Ecologically Sound Soilless Culture’s Succession
on Thin Layers of ‘Porfido’

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Abstract—A model for soilless cultures on mineral inert support was studied like a potential substitute of Grodan and NFT techniques to achieve higher ecological and economical performances. Different successions of cultures (vegetables and cut flowers) were tested. Nutrient solutions of closed cycles were managed using ‘Aquatic Chemistry’, an original computer program.

In the early 1990’s, when the successful spread of the results of rockwool substrate technique has been overshadowed by ecological drawbacks, it was paid attention to a new approach to closed systems of gravel culture.

Advice was to use media of simple local availability and to reduce dramatically the depth of inert layers to take at the same time advantage from substrate’s presence, such as plant support for example, and those typical of NFT.

From 1995, near ‘Munerati’ Agricultural Institute, it is in progress a research to get two objectives:
- to produce ecologically sound cultural protocols for high yield soilless cultures using thin layers of ‘porfido’ as inert mineral support
- to find successions of practicable cultures for maximum possible profit in local conditions

Actual results are mentioned below.

MATERIALS and METHODS

substrate of ‘porfido’ and cultural boxes
Porfido used in this research is a silicate (porphyrites) with no significant ionic exchange capacity, grounded between 0.3 to 0.5 cm of diameter.

It was revealed interesting, more than other materials, because easily available, inert, recyclable, not ecologically harmful and cheap, notwithstanding high bulk density.

Boxes of cultivation, coated with PE, useful experimented with cultural substrate of porfido consist of the dimensional characteristics in Table 1, a compromise between favourable nutritional and development conditions for roots and minimum request of inert substrate:

<table>
<thead>
<tr>
<th>length</th>
<th>800 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>depth</td>
<td>5-6 cm</td>
</tr>
<tr>
<td>width</td>
<td>150 cm</td>
</tr>
<tr>
<td>slope</td>
<td>2%</td>
</tr>
</tbody>
</table>

Table 1. Dimensions and slope of used cultivation boxes.

8 meters for length refer to a structural limit; beyond it may be possible anoxic conditions, especially for high temperatures and wide root development.

1.5 meters of width, useful for access by labor to the crop, are for a free radial distribution of roots, very strong in some culture.

Thickness ensures gas exchanges with atmosphere and controls, with slope, rate and homogeneity of diffusion of nutrient solution.

Nutrient solutions are pumped at the top of boxes through pipes in short times and high volumes to keep the medium saturated and avoid saline accumulation in surfaces.

This model results simple and powerful allowing a rapid succession of a large number of different cultures, with an elasticity of employment not present in other soilless systems. The succession in Table 2, with integral substitution of porfido after tomato culture, actually results the most profitable.

<table>
<thead>
<tr>
<th>culture</th>
<th>transplant</th>
<th>harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>butter head lettuce</td>
<td>05 January</td>
<td>15 March</td>
</tr>
<tr>
<td>beefsteak tomatoes</td>
<td>20 March</td>
<td>10 July</td>
</tr>
<tr>
<td>lilium cut flowers</td>
<td>05 August</td>
<td>25 October</td>
</tr>
</tbody>
</table>

Table 2. Cultures and times of the most interesting succession.
**no pesticides!**

A white net against aphids was put on lateral and entrance holes and mechanical opening of greenhouse (a glasshouse 150 m² wide) was timed.

At beginning of summer, on external supports, it was put a black net with 50% transparency and activated a mist system on lateral nets to take some control of internal light, temperature and humidity.

We have tried microbial defence of roots using water of idro-net, relatively high concentrations of Cu⁺⁺ in nutrient solution and avoiding, as better as possible, introductions of organic matters.

From applied protections, done controls and state of cultures no pesticide necessity resulted for each culture in total period of research.

**water – nutrient solutions**

In our site underground waters have high contents of iron, sodium, chlorides and carbonates, so we used the much more expensive net water.

This water in practice is of ideal composition: with little content of dissolved salts and microbiologically controlled.

Being already equilibrated with atmosphere gases (CO₂, O₂) and temperature, the formulation of nutrient solutions results simplified.

As reference nutrient solutions it has been chosen formulations with specific ratios of macro nutrient concentrations and with defined content of micro nutrients, experimented in areas with environmental conditions similar to ours.

