Trials of a crimper-roller for killing cover crops for organic and non-herbicide, no-till cropping

C.N. Merfield

Teagasc (Irish Agriculture and Food Development Authority), Johnstown Castle, Co. Wexford, Republic of Ireland. Email: charles@merfield.com

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Abstract

Dependence on tillage for weed management in organic systems potentially reduces soil quality / health, which is contrary to the founding principle of organic agriculture: healthy soils. One weed management technique that can eliminate the need for tillage for cash crop establishment is ‘crimper-rolling’. This is where a cover crop is killed and flattened at anthesis using a ‘crimper-roller’ and the cash crop is planted into the resulting mulch. The technique was originally developed in South America and subsequently independently discovered in North America where there is currently considerable research and farmer interest. However, the agricultural and climatic conditions of the Americas differ considerably from other areas that operate generally comparable agronomic systems, such as Europe and New Zealand where the technique is less well known. Therefore, a trial was conducted in the Canterbury region of New Zealand on four cover crops: A mix of oat (*Avena sativa*) and pea (*Pisum sativum*), rye (*Secale cereale*), common vetch (*Vicia sativa*) and field / tick bean (*Vicia faba*) to study the potential of the using the crimper-rolling technique under local conditions. Analysis was made of how easy the cover crops were to kill by the amount they regrew after treatment, their weed suppressing ability and the ratios of volunteer grass spp. to white clover (*Trifolium repens*), which was considered to be an indicator of available soil nitrogen levels. The oat pea mixture showed poor weed suppression, while weed suppression and N availability were excellent under common vetch but the crop was unaffected by crimping. Rye showed good weed suppression and was completely killed by crimping but tied up soil N. Beans showed moderate weed suppression and N availability and died very quickly after crimping. The results indicate that cereal-legume mixtures e.g., rye and beans, may be preferable over cover crop monocultures in order to reduce soil nitrogen ‘robbery’ while maximising weed suppression. Nonetheless, uptake of the technique in the Canterbury region may be hampered because anthesis occurred after the standard planting dates of many common crops. Despite this lack of initial success the technique appears to have considerable potential and significant further research is required.

Introduction

Maximising soil health is a founding principle of organic agriculture. However, the decision to eschew synthetic chemical herbicides has left organics dependent on tillage for many weed control operations. There is substantial evidence that tillage damages soil health, while no-till agricultural systems are in general able to promote and maintain high soil health (Baker & Saxton, 2007). However, no-till systems rely on synthetic herbicides for weed control which are not permitted in organic production. This has resulted in a conflict within organic agriculture between tillage based weed management and the need to reduce tillage to improve soil health. The introduction of no-till techniques that are consistent with organic principles could help address this dilemma. Such techniques may also be increasingly valuable in non-organic systems because of the decreasing number of permitted and/ or effective herbicides due to the combined effects of legislative review of pesticides and increasing numbers of weeds evolving herbicide resistance.

In the 1980s, a low-tech machine was developed in South America to kill green manure / cover crops when they have reached full anthesis, without soil disturbance (Ribeiro, 2001). It consists of a smooth roller with a series of thin metal bars attached to the surface across the full width of the roller. Originally called ‘knife rollers’, they are also known as roller-crimpers in N. America, crusher-rollers and crimper-rollers. The effect of the machine is to flatten the cover crop and crimp its stems, i.e., the stem is not severed, but bent / crimped. This way, the cover crop is converted into an *in-situ* biological surface mulch, anchored in place by the plants' roots, that can suppress weeds and protect the soil. Crops planted into the mulch benefit from multiple effects, including weed suppression, moisture retention, slow release nutrient supply and improved soil conditions. In addition, the cover crops compete with weeds while they grow, thus reducing weed prevalence through interactions such as allelopathy and agronomic activities associated with cover crop establishment and management, further aiding weed suppression. As the technique was unknown in New Zealand (NZ), an initial demonstration trial was conducted to study its potential under NZ climatic and seasonal conditions.

Materials and methods

The design was a two factorial randomised complete block with four replicates. First factor was cover crop type with four treatments:

1. oats 80 kg ha^{-1} and peas 180 kg ha^{-1};
2. rye 120 kg ha^{-1};
3. vetch 25 kg ha^{-1};
4. beans 300 kg ha^{-1}.

