Comparison of Drainage Methods for Phytophthora Root Rot Control

Final Report

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Introduction

Phytophthora cinnamomi is a water borne plant pathogen. Its major effects are to root and crown tissues of over 1000 host species (Zentmyer, 1980). In New Jersey *P. cinnamomi* was described in the 1930's from azalea and was this was also the first description of the pathogen in North America (Zentmyer, 1980). In the Pinelands of New Jersey, spores (zoospores) of *P. cinnamomi* are present in most of the waterways including creeks, streams, rivers, lakes, and agricultural reservoirs (Oudemans, 1995, Oudemans, 1998). During irrigation, the zoospores are carried from reservoirs to the fields. Recent research indicates that a very large percentage (>80%) of the area cultivated with cranberries is exposed to zoospores of *P. cinnamomi* and a somewhat lesser acreage to another species *P. megasperma* (Oudemans, 1998). The symptoms of cranberry root rot include a reduction of root mass accompanied with a general decline of the plant, reduced vegetative growth and eventually death (Caruso & Wilcox, 1990). Phytophthora root rot develops in patches within cranberry beds that are poorly drained. The purpose of this project was to evaluate different drainage methods that could be implemented in existing beds that would improve drainage and thereby reduce the effects of the pathogen.

Current control methods for root rot include use of the fungicide metalaxyl, improved drainage, and resistant cultivars. None of the recommended control procedures are effective without first improving drainage. Therefore, drainage is the primary tool for managing this disease. Various techniques are used for improving drainage such as surface ditches, ADS plastic tubing, surface ditches filled with stone, and sanding to raise the level of the bed. None of these methods have been extensively studied and no studies investigating the soil types in relation to inadequate drainage have been conducted in cranberry.

Methods

In 1995 a site was identified which had a high level of acute symptoms of Phytophthora root rot. The site was very poorly drained and standing water remained for several hours after an irrigation event or rainfall. Initially soil samples were taken and a sieve analysis was done at the Rutgers University Soil Testing Lab (Cook College, New Brunswick, NJ 08903). Two samples were taken from well-drained sites and two samples were taken from poorly drained sites. The samples were analyzed in segments where each segment represented a natural transition in soil profile.

Several soil characteristics were examined on a 30' x 50' sampling grid. These included depth of topsoil, grade, water table depth, soil percolation and soil organic

content. Depth of topsoil was measured using a soil probe. Grade was measured using a laser transit. To determine water table depth, piezometers were installed on the sampling grid and the depth to the water table measured using a yard stick. Soil percolation was measured using a modified soil infiltrometer. This device was constructed from 2 3/4 " internal diameter clear plexiglass tubing cut 7" long. Each tube was sharpened at one end and graduations were marked on the side. The tube was driven into the soil (approx 1") and filled with water. The volume of water that flowed out of the tube in a 5-minute period was recorded for each sampling point. For areas with greater percolation rates, the flow rate was measured by determining the volume remaining after a shorter time interval. Soil organic content was determined by dichromate oxidation at the Rutgers University Soil Testing Lab (Cook College, New Brunswick, NJ 08903).

The area in the bed with standing water was mapped 2 hours following an irrigation event. This map was used to design the experimental layout.

Initially, three treatments were to be compared with a non-treated control.
1. Wells drilled to natural gravel (1.5' to 2' and filled with crushed rock).
2. Under-drains placed 14" below the surface.
3. Surface ditches placed through the poorly drained areas.

Treatment (1) had been tested in the fall of 1995 in areas adjacent to the proposed plots. In the spring of 1996, the wells seemed to be providing less drainage than they had soon after installation. Within two months this treatment was causing increased flooding and appeared to be clogged and therefore further testing of wells was abandoned. Two consultants were approached regarding this problem, Bruce Fowler, Senior Geo-hydrologist of Sevee and Mahar Engineering, Inc. and Tim Ruga, PE, PP of ARH Engineers. It was suggested that the crushed rock was allowing various sizes of the topsoil to enter the well and form an impermeable precipitate on the wall and bottom of the well. It was also suggested that concentrating surface water entry into the ground via wells was not a efficient solution to the problem.

