TESTING FUNGICIDE AND BIOLOGICAL PRODUCTS FOR CONTROL OF GARLIC AND ONION WHITE ROT DISEASE, 2000-2001

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Summary

In 2000-2001, a main garlic trial and a smaller border trial were planted and harvested near Madras, Oregon. Only seed treatments were included in the garlic trials in 2000-2001. In retrospect, in-furrow treatments should have been included, as these may be favored over seed treatments. In the 2000 onion trial (previously reported), post-planting seasonal drenches with Folicur® (immediately followed by irrigation) were effective in white rot control, but we did not have the onion efficacy data at the time garlic was planted, so no drenches were included in the fall 2000 garlic planting.

We suspect that product efficacy reported below was slightly less than it might have been, because aggressive seed treatment in rotating drums dislodged many of the wettable clove sheaths, leaving less product on the waxy clove surface (although stem plates were well-treated). Seed treatment may need to be gentler than conducted here.

In 2000-2001, artificial infestation with the white rot fungus was between 4 and 5 sclerotia/liter of soil, which was estimated to be enough to result in about 70-85 percent bulb infection by harvest. Due to a mild winter and longer disease activity, bulb infection averaged about 98 percent. All plant losses were attributable to white rot disease. The untreated check in the main trial yielded 1,016 lb/acre of fresh garlic bulbs ≥1 inch in diameter, only 2 percent of the original stand was harvested as symptomless bulbs, and 3.4 percent of the original stand was intact but infected. Thus, only 3.6 percent of the original stand was harvestable bulbs. In the main trial, Folicur at 0.89oz product/100 lb seed cloves was the superior treatment with respect to yield (88 percent symptomless bulbs, 92 percent harvested bulbs, 19,239 lb/acre yield). This was followed closely by the next highest rate of Folicur at 1.78 oz product/100 lb seed (83 percent symptomless bulbs, 87 percent harvested bulbs, and 18,204 lb/acre yield). Dividend®, when applied at rates of the active ingredient difenconazole similar to that of the rate of active ingredient tebuconazole in Folicur, allowed more disease to develop than Folicur, with correspondingly lower yield. The highest rate of Maxim® (0.32 oz product/100 lb seed) performed similarly to Dividend. Nevertheless, fludioxonil (either as the seed treatment Maxim or as an in-furrow spray as Scholar®) remains of high interest as a fungicide that has proven to be effective most of the season, that is likely to be easy to register for this disease, and that may allow lower rates of triazoles to be used (Folicur, Dividend). Dividend combined with Maxim did not perform as well as expected in 2000-2001. The Folicur (0.89 oz/100 lb seed) + Maxim (0.16 oz product/100 lb seed) combination was the superior treatment of all (89 percent symptomless bulbs, 95 percent harvested bulbs, 21,530 lb/acre yield. The 2001-2002 garlic planting, to be reported next year, includes in-furrow, drenches and seed treatments, and various combinations of products.

We remain convinced that Folicur (tebuconazole) moves a short distance in the soil to provide control up to perhaps a few inches away from the treated cloves. This is partly based on observations of root systems at harvest, and partly by the fact that post-plant

drenches were effective in the 2000 onion trial. Because of such limited soil movement, it may matter less about how one applies Folicur for white rot control of garlic, as long as sufficient material is applied and it is retained in the upper root zone and near the bulbs. Post-planting drenches may be critical on onions, because high rates of Folicur are phytotoxic to onion seedlings (although dispersing Folicur by coating it onto granular materials at planting, or a revised in-furrow type of treatment may be effective). Our 2001-2001 onion planting has a number of treatment combinations and methods.

