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To: Richard Vollebregt
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From: Gene A. Giacomelli
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re: Report on tomato production in retractable roof greenhouse

cc: Armando Suarez
Dr. Merle Jensen
Dr. Ursula Schuch
Dr. Chieri Kubota

Attached is the final report prepared from the 2003-2003 tomato studies of Armando Suarez at the CEAC.

I appreciate your cooperation and support of our program interests in this production system for vegetable crops, and I look forward the development of additional funding for the continuation of the program.

Report for Retractable Roof Greenhouse (RRGH) Tomato Production

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Procedures

A retractable flat-roof greenhouse with roll up sidewalls was used to grow a greenhouse variety tomato (cv. Rapsodie) during the period from December 2002 to May 2003 at The University of Arizona. Complete details of design and operations can be found in the paper by Suárez-Romero, et al., 2003. The structure (9 by 18 m) was constructed of galvanized steel frame with 3.6 m tall posts spaced 9 m in the east-west direction, and 3.6 m in the north-south direction.

Each bay was equipped with a movable glazing of translucent, water-porous, woven plastic film attached horizontally at the roof 3.6 m above the ground. Measured light transmission was 72%.

Tomatoes were grown hydroponically according to the procedure described by Rorabaugh, et al. 2002. Tomato seedlings were transplanted into 15 x 10 x 91 cm rockwool slabs that were placed end-to-end to form continuous 8 m long rows. Each of these rows consisted of a double row of rockwool slabs spaced 38 cm apart. Row to row spacing was 178 cm, and 6 tomato seedlings were transplanted at a spacing of 30 cm on each slab providing a density of 3.6 plants m^{-2}.

Nutrient delivery was with a top drip fertigation system. The pH of the solution was maintained in the range of 6.0 - 6.9, and EC was maintained at 2.4 dS m^{-1} from December 20, 2002 (transplant) until March 25, 2003, but was lowered to 1.8 thereafter, to reduce water stress of the plants.

Irrigation rate increased linearly from transplant at 250 ml day^{-1} per plant to 4500 ml day^{-1} per plant, and then was maintained unchanged until May 15th. To achieve this maximum rate, the fertigation system was activated for 2 minutes every 10 minutes.

No cluster pruning of fruit was performed. The plants were leaf pruned (to 10 leaves) and suckers were removed once a week. No manual pollination was performed, only wind pollination.

There was no insect screen on the structure. The plants received an application of Immidacloprid two weeks after transplant, and then again mid-April (at 6th harvest). Insect control also included non-chemical insecticidal soap, Neem and liquid sulfur. The primary pests were psillids and russet mites.

No shading or radiation protection was provided for the root zone to modify temperature, except for the physical component of the plants above.

There was minimal heating in the greenhouse and most nights the air temperature had low values of 13 – 14°C, well below desired minimum nighttime temperature of 16 °C. The daytime air temperature often reached 28°C during the harvest period, and the relative humidity was always too low (less than 30%).

There was no fog system for cooling or humidifying the air.

The roof was retracted (opened to allow maximum light) based on solar radiation measured by a light sensor (pyranometer), mounted above the RRGH. The goal was to expose the crop to the maximum amount and duration of direct sunlight. Whenever the solar radiation was greater than 100 W m^{-2} (200 µmol m^{-2} s^{-1} PAR) and the air temperature was 24°C or greater, the roof would be retracted, otherwise it would remain closed (covering the crops). However, if the wind speed was greater than 31 km hr^{-1} the roof and sidewalls would close. The sidewalls were manually opened and closed each day, only after the roof had retracted.

Fruit were graded at harvest as #1's, fruit weighing between 150 – 250 g; #2's fruit less than 150 g or greater than 250 g; or culls non-salable fruit.

Results

The tomato yield (number of fruit & weight) for each fruit grade (#1, #2, cull) for 24 plants during the harvest period is provided in Table 1.

Rapsodie Date	#1 count	Weight grams	#2 count	Weight grams	Cull Count	Weight grams
2/24/2003	16	3708	21	3270	15	1118
3/12/2003	61	15055	24	5440	11	1075
3/20/2003	17	5810	56	16620	0	0
3/31/2003	38	9088	93	31976	1	170
4/8/2003	97	26160	6	1105	1	265
4/20/2003	148	33530	74	10780	29	4525
5/6/2003	16	4030	40	6840	104	13535
5/15/2003	4	865	23	2727	47	4292

Table 1. Summary of harvest for the cultivar Rapsodie (24 plants).

