Crushed Glass Cullet Replacement of Sand In Topsoil Mixes

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CRUSHED GLASS CULLET REPLACEMENT OF SAND IN TOPSOIL MIXES

FINAL REPORT

Prepared for:

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Editor's note:

It has been found in other studies (see CWC reports GL97-2, *Crushed Glass as a Filter Medium for the Onsite Treatment of Wastewater*; GL97-1, *Testing Recycled Glass for Monitoring Well Packing*; and GL96-2, *Testing the Use of Glass as a Hydroponic Growth Rooting Medium*), that crushed glass has a higher permeability than natural sand of the same gradation. The reasons for this are probably a combination of the smooth non-absorbent surface of glass compared with natural aggregates, the fact that processed glass has newer fracture corners that create larger average interstitial spaces between grains, and no clay fines to stick to surfaces and inhibit flow. The glass used in this study had approximately the following gradation profile:

ASTM E-11 sieve	Percent passing
#4	100%
#8	70
#16	46
#30	25
#50	18
#100	7
#200	3

Unfortunately, a gradation analysis for the sand used in this study is not available.

As a result of these flow characteristics, it has also been found in other studies that the optimum grade of glass for any particular application may not be the same as the normally used sand or aggregate. In some cases, therefore, it is difficult to judge the efficacy of glass in a sand or aggregate application if it is not possible to perform an iterative process of trying different grades until the best one is found. This, of course, is difficult with ten week growth trials and a limited budget.

The results of this project should be judged in the light of the possibility that a different gradation would have performed better. The most important conclusions to be drawn from this study may be that the glass supported plant growth and soil drainage with no detected problems.

EXECUTIVE SUMMARY

The University of Washington Center for Urban Horticulture in Seattle, Washington conducted a study of topsoil media containing glass cullet. The study examined a topsoil that was composed of 50% compost and 50% sand and the effects of replacing portions of the sand with portions of glass cullet (50%, 30%, and 10% crushed glass). The objectives were to determine the growth performance of plants in a soil medium containing glass cullet and to determine whether these mixes would pose risks to plants or humans.

Results were measured ten weeks after three plant species were grown in the four different soil media. There were small, yet statistically significant differences in height and biomass between plants grown in the 50% sand mix, 50% glass mix, and 10% glass mix. There were insignificant differences in height or biomass between the 50% sand mix and the 30% glass mix, suggesting that a 3/5 replacement ratio of crushed glass for sand was not detrimental to plant growth.

In the tenth week, water leachate samples were collected from two replicates of each species for the 50% sand and 50% glass treatments. Chemical composition of the soil leachates revealed that nutrient levels between treatments within each species were not a significant limiting factor to plant growth. In addition, heavy metal analysis showed that the levels of lead and boron in the different mixes were no higher than in sand/compost samples. It was concluded that, within each species, the differences in plant growth between the treatments were attributed to the relationship between soil and water.

Analysis of the four soil mixes' water holding capacities (WHC) revealed that, while the 50% sand, 30% glass, and 10% glass media had similar water holding capacities, the 50% glass media had a higher WHC. The 50% glass mix also drained more quickly than the others.

A scratch test was utilized to test the safety of the soil for horticultural workers. The glass particles in the soil did not scratch a variety of materials. Further, thin vinyl gloves were worn to prevent skin abrasions while handling the different soils.

Results from this study suggest that it is feasible to use recycled glass to replace portions of sand in a standard topsoil mix. Topsoil composed of 3/5ths glass cullet instead of sand can produce plants of equal or greater growth size compared with plants grown in a standard topsoil. In addition, cost savings and a decreased reliance on virgin materials may be realized when glass is used in some portion of the mix.

1.0 INTRODUCTION

Topsoil products used by recreational gardeners and commercial landscapers typically contain compost and sand. Finding suitable replacements for virgin materials, such as sand, may increase the sustainability of urban environments and serve the needs of the growing population. The use of recycled glass cullet (i.e. crushed glass) in soil media is an intriguing concept.

In the Spring and Summer of 1997, the University of Washington Center for Urban Horticulture (CUH) in Seattle, Washington, conducted a study on the growth properties of soil media containing glass cullet. Cedar Grove Composting, Inc., with a grant from the Clean Washington Center, managed the project.

Cedar Grove currently markets a topsoil medium composed of 50% compost and 50% sand. This study examined the effects of replacing portions of the sand with varied or equal amounts of glass cullet. The objectives were to determine the growth performance of plants in a soil medium containing glass cullet and to determine whether these mixes would pose a risk to plants or humans.

