Almond Fumigant Studies: Continued Research on Methyl Bromide Alternatives and Fumigant Alternatives for Buffer Zones

Project No.: **13-AIR9-Doll**

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Objectives:

1. To continue the work of established fumigant plots for control of Prunus Replant Disease and plant pathogenic nematodes.

2. To continue the development of non-fumigant based control measures for almond replant disease and plant pathogenic nematodes within fumigant buffer zones.

Interpretive Summary:

This project continues the efforts set forth by the USDA-ARS Pacific Area-Wide Methyl Bromide Alternatives project that concluded in June 2012. Several field trials have been established in Merced County and are evaluating fumigant alternatives to methyl bromide and non-fumigant alternatives for buffer zones. These trials are located on sandy soils in almond replant situations with the presence of ring nematode. In all trials, fumigated soils have outperformed the unfumigated control. Fumigants containing Telone-II applied either as a broadcast or rowstrip treatments have provided the greatest growth response. Yield data for the oldest trial was collected in 2012 and from two plots in 2013. All fumigated plots had a higher yield than the control. The effect of field fumigation on nematode populations has been variable. Populations appear to be suppressed in fumigated soils. Re-infestation of soils occurs within 2-3 years after fumigation and sooner if significant soil movement occurs after fumigation. Regardless of nematode re-infestation, trees planted in fumigated soils appear to grow more vigorously and to date have produced more yield. Interestingly, tree growth within the spot fumigation treatments (C35 or chloropicrin) has provided similar growth to rowstrip and broadcast fumigant treatments. We have not been able to identify any fumigant alternatives that have performed as well as pre-plant soil fumigants. In two trials, backhoed tree sites have outperformed the control in tree growth. Yield and growth performance are planned to be followed and will be annually reported.

Materials and Methods:

This work will continue the efforts set forth by the USDA-ARS Pacific Area-wide Methyl Bromide Alternatives project which concluded in June of 2012. Three fumigant projects within Merced County were established over the past four years. All three projects included main plot designs testing fumigant alternatives to methyl bromide. A fourth was established in 2012 to determine fumigant alternatives for buffer zones. The trials include:

Ballico Trial. Planted in the spring of 2011 and located on a sand soil near Ballico, CA. This site compares the effect of tree row strip applications of methyl bromide (MB) at 400 lb/ treated acre, C35 tree row strip applied at 340 lb/ treated acre, Telone II tree row strip applied at 340 lb/ treated acre, Telone II 100% soil broadcast applied at 340 lb/ treated acre, tree site soil dis-infestation using steam injected through a 36" diameter by 24 inch long soil auger, and un-fumigated soil on tree growth.

This trial also contains a secondary experiment investigating tree site applied non-fumigant alternatives in comparison to a control and a C35 fumigated tree row strip applied at 540 lb/acre. These treatments included backhoeing, 50 grams of aluminum phosphide applied to a backhoed tree site, 50 grams of Soilguard biological soil fungicide® (Certis USA) and 12,000 lbs/treated acre of brassica seed meal which were both injected as a liquid suspension using a 24" diameter by 24" length prototype auger.

Varieties include Aldridge, Sonora, and Nonpareil, planted on Nemaguard rootstock and irrigated with solid-set sprinklers. This is a medium vigor plot.

Winton Trial. Treatments were applied to this loamy sand soil near Winton, CA in November, 2011 and trees were planted in the spring of 2012. This trial compares the effect of several fumigants applied at different rates and treated area on tree growth and yield. Treatments included C35 tree row strip applied at 540 lb/ treated acre, C35 tree site spot applied using a GPS guided rig to inject fumigant in a 7'x7' area centered on the tree site applied at 540 lb/ treated acre, C35 tree site spot application, using the method described above, applied at 340 lb/ treated acre, chloropicrin tree site spot application, using the method described above, applied at 340 lb/treated acre, Telone II tree row strip applied at 340 lb/ treated acre, Telone II 100% soil broadcast applied at 340 lb/ treated acre, soil dis-infestation using steam applied through a 36" diameter by 24 inch length soil auger applied at the tree site, and an un-fumigated control.

