frequently without saturation was considered necessary to promote root growth and uniformly establish plants grown in root media with different water holding capacities.

Plants were checked daily to determine if irrigation was necessary. In experiments with impatiens as the test plant (Experiments 1, 2, 3, 4, and 7), plants were irrigated at visible wilt. Impatiens foliage was found to be tolerant to wilting and normally recovered fully after watering. In experiments with multiple species (Experiments 5 and 6), plants were also checked daily for watering. A weight was determined when the plant would wilt. Water or fertilizer solution was applied when the weight of the baskets was close to the wilt weight. For treatments without RCF, WSF was applied as a normal irrigation when leaves began to turn chlorotic and flowering was reduced.

There was a difference between a normal irrigation and uniformly saturating the root media. During a normal irrigation, water was applied with methods selected to approximate watering by a consumer. Saturation of the root media was accomplished by applying water until drainage occurred and again after 30 minutes. The saturation method allowed for better uniformity and reproducibility.

The outdoor evaluation area (OEA) was a structure specifically built for the purpose of testing the garden performance of the hanging baskets. The structure consisted of wooden framework with hooks placed every 0.6x0.9 m (2x3 ft), at 2.4 m (8 ft) off the ground. Final basket height was 2 m (6.5 ft) above the ground. Snow fence with a 2.5 cm (1 in) lath placed every 7.5 cm (3 in) was placed over the top of the framework to provide some shade. The indoor evaluation area (IEA) consisted of two parallel pipes, 2.6 m (8.5 ft) off the ground located inside a glass greenhouse hallway (3 m (10 ft) wide by 46 m (150 ft) long). Baskets were placed every 0.6 m (2 ft). Final basket height was 2.1 m (7 ft) above the ground. Both evaluation areas had conditions of bright light and high air movement.

When possible, the data was statistically analyzed to determine significant treatment differences. Only differences that were statistically different are discussed.

Terminology

Several terms are used to describe the water holding capacity of the different root media. *Available water holding capacity (AWHC)* was the amount of water held in a root media between watering and wilt. A gram scale was used to weigh the baskets after irrigation and at wilt (1000 grams of water = 1 liter of water = 34 fl. oz. of water). AWHC was determined on fully developed and thoroughly rooted plants. However, plant size did not have to be identical for this comparison. The amount of fertilizer applied to the plants was calculated by determining the amount of solution applied to the pot (based on weight) and multiplying by the fertilizer concentration.

Average days between irrigation (ADI) was the frequency of irrigation over a specified number of days and was calculated by dividing the number of days by the number of times the baskets were watered. *Minimum days between irrigation (MDI)* was the shortest interval between irrigation over the same specified number of days. MDI was a measure of the amount of maintenance required for plant survival during periods of hot, dry conditions. Both ADI and MDI were dependent to some extent on plant size. Unless otherwise indicated, only plants of similar size were used for comparisons.

Experiment 1:

Effect of root media components and amendments on improving the garden performance of flowering hanging baskets.

Introduction

Considerable interest has been shown in root media that can reduce the amount of plant maintenance required after production. Root media that hold a large amount of available water are also desired to increase the time between irrigations during production to reduce the potential for water and fertilizer runoff from greenhouses.

One of the primary elements of many greenhouse container root media is peat. Several types and grades of peat are available, but in general, peat tends to have a large water and nutrient holding capacity (Puustjarvi and Robertson, 1975). The amount of non-capillary or air space can vary dramatically due to either the state of degradation of the peat or a reduction in particle size as a result of over mixing or improper handling. For these reasons, course components are blended with peat to provide aeration. The most common components used in soilless media are perlite, polystyrene, #2 or #3 vermiculite, rockwool and bark. When added to peat, the air space and AWHC of the resulting root media can vary significantly depending upon the type and particle size of the component used.

Other materials have been advertised to increase root media water holding capacity and reduce fertilizer requirements. Since these materials are added to root media at rates making up less than 10% of the total volume, they are referred to as amendments.

Water absorbent gels can absorb between 40 and 1000 times their own weight in pure water. Gels are marketed to increase the water holding capacity of the root media and thus extend the time between watering, decrease water and fertilizer runoff, increase plant quality and extend shelf life (Kuack, 1986; Sulecki, 1988; Fisons Postharvest Mix, 1990). In containerized root media, gels have been shown to increase the post production shelf life of chrysanthemums by up to 100% (Bearce and McCollum, 1977). However, while some research has shown a benefit from the gel, other research has shown no benefit at the recommended rates (James and Richards, 1986; Lamont and O'Connell, 1987).

Wetting agents can be applied to a root media to increase water absorption. Sphagnum peat is normally shipped dry to save on shipping costs. Most commercial media contain some type of wetting agent in the mix for quick and uniform rewetting (Templeton, 1987). Reapplying a wetting agent on a regular basis throughout production is recommended for some products. The constant application of Aquagro L® during production has been shown to extend the time to wilt for chrysanthemums by 3.3 days in a post production environment (Bhat et al., 1991). Bhat et al. (1989) determined that at the recommended application rate, Aquagro L® had no phytotoxic effects on a variety of species. However, at twice the recommended application rate, some phytotoxic effects were observed that were both species and cultivar dependent.

Maintaining nutrient levels in root media after production is also important for hanging basket performance. Cation exchange capacity (CEC) refers to the ability of a root media to retain positively charged ions against the leaching effects of water while still allowing the nutrients to be available to the plant. The CEC of peat can vary dramatically but is generally reported to be in the range of 1.0 to 1.2 meq g^{-1} (Bunt, 1988; Conover and Poole, 1977; Nelson, 1991) which is considered high on a weight basis. However, the actual CEC of peat in container root media on a volume basis can be low due to the low weight per unit volume.

Zeolite is a fine powdered natural silica material with a CEC between 1.4 and 2.0 meq g^{-1}. These materials also have the ability to selectively absorb specific monovalent cations such as ammonium ($NH4^{+1}$) and potassium (K^{+1}) ions. Due to its high bulk density, relatively small amounts of this material can greatly increase the CEC of a root media. Bunt (1988) found that a mixture of 90% sphagnum peat and 10% zeolite had a CEC double that of the sphagnum peat alone. The incorporation of 33.2 kg m^{-3} (56 lbs yd^{-3}) of K^{+1} enriched zeolite was able to supply all the K^{+1} needed for chrysanthemums grown in 15 cm (6 inch) pots (Hershey et al., 1980). The release of the K^{+1} by the zeolite was similar to a slow release fertilizer.

Another method of chemically amending root media is with the use of RCF. It has been reported that plants grown in root media containing RCF are much more efficient in the use of fertilizer compared with plants grown with water soluble fertilizer (Holcomb, 1979; Hershey and Paul, 1982). RCF also provides a nutrient reserve that can provide for extended periods of time.

The objective of this experiment was to look at a variety of root media components and amendments either singularly or in combination that could reduce the amount of maintenance required to keep flowering plants in hanging baskets blooming and actively growing through the summer.

Materials and Methods

Root Media Components: The basic components tested were polystyrene, #2 perlite, #2 vermiculite, and medium grade granular rockwool (Partek, Englewood CO) along with 100% peat. The peat used was Fisons Sunshine Grower Grade Canadian sphagnum peat. Peat and components were mixed in a 60:40 blend.

Water absorbent Gel: Supersorb C® (Aquatrols, Pennsauken NJ) a coarse (1-2 mm in size when dry) superabsorbent polyacrylamide gel capable of holding up to 400 times its weight in pure water, was incorporated prior to planting at the recommended rate of 0.9 kg m^{-3} (1.5 lbs yd^{-}

^{3}) into four of the original root media blends (polystyrene, #2 vermiculite, rockwool and 100% peat).

Zeolite: The zeolite (East West Minerals, San Salita, CA) used in this experiment was ground to 35 mesh or less and was incorporated prior to planting at a rate of 30 kg m^{-3} (50 lbs yd^{-3}) in three of the root media blends (polystyrene, rockwool and 100% peat/gel).

Wetting Agent: Aquagro L® was incorporated prior to planting at the recommended rate of 0.35 liters m^{-3} (9 fl.oz. yd^{-3}). In the wetting agent comparison, 100% peat with no wetting agent was compared to 100% peat +1 Aquagro L® and 100% peat +1 AC160. AC160 was an experimental wetting agent also by Aquatrols (now available as Aquagro 2000®). AC160 was incorporated at mixing at the recommended rate 0.12 liters m^{-3} (3 fl.oz. yd^{-3}).

Fertilization: Peters 20-10-20 Peatlite (Grace/Sierra, Fogelsville, PA) was applied at a rate of 300 mg $liter^{-1}$ (ppm) to half the plants. The RCF, Osmocote® 13-13-13, 8-9 month release rate (Grace/Sierra, Fogelville, PA), was incorporated prior to planting at a rate of 4.2 kg m^{-3} (7 lbs yd^{-3}) for the remaining plants. RCF was incorporated into 0.03 m^3 (1 ft^3) of each of the root media blends prior to planting with an additional 60 seconds of mixing in the cement mixer.

While the plants were being grown in the greenhouse, treatments that received WSF had the solution applied at every watering after the initial saturation on May 5. After the baskets were moved to the OEA, WSF was applied on an as needed basis. The RCF treatments only received tap water at every irrigation. Six baskets were planted for each root media/fertilizer combination for a total of 198 baskets.

Each root media blend had a starting preplant nutrient charge of 0.6 kg (1 lb) $Ca(NO_3)_2$, 0.6 kg (1 lb) KNO_3, 0.3 kg (0.5 lb) $MgSO_4$ per cubic meter (yd^{-3}). Dolomitic lime was added to bring the pH to the range of 5.8 to 6.0. (5.3 kg m^{-3} (9 lbs yd^{-3}) for the 100% peat, 3.0 kg m^{-3} (5 lbs yd^{-3}) for the rockwool blends and 4.2 kg m^{-3} (7 lbs yd^{-3}) for all the other blends.) Wetting agent (if applicable) was also incorporated as the root media was moistened.

General Methods: The basket used was a 25.4 cm (10 inch) fluted saucerless basket with a total volume of 4.9 liters (1.3 gallons) and an internal reservoir volume of 0.3 liters (10 fl.oz.). A root media capillary column allowed for direct contact with the water in the internal reservoir. Impatiens (orange hybrid) grown in a 32 cell bedding flat were planted three plants/basket on April 17, 1990.

On May 5, all the baskets were watered to container capacity with tap water and the weight recorded. From that point, baskets were watered again at visible wilt with a beaker using sufficient water for 10% leaching (1.0 to 2.0 liters (34 - 68 fl.oz.)).

On June 21, half the baskets from each treatment were sampled for shoot fresh and dry weight. Root media settling or shrinkage was determined by placing a sheet of plastic wrap over the top of the basket and adding water up to the rim of the pot. The volume of the water was determined by weighing and equaled the shrinkage volume. Root media samples were tested for pH, EC and nitrate-N levels using the saturated media extract technique (Warncke, 1986).

While outside, plants were checked daily. If visible wilt was observed in one plant, all three plants from that treatment were watered. Sufficient water was applied for approximately 10% leaching (1 to 2 liters (34 - 68 fl.oz.)). AWHC was determined by weighing for each drying cycle.

On September 5, the baskets were brought back inside the greenhouse, saturated thoroughly, and a final controlled dry-down was completed. On September 20, shoot fresh and dry weight and root media settling were determined. Root media pH, EC, and nitrate-N concentrations were determined for samples collected after mixing the entire content of the basket.

Results

Due to the plant response of the different fertilization methods, all discussions dealing with root media are for plants fertilized with WSF. The difference in the fertilizer treatments is discussed in the RCF section.

Components: All plants grown in the five root media blends were visually similar in size and quality at the end of production (June 10). The plants grown in peat/vermiculite had a greater fresh weight

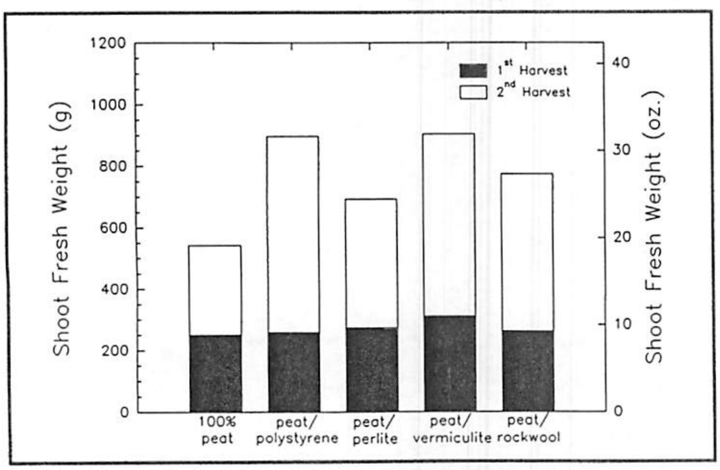

Figure 1. Shoot fresh weight from Experiment 1. Component blends were 60% sphagnum peat and 40% component by volume. The first harvest was the end of the production phase (June 20) and the second harvest was the end of the garden quality phase (Sept. 20).