At transplanting phase the resulting EC values were reduced (in practice halving calculated doses of Ca nitrate) together with distributed volumes, to help initial root development.

pH was kept between 5.0/5.5 using a stock mix of nitric, phosphoric and sulphuric acids with the same N:P:S of the reference formulation.

Entering reproductive phases N-NO₃ concentrations were modified evaluating colour, form and vigour of plants.

Growing tomatoes, to achieve greater EC in nutrient solutions, were used sodium chloride and sodium sulphate salts to control also chloride/sulphate ratio.

Solutions were restored directly in supply tanks and wasted only at the end of cultural cycle (closed system).

**analytical controls and soluble fertilizers**

Once a week nutrient solutions were controlled in laboratory.

Samples were filtered trough cellulose filter of 0.45 μm porosity and chemical analysis were carried out to determine EC, pH and concentrations of solutes with the methods in Table 3.

Knowing the following data:
- composition and total actual volume of nutrient solution
- composition and volume of water for daily system volume restoring
- percentage composition for nutrients and significant impurities in common idro soluble fertilizers

It is possible to calculate amounts of fertilizers to restore the programmed values of concentrations and grow in nutritional conditions as constants as possible.

<table>
<thead>
<tr>
<th>element</th>
<th>method of analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>nitrate - ammonium - sulphates</td>
<td>specific ion electrodes</td>
</tr>
<tr>
<td>carbonates - chlorides</td>
<td>Gran - Mohr</td>
</tr>
<tr>
<td>phosphates - borates - molybdates</td>
<td>visible spectrometry</td>
</tr>
<tr>
<td>calcium – magnesium</td>
<td>atomic absorption</td>
</tr>
<tr>
<td>iron - manganese - copper - zinc</td>
<td>spectrometry</td>
</tr>
<tr>
<td>sodium - potassium</td>
<td>flame emission</td>
</tr>
<tr>
<td>pH</td>
<td>potentiometry</td>
</tr>
<tr>
<td>electric conductivity</td>
<td>conductivimetry</td>
</tr>
</tbody>
</table>

**Table 3. Applied chemical methods of analysis.**

**Aquatic Chemistry**: a necessary software

In hydroponics it is necessary to pass quickly from data to recipe, with confidence.

So it was born ‘Aquatic Chemistry’, a software to elaborate and optimise data, based on physical chemistry principles, a progeny of research and didactic of Massachusetts and California Institutes of Technology in 1970-1980’s.

This program, an Excel file that runs under Windows 98, is a fundamental to pilot cultures in hydroponics, especially in closed systems.

We have released two versions of it: version 1, for researchers, is an interactive form; version 2 is simplified for grower’s routine (Aquatic Chemistry - Fig. 1). Basis of theory and user’s guide are available.

**Cultural succession**

In local sites (Po Delta), at North latitude 45°, at sea level, in greenhouses without heating and lighting systems the production season is from early January, transplanting lettuce, to late October and on.

Between lettuce crops only butter head lettuce results interesting for growing time, quality and quantity of production. Transplanted at early January plants are harvested in March, 7-10 days before local traditional harvesting.

From half of March, imposed by market, begins tomato culture for June productions.

More difficult is to find a third culture, with economic interesting returns, for the second semester of the year.

Temperature into greenhouses arises to 32-35°C for many hours a day from all July to 5-10 of August, notwithstanding external shading with black nets and cooling attempts using water for a soft mist in the air upon plants and current films of water upon covers.

Actually, Lilium cut flowers production seems to give the best result in respect to other cultures tested in previous years (chrysanthemum, rocket, strawberries, tomato, etc.).
RESULTS
Experimental results of cultural succession ‘lettuce – tomato – lilium’ are illustrated below.

LETTUCE
To obtain high yield of lettuce, a relatively large amount of nitrogen is necessary and consequently are possible undesirable accumulations of harmful nitrates. Otherwise, a too limited level of nitrates in nutrient solutions can depress production and promote heavy forms of tip burn.

We used a reference nutrient solution well known for high yield and quality productions, increasing EC from 1.15 to 2.0 mS/cm, with pH values into 5.5-6.0 interval.

Nitrogen plays a major role in determining growth characteristics, fruit yield and fruit quality.

Particular attention was paid to solution’s turns and volumes, making them frequent and light, especially in final heading phase.

Results were excellent in the years and for all tested butter head cultivars.

Fresh weight (plant spacing 33 x 33 cm, with 9 plants per square metre) was higher than 300 g/plant in 70-80 days. Not marketable was nearly null.

