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Soil steaming in high tunnels

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In recent years, common chickweed (*Stellaria media*) has become a widespread problem in high tunnel winter greens production in the Northeast. Chickweed is especially well adapted to growing in high tunnels; it emerges primarily in the fall, with optimal germination temperatures of 53°F to 68°F. It can flower within a month and set seed in 2 to 3 months, producing an average of 25,000 seeds per plant (Michigan State University). Chickweed is very hard to control manually, with a fibrous root system that is difficult to hoe or hand pull. Severe chickweed infestations can lead to significant or total economic losses in tunnels.

An emerging technology used by growers in the Northeast to manage weeds and pathogens is soil steaming, which has long been used in floriculture greenhouses, tobacco fields and other commodities. The current method used by most high tunnel growers is called "sheet steaming", which deploys a portable boiler to generate steam that is applied through a "sock" placed under a heavy tarp covering the soil surface, raising the temperature in the top few inches of soil as high a s 83°C (180°F).

Soil steamers: Soil steaming has been around since the early to mid 1900's, when the floriculture industry sought to "sterilize" soil. Steaming has had a resurgence in commercial use in recent years as an alternative to methyl bromide and other chemical fumigants. Used low pressure steamers from the 1950's are sometimes available, usually from the tobacco industry where it was used for tobacco seedling production. When purchasing a used steamer, it's important to make sure that the heat exchanger tubes are new, as they leak over time.

Photo credit: David Paulk, Sassafras Creek Farm

Our research demonstrated excellent chickweed control at a steam temperature of 160°F at 2 inches deep held for 30 minutes (95% control compared to unsteamed). Plots steamed at 140°F (2 inches deep, 30 minutes) showed moderate chickweed control (70% control compared to unsteamed), but with a resurgence of chickweed the following winter. Steam temperatures of 120-140°F provided limited control, with an estimated 30-40% control. Damping off was reduced in all plots steamed above 140°F, leading to improved stands of direct seeded spinach.

Moist soil, 30 minutes at	Organisms killed
115°F	watermolds (oomycetes)
120°F	nematodes
140-160°F	soil insects
140°F	most plant pathogenic bacteria and fungi
160°F	all plant pathogenic bacteria; most plant viruses
160-175°F	most weed seeds
200-212°F	heat resistant plant viruses and weed seeds

Source: Baker, K.F., 1957.

Microbes. The Biolog Ecoplates used to evaluate the impact of steaming on soil microbes reflect two things: 1) Average Metabolic Response (AMR), which measures how quickly microbes are consuming substances in the soil (e.g., microbe activity) and 2) Community Metabolic Diversity (CMD), which is a measure of the variety of substances consumed (e.g., diversity of active microbes). Data from 2020 and 2021 show that there was an initial decline in AMR (rate of microbe activity) immediately after steaming, but rebounded within a year of steaming. CMD showed no impact, indicating that the diversity of microbes was not impaired by steaming.

Since these data reflect a decline in microbe activity immediately after steaming, we recommend that growers proactively employ practices to boost their soil biology through the use of compost and other "living" soil amendments. It is important to note that this research was limited to studying effectiveness of steaming for chickweed control in winter greens production, and did not examine other applications where a higher steam temperature may be necessary, such as for crops with deeper planting depths and different pathogens (e.g., flowers or tomatoes).

Nitrate. Soil nitrate results showed a drop in nitrate at the higher steam temperatures of 160°F and 180°F, but an increase at 120°F in the immediate weeks after steaming. The samples taken at 6 months and 1 year show no long term impact on soil nitrate availability related to steaming.

Costs & yield. We compared the costs of hand weeding chickweed versus soil steaming and yields in unsteamed versus steamed plots. Unsteamed areas yielded an income of $3.15 per square foot after deducting the costs associated with handweeding. In comparison, the steamed areas had an average income of $8.74 per square foot after subtracting the expense of steaming.

Steamer purchase, accessories, & delivery	$6,500
Annual cost per tunnel if used for 10 years, 3 tunnels/ year	**$217**
Fuel (diesel or kerosene) per 30x96 ft tunnel	
55 gallons @$5/ gallon	**$ 275**
Person time	
(8 hours per tunnel @ $18/ person hr)	**$ 144**
total cost per 30x96 sq foot tunnel	**$ 636**
cost per square ft	**$ 0.22**

Steamer type: We used two types of steamers for this research: a 1950's low pressure tobacco steamer (purchased used but retubed) and a 2021 Sioux Model SF-20 steamer (rented from the Cheshire County Conservation District in New Hampshire). With both steamers, it was challenging to achieve the steam temperatures to 180°F, which we had hoped to in order to understand the impact of the higher temperature on soil microbes. We were also surprised by how unevenly distributed temperatures were within plots. A more accurate system would improve outcomes, especially with the awareness that there is a temperature range that kills chickweed but does not destroy the soil ecology.

Conclusions: Overall, this work demonstrates that steaming can play a key role to manage chickweed and soil borne pathogens. However, we also conclude that sheet steaming is fuel and labor intensive and somewhat inaccurate. It is exciting to recognize that there are modifications possible to this system, as well as more advanced steaming techniques used in larger farming systems. For example, other parts of the world utilize soil mixing and steam injection for efficient application of steam (Fennimore et al., 2014; Fennimore & Goodhue, 2016). A challenge for growers in the Northeast is to adapt this technology to an appropriate and affordable scale. In the short term, we anticipate increased adoption of sheet steaming by farmers in the Northeast, and believe that a shared use arrangements for soil steamers, such as in Maine and New Hampshire, will allows more growers to access this effective technology.

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