UC Agriculture & Natural Resources
California Agriculture

Title
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Permalink
https://escholarship.org/uc/item/8hq3x13j

Journal
California Agriculture, 72(2)

ISSN
0008-0845

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Publication Date
2018

DOI
10.3733/ca.2018a0018

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Next-generation mechanization

New advances in image-recognition technology and robotics are reducing the need for manual labor — and potentially herbicides as well.

On vegetable farms in the Salinas Valley, a shrinking farm labor pool and rising minimum wages are driving innovation and adoption of machinery that can automate manual labor tasks — thinning, weeding and, for some crops, harvest. The technology is evolving quickly, led mainly by small engineering firms collaborating with large growers.

Automation promises a number of benefits. Foremost, of course, is a reduced dependence on manual labor. But it could help in other ways too — for instance, automated weeding could remedy the declining effectiveness of some herbicides.

UC researchers and advisors are helping to advance the basic technologies involved, and also serving as key evaluators of the technology (see research article page 114). But the drive to automate also raises decades-old concerns about UC contributions to new technologies that are likely to primarily benefit only large-scale growers, at least in the short term.


Harvest Moon Automation

This modified leafy greens harvester, developed by Harvest Moon Automation in partnership with two Salinas Valley growers, uses a camera and pattern-recognition technology to spot foreign objects and diseased or damaged plants. A mechanical arm pushes such contaminants out of the way of the harvesting blades, so they are left in the field instead of being fed into the processing line.

Automated thinners and weeders

The automation of thinning (removing excess crop plants) and weeding (removing noncrop plants) involves two main steps: identifying each plant to be removed and then directing the killing of the undesired plant with a blade or a small dose of herbicide. It replaces work that would otherwise be done by hand with hoes.

Figures on the acreage being thinned by machine aren't available, but the use of automated thinners in some crops, notably lettuce, has been expanding in the Salinas Valley since its introduction in 2012 (see research article page 114).

Camera-guided automated weeders are now in use on a number of vegetable farms as well. The two in widest use in the Salinas Valley, according to several researchers and equipment suppliers, are made by two small northern European firms, Denmark-based F. Poulsen Engineering and Netherlands-based Steketee. Long-running concerns about farm labor cost and availability in Europe have driven automation innovation, and the technology has been more widely adopted there than in the United States, said Richard Smith, a UC Cooperative Extension (UCCE) farm advisor in Monterey County.

While the weeding machines are costly — roughly $150,000 to $200,000 — their use appears to be limited more by availability than by price, according to equipment suppliers and UCCE staff. Poulsen and Steketee are small operations with limited production capacity.

Britton Wilson of Pacific Ag Rentals, an equipment supplier to Salinas Valley farms, estimated that there are 15 to 20 Poulsen weeders (called Robovators) in the United States, a figure Poulsen corroborated.

"I'd love to get my hands on more" to meet local demand, he said.

Developing the machines

A crop like lettuce or broccoli represents a comparatively small market for major farm equipment makers like John Deere and Case IH. About 300,000 acres of lettuce (of all types) are grown in the United States, for instance, compared with 12 million acres of cotton or 90 million acres of soybeans.

As a result, vegetable crop automation is being led by small engineering and fabrication firms as well as growers themselves, often in close collaboration, said Mark Siemens, an associate specialist and associate professor of agricultural and biosystems engineering at the University of Arizona.

Because the technology is somewhat modular, it's possible to address the needs of a particular crop or grower by combining or modifying existing technologies and equipment.

An example: Harvest Moon Automation, a four-employee engineering firm with several clients in the

Salinas Valley, recently received a patent on a modified version of a leafy greens harvester developed in partnership with two Salinas Valley growers.

Steve Jens, Harvest Moon's president, said the new machine uses a camera and pattern-recognition technology to spot foreign objects (such as a piece of plastic or bird droppings on a leaf) and diseased (downy mildew) or damaged plants as the harvester moves across a field. A detection by the camera triggers an arm that pushes the crop leaves out of reach of the harvester's blades, keeping the contaminant from being harvested and fed into the processing line. The growers who partnered with Harvest Moon on the project funded the prototypes and testing, and now will be the first to use it.