The discussion with Bruce Fowler, Tim Ruga as well as with Chris Smith of US NRCS led to "deep homogenization" which replaces treatment (1). This method provides vertical segments of homogenized soil including topsoil and gravel from lower depths (large variations in particle size). It also breaks up any impermeable horizons that may cause water to become perched on the surface or prevent lateral drainage.

The final treatments are described below. Each treatment was made to a 15' x 15' plot and there were 5 replications. The field plots were located near the center of the bed and 4 slotted drainage pipes were laid from the edges of the beds. Solid drainpipe was then laid between the plots and used as a conduit and to carry water from treatments 2 and 3 (Fig. 1a).

1. The deep homogenization was accomplished using a 6-inch wide "Ditch Witch" trencher set to a depth of four feet. The soil was homogenized during the trenching process and was used to backfill the trenches. A 15' X 15' plot has approximately 45 linear feet of homogenized trench.
2. Underdrains were installed at 14" depth (to bottom of pipe) with the same "Ditch Witch" trencher. Homogenized fill from this 14" trench was backfilled on top of

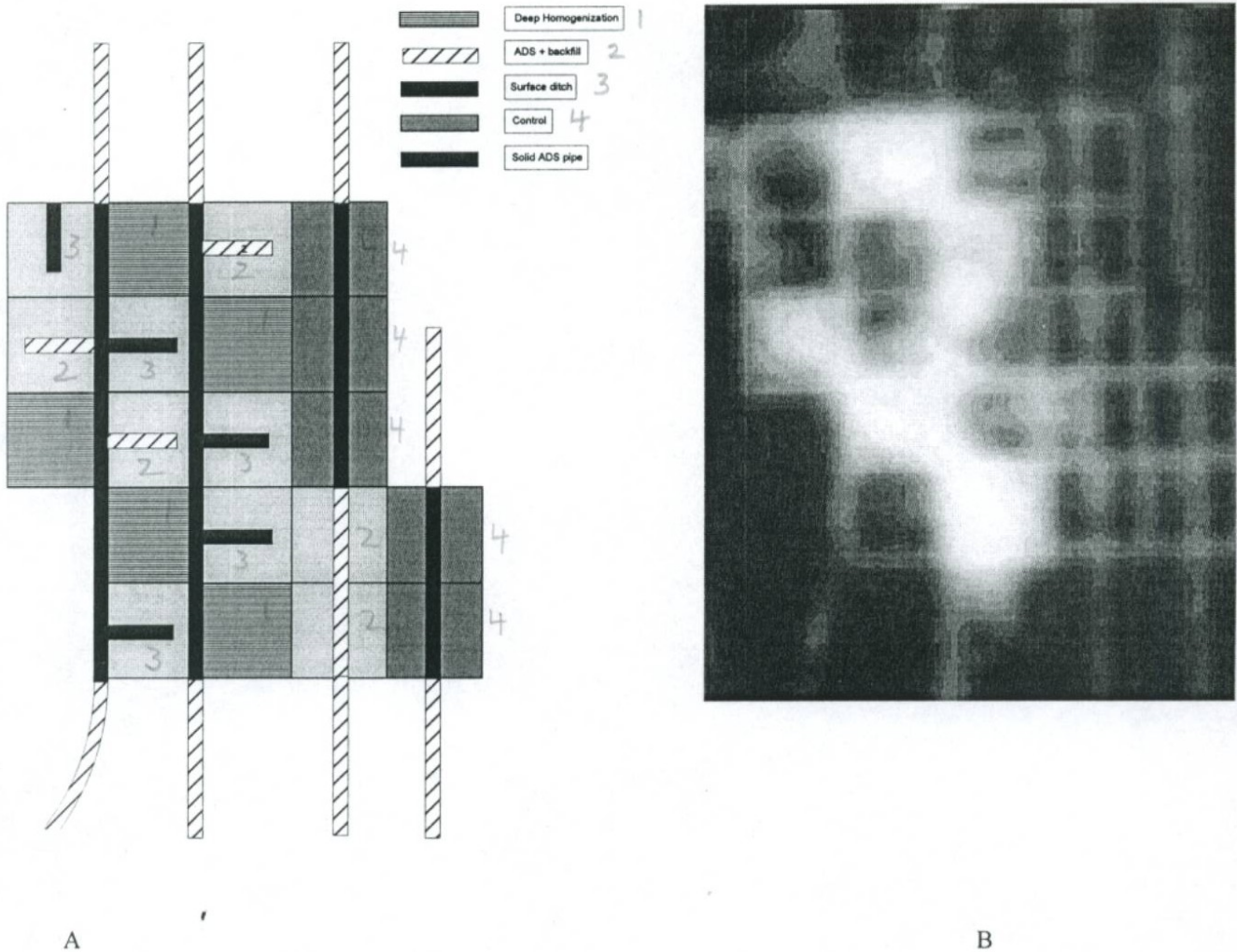A   B

Figure 1. Plot layout for drainage experiment. A. Plot layout showing placement of treatments and location of solid ADS pipe for removal of drainage water from the slotted ADS under drains and ditches. B. A infrared aerial photograph (rendered in black and white) showing the plot on 5/23/97. Areas of high luminosity represent well-drained areas and darker areas are wet or flooded.

3. the "ADS" 3-slot drainpipe. A 15' X 15' plot has 15 linear feet of drain running through the center of the plot.

4. Six-inch wide ditches were dug to a 6-inch depth. A 15' X 15' plot has 15 linear feet of ditch that drains into a larger ditch or into a catch basin connected to solid tile.

5. A control plot with no additional drainage treatments.