Colour, shining, enclosure, uniformity were judged widely optimal. Sensory evaluation was excellent.

Nitrate content in fresh material was determined with specific ion electrode: it never was more than 2500 mg/kg fresh weight, probably for a reduction of EC near harvesting moment.

Tip burn, this important quality factor not affected plants. Downy mildew (bremia lactucae) was not present in 1-16 and 1-18 resistant plants. Use of chemicals was not necessary.

TOMATO
Nitrogen plays a major role in determining growth characteristics, fruit yield and fruit quality.

We adopted a strategy of nitrogen management with four increasing levels to control development of plants in initial phases and to support final increased nutritional requirements, insuring at a time a relative constancy of N/K ratio and of K/Mg and K/Ca ratio. EC was contemporary modified between 2.0 and 3.0 mS/cm and pH kept between 5.0 and 5.5 (Table 5).

Yield achieved very high levels (Table 6), with not marketable on a small scale (nearly absent blossom end rot). Result was determined mainly by great space for roots (48 tomato plants per box of 150 x 800 x 6 cm) and by management of solution fluxes in different physical conditions into greenhouse.

The fruit quality was measured by actual and titratable acidity, and by reducing sugars content (Table 7).

Leaf samples were collected from plants apparently in ideal conditions, just below the first flower truss, in the middle of the cultural cycle to get references for future box cultivations. Leaves were separated from the petiole, washed and then dried in an oven at 75°C for 24 hours before proceeding to foliar analysis. In Table 8 are the analytical values of macro constituents.
LILIAM

In boxes used for vegetables, for first attempts to grow Lilium cut flowers in thin layers of silicates, we put L/A hybrid and Asiatic bulbs on the bottom of boxes using the least possible amount of inert medium to cover them.

Transplanting was done in first August week for late October production.

Like particular choices:
- bulbs were covered with 1-2 cm of inert for a total depth of 5-6 cm of inert
- nutrient solution was re-circulated many times a day, with higher frequency in warmer hours
- additional shading in post-transplanting period was applied to avoid overheating, using a black horizontally drown net near inert surface

Detailed nutrient solution compositions were:
- vegetative phase: (mM) Ca: 2.50, Mg: 1.10, K: 4.00, NH₄: 0.90, SO₄: 1.00, PO₄: 1.50, NO₃: 8.60; (µM) Fe: 20, Mn: 18, Zn: 4, Cu: 4, B: 46, Mo: 0.50 - pH: 5.5, EC: 1.21 mS/cm
- reproductive phase: (mM) Ca: 4.00, Mg: 2.00, K: 6.00, NH₄: 2.00, SO₄: 2.00, PO₄: 2.00, NO₃: 14.00; (µM) Fe: 20, Mn: 18, Zn: 4, Cu: 4, B: 46, Mo: 0.50 - pH: 5.5, EC: 2.00 mS/cm

Basic and stem roots advanced into substrate without difficulty and sustained the development of strong stems and shining green leaves.

Experimental results are detailed in Table 9 per Royal Ballade, Narbonne L/A hybrids and Asiatics Cordelia and Elite.

Flowering time was between 10 and 25 of October.

<table>
<thead>
<tr>
<th>reference</th>
<th>stem length cm</th>
<th>inflorescence length cm</th>
<th>first bud length cm</th>
<th>flowers per stem n°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Royal Ballade</td>
<td>80</td>
<td>0.0</td>
<td>10.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Narbonne</td>
<td>86</td>
<td>24.3</td>
<td>9.5</td>
<td>11.0</td>
</tr>
<tr>
<td>Cordelia</td>
<td>79</td>
<td>19.9</td>
<td>7.7</td>
<td>9.2</td>
</tr>
<tr>
<td>Elite</td>
<td>101</td>
<td>22.0</td>
<td>7.8</td>
<td>10.7</td>
</tr>
</tbody>
</table>

Table 9 – experimental results - ITAS ‘Munerati’ (October, 2001)

CONCLUSIONS

Experimented gravel technique on thin layers of inert silicate (grounded porfido) resulted easy, elastic, ecologically sound, of limited investments and well fitted for high vegetable’s yield and quality. It could compete with the more studied Grodan and NFT techniques in research of definition of the most interesting model of soilless culture and hydroponics installation.

It could become a more profitable alternative to the commonest techniques in cut flowers production.

S. Apollinare, December 2001