Management of Frost Injury, Fire blight, and Fruit Russetting of Pear Using Biological and Cultural Methods.

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ABSTRACT

Both the total number of indigenous bacteria in buds as well as the proportion of those bacteria that were "internal" to pear tissue varied greatly between orchards. Total indigenous bacterial populations associated with pear in the early spring in 2000 were generally substantially lower than in most other years. Generally a majority of the bacteria in buds were internal,, while the proportion that was internal decreased to a small percentage of all of the bacteria on a developing shoot after bud break. The fraction of the total bacterial population associated with pear samples that was "internal" varied from over 50% in two Sacramento county orchards to as little as about 10% in one Lake county orchard. Superficial populations are thus probably strongly influenced by weather conditions in the early spring. Bacterial populations generally increased rapidly after bud enlargement, and a progressively smaller proportion of the bacteria on such green tissues were internal to pear. Because bacterial populations were relatively low in buds in the winter and spring of 2000, the applications of eradicant bactericides before bloom did not further lower bacterial populations. Application of strain A506 with the organo-silicon surfactant Breakthru resulted in populations than on trees that were as much as 3-fold higher than when the bacterium was applied in water alone. The severity of fruit russetting on trees was reduced in most treatments in which strain A506 was applied to trees. The population size of strain A506 in pear flowers throughout the spring generally increased greatly with increasing concentrations of surfactant in which the bacteria were applied in a single application before bloom as well as with the age of the pear tissues at which the single inoculation was made. Importantly, the population size of strain A506 on flowers on trees that were inoculated only a single time at "first bloom" with Blightban A506 in 0.2% or 0.5% Breakthru were as high as or higher throughout the spring than that on trees which received weekly application of the same amount of Blightban A506. This exciting result suggests strongly that we should be able to greatly reduce the number of applications of the bacterium by applying it early in the season with a penetrating surfactant. In addition, by applying the bacterium only once early in the early spring before applications of Dithane and Terramycin and other pesticides are subsequently made

to trees, we can avoid potential problems with compatibilities of the bacterium with these other pesticides.

Colonization of pear buds and flowers with indigenous bacteria in the early spring

Work during 2000 addressed important issues in the microbial ecology of pear trees that relate to the management of fruit russet, frost injury and fire blight disease of pear. One major objective was to monitor populations of indigenous bacteria in pear buds and emerging florets during winter/early spring and relate them to weather parameters such as spring rainfall. An earlier analysis of data in which we had measured indigenous bacterial populations on the flowers of pear at the beginning of bloom revealed large variations in population size from year to year. In some years such as 1995 and 1998 there were large populations of bacteria of all types in flowers shortly after they open in the spring, while in other years flowers emerged nearly sterile and become colonized by bacteria that apparently immigrated to the open flower via the air or insect vectoring from nearby plant sources such as orchard cover crop and weed species. We had found that the number of bacteria in emerging flowers is generally correlated with rainfall abundance during the winter and early spring months before bud opening. We presumed that winter rains allow colonization of the buds and/or the emerging florets as the buds begin to open. Importantly, we had found that the incidence of early season fire blight infection is generally inversely proportional to the population size of the indigenous bacteria in the emerging flowers on control trees (ie. there is less disease in years when there are a lot of indigenous bacteria - "natural biological control" of fire blight seems to be operating). We also noted that the colonization of flowers by antagonistic bacteria such as *Pseudomonas fluorescens* strain A506 is less efficient in years when there are large indigenous bacterial populations. Fortunately, the presence of large numbers of indigenous bacteria can apparently confer some degree of "natural biological control" in those years when A506 itself is inhibited in its growth on pear by the presence of indigenous bacteria. The presence of large numbers of indigenous bacteria on emerging pear flowers is also associated with a relatively high incidence of frost injury during mild frost events compared to orchards and years when indigenous bacteria populations were low. We therefore undertook a detailed temporal analysis of the processes that allow bacteria to develop in emerging pear flowers to better understand how to manage biological control agents of fire blight disease as well as frost injury and fruit russet and to better predict when indigenous bacteria will be sufficiently numerous to present a high hazard of fruit russet and frost injury. Beginning about 3 weeks before bud break in 2000 we monitored the process of colonization of pear buds and the flowers that emerged from these buds on a frequent basis to determine how rapidly bacterial populations changed and what weather factors were associated with the development of bacterial populations in buds and flowers. Bacterial populations were monitored on buds and flowers in two commercial pear orchards in Lake County as well as in two orchards in Sacramento County. In addition to measuring the total bacterial population on buds and flowers we also measured the "internal" populations. At each sampling time the 40 bud or flower samples for each orchard were divided into two separate pools of 20 samples each. Total bacterial populations were determined by macerating the bud or flower samples from one pool individually in a small amount of buffer and plating appropriate dilutions onto non-selective media. In contrast, "internal" populations were determined as before on the other 20 samples in a

given pool after the buds or flowers were surface sterilized by treatment with 0.5% sodium hypochlorite.

Both the total number of indigenous bacteria in buds as well as the proportion of those bacteria that were "internal" to pear tissue varied somewhat between orchards (Figures 1-4). Total indigenous bacterial populations associated with pear in the early spring in 2000 was generally low, as in 1999, and was substantially lower than in other years. Average total bacterial populations ranged from less than 1000 cells/sample in two Sacramento county orchards (Figures 3 and 4) to over 20,000 cells/sample in a Lake county orchard (Figure 2). It was noteworthy that in 2000, as in 1999, little increase in bacterial populations occurred from March 1 (when all buds were tightly closed) to about April 10 (when flowers were starting to emerge in Lake county and substantial vegetative growth had occurred in Sacramento county) (Figures 1-4). The fraction of the total bacterial population associated with pear samples that was "internal" varied from over 50% in the two Sacramento orchards (Figures 3 and 4) to less than about 10% in the two Lake County orchards (Figures 1 and 2). Generally, the proportion of bacteria that were "internal" to the pear tissue was inversely proportional to the total indigenous bacterial population; as more bacteria were found on pear tissue, a lower proportion tended to be within the tissue. The reason for this relationship is unclear. (The occasional samples in which higher "internal" populations were noted than total bacterial populations is due to sampling issues since different buds were sampled to estimate total and internal populations). The larger populations of bacteria on buds in Lake County might represent more “superficial” populations that survived better under the somewhat wetter conditions of Lake County. Such superficial populations are thus probably strongly influenced by weather conditions. Indeed, the spring weather in 2000 was relatively dry with little or no rainfall occurring during most of the sampling period. The dry weather conditions in the spring of 2000 is a likely reason for the generally low overall bacterial populations on pear tissue. It might be expected that bacterial populations would be substantially higher in years such as 1995 and 1998 when more rainfall occurred during bud break and cluster development. The results of 2000 confirm our suspicions that bacterial population development in pear occurs rapidly during bud enlargement, and is not associated with large internal populations that developed during winter since the winter months of 1999-2000 were relatively wet and yet low bud populations were present in the early spring.

In contrast to the relatively stable populations of bacteria that were observed on buds and "fingers" of pear in the early spring, more rapid bacterial multiplication was noted in some orchards upon flower opening (Figures 1-4). For example, after mid-March flowers emerged in the two Sacramento County orchards and total bacterial populations increased over 10-fold within a few days (Figures 3 and 4). It was interesting to note that the increases in total bacterial populations were not associated with any increase in "internal" populations, and thus the proportion of the total bacterial population that were within pear tissue decreased to less than 0.1% (Figures 3 and 4). This study is designed to be a relatively long-term study in which we will examine colonization of pear under a variety of weather conditions over a number of years so that the influence of weather conditions on bacterial populations can be better predicted. Predictions of indigenous bacterial populations before bloom will be useful in future predictions of the severity of fruit russet and of frost injury that are associated with these indigenous bacteria.

