Vegetable growing can be intensified by means of a simple system of hydroponics - growing plants without soil - which uses resources efficiently and can be adapted to local conditions. David Midmore from the Asian Vegetable Research and Development Center (AVRDC) presents a space-saving production system which can be used worldwide.

Photo: Ming Che Chen

Simple hydroponics for food security

David Midmore

To attain self-sufficiency in food as populations increase, production systems are sought which use space efficiently and can be applied even by landless urban and rural people. A promising possibility is hydroponics.

Hydroponic, which comes from the Greek words *hudor* meaning water and *ponos* meaning working, refers to growing plants in a liquid rather than solid culture (usually, soil). Plants are provided with a constant supply of water and mineral nutrients, in an environment which does not favour the spread of disease and insects. Small units can be placed in windows, on wide window ledges or next to protective buildings or walls. During very bad weather, they can be brought inside.

To date, commercial hydroponic systems to supply mineral nutrients and oxygen to the plants need an energy source to pump air and recycle solutions. As the AVRDC system does not need an external energy source, it can be used in areas with no or uncertain electricity supply, such as in many towns and rural areas in developing countries.

The AVRDC system

The noncirculating hydroponic system initially developed at AVRDC was intended to study nutrient uptake. The system (Fig. 1) comprises the following: a) a watertight container (eg. a polystyrene box) to hold the nutrient solution; b) a framework or support structure (eg. a polystyrene lid) covering the container, and c) a support medium for the seed or seedling. The medium (eg. smoked rice hulls) may form a complete layer in the framework structure (for root or tuber crops) or be placed in separate receptacles (eg. plastic perforated cups) suspended from the support structure. Simple netting or the right size of holes in the receptacles ensure that the medium does not enter the nutrient solution.

The nutrient solution developed at AVRDC (Table 1) gives vegetables a near-optimal supply of mineral nutrients. It is commercially available in Taiwan. If the pH level of the solution rises above 7.8, as may occur in long-season crops, addition of sulphuric acid can bring it down to the preferable pH level of 5.5-6.0. Studies show that the same solution is suitable for all vegetable crops.

Oxygen through aerial roots

Initially, the solution level is set at about 2 cm above the base of the perforated cups. The medium is kept moist to ensure successful germination or transplanting. Transplanting of seedlings is recommended for slow-germinating species like lettuce. Using transplants instead of seeds improves the efficiency of time and space utilisation in the system.

The solution level drops slowly at first, as capillary rise and evaporation occur. It falls faster as roots develop and take up solution to satisfy the transpiration demand of the plants. A number of roots remain in the air space between the support structure and the surface of the solution. As these aerial roots and the roots floating on the solution surface provide oxygen for normal root function, the solution does not need to be aerated.

Water management is the key

For short-season crops (up to 6 weeks) such as leafy vegetables, the solution need not be replenished, if there is initially a depth of > 20 cm of solution, enough to satisfy transpiration demand over the growth period. For long-season crops such as tomato or for those that are repeatedly harvested, eg. *kangkong* (*Ipomoea aquatica*), the solution needs to be replenished periodically, but without covering the aerial roots. When the level of solution drops to about 20 cm below the base of the media receptacle, 5 cm of solution is added. As the solution is regularly replenished for long-season crops or almost entirely taken up by short-season crops, very little solution is discarded. This maximises the efficiency of using external resources, while minimising the environmental impact of discarded solution often associated with circulating systems.

The solution level can be checked with a dip stick or a simple depth-measuring device. Since a small volume of solution will heat up faster than a large volume, at least 10 cm of solution should remain at the base of the container. If the mean solution temperature does not rise above 28°C, shoot growth of tomato and other crops will not suffer. In the tropics, solution temperature does not exceed this in noncirculating systems, even under high outside temperatures (28°C night, 37°C day). Indeed, yields from the AVRDC hydroponic system are higher than those from small plots in test homegardens.

Local modifications

The white polystyrene boxes used by AVRDC, which are lined with black plastic to avoid algal growth and solution seepage, insulate well. However, in tests with short-season amaranth, use of wooden boxes lined with black plastic resulted in only slightly higher temperatures of the solution.

This system has also been modified in other countries. Wooden fruit crates can serve as containers and, instead of rice hulls as media, local absorbent materials such as cocopeat (Malaysia), cutoffs from the garment industry (Taiwan) or crushed bricks (Bangladesh) are used. Other sources of commercially available nutrients can replace the AVRDC solution.

Fermented liquid pig effluent has been successfully used as the liquid base for the AVRDC system. Diluted by one-half (the fully concentrated liquid with more than 200 ppm NH_4 is toxic for most hydroponic plants), the use of pig effluent is an environmentally acceptable use of an otherwise pollutant. Solid manure, eg, commercially processed cattle dung wrapped in small cotton bags submerged in the container, have also been tested in the AVRDC system. Up to 30 ppm N may be supplied in this form without reducing plant yields. This opens opportunities for future research.

Making the most of inputs

Emptying media receptacles after each short-season crop results in wastes, as does the disposal of remaining solution after each long-season crop. By topping up this solution to the level needed to start a new crop and by sowing or transplanting into the old media after removing above-ground parts, input use can be maximised. Root masses from previous crops accumulate in the container, potentially providing nutrients to subsequent crops. However, in the long term, yields may decline, possibly because of excessive build-up of organic substance. The re-use of media and remaining solution should be tested under local conditions.