This site also contains a secondary experiment investigating tree site applied non-fumigant alternatives in comparison to a control and a C35 fumigated row strip at 540 lb/acre. These treatments included backhoeing, 150 grams of aluminum phosphide applied to a backhoed tree site, 50 grams of Soilguard® biological soil fungicide (Certis USA) and 10 ozs of Basamid® (Certis USA) granular fumigant which were both augered into the hole using a 30" diameter by 24" length prototype auger.

Varieties include Sonora, and Nonpareil, planted on Nemaguard rootstock and irrigated with solid-set sprinklers. This is anticipated to be a medium vigor plot.

South Livingston Trial. Planted in the spring of 2010 and located on a loamy sand soil near Livingston, CA. This plot compares the effect of the applications of MB tree row strip applied at 350 lb/ treated acre, 65% Telone II/35% chloropicrin mixture (C35) tree row strip applied at 350 lb/ treated acre, C35 tree site spot application which uses a GPS guided rig to inject fumigant in a 7'x7' area centered on the tree site applied at 350 lb/ treated acre, Telone II 100% soil broadcast applied at 340 lb/ treated acre, and un-fumigated soil on tree growth.

This trial also contains a secondary experiment investigating tree site applied non-fumigant alternatives in comparison to a control and a C35 fumigated row strip. These treatments include soil disinfestation using steam applied through a 30" diameter by 24 inch length soil auger, applications of brassica seed meal applied at two rates, 4,000 and 8,000 lbs/treated acre, and a combination of soil disinfestations and the high rate of the brassica seed meal.

Varieties include Price, Sonora, and Nonpareil, planted on Viking rootstock and flood irrigated. This is a low vigor plot.

North Livingston Trial. Planted in the spring of 2012 and located in sand soil near Livingston, CA. This plot is surrounded by houses, a daycare, and a school. There are considerable areas within the plot that can not be fumigated due to regulations. This trial is in those non-fumigate-able areas adjacent to Telone II tree row strip fumigated trees that have been included in analysis for comparison. All treatments were applied to the tree planting hole/site. The project includes two tree replicates with five blocks (10 tree total), in order to provide the ability to test multiple products. Products that have a positive growth effect were directed to a larger scale trial in 2013.

Treatments in the first experiment included backhoe, Basamid® (Certis USA), steam soil dis-infestation, commercial yeast extract, compost tea (Mid-Valley Ag's L.C.S.), 1% hydrogen peroxide solution, and an untreated control.

Steam treatments were made using 24"diameter and 36" steam injection auger, while other treatments were applied using a 24" diameter by 24" length auger. Granular applications (i.e. Basamid) were sprinkled on the top of the soil and distributed into the soil using a specially designed auger (**Figure 1**). Other products were suspended in 5 gallons of water and injected through the auger at 15 pounds of pressure to help increase product distribution. After application of the products, the auger continued to mix the soil for 45 seconds in order to thoroughly distribute the products in the planting hole.

WIth the exception of the North Livingston trial, treatments within the trials have been monitored for tree growth, yield, and nematode control. Harvest data will be collected upon first harvest – usually the third year, and continued through the fifth year, possibly longer. Diameter and circumference measurements will be made in the dormant period following the year of growth. Visual disease severity rating are assigned during the growing season to on a scale from 0 to 5 (0=healthy and vigorous, 5=dead). Nematodes are sampled from established plots annually or semi-annually in mid-October by collecting soil from the depth of 18 inches within the dripline of the tree. Samples from the same treatment within the block will be pooled, with one sample per block sent in for analysis. Samples will be analyzed for ring, lesion, and rootknot nematode by Nematodes Inc. Samples will include roots and organic debris as a

bucket auger will be used to sample the soil. Trees within the North Livingston trial will only be monitored for growth. A timeline of the nematode sampling and growth and yield is outlined in **Table 1**.

