Fungicidal Control of Garlic White Rot in Madras Oregon, 2005-2006

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Introduction

Fungicides were applied in-furrow at planting in a replicated field trial in fall 2005 for control of garlic white rot caused by *Sclerotium cepivorum*. Some fungicides had been previously tested, others had not. Because control of white rot has proven difficult and single preplant applications must extend 8-10 months, all were applied at relatively high rates based on either product labels or company recommendations. In contrast to past trials, rates of application were expressed as the amount of product per 1,000 bed ft, which is more appropriate to product labeling for in-furrow application than the way rates were expressed in the past. The trial area was uniformly infested by spreading and tilling in high and naturally infested soil from a previous trial area. Inoculum density was moderately high (five viable sclerotia/l soil). Disease pressure was very high, a severe challenge for single at-planting applications that must provide control of white rot through to harvest. Interpretation of results was not complicated by winter damage or botrytis bulb rot disease. Yield in untreated plots averaged only 0.4 tons/acre of harvestable bulbs, with only 3 percent of plants harvested as bulbs. At least some white rot occurred in every plot. Nevertheless, mean yield in plots treated with Folicur® (tebuconazole) applied at 13.9 ml/1,000 bed ft (equal to 1 l/ha as expressed in past) was 8.1 tons/acre. Garlic in plots treated with Folicur at half this rate combined with half the label rate of PCNB yielded 8.5 tons/acre. Unfortunately, garlic may soon be removed from the PCNB product label. Garlic in plots treated with Endura® (boscalid) yielded 7.9 tons. Other products that provided less control and lower yields are discussed below. Several additional products and product combinations tested may provide good control with less disease pressure.

Materials and Methods

Infested soil from an older trial area was used to infest the new, previously noninfested trial area. Inoculum was tilled to 10 inches in early September 2005. At five sclerotia/l soil, 85-90 percent of garlic in untreated plots was expected to become infected by harvest in 2006, and five sclerotia/l soil is the upper limit at which fungicides might be expected to provide reasonable yields. Thus, this was designed to be a severe test of fungicide efficacy.

Garlic provided by ConAgra was ‘California Late’ (virus-free) and was planted October 10, 2005 with a 2-row planter (also provided by ConAgra) as per commercial practice, approximately 18-20 clovesbed ft in 2 seed lines per 36-inch bed. Plots were planted 30-ft long and fungicide products were sprayed onto the garlic cloves as they dropped across the open seed furrow by orienting a single 110-05 nozzle behind the furrow opener and in front of the closers. The planter was rigged so that 250 ml of product/seed line/30 ft was dispensed from a full 1-l bottle connected to a constant CO2-pressurized and regulated system at 30 psi. The spray system was activated and stopped manually per plot, and new bottles were attached for each plot. Spray was purged of old product and new product refilled the system in the first few feet of each plot. After spring emergence, garlic was removed from either direction of the transition point between sprays so that the plots were 25 ft long. Fungicide products used, manufacturers, and rates of application are listed in Table 1.

The trial area contained two trials: a main trial in which most products were used, and a border trial located in the outside beds surrounding the main trial, beds that could be subject to more outside influences. The border trial might or might not prove useful.

Fertility, herbicide, and irrigation practices were as per industry standard for central Oregon, and are not described in detail for this report. Irrigation was applied once in the fall after planting in 2005, resumed mid-April 2006, and terminated after June 14, 2006. Even though botrytis disease occurred widely in central Oregon in 2006, no fungicide was applied and only a small handful of plants developed botrytis disease in this field trial. All plant death was attributed to white rot. Garlic harvest and handling is described below.

Results

The winter of 2005-2006 was mild. Garlic was fully emerged by mid-April 2006 and the plants present were counted on April 19. On the other hand, the spring was very cool and damp. *S. cepivorum* is not highly active until soil temperature exceeds 50°F. First white rot was observed in late April, seemingly all from direct infections of the neck where soil was warmer. Root infections reaching the stem plate were not detected until well into May, later than normal. However, white rot rapidly progressed thereafter. In some years, there has been pre-emergence loss to white rot in such test plots, but no such pre-emergent losses were discernable in 2005-2006 (see Table 2 and associated graph). On the other hand, all products seem to have resulted in slight stand losses; such losses were noticed in the past with Folicur, but are not considered substantial enough for concern at the rates of application used.