Introduction

The entire soil population of sclerotia of *Sclerotium cepivorum* germinates in response to root leakage of germination stimulants. Root infections progress upward on root systems, spreading along the planted row via root contact. Infected plants rapidly die once the fungus reaches the stem plate, a result of both extensive root death and bulb decay. A few bulbs very lightly infected near to harvest may pass into fresh onion or garlic markets or may be passed along through garlic seed lots. A few intact but infected bulbs on which the disease has advanced somewhat further may or may not be retained for processing depending on the degree of rot and the harvesting process. Fungicidal control of white rot is difficult, requiring season-long protection in parts of the world where soil temperatures are conducive to prolonged fungal activity. Due to a lack of available controls and the abundant proliferation of the fungus, fields are commonly abandoned following one or a very few Allium crops infected with white rot.

Prior to 1970, a few very persistent fungicides (e.g. mercury compounds and PCNB) provided partial control of white rot. Since the late 1970's and previous to 1998-1999, few or no fungicides were screened against Allium white rot in the United States, on either onions or garlic. Products still labeled in the U.S. include Terrachlor® (Uniroyal Chem.; a.i. PCNB; for garlic only as a banded spray at planting); Rovral® (Rhone-Poulenc; a.i. iprodione; for garlic only as an in-furrow spray at planting), and Botran® (Gowan Co.; a.i. DCNA; eastern Oregon and Washington, western Idaho only; for onions, banded pre-seeding; for garlic in-furrow spray at planting). None of these fungicides currently are being used on full-season Allium crops for white rot because of insufficient or inconsistent control. Benlate® (DuPont; a.i. benomyl) is labeled as a garlic seed treatment for control of *penicillium* seed piece decay, and provides partial control of white rot for a limited duration, but is ineffective for season-long control. In other countries, Sumislex® (a.i. procymidone) has provided fair-to-good control of white rot, depending on the disease pressure. More recently, Folicur (Bayer; a.i. tebuconazole) has provided fair-to-excellent control in Mexico, Australia, and New Zealand, depending on disease pressure and rate and method of application. The work reported here was initiated as a result of reported successes in those countries.

An additional incentive to test Folicur was that this product proved effective against garlic rust in California, and an emergency label was granted for this use in 1998. Having a rust tolerance for Folicur should expedite labeling of Folicur for white rot, even though the methods and rates of application might differ. Another fungicide, Quadris®, had full label usage for garlic rust, but this product did not prove highly effective in our earlier white rot studies.

Fumigants have been used to lower soil populations of white rot and reduce the risk of disease spread, but have not provided sufficient control. This includes even methyl bromide, which may lower sclerotial populations by 98-99%. More recently, germination stimulants have achieved 98-99% population reduction when used at appropriate rates and methods of application. Such stimulants may be registered soon in the U.S. (United Agri Products, a.i. diallyl disulfide), and research-in-progress has shown that comparable population reduction of sclerotial populations may be achieved with commercially available dehydrated garlic powder as the source of germination stimulants– and likely at similar cost to the United Agri Products product that is derived from petroleum. Use of stimulants is of interest because of their relatively high efficacy and low cost compared to methyl bromide. As indicated above, fungicides provide less control of white rot when sclerotial populations of the white rot fungus are high. A recent concept has been to pretreat fields with germination stimulants in years prior to planting of Alliums, and then apply the more effective fungicides such as Folicur. Our trials in 1999-2000 tested the efficacy of fungicides against a high and low population of *S. cepivorum* to evaluate this concept.

In addition to direct economic control of white rot with fungicides on a specific crop, sclerotial population reduction is a goal of fungicide use. Temporary control can be misleading and sustained control elusive: if even a few Allium plants are allowed to develop white rot, which might be economically acceptable in the short term, the sclerotial population may increase, making future control more difficult. On the other hand, season-long control might lead to near-eradication if Alliums are repeatedly protected with a superior fungicide. Thus, full product evaluation must be based not only on control achieved, but also on the increase or decrease on the resultant sclerotial population.