Eradication of indigenous bacteria on pear in early spring to reduce fruit russet and enhance colonization of pear by biological control agents.

Since relatively large indigenous bacterial populations had been found on pear tissue at the time of first bloom in some previous years and since these large populations were associated with poor establishment of the biological control agent *Pseudomonas fluorescens* strain A506, we evaluated strategies to reduce such early season populations. Since the severity of fruit russet is proportional to the total population sizes of bacteria on pear tissues in the early spring (due to the contribution of IAA-produced by a subset of these bacterial populations), we were interested to know if we could reduce the population sizes of indigenous bacteria and thereby reduce the severity of fruit russet. *Pseudomonas fluorescens* strain A506, for which extensive field experimentation has been conducted over the last several years in California, has been registered as the product "Blightban A506" and commercial sales began in the 1996 growing season. We therefore conducted additional research to address issues relating to the best methods by which this bacterium can be established in pear trees to achieve biological control of frost injury, fire blight disease, and fruit russet, especially under conditions when pears might already harbor substantial populations of other bacteria in the early spring.

A field trial in which several early-season chemical eradicants were evaluated was established in a commercial pear orchard in Lake County. Both bleach (Sodium hypochlorite - 0.05%) as well as copper hydroxide (Kocide 101) were evaluated as bactericides to eradicate bacterial populations. These eradicants were applied with a high rate of this surfactant (0.5%) to determine if the bactericide could be made more accessible to the bacteria in and on pear tissues. Such eradicant treatments were made at the "finger" stage. At the time of about 10% bloom weekly applications of *P. fluorescens* strain A506 (label rate of Blightban A506) were initiated. The total indigenous bacterial populations on untreated trees and on trees treated only with streptomycin and Terramycin in this Lake county orchard were relatively low (less than about 10^5 cells/spur) in the early spring of 2000, but increased after mid-April after trees became contaminated with strain A506 from adjacent trees (Figure 5). Unlike in many other studies, we found that treatment of trees with a mixture of streptomycin and Terramycin reduced total bacterial populations during much of the spring (Figure 5). It should be noted that this contamination of trees with bacteria from other treatments in the plot was an issue in the 2000 study since fewer guard trees were used to separate treated trees than in past experiments. Our results in 2000 indicate that bacteria such as *P. fluorescens* strain A506 can move efficiently between closely adjacent trees. Thus differences in population sizes between different A506 treatments in 2000 were reduced due to such migration of bacteria from tree to tree. Because bacterial populations were already relatively low, the applications of eradicant bactericides did not further lower bacterial populations in most cases (Figure 6). The population size of *P. fluorescens* strain A506 was similar at a given sampling date on trees receiving weekly applications of Blightban A506 on trees treated with eradicant bactericides and as on trees without such earlier chemical treatments (Figure 6). In all cases, populations of strain A506 increased within a few days of initial treatment onto trees to a population of over 10^7 cells/spur and remained at close to this population throughout the rest of the sampling period (Figure 6). We also compared the colonization of pear by strain A506 when it was applied to trees in water without a surfactant and when it was applied in a solution of 0.05% Breakthru (Figure 7). As we

had seen in similar tests in 1997 to 1999, the population size of strain A506 was generally higher (by an average of about 3-fold) when applied to trees with the surfactant (Figure 7). We found that the bacterium is applied more uniformly to plant surfaces when mixed with this surfactant which has a very low surface tension. Presumably the surfactant allowed the bacterium to more fully colonize parts of the flowers and young fruit by allowing sprayed inoculum to move easily to all parts of the developing tissues. Presumably this also reflects a greater ability of the bacterium to prevent the growth of deleterious bacteria such as ice nucleation active bacteria capable of causing frost injury, of IAA-producing bacteria that cause fruit russet, and of *Erwinia amylovora*, the pathogen that causes fire blight disease.

It is interesting to note that the populations of strain A506 were substantially higher than that of *E. herbicola* strain C9-1 during the 2000 growing season (Figure 8). In past years these stains often had similar population sizes, and occationally strain C9-1 had higher population sizes than strain A506. Apparently the two strains differ in their response to weather conditions, and the relatively cool conditions present in 2000 were more favorable to growth of strain A506 than that of strain C9-1.

The severity of fruit russet on trees receiving applications of Blightban A506 was numerically lower than that of untreated trees in most cases, but because of variation in russet severity between trees often did not differ statistically (Table 1). Likewise, the severity of fruit russet was not lower on trees in which early season eradicant bactericides were applied in addition to weekly applications of Blightban as compared to where Blightban alone was applied (Table 1). It was noteworthy, that the application of Kocide 101 or bleach in the early spring apparently caused some fruit russet (Table 1). It is also noteworthy that the application of a high rate of Breakthru (0.5%) was not associated with fruit russet (Table 1). Thus this penetrating surfactant apparently does not harm pear tissues even at high rates when applied in the early spring. We did observe slightly higher levels of fruit russet on trees treated with a mixture of strain A506 in 0.05% Breakthru; we had never observed any increase in fruit russet with this mixture in the past, and in fact, had often found it to have the lowest fruit russet severity. The reason for this increase in 2000 is not clear, but it may have been due to enhanced exposure to other materials that were applied to trees with the sprayer due to the great spreading characteristics of such sprays.

Frost injury was also observed sporadically in the plot area. The mild frost that occurred after full bloom caused blistering of the calyx end of some fruit at harvest. The incidence of frost injury was observed to vary greatly from one end of the plot area to the other, and hence the severity of frost injury was not strongly associated with treatments due to the great variation due to spatial location in the plot area (Table 1).

Establishment of *P. fluorescens* strain A506 in pear flowers by single early season applications with surfactants

Given that we had observed in previous years that rapid colonization of flowers by indigenous bacteria could occur if flowers were inoculated with bacteria, we investigated approaches by which *P. fluorescens* strain A506 could be introduced into pear tissues before bloom so that flowers would be exposed to this antagonistic bacterium as soon as they opened. We evaluated the potential of introducing bacteria into pear tissues using relatively high rates of

the penetrating surfactant Breakthru. Just as we had demonstrated in walnut that this surfactant could allow topically applied solutions to penetrate into tissues, we hypothesized that suspensions of *P. fluorescens* strain A506 could be made to enter pear tissues if applied with such surfactants. Organo-silicon surfactants such as Breakthru and related compounds have the unique ability to allow water solutions to penetrate into plant tissues through natural openings due to the low surface tension of such solutions. Normal sticker-spreaders do not have a sufficiently low surface tension to permit such penetration into plants. Laboratory tests had indicated that strain A506 was tolerant to over 3% Breakthru. Thus this bacterium was compatible with even high rates of surfactant. We inoculated pear trees once at either the "popcorn" stage or at the time of the first bloom in an orchard with Blightban A506 with different concentrations of Breakthru and then measured the colonization of flowers by strain A506 after they emerged.

