Effects of Wheat Chaff and Tillage on Inoculum Density of *Pythium ultimum* in the Pacific Northwest

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ABSTRACT

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Studies were conducted to evaluate the effects of wheat chaff and tillage on inoculum density of *Pythium ultimum* in the field, and to determine the availability of chaff as a food source for *P. ultimum*. Soil and chaff samples were taken from two field sites five times between the 1984 wheat and 1985 pea harvest. Inoculum density was not affected by sampling time, tillage, or amount of chaff in the two field soils. In laboratory studies, when wheat chaff was collected from the field 1 wk after harvest and added to soil infested with *P. ultimum* in the laboratory, it became 90% colonized. Chaff collected 3 wk later became only 10% colonized. Except at the first collection date, autoclaving the chaff significantly increased colonization. Wheat chaff was not colonized by *P. ultimum* in the field and chaff from the field quickly became unavailable as a food source for *P. ultimum* even under optimum moisture and temperature conditions for saprophytic development. Lack of colonization of wheat chaff by *P. ultimum* in the field is likely due to unfavorable environmental conditions at harvest for saprophytic development and previous colonization by other microorganisms.

Additional key words: *Pisum sativum*, residue, soilborne pathogens.

Wheat (*Triticum aestivum* L.) is the primary rotation crop grown with peas (*Pisum sativum* L.) in southeastern Washington and northeastern Oregon. Grain yields exceeding 5,400 kg/ha are not uncommon and with these high yields come problems associated with excessive residue. These problems are compounded by the windrowing effect produced at harvest by the combine. Residue rates exceeding 16,000 kg/ha have been measured in chaff windrows (1). Seed sown in chaff windrows the following season result in uneven emergence and stunted chlorotic plants. Nutrient tie-up and phytotoxic compounds produced during residue decomposition have been implicated with these plant symptoms (7,12). Another possibility is root disease resulting from the development of a favorable disease environment or an increase in pathogen populations.

Incorporation of crop residues and organic matter has frequently been reported to increase root disease and populations of *Pythium* spp. (6,10,11,19,20,23). Residue of a given crop usually increases populations of *Pythium* with resultant damage to seedlings and juvenile root tissue of the same crop. However, in 1982, Allmaras et al (2) reported that *Pythium* root rot of pea was aggravated by wheat residue. In 1984, wheat chaff was identified as the primary component of wheat residue affecting populations of *Pythium* (4). Because peas growing in the aforementioned region of the Pacific Northwest are exposed to excessive amounts of wheat residue each year, this study was conducted to determine how tillage and chaff affect inoculum density of *P. ultimum* Trow. and pea growth, and secondly to evaluate the suitability of wheat chaff as a substrate for *P. ultimum*.

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MATERIALS AND METHODS

The first part of this study was conducted at two field sites in the Blue Mountain region of southeastern Washington and northeastern Oregon. Site 1, in Washington, averages 630 mm annual precipitation and a base population of *P. ultimum* of approximately 150–200 colony-forming units (cfu) per gram of soil. Site 2, in Oregon, had a base population of *P. ultimum* of 50–100 cfu per gram of soil and 400 mm precipitation (*unpublished*). Soil types were a Palouse silt loam and an Athena silt loam at sites 1 and 2, respectively. Both locations have been in a dryland pea-wheat rotation for over 10 yr.

During the 1984 wheat harvest, chaff was collected at each site as it came from a commercial combine. Combines were equipped with chaff spreaders so only chaff and not straw was collected. The chaff was then redistributed over 6-× 12-m areas at rates of 0 g/m^2, 357 g/m^2, or 715 g/m^2. One month later, one-half of each 6-× 12-m area was disked to a depth of approximately 5 cm and the other half was moldboard plowed to a depth of 20 cm, resulting in final plot sizes of 6 × 6 m. Each combination of residue and tillage was replicated three times.