Results and Discussion:

Ballico Trial: Cumulative change in trunk diameter for all fumigants (69.6mm-84.2 mm) was greater than the control and steam treatments (58.6-60.4 mm) (**Table 2**). Trees planted in soil preplant fumigated with the Telone-II broadcast (84.2 mm) treatment outgrew C35 strip (73.9 mm) and MB strip (69.6 mm) treatments. Disease severity ratings (DSR) mirrored tree growth (**Table 3**). All fumigants were rated healthier (0.1-0.8) than the control and steam plots (1.5) with the Telone-II BC and RS treatments rated healthier than the other fumigants (0.1 and 0.4 for Telone-II broadcast and rowstrip, respectively v/s 0.7 and 0.8 for C35 RS and MB RS, respectively). Yield for fumigant treatments containing Telone-II (Telone-II BC and RS, and C35 RS) (228-282 lbs/acre) outperformed MB, steam, and the control (125 - 204 lbs/acre) (**Table 3**). There were no differences in nematodes detected with the annual sampling (**Table 4**).

In the second experiment testing fumigant alternatives, cumulative increase in trunk diameter over the three years was greatest in plots treated with Telone C35 applied to the tree row strip (78.1-mm) (**Table 5**). Aluminum phosphide added to the backhoe hole (70.1-mm) and the backhoe treatment (66.7-mm) outperformed the untreated (57.1 mm) and auger control (57.1 mm). Disease severity ratings indicated healthier trees in Telone C35 treated plots when compared to other treatments (**Table 6**). There were no differences in nematodes detected with the annual sampling (**Table 7**).

Winton Trial: After two seasons, all fumigant treatments (63.4-66.7 mm) outgrew the steam and untreated control (54.3-56.7 mm) (**Table 8**). This included the chloropicrin and C35 tree spot treatments. DSR indicated that all fumigated trees appeared healthier (0.0-0.2) than the control or steam treatments (0.9) (**Table 8**). There were no differences in nematodes detected with the annual sampling (**Table 9**).

In the second experiment testing fumigant alternatives, cumulative increase in trunk diameter was greatest with C35 rowstrip (64.0 mm) (**Table 10**). All other treatments performed equally to the control. DSR mirrored the growth data with C35 RS (0.2) outperforming other treatments. Nematode counts were taken from the C35, backhoe, and untreated plots only, and there were no differences in nematodes detected with the annual sampling (**Table 11**).

South Livingston: After four seasons of growth, all fumigant treatments performed equally (93.9-99.8 mm), and all fumigants outgrew the control (81.3 mm) (**Table 12**). Interestingly among the fumigant treatments, C35 and MB RS outgrew C35 tree spot in 2013, suggesting that the tree spot treatment may be experiencing slower rates of growth as the roots grow into nematode infested soil. This trial was harvested for the second time in 2013. All treatments yielded similarly in 2013, but the cumulative yield for C35 RS, C35 tree spot, and the MB strip (284, 275.9, and 319 lbs/acre, respectively) out yielded the control (145.8 lbs/acre) (**Table 13**). Nematodes, although higher in the control plots, were not significantly different among treatments (**Table 14**).

North Livingston Trial: The Telone-II RS (77.9 mm) had a larger cumulative change in trunk diameter than all other treatments (55.4-65.9 mm) (**Table 15**). Among the non-fumigant alternatives, the backhoe treatment (65.9 mm) had a cumulative growth greater than all other fumigant alternative treatments and control (55.4-59.6 mm). Interestingly, the yeast extract, backhoe, and Telone-II fumigated trees grew similarly in 2013.

Table 1: Sampling Timeline for 2012-2016.

	Nematode Sampling				**Growth/Yield**			
Trial	S Livingston	Ballico	Winton	N Livingston	S Livingston	Ballico	Winton	N Livingston
2012	Yes	No	Yes	Yes	Both	Growth	Growth	Growth
2013	Yes	Yes	Yes	N/A	Both	Both	Growth	Growth
2014	Yes	No	Yes	N/A	Both	Both	Both	Growth
2015	No	Yes	No	N/A	Both	Both	Both	-
2016	No	No	Yes	N/A	-	Both	Both	-

Table 2. Pre-plant soil treatment effects on Nonpareil variety tree growth in a 2010 almond replant trial near Ballico, CA comparing steam and chemical fumigants. Different letters indicate statistically significant difference (ANOVA, Tukey-Kramer HSD $p < 0.05$).