The population size of strain A506 in pear flowers throughout the spring increased greatly with increasing concentrations of surfactant in which the bacteria were applied before bloom as well as with the age of the pear tissues at which the single inoculation was made (Figures 9 and 10). The population size of strain A506 applied a single time in water alone to pear trees at the "popcorn" stage of development (Figure 9) generally varied considerable in an inconsistent fashion between treatments, probably reflecting substantial “contamination” of trees with inoculum coming from adjacent trees receiving weekly applications of strain A506, for example. In contrast, the population size of strain A506 was less than about 105 cells/spur throughout the spring on flowers of trees that had been inoculated a single time at "first bloom" with Blightban A506 in water alone or in a solution of only 0.1% Breakthru (Figure 10). Importantly, the population size of strain A506 on flowers in the spring increased to over 10^7 cells/spur on trees that were inoculated only a single time at "first bloom" with Blightban A506 in 0.2% or 0.5% Breakthru (Figure 10). The population sizes of strain A506 on flowers in trees receiving a single application of Blightban A506 in the high rate of surfactant before bloom was as high as that on trees which received weekly application of the same amount of Blightban A506 on some dates throughout the spring (Figure 10). As in initial studies in 1999, the populations of strain A506 achieved by using the penetrating surfactant were generally higher when the single application was made later in the season (first bloom) than earlier (popcorn stage) (Figure 11). We conclude that the surfactant allowed at least some cells of strain A506 to invade into protected portions of developing flower parts on the tree and to rapidly proliferate upon the opening of the flowers. Another striking effect of the application of the early application of Blightban A506 in penetrating surfactants was the fact that total bacterial populations were much higher on treated trees than on trees not treated with this bacterium early in the growing season. While total bacterial populations remained less than about 10^5 cells/ spur on trees treated with a mixture of streptomycin or Terramycin or on untreated control trees (Figures 5 and 6), total bacterial populations were often least 100-fold higher early in April on trees that were treated with Blightban A506 in high rates of Breakthru at first bloom (Figure 10). These results are very exciting in that it suggests that early season application of antagonistic bacteria may be a superior means of establishing these biological control organisms on trees. These exciting results suggest strongly that we should be able to greatly reduce the number of applications of the bacterium by applying it early in the presence of the penetrating surfactant. In addition, by applying the bacterium only once early in the early spring before applications of Dithane and Terramycin and

other pesticides are subsequently made to trees, we can avoid potential problems with compatibilities of the bacterium with these other pesticides. Since strain A506 can be established on trees before these other pesticides need to be applied, and since we have already shown that the bacterium is quite tolerant of other pesticides such as Dithane and Terramycin if it has established on trees before these pesticides are applied, we can greatly reduce any possibility that they will interfere with the performance of strain A506 in biological control of frost, fire blight and fruit russet. Such an application strategy should thus also help increase the adoption of biological control strategies for fire blight and fruit russet since they will make it easier to integrate into existing management strategies. This approach will be a major focus of our work in the year 2000.

Control of fire blight and fruit russet

The relatively cool and dry conditions in the spring of 2000 caused the amount of fire blight disease to be low in most plot locations. There was insufficient fire blight disease in the Lake county plot to enable comparisons of treatments effects on disease. A large trial was also established near Wheatland to evaluate large-scale applications of Blightban A506 and to ascertain to what extent antibiotic applications could be reduced on trees treated at bloom with Blightban A506. We also evaluated the early-season application of Blightban A506 in an organo-silicon surfactant to determine is this was an effective means of inoculating of the bacterium. Thus trees were treated with Blightban A506 either weekly or once early in the spring and were oversprayed with a mixture of streptomycin and Terramycin by the grower/cooperator. While some fire blight occurred in the plot area in Wheatland it was extremely irregular in its occurrence, with over ten times the incidence of fire blight on one end of the plot than the opposite end. This complicated comparisons of treatments for fire blight control. While control trees suffered from about 0.9 strikes per tree, trees treated once with a mixture of Blightban A506 in a Breakthru solution or weekly with Blightban A506 in water had only 0.78 and 0.55 strikes per tree.

The severity of fruit russet was low in all experimental sites in 2000, including the site in Lake County. The low severity of fruit russet was expected based on low bacterial populations on young pear tissue in the early spring as noted earlier. Because of the relatively low severity of fruit russet it was difficult to discriminate the effects on fruit russet from chemical or bacterial treatments. As noted above, most applications of Blightban A506 reduced the severity of fruit russet numerically compared to control trees.

Table 1

Incidence of walnut blight disease on trees treated at various times in early spring with eradicative bactericides consisting of copper compounds combined with various concentrations of a penetrating surfactant.

Treatment	Breakthru (%)	Volume	Application Time (relative to bud break)	In-Season Spray	Disease (% of nuts)	Bacteria Recovered (log cells/sample)
Kocide + Manex	0.5	High	1 week before	No	18.09 abc	4.68 bc
Kocide + Manex	0.5	High	Bud Break	No	17.34 abcd	4.10 bcd
Kocide + Manex	0.5	High	1 week after	No	9.21 cde	2.79 def
Kocide + Manex	0.5	High	2 weeks after	No	4.22 e	2.97 def
Kocide + Manex	0.2	High	1 week after	No	4.66 e	2.00 fg
Kocide + Manex	0.1	High	1 week after	No	6.19 e	3.49 cde
Kocide + Manex	0.05	High	1 week after	No	7.92 e	1.65 fg
Kocide + Manex	0.05	High	2 weeks after	No	8.64 de	2.26 efg
Kocide + Manex	0.00	High	1 week after	No	12.29 bcde	1.99 fg
Water	0.5	High	1 week after	No	19.65 ab	1.36 g
$CuSO_4$	0.5	High	Bud Break	No	4.71 e	2.16 efg
Untreated	N/A	N/A	N/A	No	25.44 a	2.89 def
DBMPA 950 MLS	0.5	High	1 week after	No	21.12 ab	4.13 bcd
Kocide + Manex*	0.1	Low	1 week after	No	19.80 ab	
Kocide + Manex	0.5	High	Bud Break	Yes	3.23 a	1.76 fg
Kocide + Manex	0.5	High	1 week before	Yes	5.04 ab	0.95 g
Kocide + Manex	0.5	High	2 weeks after	Yes	2.02 b	1.60 fg
Kocide + Manex	0.5	High	1 week after	Yes	2.87 b	0.96 g
Untreated “Pre-season”, treated in-season	N/A	N/A	weekly by grower	Yes	10.85 b	3.72 cd

*Treatment was applied using a backpack airblast sprayer (2 gallons per tree)

Figure 1. Total bacterial populations (diamonds) and "internal" bacterial populations remaining in buds and clusters of pear that were surface sterilized with bleach (squares) that were collected from commercial Bartlett pear orchard "T" in Lake County in the spring of 2000. The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