Soil samples were taken from each plot five times at approximately 10-wk intervals between the August wheat harvest 1984 and the June pea harvest 1985 to detect changes in the inoculum density of *P. ultimum* associated with residue rate or tillage. Samples were taken from 0–10 cm in the disked plots and 10–20 cm in the plowed plots to insure sampling in the area of chaff deposition. There was no significant difference in vertical distribution of propagules in the upper 20 cm of the soil as determined by dilution plating before the study. Inoculum density of *P. ultimum* from each plot was determined by soil dilution plating on Mircetich's selective medium (17). *P. ultimum* was distinguished by growth rate and colony morphology. The 1985 pea plots were planted with a conventional planter at 15-cm row spacing in April and plant emergence was determined 4 wk later at each location. Vine growth and dry seed yields were also measured at plant maturity to evaluate treatment effects on the pea crop.

The second part of this study was conducted to determine the suitability of wheat chaff from the field as a food source for *P. ultimum*. Beginning 1 wk after wheat harvest in 1985, chaff was collected five times at 3-wk intervals from commercial fields adjacent to the original sites 1 and 2. Five random samples were taken from the plow layer and soil surface and bulked. Subsamples were sieved and washed with tap water to remove adhering soil and then plated onto potato-dextrose agar or Mircetich's medium to determine fungal colonizers of the residue. Each subsample consisted of 10 pieces of chaff per plate with a minimum of five plates per medium. A second subsample of autoclaved or nonautoclaved chaff (0.25 g) was added to 25 g of sterile field soil amended with 50 cfu per gram of *P. ultimum* gravimetrically adjusted to −1 bar matric potential, and incubated for 5 days at 21 C. This method has been used previously to evaluate the saprophytic ability of *P. ultimum* (14,18). After incubation, the chaff was sieved from the soil and checked for colonization by *P. ultimum* as previously described. Inoculum density of *P. ultimum* in the soil was determined by dilution plating, for each of the replicates. Soil infested with *P. ultimum* without chaff was used as a check at each sampling period.

RESULTS

Wheat chaff had no observed effects on populations of *P. ultimum* in the field, nor did tillage. When populations of *P. ultimum* were analyzed over time with linear regression, a correlation coefficient of $r = -0.13$ was obtained indicating no appreciable population by time interaction. For this reason, the values shown in Table 1 are means over all sampling dates. The only significant difference observed in these data was between the 357 and 715 g/m^2 chaff rate of chaff incorporation in the disked plots at site 1. However, there was no difference between the check and either of the two chaff treatments, nor was there any difference in the inoculum density of *P. ultimum* with treatments at site 2.

The amount of chaff did not significantly affect stand or yield components at either site, but tillage did (Table 2). At site 1, emergence, number of pods, and fresh pea seed weight were all significantly lower in the disked than in the plowed plots. The same trends were observed at site 2, but only pea seed weight was significantly different.

Under laboratory conditions, colonization of chaff collected from the field 1 wk after harvest ranged from 88 to 95% (Fig. 1). There was no difference in colonization of chaff from the two sites ($P = 0.05$). The ability of *P. ultimum* to colonize chaff collected after 4 wk was significantly reduced. Autoclaving the chaff before incorporation into infested soil significantly increased colonization by *P. ultimum*. Addition of field chaff to infested soil

TABLE 1. Inoculum density of *Pythium ultimum* as affected by wheat chaff and tillage at two locations[x]

Chaff rate	*P. ultimum* (cfu/g soil)[y]	
	Plowed[z]	Disked
Site I		
0 g/m^2	173 a	151 ab
357 g/m^2	225 a	229 a
715 g/m^2	132 a	73 b
Site II		
0 g/m^2	84 a	62 a
357 g/m^2	40 a	73 a
715 g/m^2	73 a	99 a

[x] Site I near Walla Walla, WA, has a Palouse silt loam soil type and averages 200 cfu of *P. ultimum* per gram of soil. Site II near Athena, OR, has an Athena silt loam and averages 100 cfu *P. ultimum* per gram of soil.
[y] Inoculum density of *P. ultimum* was determined by soil dilutions on selective media. Values in each column are the mean of five sampling dates over 15 wk and those followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.
[z] Plowing buried the chaff approximately 20 cm deep and disking mixed the chaff in the upper 10 cm. Each treatment was replicated three times.

