GARLIC WHITE ROT FUNGICIDE TRIAL
MADRAS OREGON, 2004-2005

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Abstract

Fungicide efficacy for control of *Sclerotium cepivorum*, the Allium white rot fungus, is presented for a field trial conducted in a uniformly and artificially infested field in central Oregon, 2004-2005. Two garlic varieties were used (two replications each among four total replications) and were planted at different planting rates. Both varieties were planted at too-high planting rates, which may have stressed garlic performance and enhanced white rot incidence. As a result, efficacy was best expressed in relative terms (as percentages of yield relative to the best performance) rather than absolute terms (actual disease incidence or yield). The winter of 2004-2005 was mild, elevating disease levels to the limits of control that might be expected for fungicides. White rot generally was severe in both untreated check plots and in Rovral®-treated plots. Additionally, disease control seemed to fail altogether in some plots but was high in other plots. No errors were found in product applications or data management. Erratic control failures may have been associated with occasional neck infections followed by neck-to-neck spread of *S. cepivorum*, another consequence of a too-high planting rate. Such erratic control failures were excluded from analyses. Removing such data biased the results toward products that showed good promise for control in spite of the unexplained spot-failures. As in past years, Folicur® (tebuconazole) performed well, even though it too failed in some plots. At the rates used, KIF-3535 (mepanipyrim), JAU 6476 (unknown experimental), Switch® (cyprodanil + fludioxonil), Elevate® (fenhexamide), Endura® (boscalid), and Pristine® (boscalid + pyraclostrobin) also showed good potential; Omega® (fluazinam) and CaptEvate® (captan + fenhexamide) did not provide much control. In past, fludioxonil (as either Maxim® seed treatment or Scholar® in-furrow spray) has shown reasonable control of white rot, but in other years it appears to break down late in the season. Scholar performance was erratic in this trial. The experimental product USF 2004 did not perform well when applied alone, but a combination of Folicur and USF 2004 was the outstanding treatment among all. For several “biological” products based on earthworm byproducts, either stand was reduced and/or white rot control was substantially less than for Folicur (but better than for the untreated control). Products showing reasonable promise in this trial require additional testing, we hope with fewer confounding effects than for this 2004-2005 trial. In future, we do not anticipate having the problems found in this trial.

Introduction

Fungicide for control of white rot traditionally has been applied with the seed at planting, either as in-furrow sprays or as seed treatments. Control is difficult in this manner, requiring that the fungicide remains effective through a week or 2 after irrigation cutoff the following summer, perhaps 9 months later. Higher rates have been required, making the applications expensive. Simply preventing *S. cepivorum* from infecting the bulb may not prevent the fungus from spreading through the soil among roots below the zone of protection, so if the fungicide begins to degrade, the fungus may infect and/or kill as many plants as if no product had been applied. Further, loss of control late in the season may result in a higher population of sclerotia of *S.*

cepivorum because the plants are larger and provide a larger food base. We estimate that decay of more than 2-3 percent of bulbs remaining in the field can result in an increasing population base of sclerotia, resulting in even more difficult control in the future. Thus, a fungicide must be very good to be justified.

On the other hand, a very good fungicide can result in catastrophic population loss of sclerotia of *S. cepivorum*, making future control much easier. The reason for this is that Allium roots force the *en masse* germination of sclerotia in soil, requiring the fungus to re-establish a new population base on newly infected bulbs. Full eradication by this process alone probably cannot be achieved, however, because there is a trace of reproduction in roots themselves.

Currently, there are no effective fungicides on the United States market. Past research verifies international results that Folicur® (tebuconazole) can be a very effective fungicide for control of white rot. Folicur is not a new product on the United States market for other crops, and it may yet become labeled for garlic based on past data gathered. However, there are many new fungicides now on the domestic market that have not been evaluated for control of Allium white rot. This trial was conducted to evaluate these new products, including Folicur as a comparison. Scholar® (fludioxonil) also was included, as it has provided some control of garlic white rot in the past, although erratically so; its performance is consistent with late-season degradation in soil. In this trial, Rovral® (Iprodione) was included because it is registered for use against white rot, but all recent experience demonstrates that this product now is ineffective, presumably from its too-rapid biological degradation in soil.