White rot was preliminarily rated on June 19, just prior to a public plot tour promoted for the garlic industry. These preliminary data are not shown here. Garlic was undercut on July 10, 2006. Garlic plants were hand lifted while tops were still somewhat green, and roots were cleaned of dirt from July 11to 15. From July 17 to 21, garlic was separated into two piles per plot based on F. Crowe's judgment whether a bulb would be commercially harvestable or not, primarily depending on severity of rot and size of bulb. Bulbs were discarded if infected to the point that cloves likely would shatter during mechanical harvest practices, or if bulbs were less than 1-inch diameter. Tops were fully dried by July 26, at which time the bulbs considered harvestable were counted and weighed. Rather than topping the bulbs, the amount of weight attributable to tops was subtracted from the net weight. Analysis of variance was conducted using SAS statistical software (SAS Institute, Inc., Cary, NC), and treatment means separations are expressed using Duncan's Multiple Range tests, $P \leq 0.05$.

White rot occurred in every plot, and at least some bulbs were rejected from each plot. In general, the number of infected-but-harvestable bulbs from each plot varied from 2 to 5 percent of the total harvestable bulbs, but the actual number of such bulbs per treatment is not shown. The mean numbers of harvestable bulbs and weights of harvestable bulbs per treatment appear in Tables 3 and 4, respectively, and associated graphs. In the main trial, products seem to fall into roughly three groupings: Folicur, Endura, and the combination of Folicur plus PCNB all controlled white rot relatively well and yielded quite well relative to local expectations. Switch®, Pristine®, Scholar®, the combination of a reduced rate of Folicur plus USF2004 and JAU6376 partially controlled white rot and yielded less – these products might work better with lower disease pressure. The active ingredient in Scholar (fludioxonil) has been used in the past and sometimes proved efficacious alone, but especially in combination with Folicur. Elevate®, Scala®, and KIF3535 did not exert substantial control of white rot in 2006. The labeled rate of PCNB yielded 7.1 tons/acre and the half rate of Folicur combined with the half rate of Scholar yielded very similarly, 6.9 tons/acre. In one border trial treatment, a half rate of Folicur applied in-furrow preplant was banded in spring with another half rate of Folicur applied at the base of plants. Such spring banding with Folicur has been tried in past trials with little success, and it was not fully successful for us in 2005-2006 either, even though this is a preferred and successful method of application in some onion regions where onions are treated while partially grown and just prior to the period when white rot would be most active near the bulb. The difference we believe may be explained as follows: onions are seeded quite shallow (0.5 inch or so), so the Folicur need only move a short distance compared to seed garlic that is planted 3 inches deep. However, for commercial garlic in California that is planted at 1.5 inches, perhaps bed-top banding of Folicur could have merit.

As per Tables 3 and 4, most yield loss was simply from reduction in bulb numbers. In past trials, there sometimes was an additional component of yield loss if the bulb was protected from rotting but bulb size was reduced by excessive rotting of roots. Bulb sizes commonly were high for the few bulbs that survived in plots with substantial white rot. Excluding such high-disease plots, there was a slight range in bulb sizes among high-yield plots (Table 5), but not enough difference for most mean bulb weights to be statistically separable.

Discussion

The previous trial in Oregon during 2004-2005 was confused by extreme variability in data that was assumed to result from miss-labeling of plots or from excessive infection of garlic at the neck level above the zone of fungicidal protection. Thus, it was difficult to determine what products performed the best. Our 2005-2006 trial had no such complications or confusions. Folicur and Endura performed very well, and products such as Switch, Pristine, and Scholar show some promise, especially if products in combination are tested later and if tested under less severe infestations. These five products likely should be retested alone and in various combinations at reduced rates.

PCNB alone performed reasonably in our border trial, which was somewhat surprising given general industry dissatisfaction with this product many years ago. But the combination of half rates of Folicur plus PCNB in the main trial looked the best. We tried this particular combination because PCNB is an old product with a current white rot label, but it did not perform adequately in the past by itself and it has become very expensive. In fact, the performance of PCNB in this trial was surprisingly effective. Further, we looked for creative ways to use lower rates of Folicur. Perhaps even lower rates of such combinations might be effective and less expensive. However, recent regulatory action points to the likelihood that garlic will be removed from the PCNB label.

