Winter Cover Crops Reduce Bacterial Wilt of Flue-cured Tobacco

K. L. Ong, Assistant Professor, Texas Cooperative Extension, Dallas 75252-6599; B. A. Fortnum, Professor of Entomology, Soils, and Plant Sciences, Pee Dee Research and Education Center, Clemson University, Florence 29506-9706; D. A. Kluepfel, USDA/ARS, Department of Plant Pathology, University of California, Davis 95616; and M. B. Riley, Professor of Entomology, Soils, and Plant Sciences, Clemson University, Clemson, SC 29634-0315

Corresponding author: Bruce Fortnum. bfrtnm@clemson.edu


Abstract
Bacterial wilt, caused by Ralstonia solanacearum, is a serious disease for tobacco farmers in the southeastern USA. The lack of suitable land for crop rotation and increased area of production on farms has resulted in shorter rotations, and increased losses due to bacterial wilt. Cover crops are rarely grown immediately before a tobacco crop because soil fumigation for nematode control necessitates early destruction of the cover crop. The microbial activity associated with growing winter cover crops may alter populations of R. solanacearum. This field study evaluated vetch, canola, or rye winter cover crops for suppression of bacterial wilt. Averaged over two tobacco crops, vetch preceding tobacco reduced bacterial wilt disease incidence 33% and increased crop yield and value (37% and 41%, respectively) when compared to a winter fallow. A two-year rotation involving both winter cover and summer rotation crops also showed that winter cover crops increased yields and reduced disease incidence when used following a non-susceptible summer crop. Soybean rotation followed by a vetch winter cover reduced disease incidence 73% and increased yields 132% when compared to tobacco without a summer soybean rotation and with a bare winter fallow. Data suggest that losses to bacterial wilt can be reduced significantly with use of a vetch winter cover.

Introduction
Bacterial wilt, caused by Ralstonia solanacearum (EF Smith) Yabuuchi et al., is a serious disease of flue-cured tobacco and is found in almost all warm-temperate and semitropical zones of the world (9,11,16). The disease is commonly known as Granville wilt in the United States, based on its devastating effect on the tobacco-dependent economy of Granville Co., NC at the turn of the 20th century. Since then, this disease has spread throughout the tobacco growing areas of North and South Carolina (5,9,13). In 1998, this disease caused $12 million in direct losses to tobacco farmers in South Carolina, exceeding 7% of the tobacco crop. An estimated 32% of all tobacco acreage in South Carolina is infested with R. solanacearum (5).

Bacterial wilt is managed through the use of crop rotation, resistant cultivars, and multi-purpose chemicals (5). Long term rotation, four years or more is best for control of bacterial wilt but is rarely used by farmers (1,7,9,14,17). The high value of tobacco, consolidation of allotments, and limited availability of land suitable for tobacco production have led to shorter summer non-host rotation schemes which in turn limit control of bacterial wilt (5,10,12).

A weed-free summer fallow is no better in reducing bacterial wilt than continuous tobacco, suggesting a non-host summer rotation crop does more than simply "starve out" the R. solanacearum (9,17). As a result, weed-free summer fallow is rarely used for bacterial wilt control. Tobacco fields are usually...
maintained fallow and weed-free during the winter preceding a tobacco crop. Soil is routinely fumigated for nematode control prior to planting tobacco. If winter cover crops were utilized they would need to be destroyed two months prior to planting tobacco to allow for incorporation of residues prior to fumigation. Early crop destruction minimizes biomass production by the cover crop. For this reason tobacco farmers in the southeastern USA have rarely used winter cover crops prior to planting tobacco. Enhanced microbial activity associated with a growing cover crop however may alter over-wintering populations of *R. solanacearum* in spite of minimal biomass production. The objective of this study was to determine the value of selected winter cover crops with early crop destruction for management of bacterial wilt in tobacco.