Past experience also indicates that very high populations of *S. cepivorum* may not be controlled even with an effective fungicide. This trial was conducted against a background of a uniform, moderate soil population of sclerotia.

Materials and Methods

The field was an artificially infested area on the Central Oregon Agricultural Research Center (COARC) farm. Because of white rot intensification in central Oregon during 1989-2004, both local growers and contracting seed companies agreed that infestation of the research center did not substantially increase the risk of further intensification because so many other local sources of inoculum now are present. Locating research on the experimental farm enhances research flexibility and reliability, in contrast to locating such trials in growers' infested fields.

The area to be used for the trial was infested with sclerotia grown in the laboratory on sterilized barley during 2004. In August 2004, the area was over-seeded with approximately five sclerotia/l of soil, prefertilized, then tilled 15 cm (6 inches) deep and irrigated. The area was bedded for garlic in September and planted on October 7, 2005. Based on past research and experience, the expected amount of white rot in untreated plots was about 75 percent bulb infection by harvest. In years with mild winters, this expectation may be low due to prolonged fungal activity.

Two lots of garlic seed were obtained from ConAgra: California Early (CA Early) and California Late (CA Late), both virus free, both with large-sized seed, although initially one lot was planned to be used. ConAgra also lent its two-row planter, which was returned steam cleaned and free of all dirt and debris following planting. The planter was not adjusted perfectly at the beginning, such that the CA Late seed was planted rather thickly (40 cloves/bed-ft). We decided to continue with this planting density in hopes that the entire trial would at least be planted uniformly. However, we ran out of seed too soon, and only two of four trial replications were planted with CA Late. Thus, the two additional replications were planted using the CA Early variety (30 cloves/bed-ft), still at a high rate of seeding. Typical planting rate for both varieties would be 18 cloves/bed-ft. Both varieties are equally susceptible to white rot, so there was no expected varietal difference in the data. However, white rot does spread faster from plant to plant on more dense plantings, and there could have been a more abundant root system with thicker planting, allowing white rot to establish sooner. If plant spacing is too close, the white rot fungus might even spread from neck to neck or bulb to bulb, although it cannot grow through soil more than about 1 inch from an active infection on living Allium tissue. Further, the denser planting may have led to higher water usage, greater fertility usage, etc., perhaps leading to enhanced plant stresses noted below in the CA Late half of the trial compared to the CA Early half of the trial. Effects from this are discussed more in the Results and Discussion sessions, and some data were adjusted so that numbers were comparable among plots for the purposes of analyses.

Fungicides were sprayed into each 4-inch-wide planting furrow after it was opened and before it was closed, and the spray was directed onto the garlic cloves as they dropped from the planter. Nozzles were mounted on the planter and oriented such that the bottom and sides of the planting furrow were sprayed, in addition to the seed. Fungicides were premixed an hour before treatment in 2-l bottles, one bottle per plot. At the beginning of the plot, bottles were shaken and attached, the sprayer was turned on, then the planter started forward, quickly achieved the appropriate speed and planted a plot, then stopped 30 ft later and the sprayer also was stopped. The bottle was removed and replaced with the appropriate bottle for the next plot. Products and rates were applied as per Table 1, using only 1 liter per bottle per 30 ft planted length of double rows, 36-inch beds, two seed lines per bed. Therefore, there were four seed lines treated per 30-ft plot. Plots were two beds by 30 ft long, but were trimmed in spring 2005 to 25 ft long, creating 5-ft alleys between plots. No nozzles were observed to have plugged, changed angle or otherwise demonstrated any problems during plot treatment. In addition to in-furrow spray applications, two variations were considered: (a) a solid-waste earthworm product (WG Mix) was applied by hand to the opened planting furrow, hand seeded and hand covered, and (b) Folicur was sprayed in a 4-inch band over each seeding line in very late May over either a Folicur in-furrow seeding application (Treatment 2, Table 1) or a Scholar in-furrow seeding application (Treatment 11, Table 1). The banded spray was applied immediately prior to a normal irrigation. In some world regions, such banded application of Folicur has proven beneficial when applied just before rain or irrigation.