White rot in seed areas such as central Oregon has actually become somewhat harder to control by in-furrow application. In recent years, garlic in cold regions is planted deeper in the soil to prevent freeze injury, 3 inches rather than 1.5 inches. In-furrow application with deeper planting has resulted in less fungicide product being placed in the longer neck area between bulb and the soil surface. This neck region is susceptible to direct white rot attack if soil populations of sclerotia are moderately high as in this trial. Control might be improved for the same trial located in California under shallower seed placement, and for less infested fields in central Oregon. Of course, increased rates of application or some modification of the way cloves are covered by soil also might allow for improved white rot control where seed is planted deeper.

Table 1. Products, manufacturers, and rates of application applied in-furrow in the fall of 2005 for control of garlic white rot, 2005-2006 at Madras, Oregon..

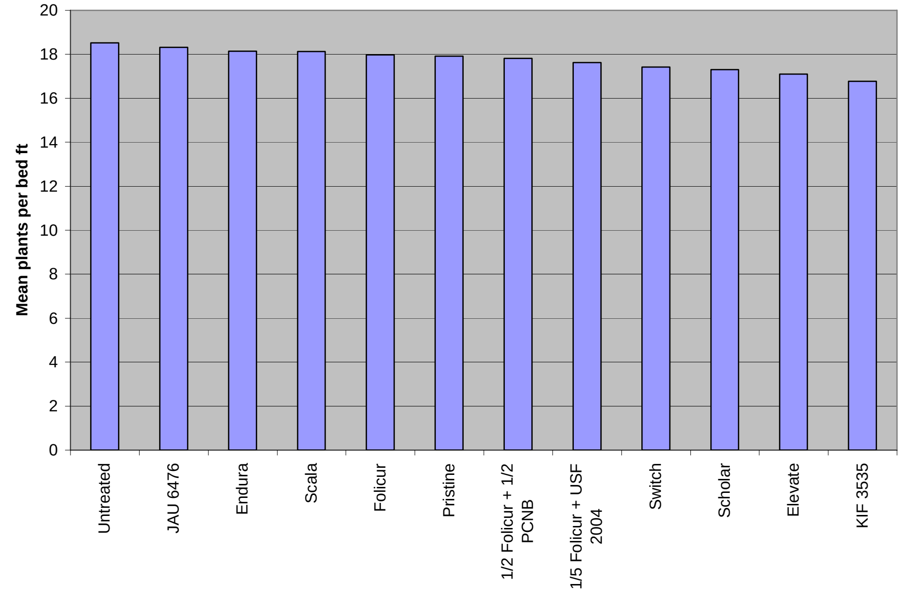
Product	Manufacturer	% Active ingredient	Rate/1,000 bed ft
Main trial			
Untreated			
Folicur 3.6F	Bayer	430 g/l tebuconazole	13.6 ml
Folicur 3.6F	Bayer	430 g/l tebuconazole	3.1 ml
+ USF2004SC	Bayer	43.7% USF 2004	3.1 ml
Folicur 3.6F	Bayer	430 g/l tebuconazole	6.8 ml
+ PCNB 75WP	Amvac	75% pentachloranitrobenzene	10 oz (=284 g)
KIF-3535 40SC	KI Chem	40% pyrimethanil	18.1 ml
JAU 6476 480SC	Bayer	41.1% JAU 6476	5.8 ml
Switch 62.5G	Syngenta	37.5% cyprodanil + 25% fludioxonil	14.0 g
Pristine WG	BASF	12.8% pyraclostrobin + 25.2% boscalid	22.0 g
Elevate 50WDG	Arvesta	50% fenhexamide	23.5 g
Endura 70WG	BASF	70% boscalid	10.0 g
Scholar 25GR	Syngenta	50% fludioxonil	7.8 g
Scala	Bayer	54.6% pyrimethanil	18.3 ml
Border trial			
Untreated			
Folicur 3.6F	Bayer	430 g/l tebuconazole	6.8 ml
+ Scholar 25GR	Syngenta	50% fludioxonil	3.9 g
PCNB 75WP	Amvac	75% pentachloranitrobenzene	20 oz (= 567.5 g)
Folicur 3.6F in furrow	Bayer	430 g/l tebuconazole	6.8 ml
+ Folicur 3.6F banded*	Bayer	430 g/l tebuconazole	6.8 ml

*On April 7, 2006, Folicur was banded 4 inches over the top of seed line on each bed in treatment D of the border trial.

