# Glass Foam Granulate as Growing Medium for Tomato and Cucumber

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**Abstract**

**Glass foam granulate was evaluated for use as a horticultural rooting medium with laboratory tests and cultivation experiments. The laboratory tests included moisture characteristics, rehydration rate and pH buffering analyses. Cucumbers and later on tomatoes were propagated in rockwool propagation cubes and planted on slabs of Growstones™ glass foam granulate. They were compared with cucumber respectively tomatoes grown on rockwool slabs.**

**Lab results show that the coarse nature of the glass foam granulate (0.5-5 cm) limits the maximum moisture content to 50%. The rehydration rate is very high, reaching more than 80% of container capacity in 5 min. The tested material initially reacts with water, raising the pH to over 10 pH units. Based on lab results a recipe for rinsing the material prior to cultivation was calculated.**

**Cucumber cultivation results show an equal production to plants grown on rockwool. The first yield on glass foam granulate is 1-2 days earlier. The susceptibility to *Pythium* is significantly lower than on rockwool. The wax layer on cucumbers grown on glass foam granulate is perceptibly thicker as consequence of an elevated silicon level of 0.25 to 1.6 mmol $L^{-1}$ in the slab solution.**

**Tomatoes on glass foam granulate show smaller stem diameters and recovered faster from blossom end rot. Yield levels on glass foam granulate and rockwool are equal.**

**In conclusion growing on glass foam granulate is equally productive as rockwool growing. The material is drier and thus less susceptible to *Pythium* and more generative in nature. Glass foam granulate can be irrigated with small and frequent irrigation cycles and the material must be rinsed with an acid solution before planting. Small amounts of silicon are released into the nutrient solution.**

## INTRODUCTION

The manufacturer Earthstone International from New Mexico in the USA has developed an industrial process to rework used glass bottles. The glass is molten and foamed and on cooling appears as coherent bodies of solid material. The material is worked into various shapes and products such as abrasives for sanding and granulate for growing plants. The latter application is concentrated in a separate business division, Growstone, and the glass foam granulate is offered as Growstones™.

In 2005 Earthstone International asked WUR Greenhouse Horticulture to evaluate glass foam granulate for growing fruit vegetables in a European context. It was decided to start with lab tests followed by a three month cucumber cultivation experiment, then followed by tomato growing for a full nine months growing season.

A full evaluation of any material offered for use as a rooting medium in commercial horticulture requires a careful selection of laboratory and field tests such as described in general manuals for substrate growing (Kipp et al., 2001; Urresterazu, 2004; Savvas et al., 2005; Raviv and Lieth., 2008).

## MATERIALS AND METHODS

### Lab Tests

The lab tests included microscope imaging, a nutrient analysis by a commercial

lab with ICP, a basic toxicity test, a water retention curve, a rehydration test and a pH buffer test. The microscope analysis included imaging at 400× magnification and the measurement of glass foam cell dimensions in the image. The nutrient analysis was a 1:5 extract according to the CEN methods for sampling and extraction (respectively CEN 13040, 1999; CEN 13652, 2001).

The toxicity was tested with a three day germination test (Blok et al., 2008, 2009). Seeds of three different plant species, garden cress (*Lepidium sativum*), mustard (*Sinapis alba*) and sorghum (*Sorghum saccharatum*) were germinated on filter paper moistened with an extract of glass foam granulate. The extract was prepared by immersing glass foam granulate in a nutrient solution for 24 hours at 25°C. The extract was then poured off of the granulate and corrected for pH. The test plates with ten seeds of one species were placed vertically and incubated for three days at 25°C, in darkness. At the end of the incubation period root and shoot length measurements were made. All assays were performed in four replicates for each of the three plant species used.

The water retention curves were produced according to CEN (CEN 13040, 1999; CEN 13041, 2006). It was noted that the material consisted of over 50% of 1-5 cm particles and particles larger than 25 mm would have to be discarded according to the sampling procedure. It was decided to deviate from the method and measure the sample without sieving. This will result in lower readings for water content and higher readings for air content as the pore volume near the wall of the CEN cylinders as the result of packaging will be notably different from the pore volume in the middle of the cylinder.

