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Aspects of steaming the soil to reduce weed seedling emergence

B. Melander, T. Heisel & M. H. Jørgensen
Danish Institute of Agricultural Sciences, Department of Crop Protection,
Research Centre Flakkebjerg, DK-4200 Slagelse, Denmark
Bo.Melander@agrsci.dk

Introduction

Physical intra-row weed control in row crops still constitutes a major challenge to weed research, although some significant results have been obtained lately. For example, combinations of flaming and mechanical methods controlled 70-90% of the intra-row weeds in direct-sown onion and leek, but 30-50 hours hand-weeding per hectare still remained to achieve full control (Melander & Rasmussen, 2001).

Steaming the soil prior to crop sowing has demonstrated the potential to kill all viable weed seeds completely in the heated soil volume. Thus, soil steaming appears to be a perspective method for eliminating hand-weeding in non-herbicidal cropping systems. Current steaming techniques for field use are extremely energy consuming, and more technical and biological research are needed to develop new devices that are more perspective for practical usage. This presentation contains some preliminary biological results from a joint project involving both technical and biological aspects of soil 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 an 7 x 8 cm circular groove made in a wooden wheel with insulation in the bottom and at the sides. Soil was steamed by a timed flow of steam through 4 rubber tubes; each connected to two tines with two 1.5 mm holes each. Four steam generators with a total effect of 8 kW produced steam. The 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, approx. 10 seeds of oil seed rape (*Brassica napus*) and approx. 15 seeds of ryegrass (*Lolium perenne*) were added per treatment 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.

Results and discussion

Steaming time was slightly curvilinearly related to the achieved maximum temperature in the soil samples (Fig. 1a). 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.1b). The curves in Fig. 1b were fitted to the total number of emerged seedlings (weeds plus rape and ryegrass) from the soil collected in the spring 2001, and 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 were 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 lowered seedling emergence significantly (P<0.001) of 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, where chilling had broken dormancy of the majority of the seeds and thus more seedlings emerged in the chilled fractions (P<0.001). The lethal effect of steaming on dormant *Polygonum spp.* seeds was, however, similar to that found for the non-dormant weed species.

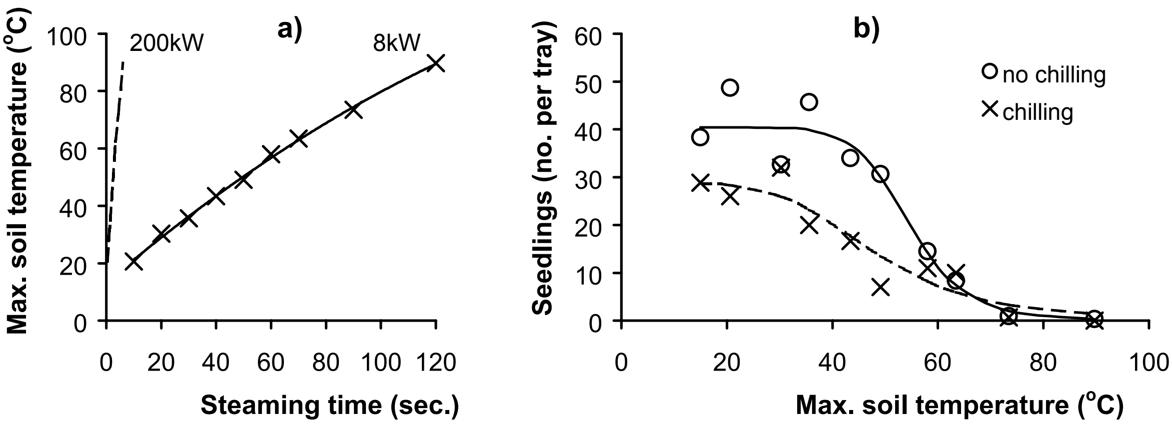

Figure 1. a): measured (x) and modelled (—) relationship between achieved maximum soil temperature and steaming time with 8 kW effect and the same theoretical relationship with 200 kW effect (---). b): relationships between number of emerged seedlings (weed plus crop seeds) and maximum soil temperature with (---) or without (—) chilling.

The determination of the relationship between weed seedling emergence and maximum soil temperature constitutes a valuable fundamental model for further studies on the effect 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 technique that only applies steam in bands 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. A band steamer would have to work at a reasonable driving speed to become relevant for practical use, otherwise the working capacity would be too low. Increasing the effect of the steam generator will affect strongly the time required to achieve a certain maximum temperature as illustrated in Fig. 1a 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.

References

Melander, B. & G. Rasmussen, 2001. Effects of cultural methods and physical weed control on intrarow weed numbers, manual weeding and marketable yield in direct-sown leek and bulb onion. Weed Research 41, 491-508.