This report addresses the third trial year. In 1998-1999, Folicur and Dividend performed well, but the garlic stand was reduced by an untimely winter freeze. In 1999-2000 we again tested fungicides, this time in two adjacent trials against both a moderately low and a moderately high soil population of *S. cepivorum*. This report is for our third year, 2000-2001, in a moderately infested soil. Our long-term goal was to identify and refine those treatments that provide full control of white rot under low to moderate infestations of *S. cepivorum*, and possibly under high infestation.

In addition, we tested fungicides at Madras, Oregon in 2000 on spring-seeded, fall-harvested onions against a moderate soil population of *S. cepivorum*. The onion trial was considered preliminary for testing methods of Folicur and Dividend application that might circumvent seedling sensitivity to these fungicides but still provide adequate disease control. These approaches included distributing fungicides more widely around the seed by coating them on granular materials planted with the seed, and spraying fungicides believed to be somewhat mobile in water directly over the seedbed prior to irrigation. The former idea was adapted from the Folicur label for onions in Tasmania, and the later idea was suggested by Mary Ruth McDonald with the University of Guelph, Ontario, based on preliminary data in Canada. Results were highly encouraging for both alternative treatment methods, but data were not available by the time the fall 2000 garlic trial was planted, so no such treatments were included. (They are included in the onion trial planted in the summer of 2001 and the garlic trial planted in the fall of 2001.)

Methods

The field was naturally infested only at trace levels that contributed very little to the disease levels experienced. The trial area was uniformly infested as in previous years with very heavily concentrated sclerotia in soil collected from the base of white rotted onion plants in a nearby field. This added inoculum was tilled to 15 cm (6 in), and upon soil assay the inoculum density was about four sclerotia/liter of soil. Based on previous experience, it was expected that 70-85 percent bulb infection or plant death would occur in untreated plots of the low infestation area. Each plot consisted of two, 30-ft bed sections. All treatments were randomized within four blocks. Two trials were created; one border trial included beds adjacent to a road on one side and a grass seed field on the other side. The main trial included rows separated from any edge effects next to the road and grass seed field, bordered only by garlic.

Fungicide products were applied onto seed by rotating seed in a rotary mixer and spraying concentrated product through an atomizer as the seed tumbled. Little product was retained by the sides of the mixer, although this was cleaned between each treatment. We became concerned that using a rotating drum for seed treatment dislodged many clove sheaths. Aqueous seed treatments seemed to wet and attach to these covering leaves better than to the waxy clove surface itself. Thus, some cloves may not have had as much product attached as desired, and a gentler seed treatment system is desired. However, substantial product did attach to the stem plate, which is the most important location for fungicide to adhere, so all cloves received product on stem plates.

In the border trial, a seed dip treatment was included by immersing a seed bag in given concentration of product, then allowing the bag to drain for several minutes, then leaving the bag to dry for several days.

The area was tilled, fertilized with 400 lb/acre 16-16-16 and pre-bedded. Beds were shaped and in the first few days of October were planted at 2.5-3 in deep with a planter provided by Basic Vegetable Products. Virus-free ‘California Early’ garlic cloves, cracked but not hot-water treated, commercially sized (a medium-sized seed lot was used, approx. 2,300 lb/acre) and planted 18 cloves per bed ft on 36-in centers. This is the first trial in which we have not hand planted because we were concerned that hand planting (about 1.5-2 in deep) was a risk for winter freezing injury. Because of machine planting, however, clove size and spacing were less uniform, and stand counts were probably more erratic. To compensate, we made the plots somewhat larger than in past trials.

The garlic crop was grown as per commercial standards for central Oregon, and no special problems were encountered. Rovral was sprayed twice in the spring of 2001 to keep botrytis from complicating white rot disease ratings. Plots were hand weeded in addition to the use of commercial herbicides. Water was cut at the end of June and the garlic undercut and hand lifted after foliage was mostly dried down. Soil was removed from the roots, by harvest, for bulbs which were not rotted or on which rot had not progressed enough to prevent machine harvest, most roots had been pruned by the white rot fungus to within a few inches below the stem plate with Folicur and some Dividend treatments, or near to the stem plate with Maxim and no treatment. Bulbs were rated as symptomless or infected, and machine harvestable or not by the judgement of the Principal Investigator, and only bulbs greater than 1 inch (2.5 cm) in diameter were retained as harvestable. After full drydown of tops, harvestable bulbs were weighed and counted.

