Rise of the Robots

Text and photographs by Louise Murray

A worldwide shortage of skilled and semi-skilled horticultural workers is driving automation. But is the fully autonomous, self-cultivating greenhouse a reality?

The precise, repeating actions of the lisianthus flower-planting robot at Waalzicht nursery in the Netherlands are mesmerising. They contrast starkly with its human caretaker, a gangly Polish lad who seems clumsy in comparison. His job is to keep three robots supplied with a constant stock of trays of tiny young plants, keeping an eye on its output and correcting the few mistakes in planting that it makes. Before the robot's introduction to the job, the young man would have been part of a team, lying on his stomach, his face just centimetres from the earth for hours on end, hand-planting each flower in 32 degree heat and near 100 per cent humidity. Since their installation in February 2018, the three robots that took over here have planted 35 million lisianthus into the giant glasshouse the size of eight rugby pitches.

Whether it's lettuce in California, strawberries in Kent or cut flowers in Holland, each year stark warnings about crops about to rot in the field or glasshouse become louder as farmers and owners struggle to recruit enough labour for jobs that are often seasonal and physically demanding. They are turning to technology for help. Coupled with advances in computer vision and machine learning, robots are influencing growing methods, cropping, harvesting and traditional plant breeding as never before. Those in the world of horticulture, already the most controlled form of growing, are leading the way by deploying robots to decrease labour needs.

The robots at Waalzicht nursery were designed and built by ISO Group, a global player in applied robotics in horticulture. Their first machines were set to work in Dutch greenhouses planting chrysanthemum cuttings in 2010. Now, over 80 per cent of all cut flower chrysanthemums in Holland are planted by a robot. 'The cuttings are taken from mother plants in low-cost labour countries in Africa and South America to a precise specification that aids their later robotic handling, before being flown in to Holland to the nurseries,' says Paul Blom from ISO. 'There are now hundreds of robots at work in Dutch horticulture.'

The mostly Polish workforce at Waalzicht still plays a vital role, for now. Humans uproot the flowering plants, gather them into bunches, pass them on to a conveyor belt (where they then have to be trimmed of their roots and have their stems cut) and finally insert them into sleeves ready for sale. But the number of people at Waalzicht nursery involved in simple harvesting and packing of lisianthus flowers suggests that there are many tasks left where automation might be introduced.


SWEEPER, the experimental sweet pepper harvesting-robot developed at Wageningen University, Netherlands

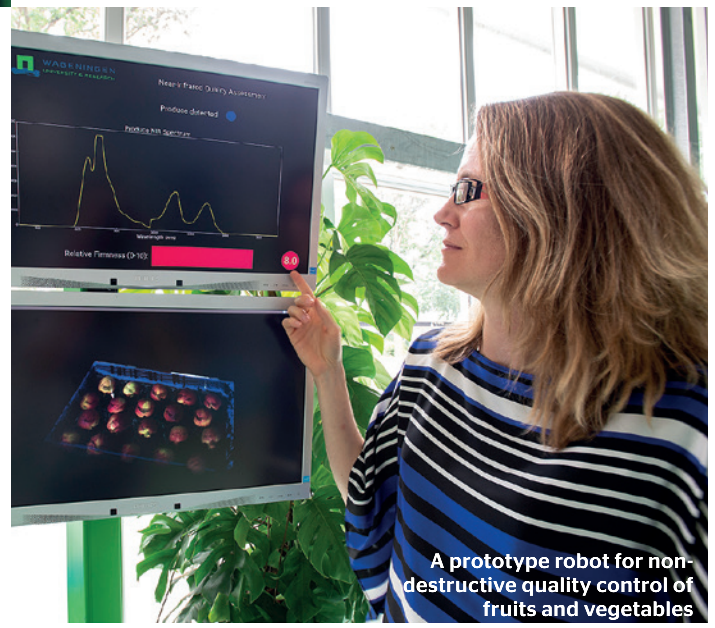
GREEN PEPPER PROBLEMS

While robots are already hard at work transplanting young plants in the commercial world, academic researchers are tackling the harder jobs in the greenhouse. Wageningen University & Research (WUR), also in the Netherlands, is a world leader in both the horticultural and agriculture sectors and is at the forefront of horticultural robotics development. 'WUR is a unique place where developers of drones, AI tools and computer vision work alongside biologists who use the equipment and interpret the data to improve the crops of the future,' says Rick van de Zedde, senior scientist in phenomics and automation at WUR.