Six-inch high berms were constructed around each plot with masonry sand. A boardwalk was constructed to move the sand into the bog without damaging recently planted cuttings in the test plots and the adjacent productive areas within the bog.

Plots were evaluated in two ways. First, plots were irrigated and the percentage area of each plot covered in water was estimated visually. This was done three times during the growing season and evaluations were made from 0-4hrs after irrigation was complete. In one evaluation the percent area covered by water was estimated at 0, 2 and 4 hours following the irrigation. The second type of evaluation was made using infrared aerial photos taken on May 23, 1998. The photo was scanned into a PC as a 256 gray scale image at 2400dpi (Fig. 1b). The image was transferred to the program Optimus (ver. 6.1) and the percentage area in each plot covered by two luminosity values determined. (129-255 and 182-255). Results for both types of evaluations were subjected to an analysis of variance and the means compared using the Student-Newman Kuels test at 5% significance.

Results

Site description and soil variables.

Four soil samples taken from either poorly drained or well-drained areas showed very similar particle size distributions (data not shown). The major difference between the well drained versus poorly drained samples was the organic content. In poorly drained soils organic content ranged from 2-10% while in the well-drained soils organic content was generally less than 3%.

To better identify the cause of poor drainage five variables were measured. The raw data for these variables is not shown. A correlation analysis was performed to examine if any relationships exist among the variables (Table 1). The findings indicate that the percolation rate was negatively correlated with organic content (-0.59) and water table depth (-0.41). Graphs of these relationships are presented in Fig. 2.

Table 1. Correlation analysis among soil and drainage characteristics.