The rehydration test is a recent but popular method to evaluate the ease of rehydration of potting soils (Raviv and Lieth, 2008). The test starts by oven drying material samples for 24 h at 105°C, in sample holders of 10 cm diameter and 7.5 cm in height. The dry samples are then weighed and placed on a coarse mesh with a permanent water table of demineralised water of 0-1 mm. The weight of the sample is measured after 0, 1, 2, 4, 8, 15, 30, 60, 120, 240 and 360 min and after one, two and seven days.

The pH buffer method is recently developed for the Dutch substrate quality board of KIWA (Blok and Kaarsemaker, 2008; KIWA, 2003). The method starts with a 360 ml sample in a cylindrical sample holder of diameter 5.0 cm. The sample is part of a recirculating system of 1.50 L. The volume is recirculated with 10.0 ml per second. The pH reached after 55 min of recirculation is reported. With titrino equipment the pH in the sample solution is brought back to and kept at pH 5.0 for 5 min (702 SM Titrino with TiNet 2.5 software by Metrohm AG, Switzerland). The amount of acid dosed by the Titrino to keep the pH at 5.0 after 10 hours dosing 5 minutes every hour is taken as a measure of the dissolution of the material investigated. Statistics were performed on the data by ANOVA with the Genstat 12 edition program (VSNI, Hempstead, UK).

**Cucumber Growing**

The cucumber cultivation experiment ran from 18 September 2006 to 12 December 2006 in Naaldwijk, the Netherlands. Cucumber (‘Shakira’) was sown in Grodan rockwool cubes of 10×10×6.5 cm. The cubes were planted on 13 October 2006. Treatment 1 was planted on plastic bags of 120×20×7.5 cm filled with glass foam granulate. Treatment 2 was planted on 120×20×7.5 cm Grodan Expert rockwool slabs. The plant density was 1.8 plants per square meter. The glass foam granulate received 55 ml irrigation cycles and 50% leaching fraction (LF), the rockwool slabs received 110 ml irrigation cycles with 30% LF which in effect meant that the irrigation interval was longer than for the glass foam granulate. Each treatment was served by three independent pumps and each pump served 5 fields of 4.4 $m^2$ which means 15 repetitions per treatment. The amount of water added and the amount of acid dosed to stabilize the pH by the nutrient unit were registered. The transparency of the drainage water was measured to monitor any possible decrease of the efficiency of UV sterilization. The nutrients levels including silicon were checked several times (commercial lab with ICP). After the final harvest on 12 December 2006 glass foam granulate slabs were steam sterilized. Plants lost during the cultivation period were registered and diagnosed.

Statistics were performed on the data by ANOVA with the Genstat 12 edition program (VSNI, Hempstead, UK).

**Tomato Growing**

The tomato experiment ran from 15 March 2007 to 18 October 2007 in Bleiswijk, the Netherlands. Tomato ('Mecano') was sown on 8 February 2007 in Grodan rockwool cubes of 10×10×6.5 cm at a commercial nursery. The cubes were planted on 20 March 2007. Treatment 1 was planted on plastic bags of 120×20×7.5 cm filled with glass foam granulate. Treatment 2 was planted on 120×20×7.5 cm Grodan rockwool slabs. The plant density was initially 2.4 plants $m^{-2}$ and from week 21 on 3.2 plants $m^{-2}$ by allowing an extra side shoot to grow. The glass foam granulate received 55 ml irrigation cycles with three drippers per slab and 50% LF, the rockwool slabs received 110 ml irrigation cycles with two drippers per slab with 30% LF which meant that the irrigation interval was longer than for the glass foam granulate. Each treatment was served by an independent pump and each pump served 10 fields of 5.4 $m^2$. The drainage water was not recirculated. The amount of water added and the amount of acid dosed to stabilize the pH by the nutrient unit were registered. The nutrients levels including silicon were measured (commercial lab with ICP). Harvesting started at 25 May 2007 till the final harvest on 17 October 2007. Stem diameter was registered throughout the experiment and leaf area was measured twice. Statistics were performed on the data by ANOVA and regression with the Genstat 12$^{th}$ edition program (VSNI, Hempstead, UK).

**RESULTS**

**Lab Results**

Microscope images reveal a homogeneous mass of 0.1-1 mm cells with incomplete cell walls (Fig. 1). The material is a granulate of 0.5-5 cm (Fig. 2).

