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Effects of Solar Heating for Control of Pink Root and Other Soil-borne Diseases of Onions

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These experiments were carried out to examine efficacy of soil solarization for control of pink root disease by means of mulching with transparent polyethylene sheets in the hot season. The effects of soil solarization on incidence of pink-root disease caused by *Pyrenochaeta terrestris* and on onion growth and on *populations* of soil fungi were investigated. Solarization was dramatically effective in reducing pink root incidence in onion seedling and harvested onion bulb. A 30-day and 40-day solarization treatment significantly improved seedling survival and increased yield of 'Changnyeong-deago' onion while decreasing incidence of pink root. Populations of soil fungi from fields planted to onion were assayed on selective media. Solarization treatment was effective in reducing populations of *P. terrestris*, *Pythium* spp., and *Rhizoctonia* sp. in soil. Increase of yield of onion bulbs was associated with control of soil-borne pathogenic fungi. Soil solarization had beneficial effects on yield, bulb diameter, or incidence of pink root.

Keywords : *Allium cepa*, *Pyrenochaeta terrestris*, soil infestation, solarization, transplanting

Onion (*Allium cepa*) has been cultivated in large areas of the Korea and become one of the major vegetable crops. In Korea, its production has increased steadily from approximately 12.352 ha in 2003 to 15,309 ha in 2005 (KREI). Pink root disease, caused by *Pyrenochaeta terrestris* (Hansen) Gorentz, J. C. Walker and Larson (Gorenz et al., 1948; Hansen, 1929), is a serious soil-borne disease of onion throughout Korea. This disease was first reported to be caused by *P. terrestris* by Kim et al. (2003) in Korea.

The pathogen attacks the root system causing pink discoloration and root destruction, and may cause heavy damage to the crop, reducing both yield and quality (Katan et al., 1980; Vaughan and Siemer, 1971). Infected onion roots are initially light pink in color, gradually turning deeper pink and finally dark purple as the disease progresses. As new roots are produced, they are infected, turn pink, and eventually die. If infection continues, plants become stunted and may appear to be suffering from drought or a nutrient deficiency, but usually do not die.

In addition, infection by *P. terrestris* can facilitate the entry of *Fusarium* spp., resulting in bulb rots (Davis and Henderson, 1973; Kreutzer, 1941). Soil-borne fungi isolated and identified from onion in Korea include *Pythium irregulare, Rhizoctonia solani, Rhizoctonia* spp., *Fusarium* spp., and *Phoma terrestris*. A new approach for controlling a variety of soil-borne pathogens and weeds by means of solar heating of the soil was developed in Israel (Katan et al., 1976). This is accomplished by covering moistened soil with transparent polyethylene sheets during the hot season. Consequently, the pathogens are weakened or killed (Katan, 1980). The method has also been adopted to pink root infection and expression (Katan et al., 1980; Rabinowitch et al., 1981). Solarization offers potential cost reduction over chemical fumigation without residue or toxicity problems.

In Korea, onions are directly seeded into seedbeds in August and September when soil temperatures 3 cm deep range from 20 to 30°C, and seedlings are transplanted into fields in October and November when soil temperatures range from 10 to 20°C. The initial pink root disease may have caused the infection of onion seedlings by the causal fungus in the seedbed. Therefore, the infection of onion seedlings before planting is often unavoidable. This study was undertaken to determine the incidence and severity of pink root on onion in Korea, and the influence of soil solarization in a seedbeds and fields naturally infested with *P. terrestris.*

Materials and Methods

Onion (*Allium cepa*) cultivar 'Changnyeongdeago' was used in the experiments, which were conducted in onion field established at the Onion Research Institute in

