Steam and fish fertilisers: A potential organic systemic herbicide?

C. N. Merfield
Lincoln University, Bio-Protection and Ecology Division, Canterbury, New Zealand.
Email: charles@merfield.com

Abstract

A number claims have been made in New Zealand that the combination of steam and foliar fish fertilisers has a systemic herbicide effect. However, these claims are not supported by robust data indicating the necessity for a comprehensive research experiment in order to prove or disprove the hypothesis. A set of experiments was conducted to determine the herbicidal effect of steam in conjunction with two fish fertilisers and two vegetable oils, one containing high levels of omega-3 and omega-6 fatty acids and the other of low chemical reactivity, on a range of pasture plant species. No evidence of a systemic weed kill was found. Similar claims exist regarding the systemic effect of the organically certified contact herbicide Interceptor® in combination with steam. No experimental evidence was found for this either. It was considered that a solid refutation of the concept would be if steam heating plants prevented a systemic herbicide from working. An experiment testing this found that when applied immediately after steaming, Roundup® (glyphosate) was still effective. It can be concluded that while the idea that steam can turn fertilisers and contact herbicides into systemic ones can not entirely be refuted, there is no concrete scientific evidence to support the concept.

Introduction

With the rejection by the organic movement of synthetic and petrochemical derived herbicides (IFOAM, 2002), organic cropping farmers have an increased reliance on soil tillage to kill weeds and to create a trash-free soil surface to facilitate the passage of interrow hoes compared with non-organic agriculture (Lampkin, 1994). However, soil tillage, especially soil inversion by mouldboard plough, is widely regarded as having a range of negative effects on soil structure and soil biodiversity (Baker & Saxton, 2007; Lal et al., 2007). This is contrary to organic principles, which have the maintenance of a healthy soil at their heart (Kristiansen & Merfield, 2006). Therefore, there is a clear need for weed management techniques that reduce soil tillage and are in keeping with organic principles. A systemic herbicide that is acceptable under organic regulations could be a major step forward in reducing tillage in organic systems and potentially creating an easier means of managing weeds.

In New Zealand (NZ), there have been a number of claims regarding the systemic herbicidal effect of applying steam together with foliar fish fertilisers. The claimants include Mr Richard Newson, the creator of the VaporJet H1200 ® steam weeder (Thermal Options Ltd., NZ), who has applied for a patent on the process and similar techniques and approaches (Newson, 2001). BioSea, a section of the Sealord Group Ltd., NZ, which manufactures a range of fish processing waste, based fertilisers. A paper was presented at the 2005 International Federation of Organic Agricultural Movements (IFOAM) conference claiming efficacy for the technique but failed to provide supporting data (Welte, 2005). If the technique were effective this could be a potentially important development for organic agriculture. Therefore, there is a strong need to address the lack of scientific support for the claims.

A range of reasons for the claimed effect have been advanced by its advocates but none of them has a good foundation in biology. The main belief is that the steam ‘opens up’ the plant tissue, allowing

the fish fertiliser to enter the vascular system. It is said to then translocate to the roots, thereby killing the whole plant. While this is not impossible, it appears rather unlikely as the principle action of thermal weeders, both flame and steam, is to coagulate proteins and burst cell walls through water expansion. These processes would more likely inhibit material from entering the plant's vascular system rather than enhance it. One of the fish fertilisers, for which the effect was claimed, contains 15% omega-3 and omega-6 essential fatty acids, which are known to be chemically highly reactive (Erasmus, 1993). It may be possible that the highly reactive fish oil is responsible for the systemic effect. However, exposing the chemically reactive and thus unstable oils to steam would likely cause them to degrade (Erasmus, 1993). This indicates that mode of action of the steam/fish oil combination remains subject to speculation rather than scientific proof.

Mr Newson also claims that using steam with the organic certified contact herbicide Interceptor® (Certified Organics Ltd., NZ) produces a systemic weed kill effect. Interceptor works by causing plants to desiccate by dissolving cell membranes. This is unusual, as most herbicides work by disrupting plant biochemistry. Interceptors' physical mode of action means that it works best in hot conditions. Using it in conjunction with steam should thus maximise its effectiveness. However, it is not clear how the steam could cause it to change from being a contact to a systemic herbicide.