The nutrient analysis of the 1:5 extract showed a high pH of 10.8. Most elements are below the detection limits of the commercial ICP apparatus but sodium (0.2 mmol $L^{-1}$), calcium (0.2 mmol $L^{-1}$), bicarbonate (0.2 mmol $L^{-1}$), silicon (0.2 mmol $L^{-1}$) and boron (0.2 µmol $L^{-1}$) were detected. The EC was 0.1 dS $m^{-1}$. The phytotoxicity test showed no general averse growth effects of the pH adjusted extract of the material (Table 1).

The bulk density is 171 kg $m^{-3}$ and the pore volume is 94% v/v. Upon delivery no moisture or carbon quantity of practical consequence is present in the material. The initial water content at container capacity is measured as 41% v/v with 53% v/v of air (Table 2). The actual water content is probably 5-10% higher as noted in the method description. The material will release 20% v/v of water when the suction force changes from -0.2 to -1.2 kPa. The air dry material will rewet to 48% within 10 min and up to a maximum of 50% v/v after 6 hours (Table 3).

The pH buffer test indicated that 360 ml of tightly packed glass foam granulate required just over 25 ml 0.1 M hydrochloric acid to stay at pH 5.0 when recirculating an aqueous solution through the sample.

**Cucumbers**

The initial yield was 230 g $m^{-2}$ for glass foam granulate and 140 g $m^{-2}$ on rockwool. Due to the inadvertently prolonged propagation stage and the low light levels, plants were affected by *Pythium* (Table 4). Fifteen rockwool grown plants and 1 glass foam granulate grown plant were affected. A waxy layer was noted on the fruits of the glass foam granulate. The cumulative yield on glass foam granulate was 12.6 kg $m^{-2}$ and on rockwool it was 12.3 kg $m^{-2}$ (Fig. 3). There was no loss of transparency of the irrigation water in time. Steam sterilization did not affect the material but handling the material easily caused smaller parts to move to the bottom.

**Tomato**

As in cucumber the initial yield for glass foam granulate was slightly higher but

the difference disappeared within days. The final cumulative yield for glass foam granulate was with 30 kg $m^{-2}$ significantly ($p<0.01$) higher than the 28 kg $m^{-2}$ for rockwool but this difference is the result of the quicker recovery of glass foam granulate grown plants from externally caused Blossom End Rot (BER, Fig. 4). Without BER both systems would have produced equal as they indeed did after the BER had disappeared. Regression lines for both treatments starting counting from day 200 were virtually identical with both $y=0.206*x$ and $R^2=0.99$. The silicon content during the experiment is 1.2 mmol $L^{-1}$ at the beginning on the glass foam granulate slabs, but diminishes to almost the same level as the rockwool slabs at day 213 (Fig. 5). The error on the measurements is 0.01 mmol $L^{-1}$. Stem diameters for plants on glass foam granulate were 8 out of 14 days significantly lower than for plants on rockwool (Fig. 6). Leaf area of plants grown on glass foam granulate was on average 14% lower but the variation was considerable ($p=0.029$).

## DISCUSSION

In contrast to many polymer foams, the glass foam cells are highly interconnected. Together with a hydrophilic nature this results in a rehydration rate of over 80% in the first five min. This qualifies the material for use in sub-irrigation systems which require rehydration within a relatively short flood period. The air content at saturation of at least 40% v/v of air filled pores is the result of the very coarse nature and the even grading of the material as well as the highly irregular shape of individual granules which promotes large open pores.

The silicate matrix of the foam is not inert as witnessed by the high initial pH of 10.8. The figures for sodium, calcium, boron and silicon all point to some dissolution but the values found are still at least ten-fold beneath normal cultivation values and therefore acceptable. The waxy layer on the cucumber fruits is the common reaction of cucumber to silicon levels of over 1 mmol $L^{-1}$. Silicon is seen as advantage rather than a disadvantage (Liang et al., 2005; Bar-Yosef, 2008). Soil grown fruits usually have the same waxy appearance.