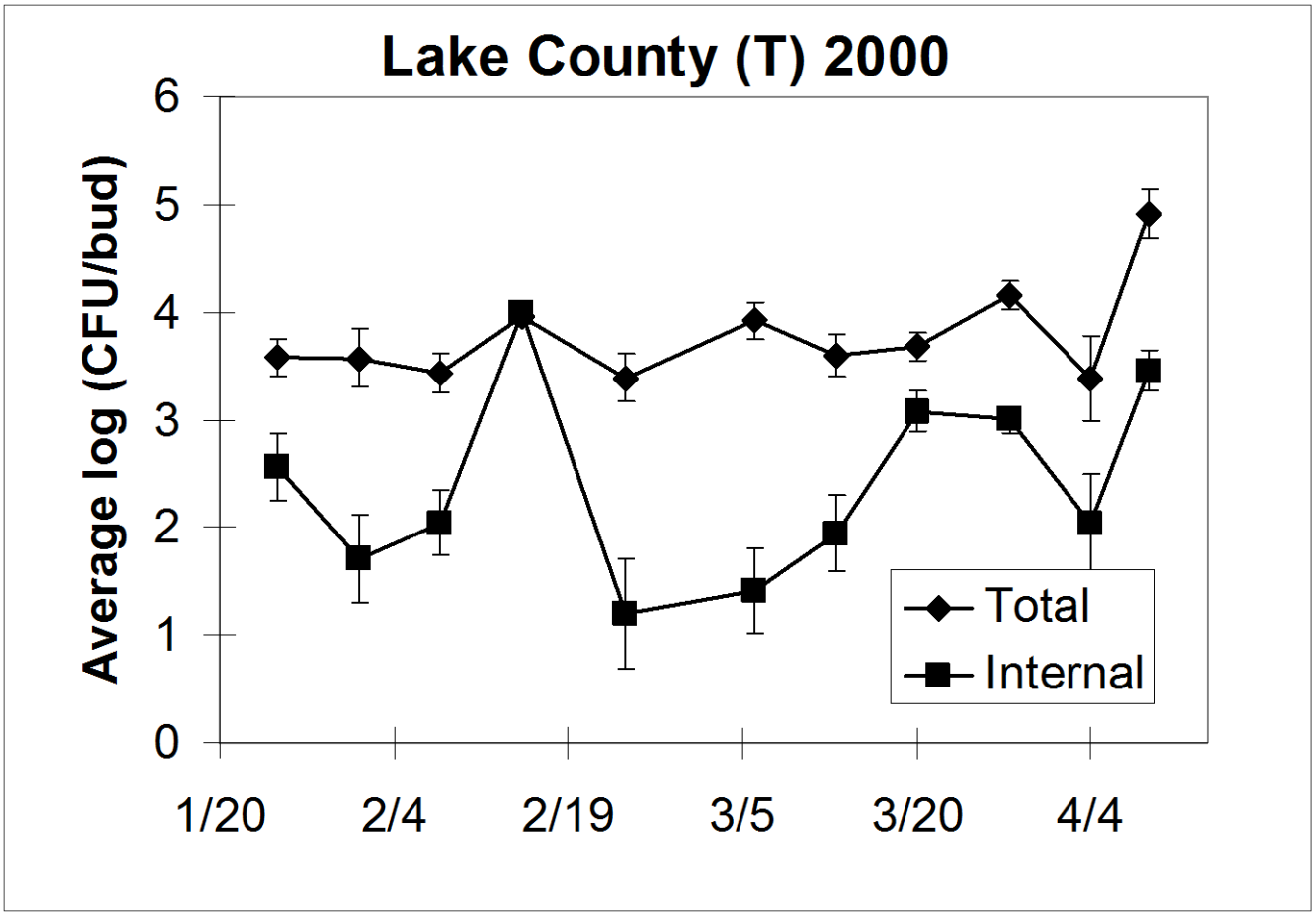

Figure 2. Total bacterial populations (diamonds) and "internal" bacterial populations remaining in buds and clusters of pear surface sterilized with bleach (squares) that were collected from commercial Bartlett pear orchard "R" in Lake County in the spring of 2000. The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

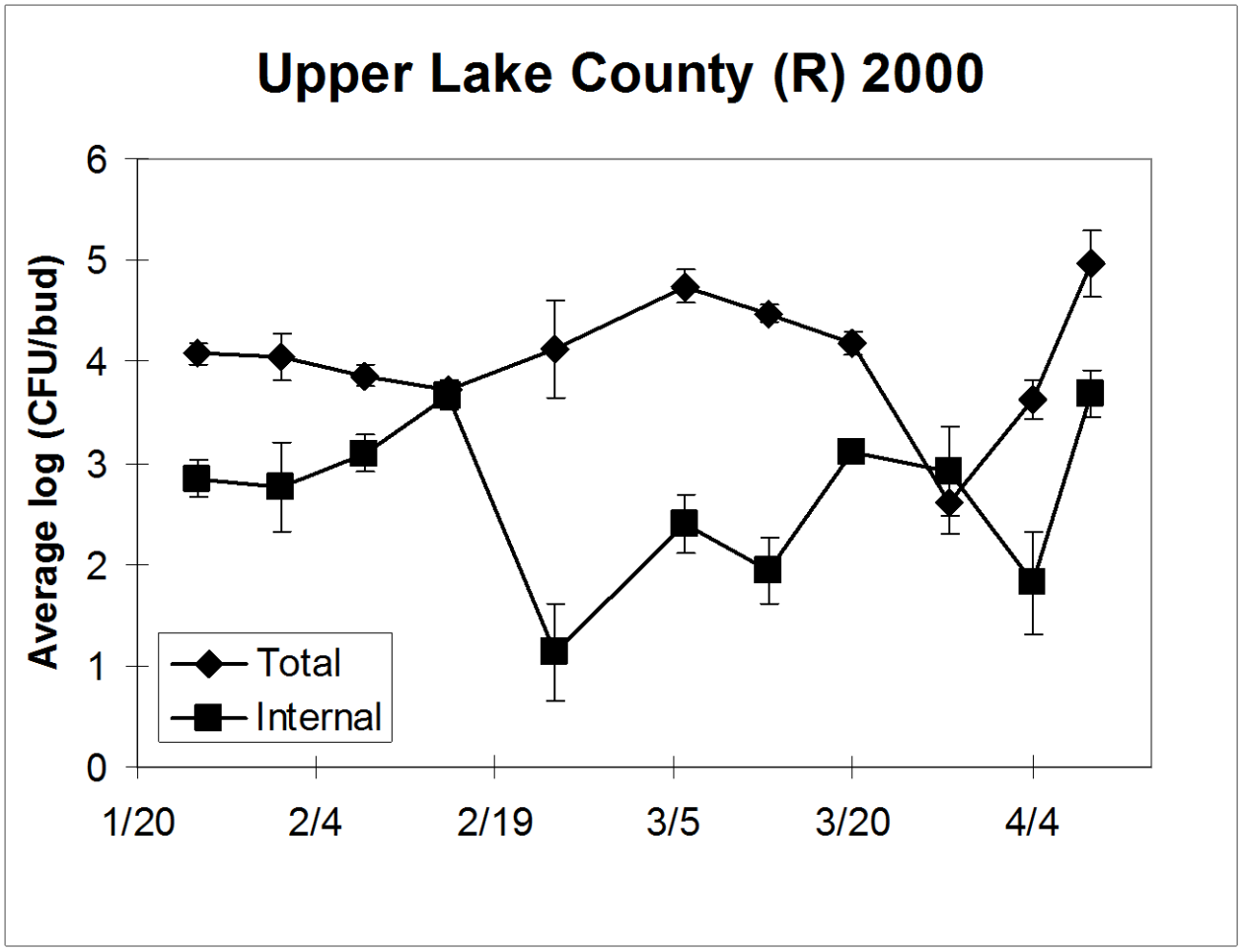

Figure 3. Total bacterial populations (squares) and "internal" bacterial populations remaining in buds and clusters of pear that were surface sterilized with bleach (diamonds) that were collected from commercial Bartlett pear orchard "M" in Sacramento County in the spring of 2000. The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