Herbicide effectiveness and automated weeding

While John Deere isn't building automated weeders for vegetable crops, it is interested in the technology involved. In 2017, Deere paid $305 million to acquire Sunnyvale startup Blue River Technology, which had developed plant-recognition technology that was incorporated in a lettuce-thinning machine used by growers in the Salinas Valley.

Since then, however, Deere has focused Blue River's technology on cotton, and, according to UC and University of Arizona extension researchers, the company no longer offers lettuce thinning services in the Salinas Valley or Yuma, Arizona (another lettuce production region).

A major motivation for the focus on cotton, and potentially other commodity crops, is the declining effectiveness of widely used broadcast herbicides like Roundup that are applied to fields of crops genetically modified to tolerate the herbicide (weeds are evolving to tolerate the herbicides). Chemical companies are struggling to develop next-generation chemicals that are effective and satisfy environmental regulators.

Weed-recognition technology could lead to a new approach to weed control — replacing broadcast herbicides with higher-potency, focused, small doses aimed directly at weeds, or, for some applications, robotic hoes — that promises less overall use of herbicide and more effective weed control. Blue River says a viable version of its technology (which uses focused doses of herbicide) for cotton is still several years from commercial release (Burger and Polansek 2018).

In vegetable crops, as with commodity crops, existing herbicides are becoming less effective, said Steve Fennimore, a UCCE weed specialist based in Salinas. But the prospects for new herbicides suitable for vegetable crops are even dimmer than those for commodity crops because vegetable crops represent a relatively small market for chemical makers.

"The chemical industry invests very little — essentially nothing — on these crops," Fennimore said.



UC Davis engineer Burt Vanucci (left) and Professor David Slaughter adjust the robotic hoes on an automated weeding machine for a trial in an organic tomato field at the Russell Ranch Sustainable Agriculture Facility near Davis.

Due to the complexity of chemical development and the high cost of the regulatory approval process, large chemical companies are effectively the only entities capable of commercializing a new herbicide, for any crop.

But for automated weeding, Fennimore noted, there are essentially no regulatory hurdles, and it doesn't take the resources of a giant company to develop working prototypes. Small firms can innovate meaningfully.

As a result, Fennimore said, the best prospects for advances in vegetable weed control are likely to be through improved machines, developed by small firms and growers, with support from UC and the research community.

Next steps for weeding technology

Currently, automated weeding systems work well in relatively simple settings — low weed density, little or no overlap of weeds and crop plants. In more complex settings, current image-recognition technology struggles to reliably identify which plants should be removed.

David Slaughter, UC Davis professor of biological and agricultural engineering, is working with nine collaborators — from UC Davis, UCCE, Washington State University and the University of Arizona — on a $2.7 million USDA-funded project to improve mechanized weed control by developing better systems for what's called crop signaling — distinguishing crop plants from weeds.

One approach uses a biodegradable straw with a fluorescent coating inserted into the soil with the crop plant. The coating is readily detected by a camera, which can then tell the weeding equipment which spots to avoid.

Another crop-signaling method uses high-precision GPS to record planting locations. "We can make a map of every seedling," said Slaughter. When it's time for weeding, all plants that aren't on the map are removed.

Slaughter noted that another general path of evolution for automation is the adaptation of growing practices — plant spacing, crop varieties, the timing of weeding and so on — to suit the available technologies.

The grant is also funding a study of factors influencing vegetable growers' adoption of automation technology (see sidebar).

Automating harvest

Harvest is generally the most costly step in vegetable production, due chiefly to the amount of labor required.

Salinas-based Taylor Farms, the world's largest salad producer, has invested heavily in harvest automation, developing romaine lettuce and cabbage harvesting equipment used by the growers it contracts with to supply the bagged salad market (see cover photo).

But for many vegetable crops, as well as other major Central Coast crops like strawberries, effective automated harvesters have yet to be proven.

