final report

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Autonomous Map and Zap Weed Program Application

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Executive summary

This project investigated developing a world-first breakthrough and transformational tool for implementing a new direction in weed identification and locating (mapping) and control (zapping or chemical pinpointing). The objective was to deliver an effective new response to a long-standing issue of weeds, currently causing lost productivity of over $1.7B per annum in New Zealand and $4B per annum in Australia. The preliminary Australian R&D team for collaboration identified as the Institute for Integrated and Intelligent Systems at Griffith University while the Australian Centre for Field Robotics at the University of Sydney is another potential collaborator. A communication strategy was developed for the life of the project. Annual and a perennial grass species were proposed to be selected for zapping studies in the next phases of the work due to initial success in weeds in New Zealand. Further, it is recommneded a perennial dicot weed species that is of economic importance (cost) to the livestock industry and is a close relative of buttercup (Ranunculus acris) for the zapping stage. However, it is not recommend zapping for Thistles due to the need for repeating the zapping process, because of their strong roots and re-growth in our initial experiments.

Table of contents

Autonomous Map and Zap Weed Program Application **1**
1 Background **4**
2 Project objectives **4**
3 Methodology **4**
4 Results **5**
4.1 Science area 1: Zapping 5
4.2 Science area 2: Mapping 6
5 Discussion **6**
6 Conclusions/recommendations **6**

1 Background

This project was undertaken to explore the feasibility of an integrated weed identification and control system using the latest sensor technologies. The agriculture, biosecurity and other industries and local councils are spending up to $2B per annum in New Zealand and $4B per annum in Australia to control weed using traditional weed control technologies. These technologies are also broadly applying systemic and non-discriminative spraying of weeds as well as other plants, animals and soil and therefore leave heavy environmental footprints. The aim of this project was to provide the proof of concept for an efficient, high throughput and accurate technology for spot targeting weeds at their very early stage of growth after their identification in an integrated system.

This project was terminated due to research priorites. Milestone 3 was underway for 6 weeks but not completed, however most of the preparations including purchase of an infrared camera to speed up the process and increase the number of species to be tested in Australia, sub-contracts with Redfern Solutions and the University of Auckland were underway. Preparation of crates and plants was started and associated travel and staff time were incurred.

2 Project objectives

To develop a weed management system that autonomously detects and selectively control agreed targeted weeds.

- Review of the Australian specific market opportunities from control of candidate weeds that may be targeted, size of the need (is not applied to all weeds), identification of, engagement and collaboration with relevant Australian stakeholders (with a focus on weed management R&D/technologies)
- Proof of concept stage that the approach:
    - enables accurate location mapping of the agreed targeted weeds via hyperspectral identification of the targeted weed's 'signature'
    - determined the most appropriate deployment time, within a season, of the system to maximise weed mortality
- Tested a system in New Zealand
- Determine the weed signature of a minimum of 4 weeds in Australia and define the most appropriate laser methodology to impact on weed growth
- Demonstrated the weed control system (on a terrestrial UAV) in Australia
- Revision of the Australian market opportunities based on proof of concept experiments
- Commercialisation approaches updated from that indicated in the proposal, given the potential opportunities (or not) in the Australian market
  Development of an automated airborne "Map & Zap" system for the weed species

3 Methodology

Weed identification efforts have been in progress in recent years across the world. However, most of these efforts have been focussed on the visible light or RGB (Red-Green-Blue) imaging. While these methods have great credibility, their error rate is high due to the use of shape and colour "only" for weed identification. There is a significant opportunity for an efficient and/or chemical-free weed control technology to improve the quality and value of primary industry production by development of novel data acquisition and analysis techniques. Our approach to hyperspectral imaging makes the step change needed in more accurate and in-field plant (weed) identification and its automation will be a long leap forward from the previous and current efforts. This "mapping" revolution alone can help New Zealand decrease its environmental footprint, even if the zapping component is not taken into account. This is because of the possibilities this accurate weed ID, coupled with location accuracy using RTK GPS technology, will at least create in the form of a precision auto-piloted chemical spraying system.

There are different laser types available in the market with the main limiting factor being the need for cooling the system and also the power vs safety of the laser. With this knowledge and having two laser scientists from University of Auckland and University of Michigan (Professors Murdoch and Galvanauskas) the team has tested three different types of laser: Carbon-dioxide laser, Thulium fiber laser, Blue laser diode bar. The latter was specifically selected by the team due to its potential to damage chloroplasts as these structures absorb blue light (wavelength) more than other wavelengths and also their low cost and light weight and no need for cooling. The final selected product will eventually need to be engineered to be fit for purpose in the field and on a drone. There was no immediate way to determine the amount of energy absorbed by the plants during laser treatment, and no feedback mechanism of the efficacy of the laser energy other than awaiting the subsequent growth (if any) of the plant. The mode of damage is primarily by heat, and the amount of heat generated in the plant leaf being targeted will vary within parameters such as density, thickness, colour, and water content. Therefore, the team led by Dr Irie used a thermal camera to monitor the heat generated in the targeted area of the laser, with the idea that this will be used to control the laser dose applied to any part of a weed. This information will be useful in the later stages of the project when weed damage will be assessed using both digital quantification and thermal imaging data.