Table 2. Spring plant stands for 2006 garlic white rot trials at Madras, Oregon.

Stand Treatment	Mean plants per acre	Mean plants per bed ft	As % of largest treatment mean	Stat grouping (5%)*
Untreated	268,910	18.5	100	a
JAU 6476	266,006	18.3	99	a
Endura	263,393	18.1	98	ab
Scala	263,102	18.1	98	ab
Folicur	261,070	18.0	97	abc
Pristine	260,198	17.9	97	abc
½ Folicur + ½ PCNB	258,746	17.8	96	abc
1/5 Folicur + USF2004	255,842	17.6	95	abc
Switch	252,938	17.4	94	abc
Scholar	251,196	17.3	93	abc
Elevate	248,292	17.1	92	c
KIF 3535	243,646	16.8	91	c

*Means with similar letters are statistically inseparable, P $\leq$ 0.05.



Stand Treatment	Mean plants per acre	Mean plants per bed ft	As % of largest treatment mean	Stat grouping (5%)*
½ Folicur + ½ Scholar	244,807	16.9	100	a
PCNB	243,936	16.8	100	a
½ Folicur + ½ Folicur spring banded	220,704	15.2	90	a
Untreated	188,470	13.0	77	a

*Means with similar letters are statistically inseparable, P $\leq$ 0.05.

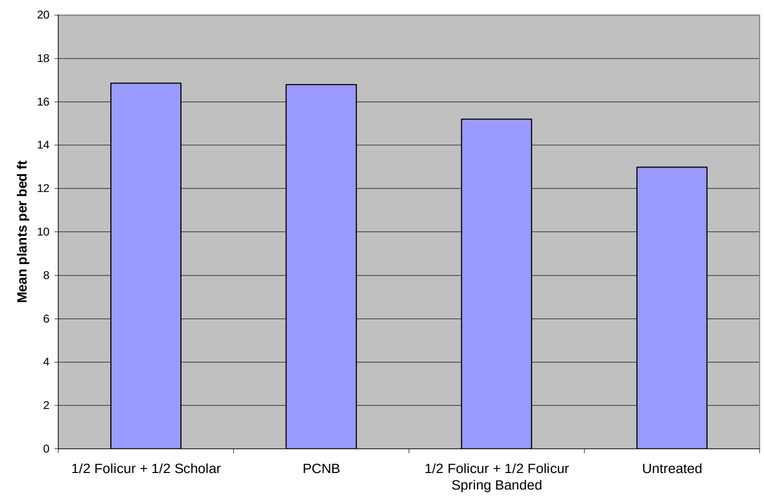
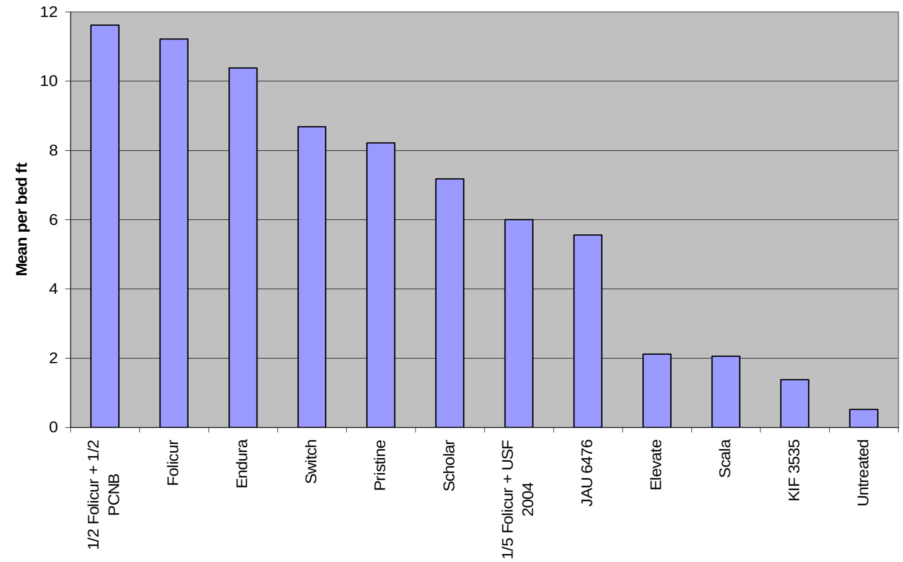