Results

Garlic was well-rooted during the late fall of 2000, but no top growth developed until mid-February through mid-March 2000. The winter of 2000-2001 was mild.

Stand

Emergence was determined on March 12, 2001. Apparent differences in stand (Tables 1 and 2) were difficult to trust, given that the trial was machine planted. The specific treatments in which the garlic appeared to stand the best don't seem to follow a logical pattern and are discounted here.

White Rot Progress

White rot progress was rated periodically during the season. Nearly all plant loss following emergence was attributed to white rot. No plants infected with botrytis were found. White rot symptoms were observed on a few plants by the end of March. Irrigation began in mid-April. White rot was present early, probably a result of prolonged activity during the relatively mild winter. By May, white rot symptoms were noticeable in untreated plots. During May, white rot symptoms appeared in plots of all treatments in which yields were low at harvest. A plot tour was held in late June, immediately prior to water cutoff on about July 1. At that time a little white rot appeared in even the best plots. Essentially all postemergence plant loss was attributable to white rot, and some white rot appeared in all treatments.

Treatment Comparisons at Harvest

Main Trial

Means are shown in Table 1 and Figure 1. The untreated check plots yielded a mean of only 2.0 percent symptomless bulbs, 3.7 percent harvestable bulbs, and 1,016-lb bulbs/acre. For Folicur at 0.89 oz product/100 lb seed, a mean of 87.9 percent symptomless bulbs, 91.9 percent harvestable bulbs, and 19,239 lb bulbs/acre exceeded the results of the higher rate of Folicur (82.9 percent symptomless, 86.6 percent harvestable, 18,204 lb/acre), but these means were not statistically separable at 5 percent. Both treatments manifested less white rot than other treatments. Dividend and Maxim treatments were of variable success, depending on rate and combination.

Border Trial

Means are shown in Table 2 and Figure 1. White rot control and yield for the combination of Folicur (0.89 oz product/100 lb seed) + Maxim (0.16 oz product/100 lb seed) were excellent, with a mean of 89.1 percent symptomless bulbs, 95.1 percent harvestable bulbs, and 21,530 lb bulbs/acre. This exceeded the results of the Folicur dip treatment, and exceeded the performance of any treatments in the main trial, although treatments between trials cannot be compared directly. In retrospect, the dip treatment (0.67 oz Folicur/100 lb seed) was probably too low a rate for optimum seed treatment, even though more clove sheaths were retained by this method.

Discussion

Even though the products used prevented much bulb infection, we continue to be impressed with how little of the root system remained by harvest, even with the best treatments. In such uniformly infested trials, the disease pressure is high and products are severely challenged. To prevent the white rot fungus from reaching the bulb is an achievement, especially for a product such as fludioxonil (Maxim, Scholar) that does not move in soil. At least a few inches of root remains with Folicur, evidence of some downward movement in soil, even though this is only a few inches.

The superior treatment used in both trials was Folicur 3.6F applied to seed at 0.25 g a.i./kg seed (0.89 oz Folicur/100 lb seed), as in previous years. In the past, higher rates of Folicur seed treatment may have resulted in decreased bulb infection but also in reduced stand, numbers of harvestable bulbs, and harvest weight, although these differences were not significant statistically and were even less in 2000-2001. Perhaps garlic, like onions, may be sensitive to Folicur. In Tasmania, Jason Dennis (personal communication, Fieldfresh) indicated that in every white rot trial where Folicur was included, onion stands were reduced. Onion roots and foliage may be adversely affected, but Folicur nevertheless provided the best control of all products tested.

