



“This way, you can
even grow fresh produce
in outer space”

Layers under LED light

There is a new global trend: growing vegetables stacked in multiple layers without daylight. This vertical horticulture takes up little space, saves water and can be done in places like disused factories. At present, its main use is for herbs and lettuce seedlings, but in Wageningen its future is being explored.

TEXT MARION DE BOO PHOTO JONAS GRATZER/GETTY IMAGES

As soon as you step inside here, you can almost smell the pesto,' says Leo Marcelis. We are standing in one of the climate chambers on the Wageningen campus. This is where Marcelis, a professor of Horticulture and Product Physiology, experiments with 'vertical gardening'. Basil plants and lettuce grow one above the other in layers. The plants do not get any daylight, but are lit with brightly coloured, energy-efficient LED lights. Each nursery has its own LED strip lights in alternating patterns of red and blue. 'We want to find out how much light these plants need for optimal production,' says Marcelis. 'We can vary both the intensity and the colour of the

light, and we can hang the lights both above and in between the plants. We are studying the plants' growth and production as well as aspects of quality such as taste, nutritional value and shelf life.'

Vertical horticulture, or vertical farming, is on the rise worldwide. In December 2021 Marcelis and his colleagues published a review article on vertical horticulture in *Nature Food*, outlining the numerous advantages of the method. Stacking containers full of lettuces, radishes or strawberry plants enables you to grow much more food in the same space than you could in a greenhouse. Carefully controlled growing conditions guarantee production

and quality all year round. No soil is needed, because the plants grow in pots full of artificial substrate.

ON THE TUNDRA

By this method, fresh fruit and vegetables can also be grown close to the consumer in densely populated urban areas, at locations such as disused factories or office buildings, empty basements, and shipping containers. Marcelis: 'This is a great way to grow fresh produce on the outskirts of cities and near large supermarket distribution centres, for example. But also on the tundra, in the desert and even in a spaceship, on the way to Mars.' >

In vertical horticulture, the water evaporated by the plants is recycled. 'Our tomatoes only need two to four litres of water per harvested kilo of produce,' says Marcelis. 'In outdoor crops in hot countries, they need at least 60 litres; in a Dutch greenhouse, about 16 litres.' Moreover, if the nurseries are hermetically sealed, few if any pests or diseases get in, so pesticides are hardly ever needed, as long as the grower observes strict hygiene and monitors the crops carefully. Nor is there any loss of nutrients to the environment in a closed system.

SUBSTANTIAL INVESTMENTS

The downsides of stacked cultivation without daylight, however, are its high energy consumption and the substantial investments required. 'You need more lamps, more racks and a more expensive climate system than in greenhouses,' says Marcelis. 'But LED lighting is revolutionizing greenhouse horticulture. LED lamps are getting more and more efficient at converting electricity into light and they are also getting cheaper. And they are available in a wide range of colours that you can play with to optimize the growth and production of your plants.'

Red light is very efficient for photosynthesis, the process by which the plant produces sugars under the influence of light. But a plant won't grow well on red light alone; it needs at least a little blue light as well. And besides photosynthesis, certain other processes in the plant are strongly influenced by light too. A plant has a number of receptors with which it perceives different colours of light, and which influence a large number of physiological processes.

Important research questions in Wageningen are whether plants' need for

light stays the same all day, and to what extent the needs of young plants differ from those of fully-grown plants. Light requirements are closely related to other growth factors such as temperature and CO₂ levels, humidity, and air currents. Marcelis: 'There is still a lot that can be optimized. For instance, we know that plants are naturally very sensitive to the ratio of red to far-red light, especially at sunset. With smart lighting, the grower can encourage the plants to grow faster and over a longer stretch of time.'

WORKING WITH INFARM

In January, WUR announced a new collaboration with Infarm. This international company with its headquarters in Berlin has already set up 1,400 vertical farms in supermarkets and large-scale

horticultural centres in 11 countries in North America, Europe and Asia. Worldwide, Infarm is experimenting with 75 different crops. Computers control the cultivation remotely, monitor it via sensors and cameras, and continuously share data via a cloud network. Data scientists analyse the measurement data to adjust production in real time. 'This has enabled us to cut the cost of our nurseries by 82 per cent since 2018, and to increase production by 240 per cent,' claims an Infarm spokesperson. 'Another important thing is that our cultivation systems are modular. Our customers can start small and gradually expand the system, which means lower investment costs at the start.' Some XL branches of Albert Heijn in the Netherlands already have Infarm vertical farming pods in which fresh herbs are grown on-site in the supermarket.