The second factor was crimping date with two treatment dates: 11 December 2006 (first) and 9 January 2007 (second). The cover crops were drilled on 6 May 2006 (autumn), into 1.70 m × 75 m beds at the Biological Husbandry Unit, Lincoln University, Canterbury, NZ (43°39'3.04"S 172°27'24.73"E). The cover crop were at anthesis at the first date and had finished flowering at the second date. A herringbone crimper-roller was used with a roller diameter of 48 cm, width 2 m, with 10 blades, 5 mm thick and 13 cm deep with the gap between blades at their tips of 20 cm (The Rodale Institute, 2007). It weighed 550 kg, contained approx. 200 kg water ballast and had additional metal ballast of 380 kg for the second crimping, as it was thought that this may improve cover crop mortality. Visual assessments including photographs of the cover crops attributes such as height and morphology and the effect of the crimper-roller on the cover crop were made over a range of dates.

On 3 February 2007, 54 d after the first and 25 d after the second crimp all weeds, i.e., all vegetation growing through the cover crop but excluding the cover crop itself, were collected from four random 0.25 m^2 quadrates per plot, hot air dried and weighed.

Clover takes up nitrogen (N) from the soilin preference to fixing it from the atmosphere due to the higher metabolic cost of N fixation. In soils with high plant available N, grasses tend to outcompete clover as they are better at N assimilation. When available soil N is low, clover has the competitive edge over grass due to fixation. Therefore, the ratio of grass to clover in a mixed pasture gives an indication of available soil nitrogen levels. Significant amounts of mostly ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) 'volunteers' germinated under the cover crops soon after planting but remaining small while the cover crops were alive. After crimping however, the grass and clover grew up through the mulch. The proportion of grass to clover growing through the cover crop was used as a surrogate measurement for available soil N under the cover crop. It was visually estimated in four random 0.25 m^2 quadrates per plot with the data from the first and second crimpings combined. Grass and clover were also classed as weeds for the above weed dry weight measurements.

The dry weight of the weeds and the proportion of grass to clover were analysed by ANOVA on untransformed data.

Results

The proportion of grass and clover and the dry weight of weeds in the respective cover crops are shown in Table 1. Rye and beans were completely killed at both treatment dates and grew the tallest. Rye showed good and beans moderate weed suppression. Vetch had very dense foliage, which formed a spreading mat that very effectively suppressed weeds. However, the crop was impossible to kill by crimping, and continued to grow strongly after treatment. There was a small amount of oat re-growth in the oat and pea mixture, which had a short open growth habit that failed to suppress weeds.

Clover was dominant under rye while beans and the pea-oat mix had close to a 50:50 ratio of glass to clover, and vetch had 75% grass, which was almost the opposite of rye.

Table 1 The proportion of grass and clover, and the dry weight of weeds growing through four crimper-rolled cover crops at two crimping dates.

	Clover	Grass	Weed dry weight first crimping	Weed dry weight second crimping
Oats and peas	55%	45%	252 g m^{-2}	105 g m^{-2}
Rye	93%	7%	113 g m^{-2}	42 g m^{-2}
Vetch	25%	75%	58 g m^{-2}	13 g m^{-2}
Beans	59%	41%	236 g m^{-2}	70 g m^{-2}
P value	< 0.001		< 0.001	
LSD0.05	24.3		35.3	

Visually, there was no noticeable benefit of using the extra weight on the crimper-roller at the second crimping, either on the crimping effect itself or crop re-growth.

Discussion

The poor weed suppression of oats and peas and the re-growth of oats mean these spp. appear unsuitable for crimping. However, pea cultivars with more biomass and particularly leafed types which are considered to be more competitive against weeds may be suitable. The strong re-growth of vetch also rules it out, however, other vetch species, e.g. hairy vetch (*Vicia villosa*), and black oats, (*Avena strigosa*), are killed by crimping, show good weed suppression and are successfully used by farmers (Anon., 2007; Baker *et al.*, 2007). Rye is considered to be allelopathic (Dhima *et al.*, 2006), which may be partly responsible for its better weed suppression than beans. As both rye and beans were effectively killed by crimping, they are considered suitable spp. to use for crimper-rolling. The lower weed suppression of peas, beans and oats may also be a function of their populations; some proponents of crimper-rolling recommend sowing rates two or even three times higher than for cash crops to maximise weed suppression and biomass production (Jeff Moyer, 2009, pers. comm.). These interacting factors indicate that it is not possible to make a final decision on any of the cover crops based on this single experiment and that considerable further research is required.

