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Band-steaming for intra-row weed control

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Abstract

Steaming the soil prior to crop sowing has the potential of eliminating weed seedling emergence completely. Thus, steaming might be a perspective technique for intra-row weed control in non-herbicidal row crops of high value, where manual weeding can be very laborious. This paper presents some preliminary results with the effects of steaming on weed seedling emergence. The work is part of a joint project involving both biological and technical aspects of steaming. The overall objective is to develop an applicable technique for applying steam in bands corresponding to the intra-row area of a row crop. Band-steaming is expected to use much less energy as compared to current steaming techniques for arable usage.

Introduction

Steaming the soil prior to crop sowing has demonstrated the potential to kill all viable weed seeds in the heated soil volume. Former investigations with steaming the soil have shown that a very effective and prolonged weed control can be obtained. Weed species, such as *Senecio vulgaris*, *Stellaria media* and *Poa annua,* can be controlled almost completely, and the effect may persist for several months. To achieve that, the temperature must be raised to more than 70°C down to 2,5 cm soil depth, and this temperature must be maintained for 6-9 minutes (Bødker & Noyé, 1994). The lethal effect of heating on weed seeds is also known from composting and mulching. Most viable weed seeds loose their germination capacity when temperatures reach approx. 60°C under mulches and in composts and persist for a longer duration (Davies et al., 1993; Grundy et al., 1998).

Thus, soil steaming appears to be a perspective method for eliminating hand-weeding in non-herbicidal row cropping, particularly in slow germinating and developing vegetable crops, such as direct-sown onion, leek and carrots, where manual weeding can be very laborious (Melander & Rasmussen, 2001). Current steaming techniques for field use are extremely energy consuming, which in the present work has lead to the idea of applying steam in bands only, corresponding to the intra-row area of a row crop. Thereby a lot of energy can be saved as compared to steaming the entire surface and down to 10-15 cm soil depth. However, more technical and biological research is needed to develop a band-steaming technique that can be applicable for practical usage. This presentation contains some preliminary biological results from a joint project involving both technical and biological aspects of band-steaming. The results are from studies aiming at describing the relationship between weed seedling emergence and maximum soil temperature achieved by steaming the soil at a range of times. The relationship is essential for determining the amount of steaming necessary to eliminate weed seedling emergence effectively.

Materials and methods

Two investigations were conducted in the laboratory, where soil steaming took place in a 7 x 8 cm circular groove made in a wooden wheel with insulation in the bottom and at the sides (Fig. 1). Soil was steamed by a timed flow of steam through rubber tubes, each connected to a tine with two 1.5 mm holes. Four steam generators with a total effect of 8 kW produced steam. A total of eight tines were placed so that the soil volume in the groove was steamed evenly. The soil temperature was continuously measured by eighth thermocouples placed evenly in the soil while steaming and in a short period after steaming had been stooped. The soil was collected from a sandy loam expected to contain many natural weed seeds of different species. Samples were collected in October 2000 for the first experiment and March 2001 for the second one. In the second experiment, seeds of oil seed rape (*Brassica napus*) and ryegrass (*Lolium perenne*) were added to the samples prior to steaming. Steaming took place a few days after soil samples had been collected from the field. After steaming, half of the soil fractions were chilled at 5ºC for 30 days in order to break seed dormancy. Both chilled and non-chilled soil fractions were germinated for 6 weeks in watered trays in the glass house, and weed seedling emergence was registered regularly on species level in the germination period. Each treatment was replicated three times.

Figure 1. A circular groove for band-steaming in the laboratory

Results and discussion

Steaming time was slightly curvilinearly related to the achieved maximum temperature in the soil samples (Fig. 2a). For example, it took approximately 90 sec. to reach a maximum soil temperature of 75^{o}C, and the temperature only dropped slowly, approximately 1^{o}C per 60 sec., after steaming had been stopped.