Table 3. Harvestable bulbs from the 2006 garlic white rot trial, Madras, Oregon. Harvestable bulbs included mostly noninfected bulbs but also 2-5 percent of bulbs infected at the stem plate or just into the cloves but which would pass through harvest handling systems.

Number total harvestable bulbs Treatment	Mean bulbs/ac	Mean per bed ft	As % of mean spring stand for each treatment	Stat grouping* (5%)
½ Folicur + ½ PCNB	168,722	11.6	65	a
Folicur	162,914	11.2	62	a
Endura	150,718	10.4	57	ab
Switch	126,034	8.7	50	bc
Pristine	119,354	8.2	46	c
Scholar	104,254	7.2	42	cd
1/5 Folicur + USF2004	87,120	6.0	34	d
JAU 6476	80,731	5.6	30	d
Elevate	30,782	2.1	12	e
Scala	29,911	2.1	11	e
KIF 3535	20,038	1.4	12	e
Untreated	7,550	0.5	3	e

*Means with similar letters are statistically inseparable, P $\leq$ 0.05.



Number total harvestable bulbs Treatment	Mean bulbs/ac	Mean per bed ft	As % of mean spring stand for each treatment	Stat grouping* (5%)
PCNB	149,556	10.3	61	a
½ Folicur + ½ Scholar	137,650	9.48	56	a
½ Folicur + ½ Folicur spring banded	102,511	7.06	46	ab
Untreated	17,714	1.22	9	b

*Means with similar letters are statistically inseparable, P $\leq$ 0.05.

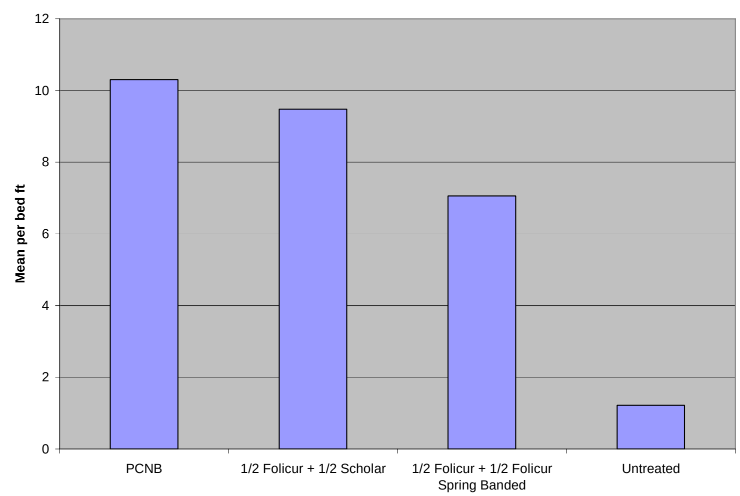
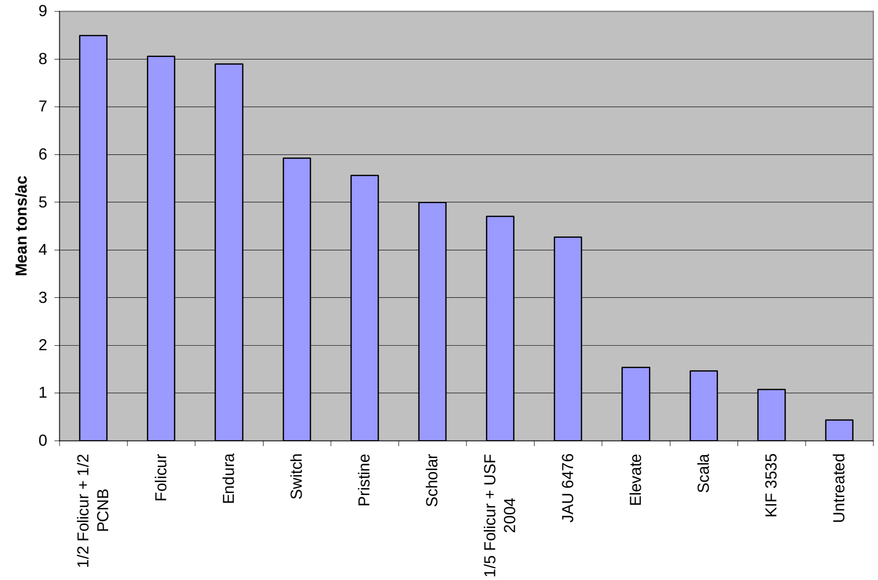