The trial was organized as a randomized block design with four replications. The trial was irrigated once following planting in the fall of 2004, and irrigation was resumed in mid-April 2005. Other farming practices are not discussed, but the plots were managed as per local commercial fields.

Notes and data collected are discussed in the next section.

Results

The late May banded application of Folicur was applied too late. Too much white rot had occurred by then, and no additional control of white rot disease occurred with the banded treatment. Thus, results below exclude further discussion of these treatments.

Stand: Stand counts were determined on 1 May 2005. Typically, we show stand counts as the mean number of plants emerged in the spring. In May 2005, there was an average of 37 and 27 plants per 25 ft of plot (two-row plots, two seed lines per row) among all plots planted with either CA Late or CA Early, respectively. Recall that each variety was planted with a different number of cloves based on planter settings. Raw data for the average of two replications per variety are shown in Figure 1a, but no statistical analyses were performed on the raw data. In order to better compare treatment effects on stand, the stand for each variety was converted to a percentage of the maximum emergence in any plot for each variety. Percentage stand was then analyzed for the four replications, and the data are shown in Figure 1. Thus, Figure 1 shows mean *relative* stands among products used, but does not show absolute stand.

In some years, stand decline can be attributed to pre-emergence white rot, but there was not substantial stand decline noted for untreated plots in 2004-2005. The only statistically significant (5 percent) reduction in stand was noted for treatments that included WG Premium Mix, a product composed of earthworm castings. We noticed that the garlic in plots treated with WG Premium Mix, together with the garlic in plots treated with WG Solution (an earthworm castings solution) were greener during the spring of 2005, which suggested that these products may have contained some nitrogen. One possible explanation for decreased stand with WG Premium Mix was direct contact of the garlic seed with too much nitrogen, but other explanations may be more sensible.

***Growth and development of garlic*:** In spite of a wet spring, the summer was hot and garlic matured a few days earlier than normal. Last irrigation was about June 17. Plots were undercut on July 11. Garlic was hand lifted and remaining dirt removed by hand on July 14-15, bulbs were trimmed and graded into either harvestable diseased and harvestable non-infected classes on July 18-19, and the classes were counted and weighed on July 20. The CA Late garlic bulbs were very small and nearly every bulb grew a scape (perhaps a sign of stress, e.g., competition for water, nutrients, light, etc…), which could be somewhat normal for this clone. The scape was removed for harvest data. CA Late bulbs were very small in 2005, probably a result of a too-high planting density and adverse growing conditions in 2005 (wet spring, very hot summer). As a result, we did not discard small CA Early bulbs that might not have been harvested. This was not a concern with CA Early, as very few bulbs were small with this variety. There were many bulbs with white rot that were too decayed for harvest. No botrytis or other diseases or pests were observed in the trial area, so all decayed plants and plants missing subsequent to spring stand emergence were classified as decayed by *S. cepivorum*.

In 2005 there were some plots that simply did not perform well. For example, white rot was very severe in one out of four replications of the Folicur treatment, whereas control was quite good in the other three replications. A similar phenomenon occurred with other products, but not consistently in the same replication. We tried to account for such diverse performance by reviewing our treatment and spray mix methodology, soil infestation methodology, and our plot plan and data recordkeeping, but failed to find an explanation for these results. As such disparity among replications for product has never been observed in other years in uniformly infested trials, we believe there are errors in our data even though we cannot account for them. As the objective is to identify products with promise for control of white rot, we decided to exclude from statistical analysis the data for replications showing product failure where two or more replications showed very good performance. Therefore, we will retain for future testing products with high potential, rather than exclude products for possible poor potential.