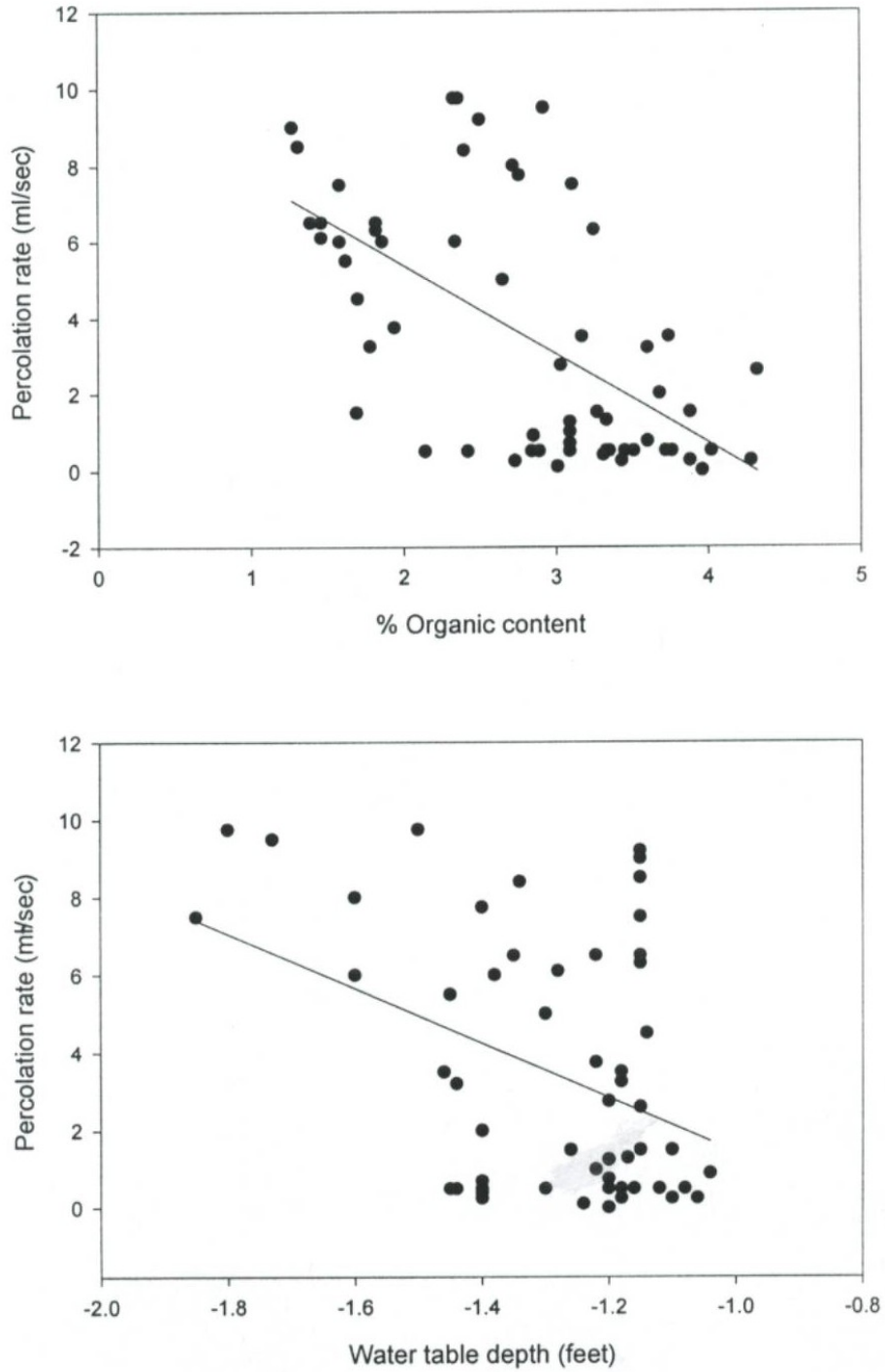|	Grade	Topsoil depth	Percolation rate	Water table	Organic content
Grade	--				
Topsoil depth	0.54	--			
Percolation rate	-0.06	0.07	--		
Water table	0.52	0.45	-0.41	--	
Organic content	-0.07	-0.09	-0.59	0.13	--

Fig. 2. Relationship of organic content (A) and depth of water table (B) on percolation rate.

A multiple regression analysis was performed to assess how much of the variation in percolation rate, water table depth and organic content explained. The regression equation (eq. 1) indicates that percolation rate is negatively effected by organic content and water table depth, however, other factors must influence percolation rate since this equation describes only 50% of the variation.