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Changnyeong, Gyeongnam. Experiments were carried out in the 2004 and 2005 production periods. This field had been planted to onion for 15 consecutive years, and was known to be severely infested with the pink root pathogen. Although the inoculum density was not quantified, levels were high enough to severely stunt and even kill susceptible onion cultivars in previous years. A randomized complete block design with three replications was used on each site. Each plot size was 5 m wide by 5 m long. The treatment consisted with non-solarized, 15 days, 30 days and 40 days solarized treatment. Soil solarization was accomplished by covering moistened soil with 20 μm thick of transparent polyethylene sheets during the summer and control plots remained to be untreated. As the plastic was buried only in the furrows of the outside seedbeds, no soil disturbance occurred to the seedbeds when the plastic was removed. Soil temperatures were continuously recorded with thermocouples at depths of 5, 10 and 20 cm, using a micrologger (Thermo recorder TR-71U, Japan) from July 14 to August 23. Seeds of 'Changnyeongdeago' onion, a pink root-susceptible cultivar, were directly seeded into seed beds (1.2 m wide and 20 cm high) on September 3 and seedlings are transplanted into each plot in November.

Before transplanting and harvesting for determination of disease incidence, fifty-five plants were selected at random from each plot and evaluated for the percentage of roots showing pink discoloration. Fifty were visually rated for the diagnostic discoloration on the basal plate and adjacent 4 cm of roots. The five remaining plants were assayed for *P. terrestris* infection by the method of Watson (1961). The diagnostic test was the development of pink pigmentation on sterilized wheat straw. Plants were prepared for assay by washing soil and debris from the roots, then excising the intact basal plate and 4 cm of root system. This material was surface-sterilized by a 10 sec dip in 90% ethyl alcohol followed by 45sec in 0.5% sodium hypochlorite with a triple rinse in distilled autoclaved water. One intact root system per plate was used. Cultures were evaluated after 26 days of incubation at room temperature. The rating scale for pink root severity was 0 to 9, with 0= no roots discolored, 1= ≤20% of roots discolored, 3= 20 to 40% roots discolored, 5= 40 to 60% roots discolored, 7= 60 to 80% roots discolored and 9= >80% of roots discolored.

The soil at the seedbed was sampled before and after treatment and before transplanting. The samples were used in separate bioassays to determine the effect of treatment on the population density and distribution of *P. terrestris*. For bioassays of field soils, 10 cores of soil were sampled from 0-20 cm in each plot, mixed thoroughly and assayed for *R. solani* and *Rhizoctonia* spp. on a modified tannic-acid benomyl medium (Sumner and Bell, 1982) with a multiple-pellet soil sampler (Henis et al., 1978), for *Pythium* spp. on pimaricin, ampicillin, rifampicin and PCNB medium (Jeffers and Martin, 1986), on modified PCNB medium for *F. solani* and total *Fusarium* spp. (Papavizas, 1967). *P. terrestris* was assayed on sterile cheesecloth in a medium prepared from 3 g $NaNO_3$, 1 g $MgSO_4 \cdot 7H_2O$, 0.5 g chloramphenicol, and 20 g agar in 1 liter of deionized water (Strobel and Lorbeer, 1990).

Fifty-five days after sowing, onion seedlings were transplanted with 20×15 cm of planting distance in the same experimental field. Irrigation water was delivered when soil matric potential reached –30 kPa, as measured by a tensiometer. A total of 77 kg P_2O_5, 154 kg K_2O and 240 kg N/ha was applied throughout the growth season on cultivar 'Changnyeongdeago'. Five applications of chlorothalonil and spinosad were applied for insect and disease control, respectively. Bulbs were harvested on June 5, 2005. More than 80% of plant tops had fallen over in all plots at harvest, indicating that the onions were mature.

Results and Discussion

Solarization increased soil temperature in covered plots to a depth of at least 20 cm at the interval July 14 – August 23, the hottest period in 2004 (Table 1). The maximum temperature in solarized plots reached 56.5°C at 5 cm, 11.5°C higher than that of untreated soil at the same depth. The average maximum soil temperature in solarized plots was 11.3, 6.0 and 3.6°C higher at 5, 10 and 20 cm depths, respectively, compared with those of untreated soils. The polyethylene film maintained high soil moisture in solarized plots, whereas considerable drying took place in untreated soil plots after the initial irrigation, allowing surface temperatures to rise.

