MANAGEMENT OF ROOT DISEASES OF STRAWBERRY

Frank N. Martin, USDA-ARS, 1636 East Alisal St., Salinas, CA 93905

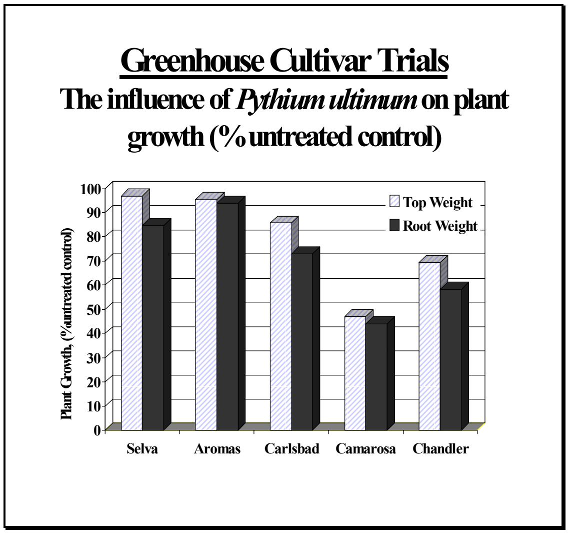
Essentially all of the approximately 25,000 acres planted to strawberry in the state of California are fumigated with methyl bromide + chloropicrin to control root diseases and weeds. Historically one of the primary reasons for soil fumigation was to reduce the incidence of Verticillium wilt, the most important lethal disease of strawberry. However, a number of other nonlethal soilborne fungal pathogens also can contribute to significant losses when strawberry is grown in nonfumigated fields. In one of the PI's field plots that did not have Verticillium wilt there was a 46% reduction in marketable yield in 1998 when the strawberry cultivar Selva was grown in nonfumigated soil; based on root isolations this yield decline was attributed to root rot caused by *Pythium,* binucleate *Rhizoctonia*, and *Cylindrocarpon* spp. Collectively these general, nonspecific pathogens cause a root disease commonly referred to as black root rot, a name that is descriptive of the appearance of the roots (reviewed in Wing et al., Advances in Strawberry Research 13:13-19). Depending on the production location, the lesion nematode *Pratylenchus penetrans* has also been associated with this disease complex (LaMonda, J. A. and Martin, S. B. 1989. Plant Dis. 73:107-110). Sample assays of test plots in Watsonville and Salinas did not reveal significant nematode levels in our research plots, so the research effort has focused on the fungal pathogens. Greenhouse trials have confirmed the involvement of the isolated fungal pathogens in the disease complex and their ability to stunt plant growth (described in more detail below; Martin, F.N. 2000. Phytopathology 90:345-353). In fact, in view of the high level of recovery of these pathogens from the roots the first 4-5 months after transplanting it is suspected that they contribute to the significant reductions in plant growth observed when strawberry is grown in nonfumigated soil. At both the Watsonville and Salinas test plot locations 10-15% reduction in shoot growth within 8 weeks of transplanting is often observed for plants grown in nonfumigated soil; the root systems of these plants also are less well developed and have necrotic lesions. This translates into a smaller, less thrifty plant in the early spring that is not able to support the fruiting level that is expected for plants in an economically viable production field. Attempts to control of these pathogens is being approached from several directions:

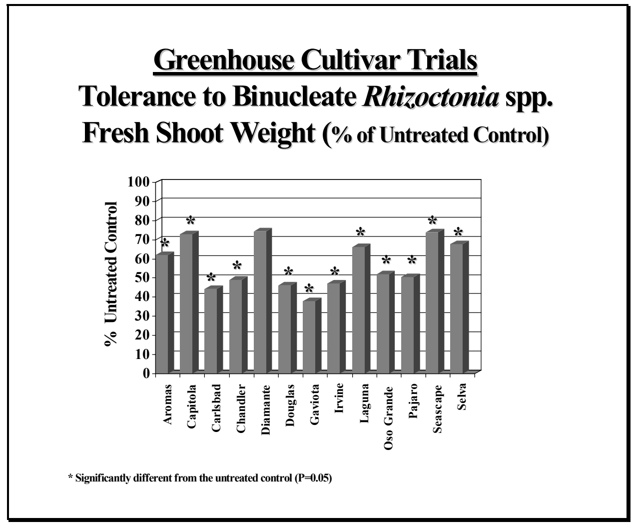
Host Tolerance

One approach for mitigating the loss of methyl bromide soil fumigation for disease control would be to plant strawberry cultivars that are tolerant to specific root pathogens. Screening programs are currently underway in other laboratories in California evaluating tolerance to Verticillium wilt and Phytophthora root and crown rot. These are two important diseases of strawberry that can cause significant crop losses by reducing yield as well as killing the plant. The efforts of the PI's research program have focused on determining the contribution of the individual pathogens associated with black root rot on the severity of the disease complex in the field as well as evaluating host germplasm for pathogen tolerance in the greenhouse and field.