Dividend did not perform as well as Folicur, even though we increased the rates of application for Dividend in 2000-2001. The active ingredients in Folicur (tebuconazole) and Dividend (difenconazole) are related but not identical triazole compounds. In the past, Novartis (now Syngenta) was reluctant to use higher rates, so we weren't sure whether Dividend had the same potential as Folicur at equivalent rates of active ingredient. Because Dividend will only be available as a seed treatment, we chose not to use this product in our 2001-2002 garlic trial.

Maxim 4FS applied as a seed treatment, especially at 0.16 oz/100 lb seed, provided impressive white rot control, especially considering that the active ingredient, fludioxonil, is not mobile in soil. However, white rot control was not quite as good as in 1999-2000. Reduced efficacy could have been due to lack of retention on clove sheaths. As before, Maxim control did not persist through to the end of the season. While perhaps insufficient by itself, Maxim (or Scholar) might greatly extend the level of control when combined with an appropriate rate of Folicur. In fact, in the border trial, the Folicur + Maxim combination was the superior treatment, and outperformed any treatment in the main trial.

Whereas the 2000-2001 results reported here support results from earlier years, the level of white rot was high and led to more disease than preferred even in the best treatments. Somewhat better control was acheived with Folicur alone and Maxim alone in 1999-2000. Even if a few bulbs are rotted, this can lead to increasing soil populations of sclerotia, and lowered control in the future. We suspect the lesser control achieved here may have been due to either reduced material on the seed pieces because of the aggressive handling during treatment, or the more intense disease pressure during a mild winter, or both.

We continue to worry that seed-treatment application based on garlic seed weight might result in high variability in actual applied material per plant and per unit area: garlic seeds (cloves) commonly are sized before planting to create more uniform growth in the crop. Seed lot sizes may vary from less than 1,500 lbs/acre (very small seed) to over 3,500 lbs/acre (very large seed) to achieve the same plant population. Our estimates suggest nearly a 2.5-fold difference in product applied per plant for cloves at the extremes of this range, although most seed lots may fall within a narrower range, perhaps 2,200-2,800 lb/acre. Further discussions with pesticide manufacturers will be needed to resolve the question of the best way to apply the product. This concern could become moot, however, as seed companies have already expressed a preference for in-furrow treatments, which are looked at in greater detail in our 2001-2002 trial.

Most likely, if Folicur becomes the material of choice, it may be applied in several ways (seed, in-furrow, drench from above), as long as equivalent rates per unit volume of soil around the bulb are achieved.

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Table 1. Main trial data, fungicides for control of white rot (*Sclerotium cepivorum*), Madras Oregon, 2000-2001.