As discussed above, the planting rate was different for two replications planted with CA Late versus the two replications planted with CA Early; thus the actual bulbs and weight do not average meaningfully well for the four replications. Raw data showing the average of two replications for each bulb classification (noninfected, infected) for both CA Late and CA Early appear in Figure 2a, with some missing data and no statistical analysis. The data from Figure 2a are very difficult to make sense of because of the differences in plant populations between the two varieties. Figure 2b shows these data converted to percentages to correct for varietal differences, and with statistical analysis shown for total bulbs only. Total harvestable bulbs are divided on each bar into noninfected and infected classes. It should be emphasized that Figure 2b best shows the *relative* ratings among products to control white rot, even though the conversion to percentages obscures how these products did in an absolute sense. Even Folicur, which is our best known product to compare other products against, did not control white rot as well in 2005 as in earlier years. For example, in other years, Folicur at the rate and method used in 2005 allowed for only 1-3 percent bulb infection and very little loss in yield weights. In 2005, Folicur performance was fair, but in plots treated with Folicur, there was substantial bulb rot along with bulb infection present at harvest.

Figure 3a shows actual harvest weights by variety and harvest class, with each bar representing the average of two replications, but no statistical analysis and with some missing plots. Figure 3b shows these data converted to percentages to correct for varietal differences in stand, and with statistical analysis shown for total weights only. Total harvestable weights are divided on each bar into noninfected and infected classes. Figure 3b best shows the *relative* ratings among products.

Relative performance among fungicides is best seen in Figures 2b and 3b. Compared to Folicur, JAU 6476, KIF-3535, Switch, Elevate, Endura, and Pristine performed reasonably well. Scala seemingly performed as well as this group, but more missing plots were present, making this comparison difficult. Comparisons with Scholar are difficult, too, both from more missing plots and more general disease, even though Scholar has been a high performer in many other field trials. Interestingly, USF 2004 did not perform well alone, but the combination of Folicur + USF 2004 was the superior treatment in this trial. Omega and CaptEvate did not perform as well as other fungicides.

WG products were difficult to compare directly with the fungicides. WG Solution did not reduce stand but white rot control was less than for the promising fungicides and greater than no treatment. WG Premium Mix lowered stand substantially (Fig. 1) and white rot control again was minimal.

In summary, 2005 was considered a severe year for white rot and a severe challenge for all products, but relative rankings among products probably are good enough to make decisions about which products merit further testing. Relative performance data were considered sufficient for selecting which products to retest.

Discussion

While disease distribution was relatively uniformly distributed as planned, white rot disease incidence was more severe in 2005 than anticipated based on past research and observations on inoculum density versus disease loss relationships. Several possible conditions may have been involved in greater severity. First, the winter of 2004-2005 was mild, allowing *S. cepivorum* activity for a longer period in late fall and early spring than normal. Second, in the two replications planted with CA Late variety, high planting density and root density may have allowed *S. cepivorum* to move more quickly from plant to plant. Limited observations of excavated disease activity seemed to confirm this possibility that neck-to-neck spread may have occurred (see next item). Third, garlic in central Oregon seed fields has been planted 3 inches deep rather than 1.5 inches deep, to better withstand winter/spring cold damage. As a result, there are several inches of garlic neck below the soil, more than in the past. Since planting depth has increased, we have noticed a higher incidence of direct neck infections by *S. cepivorum* in the zone between the bulb and soil line, suggesting that our traditional in-furrow spray is not protecting this area very well. Typically, such neck infections are very limited at low inoculum density, as there are few sclerotia distributed close to the neck. However, as inoculum density increases, there are an increasing number of sclerotia located near the neck and such neck infection becomes more prominent. Based on field and test plot observations, we estimate that the critical inoculum density where such neck infections become very noticeable (which is not a well defined total proportion of diseased plants, but a high proportion of plants showing very early top symptoms) may be around the 4-5 sclerotia/l soil range, which is what we use for uniform infestation in our plots. It may be that in future we need to consider adjusting in-furrow sprays to better treat this upper soil layer. The lesser control achieved in 2004-2005 for treatments highly effective in previous years is not attributed to fungal resistance or rapid microbial breakdown in soil, although no data were gathered to verify this assumption.

In spite of the problems encountered in the 2004-2005 trial and data analysis, we believe the data are sufficient to determine which products deserve continued investigation and which do not.