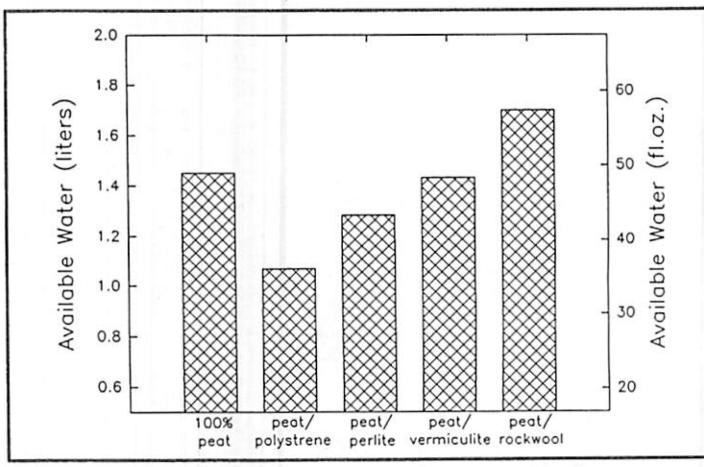

Figure 2. Average available water holding capacity (AWHC) of the base root media during the garden quality phase (June 21 to September 5) in Experiment 1.

compared to the other four peat/component blends (Figure 1).

At the end of the garden performance phase (September 10), plants grown in peat/polystyrene, peat/vermiculite and peat/rockwool were similar in fresh weight and visually similar in size and quality. The plants grown in peat/perlite had a lower fresh weight and were visually smaller but were still high quality. Plants grown in 100% peat were smaller and of reduced quality (see wetting agent discussion).

During the garden performance phase (June 21 - September 20), AWHC varied from 1 liter (34 fl.oz.) with the peat/polystyrene media to 1.7 liters (58 fl.oz.) with the peat/rockwool media (Figure 2).

The amount of available water retained in the different peat/component blends was consistent with the water holding properties of the components alone. The ADI almost doubled from the plants grown in the peat/polystyrene media (3.5 days) to the peat/rockwool media (6.1 days). The MDI was extended from one day with the peat/polystyrene media to three days with the peat/rockwool media (Figure 3). Statistical comparisons were not appropriate because the three plants in each treatment were not irrigated independently in this experiment.

The settling or shrinkage volume was different at both harvests. It reduced root media volume by 13% for the peat/perlite media and 18% for the peat/rockwool media (basket volume of 4.9 liters (1.3 gallons)). The increase in the settling between the two harvests averaged 0.12 liters or 2% of the total volume.

Superabsorbent Gel: The incorporation of Supersorb C® had no significant effect on plant size in either the production or the garden performance phase of the experiment. Supersorb C® did not increase the amount of water held by the root media (Figure 4). The ADI was increased by an average of 25% (approximately one day) over the same root media without gel. There was no increase over the MDI (Figure 5). There was no difference in the amount of settling at either harvest in root media containing gel

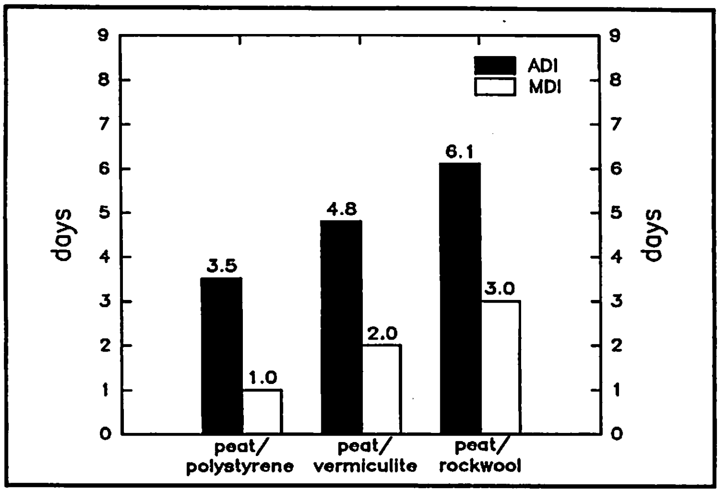

Figure 3. Average days between irrigations (ADI) and minimum days between irrigation (MDI) for plants of similar size determined during the garden quality phase in Experiment 1.

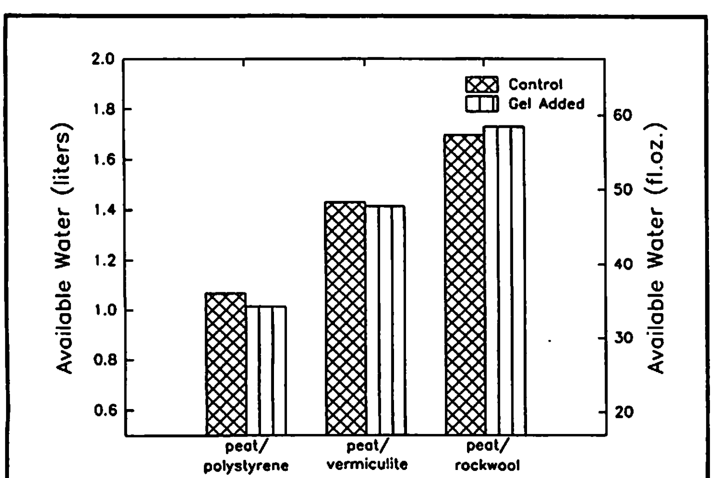

Figure 4. Effect of Supersorb C® on the AWHC of three sphagnum peat and component blends during the garden quality phase of Experiment 1.

compared with the same media without gel.

In a laboratory experiment, 1 gram of Supersorb C® was placed in a container with either Reverse Osmosis (RO) water or tap water (approximately 80 mg liter^{-1} Ca^{+2}, 40 mg liter^{-1} Mg^{+2}) containing one of three fertilizers (KNO_3, $Ca(NO_3)_2$ or Peters 20-10-20) at four different rates (0, 50, 150 or 350 mg liter^{-1} N). The gel was allowed to hydrate for a 24 hour period and then weighed to determine water absorption.

Supersorb C® absorbed 330 times its own weight in RO water and 75 times its own weight in tap water (Figure 6). Increasing levels of fertilizer decreased the amount of water absorbed by the gel, particularly in RO water. The greatest reduction in water absorption due to fertilizer was from increasing levels of $Ca(NO_3)_2$. With 350 mg N liter^{-1} from $Ca(NO_3)_2$ in the water, water absorption by the gel was similar in both types of water (RO = 39 times, tap = 31 times).

Zeolites: The incorporation of zeolite had no significant effect on plant fresh weight. The addition of zeolite did not increase the AWHC. However, there was an increase 25% in the ADI in the root media containing zeolite compared to plants grown in the same root media without zeolite. There was no increase in the MDI. In treatments receiving WSF, similar amounts of nitrate-N were applied to plants grown in root media containing zeolite compared to plants in the same root media without zeolite.

Wetting Agent: Plant size was different between each of the three wetting agent treatments. Peat + AC160 produced the largest plant (fresh weight = 874 grams) while the peat + Aquagro L® produced the smallest plant (fresh weight 542 grams). Both wetting agents (Aquagro® and AC160) allowed the 100% peat media to absorb more water (10% and 17% respectively) than the 100% peat with no applied wetting agent. The peat + Aquagro® averaged longer (7.9 days) between watering than either the peat + no wetting agent (5.6 days) or the peat + AC160 (5.5 days).

Fertilization: At the first harvest (June 20), plants fertilized with RCF had a fresh weight of 302 g (11.1 oz.) while plants fertilized with WSF which had an average fresh weight of 257 g (9.4 oz.). Average

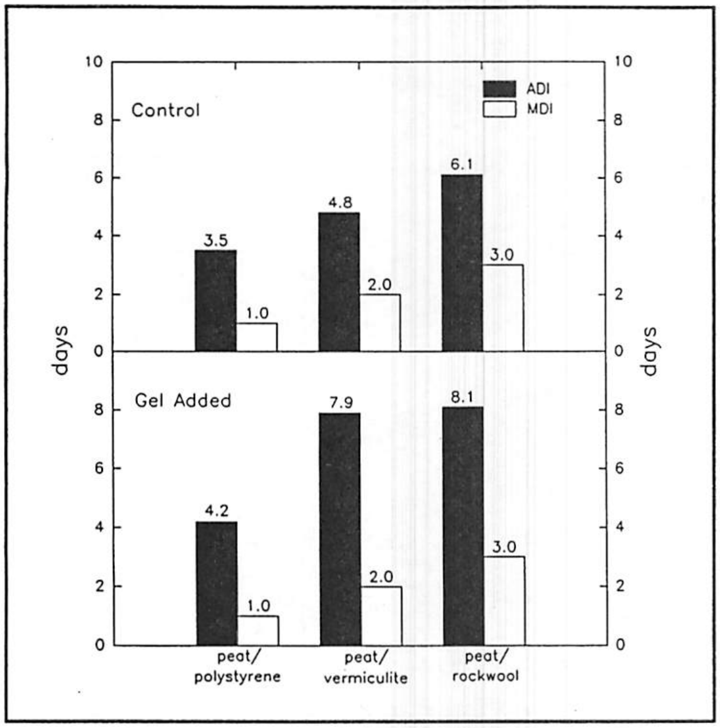

Figure 5: Effect of Supersorb C® on the ADI and MDI of three sphagnum peat and component blends during the garden quality phase of Experiment 1.

soil test values for root media fertilized with RCF were pH=6.58, EC=0.81 mS cm^{-1} and 9 mg $liter^{-1}$ nitrate-N. Average soil test values for the same root media fertilized with WSF were pH=6.01, EC=2.07 mS cm^{-1} and 153 mg $liter^{-1}$ nitrate-N.

When the baskets were returned to the greenhouse on September 4, the average temperature was held at a constant 27°C (77°F). During the two weeks the plants were in the greenhouse, plants grown in root media containing RCF became noticeably darker green in color.

At the second harvest (September 20), the average fresh weight of the plants fertilized with RCF was 426 g (15.6 oz.). The average fresh weight of the plants fertilized with WSF was 779 g (28.5 oz.) (Figure 7). Average soil test values for root media blends fertilized with RCF were pH=6.67, EC=1.08 mS cm^{-1} and 58 mg $liter^{-1}$ nitrate-N. The same root media fertilized with WSF were pH=7.59, EC=0.41 mS cm^{-1} and 2 mg $liter^{-1}$ nitrate-N.

The starting preplant nutrient charge incorporated in the root media prior to planting was 0.8 g nitrogen fertilizer per basket. The additional nitrogen fertilizer applied with RCF was 2.6 g N per basket for a total of 3.4 g N per basket. The plants receiving WSF had solution applied on average 7 times. The average amount of nitrogen fertilizer applied with the WSF was 2.7 g N for a total of 3.5 g N per basket.

Discussion

Components: High quality plants could be produced and maintained in all root media tested (Except for the 100% peat + Aquagro L® treatment - see wetting agent discussion). However, the amount of maintenance required to sustain plant growth varied dramatically for the different root media. In general, increased amounts

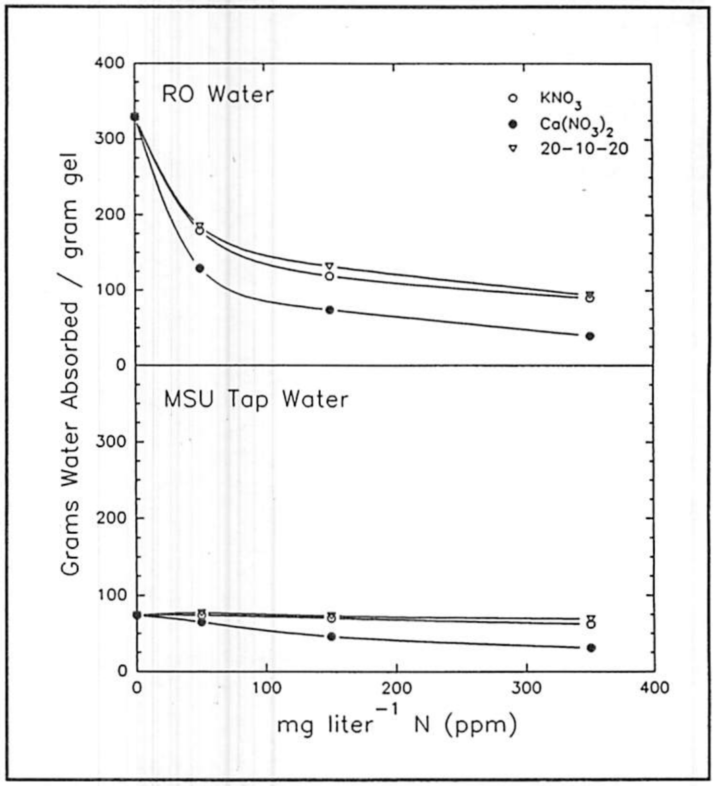

Figure 6. Effect of water quality and fertilizer salt type and concentration on the absorption of water by Supersorb C ®