Regression equation (eq. 1)

Percolation Rate =   -27.907689574
                      - 8.5941703967 * water table $R^2 = 0.501$
                      - 1.7615952972 * organic content

Evaluation of drainage treatments.

In the first evaluation (4/24/97) observations were made within 4 hours following 1" irrigation treatment. Deep homogenization provided significantly better drainage than either the under drains or the non-treated control (Table 2). In the second evaluation drainage from plots was determined at two hour intervals after irrigation with 0.77" water (~4hr of irrigation). The results show that loss of water from deep homogenization was significantly better than any other treatment immediately following irrigation however, after 2 hours was not statistically better than the other treatments but was significantly better than the control (Fig. 3, Table 2). The third evaluation was made 3 hours following a nonspecified irrigation period and similar results were obtained. Results obtained using infrared photography showed deep homogenization providing better drainage, however, in contrast to the other evaluations, under drains appeared numerically better than surface ditches when evaluated using the aerial photographs (Table 2, Fig. 1b).

Table 2. Summary of the results for drainage from plots with different treatments. Values refer to the percentage of area in each plot covered in standing water.

Treatment	4/24/97[1]	7/15/97[1]	7/15/97[1]	7/15/97[1]	7/22/97[1]	5/23/97[2]
Hours after irrigation	<4	0	2	4	3	n/a
Deep Homogenization	5.6 c	6 c	2 b	0 a	0 a	98.5 a
Underdrains	32.0 b	55 ab	32 b	23 a	35 b	19.7 bc
Ditches	20.0 bc	39 b	11 b	9 a	10 a	36.6 b
Control	53.0 a	78 a	68 a	37 a	46 b	0.0 c

[1] Treatments were evaluated by estimating the area covered with standing water
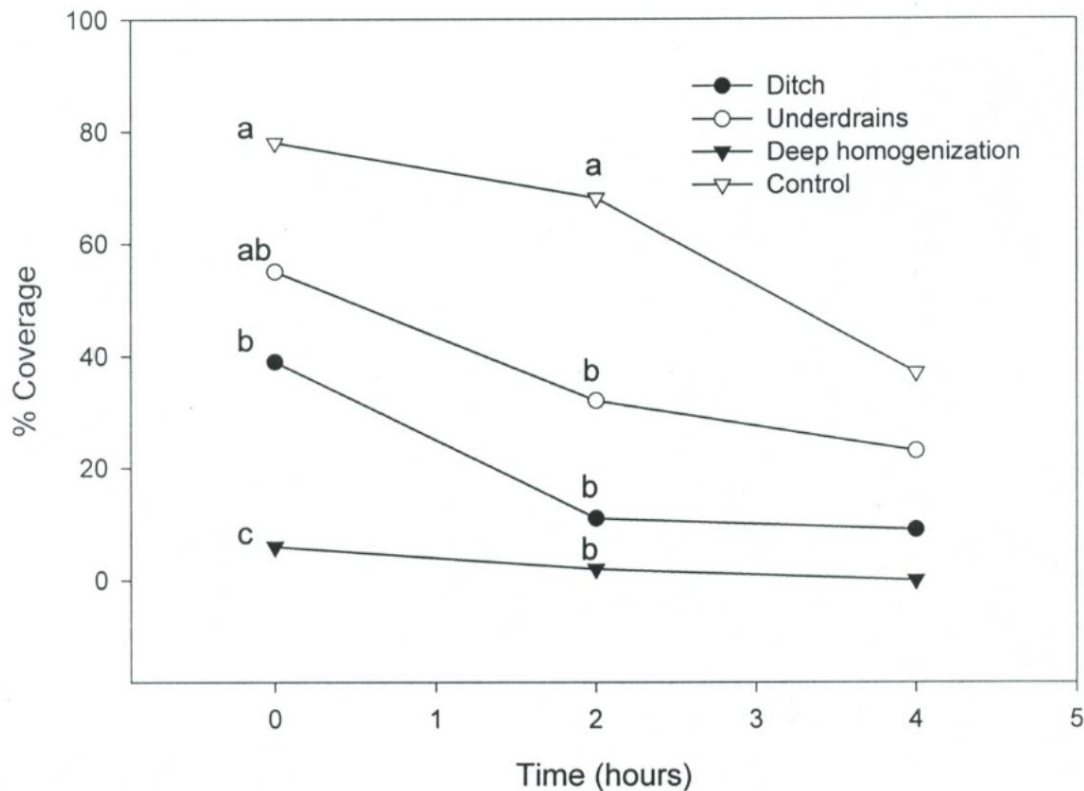[2] Treatments were evaluated by estimating the area of high luminosity digitally

