Grower Summary

CP 134

"eyeSpot" – leaf specific herbicide applicator for weed control in field vegetables

Final Report 2020

Project title:	"eyeSpot" – leaf specific herbicide applicator for weed control in field vegetables
Project number:	CP 134
Project leader:	Alistair Murdoch, University of Reading
Report:	**Final Report, July 2020**
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Key staff:	University of Reading: Professor Alistair Murdoch (PI), Dr Nikolaos Koukiasas (Researcher and PhD student), Paul de la Warr (software engineer). Concurrent Solutions llc: Dr Robert Pilgrim, Shane Sanford, Steve Bruekner.
Location of project:	University of Reading School of Agriculture, Policy and Development: (a) Agriculture Building, Earley Gate, (b) Controlled Environment Laboratory, Whiteknights and (c) Crop Research Unit, Sonning Farm. Concurrent Solutions llc (USA): (a) Benton, Kentucky, (b) Nashville, Tennessee and (c) Dallas, Texas (including linked activities not funded by AHDB).
Industry Representative:	Mr Phil Lilley, Hammond Produce Ltd., New Farm, Redhill, Nottingham NG5 8PB.
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Co-funders	Co-funders of PhD student: Douglas Bomford Trust, Edith Mary Gayton Trust Fund and the University of Reading Graduate School, University of Reading, School of Agriculture, Policy and Development) Co-funder of project: Concurrent Solutions llc funded associated development work, the prototype autonomous platform (robot) and most of the software. Concurrent Solutions llc. and Soya Bean Growers Association jointly funded the glasshouse facility at Benton, Kentucky.

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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Alistair John Murdoch

Professor of Weed Science

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GROWER SUMMARY

Headline

- Weeds up to the 4-leaf stage could be controlled leaf-specifically by applying one droplet containing either 32 µg of glyphosate or 28 µg of glufosinate-ammonium to a single leaf of the seedling.
- The economic analysis predicted that weed control using plant-specific droplet applications to weeds in UK cabbage crops and leaf-specific applications in UK leek crops would at least maintain and in many cases increase their profitability for growers. These economic benefits include the full estimated costs of an automated system for droplet application. More specifically:
    - In cabbages, three plant-specific droplet treatments with glyphosate droplets resulted in gross margins above the total costs of weed control estimated at £32,000 ha^{-1} for savoy cabbages in 2016, which was significantly higher than the £22,000 ha^{-1} when weeds were managed by conventionally-sprayed pre-emergence pendamethalin. For the white cabbage crops grown in 2017, differences between weed control regimes were not significant largely because the crop competed effectively against the weeds. Importantly however, plant-specific weed control did not reduce the profitability of the crop.
    - In leeks, ten leaf-specific applications of glyphosate droplets at approximately weekly intervals in both 2017 and 2018 and a similar treatment using glufosinate-ammonium in 2018 achieved gross margins of £29-32,000 ha^{-1}, much higher than the £10-17,000 ha^{-1} for the conventionally-applied pre-emergence pendamethalin spray.
    - To support growers in deciding whether to adopt leaf-specific weed control, simulation modelling predicted that there was over an 80% chance that a grower would make more profit by controlling weeds in leeks leaf-specifically compared to conventional spraying. Gross margins after accounting for all weed control costs, were predicted to ***increase*** by more than £10,000 ha^{-1} (per year) in 60% of cases.

- In terms of the efficacy of weed control, over 90% weed control was achieved with leaf-specific droplet treatments, even though herbicide inputs were reduced by up to 82 and 94% in transplanted leeks and cabbages, respectively.
- A prototype platform (Figure 1) for leaf-specific weed control was developed for the project by Concurrent Solutions llc and was demonstrated to growers and other interested parties in July 2019. Commercialisation under present market conditions requires further investment and also a larger market than exists in the UK alone.

Figure 1 Prototype robotic platform specially designed, developed and built for the eyeSpot project by Concurrent Solutions llc in the USA. The platform was designed to treat four rows of vegetables planted in beds of two metres width. The platform is shown at Sonning Farm in July 2019 with four rows of cabbages (50 cm between rows; 30 cm between plants in rows.) The black tapes along each row are the drip irrigation system. The platform was demonstrated to growers and others in July 2019 at an AHDB Open Day, which was organised to disseminate and demonstrate the results of the eyeSpot project.

Background

Weeds and their control play a vital role in maintaining vegetable yields and quality and herbicides are a highly efficient method of managing weeds. Herbicides account for 40% of the total amount of pesticides applied by vegetable growers compared to 31 and 24% for fungicides and insecticides, respectively (Garthwaite *et al.*, 2017). However, improper or inappropriate use of herbicides may have adverse effects on human health and the environment. Even though herbicide use is subject to stringent regulations, the EC Regulation No. 1107/2009, the Water Framework Directive (2000/60/EC) and the Sustainable Use Directive (2009/128/EC) are leading to the loss of herbicide actives and make it more difficult for new compounds to gain approval. This predicament is exacerbated for field vegetable growers because they rely on a limited range of older herbicides released in the 1960s and 1970s, which require a lot of funding and effort in order to keep them in the market.