**Field Experiments**

The test site, near Bayboro, SC, had a Norfolk sandy loam soil (75% sand, 17% silt, 8% clay, 0.08% organic matter, pH 5.9) and a history of bacterial wilt losses. Tobacco had been planted on the site the summer prior to the initiation of the trials, 1996. Disc harrowing preceded all winter cover treatments. Selected winter cover crops were planted into naturally infested plots in a 1-year cycle rotated with tobacco grown during the summer months. The test was conducted in 1997 and 1998. Winter cover crops, canola (*Brassicca napus* L. cv. Calgene 128), common vetch (*Vicia sativa* L. cv. Catawba), and rye (*Secale cereale* L. cv. Abrusi), were planted on 1 and 2 November 1996 and 5 December 1997. Winter fallow was used as a control. Each winter cover crop was planted with a grain drill (15-cm row spacing) into plots (6-m wide × 104-m long rows) and was replicated three times in a randomized complete block design. Winter cover crops were sprayed with paraquat (1 kg a.i./ha), and disked into the soil in mid-February 1997 and 1998. On 26 February 1997 and 6 March 1998, the fumigant nematicide 1,3-D (56 liters/ha, 6.7 ml/row) was applied with a positive-pressure electric pump system and injected 15 cm deep with a single chisel placed in the center of a 60-cm-wide bed. Bedding disks were used to seal the chisel opening and form a 36-cm-high bed with fumigant placement 40 cm from the top of the bed. Plots were planted with tobacco cultivar K149 because it exhibits moderate to high resistance to bacterial wilt and is commonly grown in infested fields (5). Tobacco seedlings were transplanted on 7 April 1997 and 21 April 1998 into four-row plots (1.22 m wide × 104 m long). Mature tobacco leaves were harvested three times from the two middle rows in each plot during 1997 and 1998 and cured.

Cured leaves were graded for quality based on standard grades established by the Agricultural Marketing Service of the US Department of Agriculture (3). Tobacco leaves were assigned a quality rating on a 0-to-100 scale, where 0 = unusable leaf and 100 = high quality usable leaf (3). Prices of the tobacco leaf were based on the average price paid during that year for each grade. All plots were maintained for weed and insect control by standard agronomic practices and supplemental irrigation was supplied (6,8). Percent disease was determined by dividing the number of diseased plants at final harvest by the total number of plants per plot. A plant was considered diseased when advanced symptoms (unilateral wilting and black streaks within the stem) were evident.

Data were analyzed using analysis of variance (ANOVA), and contrasts (18). Statistical analyses were completed using SAS (SAS Institute Inc., Cary, NC). Separate experimental plots were set up in the same field to study the effects of winter-summer rotation crop sequences on bacterial wilt incidence. Main plots were the winter cover treatments canola, vetch, rye, or fallow. Subplots were the summer crops, soybean, corn, or continuous tobacco. The plots were arranged in a split-plot randomized complete block with three replications. Winter cover crops were planted as described previously. Fumigant nematicide 1,3-D was applied as previously described. Seeding rates for corn and soybean were six or 23 seeds/m of row, respectively, in subplots consisting of six rows (1 m wide × 104 m long) centered in the plots. In 1997, corn (cv Pioneer 3165) and soybean (cv Asgrow 5901) were planted on 22 March and 23 May, respectively, and tobacco seedlings transplanted on 7 April. In 1998, tobacco seedlings were transplanted to all plots on 21 April. In 1998, tobacco leaves were harvested,
cured, graded and assigned a quality rating as described previous. Prices of the tobacco leaf were based on the average price paid during that year for each grade. Data were analyzed as a split-plot design using ANOVA (SAS Institute Inc., Cary, NC).

**Effects of Winter Cover Crops on Tobacco Yield, Value, and Disease Incidence**

No significant year × cover crop interaction was observed for percent disease, yield, value, or price; thus data is presented over year. Crop yield, value, and price were greater in 1998 than 1997 \((P \leq 0.05)\) and reflect a more favorable growing season. Disease incidence did not vary between years \((P = 0.05)\). A vetch winter cover crop preceding tobacco increased the yield and value of tobacco 681 kg/ha and $2820/ha, respectively, and reduced disease incidence 33% in comparison to tobacco proceeded by a bare winter fallow (Table 1). The leaf price ($/ka) of tobacco preceded by vetch winter cover was higher \((P \leq 0.01)\) than tobacco preceded by a bare winter fallow ($3.77/kg vs $3.55/kg, respectively). Averaged over all winter cover crops and years (1997 and 1998), a winter cover increased tobacco yields and value \((P \leq 0.03)\) and reduced disease incidence \((P \leq 0.02, 1997)\) when compared to tobacco preceded by a bare winter fallow. In 1998, the effect of winter cover crops preceding tobacco on yield and bacterial wilt incidence was less pronounced, although the numerical trends were similar to those observed in 1997.