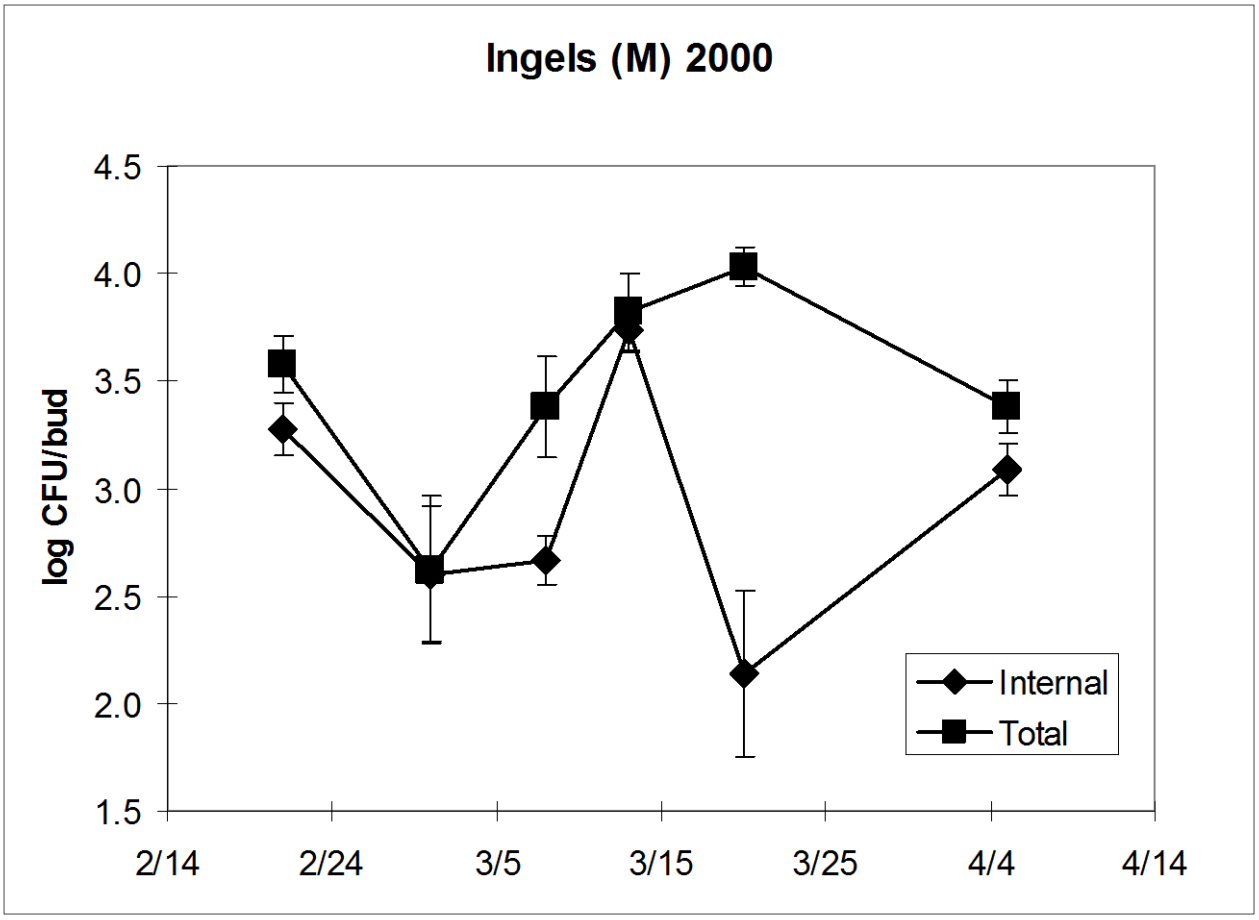

Figure 4. Total bacterial populations (squares) and "internal" bacterial populations remaining in buds and clusters of pear surface sterilized with bleach (diamonds) that were collected from commercial Bartlett pear orchard "T" in Sacramento County in the spring of 2000. The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

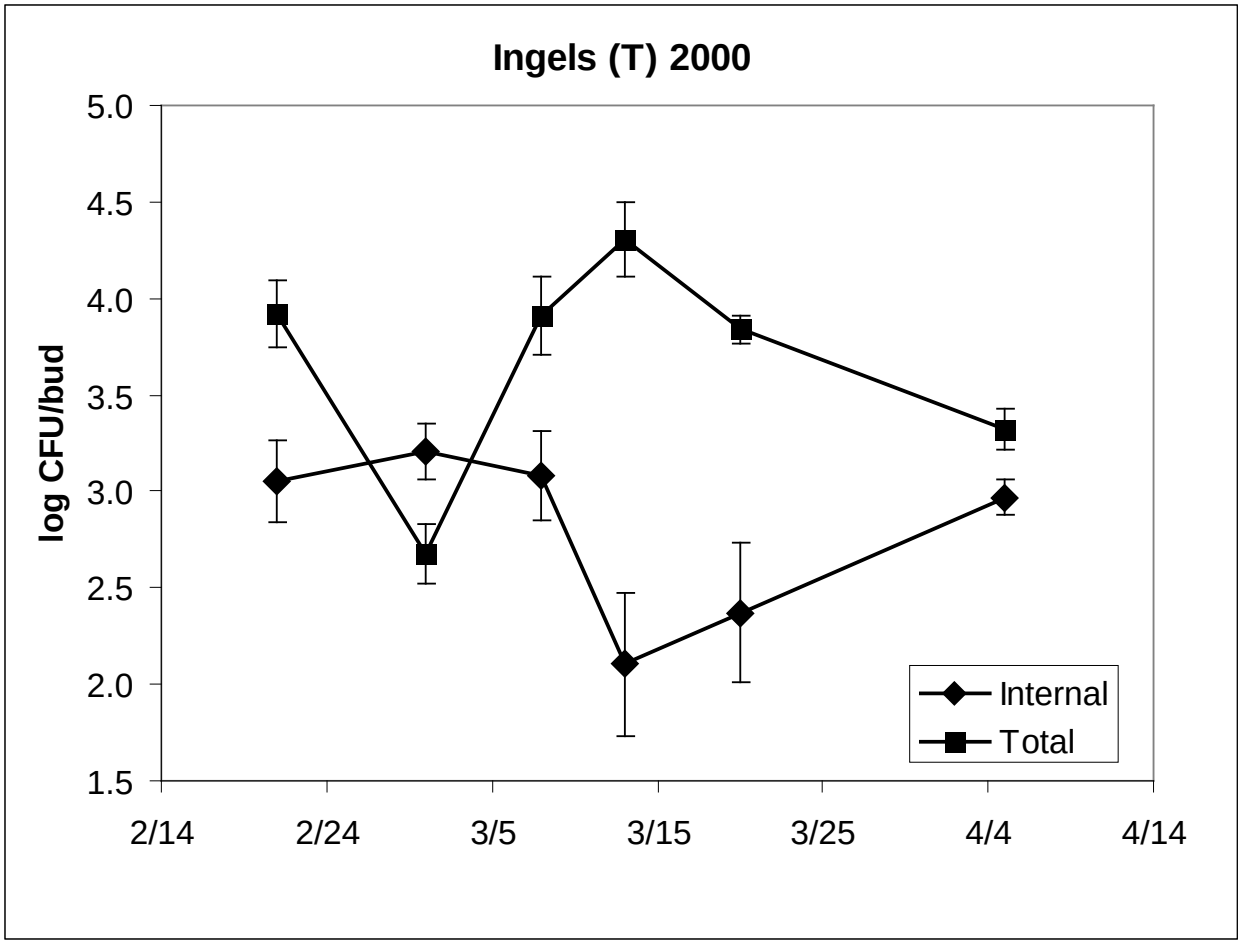

Figure 5. Total bacterial populations (diamonds and triangles), and populations of *Pseudomonas fluorescens* strain A506 (squares and circles) on untreated Bartlett pear trees (diamonds and squares) or on trees treated weekly with a mixture of streptomycin or Terramycin (triangles and circles) in a Lake County plot in 2000. The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