Greenhouse trials

Greenhouse evaluations for tolerance to *Pythium ultimum* and different anastomosis groups (AGs) of binucleate *Rhizoctonia* (a mixture of isolates in AG-A, –G, and -I) revealed different levels of tolerance to these pathogens among the various cultivars. In evaluations with *P. ultimum* at 200 p/g soil, Selva, Aromas and Carlsbad exhibited lower levels of inhibition of root or shoot growth whereas Camarosa and Chandler exhibited significant reductions in shoot and root growth. Similar results also were observed for Seascape (tolerant), Torrey and Pajaro (susceptible; data not shown). The presence of binucleate *Rhizoctonia* caused significant reductions in shoot growth for all cultivars examined; similar results were observed for root weights as well (data not shown).

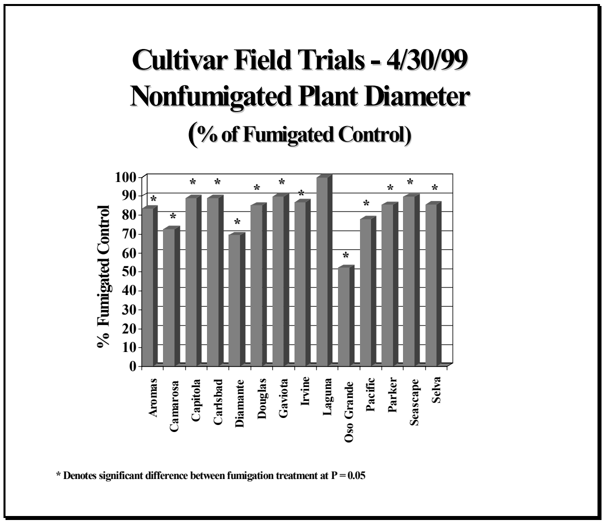


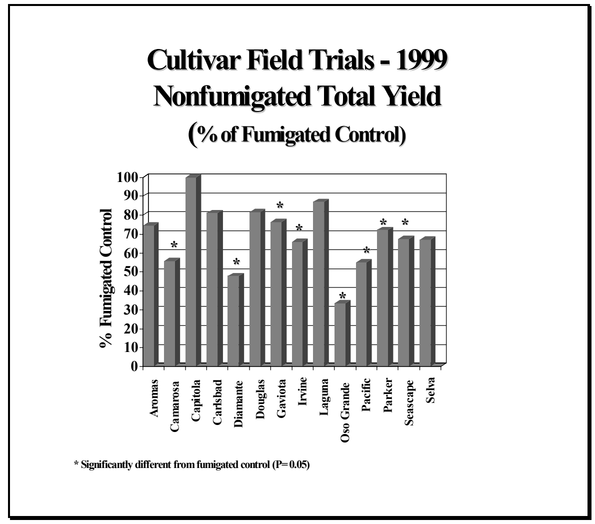


Filed Evaluations

Field trials to evaluate cultivar performance in nonfumigated soil have been conducted in test plots in Salinas. The location has not been previously fumigated and is naturally infested with the pathogens associated with black root rot. Importantly, Verticillium wilt and Phytophthora root and crown rot have not been a problem at this test location, so trials evaluating the contribution of the general root pathogens associated with black root rot on plant growth and yield can be conducted independent of these lethal pathogens. In an effort to build up black root rot pathogens in the plots, strawberry was cropped in the test plots for two years prior to initiating these trials.

There were dramatic differences in growth and yield performance among the cultivars. Analysis of variance reveals that these differences are significant ($P < 0.001$ between fumigation treatments; $P < 0.001$ between cultivars; $P = 0.0032$ for fumigation x cultivar interaction). With the exception of Laguna, all cultivars exhibited significant reductions in plant diameter measurements when grown in nonfumigated soil compared to the MB + Pic fumigated control. The greatest reduction in growth was observed for Oso Grande, which had approximately a 50% reduction in plant diameter.





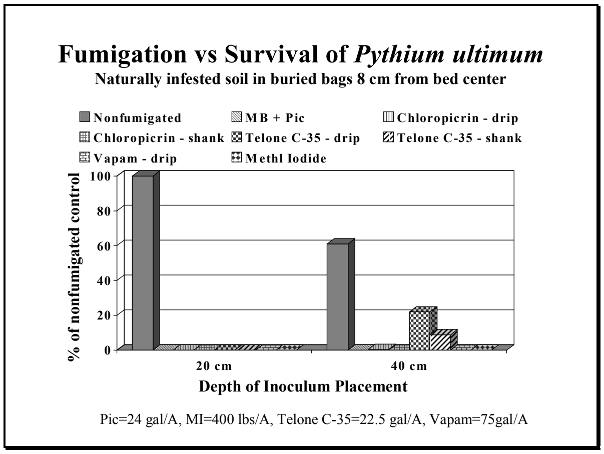
A wide range in yield also was observed among cultivars (the data for the nonfumigated treatments in the above figure is expressed as the percentage of yield obtained in the methyl bromide + chloropicrin fumigated controls). For example, there was no difference in total yield for Capitola grown in nonfumigated compared to the fumigated control; in contrast Oso Grande exhibited approximately a 70% reduction in yield when grown in nonfumigated soil. While the yield in nonfumigated soil was proportional to the yield in fumigated soil for some cultivars, this was not observed for all comparisons. For example, total yield in fumigated soil for Gaviota, Irvine, Laguna, and Oso Grande were similar (data not shown), however, in nonfumigated soil Oso Grande has dramatically lower yields than the other cultivars.

