Billions of high quality transplants (small plants) are needed at low costs to solve global issues on:

1) Food,
2) Energy/Resource and
3) Environment
Open Transplant Production Systems such as Greenhouses with/without supplemental light

Energy/mass exchanges between inside and outside the system cannot be controlled as desired.

Closed transplant Production Systems:
1) Covered with opaque thermal insulators,
2) Ventilation is minimized,
3) Artificial light only.
Advantages of closed transplant production systems:

- Easy environment control,
- No need of pesticide and no emission of agro-chemicals,
- Water and CO$_2$ can be recycled,
- Comfortable working environment
- Multi-shelves can be used for efficient production

Our recent research revealed that, in the well designed closed systems, :

1) Electricity cost is low.
2) Quality of transplants is high.
3) Initial cost is low.
Electric energy required for lighting is small, because

1) PPF is 200-400 $\mu$mol m$^{-2}$s$^{-1}$, 
2) Production period is 15-30 days, 
3) Planting density is 400-1000 plants m$^{-2}$, 
4) Transplants are placed 20-30 cm below fluorescent lamps.

**Production of value-added transplants**

1) Pathogen and pest free sweetpotato, 
2) Tomato and eggplant with enhanced flower bud development, 
3) Spinach with delayed bolting, 
4) Vigorous Chinese cabbage
Lab. Scale Model of the Closed System

3 shelves, 5 trays/shelf

Electricity consumption, $E$
7 MJ (2.2 kWh) per plug tray per week

<table>
<thead>
<tr>
<th>No. of cells/tray</th>
<th>$E$/plant/2 weeks</th>
<th>kJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td></td>
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<tr>
<td>200</td>
<td>70</td>
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<tr>
<td>100</td>
<td>140</td>
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<tr>
<td>50</td>
<td>300</td>
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</tbody>
</table>
Plant material
Sweet Potato (*Ipomoea batatas* L. (Lam) cv.: Beniazyma)

Photographs of tomato, eggplant, Chinese cabbage, spinach etc.
Tomato
*(Licopersicon esculentum* Mill.)*

Eggplant
*(Solanum melongena* L.)*
Spinach
(*Spinacia oleracea* L.)

11 days after sowing
Percentages of Electric Energy Consumption of the Components of the Closed System

Lamps: 76%
Air Conditioner: 16%
Fans etc.: 8%

Price of Electricity per KWh in US cents
Japan 15-20
USA 5-10
Canada 3-6
**CO₂ utilization efficiency**

\[
\frac{\text{Fixed}}{\text{Supplied}} = \frac{5.6}{6.1} = 0.92
\]

**Water utilization efficiency**

\[
\frac{D + C_p + C_s}{\text{Irrigated} + \text{Humidified}} = \frac{55.9}{49.5 + 24.3} = 0.93
\]
The closed transplant production system is physically divided into:

1) Transplant production area,
2) Working area,
3) Storage area,
4) Equipment area, and
5) Passing area

1) No workers can enter the transplant production area.
2) Trays are transported automatically between transplant production area and working area.
3) Nutrient solution supply in the transplant production area is also conducted automatically.
The computer software system consists of:

1) Environment measurement and control subsystem,
2) Tray transportation subsystem,
3) Plant growth measurement subsystem,
4) Production support subsystem,
5) Alarm subsystem.
The basic module with 7 shelves is:

1) 400 cm high, 267 cm long, and 69 cm wide,
2) holds 56 plug trays,
3) with 112 fluorescent lamps (36 W),
4) with a distributed, intelligent microcomputer
Conclusion

• Transplant production in closed systems is not energy and material efficient and does not pollute environments significantly.

• Quality/productivity of transplants are high when produced in closed systems.

• Its commercialization will be realized in the near future.

In Northern countries, the contribution of supplemental artificial light energy over total (natural + artificial) light energy accounts for 30-50 % during the winter.

To use natural light, much fuel is used for heating.
In tropical countries, much energy and costs are needed to control the greenhouse environment for transplant production.

Research unit for closed-type transplant production system
Solar panels

A transportation/irrigation system
All major equipment are for home-use

Home-use air conditioners

Fans

Humidifier

A transportation/irrigation system
A measuring system on transportation/irrigation system

Microprecision irrigation systems