The goals established for this study were to:

- recycle glass;
- reduce costs to Cedar Grove and its subsidiary, Emerald City Recycling;
- reduce the purchase cost of sand;
- reduce the use of virgin material; and
- create a topsoil product containing greater proportions of recycled materials.

2.0 PROCEDURES

Three plant species, **Ed Humes' early bush bean, 'Contender', Lily Miller's tomato, 'Early Girl'**, and **Yoder's garden chrysanthemum, 'Akron'**, were grown in four different media. The beans and tomatoes were grown from seed and the chrysanthemums from rooted cuttings. The media contained the following proportions of sand, glass cullet, and compost:

50% Sand Medium: 50% Sand, 50% Compost (Cedar Grove's current product)

50% Glass Medium: 50% Glass, 50% Compost

30% Glass Medium: 30% Glass, 20% Sand, 50% Compost

10% Glass Medium: 10% Glass, 40% Sand, 50% Compost

Soil media were initially hand-mixed into 3 11/16" pots, and 23 pots of each soil treatment were planted to each species. For safety measures, the glass was wetted before mixing to avoid inhalation of glass dust and vinyl gloves were worn to prevent hand abrasions when handling the soil mixes. At planting time, the chrysanthemums received a top-dressing of Apex Nursery Supreme 14-14-14 fertilizer. Tomato seeds were planted three to a pot to ensure adequate seedling survival and were thinned to one plant per pot two weeks after planting. Pots were arranged in the CUH greenhouse to negate the effects of any lighting or other environmental variation within the propagation bench.

One week after transplanting, the plants received Peter's Peat-Lite Special (15-16-17) fertilizer at 100 parts per million (ppm). 'Safer' Insecticide Soap was also applied at this time because the bean plants were suffering from an attack by thrips and whitefly **(Figure 1)**. Thrips did considerable damage to the bean plants. As a preventative measure, the soap was used on the tomatoes and chrysanthemums.

Five weeks after initial planting, the plants were transplanted to one-gallon containers. The soil media used in the one-gallon containers were bulk-mixed using a shovel and pitchfork. As mentioned under *Discussion*, materials for this transplanting were different from materials used in the initial potting. Support stakes were placed in the bean and tomato containers on the seventh week **(Figure 2)**.

During the tenth week, water leachate samples were collected from two replicates of each species under the 50% sand and 50% glass treatments **(Figure 3)**. Leachates were analyzed at the Soil Analysis Laboratory (University of Washington, College of Forest Resources) for heavy metal and nutrient concentrations, including lead, boron, zinc, magnesium, calcium, and iron (Table 1).

Growth success was measured after ten weeks' growing time. The 20 most uniform plants were selected. Severely diseased or broken replicates were eliminated and the tallest and shortest replicates were discarded. The plants were measured for height, biomass top, and root biomass; the number of pods was also recorded for bush beans. Biomass tops were removed with a pruner and placed in numbered paper sacks. For root biomass, a hose was used to wash the soil off roots; the roots were also placed in numbered paper sacks (**Figure 4**). The sacks were placed in a drying oven for 24 hours at 90º C. The dried plant materials were then weighed.

A scratch test was used to test the safety of the soil media for horticultural workers. The test involved running cherry tomatoes through troughs of each medium. Samples were then examined under a dissecting microscope (**Figure 5)**. The tomatoes burst under the pressure of being pushed through the mixes, but were not pierced by glass particles from any of the soil media. Other tests included running moleskin and Styrofoam packing 'popcorn' through the media. Glass did not catch in either of these materials. Throughout the study, handling the glass was not a source of discomfort **(Figure 6)**. As state previously, vinyl gloves were worn to prevent skin abrasions. However, it was later found that the gloves were not necessary to wear while mixing the soil media.

The water holding capacity (WHC) for each of the soil media was measured. Small volumes of each medium were saturated and then drained to field capacity (the amount of water a saturated soil will hold without further drainage). These samples were weighed, then placed in a drying oven for 24 hours at 102.5°C. The samples were weighed again and the difference in weights indicated the quantity of water in the soil at field capacity.

3.0 ANALYSIS

In order to analyze growth success data, the SAS program (General Linear Model Procedure) was used to perform one-way analysis of variance (ANOVA) for each species. The species were compared for height, top biomass, root biomass, total biomass, and number of bean pods. See *Appendix* for a complete set of these analyses.

4.0 RESULTS

Test results revealed small, yet statistically significant differences in height, biomass and number of bean pods between plants grown in the 50% sand mix, 50% glass mix, and the 10% glass mix **(Figures 7-13)**. There were negative but not statistically significant differences in height or biomass between the 50% sand mix and the 30% glass mix, suggesting that a 3/5 replacement ratio of crushed glass for sand had no detrimental effect on vegetative plant growth.