Table 4. Weight of bulbs harvested from 2006 garlic white rot trial, Madras, Oregon.

Weight harvestable bulbs Treatment	Mean lbs/ac	Mean tons/ac	As % of largest treatment mean	Stat grouping* (5%)
½ Folicur + ½ PCNB	16,988	8.5	100	a
Folicur	16,117	8.1	95	a
Endura	15,798	7.9	93	a
Switch	11,848	5.9	70	b
Pristine	11,122	5.6	65	bc
Scholar	9,990	5.0	59	bc
1/5 Folicur + USF2004	9,409	4.7	55	bc
JAU 6476	8,538	4.3	50	c
Elevate	3,078	1.5	18	d
Scala	2,933	1.5	17	d
KIF 3535	2,149	1.1	13	d
Untreated	871	0.4	5	d

*Means with similar letters are statistically inseparable, P < 0.05.



Weight harvestable bulbs Treatment	Mean lbs/ac	Mean tons/ac	As % of largest treatment mean	Stat grouping* (5%)
PCNB	14230	7.1	100	a
½ Folicur + ½ Scholar	13736	6.9	97	a
½ Folicur + ½ Folicur spring banded	8305	4.2	58	a
Untreated	1946	1.0	14	a

*Means with similar letters are statistically inseparable, P < 0.05.

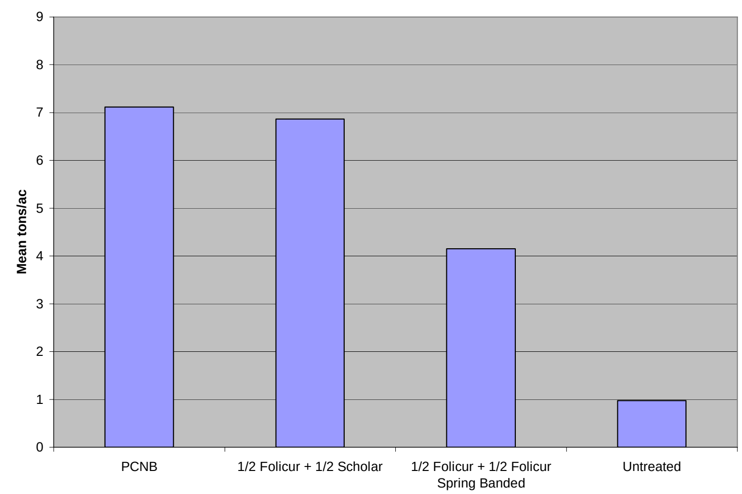


Table 5. Weight per bulb for bulbs harvested from 2006 garlic white rot trial at Madras, Oregon.

Weight per harvestable bulb Treatment	Mean g/bulb	Stat grouping* (5%)
KIF 3535	51.756	a
1/5 Folicur + USF2004	49.940	ab
JAU 6476	48.578	ab
Endura	48.124	ab
Untreated	46.762	ab
½ Folicur + ½ PCNB	45.400	ab
Elevate	45.400	ab
Folicur	45.400	ab
Scholar	43.130	ab
Switch	42.676	ab
Scala	42.676	ab
Pristine	41.768	b

*Means with similar letters are statistically inseparable, P $\leq$ 0.05.

Weight per harvestable bulb Treatment	Mean g/bulb	Stat grouping* (5%)
Untreated	49.032	a
½ Folicur + ½ Scholar	44.492	a
PCNB	42.676	a
½ Folicur + ½ Folicur spring banded	32.688	a

*Means with similar letters are statistically inseparable, P $\leq$ 0.05.