Considerably high soil temperatures were generated in solarized field plots in 2004. This was due to a larger-covered plot and hotter clear weather during the solarization period. Cumulative hours between 50°C to 55°C at 5 cm depth were 74, while those at between from 45°C 50°C at 10 cm depth were 73 (Table 2). Cumulative hours of soil temperature above 40°C at 20 cm depth were increased by

Table 1. Effect of solarization on soil temperatures during treatment in July-August 2004

Depth (cm)	Soil temperatures (°C)					
	Solarization			Control		
	Max. (avge)	Min. (avge)	Range (max.)	Max. (avge)	Min. (avge)	Range (max)
5	51.5	20.4	25.1-56.5	40.2	18.7	22.6-45.0
10	42.7	22.1	27.1-48.4	36.7	19.4	23.3-39.9
20	34.5	24.3	28.3-39.0	30.9	19.9	24.8-33.7

Table 2. Cumulative heat exposure of solarized and non solarized soil profiles in July-Agust 2004

Depth (cm)	Cumulative hours of Soil temperatures(hr)										
	Solarized						Not solarized				
	25-30°C	30-35°C	35-40°C	40-45°C	45-50°C	50-55°C	20-25°C	25-30°C	30-35°C	35-40°C	40-45°C
5	141	326	194	128	97	74	46	381	301	170	62
10	72	259	369	187	73	–	15	385	458	102	–
20	67	230	631	32	–	–	7	269	684	–	–

Table 3. Populations of fungi in soil and comparisons of interest in an onion field in 2004

solarized period (day)	*P. terrestris* (CFU/g)[z,y]			*Pythium* sp. (CFU/g)[z,y]			*Rhizoctonia solani* (CFU/100 g)[z,x]		
	10 Jul.	25 Aug.	3 Nom.	10 Jul.	25 Aug.	3 Nom.	10 Jul.	25 Aug.	3 Nom.
Untreated	17a	16b	20b	25a	26b	35c	12a	11b	15b
15	15a	2a	3a	23a	5a	12b	11a	1a	5a
30	16a	0a	1a	28a	3a	5a	12a	0a	2a
40	14a	0a	0a	25a	1a	4a	13a	0a	1a

[z]Means followed by the same letter within columns do not differ significantly (Duncan's multiple range test, $P = 0.05$)
Soil was solarized on July 14, 2004.
[y]CFU/g; colonies forming on selective media per gram of soil.
[x]CFU/g; colonies forming on selective media per 100 g of soil.

Table 4. Effect of soil solarization on disease of onion seedlings naturally infested with *P. terrestris* in July-August 2004

solarized period (day)	No. of leaves[z]	Longest leaf length (cm)[z]	Pink root incidence (% of plant)[z,y]	Pink root severity[z,x]	damping-off disease (% of plant)[z]
Untreated	4.5a	33.6b	99.5c	9.0b	20.0b
15	4.4a	40.1a	8.5b	0.7a	4.5a
30	4.2a	40.8a	3.5a	0.2a	1.7a
40	4.7a	40.7a	0.5a	0.2a	1.3a

[z]Means followed by the same letter within columns do not differ significantly (Duncan's multiple range test, $P = 0.05$)
[y]Percentage of plants exhibiting root discoloration.
[x]Visual rating of plants; 0= no roots discolored, 1 = <20%, 3= 20 to 40, 5= 40 to 60, 7= 60 to 80, 9= >80% of roots discolored.

solinization. Untreated soil temperature at 5 cm also reached high levels by drying after the initial irrigation, but the rest of the profile remained at moderate temperatures throughout the treated period.

