# Back to the future - electrothermal, systemic, weedkiller

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Permanent Agriculture and Horticulture Science and Extension

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Live, like you'll die tomorrow;
Farm, like you'll live for ever.

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Addendum May 2018. A lot has happened in the electrothermal space since this article was written. A short update on the current situation is given in the 2018 V2 edition of the FFC Bulletin www.bhu.org.nz/future-farming-centre/information/bulletin/2018-v2/electrothermal-weeding-update and a few corrections have been made to this article due to improved knowledge.

# 1. Introduction - systemic thermal weeding

To date, the only practical and successful thermal weeding techniques have been steam and flame. While effective in defoliating plants, these techniques only kill the parts they contact, i.e., they are a contact kill, not systemic weed kill, unlike systemic herbicides that kill the whole plant. This is a key reason why thermal weeding has been unable to supplant herbicides, especially broad-spectrum, systemic herbicides, and also because thermal treatment costs are much higher. For thermal weeding to have a chance to supplant herbicides, it needs to be systemic and cheaper than flame and steam. That is what makes electrothermal weeding stand out. It is both systemic and is lower cost than steam and flame which is why its resurrection reopens a window for non-chemical weed control for both urban / amenity areas and agri/horticulture.

This article gives a brief overview of the history and physics of electrothermal weeding, analyses its potential for a range of uses from amenity to agriculture and forestry and concludes with information on the newly available electrothermal weeder.

# 2. Electrothermal weeding history

Electrothermal weeding has a long history, going back at least to the 1890s when patents were issued for 'electric vegetation exterminators'. There was a upsurge of research in the 1970s and 80s including in the USA where the Lasco Corporation manufactured machines for sale [10], in Russia, and in the UK where there was particular interest in using it to control bolters in sugar beet crops [1, 2, 3, 4, 5]. However, the technique did not achieve commercial success, mainly due to herbicides being better understood by farmers that electrothermal machines, in what was then a small market [4].

# 3. Surfing the zeitgeist - alternatives to herbicides

Things have changed considerably in the past 30 years: herbicides are facing multiple problems including evolved resistance, legislative prohibition and disquiet among consumers and retail chains - being able to claim to be 'spray free' is often a significant marketing advantage. There is therefore a growing need for non-chemical weed control techniques to replace herbicides. Electrothermal weeding may be one of those technologies from the past that is about to come back to the future.

# 4. How electrothermal works

Electrothermal weeding uses high voltage (5,000 - 15,000 volts), but low amperage (0.5 - 2 amps) electricity to kill plants [9]. When the electrode touches the plant, electricity flows down the stem from the point of contact, into the roots and then into the soil, where it completes the circuit though an earth on the weeder. The electricity rapidly heats the plant to the point that the water in the tissues boils into steam which then causes cell destruction, which results in plant death.

This contrasts with flame and steam, the heat is typically applied to the foliage because it is not practical to get the heat into the ground, and therefore kill the roots, due to the huge thermal mass of soil. In addition, the heat from steam and flame has to transfer from the surface to inside the plant by conduction - which is very slow. This means that as plants grow, and have thicker stems, it becomes harder and harder to get the heat into the meristems (buds) from which plants grow. If the buds are not killed the plant simply regrows after treatment.

## 4.1. Systemic kill - penetrating the root system

In electrothermal weeding, the electricity instantaneously spreads through the plant's tissues between the electrode and the soil, so the entire stem and roots are heated to lethal temperatures. And by focusing on the ground level stem, less plant tissue has to be heated, so less energy is used. By killing the plant tissues where the stem and roots join (the hypocotyl) it is akin to strangling a plant or 'going for the jugular' and it is even more effective than the equivalent treatment of ring-barking as both phloem and xylem are destroyed - plants cannot survive such treatment.

There is a limit to how deep the electricity will penetrate the root system, as it is will be 'leaking' out of the roots and into the soil to return to the earth by the path of least resistance. The rate of leakage will therefore depend on the relative conductivity of the root and soil. In favour of the electricity travelling through the root is that there is water in the vascular system of the plant and dissolved mineral salts. If the soil is also moist or wet then leakage will be faster, while in dry soil, the electricity is likely to travel further down the roots as they will have lower resistance than the soil. As an example of what is possible a Californian thistle (Cirsium arvense) root was killed 23 cm below ground level [5].