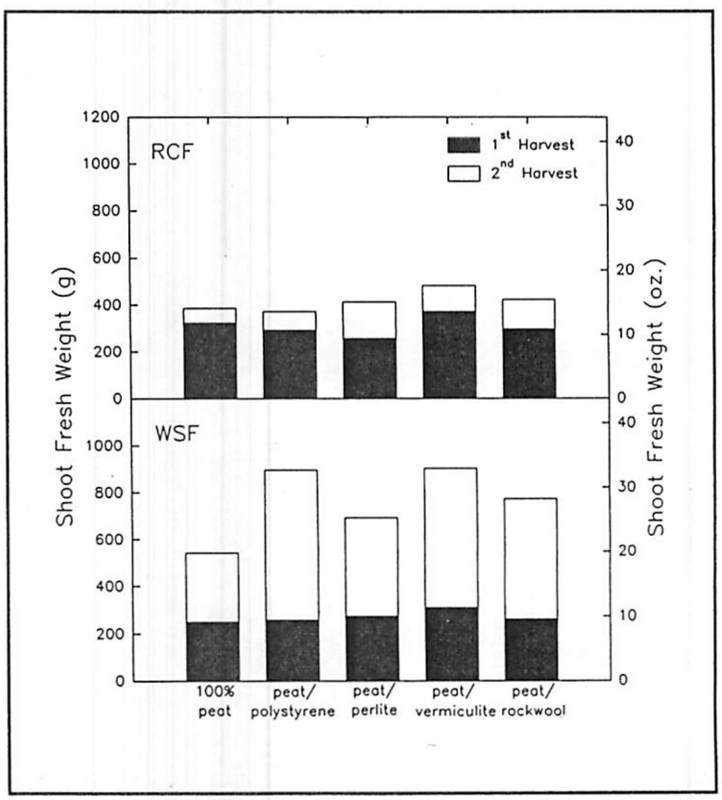

Figure 7. Shoot fresh weight of plants fertilized with RCF or WSF at the first and second harvest in Experiment 1.

of available water increased both the ADI and the MDI.

One common perception of root media that hold large amounts of water is that it is difficult to apply sufficient fertilizer early in the crop because the root media is not irrigated as often. However, the amount of fertilizer applied is not only a function of the number of applications but also the amount applied at any one time. The greater the water holding capacity of the root media, the greater the amount of fertilizer that can be applied at any one time.

This can be illustrated by comparing the fertilization of the peat/rockwool media and the peat/polystyrene media. During the garden performance phase of the experiment, the peat/polystyrene media held 1.0 liter (34.0 fl.oz.) of available water after an irrigation. When the plants were irrigated with a fertilizer solution at a concentration of 300 mg $liter^{-1}$, 0.3 g nitrogen fertilizer was applied to the peat/polystyrene media. The peat/rockwool media held 1.7 liter (57.5 fl.oz.) of available water. When plants grown in the peat/rockwool media were irrigated with the same fertilizer concentration, 0.51 g nitrogen fertilizer was applied. In this case, 70% more nitrogen fertilizer was applied to the peat/rockwool media compared to the peat/polystyrene media.

Between April 17 and September 20, 1990, plants grown in the peat/polystyrene media were fertilized 7 times for a total fertilizer application of 2.4 grams nitrogen from WSF. Over the same time period, plants grown in the peat/rockwool media were fertilized six times and received a total of 2.9 grams nitrogen or 20% more nitrogen fertilizer from WSF. If converted to dry fertilizer with 20% nitrogen, plants grown in the peat/polystyrene media received 12 g (0.43 oz.) per basket while the peat/rockwool media received 15 g (0.52 oz.) per basket.

Root media that hold large amounts of water after an irrigation may require different management. For these types of root media, a greater percentage of the total amount of fertilizer applied to the crop is applied at a single irrigation. A missed fertilization becomes greater in importance because of the longer period of time root media that hold large amounts of water may go between irrigations, especially at the beginning of the crop.

Vermiculite is often added. Since there was no difference in growth or the fertilizer requirement of plants grown in root media containing vermiculite verses polystyrene, rockwool, or perlite with low cation exchange capacity (CEC), the importance of CEC was not validated in this case.

Low leaching levels may help a root media to retain nutrients using an intermittent liquid fertilization program. The low levels of leaching used in the experiment (approximately 10%) may not have tested the ability of root media with different CEC to retain nutrients.

Superabsorbent Gel: The gel did not increase the AWHC of the root media. However, the ADI was increased compared to the same root media without gel. If the water held by the gel was similar to the water held in the root media, then there would not have been an increase in the time between irrigations. Thus, the water held by the gel may have been less available to the plant compared to the water being held by the root media and the plant may have therefore used less water. With high transpiration rates, the gel did not increase the time between irrigations, possibly because the plant was not able to absorb the water in the gel fast enough.

Supersorb C® may require up to 8 hours to fully hydrate in RO water (Wang and Gregg, 1990). Thus, during one irrigation, the application of water occurs over too short a time period to fully hydrate the gel. Wang and Gregg (1990) found that Supersorb C® required 15 daily irrigations in pots without plants to fully hydrate the gel. For some commercially available root media which contain gel (Fisons Postharvest Mix), the manufacturer recommends multiple irrigations to allow for maximum water absorption by the gel. In this experiment, the plants grown in root media containing gel were never irrigated specifically to allow the gel to absorb water. Other evidence to indicate that the gel in the root media was not fully saturated was that the root media never significantly increased in volume as previously reported (Sulecki, 1988). For example, Fisons Postharvest Mix is expected to expand by 15-20% in volume after thorough watering.

Without frequent multiple irrigations, the easily available water contained in root media after irrigation is the sole source of water for the gel to absorb. The greater the amount of available water contained in a root media, the more water that can be absorbed by the gel. The peat/vermiculite and peat/rockwool media have a large AWHC and the addition of Supersorb C® increased the ADI by three days and two days respectively. The peat/polystyrene media has a lower AWHC and the addition of Supersorb C® increased the ADI by less than one day.

The hydration of a gel may be decreased by soluble salts dissolved in the water, specifically, divalent cations such as calcium (Ca^{+2}), magnesium (Mg^{+2}), or iron (Fe^{+12}) (James et al., 1986; Wang and Gregg, 1990). Increasing levels of fertilizer salts decreased the hydration of the gel. Increasing Ca^{+2} levels caused a greater decreased in the hydration of the gel than with the other fertilizer salts tested which are consistent with the findings of other researchers (Wang and Gregg, 1990; Bowman et al., 1990). Bowman et al. (1990) also found that the effect of Ca^{+2} on gel hydration was not reversible with subsequent rinses with RO water. Thus, the presence of Ca^{+2} in the irrigation water may have reduced the effectiveness of the gel.

Water quality, fertilizer type and concentration, and irrigation method effect gel hydration. Perhaps this may help explain why some growers obtain a benefit from water absorbent gels while others do not.

Zeolite: One objective of this experiment was to test the effect increased exchange capacity in different root media. The intent was that if fertility levels became too high, from excess release from RCF for example, the nutrients would be held by the root media instead of contributing to high soluble salt levels or being leached from the pot.

Most of the exchange sites in zeolite are located in 'holes' within the crystal structure that allow for the exchange of only specific size ions. Naturally occurring zeolite tends to absorb K^{+1} and ammonium (NH_4^{+1}) ions.

At the second harvest, there was no difference in the shoot fresh weight of plants grown in root media containing zeolite compared to plants grown in the same root media without zeolite with either method of fertilization.

Wetting Agent: Aquagro L® has been shown to be phytotoxic to impatiens (Bhat et al., 1989). Plants grown in the 100%

peat + Aquagro L® were significantly smaller than all other treatments. Since the decrease in growth was not observed in any other root media treated with Aquagro L® as the wetting agent, including two other treatments that were 100% peat, the basis for the problem was not clear.

The use of both wetting agents did increase the amount of water absorbed by the 100% peat. An additional 0.2 liters (7 fl.oz.) of water absorbed by the root media with AC160.

Fertilization: The slow start of the plants fertilized with WSF may have been due to the decision to use tap water in the initial saturating irrigation (May 5). Because of the large volume of water applied, some treatments were not fertilized for four weeks after the saturation. One application of the 300 mg $liter^{-1}$ N fertilizer solution was equal to approximately 33% of the total amount of nitrogen fertilizer applied during production. If fertilizer solution was applied at the time when the baskets were first saturated, the problem with the WSF plants may not have occurred.

Plants with the incorporated RCF quickly began to grow after becoming established, approximately two weeks after planting. Plants fertilized with RCF were consistently larger than the plants grown with WSF while in the greenhouse. The difference in fresh weight at the first harvest between the two fertilizer treatments was 50 g (0.12 lb) or 20% greater fresh weight in the plants fertilized with RCF. However, both methods of fertilization produced acceptable plants by the end of the production phase.

Upon being placed outside, plants fertilized with RCF quickly began to show signs of low nutrition such as yellowing leaves and understory leaf drop. Very little new growth was observed. As the summer progressed, these symptoms became more pronounced (Figure 8). Yellowing of leaves and understory leaf drop were kept to a minimum with plants fertilized with WSF since fertilizer solution was applied if these symptoms were to appear. The fresh weight of plants grown with RCF had increased by one third from the end of the greenhouse phase to the end of the garden performance phase (June 21 - September 4, 1990). Plant fresh weight tripled in some case with plants fertilized with WSF over the same time period.

Soil test nutrient levels at harvest one (June 20) in root media containing RCF were EC=0.81 mS cm^{-1} and 9 mg $liter^{-1}$ nitrate-N. While the EC was in the acceptable range for a SME, the nitrate-N concentration would be considered very low (Warncke and Krauskopf, 1983).

Similar amounts of nitrogen fertilizer were applied using either WSF or RCF. Therefore, a sufficient quantity of nitrogen fertilizer was incorporated with the RCF prior to planting to maintain the plant over the six months of the experiment if 100% of the nutrients were released at the proper time. It is possible that the nutrients contained in the Osmocote® were released at a higher than expected rates inside the greenhouse leaving inadequate nutrient levels through the garden performance phase. Since little leaching occurred while the plants were in the greenhouse, high levels of nutrients would have been expected in the soil tests at the end of the production phase. This was not the case.

The release from Osmocote® 13-13-13 is based on 80% of the nutrients being released over 8-9 months at 20°C (68°F) (Rutten, 1980). If only 80% of the nutrients were released by the RCF, a total of 2.1 g N would have been applied to the RCF treatments. This may have been a sufficient amount to sustain the plants through the summer. However, the actual time period (5 months) was shorter than the optimal 80% release duration of the RCF. The conclusion therefore is that sufficient amounts of RCF were not incorporated into the root media for the duration of the experiment.

Since the release of the fertilizer salts in the RCF is based solely on temperature, a decrease in the average temperature by 5°C (9°F) will decrease the release rate by 25% (Rutten, 1980). The average air temperature for the month of July 1990 was 23/19°C (73/66°F) day/night. When the plants were returned to the greenhouse (September 4 - September 20), the average day/night temperature inside the greenhouse was approximately 27°C (80°F). The plants grown in root media containing RCF responded by increased growth and darker foliage. Soil test nutrient levels at harvest two (Sept. 20) were an EC of 1.08 mS cm^{-1} and 58 mg N $liter^{-1}$. These nutrient levels were considerably higher than in the root media of plants fertilized with WSF although the plants fertilized with RCF were considerably smaller in size and much lower in quality.

Summary

Acceptable garden performance was maintained in all the media treatments. The amount of available water held in the media after watering ranged from 1.0 to 1.7 liters (34 - 57 ounces). The peat/rockwool blend held the greatest amount of available water. There was a difference in the average days between watering ranging from 3.5 to 8.1 days and the difference in the minimum number of days between watering ranged from one to three days.

The addition of Supersorb C® polyacrylam-

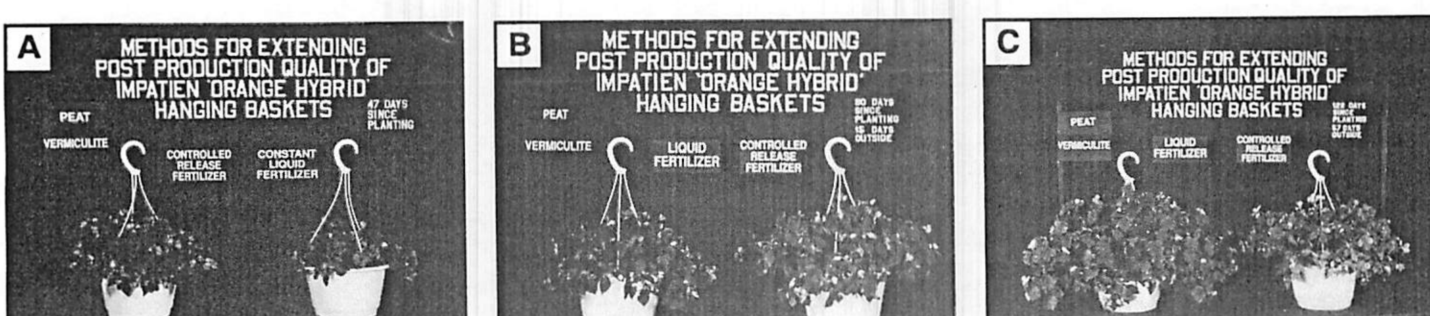

Figure 8. Comparison of RCF and WSF in peat/vermiculite blend from Experiment 1. Picture A was prior to the plants being placed outside (7 weeks from planting). Picture B was two weeks after being placed outside (9 weeks from planting). Picture C was eight weeks outside (18 weeks from planting).