Table 1. Effect of winter covers on disease incidence, yield, and value of flue-cured tobacco in a field with a history of bacterial wilt. Data are averaged over two years.

<table>
<thead>
<tr>
<th>Winter cover</th>
<th>Yield (kg/ha)</th>
<th>Value ($/ha)</th>
<th>Price ($/kg)</th>
<th>Disease incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallow</td>
<td>1845</td>
<td>6904</td>
<td>3.55</td>
<td>33</td>
</tr>
<tr>
<td>Vetch</td>
<td>2526</td>
<td>9724</td>
<td>3.77</td>
<td>22</td>
</tr>
<tr>
<td>Canola</td>
<td>2247</td>
<td>8452</td>
<td>3.62</td>
<td>27</td>
</tr>
<tr>
<td>Rye</td>
<td>2117</td>
<td>7900</td>
<td>3.62</td>
<td>29</td>
</tr>
</tbody>
</table>

**Contrasts**

<table>
<thead>
<tr>
<th>Contrasts</th>
<th>Yield (kg/ha)</th>
<th>Value ($/ha)</th>
<th>Price ($/kg)</th>
<th>Disease incidence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallow vs. vetch (^*)</td>
<td>0.01**</td>
<td>0.01**</td>
<td>0.01**</td>
<td>0.05*</td>
</tr>
<tr>
<td>Fallow vs. canola</td>
<td>0.10</td>
<td>0.10</td>
<td>0.3</td>
<td>0.26</td>
</tr>
<tr>
<td>Fallow vs. rye</td>
<td>0.28</td>
<td>0.28</td>
<td>0.344</td>
<td>0.45</td>
</tr>
<tr>
<td>Fallow vs. all cover</td>
<td>0.03*</td>
<td>0.03*</td>
<td>0.06</td>
<td>0.12</td>
</tr>
</tbody>
</table>

\(^*\) Percent disease is calculated as a percentage of total diseased plants observed throughout the season. Means are averages of three replications.

\(^\times\) \(*\) = significant at \(P \leq 0.05\), \(*\ast\) = significant at \(P \leq 0.01\), values followed by no indication are not significant at \(P \leq 0.05\).

No interaction of winter cover × summer crop for yield, value, and quality index was observed. A significant winter cover × summer crop interaction occurred for disease incidence and tobacco leaf price. Bacterial wilt incidence in tobacco following a 2-year winter cover × summer crop rotation ranged from 9% (vetch-soybean-vetch) to 36% (canola-tobacco-canola) (Table 2). Summer rotation crops affected yield, value, price, quality, and disease incidence \((P \leq 0.05)\) (Table 2). Averaged over winter cover crops, yield, value, and quality index were increased \((P = 0.05)\) when corn or soybean preceded tobacco than when tobacco preceded tobacco. Averaged over summer rotation crops, yield, and value of the tobacco grown after a vetch winter crop were 46% and 50% higher \((P \leq 0.05)\) than when no winter cover was planted (Table 3).
Table 2. Effect of winter and summer cover crops on disease incidence in a field with a history of bacterial wilt

<table>
<thead>
<tr>
<th>Summer crop</th>
<th>Winter crop</th>
<th>Vetch</th>
<th>Canola</th>
<th>Rye</th>
<th>Fallow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>9 b</td>
<td>19 b</td>
<td>19 b</td>
<td>17 b</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>18 ab</td>
<td>10 b</td>
<td>18 b</td>
<td>32 a</td>
<td></td>
</tr>
<tr>
<td>Tobacco</td>
<td>29 a</td>
<td>36 a</td>
<td>35 a</td>
<td>33 a</td>
<td></td>
</tr>
</tbody>
</table>

Y Percent disease is calculated as a percentage of total diseased plants observed throughout the season. Means are averages of three replications.  
Z Means followed by the same letter are not significantly different according to an LSD test ($P = 0.05$).