The pH of 10.8 is unacceptable for plant growth. For normal plant growth a range of 5.0-7.0 is advised (De Kreij, 1995). To grow plants on this material it is necessary to wash off the pH effect by rinsing with an acid solution. The maximum acid consumption as measured with the pH buffer test was halved in to avoid temporarily overdosing of acid. The dry slabs were filled with clean water with 1 mmol $HNO_3$ $L^{-1}$, followed by rinsing with the same solution with nutrients added and leaching 10 L per $m^2$ (for a system with 5-15 L glass foam granulate per $m^2$).

The initial higher yield of cucumbers on glass foam granulate as well as the higher resistance against *Pythium* are interpreted as a consequence of the drier nature of glass foam granulate. Both effects have been reported for perlite when compared to rockwool (Van der Gaag and Wever, 2005). As with perlite the initial yield advantage soon disappears. In tomato the drier nature of glass foam granulate is reflected by a more generative growth as shown by the lower stem diameter and incidentally lower leaf areas. It is also reflected by the faster recovery from BER which is more severe in vegetative plants. No effect of the higher silicon content was expected nor found.

In conclusion the glass foam granulate is a new rooting medium, fit for cultivating on a professional level. It offers advantages in the amount of air filled pores and rehydration rate. It requires rinsing before use and releases silicon.

## ACKNOWLEDGEMENTS

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## Tables

Table 1. Results phytotoxicity testing (n=40, LSD-5% is 7.8).

| Sample | Root (mm) | | | Shoot (mm) | | |
|---|---|---|---|---|---|---|
| | *Sorghum* | *Sinapis* | *Lepidium* | *Sorghum* | *Sinapis* | *Lepidium* |
| Glass foam granulate | 49.2 a | 38.7 a | 43.4 a | 50.1 a | 57.0 a | 60.6 a |
| Irish white peat* | 50.0 a | 47.8 b | 43.3 a | 56.5 a | 56.9 a | 58.2 a |

* Reference material as required in the method.
Different suffixes (a and b) in the same column indicate significant differences.

Table 2. Water volume in % at different suction forces.

| Substrate | Suction force | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CC** | | 0.5 kPa | | 0.75 kPa | | 1.25 kPa | |
| | Water | Air | Water | Air | Water | Air | Water | Air |
| Glass foam granulate | 41 | 53 | 35 | 59 | 30 | 64 | 22 | 72 |
| Irish white peat* | 83 | 10 | 80 | 13 | 76 | 17 | 62 | 31 |

* Reference material as required in the method.
** CC = Container capacity.

Table 3. Rehydration rate in % v/v versus the time of contact with free water.

| Time (days) | | | | | | | | | | | | 1 | 2 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time (min) | 0 | 1 | 2 | 4 | 8 | 15 | 30 | 60 | 120 | 240 | 360 | 1440 | 2880 | 5760 |
| Glass foam granulate | 0 | 26 | 35 | 40 | 44 | 47 | 48 | 49 | 49 | 49 | 50 | 50 | 50 | 50 |
| Irish white peat* | 1 | 2 | 2 | 3 | 4 | 6 | 10 | 16 | 28 | 40 | 47 | 63 | 65 | 70 |

* Reference material as required in the method.

Table 4. Number of plants affected with *Pythium* (n=15, LSD-5% is 8.7).

| Rockwool | | Glass foam granulate | |
|---|---|---|---|
| Number of fields | Number of plants | Number of fields | Number of plants |
| 9 | 15 a | 1 | 1 b |

Different suffixes (a and b) in the same row indicate a significant difference.

**Figures**

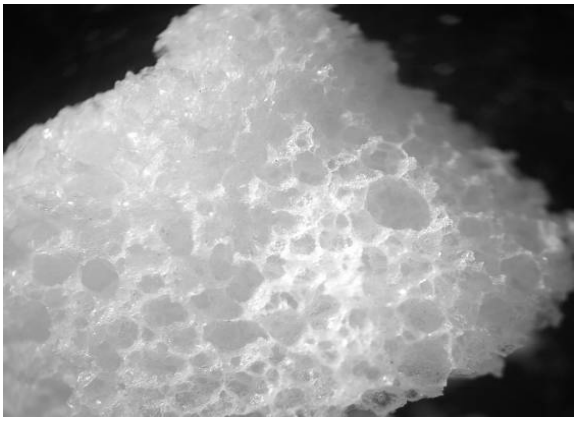

Fig. 1. Glass foam granulate magnified 40×.

Fig. 2. Healthy roots, branching into hair roots above the water level.