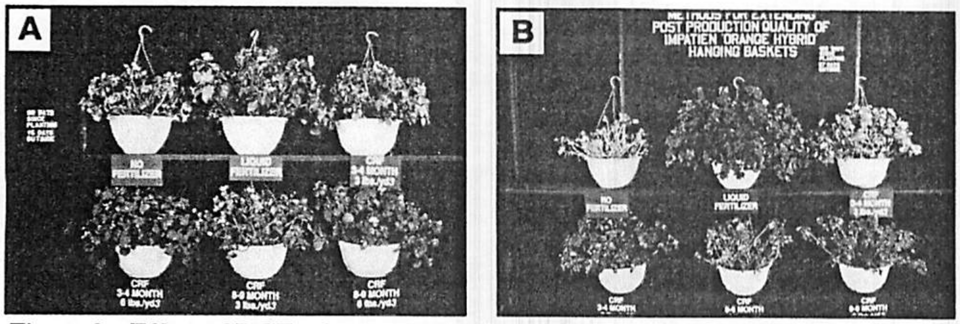

Figure 9. Effect of RCF release rate on the garden quality of impatiens in Experiment 2. Picture A was taken two weeks after being placed outside (9 weeks from planting) and Picture B was taken eight weeks after being placed outside

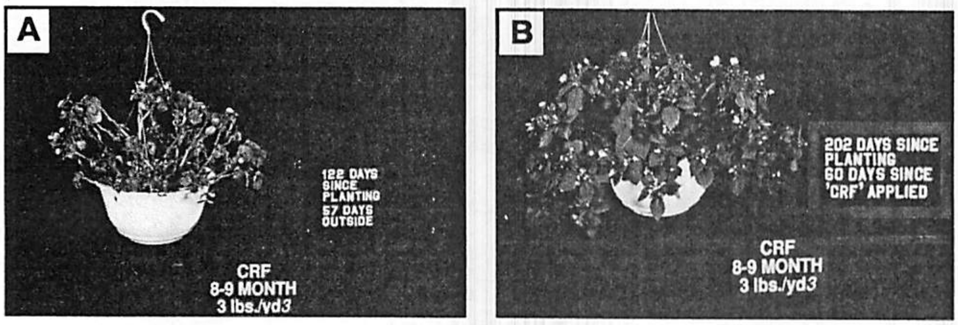

Figure 10. Effect of surface application of Osmocote® 14-14-14 applied at the end Experiment 2. Picture A is plant prior to application and Picture B is the same plant nine weeks after RCF application.

ide gel and zeolite did not improve plant quality under the conditions of the test. These amendments did extend the average period between watering by approximately one day.

Once outside, the RCF plants did not maintain growth and quickly declined in quality. The plants fertilized with WSF continued to grow through the end of the experiment.

Experiment 2:

Effect of the release rate of resin coated fertilizer on the garden performance of impatiens hanging baskets.

Introduction

RCFs are sold by the NPK ratio and the release time. Release rates for greenhouse crops are typically selected based on the 8-16 week production phase. Since less material is applied with the 3-4 month release products compared to the 8-9 month release rate materials, the cost per unit is lower. In the case of hanging baskets, the additional cost of an 8-9 month release rate material is significant ($0.05 per basket for the 3-4 month material compared to $0.08 per basket for the 8-9 month material), but perhaps can be justified by improved garden performance.

The objective of this experiment was to compare the effect of RCF release rates on plant growth during both production and garden performance.

Materials and Methods

The two types of RCF tested were Osmocote® 14-14-14 (3-4 month release rate) and Osmocote® 13-13-13 (8-9 month release rate). Both were incorporated prior to planting at either 1.8 kg m^{-3} (3 lbs yd^{-3}) or 3.6 kg m^{-3} (6 lbs yd^{-3}). The 4 RCF treatments were compared to the application of either no additional fertilizer or WSF applied at the first signs of leaf chlorosis. These rates were selected based on previous research by Yelanich and Biernbaum (1992) but were well below the manufactures recommended incorporation rates of 5.3 kg m^{-3} (9 lb yd^{-3}) for the Osmocote® 14-14-14 and 7.7 kg m^{-3} (13 lb yd^{-3}) for the Osmocote® 13-13-13 in greenhouse crops.

The type of basket used was a 25.4 cm (10 inch) round bottom basket with a volume of 4.9 liters (1.3 gallons) and an external reservoir. The root media was a commercially available Canadian sphagnum peat/polystyrene/vermiculite #3 mix (Suremix, Michigan Grower Products, Galesburg MI). Impatiens (orange hybrid) from a 32 cell bedding flat were planted three plants/basket on April 17, 1990.

On May 5, the root media was saturated with tap water in all treatments and the weight recorded. Water was applied with a beaker using a sufficient amount of water for approximately 10% leaching (1 to 1.5 liters (34 to 51 fl.oz.)) at every irrigation. The WSF treatment received the fertilizer solution (Peters 20-10-20 Peatlite at 300 mg $liter^{-1}$ N) at every irrigation.

On June 28, three uniform baskets from each treatment were moved to the OEA. The root media from the remaining plants were sampled for pH and EC using the SME technique.

On September 4, 1990, 20 grams (3 1/3 tsp.) of Osmocote® 14-14-14 was surface applied ("top dressing") to each of the basket's that originally received Osmocote® 13-13-13 (3-4 month) incorporated at a rate of 1.8 kg m^{-3} (3 lbs yd^{-3}). The plants had stopped flowering and had very little foliage due to lack of sufficient fertilizer. The plants from this treatment was maintained for another 10 weeks until November 20, 1990. All other plants were discarded.

Results and Discussion

Prior to the plants being placed outside, the was little visual difference in the quality of any of the treatments receiving some type of fertilizer. The plants that received no additional fertilizer were smaller in size and chlorotic but were still blooming. At the June 28 sampling date, the root media EC averaged 1.2 mS cm^{-1} for all treatments receiving fertilizer. The treatment that did not receive fertilizer had an EC of 0.9 mS cm^{-1}.

Within two to three weeks of being placed outside, all plants with either rate of the 8-9 month Osmocote® or the 3-4 Osmocote® incorporated at 1.8 kg m^{-3} (3 lbs yd^{-3}) rapidly became chlorotic with reduced flowering. Plants fertilized with 3-4 month Osmocote® incorporated at 3.6 kg m^{-3} (6 lbs yd^{-3}) maintained their leaf mass and dark green color for two to three weeks longer (Figure 9). By early September, there was no noticeable difference for the TWO RCF's at the high incorporation rate.

Greater incorporation rates of the 3-4 month RCF would probably not have affected plant growth through the summer. The 8-9 month RCF had a sufficient release duration to last through the summer but there was not a large enough release rate to sustain growth once the plants were placed outside. With Osmocote® fertilizer, there typically is a higher initial release rate due to imperfections in the prill coat (Harbaugh and Wilfret, 1982). This early release may have provided adequate nutrition in the greenhouse but was probably depleted by the time the plants were moved outside. Greater incorporation rates for the 8-9 month RCF may have been sufficient for continued plant growth though the summer.

For the plants that received the top dressed RCF on September 4, the few remaining leaves turned darker green within one week. After two weeks, rapid leaf growth was apparent. After sixty days when the plants were discarded, there was a full flowering leaf canopy (Figure 10).

It could be concluded that the decrease in quality seen in the RCF baskets upon being taken outside was probably due to macro-nutrient deficiencies (probably nitrogen). Growth and greening occurred with additional Osmocote® 14-14-14, which did not contain micronutrients.

Experiment 3:

Effect of commercial root media on the garden quality of flowering hanging baskets.

Introduction

Experiment 1 was designed to characterize the water holding characteristics of root media components when mixed with one type of peat. The first objective of this experiment was to quantify the water holding capacity of commercially available root media. A second objective was to test the effect of a wetting agent on the water holding capacity of the root media.

Materials and Methods

The commercially available root media used in this experiment are presented in Table 1. The basket used was a 25.4 cm (10 inch) saucerless basket with a total volume of 4.9 liters (1.3 gallons) and an internal reservoir volume of 0.3 liters (10 fl.oz.). In this type of basket, there was no root media capillary column to allow for direct contact with the water in the reservoir. Four impatiens plugs (Shady Lady Pastel Mix) from a 406 plug tray were directly planted into each basket on March 15, 1991.

One liter of fertilizer solution (Peters 20-10-20 Peatlite, 300 mg liter^{-1}) was applied on April 8 with the addition of acid (0.5 mls H_2SO_4 (93%) per 3.8 liters (1.8 oz. per 100 gallons)) to lower the root media pH. From April 8 until May 10, fertilizer/acid solution was applied two more times to all the baskets for a total fertilizer application of 0.9 g N per basket.

On May 10, the baskets were moved to the IEA, watered twice using a hose and breaker to thoroughly saturate the root media, and the weights were recorded. For all later irrigations, water was applied with a hose and breaker until drainage occurred. WSF (Peters 20-20-20 Peatlite, 300 mg liter^{-1}) was applied as a normal irrigation when leaves in the plant canopy became chlorotic. Peters 20-20-20 was selected because this formulation is more commonly available to the consumer then 20-10-20. AWHC was determined at each irrigation. On June 6, half the baskets were saturated with tap water containing the wetting agent Aquagro 2000® (Aquatrols, Pennsauken NJ) at a rate of 556 mg liter^{-1}. The remaining baskets were saturated with only tap water. On July 11, a hole was placed in the bottom of the basket to determine the effect of the internal reservoir on available water. The hole was placed so that no water would remain in the reservoir after watering but could be plugged when needed.

On September 17, baskets were watered twice to saturate the root media and weighed. After one day in the evaluation area, the baskets were placed in a room under constant temperature and 24 hours of light from cool white fluorescent lamps. The time and weight was first recorded when a slight wilt was observed. Weights were recorded every six hours until the basket reached a hard wilt. Once the baskets reached a hard wilt, water was applied and the baskets were moved back to the greenhouse.

Shoot fresh weight and root media shrinkage was determined on 30 September. Root media samples were collected to determine final pH (1:1 water to media; v:v) and EC (2:1 water to media; v:v) measurements.

Root media physical properties were determined with the method outlined by White and Mastalerz (1966). A 15 cm (6 inch) standard pot containing root media was placed into a water tight container. Water was slowly added so it entered the bottom of the pot and was applied until it reached a height similar to the container height. The root media was allowed to saturate for 24 hours. The saturated root media was weighed, allowed to drain for one hour and weighed again. The weight after one hour was considered the container capacity weight. The root media was then placed into a drying oven at 70°C (160°F) until the pot reached a constant weight. The difference between the saturation weight and the container capacity weight was used to calculate percent air space. The difference between the container capacity and the oven dried weight was the percent total water and the remainder calculated by subtraction was the percent solid. This procedure was done for each root media three separate times.

Table 1. Commercial root media used in Experiment 3.

Root media	Components
Baccto	Michigan sphagnum peat, perlite, #3 vermiculite
Baccto Rockwool Blend	Michigan sphagnum peat, Bacctite, rockwool
LC1	Canadian sphagnum peat, perlite
Metro Mix 360	Canadian sphagnum peat, #3 vermiculite, bark ash, sand
OPM #8	Canadian sphagnum peat, rockwool, perlite
Peatwool	Canadian sphagnum peat, rockwool
Postharvest Mix	Canadian sphagnum peat, perlite, gel, calcined clay
Pro-Mix BX	Canadian sphagnum peat, perlite, #3 vermiculite
Suremix	Canadian sphagnum peat, polystyrene, #3 vermiculite
Suremix Rockwool Blend	Canadian sphagnum peat, rockwool, #3 vermiculite, perlite

Results

Root Media: During production, plants grown in 8 of the 10 root media were of similar visual size and flowering quality. Plants grown in the Peatwool and the Baccto Rockwool Blend were smaller in size but were still high in flowering quality. Once moved to the IEA, plants grown in the Peatwool quickly grew in size so that there was no visual difference compared to the other root media. Throughout the summer, the plants grown in the Baccto Rockwool Blend maintained a more compact growing habit and remained smaller in size compared with plants grown in the other root media.

At the final harvest, the average plant fresh weight was two kg (4.4 lbs) and ranged between 1.6 kg (3.5 lbs) and 2.5 kg (5.5 lbs). While there was a visual difference in plant size over the course of the experiment, plants grown in all 10 root media maintained adequate green foliage and flowering.