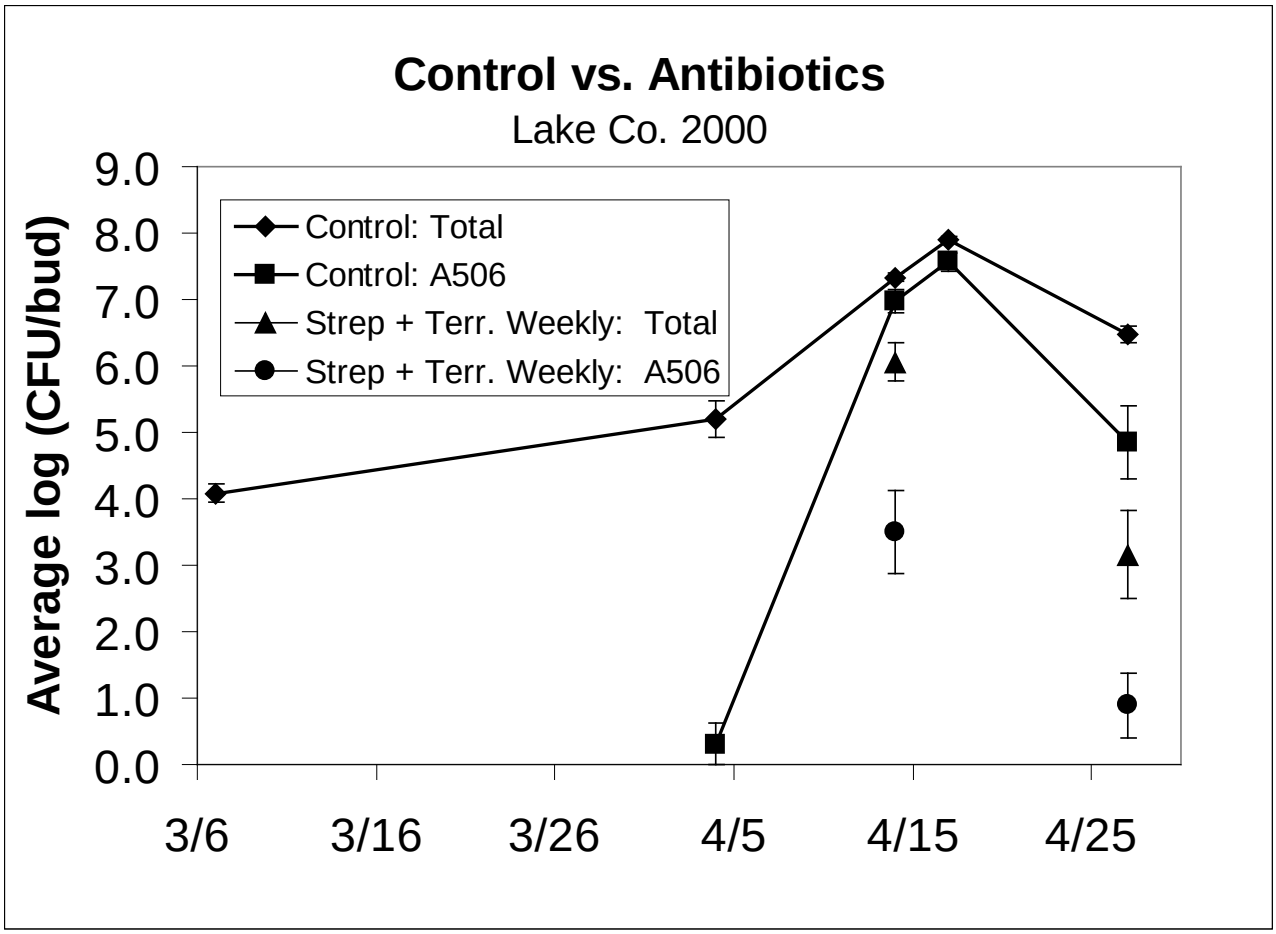

Figure 6. Total bacterial populations (diamonds, x's, open squares, and open triangle), and populations of *Pseudomonas fluorescens* strain A506 (filled square, filled triangle, dark circle, and grey circle) on Bartlett pear trees treated weekly starting at first bloom with Blightban A506 in water to trees receiving no previous treatment (grey circle and open triangle) or to trees treated at finger stage with Kocide 101 in 0.5% Breakthru (filled triangle and x's) or to trees treated at finger stage with 0.5% sodium hypochlorite in 0.5% Breakthru (open square and dark circle). Bacterial populations on untreated control trees are also shown (diamonds and grey square). The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

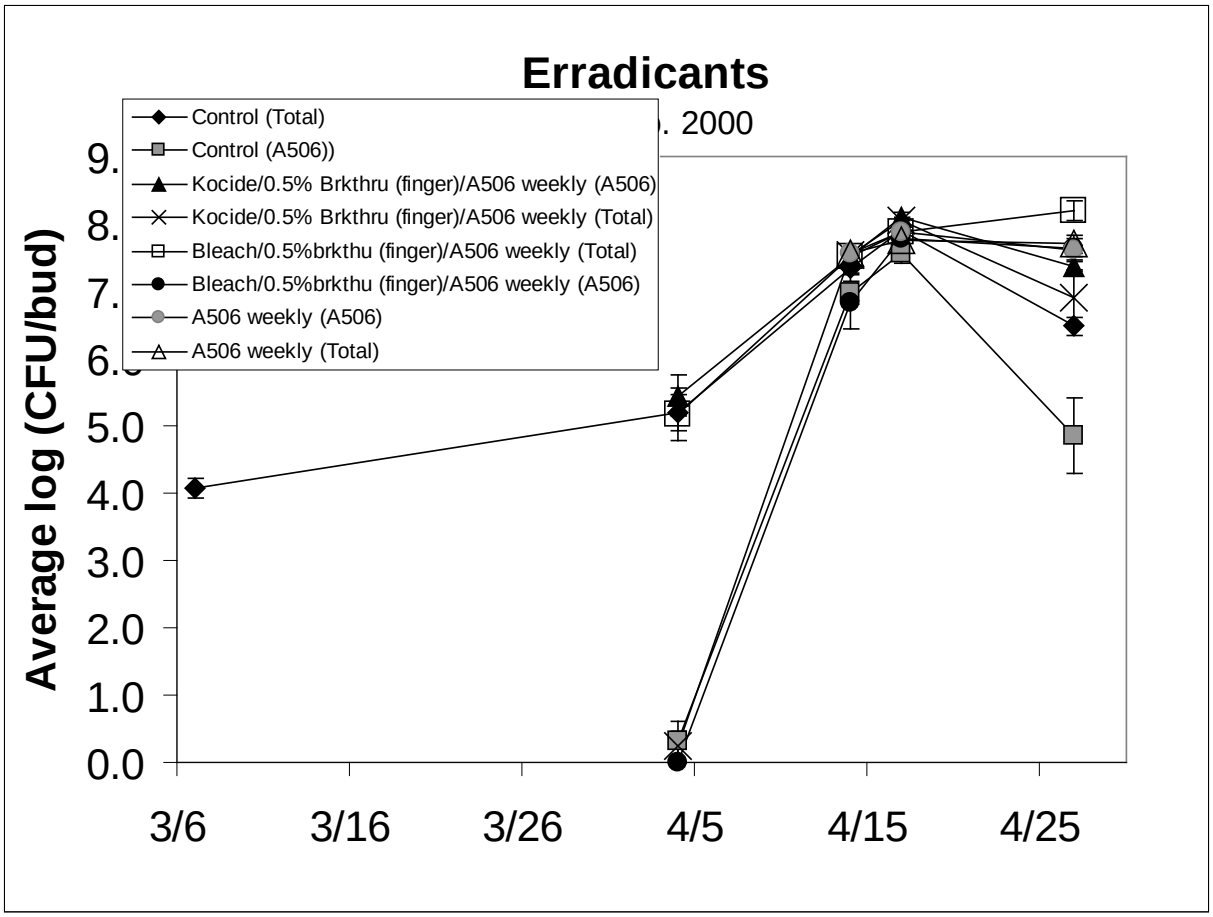

Figure 7. Total bacterial populations (diamonds and triangles), and populations of *Pseudomonas fluorescens* strain A506 (square and x's) on Bartlett pear trees treated weekly with a label rate of Blightban A506 in water alone (triangles and x's) or in 0.05% Breakthru (diamonds and squares). The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