The polystyrene boxes used by AVRDC as containers are covered by tight-fitting polystyrene lids, drilled with openings, which vary per box according to plant size and spacing between containers. As a rule of thumb, planting density should be 10-20% more than in the field. Although the size of boxes can vary according to local needs, if space and resources permit larger-scale production, joining several small boxes rather than using one large box prevents potential spread of solution-borne diseases. They are also easier to move, particularly if required during storms. The standard spacing for a 54 x 34 cm surface area per box is for 15 pots (3 rows, each with 5 holes). All holes for receptacles are filled if leafy vegetables are being grown, but only 2-3 for longer-season crops such as tomato or cauliflower.

Mixing species

The flexible management of small boxes, easily re-arranged to reduce inter-container competition for light (eg. tall crops placed where they cause least shading) is an advantage of this simple system over more sophisticated fixed units. Since the solution composition in this system does not vary markedly between species, mixtures of species can be grown in one container. This diversity is important if a household has only few containers, as it brings variety for cooking. Serial sowing (planting on more than one date in a container) is not recommended. As water-level needs differ, satisfactory development of aerial roots cannot be ensured while establishing other plants.

Pesticide-free products

Mixing of species within and between containers is an effective way to reduce build-up of insect pests. Using insect-proof net (1.0 mm mesh size) and sticky yellow traps, pesticide-free hydroponic vegetables have been grown. In more sophisticated structures with a protective roof of polyethylene, the reduced light intensity enhances the texture of leafy vegetables. These, coupled with their recognised pesticide-free status, can be sold to retailers at a premium price.

Cooperative production and marketing of hydroponic produce by small-scale producers could maximise profits (large-scale marketing,while buffering risks). This is currently planned for Vietnam and would fit well into development plans for urban, peri-urban and other densely-populated areas elsewhere in the tropics. Commercial production of household units is also reported from Singapore, Malaysia and Taiwan. One constraint is the reduced productivity during the hot summer months (May - August). This is similar to the troughs of productivity in the field, but still merits further research.

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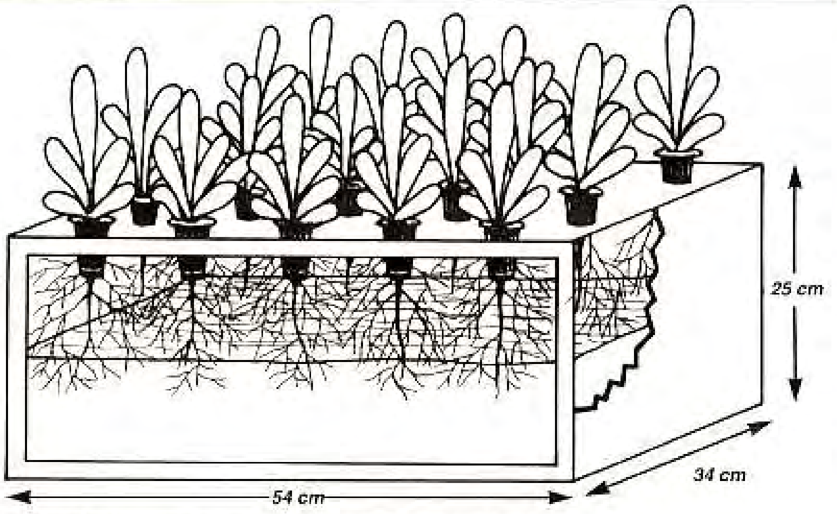

Figure 1: AVRDC hydroponics system for leafy crops (modified from Imai 1987)

Table 1: Constituents of stock nutrient solutions (adapted from Imai 1987)

Solution	Chemical formula	Amount in one litre[1]	Concentration (element)/ppm[2]
A	$Ca(NO_3)_2 . 4H_2O$	0.5904 g	(N) 70.0, (Ca) 100.2
	KNO_3	0.2166 g	(N) 30.0, (K) 38.0
	K_2HPO_4	0.0844 g	(P) 15.0, (K) 83.8
	$MgSO_4 . 7H_2O$	0.0499 g	(Mg) 48.6
B	C10H 1208NaFe.H_2O = Fe-EDTA	2260 mg	(Fe) 3.0
	$MnSO_4 . H_2O$	153.8 mg	(Mn) 0.5
	$CuSO_4 . 5H_2O$	7.9 mg	(Cu) 0.02
	$ZnSO_4 . 7H_2O$	22.0 mg	(Zn) 0.05
	H_3BO_3	286.0 mg	(B) 0.5
	$NaMoO_4 . 2H_2O$	2.5 mg	(Mo) 0.01

1. Ten ml of solutions A and B are added to 1 litre of water to form the culture solution.
2. Total concentration of macroelements N, P, K, Ca and Mg are 100, 15, 121.8, 100.2 and 48.6 ppm and of microelements Fe, Mn, Cu, Zn, B and Mo 3.0, 0.5, 0.02, 0.05, 0.5 and 0.01 ppm in the culture solution.

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