Table 3. Effect of a winter cover crop on yield, value, and quality index of flue-cured tobacco grown in a field with a history of bacterial wilt (1998). Data are means of three previous summer rotation crops, and three replications.

<table>
<thead>
<tr>
<th>Winter cover</th>
<th>Yield (kg/ha)</th>
<th>Value ($/ha)</th>
<th>Quality index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vetch</td>
<td>1975 a</td>
<td>6985 a</td>
<td>49 a</td>
</tr>
<tr>
<td>Canola</td>
<td>1675 ab</td>
<td>5899 ab</td>
<td>53 a</td>
</tr>
<tr>
<td>Rye</td>
<td>1653 ab</td>
<td>5868 ab</td>
<td>47 a</td>
</tr>
<tr>
<td>Fallow</td>
<td>1353 b</td>
<td>4652 b</td>
<td>47 a</td>
</tr>
</tbody>
</table>

Y Average of tobacco quality grade rated according to a USDA tobacco grading standard.  
Z Means followed by the same letter are not significantly different according to a student t-test ($P = 0.05$).

Soybean as a summer crop resulted in the lowest disease incidence (16%). Yield was greater when corn (1720 kg/ha) or soybean (1920 kg/ha) was grown the previous summer than continuous tobacco (1353 kg/ha, $P \leq 0.01$). Value of the tobacco crop increased by 28 to 46% ($P \leq 0.01$) when either corn or soybean was planted the preceding year. Tobacco rotated with corn or soybean increase the quality of the tobacco by 10 quality points when compared to continuous tobacco.

Rye planted as a winter cover resulted in an increased price ($3.68/kg) when soybean was planted in the preceding summer, but not corn ($3.44/kg) or tobacco ($3.34/kg). Not using a winter cover and continuous planting of tobacco resulted in tobacco receiving the lowest price based on leaf quality. The summer rotation component of the experiment was not repeated; however, it reinforces the winter cover crop effect observed in the previous experiments.

Conclusion

Crop rotation is the foundation of soilborne disease management in tobacco (5,13). Summer rotations of soybean or corn have been shown previously to reduce the intensity of bacterial wilt and are commonly used by farmers in the southeastern USA. Winter cover crops are rarely used due in part to the widespread use of fumigants for control of soilborne diseases. Soil fumigation with 1,3-D or chloropicrin containing fumigants is routinely used to control nematodes and soilborne diseases. Root-knot nematodes are widespread and routinely reduce yields if adequate control measures are not implemented in addition to rotation. Fumigants require a soil free of excess organic matter and require a three-week waiting period before tobacco can be transplanted into treated soil. This limitation requires destruction of a winter cover in mid-February prior to soil fumigation in early March. Although a cover crop will actively grow during this short winter interval, significant biomass production does not occur. Farmers may therefore underestimate the effect of the ground cover on soil ecology based on the limited biomass production.
Although all winter cover crops tended to reduce bacterial wilt incidence and increase yields in the following tobacco crop, a winter vetch crop was the most effective in this regard. The selection of crops used in rotations is an important factor in developing the most effective rotation sequence. Vetch has been shown in previous studies to increase yields of tobacco (4,19). Vetch also benefits other crops such as corn, soybean, and cotton when included in a rotation sequence (15,17). Canola, incorporated as green manure, has been shown to reduce the level of bacterial wilt (2) in potatoes. The factors associated with cover crops suppressing disease and increasing yield are not clearly understood. Previous research showed the effects of a cover crop on yield of following crops is correlated to the amount of growth made by the cover crops (15). Although biomass production by vetch was minimal over the short growing season of these tests, the impact on bacterial wilt was significant. It is unlikely that nitrogen accumulation played a significant role in the increased yields or reduced bacterial wilt incidence observed in our trials. A bare winter fallow, much like a bare summer fallow, maintained R. solanacearum populations and contributed to higher bacterial wilt losses. Use of a winter cover can provide additional nonchemical control for bacterial wilt in spite of limited biomass accumulation.

**Contribution Number**

Technical contribution No. 4931 of the Clemson University Experiment Station.

**Literature Cited**