Folicur is believed to move at least a little distance in soil with water. Band applications to the base of garlic plants are used in Mexico late in the season and give some partial control of late season white rot disease. Onions that were band sprayed in New Zealand achieved good control through application to young onions when conditions were conducive for *S. cepivorum* to grow into the bulbs, although the distance moved for seed onions is shallower than for more deeply placed garlic. Interestingly, there have been control failures in recent years with this method in New Zealand; although the reasons for failure are not clear, there is some concern that product formulation has changed, making Folicur less mobile in soil.

We have had difficulty using post-emergence band spraying of Folicur as an effective tool for control of white rot on either over wintered seed onions or garlic in arid central Oregon. For seed onions, we cannot easily apply Folicur with true seeding because of phytotoxicity to seedlings. We would like to apply as late in the fall as possible but before we lose irrigation water (typically around October 10) so that we can move the product downward. For garlic, we cannot reliably apply in spring until after mid-April when irrigation water becomes available. In several trials with both onions and garlic in central Oregon, we have either damaged young onions in fall, or failed to get Folicur on early enough in spring to control white rot, especially if the winter was mild and white rot is active early. In 2005, we might have applied earlier than we did and with good effects, but we were late in our application. We may again try to time spring-banded Folicur sprays of garlic in future.

Table 1. Product, manufacturer, and application information for 2004-2005 Garlic White Rot Trial, Madras Oregon.

Product	Manufacturer	% active ingredient	Appl. method	Product/1,000 linear bed ft
1. Folicur 3.6F	Bayer	430 g/l tebuconazole	In furrow	13.8 ml
2. Folicur 3.6F	Bayer	430 g/l tebuconazole	In furrow	13.8 ml
+ in-season Folicur drench		430 g/l tebuconazole	Banded at plant base	6.9 ml
3. USF 2004 500 SC	Bayer	43.47%	In furrow	4.8 ml
4. Folicur 3.6F	Bayer	430g/l tebuconazole	In furrow	3.1 ml
+ USF 2004 500 SC	Bayer	43.47%	In furrow	3.1 ml
5. JAU 6476 480SC	Bayer	41.1%	In furrow	5.8 ml
6. Scala 600SC	Bayer	64.6 % pyrimethanil	In furrow	18.3 ml
7. KIF-3535 40%SC	KI Chem	40% mepanipyrim	In furrow	18.1 ml
8. Omega 500F	Syngenta	500 g/l fluazinam (= 40%)	In furrow	8.3 ml
9. Switch 62.5G	Syngenta	37.5% cyprodanil+25% fludioxonil	In furrow	14.0 g
10. Scholar 25GR (50%a.i.)	Syngenta	50% fludioxonil	In furrow	7.8 g
11. Scholar 25GR (50%a.i.)	Syngenta	50% fludioxonil	In furrow	7.8 g
+ in-season Folicur drench		430 g/l tebuconazole	Banded at plant base	6.9 ml
12. Elevate 50WDG	Arvesta	50% fenhexamide	In furrow	23.5 g
13. TM-45002 (CaptEvate)	Arvesta	54% Captan + 14% fenhexamide	In furrow	82.1 g
14. BAS510 04F (Endura)	BASF	70% boscalid	In furrow	10.0 ml
15. BAS516 04F (Pristine)	BASF	12.8 pyraclostrobin+25.2 % boscalid	In furrow	22.0 g
16. WG Solution	CA Vermiculture	earthworm casting solution	In furrow	full strength
17. WG Premium Mix	CA Vermiculture	earthworm castings	In furrow[a]	125 gal
18. WG Solution	CA Vermiculture	earthworm casting solution	In furrow[a]	full strength
+ WG Premium Mix	CA Vermiculture	earthworm castings	In furrow[a]	125 gal
19. Rovral 50WP	Rhone Poulenc	50% iprodione	In furrow[b]	67.0 g
20. Untreated check	--			

[a]For Treatments 17 and 18, beds were hand planted after dispensing worm castings into furrow by hand, and spraying WG Solution by backpack for Treatment 18.
[b]Rovral now is marketed by Bayer in either 74W or 4F formulations.

Figure 1. Stand counts
, 2004-2005 Garlic White Rot Trial, Madras Oregon.