During harvest dates 3/20 & 31, and 4/20, the percent of #1 fruit dropped from 70% to 20% due to the average fruit weight being 350 grams, and with many fruits reaching 600-750grams. This exceeded the criteria of #1 fruit being less than 250 grams. The EC was lowered on 3/25/2003 from 2.4 dS m^{-1} to 1.8 after which time the percentage of #1 fruit increased from 20% to over 90% because the fruit size was reduced. Generally high EC has been demonstrated to reduce fruit size, still 2.4 dS m^{-1} is not excessively high to begin with. We believe that the excessive fruit size was the result of low night air temperature.

Losses due to insects were negligible, and there were no problems due to virus. Psillids were the major pests which caused virus like symptoms on the plants but appeared to have no effect on the tomatoes.

The results can be summarized and compared for the cumulative yield of Rapsodie during a 5 month long growth period, and a harvest season of 11 weeks (2.75 months):

<u>For #1's only</u>:
14,736 g/m2 / 5 months (annualized yield = 35368 g m^{-2} yr^{-1} or 35 kg m^{-2} yr^{-1})

14,736 g/m2 / 2.75 months (annualized yield = 64302 g m^{-2} yr^{-1} or 64 kg m^{-2} yr^{-1})

<u>Assumes</u> yield rates will continue equally throughout the year, which is not expected because of seasonal changes. The question is how much variability will occur. We will learn more from the current test, but really need to evaluate over a one year period in a future experiment.

The fruit quality was inconsistent because of the fluctuating environmental conditions (figure 1). Figure 2 is the monthly yield of #1 and #2 and shows a rapid decay in quality and quantity at the beginning of May. However, if more of the #2's could have been #1's, with improved cultural practices, then theoretical maximum yields are determined below.

<u>For #1's & #2's</u>:
26,550 g m^{-2} / 5 months (annualized yield = 63720 g m^{-2} yr^{-1} or 64 kg m^{-2} yr^{-1})

26,550 g m^{-2} / 2.75 months (annualized yield = 115855 g m^{-2} yr^{-1} or 116 kg m^{-2} yr^{-1})

<u>Assumes</u> 100% of #2's could be grown to be #1's. This depends on grower cultural practices and expertise. <u>Also assumes</u> that yield rates will continue equally throughout the year, which is not expected because of seasonal changes.

<u>For #1's & #2's with season yield variability</u>:

Given that the 3 month harvest period (spring quarter) was 26.5 kg m^{-2}. Assume that due to seasonal changes in environment, this yield is reduced by excessive air temperatures 20% for summer quarter (21.2 kg m^{-2}), and is reduced by excessive air temperatures 20% for fall quarter (21.2 kg m^{-2}), and is reduced by lower solar radiation 40% for winter quarter (15.9 kg m^{-2}). This gives a yearly total of 84.8 kg m^{-2} yr^{-1}.

Conclusions and Recommendations

To our knowledge, this was the first time in the world that tomatoes were grown in a research setting in a retractable roof greenhouse in a semi arid climate. Consequently there were no previous references as to best management and cultural practices to control and integrate the retractable greenhouse roof, sidewalls and hydroponic system to maximize the yield, quality and crop timing.

In spite of that, the data from this first experiment indicated that there was a great potential for exceeding the production rates of traditional greenhouse production systems, assuming that the crop management procedures can be improved. The potential yield of 84 kg per year exceeds average tomato yields in conventional greenhouses which range from 20 – 65 kg per year. The investment in a large commercial size retractable roof greenhouse as tested is approximately $25 per square meter compared to the $30 - $100 per square meter invested in most conventional commercial greenhouses.

The following areas should be considered for further research to achieve the maximum yearly yield of tomatoes and prevent the production of oversize fruit:

- optimize the automatic controls of the retractable roof and walls
- integrate the irrigation timing with the roof and wall position
- maintain warmer nighttime temperatures in the winter either through the installation of an energy screen or increased heating
- increased cooling in the summer of media temperatures in the grow bag
- reduce transpiration in the summer through the installation of a fog system
- interplanting and timing practices to fit 3 or 4 crops in a year (limited truss systems).
- comparison between greenhouse and field varieties
- growing in soil

Other continuous fruiting crops that could potentially be commercially viable to grow in a retractable roof greenhouse include peppers, cucumbers, personal size watermelon, cantaloupe, blueberries and strawberries.

References Cited

Rorabaugh, P.A., M.H. Jensen, and G.A. Giacomelli. 2002. Production Procedures for Greenhouse Tomatoes in Arizona With a Focus on Nutrition in Hot Climates. Proceedings of the 30th National Agricultural Plastics Congress, American Society for Plasticulture, San Diego, CA. February 23-26. pps 54-59.