Growth differences were found for the chrysanthemums and beans planted in the 50% glass mix and the 50% sand mix and in the tomatoes and beans planted in the 10% glass mix and the 50% sand mix. The growth differences are summarized by species below.

Chrysanthemums

The 50% glass mix produced chrysanthemums with slightly shorter heights and lower biomass than the 50% sand mix **(Figures 7 and 8)**. While these differences are statistically significant, the amount of growth difference was visually unrecognizable. The chrysanthemums grown in all of the media appeared visually to be vigorous.

Tomatoes

The 10% glass mix produced tomatoes with lower heights and biomass than the 50% sand mix **(Figures 9 and 10)**. This height difference was visually obvious. The 30% glass mix produced tomatoes with a greater height and biomass than the 50% sand mix. Ironically, the higher level of glass replacement fared well and the lower level fared poorly. This phenomenon is discussed more fully under *Discussion*.

Beans

The 50% glass mix produced beans with lower height, biomass, and bean pods than the 50% sand mix. The 10% glass mix produced beans with lower root biomass than the 50% sand mix **(Figures 11-13)**. However, the beans were severely damaged by thrips and whitefly during week one, which may have influenced actual plant growth.

5.0 DISCUSSION

The objectives of this study were to test plant growth performance when crushed glass was used to replace sand in soil mixes. Results indicated that using 30% glass in the mixes was safe and had an insignificant negative impact on plant growth. Safety tests, like the cherry tomato scratch test and experimenter experience, indicated that properly crushed glass is safe to use.

Differences in plant growth may have been due to differences in physical and/or chemical properties between the soil mixes. Soil composition dictates physical properties and affects the availability of nutrients and water to plants. Nutrients and water are independent variables to plant growth when light, temperature, and carbon dioxide (CO_2) concentration are held constant between plants. Plant species require growth environments with species-specific nutrient and water levels. Since tomatoes do not occupy the same horticultural niche as chrysanthemums, finding a soil medium that satisfied both species' water and nutrient requirements may not have been realistic. For that reason, it was expected that the different species would respond differently to the soil media.

The chemical composition of the soil leachates showed that nutrient level between treatments within each species was not a significant limiting factor to plant growth; nutrients were not the cause for differences in plant growth. In addition, heavy metal analysis revealed that the levels of lead and boron in the different mixes were not higher for glass mixtures than for sand mixtures (Table 1). Therefore, it was concluded that, within each species, the difference in plant growth between the treatments was attributed to the soil/water relationship.

Variation in particle size and soil texture led to different water holding capacities (WHC) in the soil media. While the 50% sand, 10% glass and 30% glass media had similar WHCs, the 50% glass medium had a higher WHC **(Figure 14).** Further study of this phenomenon would be helpful in understanding differences between the soil mixes

Factors that may have influenced the results of this study included time, insect damage, collection technique for root data, and a lack of consistent material supply.

Time

Ten weeks was an insufficient growing period for the chrysanthemums and tomatoes to flower and fruit.

Insect Damage

Thrips and whitefly caused a significant amount of damage to the bush beans. The high nitrogen content of the bean leaves may have attracted the insects. Adding fertilizer to the water may have boosted the nitrogen levels in the plants and exacerbated the problem. Further studies should monitor insect damage and avoid over-fertilization.

Root Data Collection Technique

In order to remove a majority of the heavy soil materials, some root material was sacrificed. Height and top biomass figures are more accurate than total biomass and root biomass figures.

Materials

Materials used to create the initial potting soil mix were different than materials used to create the transplant mix. The initial potting mix was composed of a gravely sand and crushed bottle glass (from Orcas Island, Washington), and Cedar Grove 7/16” compost. The transplant mix was composed of finer sand and crushed window glass (from Bend, Oregon) and Cedar Grove compost.

Both sources of glass were processed in similar community glass processing systems manufactured by Andela Tool & Machine of Richfield Springs, New York. The glass from Orcas Island was community drop-box container glass. The glass from Bend, Oregon, was post-industrial plate glass from a window manufacturer **(Figure 15)**. Both types of glass are called "soda-lime" glass and have similar chemical compositions; plate glass is somewhat harder and slower annealing than container glass. Also, there may have been a small amount of residual organic material on the container glass. Both sources of glass were crushed and screened through a 4 mesh rotating trommel.