	Spring stand (Mar 12, 2001)	No. bulbs ≥1iInch in diameter per plot at harvest (Aug 15, 2001)			Yield (lbs/acre) of bulbs >1 inch in diameter at harvest (Aug 15, 2001)		
Treatments[1] oz/100 lb seed	Plants/60 bed ft (% of seeded[2])	Symptomless bulbs (% of stand)	White rot infected but intact (% of Stand)	Total (% of stand)	Symptomless bulbs	White rot infected but intact	Total
Folicur 0.89	762 (79.4) b	670.5 (87.9) a	29.5 (3.9) cd	700.0 (91.9) a	18,519 a	720 cd	19,239 a
Folicur 1.78	840 (87.5) ab	696.3 (82.9) a	31.0 (3.7) cd	727.3 (86.6) a	17,448 ab	756 cd	18,204 a
Dividend 3.0	856 (89.1) ab	422.5 (49.4) b	94.0 (11.0) ab	536.5 (62.6) ab	12,530 bc	2,347 ab	14,877 ab
Dividend 1.5	782 (81.5) b	371.5 (47.5) b	65.8 (8.4) abcd	437.3 (55.9) bc	9,734 cd	1,742 abcd	11,477 bc
Maxim 0.32	823 (85.7) ab	313.8 (38.1) bc	92.5 (11.2) ab	406.3 (49.3) bc	9,008 cde	2,414 ab	11,422 bc
Maxim 0.16 + Dividend 0.75	937 (97.6) a	314.8 (33.5) bc	81.3 (8.7) abc	396.0 (42.3) bc	8,942 cde	1,978 abc	10,920 bc
Maxim 0.16 + Dividend 3.0	829 (86.4) ab	290.8 (35.1) bcd	118.0 (14.2) a	408.8 (49.2) bc	7,399 cde	3,049 a	10,448 bc
Maxim 0.16 + Dividend 1.5	779 (81.1) b	249.0 (32.0) bcde	73.8 (9.5) abc	322.8 (41.4) cd	6,643 cde	1,972 abc	8,615 cd
Maxim 0.16	818 (85.2) ab	120.0 (14.7) cdef	43.5 (5.6) bcd	163.5 (20.0) de	4,435 ef	1,300 bcd	5,735 cd
Maxim 0.08	853 (88.8) ab	98.5 (11.5) def	85.0 (10.0) abc	183.5 (21.5) de	3,412 ef	2,323 ab	5,735 cd
Dividend 0.75	838 (87.3) ab	95.0 (11.4) ef	68.3 (8.2) abcd	163.3 (19.5) de	3,557 ef	1,863 abcd	5,421 cd
Untreated	821 (85.5) ab	17.0 (2.0) f	13.5 (1.6) d	30.5 (3.7) e	629 f	387 d	1,016 d

[1]Treatments ranked by order of total yield per acre. Products included Folicur 3.6F; Dividend 3FS, and Maxim 4FS. For seed treatments, cloves were tumbled while a highly concentrated solution of product and water was sprayed over the seed with an atomizer.
[2]Plots were machine planted with commercial seedlots (not sized), at approx. 18 cloves per bed foot.

Table 2. Border trial data, fungicides for control of white rot (*Sclerotium cepivorum*), Madras Oregon, 2000-2001.

	Spring stand (Mar 12, 2001)	No. bulbs $\geq$1 inch in diameter per plot at harvest (Aug 15, 2001)			Yield (lbs/acre) of bulbs >1 inch in diameter at harvest (Aug 15, 2001)		
Treatments[1]	Plants/60 bed ft (% of seeded[2])	Symptomless bulbs (% of stand)	White rot infected but intact (% of stand)	Total (% of stand)	Symptomless bulbs	White rot infected but intact	Total
Folicur + Maxim Seed Trt [0.89 oz + 0.16 oz per 100 lb seed]	874.3 (91.1)	778.7 (89.1) a	53.0 (6.1) ab	831.7 (95.1) a	20,643 a	968	21,530 a
Folicur Seed Dip (0.67 oz per 100 lb seed)[3]	892.0 (92.9)	534.0 (59.9) a	98.7 (11.1) a	632.7 (70.9) a	16,408 a	2,944	19,352 a
Untreated	933.0 (97.0)	101.3 (10.8) b	32.0 (3.4) b	133.3 (14.3) b	2,388 b	887	3,355 b

[1]Treatments ranked by order of total yield per acre. Products included Folicur 3.6F and Maxim 4FS. For seed treatments, cloves were tumbled while a highly concentrated solution of product and water was sprayed over the seed with an atomizer. For dip treatment, mesh seed bags were dipped into a solution of 2.5 oz Folicur per 4 gal water. Bags were allowed to drip over the suspension for 2-3 min or until draining had stopped. Seed in bags was air-dried for 4 days prior to planting. Rate of application was determined by subtraction, ignoring product retained by loose mesh bags.
[2]Plots were machine planted with commercial seedlots (not sized), at approx. 18 cloves per bed foot.