While the grass and clover that had established itself at the time of cover crop sowing grew little while the cover crop were standing, they rapidly grew through the mulch after crimping. This is considered a clear example of the need for effective weed management within the cover crops, with higher sowing rates probably making an important contribution. With the caveat that the effect of soil N on the grass: clover ratio is an assumption in the context of this experiment, i.e., no direct relationship was established between soil N and grass: clover ratio, the relative proportions of grass and clover are still illuminating. If a cash crop planted through the mulch is to grow vigorously there must be enough soil N available. A high clover content indicates that N is low and that therefore crop growth could be restricted. The dominance of clover in the rye indicates that available soil N was scarce, which is likely due to rye having taken up a large proportion of soil N during growth, which had yet to be released by decomposition of the straw. The leguminous spp. on the other hand had more grass, which is expected for N fixing legumes. A common recommendation for cover crops is a 50:50 mix of legume and cereal, because the cereal has a high N demand forcing the legume to fix N thereby maximising fixation while minimising leaching. Assuming the grass: clover ratio is an accurate reflection of soil N availability, the results presented here support the idea of such mixtures. A combination of rye and beans would appear to be good contenders due to the large biomass, good weed suppression and rapid death on crimping, although the optimum ratio of rye to beans for crimping may not necessarily be 50:50. This needs to be studied in more detail. Other vetch spp. that are suitable for crimping should also be tested due to their good weed suppression and high levels of N fixation (see below).

It was initially planned to sow a cash crop following crimping, in order to assess the follow on effects, such as weed suppression and soil N availability. This was prevented, not only by the late date of anthesis, but also by the impenetrability of the dense mats of the crimped cover crop vegetation by any available drill high residue seed drills. North American researchers using this technique find that only purpose designed no-till drills have the capability of successfully drilling through such thick residues (John Luna and Jeff Moyer, 2009, pers. comm.). An alternative approach may be to drill into the standing cover crop, which high residue drills may be able to penetrate, and then crimp after drilling. However, this approach may be impossible with vetch spp. due to the dense mat of interwoven stems and branches that they form.

A major problem for crimper-rolling in Canterbury was the date of anthesis, which occurred in late November (mid summer). This is far later than the September to October planting date of most summer annual crops, which means the technique would be of no value for any but the latest planted crops. However, for late-planted crops such as squash (*Cucurbita mixta*) the technique could be especially advantageous, as the mulch could keep the pepo (fruit) off the soil surface thus improving skin quality. It may also be practical for crops that are manually transplanted, e.g., vegetables such as cabbages (*Brassica* spp.). The technique may be viable for more crops in climates that experience longer summers and shorter winters. Alternatively if cover crop species and/or cultivars can be identified that flower sufficiently early, especially if flowering date can be manipulated through cultural means, e.g., earlier planting dates, then it may be applicable to a wider range of crops within New Zealand.

While crimper-rolling is proving to be a valuable technique globally, to date, no research is known that has studied its effect on plant physiology (Miguel Altieri, 2008; John Luna and Jeff Moyer 2009, pers. comm.). It is considered important that to improve our understanding at a more fundamental level, i.e., understand causal mechanisms, and establish why crimping kills plants while rolling or mowing does not. Such research should be able to assist in designing better crimper-rollers with optimum blade spacings, weight and effectiveness, determine why some, often closely related, plant species react differently to crimping, all of which could lead to improvements in the technique.

Conclusions

Crimper-rolling has the potential to allow short-term no-till organic cropping in NZ with the potential benefits of reduced tillage for weed management and soil preparation. However, the lateness of anthesis in the Canterbury region for the cover crops tested means that other species and cultivars need to be investigated. Mixtures of cereals and legumes are likely to offer the best combination of weed suppression and soil N availability for the following crop and cover crop plant population may also be a critical factor. Clearly, a substantial amount of further research is required including fundamental work on the effects of crimping on plant physiology, determining the best mixtures of cover crops that provide optimum weed suppression, high residual soil nitrogen, and good cover crop mortality; as well as establishing specific farmer guidelines for individual cover crop × cash crop combinations. It is hoped that such research would make crimper-rolling a viable new technique for both organic and non-organic farmers, in NZ and other locations, to improve environmental sustainability and profitability of farm systems.

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