TABLE 2. Effects of tillage on stand and pea yield components[x]

Tillage[y]	Emergence	Dry top wt. (g)	Pods	Dry pea wt. (g)
Site I				
Plowed[z]	137 a	479 a	369 a	246 a
Disked	98 b	439 a	273 b	145 b
Site II				
Plowed	218 a	584 a	382 a	191 a
Disked	204 a	571 a	327 a	142 b

[x] All values are from plant measurements taken from two 6-m rows in the center of each plot. Stand counts were taken 4 wk after planting and all other components were measured at plant maturity. Values followed by the same letter are not significantly different ($P = 0.05$).
[y] Plowing buried the chaff approximately 20 cm deep and disking mixed the chaff in the upper 10 cm. Each treatment was replicated three times.
[z] Chaff treatments did not affect any of the yield components so the presented values are an average over chaff rates.

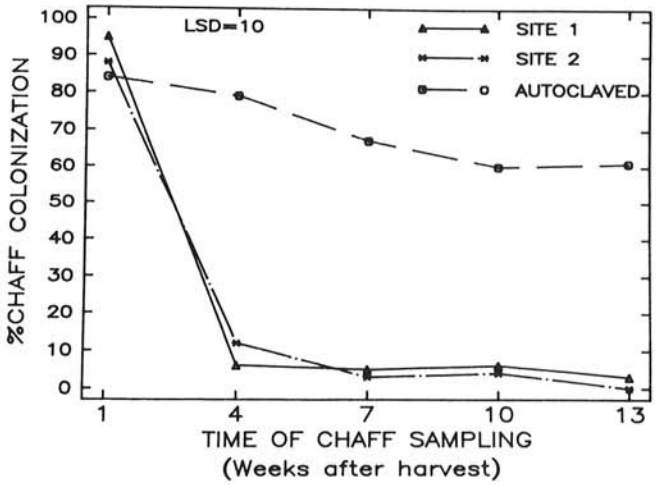

Fig. 1. Percent colonization of wheat chaff by *Pythium ultimum* as affected by time of chaff sampling. Chaff was gathered from sites 1 and 2 in Washington and Oregon, respectively, at 3-wk intervals after wheat harvest, brought to the laboratory and placed in sterile field soil artificially infested with 50 cfu per gram of soil of *Pythium ultimum*. A portion of the chaff was autoclaved before soil amendment. After 5 days incubation at −1 bar matric potential and 21 C, the chaff was sieved from the soil, washed, and plated onto Mircetich's selective medium. Percent colonization of the chaff was determined 48 hr after plating. LSD value is for $P = 0.05$.

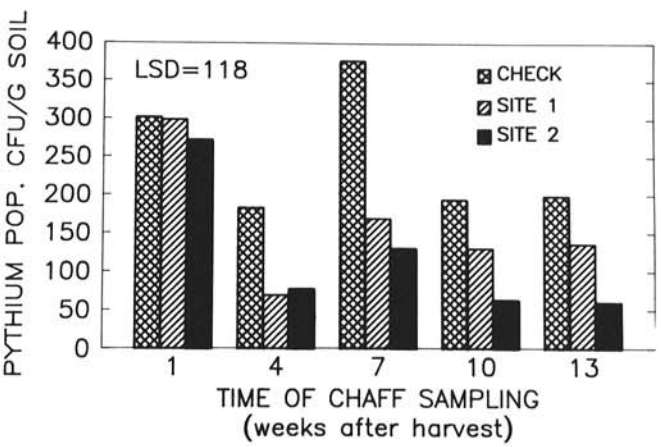

Fig. 2. *Pythium ultimum* populations in soil amended with nonsterile wheat chaff. Chaff was gathered at 3-wk intervals after wheat harvest from sites 1 and 2, brought to the laboratory and placed in sterile field soil artificially infested with 50 cfu of *P. ultimum* per gram of soil. After 5 days incubation at −1 bar matric potential and 21 C the chaff was sieved from the soil. Infested soil without added chaff served as a check. Soil dilutions were then plated onto Mircetich's selective medium to determine the degree of population increase. Inoculum densities of *P. ultimum* in chaff-amended soils were compared at each date with those in unamended soil. LSD value is for $P = 0.05$.