The relationship between weed seedling emergence and maximum soil temperature was adequately described by an S-shaped dose-response curve for both the chilled and non-chilled seeds Fig. 2b). The curve in Fig. 2b was fitted to the total number of emerged seedlings (weeds plus rape and ryegrass) from the soil collected in the spring 2001, but data from the autumn 2000 sampling showed the same relationship. Individual weed species including the crop seeds all showed this S-shaped relationship, but the maximum temperature at which no seedlings emerged any longer was

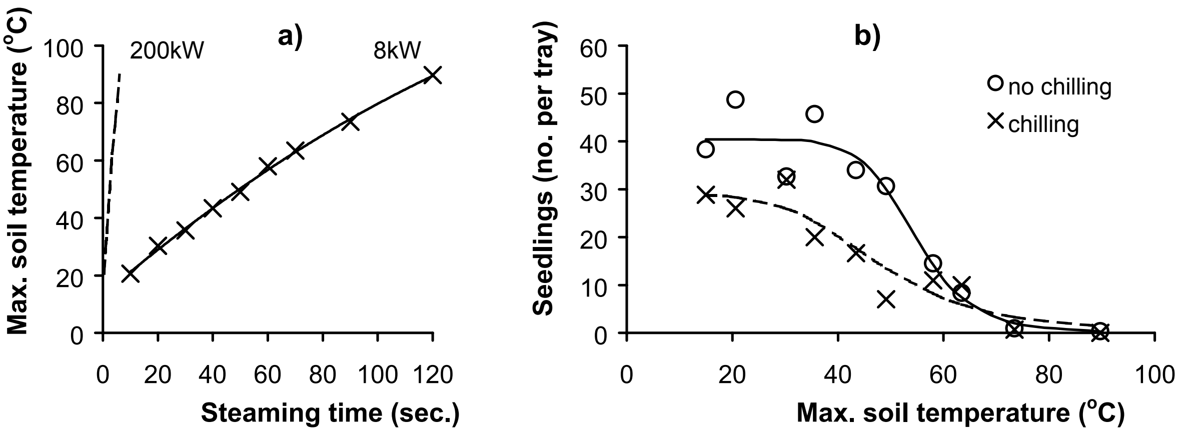

Figure 2. a): measured (x) and modelled (—) relationship between achieved maximum soil temperature and steaming time with 8 kW effect and the same theoretical relationship with 200 kW effect (---). b): relationships between number of emerged seedlings (weed plus crop seeds) and maximum soil temperature with (---) or without (—) chilling.

different: *Capsella bursa-pastoris* 70°C; *Chenopodium album* 65°C; *Tripleurospermum inodorum*, *Polygonum spp.* and grass weeds 60°C; ryegrass and rape 75°C. Chilling generally lowered seedling emergence of all the weed and crop species in the untreated trays and in those where the maximum temperature did not exceed 40 °C, probably because chilling caused non-dormant seeds to become dormant. However, the opposite was true for *Polygonum spp*. in the soil collected in the autumn 2000, where chilling had broken dormancy of the majority of the seeds, and thus more seedlings emerged in the chilled fractions. The lethal effect of steaming on dormant *Polygonum spp.* seeds was, however, similar to that found for the non-dormant weed species.

Figure 3. A prototype band-steamer with a 200kW steam generator. Thirteen steaming tines are placed along a 7-cm wide line on the towed frame that is mounted to the 3-point linkage of the tractor.

The determination of the relationship between weed seedling emergence and maximum soil temperature constitutes a valuable fundamental model for further studies on the effects of steaming. The next experiments will focus on the lower part of the curve, where weed seedling emergence is reduced by more than 70%. It is planned to investigate the influence of factors, such as soil type, soil moisture content, texture of the seedbed (fine versus coarse), and characteristics of the weed seeds in terms of thickness and hardness of the seed coat. In the technical part of the project, it is planned to develop a prototype band-steamer for field use, and the first version has already been build (Fig. 3). A band-steamer would have to work at a reasonable driving speed to become relevant for practical use, otherwise the working capacity would be to low. Increasing the effect of the steam generator will affect strongly the time required to achieve a certain maximum temperature as illustrated in Fig. 2a for a 200kW steam generator under ideal conditions. Another aspect of interest is the perspective of sowing crop seeds in the heated soil shortly after steaming, so that steaming and sowing can be done in the same pass. The current prototype uses a 200kW-steam generator, and it is planned to rear-mount sowing equipment.

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