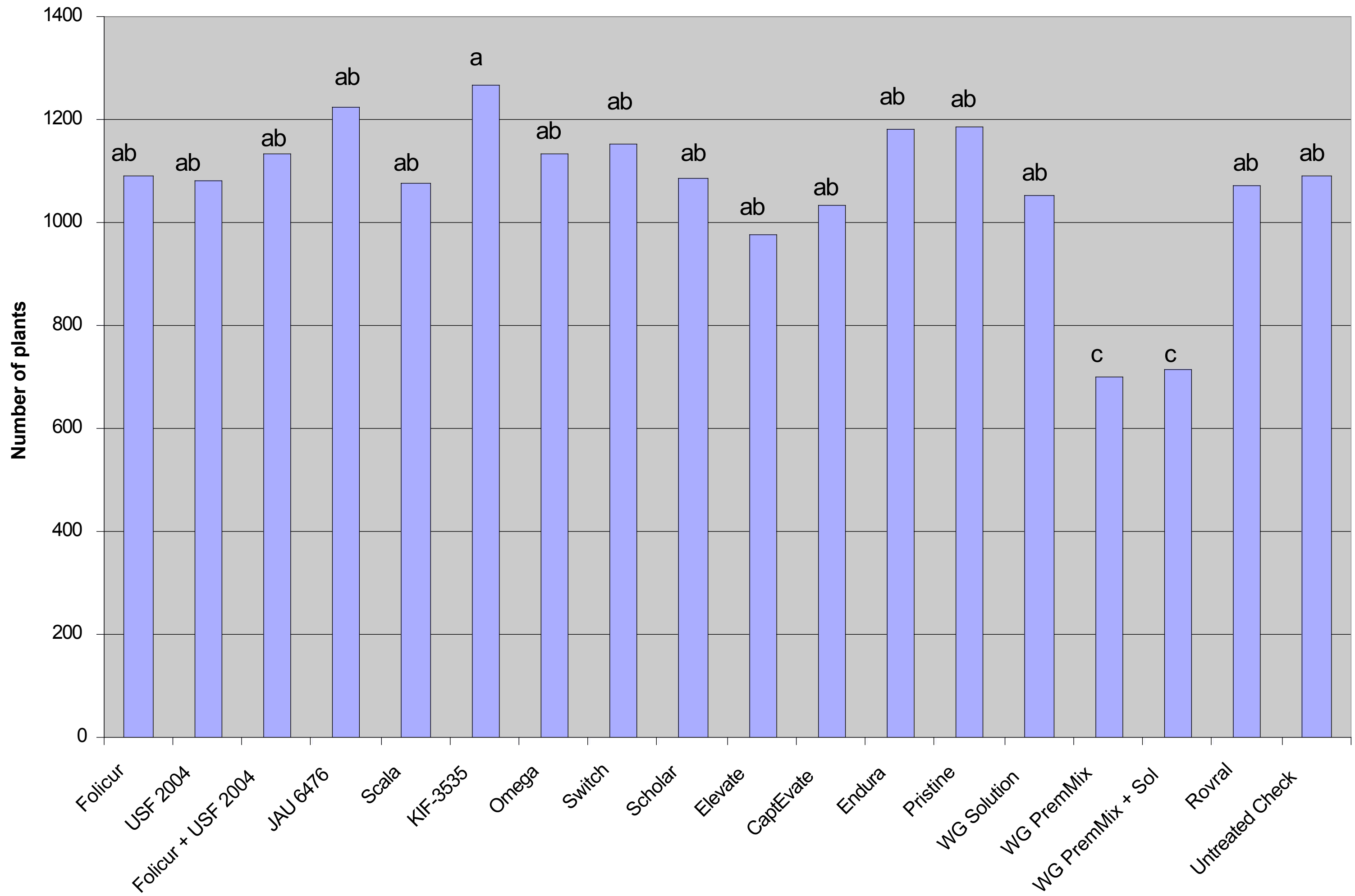

Figure 2a. Harvested bulb counts, 2004-2005 Garlic White Rot Trial, Madras Oregon.