## 4.2. No possibility of resistance

All living things have a thermal death point, so it is impossible for weeds to developed resistance to thermal weeding techniques, so there is no risk of weeds becoming resistant in the future.

## 4.3. Energy efficiency

The core reason for the very poor energy efficiency of flame and steam is that it is very difficult to get the heat into the plants without also heating the surroundings, i.e., air, soil, and machinery, which is why flame and steam weeding often have heat transfer efficiencies below 1% [6]. Electrothermal has the advantage that ancillary heating is kept to a minimum, because there is highly efficient energy transfer between electrode and plant, with the main energy loss being to the soil, but only after, it has done its job of heating the plant. So coupled with targeting the stem of the plant, electrothermal is much more energy efficient than both flame and steam. Agricultural steam and flame weeders have outputs of between 200 to 400 kW per meter width, electrothermal has an energy input of 10 kW per meter width.

## 4.4. Weather conditions

Electrothermal is effective in windy conditions and immediately before rain is due, that would prohibit or reduce the efficacy of herbicides due to spray drift and wash-off, and mechanical weeding due to rain increasing survival rates of cut weeds. However, rain, or plants that are wet, will prohibit electrothermal use due to the electricity earthing through the water on the outside of plants. Electrothermal poses a small fire risk due to the intense heat at the point of contact with the plant which can produce small sparks . Its use in dry conditions would be a fire hazard, but entirely manageable with suitable training and fire fighting equipment.

## 4.5. Safety

Finally, it is the combination of high voltages (5,000 to 15,000 volts) AND mains frequency of 50 Hertz that are dangerous (as a comparison, welders use low voltages, e.g., 10-40 volts but high amperages, e.g., 300-500 amps). Safety procedures are therefore essential when using electrothermal weeders [4], but, they are also important for alternatives, such as herbicide application and machinery such as line trimmers (aka weed-whip, whipper-snipper, weed-whacker, weed eater, strimmer!). However, fundamentally it is the frequency that is the dangerous component because at 50 Hertz, the

electricity causes the ions in animal nerve cells to move in and out of the axon stopping nerve signals, which in turn causes muscles to lock up, which if this causes the heart muscles to lock up is clearly lethal. New models of electrothermal weeder are therefore using very high frequencies, e.g., >10,000 Hertz, which is so fast the ions in the nerves are unaffected so there is no muscle paralysis, and therefore risk of death. However, with the significant amounts of power (i.e., Watts) flowing through the weeders, e.g., 5 to 10 kW, contacting an electrode of a high frequency electrothermal weeder would still cause a shock and localised tissue heating, possibly burns if contact was sufficiently long.

# 5. The potential

With its unique properties, electrothermal is considered to have a wide range of potential uses, including:

- Amenity / urban areas;
- Control of woody weeds such as gorse, broom and wilding pines;
- Cropping, (e.g., arable and vegetables) particularly for control of intrarow weeds overtopping the crop;
- Pasture, for killing tall weeds, e.g., thistles, ragweed, and docks.

## 5.1. Amenity / urban areas

The use of herbicides in amenity and urban areas is under pressure from citizens and governments, with some European countries already banning their use. However, alternatives such as flame, steam, and mechanical control, e.g., brushing, are far from optimal replacements, due to their higher costs, fire hazards and particularly lack of systemic kill [8]. Thermoelectric is the only non-chemical alternative that has a systemic effect and therefore is comparable to herbicides in effectiveness.

## 5.2. Woody weeds

Woody weeds, such as gorse (Ulex europaeus), broom (Cytisus scoparius) and wilding pines (Pinus spp.) are often difficult to control by any current means: they can have high tolerance to herbicides, and if they are cut down, many will regrow from the stump (i.e., true stem). To kill them either the stump has to be removed or treated with weedkiller, which increases costs, and root removal disturbs the soil which encourages seed to germinate and on slopes can result in soil loss. In theory flame and steam could be used to ring-bark woody weeds, but in practice it is very difficult to ensure sufficient heat is applied around the full circumference of the stem, all the way down to the true roots to prevent the plants re-growing. Electrothermal, targeted at the base of the stem or trunk, can kill all of the stem below the contact point and into the root system. Once this hypocotyl zone is killed then the plant cannot regrow and the foliage dies for lack of water. Electrodes can be fitted to long poles so they can reach through the foliage to the stem, so there is a reduced need to cut foliage back to reach the stem.