Fig 3. Drainage from plots with different treatments. Measurements were made on 4/15/97. Letters above points refer to significant differences within each time period.

Discussion

This study tests and describes soil conditions that can lead to reduced soil drainage conditions resulting in poor establishment of cranberry cuttings and ultimately reduced yields. Furthermore, comparisons are made among three drainage methods to assess the relative efficiencies for reducing the period free water remains on the bed surface. Previous research has demonstrated a strong correlation between poor drainage and *Phytophthora* infection for many crop plant species (Erwin & Ribero, 1996, Zentmyer, 1980). Thus, although no isolations accompany this study, the background research should be sufficient to justify the assumption that improved drainage will lead to reduced root rot infection.

In the first part of this study a percolation device was employed to estimate spatial variations in drainage. The percolation measurements were made across a marked grid and several other measurements including physical characteristics of the site were made across the same grid. These data permitted a correlation analysis to be conducted among the various measured factors. The results suggest that two factors, organic content and depth of the water table, contributed significantly to the reduced drainage (i.e. percolation rate). Based on a multiple regression analysis only approximately 50% of the observed variation in percolation rate was explained by these two variables. Other factors that were not measured in this study must also contribute to poor drainage, however, these factors remain to be determined. Furthermore, these results apply to the bed in which this research was conducted and before they can be applied to other cranberry beds soil analyses must be conducted. It is likely that many other factors affect drainage such as soil layering, compaction, hard pans and other subsurface features such as clay lenses.

Of the three drainage methods tested, deep homogenization was significantly superior. This method provided very rapid drainage and was effective throughout the entire season. This method presumably acts by creating a porous backfill that allows rapid drainage from the surface. The homogenization of gravely soils from lower soil strata probably dilutes the more organic soils responsible for reducing drainage. In addition, clay lenses may also be broken by this treatment allowing the surface water to flow to the water table. It is possible that this method will not be effective under all conditions. For example, in beds built on a clay base deep homogenization could conceivably reduce drainage by increasing clay content of the topsoil. In these trials deep homogenization, and placement of ADS pipe were visible in the aerial photography due to increased drainage. The effect was similar for both the solid as well as the slotted ADS pipe. It is possible that disruption of the soil surface for approximately 18" is sufficient to increase drainage. The underdrains had were laid in 15 linear feet while the deep homogenization was placed 45 linear feet per plot. Thus the dramatic effect may also be due to the higher number of linear feet. However, in terms of use with cranberry culture this approach is inexpensive, and can be placed on existing beds with little effect on producing acreage. A comparison of the methods is presented in Table 3. The ADS underdrains are more expensive but also have little effect on producing acreage while ditches seem effective, but do impair the harvest process and also reduce the producing acreage. Other methods that involve use of crushed rock backfill may suffer form the problems found with the wells in that they can become rapidly clogged. The deep homogenization method used in this study provides an inexpensive and environmentally rational method (no plastic placed in ground) that should be widely applicable in New Jersey cranberry farms.

Table 3. Comparison of treatment methods for implementation into existing cranberry beds.

Treatment	Cost/ foot	Advantages	Disadvantages	
Under drain	.80	No effect on harvest	Plastic pipe placed in ground.	Highest cost
Deep homogenization	.25	No loss of area. Inexpensive	May works under limited conditions	
Ditches	.15	Inexpensive	Annual maintenance	Disrupts harvest

References

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