One of WUR's developments, the result of three years of research, is SWEEPER, the first sweet pepper harvesting-robot designed to work in commercial greenhouses. SWEEPER's cameras scan the bottom of the pepper for a colour indication of ripeness and maturity, before cutting the stem and dropping the fruit into a waiting robotic hand. The prototype system is still some way from commercial use as it takes about 24 seconds to harvest one pepper and currently only works well on yellow-coloured varieties where there is


At Waalzicht Nursery a young Polish worker trims and packs the picked flowers ready for auction

The robots are dealing with living things – pick up a cutting or a fruit with too great a pressure and the living tissue may be fatally crushed


A prototype robot for non-destructive quality control of fruits and vegetables

a strong contrast between the fruit and the leaves, but Jochen Hemming, a WUR researcher, thinks there is potential for this to improve. 'Peppers are one of the most challenging crops for robotic pickers as the fruit is often hidden inside the leaves,' explains Hemming. 'We are in discussion with breeders and they see possibilities to make crops more robo-friendly in the future, with longer internodes between the leaves and less clustering of the fruits, perhaps even changing the growing method. Once we have mastered the pepper harvest, the technology will be easily transferable to other cropping systems.'

In general, horticultural robot designers face far greater challenges than their compatriots working on industrial assembly lines. First, the robots they build are dealing with living things – pick up a cutting or a fruit with too great a pressure and the living tissue may be fatally crushed or damaged enough to allow ingress of disease. The grippers that these robots use have to be far more sophisticated than those on your average paint spraying machine. The robotic picking and handling interface with the tomato, berry or stem has to be designed both specifically for that crop and also for the task in hand. Planting cuttings and seedlings requires a very different approach than that used for harvesting – a tweezer-like tip for a cutting manipulator and a suction cup to harvest ripe strawberries.

Secondly, these robots need to be able to precisely interpret what they see as they handle highly variable living things – planting a cutting upside down just won't work. Teaching them to see and, more importantly, interpret and act upon an image requires machine learning. The robot must be taught to identify a leaf, stem, flower or fruit and to categorise each correctly. From that information it must know where to pick up a cutting or harvest fruit. It is still very difficult to get a robot to see a green pepper hanging behind a green leaf in a green crop.

Janneke de Kramer leads the agro-food robotics programme at WUR. 'We are developing technology that assesses quality at all stages of the crop, from the seed, to post-harvest grading and consumer tasting,' she says. Seeds are assessed using automated near-infrared spectroscopy. The system analyses the seed quality using parameters such as moisture content, protein and fat, to determine the germination capacity and then discards low quality seeds. At the seedling stage, 3D cameras can measure the shape and surface area of the early leaves, while other computer vision techniques quantify photosynthetic activity so that only the strongest plants are grown. During growth, crop sensors scan for the earliest presence of diseases or insect infestation and in the future drones may fly through crops to deliver precise spot treatments. Currently, 80 per cent of chemical treatments do not end up on target, so precise application of chemicals will allow growers to use less.

Once the crop is harvested, WUR is looking to introduce rapid non-destructive testing of fruit such as apples. 'Automated quality control by machines can replace repetitive grading tasks performed by humans, and is more objective. Where people would each grade somewhat differently, automation can ensure a consistent accuracy,' says de Kramer. The team have built a prototype quality control robot for grading apples and pears. It uses a laser sensor and hyperspectral infrared camera to penetrate the interior of the fruit. The values are compared against a spectral curve model of a perfectly ripe specimen. The robot then uses a standard RGB camera to locate and pick up each item, sorting them into bins after the analysis. Knowing the exact stage of ripeness of each fruit will help to improve the storage life of the crop.