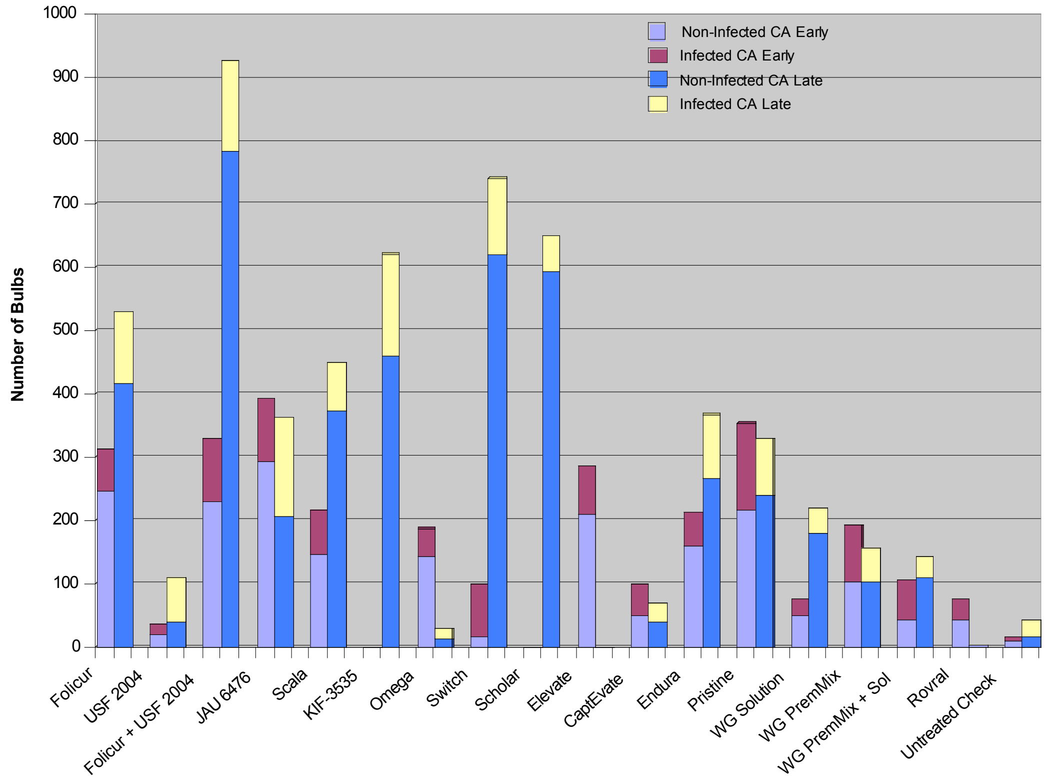

Figure. 2b. Harvested bulb counts converted to percentages of total to correct for varietal differences in stand.