Between May 11 and June 5, the ADI ranged from 6.3 days (Baccto Rockwool Blend) to 4.5 days (LC 1 (Table 2). The MDI ranged from 4.0 days (Baccto Rockwool Blend) to 3.0 days (Pro-mix BX). Over the same time period, the AWHC of the root media averaged 2.0 liters (67.6 fl.oz.) with the type of irrigation used in the experiment. AWHC in the 10 root media ranged from 2.3 liters (77.8 fl.oz.) (Pro-mix BX) to 1.6 liters (54 fl.oz.) (Baccto Rockwool Blend) (Table 3).

Placing a hole in the bottom of the reservoir decreased the amount of available water by approximately 0.25 liters (8.4 fl.oz). In the style of basket used, the root media was not in contact with the water held in the reservoir. However, at the time when the hole was placed in the reservoir, roots were visible in the reservoir.

In the determination of root media physical properties, container height is one of the main controlling factor (Bilderback and Fonteno, 1987). A 15 cm (6 inch) standard pot and the 24.5 cm (10 inch) saucerless basket used in the experiment have a similar height. The determination of the physical properties of the different root media was completed in 15 cm (6 inch) standard pots and is presented in Table 3. The physical properties at container capacity averaged over all root media were 21% air space, 58% total water space and 21% solid space. In general, the addition of rockwool decreased solid space and increased air and water space.

The amount of available water measured in a low light environment was 1.9 liters averaged over all root media. This was an increase in available water of 0.2 liters over the measured available water determined in high light without the reservoir. The difference in available water between first wilt and hard wilt averaged only 0.1 liters or 5.4% of the total amount of available water. The average amount of time required to go from first wilt and hard wilt was 12 hours.

The amount of settling or shrinkage in volume ranged from 0.55 liters with the Pro-mix BX to 1.2 liters with the Peatwool. This change corresponds to a root media volume reduction of 11% for the Pro-mix BX and 24% for the Peatwool assuming a basket volume of 4.9 liters (1.3 gallons). The majority of the changes in volume was due to settling that occurred with the first irrigation.

Wetting agent: The application of Aquagro 2000® had no effect on the visual quality or the final plant fresh weight except for plants grown in the Baccto Rockwool Blend. In this case, there was a 30% increase in shoot fresh weight with the wetting agent application.

There was no effect of wetting agent on the ADI or MDI. The effect of Aquagro 2000® on the AWHC was not consistent across all root media. In general, the AWHC of the root media with a wetting agent application was similar to same root media without the wetting agent. However, for Baccto and the Baccto Rockwool Blend, the application of a wetting agent increased AWHC by 50%.

Discussion

There are two main properties of a root media that will determine how long similar size plants will go between irrigations. The first is the amount of water held in the root media after an irrigation and the second is the relative availability of the water to the plant.

The amount of water held in a root media is based on physical properties. The physical properties of an ideal peat based container root media in a 15 cm (6 inch) standard pot is reported to be 10 to 15% solid, 20% to 25% air space and 60% to 70% water. (DeBoote and Verdonck, 1972). The average physical properties of the commercial root media tested indicate a lower water holding capacity and a greater percentage of air and solid space than the proposed ideal root media.

The amount of settling or shrinkage reduced the volume of the root media and thus the pore space. Based on results from Experiment 1, we concluded that the greatest amount of shrinkage occurred during production and may have occurred during the first irrigation. This observation is supported by other researchers (Blom and Piott, 1992). Averaged over all root media, the amount of settling that occurred between planting and the final harvest (28 weeks) was 0.9 liters (30 fl.oz.).

The average measured AWHC of the root media without the effect of the reservoir (1.7 liters (57 fl.oz.)) divided by the water holding capacity from the physical property data (59%) multiplied by the volume of the container (4.9 liters (166 fl.oz.)) minus the shrinkage (0.9 liters (30 fl.oz.)) is an estimate of the percent of water that was available to the plant. Using this method, 73% of the total calculated volume of water held in the root media was available to the plant. Fonteno and Nelson (1990) determined that the amount of available water held in two commercial root media was 80% of the total water held at container capacity. Either a lower percentage of the total water was available to the plant than is determined using laboratory methods or our normal irrigation was not sufficient to bring the root media up to container capacity. We concluded that the method used for irrigation in this experiment was not sufficient to rehydrate the root media to the same water holding capacity as when container capacity was determined in the laboratory.

Another factor that can influence the amount of available water held in a root media is how easily or efficiently water is absorbed by the root media. Water absorption efficiency can influence the amount of water that is required to be applied at an irrigation and can be illustrated with an example using two root media. When high volumes of water (1.8 - 2.0 times AWHC) were applied to both root media A and B , the amount of available water which remained in the root media was 1.8 liters (60 fl.oz.). When low volumes of water (1.0 - 1.2 times AWHC) were applied to the same root media , root media A held 1.5 liters (51 fl.oz.) of available water while root media B held 0.95 liters (32 fl.oz.) of available water. Thus root media A was more efficient at absorbing water at low applied volumes of irrigation water.

During this experiment, high volumes of water were normally applied. In comparison, relatively low volumes of water were applied to the root media blends in Experiment 1. Perhaps this could explain why there was a large difference in the AWHC of the commercial root media (average 2.0 liters (69 fl.oz.) compared with the root media blends used in Experiment 1 (average 1.3 liters (44 fl.oz.)). With the exception of the Baccto Rockwool Blend, the difference between the highest and lowest AWHC of the commercial root media (0.5 liters (17 fl.oz.) was less than the difference found in Experiment 1 for blends of components mixed at MSU (0.8 liters (27 fl.oz.)).

The second property of a root media that determines how long similar size plants go between irrigation is the availability of the water or the moisture release characteristics of the root media. In a comparison of two of the root media, there was a 0.47 liter (16 fl.oz.) difference in the amount of available water but there was no difference in the ADI or MDI. Root media C held more water but this water may have been easily available to the plant and was used rapidly. Root media D held less water but it was less available to the plant so it was used more slowly by the plant. The result was that the time between irrigations was similar for both root media. The regulatory role of moisture availability and the plant must be considered when comparing root media.

When AWHC was determined in a low light environment for mature plants with thorough root penetration of the root media, the difference from the start of visible wilt to severe wilt was only 5% of the total amount of available water and may have been due in part to water lost from the impatiens foliage. When visible wilt is observed in a plant grown in a peat-lite mix, there is very little less available water for the plant to use and permanent wilt will occur unless water is applied rapidly. Other researchers have come to a similar conclusion (DeBoodt and Verdonck, 1972; Beardsell et al., 1979; Fonteno and Nelson, 1990).

The greatest complaint consumers had with hanging baskets was keeping them adequately watered (Zehner and Krauskopf, 1991). None of the plants grown in the commercial root media tested averaged less than four days between irrigation. Only LC1 and Suremix went a minimum of two days between watering. This would indicate that the root media being used in the baskets are not the problem. Perhaps the retailer/consumer is not applying a sufficient amount of water at each irrigation to get the full benefit of the root media's water holding capabilities.

Table 2. Available water holding capacity (AWHC), average days between irrigation (ADI) and minimum days between irrigation (MDI) of 10 commercial root media in Experiment 3 between May 10 and June 6. Root media are listed in alphabetical order. Value takes into account the water reservoir in the basket.

root media	AWHC liters (fl.oz.)	ADI	MDI
Baccto	1.80 (61)	4.7	3.0
Baccto Rockwool Blend	1.51 (51)	6.3	4.0
LC1	1.89 (64)	4.5	2.0
Metro Mix 360	2.13 (72)	4.8	3.0
OPM #8	1.95 (66)	4.9	4.0
Peatwool	2.10 (71)	6.3	4.0
Postharvest Mix	2.04 (69)	4.6	3.0
Pro-Mix BX	2.28 (77)	4.7	3.0
Suremix	1.86 (63)	4.3	2.0
Suremix Rockwool Blend	2.16 (73)	5.0	4.0
Average	1.98 (67)	5.0	3.2
LSD[z]	0.13 (4.4)	0.7	1.0

[z]Least significant difference between any two means that in different at a 95% level of confidence statistically.

Table 3. Percent air space, total water space, and solid for ten commercial root media in a 15 cm (6 inch) standard pot. Each value is the mean of three determinations completed at different times. Root media are listed in alphabetical order. Values are the percent of the total volume of the pot (volume 1.7 liters (57 fl.oz.)).

root media	% air	% total water	% solid
Baccto	16	55	29
Baccto Rockwool Blend	18	61	21
LC121	55	24	24
Metro Mix 360	20	63	18
OPM #8	25	53	23
Peatwool	24	62	14
Postharvest Mix	22	64	14
Pro-Mix BX	21	57	22
Suremix	17	54	29
Suremix Rockwool Blend	22	59	19
Average	21%	58%	21%
LSD[z]	4%	4%	4%

[z]Least significant difference between any two means that in different at a 95% level of confidence statistically.

Wetting Agent

The effect of the wetting agent was dependent primarily on the type of peat used in the root media. In this experiment, the wetting agent had the greatest effect on the Baccto Rockwool Blend that contained a more degraded Michigan sphagnum peat with short fiber and a large amount of peat dust compared to long fibered Canadian sphagnum peats used in most of the other root media. We concluded that the need for additional wetting agent applications should be determined for each root media independently. The grower should use the method for determining the AWHC used in these experiments on baskets that are almost ready for ship.

Experiment 4:

Effect of commercial production on the garden quality of flowering hanging baskets.

Introduction

This experiment was a continuation of Experiment 3 in that commercially available root media were evaluated for AWHC. Since the baskets evaluated came from 10 different commercial greenhouses, basket style, impatiens cultivar, and production method were also variables.

Materials and Methods

Twenty five centimeter (10 inch) impatiens baskets were obtained from 10 different wholesale and retail commercial greenhouse growers throughout the state of Michigan between April 23 and May 14, 1991. The basket internal volume varied from 4.9 to 6.8 liters (1.3 to 1.8 gallons). Baskets were maintained inside a MSU greenhouse until May 30, at which time they were placed in the IEA. Water, fertilizer and wetting agent application methods were the same as Experiment 3. On June 28, half the baskets were saturated with tap water containing the wetting agent. The remaining baskets were saturated with only tap water. On September 23, plants were sampled to determine shoot fresh weight.

Empty baskets were also collected from the different commercial growers to determine the volume of the different styles. Volume was determined by taping the drainage holes and filling the basket with water to the rim or 2 cm (0.8 in) below the rim. The volume of the reservoir was measured separately by filling until water drained from the basket.

Results

Root Media: Throughout the summer, there was a difference in the visual size of the grower produced plants (Figure 11). Shoot fresh weight at the end of the experiment ranged from 1.0 kg (2.2 lbs) to 2.2 kg (4.9 lbs).

Between May 30 and July 26, the average AWHC was 2.0 liters (67.6 fl.oz.) and ranged from 2.5 liters (84.5 fl.oz.) to 1.8 liters (60.8 fl.oz.). The ADI was 4.2 days and ranged from 5.9 days to 2.4 days. The MDI ranged from one to three days (Table 4).

Total basket volume was 4.8 liters (1.3 gallons) in 8 of the 10 baskets used by the commercial growers. The volume of the basket determined 2 cm (0.75 inches) below the rim was reduced by an average of 1 liter (0.26 gallons). Two growers used baskets with a volume of 6.4 liters (1.8 gallons) or 5.5 liters (1.5 gallons) respectively. The volume of these baskets determined 2 cm (0.75 inches) below the rim was 5.3 liters and 4.7 liters. The volume of the reservoir ranged from 0.70 liters (23 fl.oz.) to 0.06 liters (2 fl.oz.). In general, saucerless baskets had a 50% greater reservoir volumes than baskets with external saucer reservoirs.

Wetting agent: The application of Aquagro 2000® had no effect on the final plant fresh weight compared with plants that received a tap water application. Wetting agent had no effect on the AWHC averaged over all root media—or on the ADI or MDI.

Discussion

Root media characteristics in this experiment were similar to Experiment 3. However, there were several other differences worth noting. There were extreme differences in the plant size of the baskets produced by commercial growers. These differences were due either to cultivar or cultural practices. Figure 11 illustrates impatiens baskets from two different commercial growers. In both cases, the plants would have been acceptable to the consumer. Both of the plants were grown in root media containing a peat/rockwool blend that held approximately 1.9 liters (64 fl.oz.) of available water. The larger plant used an average of 0.74 liters (25.0 fl.oz) of water per day between May 30 and June 27 in the IEA compared to an average of 0.36 liters (12.1 fl.oz.) per day for the smaller plants. The larger plants were watered twice as often as the smaller plants. It can be concluded large plants may be more susceptible to drying out and a smaller plant will require less maintenance during the first few weeks after sale.

Figure 11. Example of the difference in plant size from different commercial growers in Experiment 4.

