HOT WATER TREATMENT AS A PROMISING ALTERNATIVE TO METHYL BROMIDE

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Developmental History and the Concept

In Japan, soil-borne disease caused by continuous cropping is the most important obstacle to be overcome for the stable production especially in the protected horticulture. Methyl bromide (MB) has been used to fumigate the infested soil because of its broad spectrum and simplicity in the use. Although various trials have been conducted to find viable alternative agrochemicals to cope with the MB fadeout, the hot water treatment has recently been received special attention in Japan as the most promising MB alternative. In the late 1970s, prototype of hot water application system has been developed independently by the Kanagawa Horticultural Experiment Station in Ninomiya and the National Agricultural Research Center in Tsukuba. Both prototypes, though different in the hot water delivery method, apply hot water of 70 to 95°C onto soil surface and raise the soil temperature up to the lethal level to the plant pathogens as well as pests and weed seeds by wet-heat pasteurization.

Equipments and Procedure

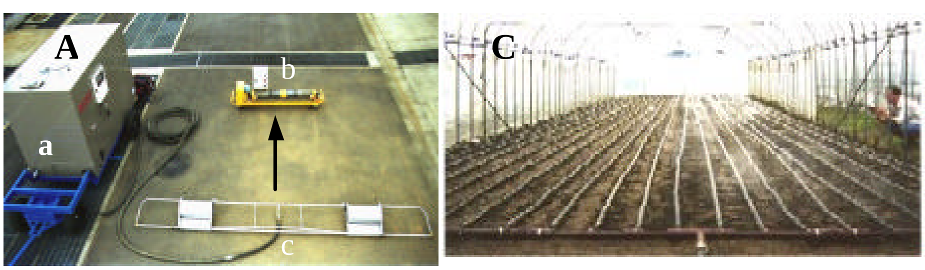
There are 2 types of application systems in the hot water treatment now on the Japanese market: dragging and tube-watering systems (Fig.1). The dragging system consists of three equipments: boiler, winch and hot water sprayer (Fig.1-A). The hot water sprayer has rectangular frame made of stainless, inch-size pipe with two rolling floats and can treat 4.5 to 9m in the width. When operated, hot water prepared by a diesel-fired boiler of ca.380,000kcal/h is supplied at flow rate of 70 to 100L/min to the sprayer placed under the plastic film *via* heat tolerant hose. While dragging the sprayer by a winch with a set of wires at speeds of 1.5 to 5m/h, hot water is sprinkled out over the soil surface from small holes along side the rear pipe (Fig.1-B). The amount of hot water to be treated can be adjusted by the width of the sprayer and the dragging speed. Generally, this dragging system can treat 45 m^2/h with the maximum sprayer width and dragging speed, thus, is well suited for large-scale treatments in flat fields. In the tube-watering system, on the other hand, hot water is supplied from a boiler and sprinkled out from heat-resistant tubes with small holes placed on the soil surface pre-covered with plastic film. Tubes are generally set up with intervals at 20 to 60cm depending on the target diseases and the amount of hot water treated (Fig.1 -C). This system is suitable for small-scale treatments and sloped fields. In both systems, the cost ranges from 300 to 600 thousand yen (ca.2.5 to 5 thousand dollars) per hectare in total depending on the amount of hot water treated and the price of the fuel.

Control Effect

When hot water is applied onto the soil, the surface is immediately heated but soon cools down whereas the temperature of the deeper soil gradually increases and remains high for few days after the treatment. In the 30cm depth, temperature over 55°C, the lethal temperature for the Fusarium, was shown to be maintained for as long as 22hr (Fig.2). Actually, when *Fusarium oxysporum* f.sp. *lycopersici* present within the 30cm depth soil was exposed to the lethal temperature, complete disinfestation was successfully achieved leading to the effective suppression of the wilt disease (Table 1). As not a few saprophytic microorganisms in the soil have higher heat tolerance than that of plant pathogens, relatively large populations of saprophytes and free living nematodes are still found in the soil even after hot water treatment. As shown in Table 2, promising effects of hot water treatment on the soil-borne disease control have been confirmed in various crops such as tomato, melon, strawberry, spinach, rose, sweet pea and carnation etc. Rockwool media contaminated with Phytopthora root rot of gerbera in a hydropoic culture was also effectively disinfested.

Future perspectives

The hot water treatment is easier to use than steam sterilization and, unlike solar heat sterilization, its application is not limited to the summer season. Because the wet-heat provided by the hot water does not wipe all the living organisms out, this technology is regarded as an eco-friendly MB alternative that can widely be applied to various crop production. As an additional effect, we have observed prominent growth promoting effects on any crops by the hot water treatment probably due to the conspicuous improvement of the chemical and physical soil property as a result of the washout by huge amount of hot water. Some pioneering growers of greenhouse tomato and rose have already been adopting this technology for more than 10 years. Many of the Farmers' associations engaged in the production of organic crops and/or less agrochemical-input vegetables have also started introducing this hot water treatment. Although the total system is still expensive, we believe that the hot water treatment will come into wider use after the MB fadeout.