Soil solarization reduced populations of *P. terrestris*, *Pythium* sp., and *Rhizoctonia* sp. in soil of seedbed in August (Table 3). The plots treated with 30-day and 40-day were the most effective in reducing populations of soil fungi and 15-day were less effective, compared with no solarization (Table 3). The temperature and time exposure in 2004 was sufficient to project substantial control of many soil-borne pathogen based on previous reports (Martyn and Hartz, 1986; Pullman et al., 1981b). Pullman et al. (1981a) determined laboratory thermal death curves for *Thielaviopsis basicola, Rhizoctonia solani*, *Pythium ultimum*, and *Verticillium dahliae*, demonstrating 90% control with exposure to 42°C for 45 hr or less, depending on species. Solarization was clearly effective in reducing pink root incidence and expression in onion seedling (Katan et al., 1980). Nearly all plants in untreated plots of cultivars exhibited some degree of root discoloration, while pink root incidence in 30 days solarized plots was less than 5% and disease severity index in solarized plots was less than 1 (Table 4). Plant growths were found to be reduced in non-solarized soil as compared to plants grown in solarized soil. There were no significant differences among treatments in leaf number but was a significant increase in leaf length (Table 4).

Solarization significantly improved stand establishment. Substantial damping-off was 20% in untreated plots but was <5% in solarized plots (Table 4). The pathogens involved in damping-off were mostly identified as *Rhizoctonia solani* (data not shown). Solarization of the onion seedbeds dramatically decreased disease incidence in transplants, but did not confer lasting benefit on those transplants when grown to maturity in treated plots. Improvement in stand establishment by solarized method of soil disinfestations corroborated previous reports of pink root influences on onion stands (Katan et al., 1980; Lacy and Roberts, 1982;

Table 5. Effect of soil solarization on disease and growth of onion naturally infested with *P. terrestris* in 2004-2005

solarized period (day)	Bulb diam. (mm)	Bulb heig. (mm)	Bulb wt (g)	Pink root incidence (% of plant)[z,y]	Pink root severity[z,x]
Untreated	63.8b	66.5b	111c	99.9c	9.0c
15	65.6b	64.2b	131b	60.9b	3.5b
30	71.8a	77.4a	168a	9.5a	1.4a
40	72.4a	76.6a	172a	5.2a	1.2a

[z]Means followed by the same letter within columns do not differ significantly (Duncan's multiple range test, $P = 0.05$)
[y]Percentage of plants exhibiting root discoloration.
[x]Visual rating of plants; 0= no roots discolored, 1= <20%, 3= 20 to 40, 5= 40 to 60, 7= 60 to 80, 9= >80% of roots discolored.

Rabinowith et al., 1981).

Solarization reduced pink root expression dramatically in the field plots (Table 5). Before harvesting, the rate of diseased plants in the untreated plots reached nearly 100%, while at the same time less than 10% expressed symptoms in the 30-days solarized plots and disease severity index was <2 (Table 5). Obvious differences in growth existed, with plants in solarized plots being larger and exhibiting less leaf tip burn. Onion growths in solarized plots were superior to untreated plots with respect to bulb diameter and weight, but no significant difference was shown between 30-day and 40-day solarized treatment in 2005. Solarization increased mean bulb weight to 151% and 155%, respectively, as compared to that of bulbs in untreated plots (Table 5). The excellent control of *P. terrestris* by solarization was attributed to the considerably higher soil temperatures. Solarization of larger plots may yield even better results because of even higher temperatures due to a further reduction in edge effects. Vauhan and Siemer (1971) reported that seedbed treatment effects would have been evident if the transplants had been subsequently planted into a non-infested field soil (Katan et al., 1980; Rabinowitch et al., 1981). Soil solarization has been used effectively to reduce populations of soilborne pathogens, including *P. terrestris*, in Israel (Katan et al., 1980) and Australia (Porter et al., 1989). Although soil solarization has been successfully for control of pink root disease, there was hardly known about the proper solarization periods for control of pink root disease. Accordingly, we concluded that solarization periods of 30 days or more is appropriate for effective disease control, healthy growth of onion and higher yields as well.

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