Table 4. Available water holding capacity (AWHC), average days between irrigation (ADI) and minimum days between irrigation (MDI) of impatiens hanging baskets from 10 commercial growers in Experiment 4 between May 30 and June 27. ADI and MDI are an average from six baskets. Growers were arbitrarily numbered 1 - 10.

grower	basket volume liters (gallons)	AWHC liters (fl.oz.)	ADI	MDI
1	4.8 (1.3)	1.86 (63)	5.1	4.0
2	4.8 (1.3)	2.00 (68)	4.7	4.0
3	4.8 (1.3)	1.84 (62)	3.9	2.8
4	6.4 (1.8)	2.75 (93)	4.0	3.0
5	4.8 (1.3)	1.89 (64)	2.5	1.7
6	4.8 (1.3)	1.81 (61)	4.0	3.2
7	4.8 (1.3)	2.01 (68)	4.0	3.2
8	5.5 (1.5)	2.49 (84)	4.6	3.0
9	4.8 (1.3)	2.19 (74)	5.8	4.5
10	4.8 (1.3)	2.10 (71)	3.7	2.7
Average		2.09 (71)	4.2	3.2
LSD[z]		0.19 (7)	0.8	1.1

[z] Least significant difference between any two means that in different at a 95% level of confidence statistically.

The other difference in commercial baskets was basket style. When asked, many growers said that there was a difference in volume between the various styles of 25 cm (10 inch) hanging baskets but none had made any measurements. Eight of the 10 different basket styles collected had similar volumes. When the largest style basket was compared with the "standard" baskets using the same root media (Metro Mix 360; Experiment 3), the larger basket contained an extra 0.27 liters (9.1 fl.oz.) of available water. Between May 30 and June 27, the average plant used 0.49 liters (16.6 fl.oz.) of water per day. This means the larger basket might provide an extra half day between irrigations.

Smaller diameter baskets, 20 cm (8 inch) or even 15 cm (6 inch), are still sometimes sold by retailers. However, baskets that have diameters smaller than 25 cm (10 inch) may not be good investments for the consumer. In general, a 20 cm (8 inch) basket holds only 42% and a 15 cm (6 inch) basket holds 14% of the root media contained in a 25 cm (10 inch) basket (Potting guide, Michigan Peat Co., Houston TX). Recent trends in Michigan appear to be for increasing availability of 30 cm (12 inch) baskets. These baskets have a volume of approximately 9 liters (2.3 gallons).

Experiment 5:

Water and fertilizer requirements of six species at two outdoor light levels.

Introduction

The main source of information the consumer has about the cultural need of flowering hanging baskets comes from plant care tags (Zehner and Krauskopf, 1991). The information consumers want on the plant care tags are preferred plant location, watering, and fertilization instructions. Most consumers do consider the specific location where the hanging basket is to be placed before it is purchased.

There is little or no published information about differences in water or fertilizer requirements of species used in hanging basket production. The objective of this experiment was to determine the water and fertilizer requirements of six different basket species grown at two different light levels.

Materials and Methods

Six different species (impatiens 'Accent White'; New Guinea impatiens 'Aglia'; ivy geranium; zonal geranium 'Pinto Red'; non-stop begonia 'Orange'; and fuchsia 'Marinka') were planted on March 7, 1991. The fuchsia, New Guinea impatiens and the non-stop begonias were rooted cuttings in 72 count cell flats and were planted four plants per basket. The ivy and zonal geranium transplants were in 9 cm (3.5 inch) standard pots and planted three per basket. The impatiens transplants were from 32 count cell bedding flats and were planted three per basket.

The basket was the same as in Experiment 3. The root media was a commercially available peat/rockwool/perlite mix (Suremix Rockwool Blend, Michigan Growers Products, Galesburg MI).

While the plants were in the greenhouse, water or fertilizer solution was not applied in great enough quantities for leaching to occur. Water and fertilizer solution were treated with acid (0.5 mls H_2SO_4 per 3.8 liters (1.7 oz./100 gallon)) to reduce the alkalinity of the water to 80 mg liter^{-1} $CaCO_3$.

Six baskets from each species were moved to the OEA on June 3. For the high level light treatment, baskets were placed on the south side of the structure and the snow fence was removed from over the top of the row. For the low light level treatment, baskets were placed on the north side of the structure under a double layer of shade cloth which reduced light levels to 25% of full sun.

Plants were checked daily by lifting the baskets to determine if the pots were close to the wilt weight. At that point, tap water was applied with a hose and breaker until it began to drain from the basket. Fertilizer solution (Peters 20-20-20 Peatlite, 300 mg liter^{-1}) was applied to each species (3 baskets) within a light level treatment as needed. AWHC was measured by weighing at each irrigation to determine the amount of water and or fertilizer that remained in the root media. The ivy and zonal geraniums, begonias and fuchsia had dead flowers removed on a continuous basis while the plants were outside.

On August 29, thermocouples were inserted into the center of the root mass from a hole in the side of the basket. Temperatures from four different species in either full sun or partial shade were recorded along with ambient air temperature and light levels in full sun and partial shade. The species tested were impatiens, ivy and zonal geraniums and fuchsia. Data was recorded every 30 minutes, 24 hours a day for 10 days.

On September 17, the baskets were brought back into the greenhouse. They were maintained inside the greenhouse until October 16, at which time the plants were sampled to determine shoot fresh weight. Baskets were maintained inside the greenhouse for four weeks to allow the experiment to last until mid October. No WSF was applied during the final 4 weeks.

Results

Averaged over all species, the amount of water used per day was 0.56 liters (19 fl.oz.) in plants grown in full sun while in partial shade the plants used 0.51 liter (17 fl.oz.) of water per day. Between June 3 and September 17, plants grown in full sun averaged 4.0 days between irrigations while the plants grown in shade averaged 4.3 days. The difference in the amount of fertilizer applied to the baskets in the two locations was 0.48 grams N or 1.6 liters (54 fl.oz.) more fertilizer solution applied to the plants grown in full sun.

For the species tested, the greatest difference in water and fertilizer use occurred between the ivy geraniums and the non-stop begonia (Table 5; see page 14). Between June 3 and September 17, water use ranged from 0.73 liters (25 fl.oz.) per day for the ivy geraniums to 0.22 liters (7 fl.oz.) per day for the non-stop begonias. The ivy geraniums averaged 2.8 days between irrigation while the non-stop begonia went 8.4 days between irrigation. The amount of N-fertilizer applied ranged from 8.2 grams N for the ivy geraniums to 4.3 grams N for the non-stop begonias.

The average temperature of the root media in the baskets averaged 21°C (70°F) in both full sun and partial shade between August 29 and September 7. The outside air temperature averaged 22°C (71°F) over the same time period. When the day and night temperatures were separated, the root media in the baskets averaged 1.4°C (2.5°F) lower than the average air temperature during the day and 1.1°C (2.0°F) higher than the average air temperature

Table 5. Shoot fresh weight taken 8 months after planting in Experiment 5. Applied nitrogen in the total amount applied over the 8 months of the experiment. Average days between irrigation (ADI) and amount of water used per day are both calculated from the data collected during the time the baskets were outside.

Full sun	Shoot Fresh Weight (g)	Nitrogen-N Applied (g)	ADI	Water Use per Day (liters (fl.oz.))
Fuchsia	517	7.08	3.0	0.64 (22)
Ivy Geranium	1516	9.19	2.8	0.73 (25)
Impatiens	1387	7.46	3.6	0.59 (20)
N.G. Impatiens	NA[z]	6.67	3.3	0.56 (19)
N.S. Begonia	672	4.78	8.4	0.24 (8)
Zonal Geranium	888	7.33	3.2	0.60 (20)
Average		7.09	4.0	0.56 (19)
Partial Shade (25% full sun)				
Fuchsia	505	6.68	3.3	0.58 (20)
Ivy Geranium	1526	8.10	3.1	0.70 (23)
Impatiens	1488	7.38	4.3	0.48 (16)
N.G. Impatiens	NA	6.42	3.3	0.61 (20)
N.S. Begonia	1260	4.61	8.2	0.22 (7)
Zonal Geranium	823	6.17	3.7	0.49 (16)
Average		6.56	4.3	0.51 (17)
LSD[z]		1.02	0.8	0.10 (3.5)
Species		***	***	***
Light		*	*	NS
Species*Light		NS	NS	NS

[z]NA (not available). New Guinea impatiens died prior to fresh weights being recorded.
[y]Least significant difference between any two means that in different at a 95% level of confidence statistically.

during the night. The temperature of the root media in the fuchsia basket in full sun averaged 3.1°C (5.7°F) higher during the day and 1.7°C (3.0°F) lower during the night compared with the root media of the other basket species. The highest media temperature recorded in the fuchsia was 42°C (108°F) while the highest temperature in any of the other species was 34°C (94°F).

Plants grown in full sun were visually smaller through most of the summer. However, by the end of the experiment, there was no difference in fresh weight from the different species from the two locations except for the non-stop begonias. Non-stop begonias grown in partial shade were two times greater in fresh weight compared with plants grown in full sun. New Guinea impatiens died due to stem rot prior to plant sampling.

Discussion

Plant tolerances: All six species performed well in partial shade (25% full sun) but did not perform equally well in full sun. The tolerance to growing in full sun ranged from no difference in the visual quality of plants in either full sun and partial shade (sun tolerant plants) to a reduction in overall plant size and chlorotic leaves compared to plants grown in partial shade (sun sensitive plants). Ivy and zonal geraniums were examples of sun tolerant plants and non-stop begonias were examples of sun sensitive plants. The tolerance to growing in full sun in decreasing order were ivy geranium = zonal geranium > fuchsia > New Guinea impatiens > impatiens >>> non-stop begonias.

Based on pictures and observations (Figure 12), the growth of sun sensitive plants was greater in partial shade during most of the summer. The leaf size of both sun sensitive and sun tolerant plants was reduced in plants grown in full sun compared to partial shade. However, there was no difference in shoot fresh weight between those baskets grown in full sun compared to the baskets grown under partial shade for impatiens, fuchsia, ivy geraniums, and zonal geraniums when the plants were harvested on October 16. There was a flush of new growth observed in all the plants during the end of August to the middle of September. Perhaps the optimal growth conditions had shifted from partial shade to full sun at this time allowing for a quicker growth rate of the sun sensitive plants in full sun.

Evapotranspiration rates are normally expected to be higher with higher light levels. Both water used per day and days between irrigation were not significantly different between light levels. The similarity in water use between the two light levels may have been due in part to the smaller physical size of the plants grown in full sun during much of the experiment. Fully expanded leaves from all species (except New Guinea impatiens) were sampled to determine leaf area on October 17. The average area per leaf was 30% less from plants grown in full sun compared with the same species grown in partial shade. The smaller physical size and smaller leaf area may have reduced the higher evapotranspiration rates of plants grown in full sun.

Fertilizer requirements: Plants grown in full sun did receive an additional amount of nitrogen fertilizer compared with the same species grown in partial shade. This additional amount of nitrogen fertilizer amounted to an application of 1.6 liters (52 fl.oz.) of the fertilizer solution or approximately one irrigation if converted into the concentration of WSF used in the experiment. Additional fertilizer requirements for plants grown in higher light are normally associated with an increase in shoot fresh and dry weight accumulation. Since the plants grown in this experiment were similar in fresh weight over the two locations, it could also be expected that fertilizer requirements would be similar.

Temperature: The average outside air temperature was a good indicator of the average root media temperatures over the short time it was measured. In general, the temperature fluctuations were much less in the root media compared with the air temperature.

The greater fluctuation in root media temperature in the fuchsia baskets may have been due to the open leaf canopy habit of this species. The leaf canopy of all the other species covered the top of the root media. The shading effect of the leaves would have kept the day temperature of the root media lower during the day. At night, the leaves would have reduced the radiant heat loss.

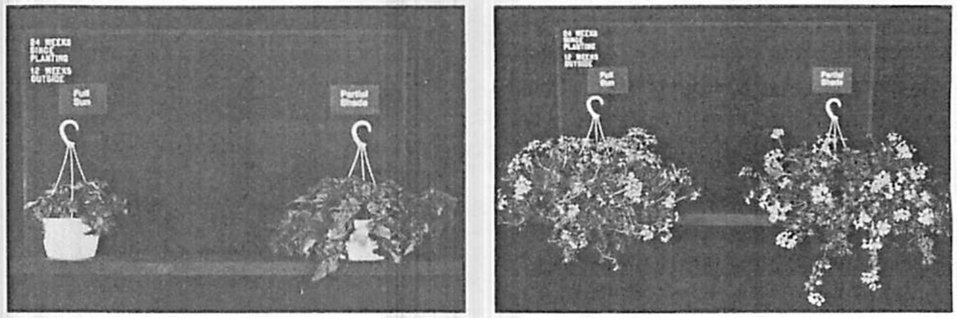

Figure 12. Examples of sun sensitive plants (non-stop begonia, left) and sun tolerant plants (Ivy Geraniums, right) from Experiment 5. Pictures taken twelve weeks after being placed outside.

Experiment 6:

Effect of two resin coated fertilizers on the production and garden quality of six flowering hanging basket species.