## 5.3. Cropping

Cropping (vegetables and arable, aka row crops) is the production system for which electrothermal was originally targeted in the 1980s. The main current use for flame weeding in cropping is killing newly germinated weeds for stale seedbeds [7]. However, it is considered hard for electrothermal to kill newly emerged weeds as they are small and very close to the soil, so it is difficult to ensure the electricity travels through the weeds and does not bypass them and earth directly to the soil. It is therefore considered that electrothermal is unlikely to replace flame weeders for this purpose.

However, there are many situations were weeds stand above the crop which is where electrothermal should be a valuable new weeding solution. Killing such tall weeds was the original aim of the

machines in the 1980s where they targeted weeds such as sugarbeet bolters and fat hen / lambs quarters (Chenopodium album). A key point is that weeds in both the interrow, and much more importantly, the intrarow would be killed, and as intrarow weeds are much more difficult to control once they are established, this could be a particular advantage for electrothermal.

It is also possible to create an electrothermal interrow hoe, where the electrodes replace the hoe blades, travelling a few centimetres above the soil surface to kill weeds between the crop rows. Where weeds are small, e.g., less than four true leaves / 5 cm high), interrow hoes will probably still be cheaper, especially as they can operate at high speeds, e.g., up to 20 kph, but their effectiveness reduces considerably once weeds get bigger. This could be an important niche for electrothermal as it will still be effective at killing larger weeds. It could therefore be a valuable compliment and backup to interrow hoeing, which sometimes fails due to problems such as the field being too wet for horizontal hoe blades to work effectively, which allows the weeds to get away. Electrothermal interrow weeders could come to the rescue and they could kill bigger weeds that hoeing missed, and electrothermal could kill weeds when soil moisture is too high for hoe blades to work effectively. In addition, unlike most mechanical weeding techniques that benefit from hot dry windy conditions to help kill the weeds, electrothermal directly kills the plants so it should still achieve high kill rates in cool wet conditions.

## 5.4. Pasture

Pasture weeds often stand proud above the pasture, especially after grazing as they are unpalatable to stock. So, like weeds that stand tall over crops, (see 5.3 above) these are ideal targets for electrothermal weeding, in the same way they are good targets for weed-wipers. An additional point is that pasture weeds typically have protected growing points at their base or just below the soil surface, such as biennial thistles e.g., scotch thistle (Onopordum acanthium), ragwort (Jacobaea vulgaris), and docks (Rumex spp.) as this is what allows them to survive grazing and mowing. To physically kill the plant it has to be removed down to the roots. Electrothermal weeding should be able to kill these plants as the electricity kills all the way down the stem and into the roots, while leaving surrounding pasture unharmed.

# 6. Commercial machines

The reason for this article and the renewed interest in electrothermal weeding, is that after a 30 year hiatus, the idea has been resurrected by Ubiqutek http://ubiqutek.com/ which was established by the sons of Dr Mike Diprose, who was a key researcher looking at thermoelectric weeding in sugarbeet and other crops in the UK in the 1970s and 80s (see references). The machinery and science behind it is considered to have a solid scientific pedigree.

## 6.1. Evaluation

The above analysis is based on the electrothermal publications listed in the references and other sources. While the analysis concludes there is considerable potential, there is a clear need for independent evaluation of this machine, for all its potential uses, including determining optimum treatment durations for a wide range of weeds over a range of soil moistures, as well as working out work rates and therefore total operating costs.

A number of land managers, connected to the Future Farming Centre are discussing the potential for evaluating a Ubiqutek machine. If you are would like information on this group, please email charles.merfield@bhu.org.nz for more information.

# 7. Disclaimer

Neither the Future Farming Centre or any of its staff have any commercial or other interest in Ubiqutek. This article is an independent analysis of electrothermal technology as a whole and has been provided to inform land managers of a newly available, potentially valuable, thermal weeding technology. It is not an endorsement or otherwise of Ubiqutek.

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