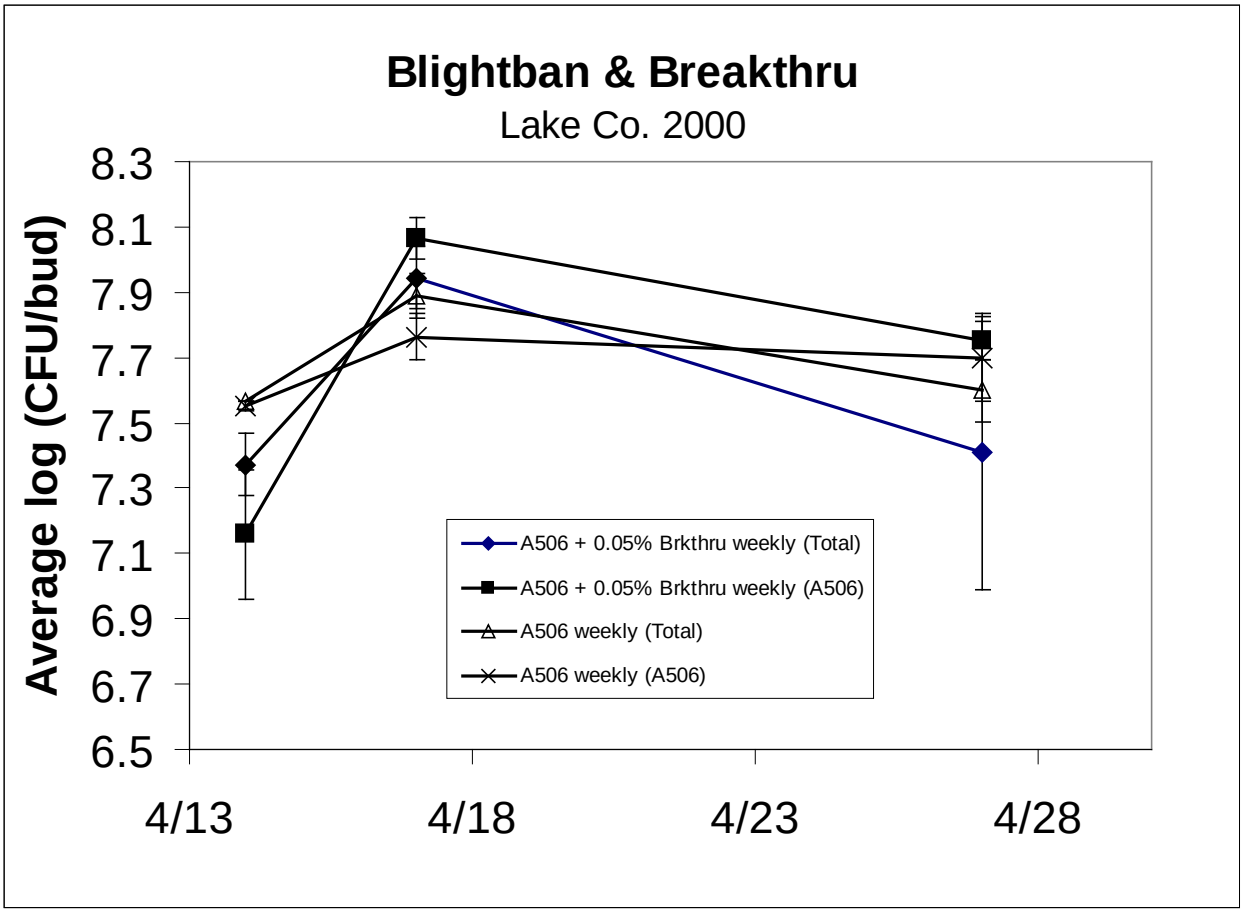

Figure 8. Populations of *Pseudomonas fluorescens* strain A506 (squares) and *Erwinia herbicola* strain C9-1 (diamonds) on Bartlett pear trees treated weekly starting at 10% bloom with either of these strains respectively in a plot in Lake County in 2000. The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

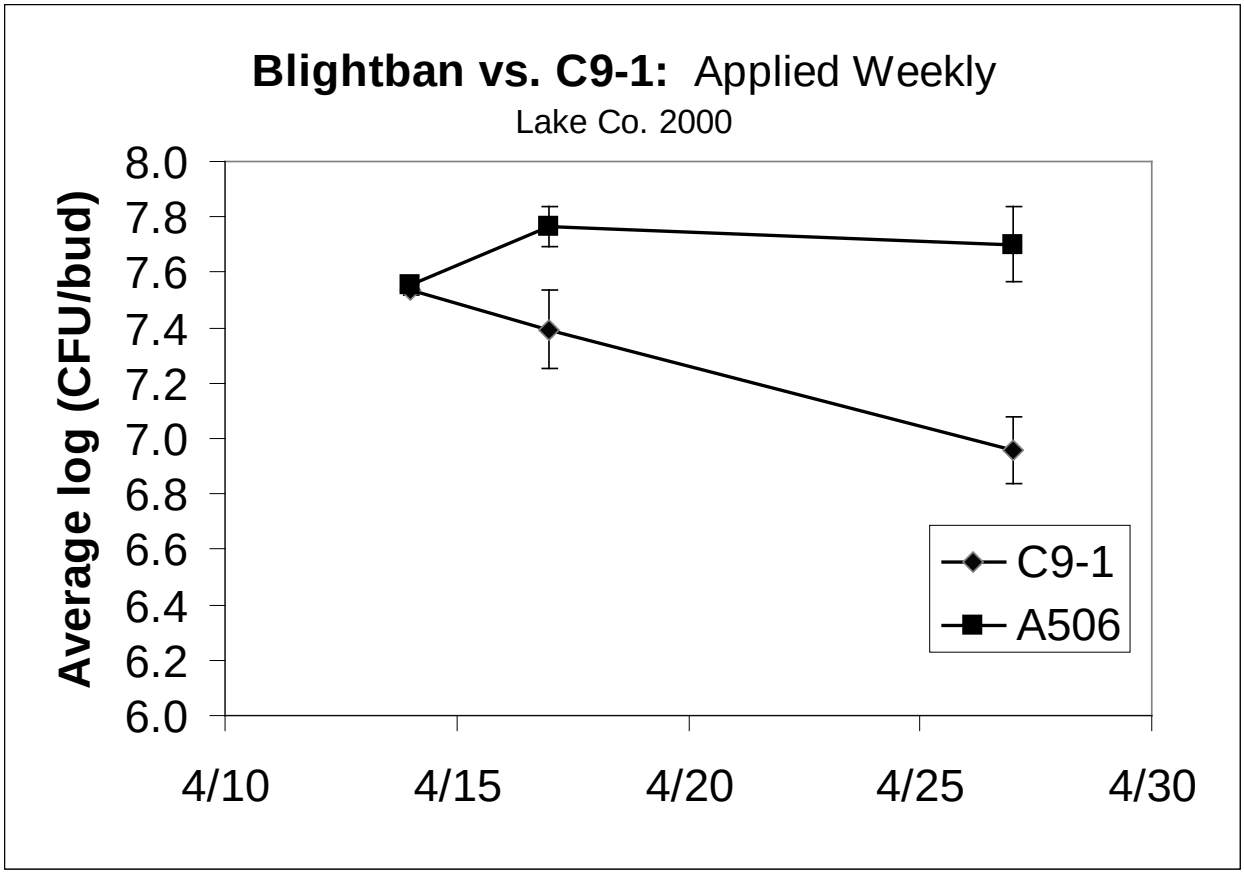

Figure 9. Populations of *Pseudomonas fluorescens* strain A506 on Bartlett pear trees treated once only at the (squares) or 0.5% Breakthru (diamonds) compared with weekly applications of Blightban A506 in water (x's) in a Lake County plot in 2000. The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