Leo Marcelis, professor of Horticulture and Product Physiology

PHOTO GUY ACKERMANS

‘Our tomatoes only need four litres of water per harvested kilo’

Over the next four years, Infarm will be financing research by two Wageningen PhD students and one postdoc on the stacked cultivation of tomatoes. Marcelis: ‘We are going to work with dwarf tomato plants, no taller than about 20 to 50 centimetres. We want to know how you can grow tomatoes that are optimally healthy and nutritious without daylight and using as little energy as possible. We shall evaluate their growth rate, health and nutritional value, using sensors and 3D scanners.’

ATTRACTING CAPITAL

Investors believe in vertical horticulture. In December 2021, Infarm raised 200 million dollars in capital, earmarked for the expansion of its global operations. In 2023, the company will open a research centre in the desert state of Qatar. A competitor from San Francisco, Plenty, raised 400 million dollars from investor SoftBank and supermarket chain Walmart in January 2022. Plenty sells vertical farming systems to supermarkets. The company claims that its system can produce as much food on one hectare as a conventional farm on 360 hectares, while using 95 per cent less water. In Amsterdam, the vertical-farming company GROWY is already growing 50 varieties of lettuce, herbs and microgreens for restaurants and delicatessens. And in Poeldijk, Future Crops is pioneering the vertical cultivation of herbs.

Marcelis: ‘Until about 10 years ago, I was sceptical about vertical horticulture. Dutch greenhouse horticulture has a strong competitive position. Although we often grumble about our climate, viewed year-round, a temperate climate is actually very favourable for greenhouse horticulture.’ Further north it is too dark, further east it is too cold in winter, and further south it is too hot and dry in summer.

Dutch greenhouse horticulture is also

highly developed, and the horticulturalist has everything under control. When it gets too cold, the heating is switched on. When it gets too hot, the windows are opened. And when it is too dark, there is additional lighting. Marcelis: ‘Vertical horticulture is a logical next step. Both growing systems will exist side by side and will partially overlap. There are already growers who use vertical horticulture to grow young plants, only putting them in the greenhouse in the final phase, when the need for light is greatest.’

BOOMING

Vertical horticulture is rapidly gaining ground in America and Asia. According to Marcelis, Dutch growers work very efficiently and keep a close eye on costs. ‘That is why they can produce fairly cheaply. Vertical horticulture will have to compete with that. But increasingly, it will not just be about the cost price. Vertical horticulture is more likely to take off in other countries where horticulture is less developed and the climate is often less favourable,’ he expects. ‘Water-saving growing systems with climate control are especially welcome in hot desert countries.’

Marcelis cannot make categorical statements about the costs of vertical farming. But he doesn’t believe vertical farming will be viable for bulk crops such as cereals because of the investments involved. ‘The system is still so new that everything is changing all the time. That is why we do not have good objective figures yet. Of course, it is nice for consumers to see mint and coriander growing in cabinets in the supermarket, but that will only be a small section of the market. The entire horticultural industry, vertical or otherwise, is working on systems for farming autonomously and on an ever-larger scale.’ ■

www.wur.eu/verticalfarming

IDEAL PLANT SHAPE

The ideal plant has its leaves neatly spread out, without overlap, so that all the light is caught and is evenly distributed over them. In practice, a lot of light still falls on the ground and goes unused. In Wageningen, researchers are going to use a 3D scanner to depict the structure of the plant. How compact can or should a plant be? How is the light intercepted and distributed by the various layers of leaves? Another important question is how the sugars produced by photosynthesis are distributed between the leaves and the fruit. The researchers also make simulation models of the light interception, photosynthesis, plant shape and nutritional supply for every conceivable combination of varieties. The shape of the plant can be influenced by directing the light onto particular parts of it. Plant breeders may also be able to further optimize the position of the leaves.