FLOODING FOR THE ERADICATION OF THE ONION AND GARLIC WHITE ROT FUNGUS, *Sclerotium cepivorum,* FROM INFESTED FIELD SOIL

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Abstract

A 20-acre field of "seed" garlic in central Oregon, which was not harvested due to widespread activity of the onion and garlic white rot fungus *(Sclerotium cepivorum)*, was flooded continuously beginning in June, 1989, extending into November, 1989. flooding accomplished several objectives: (1) all white rot disease activity stopped at the onset of flooding, effectively preventing further fungal reproduction, (2) survival of sclerotia, which had formed prior to flooding, was reduced 100, 35, 19, 7, 1, and 1 percent after 0, 2, 6, 9, 11, and 13 weeks of continuous flooding, respectively, in contrast to an expected near-100 percent survival in the absence of flooding, and (3) except for formation of a few aerial bulblets, all garlic cloves decayed during the course of flooding, thus nearly eliminating garlic volunteer plants in future seasons. Soil temperatures at 4 inches were 71, 71, 62, 61 and 59°F after 2, 6, 9, 11, and 13 weeks of continuous flooding, respectively. Decay of dead sclerotia was observed after seven weeks of continuous flooding. Inoculum density in 1990, based on random soil samples, was below the general limit of detectability (1 sclerotium/L soil), in contrast to an expected recovery of 1,000-10,000 sclerotia/g if the field had remained untreated. Nevertheless, in 1990 some surviving sclerotia could be recovered near the centers of abundant early plant loss in 1989. Due to prevention and partial eradication of high potential inoculum buildup, flooding greatly reduced -- but did not totally eliminate -- the risk of movement of sclerotia from this field.

Introduction

We hoped to achieve eradication of the white rot fungus, and of the infested garlic cloves, by flooding an infested 20-acre garlic field in central Oregon during the summer and fall of 1989. In this field, white rot was active in the spring and early summer of 1989. Many garlic plants were decayed, with an abundance of newly-formed sclerotia produced. Disease was evident throughout the field, either in large zones in which plants were 100 percent infected, or in pockets of 1-20 plants separated along beds by 1-20 feet. Because of the presence and severity of white rot, the crop was abandoned for any commercial purpose.

The field was furrow irrigated, with a slope of about 1:100 (rise:run), which was suitable for diking and flooding.

At the time of flooding, we were unaware of any previous attempt to eradicate the white rot fungus with summer flooding. We based our attempt on the information, that poorest survival of sclerotia of the white rot fungus occurs in soils with highest moisture retention (5). In the laboratory, 100 percent of sclerotia of the white rot fungus died within three weeks in saturated soil held at 70°F or higher. Less died during this period of time for lower temperatures, and in non-saturated soils (2). Three weeks of late winter flooding (March-April, 40-65°F) on muck soil in areas of Canada reduced populations of white rot sclerotia by 80 percent in 1986 (1). A related fungus, *Sclerotinia sclerotiorum,* may be eradicated by a 23-45 day flooding period in Florida soils, at temperatures of 75-80°F (4).

Materials and Methods

Prior to flooding, areas of extensive disease loss in the upper end (west), middle and lower end (east) of the field were flagged so these could be located after flooding. The garlic crop was left in the field, without any plant or soil treatments other than flooding. Wide-mesh bags were used to contain diseased plant material and soil in each area, for ease of recovery.

Dikes of non-infested soil were erected by the grower around the entire 20-acre field. The field was flooded by the grower beginning June 26, 1989, and irrigation water intermittently was added through October 15, 1989, to replace evaporation and infiltration. This resulted in continuous flooding through November 1, 1989 (week 18). During this period, the depths of the water on the east and west sides were maintained at 6 to 12, and 28 to 36 inches, respectively. Subsequently, the field was allowed to drain naturally, although soil saturation persisted through December, 1989.

Soil plus garlic plants from the field were sampled on dates shown in Table 1. Each time samples were removed, the temperature of the soil was taken at 4 inches (see Table 2).

Garlic bulbs and cloves were observed from each sample period. Each sample of soil and plant material was sieved through 20- and 60-mesh screens to reduce the soil volume and retain sclerotia on the 60-mesh screen. The residue retained on the 60-mesh screen was then examined under the dissecting microscope. At least 100 intact white rot sclerotia were removed with forceps from two or three of the samples. The sclerotia were then surface sterilized and plated onto either water agar or potato dextrose agar to check for viability by the presence of characteristic fungal growth (3).

In 1990, two soil samples, each composed of twenty 8-inch deep x 1-inch diameter cores collected in an "X" pattern, were taken from quadrants of the field. Also, soil samples were collected from areas flagged in 1989 in which early and extensive pathogen reproduction had occurred. Soil samples were processed as per Crowe, et al. (3), and the inoculum density estimated.

Results

Soil temperature remained at or above 70°F for nearly eight weeks (Table 2). This was followed by four weeks in the 60's°F. During the 12th week of flooding, the temperature dropped just below 60°F. In November, (week 21), the temperature in drained soil was 42°F and 46°F in the remaining flooded area.

The garlic bulbs began to appear translucent about one month after flooding although they still remained firm. By the end of August (week 9), the bulbs all were soft and rotten when gently squeezed.

