# INTEGRATED PRE-PLANT ALTERNATIVES TO METHYL BROMIDE FOR ALMONDS AND OTHER STONE FRUITS

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**Introduction.**

This project is part of the Pacific Area-Wide Pest Management Program for Integrated Alternatives to Methyl Bromide (MB). Its overall goal is to promote stable adoption of alternatives to pre-plant soil fumigation with MB for production of almonds and stone fruits.

The useful economic life of an almond orchard is typically 22 to 25 years, while that of stone fruit orchards is 15 to 20 years. When orchards are replaced, growth and productivity of the succeeding generations of trees are often suppressed by "replant problems" unless precautions are taken. Replant problems can result from interacting physical, chemical, and biological factors, but the biological factors often dominate. Parasitic nematodes (ring, lesion, and, on some rootstocks, root knot nematodes) cause root damage in some of California's almond and stone fruit orchards, and the ring nematode has been associated with the bacterial canker complex on sandy soils. Prunus replant disease (PRD) occurs widely in California, causing growth suppression and, in severe cases, tree death. Pre-plant soil fumigation is used widely to prevent almond and stone fruit replant problems.

Orchardists have shifted towards use of 1,3-dichloropropene (1,3-D) instead of MB for soil fumigation, but use of 1,3-D is subject to township caps and has not controlled PRD adequately. Use of all soil fumigants is increasingly impacted by regulatory constraints in California.

Below, we report on continuing work to test and demonstrate integrated chemical and cultural alternatives to MB.

**Objectives.**

1. To develop and demonstrate optimized integrated pest management strategies for control of almond and stone fruit replant problems without MB.
2. Provide comprehensive economic assessments of alternative replant management strategies.
3. Conduct educational outreach facilitating adoption of effective MB alternatives in almond and stone fruit industries.

**Progress Summary.**
Almond replant trials testing and demonstrating MB alternatives have been established in Colusa County (1 trial), Merced County (1), Madera County (4), and Fresno County (1). Peach replant trials have been established in Fresno County (2). The trials, collectively, are evaluating the following: alternative fumigants (MB, the standard; 1,3-D; chloropicrin [CP]; iodomethane:CP; and mixtures of 1,3D and CP); rates of fumigants (38 to 540 lb per orchard acre); application methods for fumigants (spot treatment using GPS-controlled shank injection; spot treatment using subsoil drip application; and strip and broadcast treatments using conventional shank injection); and integrations with non-fumigants (fallowing, crop rotation). Efficacy of the treatments is being assessed by annual measurement of tree trunk circumference, the proportion of photosynthetically active radiation (PAR) that is absorbed by the tree canopies, crop yield, and incidence of nematodes and soilborne disease. Cost-benefit analyses are being completed by K. Klonsky in a companion Pacific Area-Wide project. Educational outreach is being achieved by oral presentations, field demonstrations, and newsletters. This project is contributing significantly to development of spot fumigation technology and validation of the relationship of % PAR absorbed by tree canopies and crop yield. The latter efforts will facilitate economic assessment of MB alternatives.

Data from selected trials are presented below. All trials presented involved replanting almond or peach after removal of an orchard on Nemaguard peach rootstock. In one of the oldest Madera County trials where trees in control plots were affected moderately by PRD in the first year after planting, row strip treatments with several fumigant alternatives have performed as well as MB (Table 1). Similar results appear to be accumulating in a more recent Madera County trial (Table 2). In addition, in the latter trial, efficacy of GPS-controlled preplant spot treatments (i.e., treating 8'x8' areas centered on tree sites) has maintained very good tree growth with large savings in fumigant, compared to strip and broadcast treatments (Table 2). In two trials near Parlier that tested strip and spot treatments with MB alternatives with and without integrations with fallowing or crop rotation, strip treatments with MB alternatives were highly effective, followed by spot treatments, which stimulated crop growth equivalently to MB (Tables 3, 4). The fallowing and rotation treatments showed a significant tree growth benefit in the first year after planting, but the response is of doubtful economic value. Utility of PAR assessment was shown in the more recent trials (Tables 2-4). Economic assessments of these trials are being completed.

**Table 1.** Effects of preplant shank applied strip and broadcast fumigation treatments in Madera County trial planted in 2004

| Fumigant, rate | Plot area treated | Mulch system | Yield (kernel pounds/acre) | | | Cumulative kernal yield (lb/a) |
|---|---|---|---|---|---|---|
| | | | 2006 | 2007 | 2008 | Cum. 2006-08 |
| Control | None | None | 370 de | 1669 e | 2641 c | 4680 e |
| Control | None | VIF | 294 e | 1811 de | 2868 bc | 4974 e |
| MB, 400 lb/a | Br. (100%) | None | 481 bcd | 2062 abcd | 3103 abc | 5647 abcde |
| MB, 400 lb/a | R. strip (38%) | None | 424 cde | 1894 cde | 3197 ab | 5515 abcde |
| MB, 400 lb/a | R. strip (38%) | VIF | 438 cde | 2081 abcd | 3023 abc | 5541 abcde |
| Telone II, 340 lb/a | Br. (100%) | None | 547 abc | 2199 abc | 3111 abc | 5857 abcd |
| Telone II, 340 lb/a | R. strip (38%) | None | 483 bcd | 2026 abcde | 3062 abc | 5572 abcde |
| Telone II, 340 lb/a | R. strip (38%) | VIF | 472 bcd | 2059 abcd | 2935 abc | 5466 abcde |
| Telone C35, 535 lb/a | Br. (100%) | None | 637 ab | 2385 a | 3458 a | 6480 a |
| Telone C35, 535 lb/a | R. strip (38%) | None | 696 a | 2133 abcd | 3087 abc | 5916 abcd |
| IM:CP (50:50), 400 lb/a | Br. (100%) | None | 682 a | 2364 a | 3246 ab | 6292 ab |
| IM:CP (50:50), 400 lb/a | R. strip (38%) | None | 632 ab | 2241 abc | 3309 ab | 6182 abc |
| CP 400 lb/a | Br. (100%) | None | 554 abc | 2191 abcd | 2938 abc | 5683 abcde |
| CP 400 lb/a | R. strip (38%) | None | 680 a | 2301 ab | 3212 ab | 6193 abc |
| CP 400 lb/a | R. strip (38%) | VIF | 714 a | 2267 abc | 2909 abc | 5891 abcd |