The use of varied materials may have created differences in the physical properties of the soil mixes. Soil texture (a measure of distribution of particle size) impacted physical properties, such as water holding capacity and root penetrability. Differences in soil texture (i.e., one may be finer than the other) along the soil profile may have created interfaces which interfered with root penetration and hydrology within the container.

6.0 CONCLUSION

The results of this study suggest that it is feasible to utilize recycled glass instead of sand in Cedar Grove's standard topsoil mix. This research indicates that replacing 3/5ths of the sand with glass cullet produces plants with equal or greater growth success as plants grown in the standard topsoil. Further research may prove that a higher proportion of glass replacement would be successful as well. In order to understand the complex relationship between plant growth and these soil media, further research should include quality control to ensure uniform materials, and detailed analyses of the physical properties of the glass materials.

Further, use of recycled glass would reduce operating costs for Cedar Grove and its subsidiary, Emerald City Recycling. Glass replacement would also reduce the consumption of virgin materials and allow Cedar Grove to offer its customers a more "environmentally-friendly" topsoil product for commercial landscaping and gardening.

APPENDICES

Table 1 - Nutrient Analysis of Soil Leachate By Species

	Al	As	B	Ba	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	NI	P
50% Glass: Tomatoes	2.04	ND	0.44	0.12	41.61	0.02	0.05	0.08	2.66	380.4	10.72	0.19	0.03	86.73	0.04	11.99
50% Sand: Tomatoes	7.25	TR	0.5	0.13	105.3	0.02	0.08	0.05	5.27	273.4	32.14	0.25	ND	65.81	0.03	2.105
50% Glass: Chrysanthemums	0.28	ND	0.25	0.02	9.88	0.02	0.02	0.05	0.61	120.7	2.38	0.03	ND	35.14	0.01	8.776
50% Sand: Chrysanthemums	14.5	TR	0.48	0.14	69.07	0.02	0.08	0.06	10.2	207.1	21.54	0.34	ND	54.85	0.04	3.121
50% Glass: Beans	1.94	ND	0.47	0.12	51.23	0.02	0.05	0.09	2.69	453.5	14.65	0.2	TR	96.87	0.04	13.16
50% Sand: Beans	7.291	ND	0.47	0.11	77.84	0.02	0.07	0.05	5.42	258.6	23.7	0.22	ND	53.94	0.04	2.876

	Pb	S	Se	Zn	Si
50% Glass: Tomatoes	TR	33.3	0.17	0.71	26.4
50% Sand: Tomatoes	TR	35.7	0.29	0.23	21.11
50% Glass: Chrysanthemums	ND	10.5	TR	0.37	12.1
50% Sand: Chrysanthemums	TR	45.7	0.35	0.38	33.6
50% Glass: Beans	TR	32.8	0.2	0.73	28.6
50% Sand: Beans	0.1	30.3	0.27	0.33	21.2

Fig. 1 Thrip and Whitefly damage to bean plants.

Fig. 2 Staked tomatoes in the 7th week of the experiment.