Introduction

Currently, there are two main sources of RCF for the greenhouse industry: Sierra® Controlled Release Nutrients (CRN) and Osmocote®, or Nutricote®. For Sierra CRN/ Osmocote® materials, the rate of release is based on an average temperature of 21°C (70°F) (Rutten, 1980). For Nutricote® materials, the rate of release is based on an average temperature of 25°C (77°F) (Shibata et al., 1979).

Another difference between the Sierra® and Nutricote® materials are in the resin coating used to control the release rate of the fertilizer salts. The release rate of Sierra/ Osmocote® products are altered by changing the number of coatings of resin. It has been reported that imperfections in the coating may allow for 10 to 20% of the fertilizer to be released in the first week after incorporation (Harbaugh and Wilfret, 1982). The release rate of Nutricote® products are dependent on a property of the resin coating. The release characteristics are reported to have a gradual initial release rate (Shibata et al., 1979).

In Experiment 1, the low recommended rate of incorporation for Osmocote® (13-13-13, 8-9 month) was not sufficient to keep impatiens actively growing over a six month period. It was concluded that higher levels RCF must be incorporated prior to planting to maintain nutrient levels through the four to five months of the summer.

Current recommendations for the incorporation of these two products prior to planting do not differentiate between different species used for flowering hanging basket production. The highest rate of incorporation is normally recommended for these "greenhouse crops". For Nutricote® with a release rate based on 140 days, the rate recommended is 7.1 kg m^{-3} (12 lb yd^{-3}) and for Sierra CRN® with a release rate based on 8-9 months, the recommended rate is 7.7 kg m^{-3} (13 lb yd^{-3}).

Materials and Methods

The two types of RCF tested were Sierra® CRN 17-6-10 plus minors, 8-9 month release rate (Grace/Sierra, Fogelsville, PA) and Nutricote® 18-6-8 plus minors, type 140 (Plantco Inc., Brampton, Ontario). The rates of incorporation were: 5.0, 5.9, 6.8, 7.7 kg m^{-3} for Sierra CRN® (8.5, 10, 11.5, 13 lb yd^{-3}) and 3.6, 4.7, 5.9, 7.1 kg m^{-3} for Nutricote® (6, 8, 10, 12 lb yd^{-3}). The experiment consisted of 8 fertilizer treatments and six species, the same as in Experiment 5, for a total of 48 baskets. There was no true experimental replication since replication of the different fertilizer treatments was made across species.

Between March 15 and June 3, all the baskets were leached heavily three times to reduce high soluble salts. The reason for leaching was the severely stunted appearance of the New Guinea impatiens and non-stop begonias. Root and stem rot severely affected the non-stop begonias so that this species was dropped from the experiment. After leaching, a combination of Subdue - 15 mls per 380 liters (100 gallons) and Benlate - 0.9 kg per 380 liters (2 lbs/100 gallons) was applied to control root rot. No other leaching occurred while the plants were in the greenhouse.

The baskets were moved to the OEA on June 4, 1991. Plants were maintained and irrigated with the same method used in Experiment 5 except that AWHC was not determined at each irrigation.

On September 17, the baskets were brought back into the greenhouse. They were maintained inside the greenhouse until October 14, at which time shoot fresh weight was determined. Root media samples were collected to determine final pH (1:1 (v:v)) and EC (1:2 (v:v)).

Results

During production, the effect of the different fertilizers was both species dependent and brand dependent (Figure 13, page 16). There was no difference in the visual quality of the ivy or zonal geraniums at the different incorporation rates and for either fertilizer. The growth of the New Guinea impatiens and non-stop begonias were stunted at the higher incorporation rates of both products. At the low incorporation rates, plants grown in root media containing the Nutricote® showed no signs of stunting. Plants grown in root media containing Sierra CRN® were stunted with downward curling leaves.

There was a shift in the effect of the different fertilizer treatments outside. By 19 weeks after planting (7 weeks outside), there was no difference in the visual quality of the New Guinea impatiens or zonal geraniums at any of the four rates or between the two products. The fuchsia were still stunted at the high rates of incorporation of both products. Impatiens and ivy geraniums were showing signs of low nutrition at the low incorporation rate of Nutricote®.

By 24 weeks after planting (12 weeks outside), impatiens and zonal geraniums were chlorotic with all RCF treatments. Ivy geraniums and fuchsia were showing low nutrition at the two lowest rates in

Nutricote® and the lowest rate of Sierra CRNR. Stem rot was observed in the New Guinea impatiens. By the time the plants were brought inside the greenhouse at the end of the experiment, all the New Guinea impatiens had died.

The average pH measured in the root media at the end of the experiment or 8 months after planting was 8.3 for the Sierra CRN® fertilizer and 8.2 for the Nutricote® fertilizer. Similar pH levels were measured over the different incorporation rates for each product. Soluble salt levels measured with the 1:2 (v:v) testing method in the same sample was 0.38 mS cm^{-1} for the Sierra CRN® fertilizer and 0.37 mS cm^{-1} for the Nutricote® fertilizer. The range of EC levels for the different RCF over the incorporation rates were 0.32 to 0.43 mS cm^{-1} in the Sierra CRN® and 0.34 to 0.40 mS cm^{-1} for the Nutricote®.

Table 6 is a comparison of the shoot fresh weight from the largest treatment fertilized with incorporated RCF (Sierra CRN® at 7.7 kg m^{-3} (13 lbs yd^{-3}) from this experiment compared with the fresh weight of the average plant fertilized with WSF (Experiment 5). The difference in the fresh weight ranged from 1.4 to 2.4 times greater in plants fertilized with WSF.

Greater amounts of N-fertilizer were applied to different species used in Experiment 5 receiving WSF compared to highest rate of either Sierra CRN® (6.2 g N) or Nutricote® (6.1 g N) and ranged from 6.8 g N for the zonal geraniums to 8.7 g N for the ivy geraniums. The equivalent amount Sierra CRN® containing 17% N ranged from 8.4 to 10.8 kg m^{-3} (14.2 to 18.1 lbs yd^{-3}). The equivalent amount of Nutricote® containing 18% N ranged from 7.9 to 10.2 kg m^{-3} (13.4 to 17.2 lbs yd^{-3}).

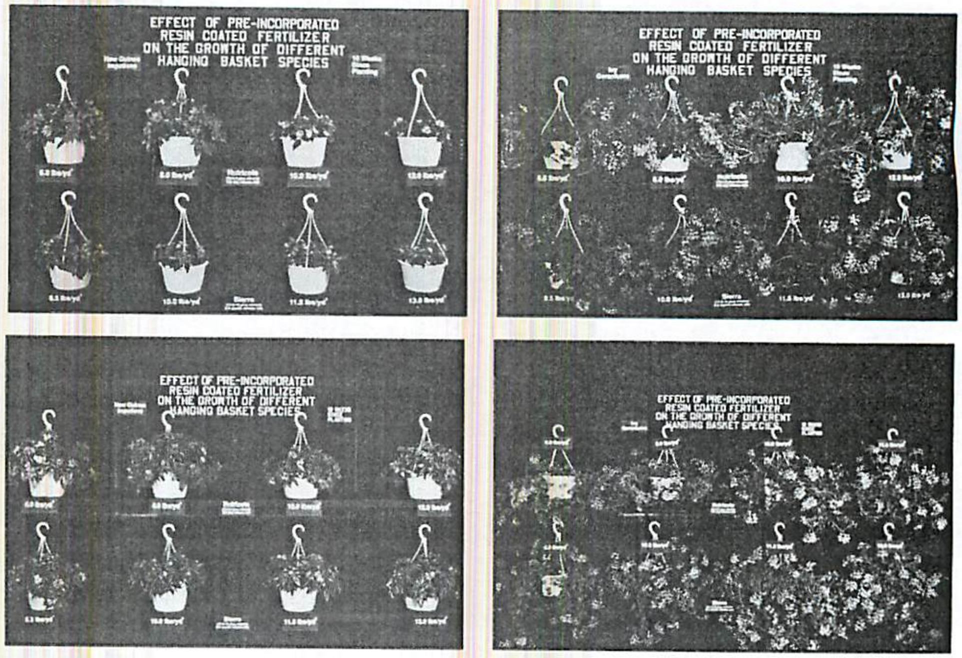

Figure 13. Example of fertilizer-sensitive plants (New Guinea impatiens) and fertilizer-tolerant plants (ivy geraniums) from Experiment 6. Pictures A and B were taken 10 weeks after planting. Pictures C and D were taken 19 weeks after planting or 7 weeks after being placed outside.

Discussion

From results of this experiment, we concluded that the species tolerance of high root media nutrient levels due to the increasing rates of incorporation of RCF varied dramatically. At one extreme were the fertilizer-tolerant plants, ivy and zonal geraniums. Increasing levels of fertilizer did not effect early growth. At the other extreme were the fertilizer-sensitive plants, New Guinea impatiens and non-stop begonias. At the high rates of incorporation, both species had stunted shoot growth with leaves curling downwards which is an indication of high soluble salts. Fuchsia and impatiens were moderately tolerant of high root media nutrient levels.

For the fertilizer-sensitive plants, the degree of stunting was also brand dependent. New Guinea impatiens grown in root media containing Sierra CRN® were stunted at all incorporation rates. This stunting may have been due to the high initial release of fertilizer salts that is reported for Sierra® products (Harbaugh and Wilfret, 1982). New Guinea impatiens grown in root media containing Nutricote® were stunted at the two high incorporation rates but grew normally at the two low incorporation rates. However, a direct comparison between the two products is difficult since the low rates of incorporation of the two products were not similar.

The rate at which the fertilizer salts are released for both types of fertilizer is solely dependent on temperature (Shibata et al.,

Table 6. Comparison of the average shoot fresh weight of plants fertilized with water soluble fertilizer from Experiment 5 and the shoot fresh weight of the largest plant from the different RCF treatments in Experiment 6. Applied N from WSF is the average amount of fertilizer applied to both light treatments from Experiment 5. Equivalent amounts of Sierra CRN® and Nutricote® are calculated using 17% N and 18% N respectively and assume 100% release rate. Recommended incorporation rates for Sierra CRN® is 7.7 kg m^{-3} (13 lb yd^{-3}) and for Nutricote® is 7.1 kg m^{-3} (12 lb yd^{-3}).

	Shoot Fresh weight WSF plants (g)	Shoot Fresh weight RCF plants (g)	Applied grams N from WSF (20-20-20)	Equivalent Sierra CRN® kg m^{-3} (lb yd^{-3})	Equivalent Nutricote® kg m^{-3} (lb yd^{-3})
Fuchsia	511	253	6.88	8.6 (14.5)	8.1 (13.7)
Ivy geranium	1521	699	8.65	0.7 (18.1)	10.2 (17.2)
Impatiens	1438	1013	7.42	9.3 (15.6)	8.7 (14.7)
Zonal Geranium	855	357	6.75	8.4 (14.2)	7.9 (13.4)

1979; Rutten, 1979). For every increase of 5°C, there is a 25% increase in the rate of release for both these products. During April and May of 1991, there were periods of 90°F (32°C) temperatures inside the greenhouse which may have caused excessive release of fertilizer salts. Most of the baskets produced in Michigan are scheduled for a late April ship date. The baskets produced at MSU in 1991 were scheduled to be placed outside on June 1. The later in the season, the higher temperatures that can be expected inside the greenhouse which may have contributed to the high fertilizer salt problem.

When high fertilizer salts become a problem, leaching with clear water is the normal recommendation. However, for many greenhouse bedding plant operations, leaching is not an option. Many commercial operations place hanging baskets directly over bedding flats. If baskets are leached, flats may be overwatered, washed out, or fertilized excessively by the leachate from the baskets.

When the fertilizer was applied may be as important as how much fertilizer was applied. From Experiment 5, New Guinea impatiens and zonal geraniums required similar amounts of nitrogen fertilizer between March 7 and September 17. However, New Guinea impatiens go through a period after planting when no new foliar growth is observed and appear to be sensitive to high root media nutrient levels at this time. Konjonian (1991) recommends waiting for one or two weeks before applying the first WSF and other growers wait until the plants begin to actively grow or roots reach the outside of the soil mass.

Zonal geraniums are normally much larger with a more developed root system early in production and may start growing almost immediately after planting. Zonal geraniums appear to be tolerant of high nutrient levels early after planting. Perhaps the time difference as to when active growth is observed could account for the differences in early fertilizer sensitivity between New Guinea impatiens and zonal geraniums.

Once the baskets were placed outside, leaching occurred and the stunted New Guinea impatiens began to grow. Perhaps lower temperatures outside also reduced the amount of fertilizer salts being released. By the beginning of August (19 weeks after planting), there was no visual difference in the quality of the baskets at any incorporation rate except for the lower rate of Nutricote® in the New Guinea impatiens.