Crop rotation

A number of strawberry root pathogens have a broad host range and are capable of infecting other crops, so in the absence of effective soil fumigation crop rotation can have a significant influence on maintaining populations of soilborne pathogens. Field trials evaluating the influence of rotation with broccoli, Brussels sprouts, or lettuce on the population dynamics of *Pythium* spp. and *Verticillium dahliae* are in progress at the Watsonville test site (done in collaboration with Drs. Subbarao and Shetty and Steve Koike). The field was cropped in vegetable rotation in the 1997 season, strawberry (Selva) in the 1998 season, vegetable rotation in 1999 and was in strawberry in 2000. After harvesting the vegetable crops, the stubble was mowed with a flail mower, allowed to dry on the soil surface for several days and then incorporated into the soil. Two cropping cycles were planted for broccoli and lettuce and one for Brussels sprouts. While cropping practices had no consistent influence of population densities of total *Pythium* spp., broccoli and Brussels sprouts reduced *V. dahliae* inoculum densities by 80-90% (to a final inoculum density of 1-2 microsclerotia/g soil). Although the market yield for all rotation treatments was below the MB + Pic fumigated controls in 1998, strawberry grown in the broccoli rotation plots had only a 23% reduction in yield compared to the fumigated control while Brussels sprouts and lettuce had yield reductions of 31% and 39%, respectively. Strawberry yield data for the 2000 season is currently being analyzed. These trials have been expanded at the Watsonville test site to include larger test areas as well as the addition of a test plot in an organic production field. Similar experiments (rotation with broccoli, cauliflower, or lettuce) also are underway at the Salinas plots as well.

The influence of root colonizers of root health, plant growth, and yield
Preliminary investigations on the population structure and seasonal fluctuations of fungal, bacterial, and actinomycete root colonizers have been done for plants grown in fumigated and nonfumigated soils. A number of the recovered isolates have been evaluated for their effect on shoot and root growth in greenhouse/growth chamber trials. While most isolates had no effect on plant growth, some were identified that increased either shoot growth (up to a 40% increase), root growth (up to a 138% increase), or a general stimulatory effect on both shoot and root growth. Several isolates also were identified that had inhibitory effects on root growth (up to a 26% reduction). Trials in the 1998 season at the USDA test site in Salinas in nonfumigated soil identified several beneficial isolates that significantly increased yield over the untreated control plants when plants were treated at the time of transplanting (one isolate gave a 35.5% increase in marketable yield). However, trials in the 1999 season did not reveal significant differences among the treatments. One possible reason for this could be that there was much less rainfall in 1999 compared to 1998 (31 vs 74 cm, respectively). Since soil moisture can have a significant effect on the ability of introduced microbial inoculants to colonize roots, the drier conditions in 1999 could have lead to lower root colonization levels which in turn would lead to a reduced effect on strawberry yield. To alleviate potential problems with insufficient root colonization, trials are in progress this season with several of these isolates where additional treatments with the microbial inoculants are applied via the drip system. Trials evaluating the efficacy of several commercial biological control agents are underway as well.

Fumigation trials
Fumigation trials have been done in collaboration with Husein Ajwa to evaluate the efficacy of alternative fumigants and methods for application for their ability to control *Pythium ultimum*, the most commonly recovered *Pythium* spp. from strawberry in the central coastal production area of California. Naturally infested soil was placed into nylon mesh bags and buried at two depths 8 cm from the center of the strawberry beds. The bags were recovered 6.5 wks after fumigation and the pathogen populations determined by plating on a selective medium. All fumigation treatments completely eliminated *P. ultimum* with the exception of the Telone C-35 treatments at the 40 cm depth (20% and 10% survival for the drip and shank treatment, respectively). One possible reason for this could be spacing of the drip tape or bed fumigation shanks that were used in this experimentation; this will be discussed more fully in the presentation.


Fumigation vs Survival of *Pythium ultimum*
Naturally infested soil in buried bags 8 cm from bed center
Nonfumigated
MB + Pic
Chloropicrin - drip
Chloropicrin - shank
Telone C-35 - drip
Telone C-35 - shank
Vapam - drip
Methl Iodide
% of nonfumigated control
100
80
60
40
20
0
20 cm
40 cm
Depth of Inoculum Placement
Pic=24 gal/A, MI=400 lbs/A, Telone C-35=22.5 gal/A, Vapam=75gal/A