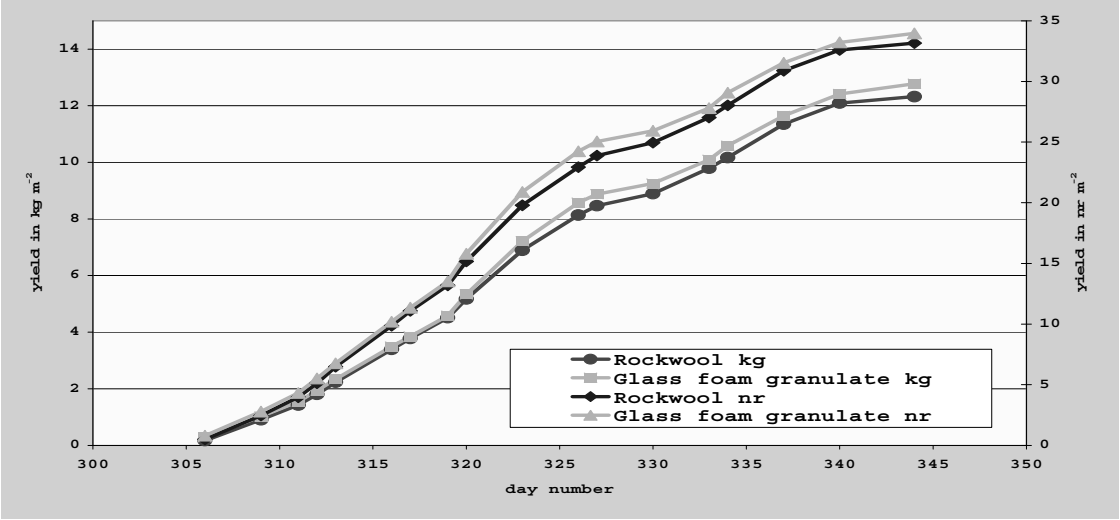


Fig. 3. Cumulative yield and number of cucumber fruits (second Y-axis). Differences are nowhere significant for p=0.05, per data point n=15.

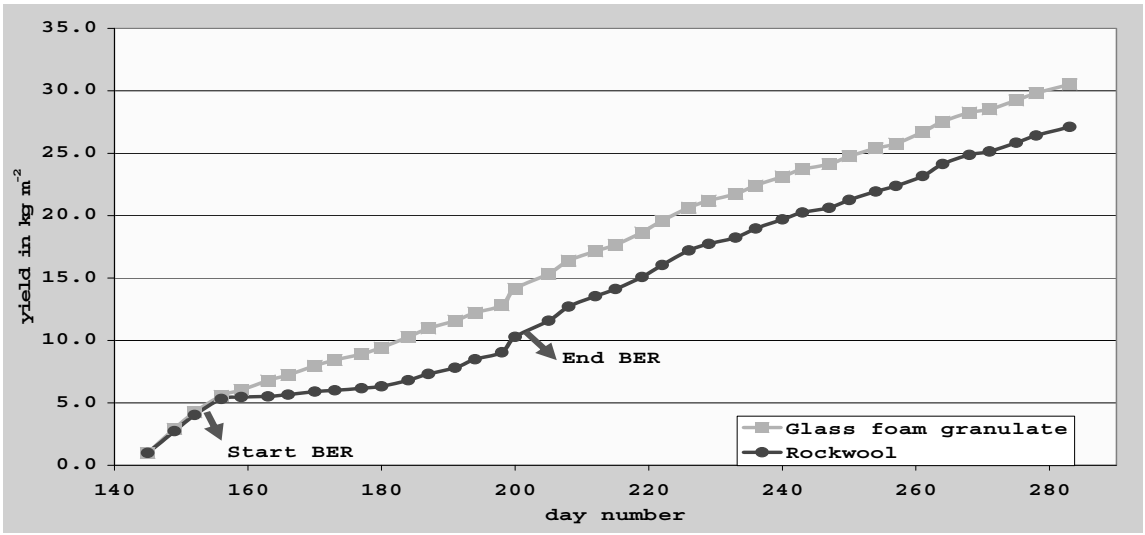


Fig. 4. Cumulative yield of tomato. From day 140 to 155 yields are equal. From day 165 to 190 the treatments differ with p<0.01 because of a BER problem. Restarting from day 200 yields are equal again (per data point n=10).