Suárez-Romero, A., G. Giacomelli, M. Jensen, U. Schuch, and S. Kania. 2003. Environmental and Plant Growth Experiences in a Retractable Roof Greenhouse Under Semi-Arid Conditions. Proceedings of the 31st National Agricultural Plastics Congress, pps. 17-25.

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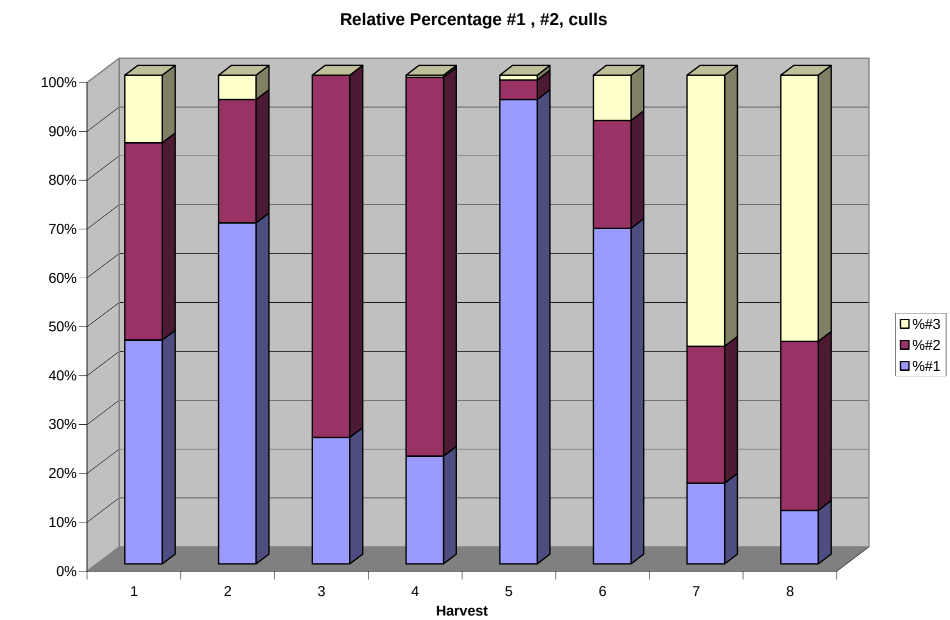

Fig 1. Percentage of #1, #2 and cull tomato fruit in each harvest (spring 2003)

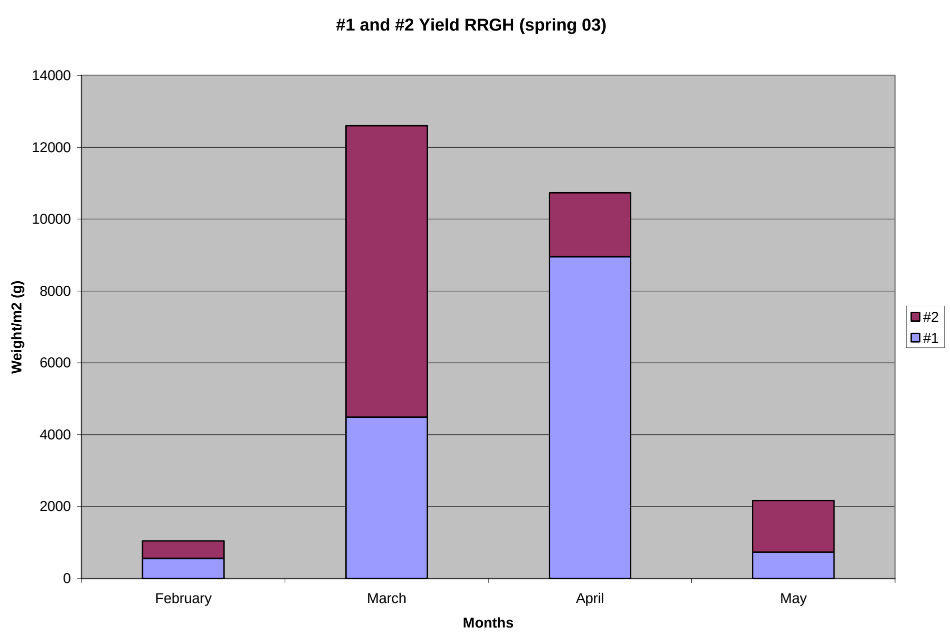

Fig 2. Monthly Yield #1 and #2 Tomatoes in the RRGH (spring 2003)