"Automating the harvest — that's the Holy Grail for pretty much everybody," said Brian Antle, who runs the planting automation company PlantTape and is a member of the family that co-owns Tanimura & Antle, one of the largest fresh produce growers in the Salinas Valley.

An intermediate step is "co-robotics" — designing robots to work alongside human laborers, with the robots handling simple tasks while people continue to perform the more complex and delicate actions. One example is self-guided carts that assist human strawberry pickers by carrying full trays of (hand-picked) strawberries out of the field and returning with empty trays.

"The recognition is that the agricultural environment is very complex, and we may not see full autonomy in the next decade," said Slaughter.

Automation and farm scale, fraught history

In the 1960s, the release of a processing tomato harvester, developed by two UC Davis researchers, transformed the production of that crop. Only larger growers could afford one, and because the machine dramatically reduced the costs of harvesting, it created a powerful economy of scale that encouraged big growers to expand. In the first few years after the harvester's introduction, a large fraction of the state's tomato growers left the business.

Advocates for small farmers and farm workers organized to criticize UC's role in developing the harvester and to push for more UC support for small farmers. In a 1979 lawsuit, they argued that the tomato harvester favored large farmers, violating the public benefit mission of land-grant university research as established by the Hatch Act of 1887.

UC prevailed in court after a 10-year legal battle. But the conflict drove lasting changes at UC and elsewhere. Federal funding for automation research declined, and agricultural engineering departments shifted focus to other types of research, Slaughter said. UC also created programs focused on small farms. Today, UC ANR programs targeting small farms include the Sustainable Agriculture Research and Extension Program and the UC ANR Small Farm Working Group.

Like previous waves of mechanization, automation in vegetable crops stands to mainly benefit larger farms, at least initially. Large, highly standardized fields of a single crop tend to be better suited to mechanization than the fields of a small farm growing a variety of crops. And, as noted earlier, large growers are currently the main market for — and often the lead investors in — novel automation technologies, which tend to be designed to solve the problems they face on their own (large) farms.

Margaret Lloyd, a UCCE small farms advisor in Yolo County, said that automation technologies can benefit small farms too — but small growers need versions of the machines that are less expensive, more versatile, and designed with small scale in mind.

"Could you make a machine that does four rows at a time, but also make one that is simpler and cheaper and only does one row?" she said.

Yes, probably, said UCCE's Fennimore — once the technology is well developed.

"Do tractors only benefit large growers? No, because we now know how to build tractors and there are lots of them, new and used, and thousands of grower customers are each paying a small fraction of the research and development cost to improve tractors," he said.

"Eventually this will be true for weeders and other smart technology." CA

—Jim Downing

Reference

Burger L, Polansek T. 2018. Robots fight weeds in challenge to agrochemical giants. Reuters. Published May 21, 2018. www.reuters.com/article/us-farming-tech-chemicals-insight/robots-fight-weeds-in-challenge-to-agrochemical-giants-idUSKCN1IN0IK

Adoption of automation technologies: Preliminary survey results

Laura Tourte, UCCE farm advisor for Santa Cruz, Monterey and San Benito counties, is leading a study of vegetable growers' adoption of automation technologies for transplanting, thinning, weeding and harvest. The study is part of the USDA-funded project led by David Slaughter of UC Davis (see main text).

Initial results indicate that, in deciding whether to use these technologies, top considerations for vegetable growers include labor issues (difficulty finding workers, cost of labor, related regulations and workforce productivity), the desire to reduce production costs, and the reliability of the technology. Considerations that ranked lower include vulnerability to hacking, and access to specialized training and tech support.

Some of the reported barriers to technology adoption are problems with reliability and accuracy of automated equipment (seen as a definite obstacle). The investment cost and need for technical support or specialized training were seen as less of an impediment (only somewhat of an obstacle).

The initial results are based on surveys of 98 vegetable growers in California. Most farm more than 1,000 acres, and many are mixed conventional and organic operations.

Tourte plans to conduct an additional survey of Washington state vegetable growers as part of the project. She and her UCCE colleagues are also evaluating costs and labor savings associated with these new types of equipment.