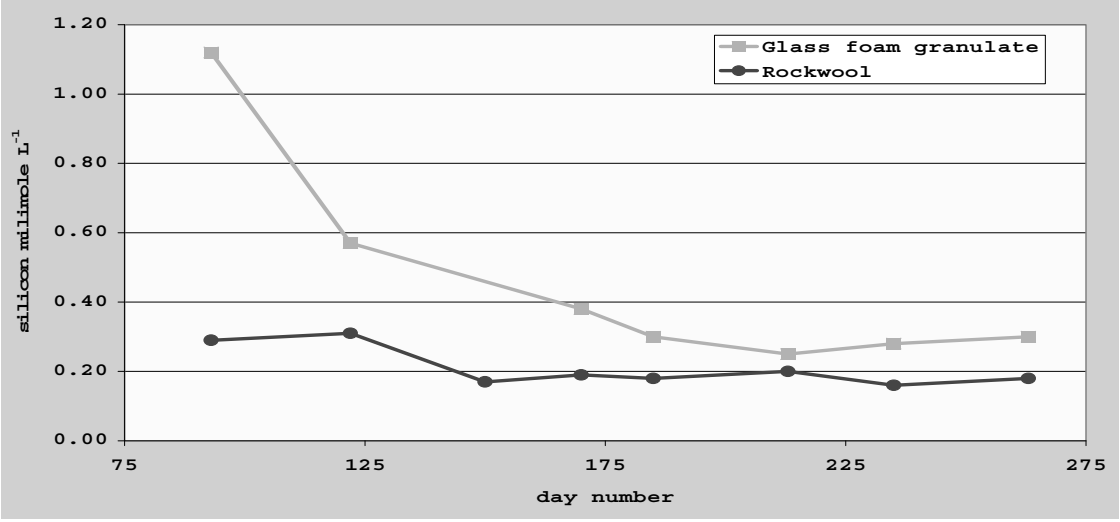


Fig. 5. Silicon content in time in the root environment of tomatoes (per data point n=1, standard error is 0.01 mmol $L^{-1}$).

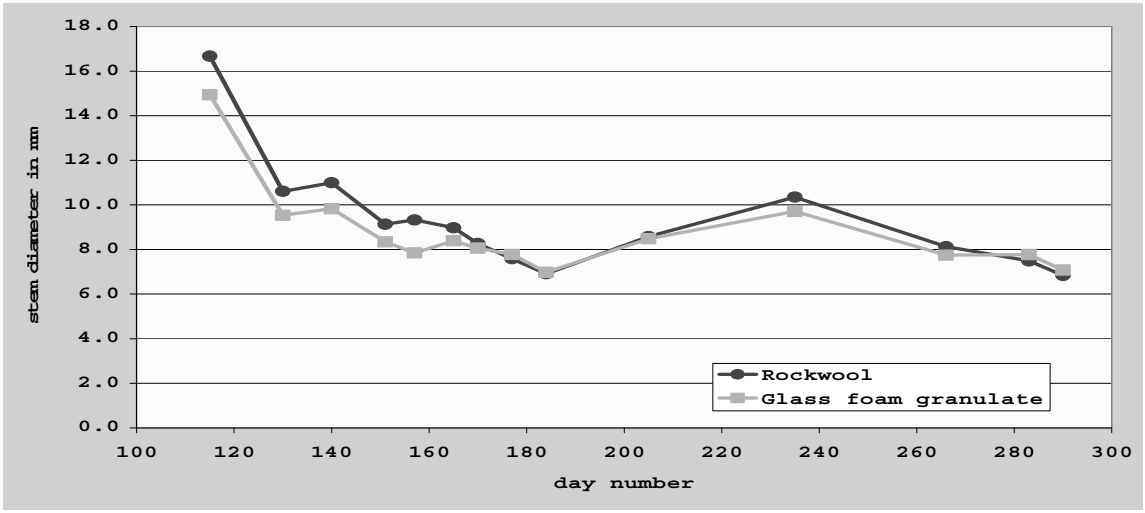


Fig. 6. Stem diameter of tomatoes (per data point n =60, LSD-5% is 0.20).