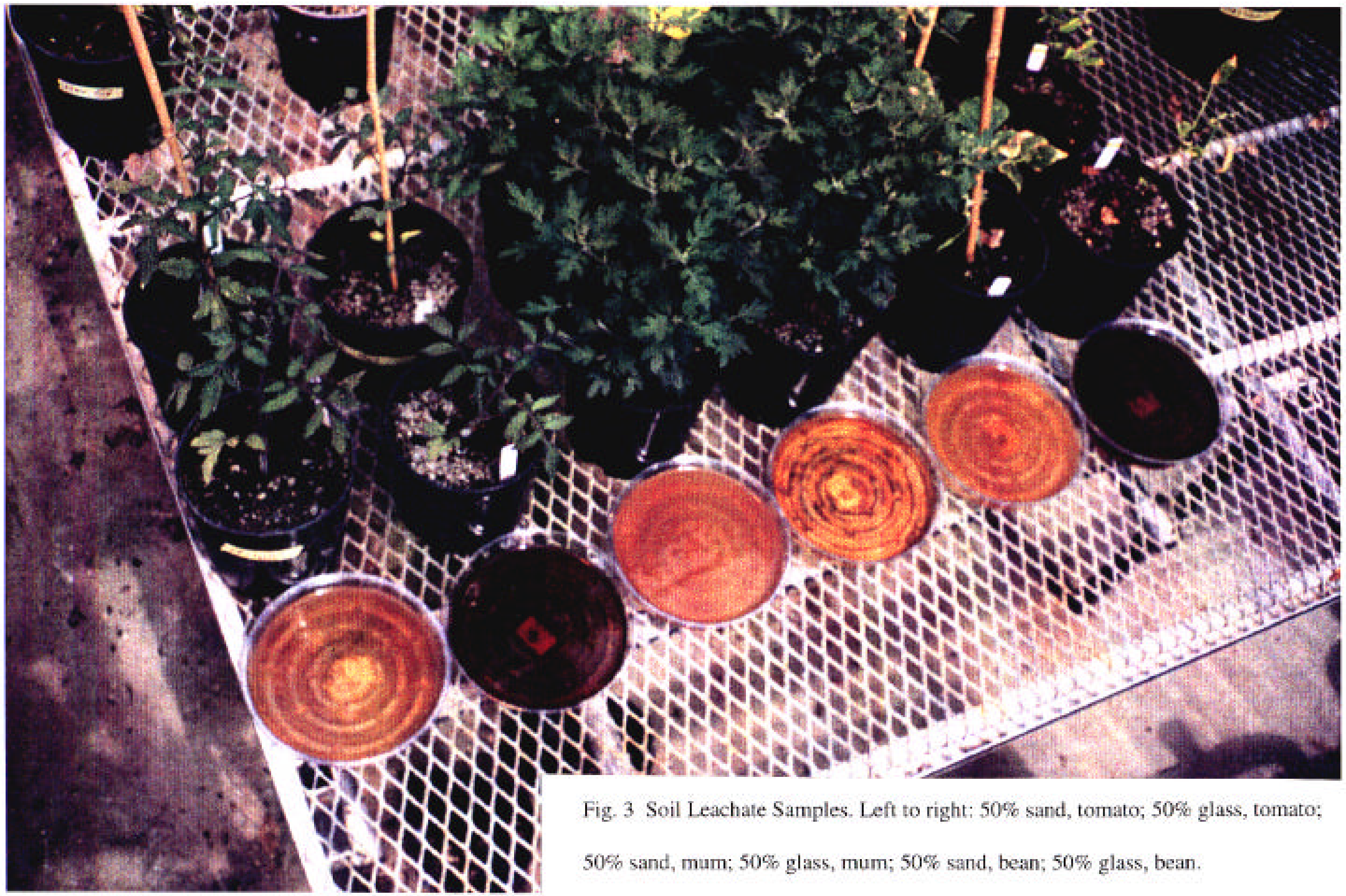

Fig. 3 Soil Leachate Samples. Left to right: 50% sand, tomato; 50% glass, tomato; 50% sand, mum; 50% glass, mum; 50% sand, bean; 50% glass, bean.

Fig. 4 Biomass Collection. Roots and tops were separated and oven-dried.

Fig. 5 Scratch Test Apparatus. Cherry tomatoes were run through these troughs to test for penetrability of materials in each soil medium.