**Table 2.** Effects of preplant shank applied spot, strip, and broadcast fumigation treatments in Madera County almond trial planted in 2007

| Fumigant, rate per treated area[a] | Treated area in tree row (and % of total area) | Fumig. per orch. acre (lbs) | Incr. trunk cir. 2007 (cm) | Incr. trunk cir. 2008 (cm) | Absorbed PAR (7/09) (%) |
|---|---|---|---|---|---|
| Control | None | 0 | 3.0 | 13.4 | 12 |
| Methyl bromide, 400 lb/a | 8-ft strip (38%) | 152 | 4.9 | 15.9 | 15 |
| Telone II, 350 lb/a | 8-ft strip (38%) | 133 | 5.8 | 18.6 | 18 |
| Chloropicrin (CP), 400 lb/a | 8-ft strip (38%) | 152 | 9.0 | 22.1 | 25 |
| CP, 300 lb/a | 8-ft strip (38%) | 114 | 9.0 | 22.4 | 23 |
| CP, 200 lb/a | 8-ft strip (38%) | 76 | 9.0 | 23.1 | 27 |
| CP, 400 lb/a | 8x8-ft tr. sites (17%) | 68 | 7.9 | 22.4 | 21 |
| Midas (IM:CP. 50:50), 300 lb/a | 8-ft row strip (38%) | 152 | 8.3 | 22.2 | 26 |
| Telone C35, 550 lb/ac | 8-ft row strip (38%) | 209 | 8.8 | 23.2 | 25 |
| Pic-clor 60, 550 lb/ac | 8-ft row strip (38%) | 209 | 9.2 | 22.8 | 26 |
| Pic-clor 60, 400 lb/ac | 8-ft row strip (38%) | 152 | 8.2 | 22.1 | 26 |
| Telone C35, 550 lb/ac | 8x8-ft tr. sites (17%) | 93 | 7.5 | 20.4 | 21 |
| Telone C35, 550 lb/ac | Broadcast (100%) | 550 | 8.8 | 22.6 | 26 |
| *Min. sig. difference based on 95% confidence intervals:* | | | *2.8* | 4.7 | 7 |

**Table 3.** Effects of preplant shank and drip applied spot and strip fumigation treatments, with and without a pre-treatment rotation with sudan grass, in Fresno County peach trial planted in 2008

| Fumigation treatment (Oct 2007) | Fum. per treated acre (lbs) | Fum. per orchard acre (lbs) | Sudan grass (Jul-Sep 2007) | Increase in trunk cir. 2008 (cm) | PAR absorbtion July 2009 (%) | Mkt. fruit yield July 2009 (kg) |
|---|---|---|---|---|---|---|
| Control | 0 | -- | no | 3.9 | 1 | 2.0 |
| | | | yes | 7.1 | 6 | 5.3 |
| MB, shank strip | 400 | 168 | no | 10.4 | 17 | 12.1 |
| | | | yes | 9.5 | 15 | 10.0 |
| Tel. C35, shank strip | 540 | 227 | no | 12.5 | 20 | 21.1 |
| | | | yes | 13.9 | 21 | 20.3 |
| Tel. C35, sh. spot 5x 6' | 540 | 81 | no | 9.7 | 10 | 12.5 |
| | | | yes | 11.0 | 13 | 14.3 |
| Inline, drip spot, 4' dia | 540 | 43 | no | 9.1 | 10 | 9.3 |
| | | | yes | 9.6 | 10 | 10.0 |
| Chlorop. sh. spot 5x6' | 400 | 60 | no | 10.5 | 14 | 14.7 |
| | | | yes | 11.6 | 16 | 16.1 |
| None, yeast extract | 0 | -- | no | 5.5 | 5 | 3.6 |
| | | | yes | 6.6 | 5 | 5.5 |
| | | | *MSD, 95% CI:* | *3.5* | *6* | *9.2* |
| | | | P value, fumigation trt: | *<0.0001* | *<0.0001* | *<0.0001* |
| | | | P value, rotation trt.: | *0.02* | *0.16* | *0.45* |

**Table 4.** Effects of preplant shank strip fumigation treatment with CP, with and without crop rotations or fallowing in Fresno County almond trial planted in 2008

| Pre-plant fumigation treatment | Pre-plant cropping | Increase in trunk circumference 2008 (cm) | PAR absorbtion July 2009 (%) |
|---|---|---|---|
| Control | Peach | 5.6 | 10 |
| | Fallow | 6.9 | 15 |
| | Mustard | 7.2 | 14 |
| | Wheat-Sudan | 6.8 | 14 |
| Chloropicrin 400 lb/A | Peach | 10.5 | 21 |
| | Fallow | 11.6 | 30 |
| | Mustard | 12.2 | 30 |
| | Wheat-Sudan | 12.8 | 30 |
| | *MSD, based on 95% CI:* | *2.1* | *8* |
| | *P value, fumigation trt:* | *<0.0001* | *<0.0001* |
| | *P value, pre-plant cropping trt.:* | *0.0009* | *0.004* |