In order to examine these claims experimentally, it was decided to test two fish fertiliser products, as well as raw organic linseed/flax oil (*Linum usitatissimum* L.), which is also known to contain high levels of omega-3 and -6 essential fatty acids, a refined, bleached and deodorized (RBD) canola (*Brassica napus* subsp. *oleifera* DC.) cooking oil, which has low chemical reactivity (Erasmus, 1993), and the organic certified contact herbicide Interceptor for their weed killing efficacy in combination with steam.

There is also no scientific evidence as to when the fish fertilizers should be applied to the vegetation in relation to the steam to achieve the best possible weed control effect. If applied before the steam, the fertilizers would be heated while in contact with the plant material. If applied at the same time, they would be heated before contacting the plant. If applied afterwards, they would be heated to much lesser extent. These all could potentially result in varying levels of efficacy or even mode of action. Therefore, three approaches were tested, applying materials onto the vegetation; immediately before the steamer, at the same time as the steam, and just after the steamer has passed.

The failure to achieve systemic plant death in the Interceptor or fish fertiliser and oil trials showed that steam was not able to convert these materials into systemic herbicides. This prompted the question if steam could prevent translocation of a known systemic herbicide. If so, this would demonstrate that the claim that steam 'opened up' the plant tissues to facilitate the introduction and translocation of materials sprayed onto the plants was incorrect. A final trial was conducted to see if steaming could prevent Roundup® from killing plants.

Methods

For the fish fertiliser and vegetable oil trial, a randomized complete block (four blocks) split-plot design was used with spray material and application position as the two factors with product as the main plot and application position as the sub-plot. Application position refers to where the products were applied in relation to the steam. The materials used were 'BioSea Omega +' (Sealord Group Ltd., NZ), 'Simply Organic' (Fluid Fertilisers NZ Ltd., NZ), raw organic linseed/flax oil (Functional Wholefoods Ltd., NZ) and RBD canola cooking oil (Gold Crown). In addition to the four materials, there was a steam only treatment and a null control. The steam weeder was the prototype direct-fired steam weeder as described by Merfield (2006). The materials were applied

using one of three spray booms, which were positioned approximately 50 cm above the top of the plants to ensure even coverage. The booms were positioned at 90° to the direction of travel in order to treat all the vegetation that passed under the steam weeder hood. The first boom was situated at the front of the steam weeder's hood, so that it sprayed the vegetation before it was heated by the steam (before). The second was situated in a modified chamber at the front of the hood, next to the steam injection duct, so that the spray entered the steam 'curtain' just before the steam reached the plants (during). The third boom was positioned at the rear of the hood spraying the steamed vegetation just after the hood had passed over it (after).

It was originally planned to apply the vegetable oils as emulsions as the BioSea Omega and Simply Organic products had to be diluted in water (1:4) before application due to their viscosity. However, effective emulsification was not possible using available equipment so the oils were applied undiluted at a quarter of the rate of the diluted fish products. The materials were applied through TeeJet 800 (Spraying Systems Co. Illinois, USA) nozzles at 1.8 L min^{-1} at 1.4 bar using a Shurflo diaphragm pump. Application speed was 1 kph giving an application rate of 750 L ha^{-1} which was considered a high application rate for both steam and materials.

Three trials were conducted; two on mixed pasture swards approximately 10 cm high containing grasses, predominately *Lolium perenne* (L.), white clover *Trifolium repens* (L.) and chicory *Cichorium intybus* (L.), the other was a predominantly red clover *Trifolium pratense* (L.) stand with some grass, which was approximately 8 cm high. The pastures were situated at the Biological Husbandry Unit (BHU) and Kowhai Farm at Lincoln University, NZ, which are both, certified organic. The plots were 2.5 meters wide with the treated area being 1.75 m wide (internal width of the steam weeder hood). Plot lengths were 5 m with approximately 10 m headland between plots to allow for changeover between the different products.

For the BHU mixed pasture and the red clover trials herbage samples were taken six weeks after treatment by randomly placing a 0.25 m^2 quadrat within the central treated area of the plot and cutting all vegetation off as close to the ground as practical. From each plot, three quadrat samples were taken. The vegetation was then hot air dried for 48 h and weighed. Stock got into to the third trial at Kowhai Farm before samples were taken so no dry matter analysis was possible. In addition, visual inspections were made of all trials.