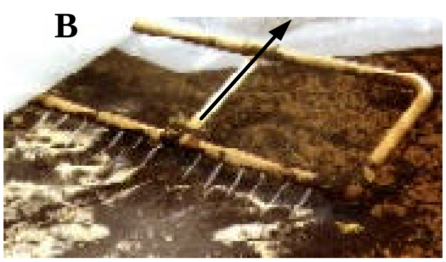


Fig.1 Equipments used in the hot water treatment systems. A: Dragging type; boiler(a), winch(b), sprayer(c). B: Hot water being applied under plastic film. Arrows indicate dragging directions. C: Tube-watering type. *Plastic film is removed for taking the photo.

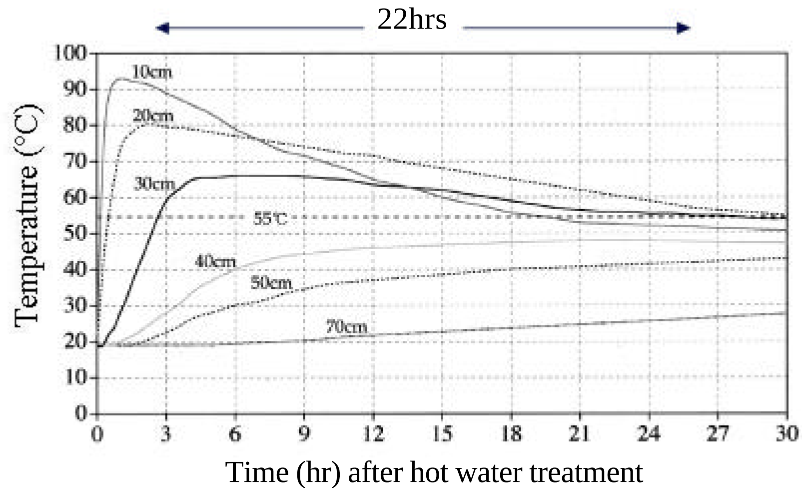


Fig.2 Chronological changes of soil temperature in the different depth after hot water treatment by the dragging system. Application volume : 300L/m^2 , Treatment speed : 12m^2/h.

Table 1. Effect of hot water treatment on the viability of *F.oxysporum* f.sp. *lycopersici* (Fol) and the suppression of the wilt disease occurrence

Treatment	Soil Depth	Density of Fol[1]	Disease severity[2]
	cm	cfu	
Hot water	10	0	0
	20	0	0
	30	0	0
	50	4.35×10^2	4.2
	70	2.94×10^4	8.3
Non-treated	-	4.69×10^7	45.8

[1]Before the hot water treatment, Fol infested soil wrapped with cheesecloth was berried in the different depth and taken out respectively from the soil 7 days after the treatment. Values represent colony forming unit (cfu) per 1 g of dry soil. [2]Culculated from $100\times\Sigma$(wilt disease index from 0 to 4×number of the diseased plants)/(4×number of the total plants examined).

Table 2. Examples of experiments on the control effects of hot water soil sterilization*

Crop	Disese/Pest (Pathogen/Nematode)
Carnation	Fusarium wilt (*F.oxysporum* f.sp. *dianthi*)
	Bacterial wilt (*Burkholderia caryophylli*)
Celery	Fusarium yellows (*F.oxysporum*)
Chinese cabbage	Clubroot (*Plasmodiophora brassicae*)
Chrysanthemum	Root and stem rot (*Rhizoctonia solani*)
Cucumber	Damping off
	Phomopsis root rot (*Phomopsis* sp.)
Eggplant	Bacterial wilt (*Ralstonia solanacearum*)
Gerbera	Phytophthora root rot (*P.cryptogea*)
Green pepper	Phytophthora blight (*P.capsici*)
	Black-dot root-rot (*Colletotrichum coccodes*)
Japanese radish	Yellows (*F.oxysporu m* f.sp. *raphani*)
	Cobb root-lesion nematode (*Pratylenchus penetrans*)
Melon	Monosporascus root rot (*M.cannonballus*)
	Fusarium wilt (*F.oxysporum* f.sp. *melonis*)
	Sclerotinia rot (*S.sclerotiorum*)
Parsley	Root knot (*Meloidogyne incognita*)
Rose	Crown gall (*Agrobacterium tumefaciens*)
Soybean	Root necrosis (*Calonectria llicicola*)
	Southern blight (*Sclerotium rolfsii*)
	Soybean cyst nematode (*Heterodera glycines*)
Spinach	Fursarium wilt (*F.oxysporum* f.sp. *lycopersici*)
	Foot rot (*Rhizoctonia solani*)
Strawberry	Root lesion (*Pratylenchus vulnus*)
Sweet pea	Danping off (*Rhizoctonia solani*)
Tomato	Fusarium wilt (*F.oxysporum* f.sp. *lycoprsici*)
	Bacterial wilt (*Ralstonia solanacearum*)
	Verticillium wilt (*V.dahliae*)
	Corky root (*Pyrenochaeta lycopersici*)
	Crown and root rot (*F.oxysporum* f.sp.*radicis-lycopercisi*)
	Root knot (*Meloidogyne incognita*)
Watermelon	Monosporascus root rot (*M.cannonballus*)
	Fusrium wilt (*F.oxysporum* f.sp. *niveum*)
	Root knot (*Meloidogyne incognita*)
Wheat	Take-all (*Gaeumannomyces graminis* var. *tritici*)
	Flag smut (*Urocystis agropyri*)

*Adapted from Nishi (Farming Japan 37-2:35-41, 2003) with slight modification.