THE FUTURE OF BREEDING

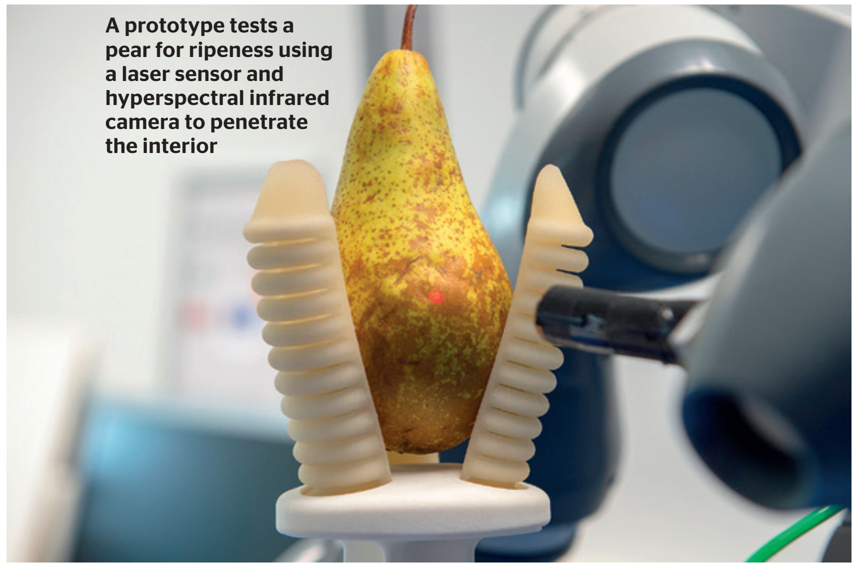
Robots are also transforming the way that plants are grown long before they are harvested for commercial use. It is probably in plant breeding that robotics technology will ultimately have the greatest impact. The phenotype of a plant – what it looks like and how it performs – is the result of the interaction of its genes and the influence of the environment in which it is grown. Plant breeders have been observing phenotypes and selecting the best performing plants for centuries to create higher yielding vegetables or more floriferous decorative plants. WUR's van de Zedde explains how robots are being used to move this process forward. 'We use advanced cameras, drones and sensors to screen large numbers of plants automatically, measuring plant characteristics such as leaf shape, plant architecture and physiology,' he says. 'Because we take genetic samples from each seedling at the beginning of its life we can increasingly correlate plant performance to its genetics directly.'

This type of automated data collection saves time and money. It also improves the quality of data. As well as physical attributes, WUR can measure photosynthetic efficiency in the plant in real-time using chlorophyll fluorescence imaging. This indicates how well a plant can convert light into growth. As plants only use one per cent of sunlight for actual plant growth, a small change here could result in large improvements in yield and production. By analysing this data researchers at WUR hope to breed better varieties that may be more disease resistant or better able to cope with climate change stresses. They are also focussing on post-harvest traits to develop tomatoes and strawberries that are more appealing to consumers, taste better and have a longer shelf life.

Van de Zedde is now setting up the Netherlands Plant Eco-Phenotyping Centre to continue this work, a €22m joint WUR and University of Utrecht project aimed at keeping the Dutch at the forefront of horticultural practice. We are probably some decades away from dispensing with the human workforce in horticultural crops altogether, but task by task, automation is transforming the business. ●

An employee at Beekenkamp nursery conducts a quality control check of chrysanthemum cuttings planted by six robots

It is still very difficult to get a robot to see a green pepper hanging behind a green leaf in a green crop


A prototype tests a pear for ripeness using a laser sensor and hyperspectral infrared camera to penetrate the interior


Proud parents: TrimBot navigates the test garden

AT THE CUTTING HEDGE

■ Robots often get a bad press but no one could argue that TrimBot is a bad bot. Combining robotics and 3D vision, this EU-funded project sets out to automate plant trimming in the garden. Moving around on a modified Bosch automated lawnmower, TrimBot navigates its test garden in Wageningen using 3D scene analysis, cutting box hedges and topiary to shape and learning to prune rose bushes while avoiding the posts of the pergola and the bunkers of the flower beds. For a gardener these are simple if boring jobs. For a robot it's a big ask.

Robotics engineer Bart van Tuijl, designer of TrimBot's cutting head for boxwood and hedge topiary, explains how it works: 'TrimBot has to be able to accurately cut and shape as it moves around the plant. I was thinking about how to improve the design of the cutting head one morning while shaving and got the idea to use counter rotating blades similar to those in my electric razor. That design helps the robot cut even when the plant moves.' The autonomous gardener uses novel algorithms to see through the overgrown shape of a bush comparing it to an ideal surface shape as it trims.

With a different cutting head at the end of its arm, TrimBot attempts to tackle rose pruning, a thorny task at the best of times but, as strong winds blow ahead of a summer thunderstorm, an impossible one for the small robot. Once the storm has passed and the winds have dropped however, TrimBot is ready to get back to work, approaching the rose bush, correctly identifying the leaf stem junction and snipping it into shape.

The ultimate goal is to deliver a small battery powered machine that can work autonomously while the gardener watches, cup of tea in hand, as a later iteration of TrimBot mows the lawn and stops to trim the hedge along the way.