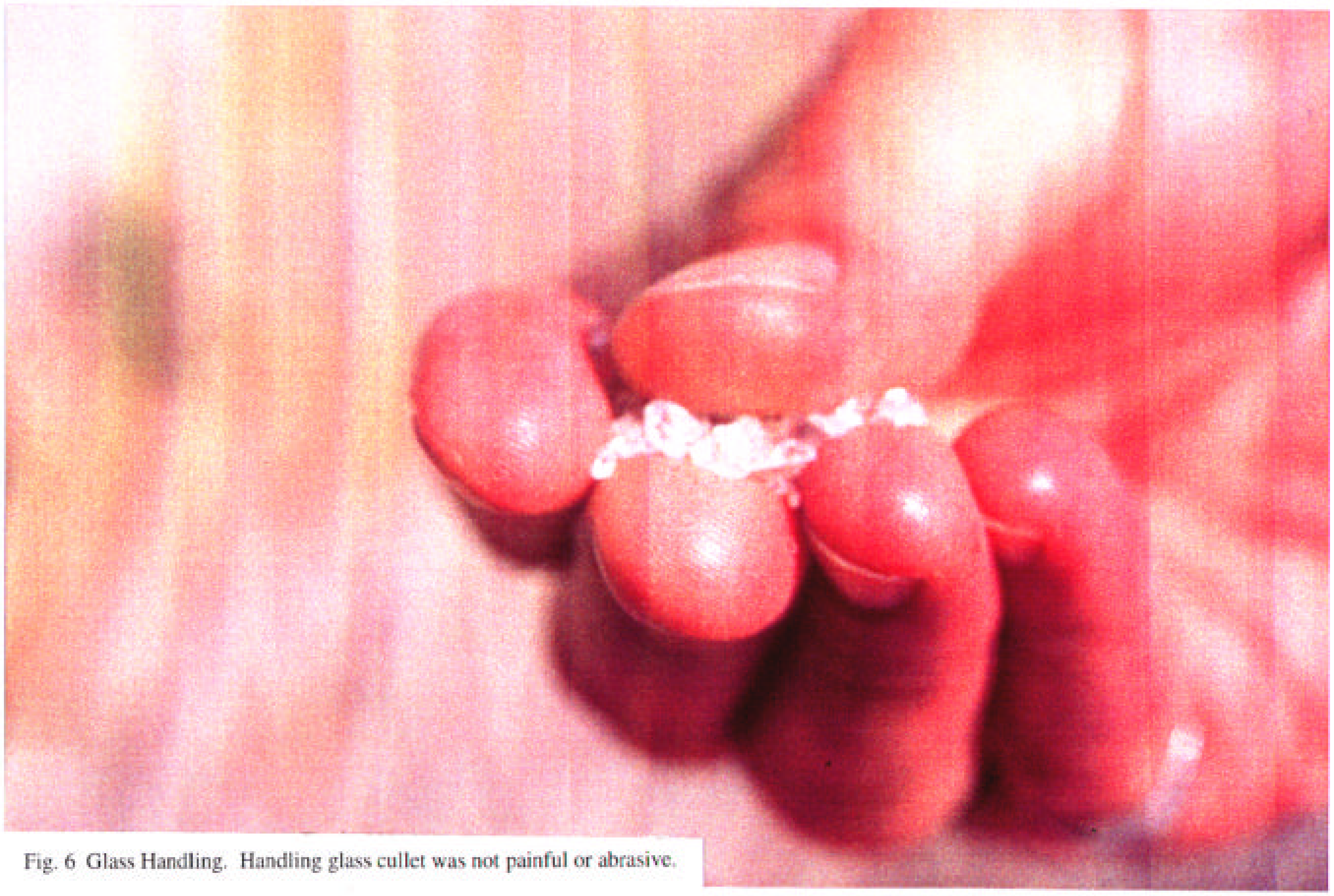

Fig. 6 Glass Handling. Handling glass cullet was not painful or abrasive.

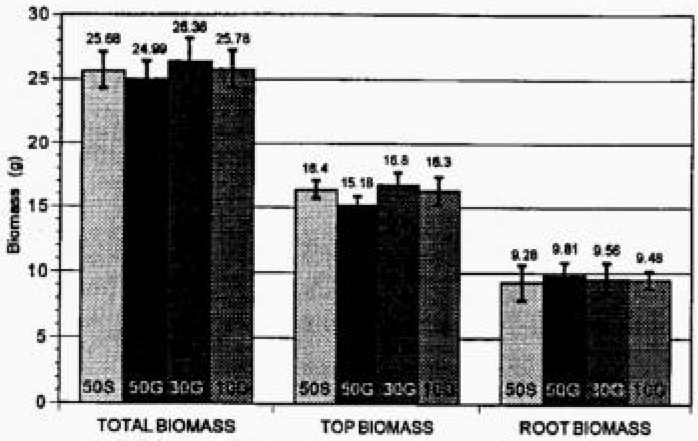

Fig. 7 Chrysanthemum Biomass. Biomass of chrysanthemums grown in four soil media.

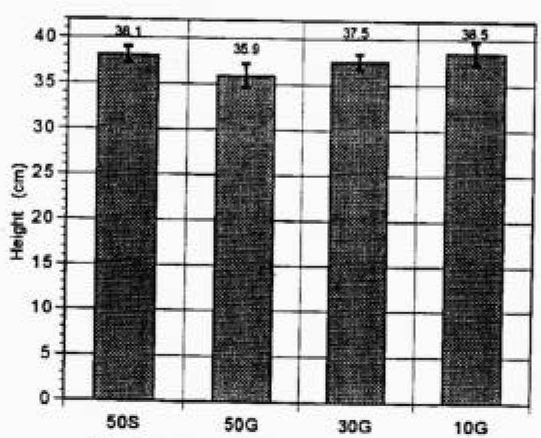

Fig. 8 Chrysanthemum Height. Height of chrysanthemums grown in four soil media.