For the Interceptor trial, a complete randomised block design was used, the treatments being the three application timings, a steam only and null controls. The trial was conducted on a mixed pasture, predominately grass and red clover with some chicory, at the BHU. The Interceptor was applied using the same equipment as the previous experiment at the same rate, dilution, and pressure. Plot size, layout, sampling and analysis were also the same as the previous experiment.

All data were analysed by ANOVA.

For the Roundup trial, a randomised complete block design was used with four treatments being steam and Roundup applied at the rear of the steamer, steam on its own, Roundup without steam and a null control. The trial was conducted on 5 cm high ryegrass at the Lincoln University Horticultural Research Area. The glyphosate was diluted at a rate of 1 kg in 200 L water. Application method and rate were the same as for the other trials. Three weeks after treatment, the plots were visually inspected. No statistical analysis was undertaken.

Results

For the fish fertiliser and vegetable oil trials, there was no statistical or significant biological difference between the dry herbage weights among all treatments and the control (Table 1). Visual assessment on all three trials found that all treatments using steam caused extensive desiccation of above ground plant foliage one day after treatment. However, after six weeks, there was no evidence of systemic plant death as all plots had re-grown.

Table 1. Herbage dry matter weight (g) of two different pasture communities six weeks after treatment with two foliar fish fertilizers and two vegetable oils in conjunction with steam, steam only and an untreated control.

	BioSea	FluidFert	Linseed	OSR	Steam	Control	p value	$LSD_{0.05}$
Red clover	53	40	52	43	48	44	0.150	13.9
Mixed pasture	56	51	55	51	49	52	0.932	26.5

For the Interceptor trial, there was no statistical or biological difference among the five treatments (Table 2). Visual inspection one day after treatment found that all foliage was dead and very desiccated, having turned almost white. However, three days later green re-growth could be seen at the base of the grasses and new shoots emerging from clover stolons. Six weeks after treatment, the pasture was growing with little sign that the treatments had been imposed. Pasture on all plots was green and growing without any apparent ill effect as a result of the treatment.

Table 2. Herbage dry matter weight (g) six weeks after treatment with Interceptor applied before, during or after steam application, steam only and an untreated control.

	Control	Before	During	After	Steam only	p value	$LSD_{0.05}$
Herbage yield (g)	44	42	31	36	34	0.468	17.3

In the glyphosate trial, the Roundup and steam and Roundup only treatments killed the grass and any other plant species present (assessed visually based on all foliage turning brown), while the grass in the steam only and null control plots was green.

Discussion and conclusions

The fish fertiliser and vegetable oil and the Interceptor trials found no evidence of any systemic weed killing effect for any of the treatments. Considering three trials were conducted, the number of products tested, the use of three application timings, the high dose rates for both the products and steam, it is clear that none of the products had any systemic weed killing effect whatever when used in combination with steam and that the claims made regarding the effect are unfounded.

The foliage of plants that were steamed was destroyed but re-grew. This is in keeping with studies by Merfield (2006) that showed that ryegrass cannot be killed by thermal techniques at any life stage due to the apical meristem being protected under the soil. These results are considered likely to hold true for all monocotyledons. Many dicotyledons cannot be killed at growth stages beyond the eight true leaves stage because their meristems are either protected by growing stems, or, for example for clover, in stolons under the soil surface (Merfield, 2006). For the Interceptor trial, the destruction of the plant foliage was considered very effective compared with previous experience of the product use in farming situations (Merfield unpublished observations). The use of steam

appeared to have improved the efficacy of the product, which is in accordance with the application requirement to use the product in hot and sunny conditions due to its physical mode of action.

The results of the Roundup trial were unexpected, with the steam failing to prevent the translocation of the Roundup and plant death. It was expected that the thermal treatment would immediately destroy the vascular system preventing Roundup translocation.

This result suggests that the idea of steam assisting the introduction and translocation of materials in plants that otherwise could not do so, can not be refuted entirely. It could thus be possible for introduced compounds to kill the whole plant. However, the results of all other trials presented here indicate that there is no evidence to support the concept. It is considered that further work in this area is unwarranted.

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