never increased the inoculum density of *P. ultimum* above that in soil without chaff added as a food base (Fig. 2). Instead, nonsterile field chaff decreased the inoculum density below that of the control. In 1985, after five sampling dates from two locations, *P. ultimum* was never directly isolated from chaff collected from the field. However, at each sampling period numerous other fungi were isolated. These included *Pythium oligandrum*, *Penicillium hordei*, and unidentified species of *Mucor*, *Rhizopus*, *Mortierella*, *Chaetomium*, and *Fusarium*. Members of the *Mucorales* were the predominant organisms isolated.

DISCUSSION

The results of this study are at variance with most reports concerning the response of *Pythium* spp. to residue incorporation, but can be explained by evaluating the specific circumstances in which the pathogen and residue are brought together. In southeastern Washington and northeastern Oregon most wheat is harvested in July or early August. Most farmers do not plow-under the residue until the soil becomes friable after rains in September and October. Therefore, in this agroproduction system, the wheat residue remains on the soil surface up to 2 mo before incorporation. A slight variation of this procedure, used when residue rates are exceptionally high, is to disk the residue immediately after harvest, thereby incorporating the residue into the upper 5–10 cm of the soil. Although the majority of propagules of *P. ultimum* are found in the upper 15–20 cm of the soil (2,13), their ability to saprophytically colonize the newly incorporated residue is restricted due to low soil moisture and previous colonization by other microorganisms.

July, August, and September are traditionally the hottest, driest months in the Pacific Northwest. The mean air temperature during these 3 mo over a 27-year period was 19 C and the mean precipitation 16.5 mm. Although this temperature is near optimum for colonization of incorporated organic residues by *P. ultimum* (12), the upper 5 cm of the soil surface where the majority of residue is located is subject to extreme temperature fluctuations. Temperatures measured in this layer have been found to exceed 45 C (D. Wilkins, *personal communication*). Even with adequate moisture, germinating propagules would most likely lyse when exposed to such high temperatures (14). Insufficient soil moisture for saprophytic development is also a limiting factor during these months. Mansour et al (16) measured soil moisture at different levels beneath a dryland wheat crop and found soil water potential at 30 cm was <-20 bars by the last week in June. This value corresponds with measurements taken by the first author in 1985 at the two test sites. It is probable that saprophytic activity of *P. ultimum* at this soil water potential would be nil. This conclusion is supported by results from previous studies (9,15,21).

Colonization by microorganisms is perhaps the principal reason *P. ultimum* was not isolated from wheat chaff taken from the field. Previous studies have shown that sterile wheat chaff can be used as a food source by *P. ultimum* (4,18). Its addition to a soil infested with *P. ultimum* will result in a significantly higher inoculum density than soil without chaff. Wheat chaff collected from the field 1 wk after harvest and placed in artificially infested sterilized field soil with optimum conditions for saprophytic growth of *P. ultimum* became 90% colonized. Chaff collected just 3 wk later was colonized only 8–12%. Autoclaving increased the percent colonization to 79%. At no time did the addition of chaff to soil infested with *P. ultimum* result in final inoculum densities of *P. ultimum* equal to those in soil without chaff. This suggests that in the field, even if optimum temperatures and moisture conditions develop soon after wheat harvest, *P. ultimum* is unable to use the residue as a food source because of previous colonization by other microorganisms. These results strongly support the pioneer colonist concept espoused by numerous authors (3,5,8,22).

In the field, high levels of wheat chaff did not increase populations of *P. ultimum* nor appear to be available as a food source after 4 wk. Residue could be responsible however for altering the soil environment resulting in conditions that favor the growth of *P. ultimum* at the expense of the host. It is generally recognized that the soil microenvironment under a minimum or no-till system stays cooler and wetter than with conventional farming practices (5). Further research is needed to elucidate the effects of wheat residue and tillage on severity of pea root disease caused by *P. ultimum*. Studies that separate the detrimental effects of cold, wet soil on seedling development from pathogenic damage should be emphasized.

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