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Band-steaming reduces laborious hand-weeding in vegetables

By Bo Melander, Lars Elsgaard and Martin Heide Jørgensen, Danish Institute of Agricultural Sciences.

Weeds in the rows of organic row crops cause serious problems for organic growers because hand-weeding may be the only option for sufficient control. Particularly slow germinating vegetables with low initial growth rates such as carrot, direct-sown onion and leek may require many hours of hand-weeding: 100-500 hours per ha have been reported in Danish and Swedish studies. Insufficient weed can reduce yields, impede harvest operations and promote the build-up of future weed populations.

Physical weed control

Physical weed control can lighten the burden of hand weeding. Former research has shown that flaming combined with subsequent mechanical methods, such as hoeing close to the row or vertical brush weeding, significantly reduces weed numbers (Melander 1998a; Melander & Rasmussen, 2001). However, successful weed control requires an accurate timing of individual treatments that may not always be possible under difficult weather conditions. It should be expected that physical intra-row (in the row) weed control will be followed by some need for hand-weeding to obtain sufficient control - particularly on organic fields with high weed numbers.

Mobile soil steaming

To solve the problems with intra-row weeds, there is a need to look for methods and strategies that are less weather dependent and provide high and consistent effects with no or little demand for subsequent hand-weeding.

Soil steaming is a method that possesses the potential for meeting such requirements. Mobile soil steaming is commercially used on raised beds and especially in short-

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term field salad crops with a strong need to control soil-borne pathogens. Steam is applied to the whole bed area and down to 50-100 mm soil depth depending on the steaming time. A high kill of weed seeds in the steamed soil volume follows soil steaming, which leads to very effective and prolonged weed control.

In relation to organic farming, however, current soil steaming technology has two major disadvantages. Firstly, the consumption of fossil energy is extremely high, ranging from 3,500–5,000 l oil per treatment per ha. And secondly, the work rate for one treatment is very low with 70–100 hours per treatment per ha. Danish organic guidelines do not allow field steam sterilization at present, mainly because of the energy consumption and the overall lethal effect on other soil organisms. Therefore, steaming needs to be applied in smaller amounts and only to areas of the soil where it is most needed. With such modifications steaming may meet the organic requirements and may also become a feasible technique for conventional growers.

Band-steaming - a new technology

The need for modification of current steaming technologies has lead to the idea of band-steaming (Melander et al., 2002) where only a limited soil volume is steamed - just enough to control weed seedlings that would otherwise emerge in the rows.

The width of the intra-row area depends on the closeness to the crop plants at which inter-row cultivation may take place, and the depth of steaming would be determined by the actual weed flora. Inter-row hoeing in onion, leek and carrot can be as close as 25 mm from the crop plants with no negative impact on crop growth and yield (Ascard & Mattsson 1994; Melander & Hartvig, 1997; Melander & Rasmussen, 2001). Steaming down to a moderate soil depth of 50-60 mm appears to be enough considering that most weed seeds in the seedbank are from weed species producing small seeds that predominantly will germinate from the upper 0-20 mm soil layer.

Photo: Band-steaming in the field. Left, upstart. Right, operation.

High weed effects

A series of experiments have been conducted in the laboratory to study important biological key-factors that are essential for the development of band steaming technology. Results showed that the rise in soil temperature, that followed steaming, strongly affected subsequent weed seedling emergence from steamed soil (Figure 1). Seedling emergence from natural weed species was reduced by 90 percent when the maximum soil temperature reached 60°C. A further rise in temperature to 70°C gave a 99 percent reduction.

Further investigations showed that soil type, soil moisture content and soil structure (aggregate size) influenced the lethal effect of soil steaming when the maximum soil temperatures were below 70°C. Steaming was more effective in a sandy soil than in a loamy soil, and increasing soil moisture content generally increased the susceptibility of weed seeds to steam.

More weed seeds survived the lethal effect of steam in soil containing many large aggregates, presumably due to poorer steam penetration of the large aggregates. However, all the factors mentioned were no longer significant when maximum soil temperature reached more than 70°C.

Test-driving with a prototype band steamer showed that a maximum soil temperature of 90°C was necessary in the field situation to obtain the same weed control level achieved at 70°C in the laboratory. To reach 90°C, the prototype consumed approximately 350 l of fuel oil per ha. However, further modifications of the techniques are expected to lower the maximum soil temperature needed, whereby also the energy consumption will be lowered.

Steaming and crop sowing in the same pass

Studies in the laboratory, where crop seeds were sown immediately after steaming, showed that seeds of sugar beets, maize, leek, onion and partly carrots were surprisingly tolerant to the heat. This implies that crop sowing might be integrated with steaming, so that steaming and sowing can be done in the same pass, with sowing to be done after steaming.

Effects on other soil organisms

A major concern about steaming the soil is the lethal effects on other soil organisms than weed seeds. Thus, many non-target organisms are most likely killed, and the time it takes for the soil to recover is not known. Some of these aspects were studied in 2003, and the results indicated that the recovery process is rather slow.

Bacteria responsible for oxidation of ammonium-N were significantly inhibited and the population had not recovered after 90 days. Concurrently, a large increase in soil ammonium-N was observed, whereas nitrate contents were unaffected. Also, fungi and enzyme activities were reduced significantly, but physical and chemical soil conditions, such as water content, pH, and water-soluble carbon, were not affected.

It is not clear whether these effects will affect crop growth negatively or whether some may even be beneficial. Thus, further studies are needed to describe the effects of steaming on soil organisms and other soil properties and how these effects may affect crop growth.

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