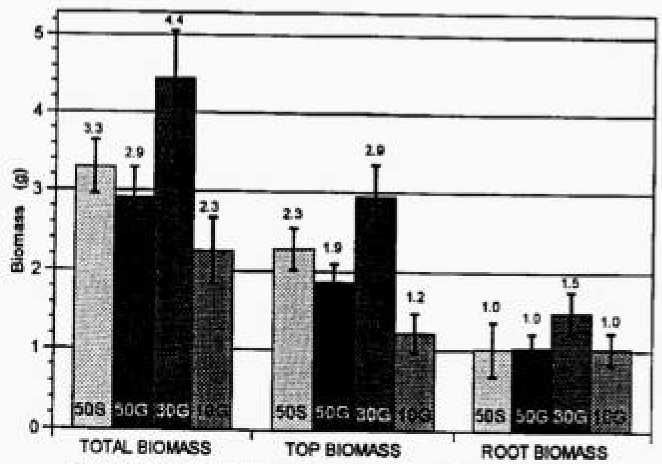

Fig. 9 Tomato Biomass. Biomass of tomatoes grown in four soil media.

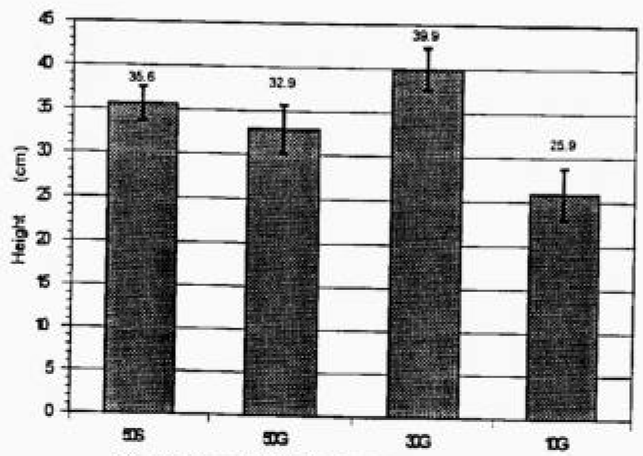

Fig. 10 Tomato Height. Height of tomatoes grown in four soil media.

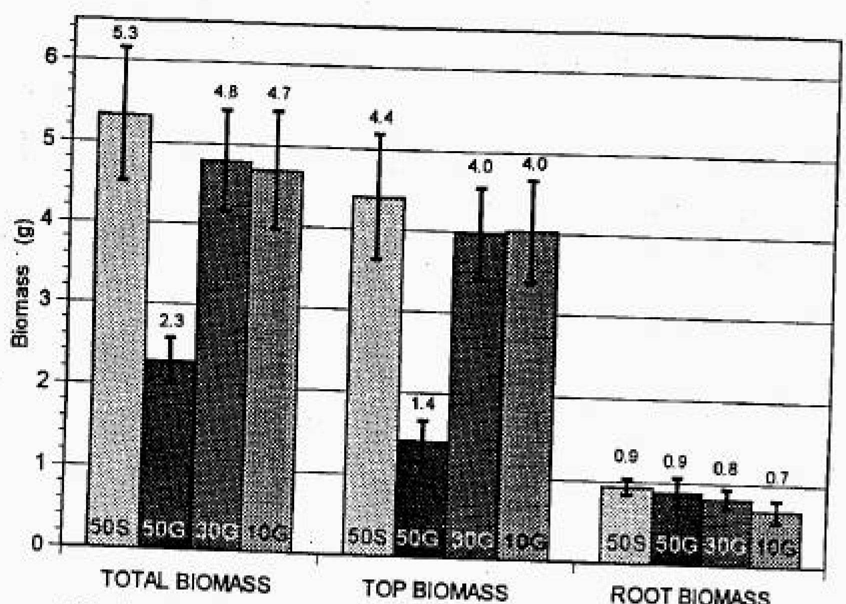

Fig. 11 Bean Biomass. Biomass of beans grown in four soil media.

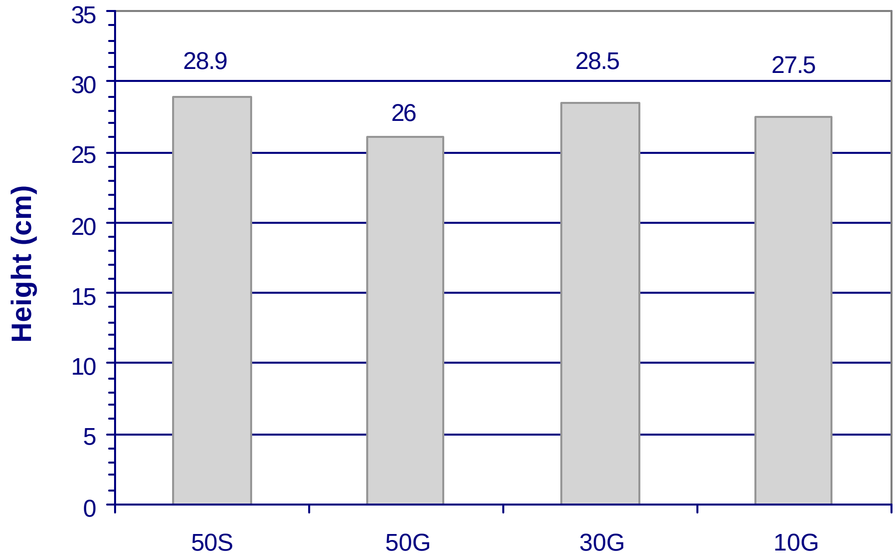

Fig. 12 Bean Height. Height of bean plants grown in four soil media.