At the end of August, increased growth was observed in the plants fertilized with WSF (Experiment 5). During this same period of time, symptoms of low nutrition were observed in all RCF incorporation rates. Plants fertilized with WSF were on average two times larger than the largest plant fertilized with RCF. This could have been due, in part, to the stunting. However, from the middle of August until the plants were brought inside the greenhouse in September, plants fertilized with RCF decreased in quality. The baskets were beyond the release time for the Nutricote® (20 weeks at 77°F (25°F)) but was still within the release time for the Sierra® (32-36 weeks at 70°F (21°C)). The average temperature of the root media may have decreased below that needed for the projected release rate. Between August 22 and September 3, the average outside air temperature was 71°F (22°C) but temperature data were not available after September 3.

There was no practical way to determine the amount of fertilizer that was still left in the RCF.

Experiment 7:

Surface application of resin coated fertilizer as a method of improving the garden performance.

Introduction

RCF can be applied to the surface of the root media at any time during the growing period or at shipping. Surface application or top dressing could also be a method of fertilization that a retailer could apply to a flowering hanging basket prior to being sold to a consumer. Another possibility is that a small package of RCF could be sold along with the hanging basket for the customer to apply to the basket.

Materials and Methods

Twenty five centimeter (10 inch) baskets flowering with impatiens were obtained from two producers in the state of Michigan between May 1 and May 7, 1991. Two liters of fertilizer solution (Peters 20-10-20 peatlite, 300 mg $liter^{-1}$) were applied to each basket to maintain quality. Water was applied at all other times at visible wilt.

On June 5, RCF treatments were applied to the baskets as they were moved to the OEA. Treatments consisted of 1) No fertilizer, 2) WSF, 3) 12 g (2 tsp) RCF "top dressed", 4) 18 g (3 tsp) RCF "top dressed", 5) 24 g (4 tsp) RCF "top dressed", 6) 2 RCF plugs (15 g) and 7) 3 RCF plugs (22.5 g). The WSF used was Peters 20-20-20 Peatlite at a concentration of 300 mg $liter^{-1}$ applied as needed. The "top dressed" RCF was Sierra® 17-6-10 plus minors with a release rate of 8-9 months. The RCF plug was Sierra Tablets® 16-8-12 plus minors with a release rate of 8-9 months (Grace/Sierra, Fogelsville, PA). Plants were checked daily and irrigated at visible wilt. Between September 17 and October 20, all the baskets were watered with tap water. On October 20, plants were sampled to determine fresh weight. Soil samples were collected to determine root media pH and EC.

Results

Plants with no additional applied fertilizer quickly decreased in quality and after two weeks were noticeably chlorotic with a decreased number of blooms. After 7 weeks, the low rate of RCF became noticeably chlorotic. After 12 weeks, the medium rate of RCF and the two RCF plugs became chlorotic. Plants fertilized with the highest rates of RCF continued to flower and grow normally until the end of August (Figure 14). At the end of August, all plants fertilized with RCF began to show symptoms of leaf chlorosis and abscission.

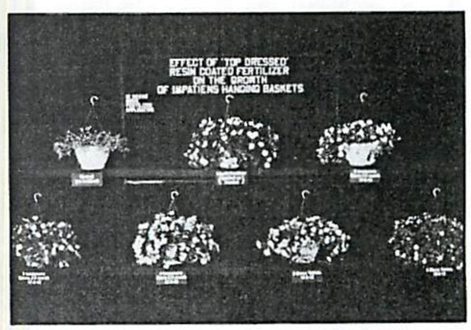

Figure 14. Effect of surface applied RCF on lasting quality of impatiens in Experiment 7. Picture taken 12 weeks after surface application.

At the end of the experiment, plants grown with RCF were of smaller size and lower visual quality compared with plants fertilized with WSF. Averaged over the plants from both growers, the fresh weight of the plants fertilized with RCF ranged from 800 g (1.7 lb) from plants fertilized with 12 g (2 tsp) RCF to 1000 g (2.2 lb) from plants fertilized with 3 RCF tablets (data not shown). Plants fertilized with WSF had an average fresh weight of 1480 g (3.3 lb) or were 50% larger than the largest plant fertilized with RCF.

Discussion

Decline in quality was related to the amount of fertilizer applied. The greater the amount of RCF applied initially, the longer the period of active growth. As with Experiment #6, plants that were fertilized with RCF were not able to sustain the flush of growth at the end of the summer even at the high top dressed rate. If RCF is applied to a basket, consumers may need to apply WSF once or twice at the end of the summer to maintain adequate nutrient levels in the root media for the new growth. An alternative may be to provide a RCF with a delayed release pattern.

Summary of All Experiments

An increase in AWHC increased the time between irrigations when a single component was mixed with one type of Canadian sphagnum peat. The AWHC of the 60% peat/40% component blends in decreasing order were rockwool > #2 vermiculite > perlite > polystyrene. The peat/rockwool blend had the greatest AWHC and the plants grown in the peat/rockwool blend went the greatest length of time between irrigations.

Water absorbent gel or zeolite did not effect the AWHC of the root media. The water absorbent gel Supersorb C® increased the ADI by 25% or one day compared to the same root media without gel but did not effect the MDI. In a laboratory experiment, the hydration of the gel decreased as soluble salts increased. The decrease in the hydration of the gel was greatest when calcium and magnesium were present. The incorporation of zeolite at 30 kg m^{-3} (50 lbs yd^{-3}) had no effect on the amount of fertilizer applied or plant growth but did increase the ADI by one day over plants grown in the same root media without zeolite. A wetting agent increased the amount of water held in 100% peat by 17% but did not increase the AWHC of commercial root media under the conditions of the tests. This may have been an effect of how the baskets were watered or from the fact that commercial root media were already treated with a wetting agent.

There was a difference in the AWHC of impatiens baskets produced in commercial root media ranging from 1.5 to 2.3 liters (51 to 77 fl.oz.). However, there was little difference in the average time between watering. We concluded that this was due, in part, to the way the water was released by the root media to the plant. The greatest difference in commercially produced impatiens baskets was in the size of the plant. The range in the daily water use of the largest and smallest plant was 0.32 to 0.75 liters (11 to 22 fl.oz) of water per day. In general, the larger the plant in a hanging basket, the more water that plant used per day. Another difference was in the volume of the 10-inch baskets. The majority of 10-inch baskets used had a volume of 4.9 liters (1.3 gallons). Only two commercial growers used 10-inch baskets with larger volumes. The greatest volume for a 10-inch basket was 6.8 liters (1.8 gallons). The greater root media volume in the 6.8 liter (1.8 gallon) basket increased the AWHC by 25%.

Based on comparisons of water soluble fertilizer (WSF) or resin coated fertilizer (RCF) either incorporated prior to planting or surface applied at some later time, we concluded that incorporated levels of RCF that produce the largest growth in the greenhouse are not sufficient for active growth outside during the summer. At high levels of incorporated RCF, the growth of some species such as New Guinea impatiens were stunted due to high soluble salts. Other species such as ivy geraniums showed no sign of stress at these same high incorporation rates.

Most commercial root media have a starting nutrient charge roughly equal to 0.6 kg (1 lb) $Ca(NO3)2$, 0.6 kg (1 lb) KNO3, and 1.2 kg (2 lbs) 0-20-0 per cubic meter (yd-3) plus some form of trace elements. This starting charge is equivalent to approximately 0.78 grams N per basket. This is a sufficient amount of fertilizer to keep a mature basket growing for a minimum of two weeks. This should be a sufficient amount of fertilizer for two to four weeks with a newly planted rooted cutting or seedling if no leaching occurs. From Experiment 5, we concluded that an additional 1.5 grams N would be required to produce a salable plant in a basket over 12 - 14 weeks. The majority of nitrogen fertilizer (5 to 6 grams N) is required after production.

If RCF were to be specifically designed for basket production, the duration of release would be approximately 7 to 8 month duration. The RCF should have very little release during the first two weeks of production. After the initial two week period, 1.5 grams N would release over 10 weeks. After production, 5 - 6 grams N would release over a 20 week period for a total release of 6.5 - 7.5 grams N. More nutrients should be released later in the summer when the temperatures are lower and plant growth is increased. If this fertilizer were 20% nitrogen and 80% of the fertilizer salts were to be released over the specified time period, 8.6 - 9.8 kg m^{-3} (14.5 - 16.5 lbs yd^{-3}) of the fertilizer would need to be incorporated prior to planting.

The main hanging basket species grown are fuchsia, ivy and zonal geranium, impatiens, New Guinea impatiens and non-stop begonias. All the species tested grew well in partial shade (25% full). There was a difference in how the species grew in full sun ranging from sun tolerant plants, such as ivy geraniums, that grew equally well in full sun and partial shade to sun sensitive plants, such as impatiens, that were visually smaller and chlorotic during most of the summer compared to the impatiens grown in partial shade. Non-stop begonias grown in full sun were severally stunted and therefore we conclude that they should not be grown in full sun. When the plants were harvested, there was no difference in shoot fresh weight between the two light locations except for the Non-stop begonias. However, since only one cultivar of each species was tested, more cultural testing in full sun and shade should be completed before categories such as these are widely applied.

There was not a significant difference in the amount of water used per day by the different species in full sun compared to partial shade. The water use of the species ranged from 0.74 liters (25 fl.oz.) per day for the ivy geranium to 0.21 liters (7 fl.oz.) per day for the non-stop begonia. There was difference in the amount of fertilizer applied to species in the different light levels was less than the amount of fertilizer applied at one normal fertilization. However, the difference between the species ranged from 8.2 grams N for the ivy geraniums to 4.3 grams N for the non-stop begonias.

Flowering plants in hanging baskets produced under generally accepted management practices lasted through the summer and continued to flower and actively grow. The best methods of improving garden performance of flowering hanging baskets is to continue good production practices and to educate the consumer about how to maintain hanging baskets through the summer. Recommendations for the hanging basket producer and to help educate the consumer based on this research are included in this report.

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Root Media Component and Amendment Costs

The cost of root media components and amendments and estimated cost per basket based on 10 inch hanging baskets filled at a rate of 6 baskets per ft³ or 162 baskets per yd³. Actual prices may vary. This list is for comparison purposes only.

Components	$/yd³	$/ft³
Canadian sphagnum peat	$28-$37	$1.00-$1.36
perlite	$38-$51	$1.40-$1.90
vermiculite #2	$49-$57	$1.80-$2.10
polystyrene	$5-$6	$0.19-$0.23
rockwool	$38-$48	$1.40-$1.80
commercial root media	$54-$108	$2.00-$4.00

Amendments	$/lb.	$/yd³	$/basket
calcined clay			
(50 lbs./yd³)	$0.11-$0.12	$5.35-$5.70	$0.033-$0.035
zeolite			
(50 lbs./yd³)	$0.10-$0.12	$5.00-$5.70	$0.031-$0.035
Supersorb C®			
(1.5 lbs/yd³)	$6.23-$7.60	$9.35-$11.40	$0.058-$0.070
Aquagro L®			
(9 fl.oz./yd³)[1]		$1.62-$2.25	$0.010-$0.014
(1000 ppm drench)		$1.87-$2.60	$0.012-$0.016
(2500 ppm drench)		$4.68-$6.50	$0.029-$0.040
Sierra® RCF	$1.00-$1.40		
incorporated			
(7 lbs./yd³)		$7.00-$9.80	$0.043-$0.060
(8.5 lbs./yd³)		$8.50-$11.90	$0.052-$0.073
(10 lbs./yd³)		$10.00-$14.00	$0.062-$0.086
(11.5 lbs./yd³)		$11.50-$16.10	$0.071-$0.099
(13 lbs/yd³)		$13.00-$18.20	$0.080-$0.112
top dressed			
(2 tsp./basket)		$4.21-$6.00	$0.026-$0.037
(3 tsp./basket)		$6.48-$9.07	$0.040-$0.056
(4 tsp./basket)		$8.59-$12.00	$0.053-$0.074
Sierra® tablets	$1.94-$2.18		
(2 tablets-15 grams)		$10.37-$11.66	$0.064-$0.072
(3 tablets-22.5 grams)	$15.55-$17.50	$0.096-$0.108	
Nutricote® RCF	$1.20-$1.50		
incorporated			
(6 lbs./yd³)		$7.20-$9.00	$0.044-$0.056
(8 lbs./yd³)		$9.60-$12.00	$0.059-$0.074
(10 lbs./yd³)		$12.00-$15.00	$0.074-$0.093
(12 lbs./yd³)		$14.40-$18.00	$0.089-$0.111
Liquid Fertilizer	$0.40-$0.50		
Other Costs			
baskets		$81.00-$121.50	$0.50-$0.75
plant material	$0.05-$0.80/plant		
(3 plants/basket)		$24.30-$388.80	$0.15-$2.40
(4 plants/basket)		$32.40-$518.40	$0.20-$3.20
(5 plants/basket)		$40.50-$648.00	$0.25-$4.00

[1]Assume 1 drench application would be 1.9 liters (64 fl.oz.) per basket.

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For additional information on research funded to date or association activities, contact:

BPFI

P.O. Box 27241, Lansing, Michigan 48909-0517
Phone: (517) 694-8537 • Fax: (517) 694-8560