We were primarily concerned with determining when no more viable sclerotia could be found. We chose to destructively sample from specific areas of the field in which sclerotia were clustered in pockets around the base of rotted plants. Under these conditions, precise and predictable quantitative measures of sclerotia were not possible to derive. By gently squeezing each sclerotium, its physical integrity can be determined (2). As the season progressed, it became more difficult to recover intact sclerotia from the flooded field. Intact sclerotia were recovered in abundance in the first seven weeks, and in moderate amounts through about week 11. In weeks 12 and 13, we had to look carefully to find non-rotted sclerotial bodies.

By growing intact sclerotia on various culture media, it may be determined whether sclerotia are alive and/or heavily parasitized, or dead (2). We were not fully able to distinguish between sclerotia that might be sick and dying, and those fully capable of infection. Conservatively, if a sclerotium was able to show characteristic growth, it was determined to be viable (2). Viability results are listed below (Table 1). Even by July 10, 1989 (two weeks of flooding), viability was only 33-37 percent, which was less than the near 100 percent viability found for intact sclerotia recovered from normal field soil prior to flooding. Viability continued to decline through September 26, 1989 (13 weeks continuous flooding), when only 1 percent of seemingly intact sclerotia proved viable. Although we expected contamination from other organisms, bacteria and other fungi were found growing from only about 2 percent of all intact, surface sterilized sclerotia throughout weeks 2-13.

Inoculum density from quadrants in 1990 was below the level of detectability (1 sclerotium/L soil). However, a few viable sclerotia could be recovered when soil was selectively sampled from "hot spots" of white rot incidence in 1989.

Discussion

Between the drop in numbers of seemingly intact sclerotia recovered (these were not quantitatively collected relative to total field populations), and the loss in viability of seemingly intact sclerotia (Table 1), flooding proved successful in greatly lowering the initial population of sclerotia immediately following the disease incidence in June, 1989.

Continued decay of dead sclerotia, combined with survival of some sclerotia likely resulted in an increase in the proportion of viable sclerotia after week seven. Although it appears as if 99 percent of the sclerotia that were viable at the initiation of flooding were dead after 13 weeks, in fact the proportion was likely much higher (e.g. 99.9 to 99.99 percent). Possibly, if soil temperatures had remained above about 60°F, total eradication may have been achieved.

Subsequent sampling in 1990 revealed that inoculum density across the field was below the level of detectability. Crowe et al. (3) found that soil infestations a year after extensive white rot incidence was between 1,000 and 10,000 sclerotia/L soil when the disease was left unchecked. It appears that flooding to prevent further reproduction, combined with loss of already-formed sclerotia, resulted in 1,000 to 10,000 times fewer sclerotia than might have been present if the field was not treated.

In unpublished experimentation, F. Crowe and D. Hall found that 400 lb/a of commercially-injected and tarped 67/33 percent methyl bromide/chloropicrin killed 99 percent of sclerotia in a California field soil. The one percent remaining averaged over one sclerotia/liter soil, which proved sufficient to incite economically unacceptable losses (approximately 60 percent plant loss) in garlic replanted into the experimental area the next year. For the flooded field, recovery of no sclerotia from normal randomly selected sampling indicates that disease loss would be less than 10 percent of plants if the field were replanted to garlic. On the other hand, recovery of some sclerotia from selected samples where inoculum density would be expected to be highest suggests that at least some plant loss would occur. Perhaps more importantly, these data indicate that future movement of sclerotia away from this field by equipment, etc., would be far less than if left untreated, but that some small risk of such movement of sclerotia remains.

In parts of the world in which summer flooding can be maintained such that soil temperatures remain above about 60°F for longer than 13 weeks, flooding could possibly result in total eradication of the white rot fungus from infested soil.

In subsequent communication with Dr. Eliseo Redondo, governmental pathologist in Mexico, we have discovered that he has similar, but unpublished results from continuous summer flooding of test plots in the state of Guanajuato. At the time of publication of this report, experimentation is in progress in Mexico and Oregon to document the extent of reduction of inoculum density with continuous summer flooding, based on pre-determined inoculum densities.

References

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Table 1.

Percentage viability of intact (non-decayed) sclerotia (200-300 sclerotia per date) from soil collected in 1989 from a flooded field in central Oregon infested with the onion and garlic white rot pathogen, *Sclerotium cepivorum.* [Note in text that actual survival after week 7 was likely much lower than percentage viability, due to increasing decay of dead sclerotia.]

Date	Weeks Flooded	East	Field Location Middle	West
7/10	2	37		33
7/24	4	*	*	*
8/7	6	28	14	14
8/14	7	*	*	*
8/21	8	24		0
8/28	9	6		8
9/5	10	3.4		7
9/11	11	2		0
9/18	12	1		1
9/26	13	1		1
11/22	21	6		8

* Viability test not reliable.

Table 2.

Temperature (degrees F) from soil collected in 1989 at four inches deep from a flooded field in central Oregon infested with the onion and garlic white rot pathogen, *Sclerotium cepivorum.*

Date	Weeks Flooded	Field Location		
		East	Middle	West
7/10	2	72	72	68
7/24	4	77	76	78
8/7	6	71	71	71
8/14	7	72	71	71
8/21		67	69	69
8/28	9	60	62	64
9/5	10	68	68	68
9/11	11	60	62	62
9/18	12	56	56	58
9/26	13	58	58	60
11/22	21	42	42	46