4 Results

4.1 Science area 1: Zapping

We selected four NZ weed species for the laser zapping trials: buttercup (Ranunculus acris), thistle (Carduus tenuiflorus), yellow bristle grass (Setaria pumila) and windgrass (Anemanthele lessoniana). These were grown to two different stages of development, seedling (stage 1) and pre-flowering (stage 2), at AgResearch's Ruakura campus and then transported to the University of Auckland for laser treatment. The procedures followed for both the CO_2 and blue laser diode trials were identical. A total of 30 pots of each weed, at each stage of development, were prepared. Of these 10 were treated as a control and not exposed to laser radiation. The remaining 20 pots were exposed to 10 seconds of laser radiation. The laser beam was manually targeted to hit the crown or point of growth of each plant. To aid with targeting a low power red laser beam was co-aligned with the CO_2 laser. For the blue laser diode, the pulse-width-modulation input of the laser was used to reduce its average power to several mW for targeting. All 30 pots were then returned to their base in AgResearch, Ruakura, where their continued growth was monitored. After 8 days, 10 of the treated pots were returned to Auckland for a second identical laser treatment (termed: Re-zapping). These were again returned to Ruakura for continued monitoring. For the seedling (stage 1) samples, the laser proved to be 100% effective at killing all four weed species tested. For the pre-flowering (stage 2) samples the results showed that the system is still 100% effective at killing the two grass species, whilst for the thistle and buttercup samples ~ 70% of the samples survived the initial zap. A subsequent retreatment (Re-zap) proved reasonably effective for the buttercup samples (50 % mortality) but was unable to kill any of the thistle samples. These results can be understood primarily in terms of the specimen size - not surprisingly it is harder to kill larger weeds. The size of the seedling samples of all four species were smaller than ~5 cm in diameter. Illumination of the central 1 cm region around the meristem thus caused significant thermal damage to the samples and none survived. The pre-flowering samples were much larger: ~ 10-15 cm in diameter, with the grasses up to 20 cm in height. These larger samples presumably also have a more developed (and deeper) root structure, and as such are harder to kill. For all samples, clear visual damage to the weed was apparent after treatment. It is therefore highly likely that the rate of growth of all samples was slowed because of the laser treatment.

4.2 Science area 2: Mapping

The Hyper Spectral Imaging (HSI) of plants pre- and post-treatment was conducted using both the Ximea snapshot (32 band 600-975 nm only) camera and the Headwall line-scan Short Wave Infrared (SWIR, 900-2500nm) and Very Near Infrared (VNIR, 400-1000nm) cameras. Our engineers have started the process of developing a controlled lighting mobile environment to enable the treated weeds to be scanned in real-time. Images were obtained from potted buttercup and thistle plants for initial model development for the discriminatory power of hyperspectral imaging between the two species. Prototype buttercup/thistle vegetation masks were then developed based on SWIR/VNIR images and used to test the ability of the model to classify vegetation, which will then allow selective zapping of undesirable plants.

5 Discussion

We have shown the potential power of hyperspectral imaging for weed identification compared to previous RGB-based weed ID methods. This will benefit the industry as if used alone or in combination with RGB imaging, it will be possible to identify species based on their chemical composition/signature rather than shape and colour only, which normally creates error if plants with similar leaf shapes are co-existing in the field.

We have also shown that laser has the potential to damage a high percentage of weed irreversibly. This technology will benefit the industry as if the right type of laser is used, the technology can provide a safe and fast tool for weed control without any environmental residue.

There are still unanswered questions such as the extension of this identification technology to other weed species and whether HSI or HSI/RGB combination can discriminate *any* type of weed. Further, we would need to prove that the laser system is practically usable on aerial or ground based drones. This has not been tested yet.

The team approach and monthly meetings to keep all members of the team on the same track helped on time delivery of the deliverables but the lack of cheap and light HSI scanners or cameras was a serious issue

6 Conclusions/recommendations

We would like to continue the integration of the Mapping and zapping systems in our program to deliver a prototype system capable of implementing two components of the operation in the field. The implications of such system will be lower cost of farming for the red meat industry with minimal environmental footprint for an industry already under pressure for its other environmental footprints.