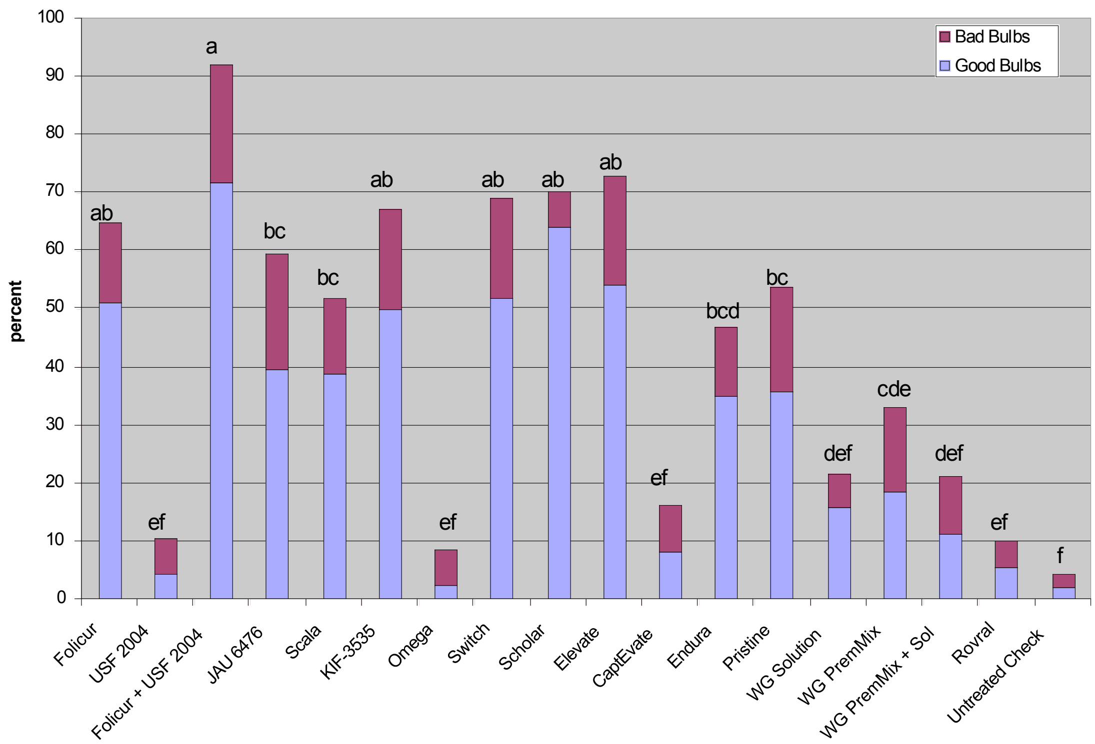

Figure 3a. Harvested bulb weights, 2004-2005 Garlic White Rot Trial, Madras Oregon.

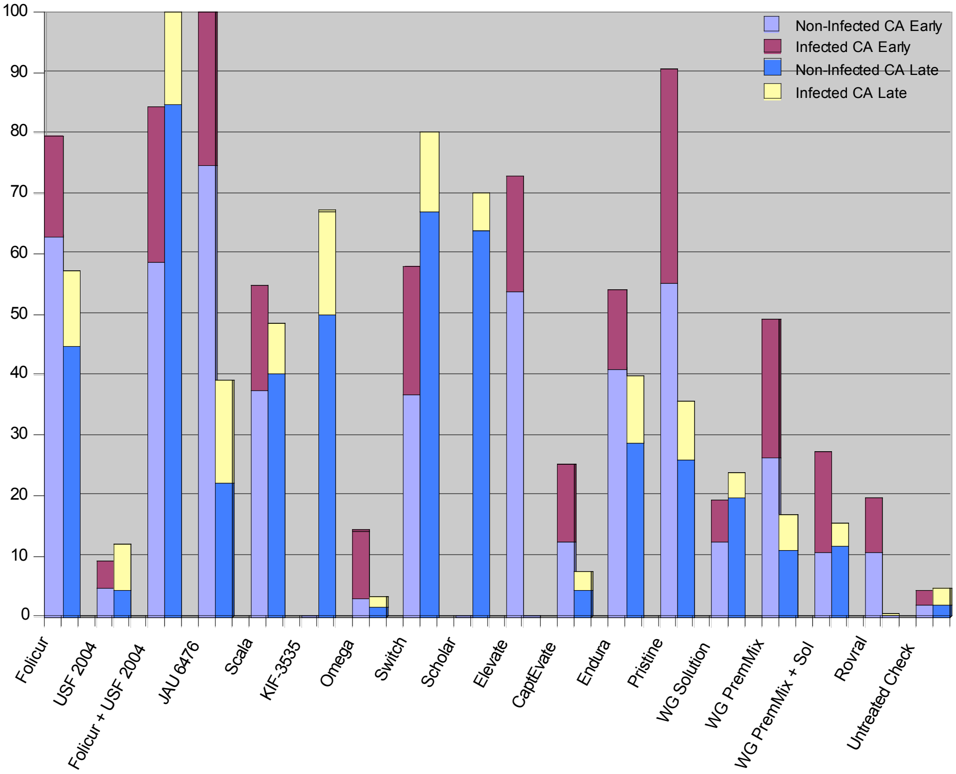

Figure 3b. Harvested bulb weights converted to percentages of total to correct for varietal differences in stand.