This project offers a paradigm shift for post-emergence weed control in field vegetables. Some use of chemicals is retained, but the focus was to develop a novel engineering solution. The concept was to control individual weeds plant- or leaf-specifically by applying single droplets of a non-selective, systemic herbicide to the unwanted plants. As far as possible, direct herbicide applications to the crop or the soil were to be avoided.

Overall objectives were to:

- minimize herbicide inputs and meet demand for more sustainable crop production, providing an efficient, cost-effective and environmentally-sustainable means of controlling weeds in vegetables;
- eliminate herbicide drift and reduce run-off to the soil, crop and non-target organisms; and
- provide an alternative to conventional spraying for transplanted field vegetable crops where few post-emergence herbicide options are available.

Plant specific weeding by hand is what growers have traditionally done. Individual plants are examined and the unwanted ones are hoed or removed. Even were the labour available and willing to hand-weed crops, the process is unlikely to be cost-effective and the task is dull, difficult, dirty and perhaps even dangerous (the four “Ds” of robotics).

The proposed system also offers advantages over mechanical intra- and inter-row tillage systems. Energy and fuel use are expected to be lower and the absence of soil disturbance means fewer weed seeds will be stimulated to germinate and the likelihood of soil erosion will be lower.

The project was therefore funded to explore the possibility of achieving leaf-specific weed control using an autonomous platform. The project is an alternative to other possible plant specific weed control systems which have been proposed using directed sprays, lasers or electrocution. The former is currently available and the latter two have been investigated but, as of now, appear to have been deemed unsuitable for commercial development. A detailed comparison of the directed spraying option with eyeSpot was carried out prior to this project receiving funding and perhaps the essence of the difference is that the former targets large individual weeds such as potato volunteers, whereas eyeSpot is designed to reach weed seedlings with a leaf area of 1 cm^2, i.e. soon after they emerge at cotyledon or first true leaf growth stages.

Summary

Precision targeting of herbicide droplets to the leaves of weeds involves use of very small droplets (1-2 microlitres) – so that one teaspoonful (5 ml) was enough to treat 2500-5000 individual weeds if one droplet is put on each weed. Nevertheless, the droplets are much larger than those used when spraying conventionally so that there is no risk of spray drift. There is still a potential for spattering on impact and some shattering of droplets on ejection from an applicator and the droplets are likely to be deflected by wind. We therefore carried out preliminary trials with a prototype droplet ejector to investigate how applicator pressure and distance from target affected spattering. The effect of wind on deflection of droplets was also investigated in a multifactorial experiment comprising windspeed and direction, applicator pressure and distance from target as factors. Provided windspeed and direction are known, deflection could be modelled and compensated for. Applicator pressure of 138 kPa (20 psi) avoided all spattering and droplet shattering after ejection in our tests.

Our initial experiments all related to use of glyphosate – in many ways an ideal active ingredient because of its mode of action, efficacy against most weeds, low cost and, most importantly for droplet applications, its systemic behaviour in plants. To reduce the risk of creating a selection pressure for glyphosate resistance in weeds and to explore alternatives should glyphosate lose its approval, we have also tested glufosinate ammonium and 2,4-D and mixtures of these products. Although glufosinate ammonium has limited systemic action, it achieved reasonable efficacy. 2,4-D is systemic, but would not control grass weeds.

Doses applied in every case are linked approximately to the ground cover of the weeds. As a general recommendation, weeds that are up to the 4-leaf stage can be controlled with a dose of 32 µg of glyphosate and 28 µg of glufosinate-ammonium when these amounts are applied plant-specifically, that is as a single droplet per seedling. There is a potential issue as regards approval, for although the amount of product applied to each square metre of field will always be less than the permitted dose, the same cannot be guaranteed for every square centimetre. There are of course 10000 cm^2 in each square metre but the current approvals were devised for broadcast spraying and do not take account of the focussed targeting of individual plants or leaves achievable by robotic weeders.

In field trials (2016 to 2018) with plant- or leaf-specific weed control droplets, herbicide inputs were reduced by over 90% and 70% in cabbages and leeks, respectively, compared to a pendimethalin pre-emergence spray. Efficacy of weed control and crop yields were not significantly lower than in the hand-weeded, "weed-free" controls.

Financial Benefits

A detailed economic analysis showed that, after accounting for all fixed machinery costs and all the variable costs of weed control, leaf-specific weed control could ***increase*** profits by over £11000 and £1500 per hectare per year for leeks and cabbages, respectively. Bearing in mind that these are average estimates, a novel further analysis was introduced to give growers an idea of risk. This indicated that leaf-specific weed control could offer UK leek growers an 82-86% probability of making a higher profit, and a 60% probability that that increase in profit would exceed £10000 per hectare per crop.

Action Points

The research and prototype platform produced in this project (Figure 1) should encourage growers towards a paradigm shift in their thinking about weed control. It is a win-win situation where growers could increase profits while benefiting not only environmental benefits through lower herbicide use but also potentially improving consumers' perceptions of food quality since no direct herbicide applications would be made to the crop.

It is, however, necessary to ensure expectations are realistic. The project's prototype is not a commercial product and, as of now, a considerable investment of time and money would be needed to bring the prototype platform demonstrated to market.

The project team would be interested in hearing from growers who would consider purchasing such a system and to indicate whether they would prefer a completely autonomous platform (robot) or a tractor mounted application module.