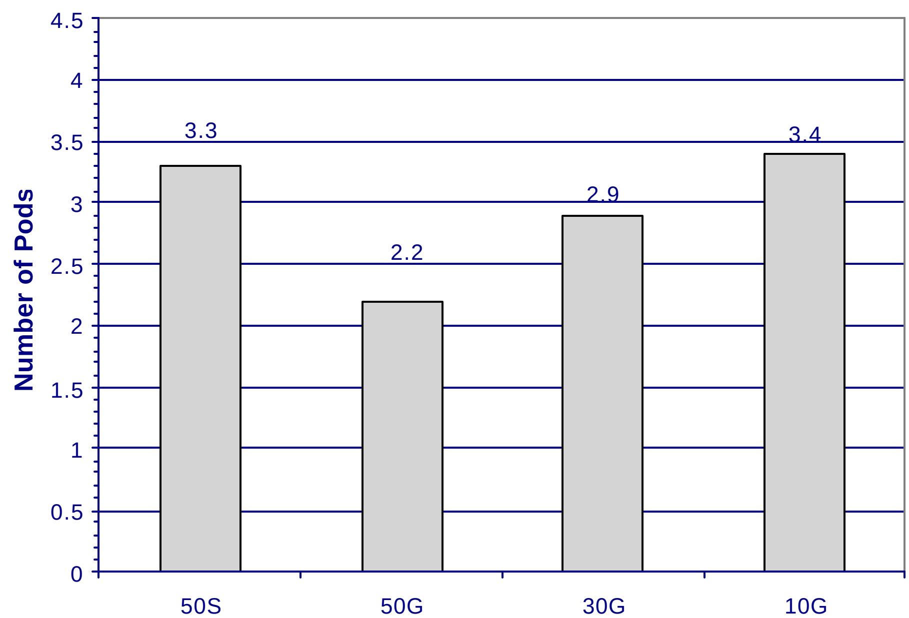

Fig. 13 Bean Pods. Number of bean pods per bean plant for four soil media.

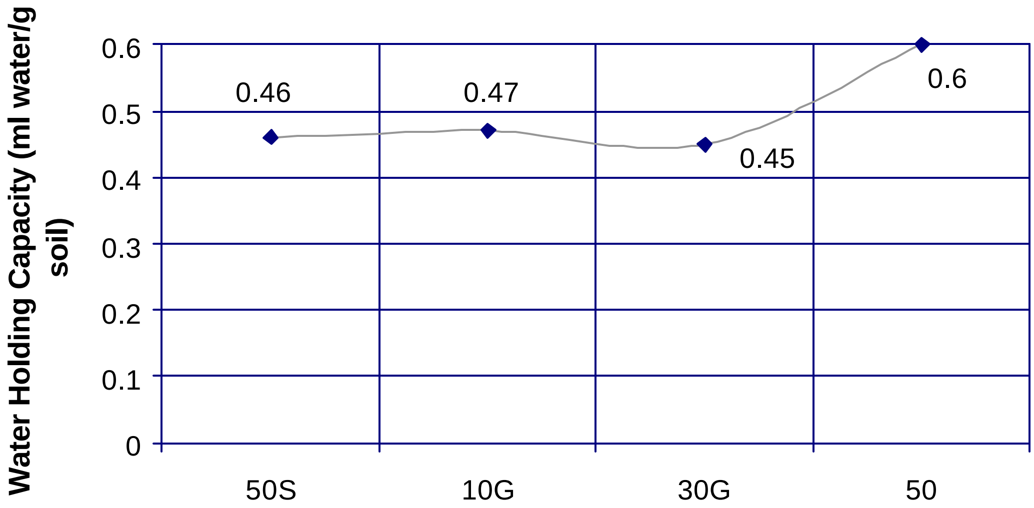

Fig. 14 Water Holding Capacity of Four Soil Media. Water holding capacity is a measure of water in soil at field capacity and does not necessarily reflect the availability of water to plants

Fig. 15 Glass Cullet. Post-industrial plate glass from an Oregon window manufacturer.