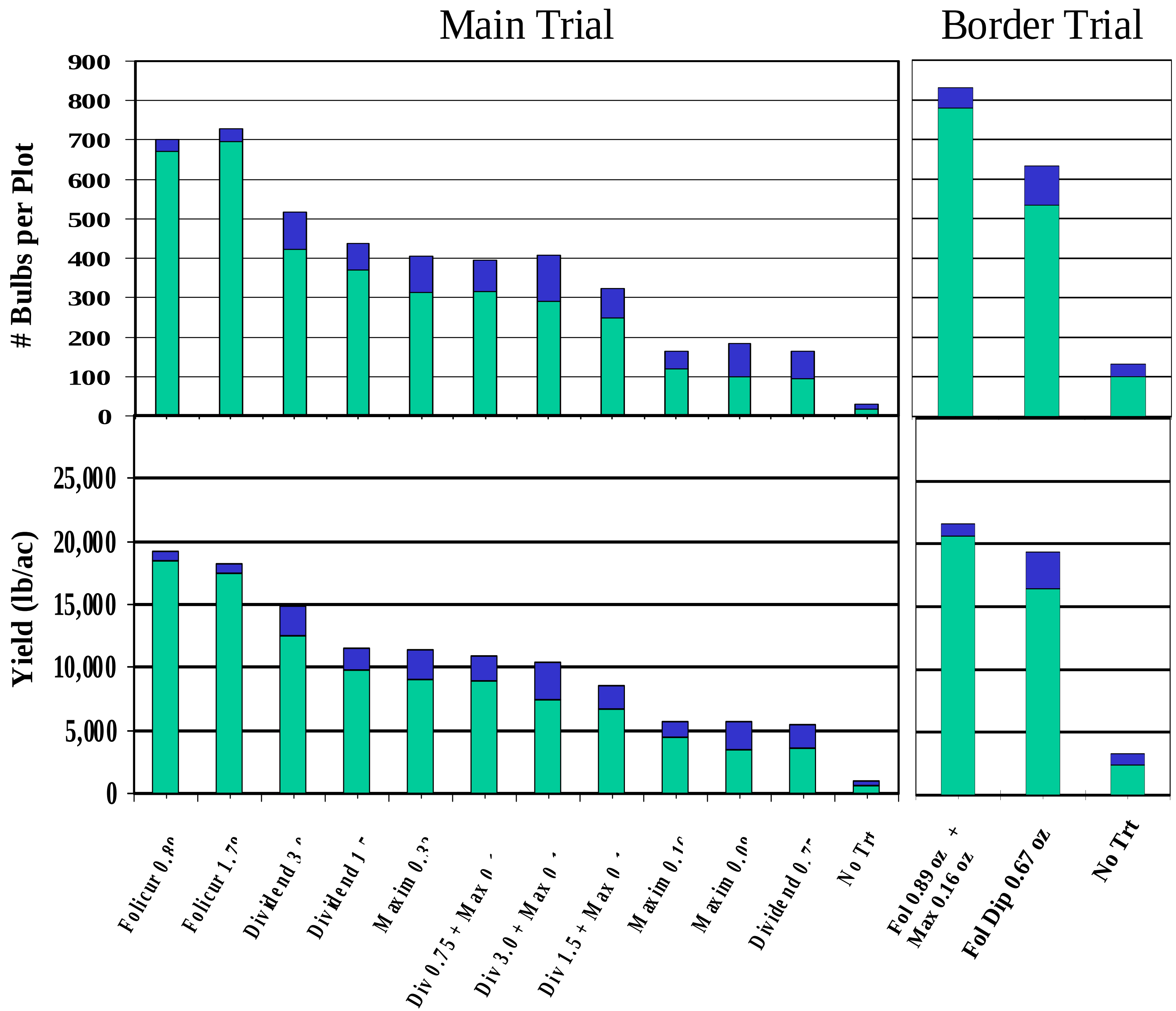

Figure 1. 2000 – 2001 Garlic White Rot Fungicide Trial