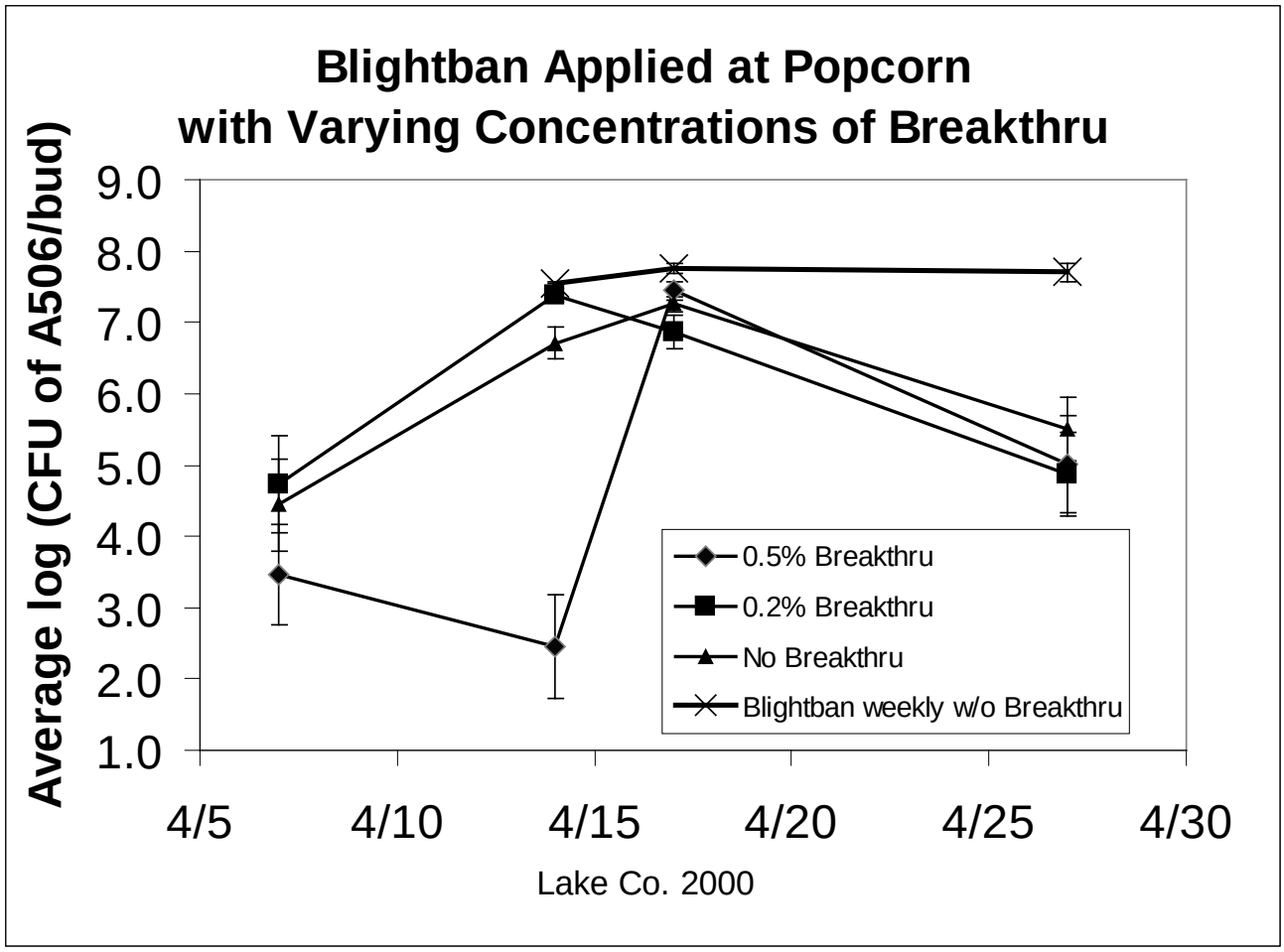

Figure 10. Populations of *Pseudomonas fluorescens* strain A506 on Bartlett pear trees treated once only at the "first bloom" stage of growth [when only a few flowers were observed in an orchard] with a label rate of Blightban A506 in water alone (diamonds) or in 0.1% Breakthru (squares), 0.2% Breakthru (triangles) or 0.5% Breakthru (x's) compared with weekly applications of Blightban A506 in water (stars) in a Lake County plot in 2000. The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.

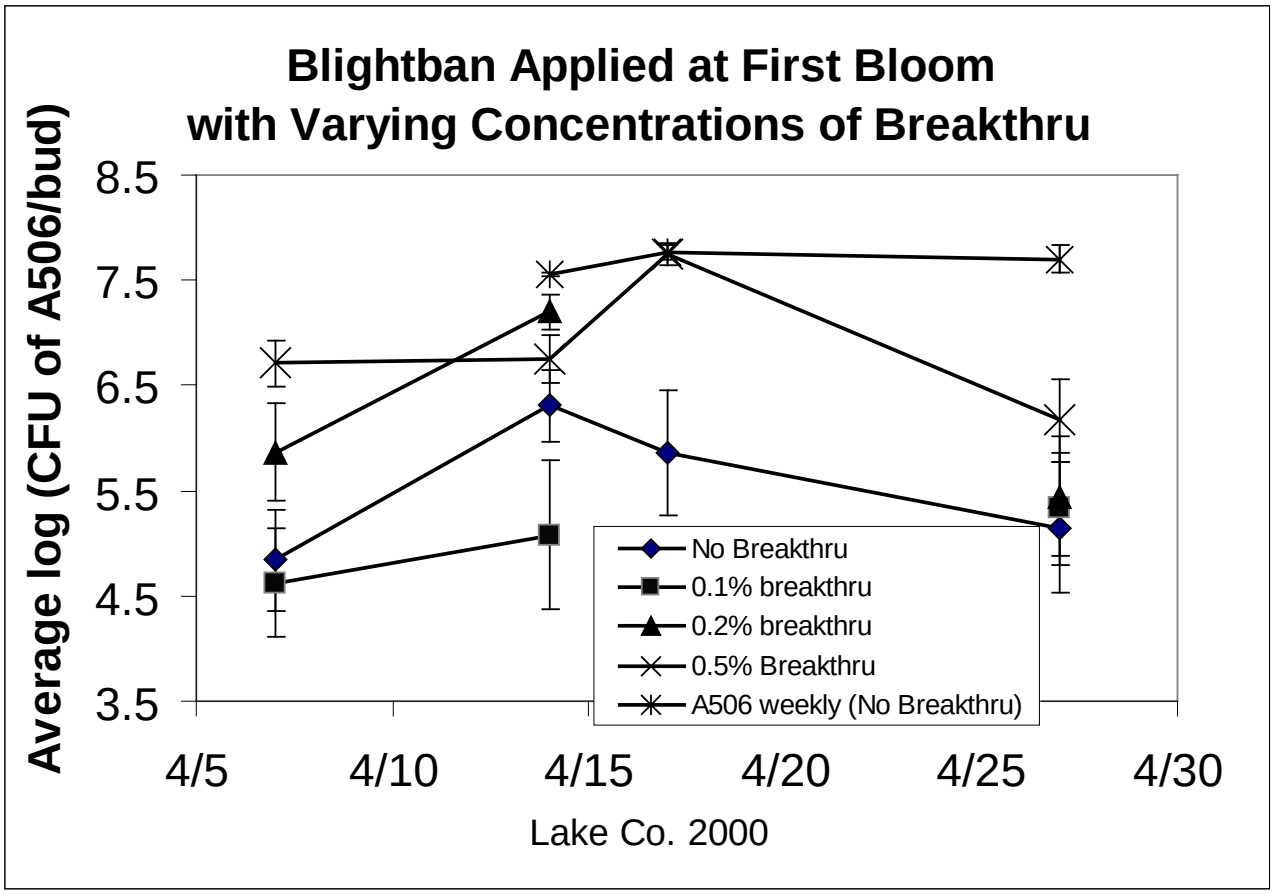

Figure 11. Populations of *Pseudomonas fluorescens* strain A506 on Bartlett pear trees treated only once with a label rate of Blightban A506 in 0.5% Breakthru at the "popcorn" stage of growth (diamonds) or at "first bloom" (squares) in a Lake County plot in 2000. The vertical bars represent the standard error of the mean of log-transformed bacterial population sizes.