Treatment		**2011 change in trunk diameter (mm)**	**2012 change in trunk diameter (mm)**	**2013 change in trunk diameter (mm)**	**Cumulative change in trunk diameter (mm)**
Fumigant	**Rate (lb/A)**				
Telone II broadcast[1]	340	26.4 a	33.4 a	24.4 a	84.2 a
Telone II strip	340	25.7 a	30.0 ab	23.5 ab	79.2 ab
Telone C35 strip	540	26.1 a	28.6 bc	19.7 bc	73.9 bc
MB strip	400	24.8 a	25.2 c	19.6 bc	69.6 c
Steam	0	20.7 b	21.0 d	17.4 c	58.6 d
Untreated	0	20.8 b	20.4 d	19.2 c	60.4 d
***P* value**		**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

[1] Strip and broadcast applications were 11- and 22- feet wide and the length of the plot. [2]Different letter indicate statistical difference.

Table 3. Pre-plant soil treatment effects on Nonpareil disease severity and yield in a 2010 almond replant trial near Ballico, CA comparing steam and chemical fumigants. Different letters indicate statistically significant difference (Steel-Dwass All Pairs or ANOVA Tukey-Kramer HSD $p < 0.05$).

Treatment		Disease Rating 2011 (0-5 , 0=healthy, 5=dead)	Disease Rating 2012 (0-5 , 0=healthy, 5=dead)	Disease Rating 2013 (0-5 , 0=healthy, 5=dead)	2013 Yield (lbs/acre)
Fumigant	**Rate (lb/A)**				
Telone II broadcast[1]	340	0.1	0.1 b	0.1 a	282 a
Telone II strip	340	0.4	0.2 b	0.4 ab	236 a
Telone C35 strip	540	0.3	0.2 b	0.7 bc	228 a
MB strip	400	0.1	0.2 b	0.8 c	204 b
Steam	0	0.3	1.2 a	1.5 d	125 b
Untreated	0	0.3	1.1 a	1.5 d	140 b
***P* value**		**0.0011**	**<0.0001**	**<0.05**	**<0.0001**

[1] Strip and broadcast applications were 11- and 22- feet wide and the length of the plot. [2]Different letter indicate statistical difference.

Table 4. Nematode counts from fumigant and steam treatments taken after two years of growth at the Ballico fumigant trial. Sampling performed in 2013. No significant differences among treatments were observed (Steel-Dwass All Pairs of ln (count+1), $p>0.05$.

Treatment		Root Knot	Ring	Lesion	Stubby Root	Pin	Free Composite
Fumigant	**Rate (lb/A)**	**----- nematodes/500g soil -----**					
Telone II broadcast[1]	340	6.8	76.8	40	5.6	0	68.2
Telone II strip	340	6	116.8	0	13.6	0	120.2
Telone C35 strip	540	5.2	1.6	2.4	10.8	0	19.4
MB	400	50.4	56	1.6	4	0	13
Steam	0	0.4	62.4	62.4	8.4	0	34.4
Untreated	0	13.6	76.8	40	5.6	0	68.2

Table 5. Effects on tree growth of various non-fumigant treatments compared to Telone C35 row strip near Ballico, CA. Different letters indicate statistically significant difference (ANOVA, Tukey-Kramer HSD $p < 0.05$).

Treatment	2011 change in trunk diameter (mm)	2012 change in trunk diameter (mm)	2013 change in trunk diameter (mm)	Cumulative change in trunk diameter (mm)
C35 tree row strip[1]	26.5 a	31.2 a	20.4 a	78.1 a
Backhoe-incorporated AlP	24.2 b	25.0 b	20.9 a	70.1 b
Backhoe	22.1 c	24.1 bc	20.5 ab	66.7 bc
Brassica seed meal	22.9 bc	21.3 bcd	17.9 ab	60.3 bcd
Untreated	19.5 d	21.2 cd	16.6 b	57.1 d
Soilguard	21.7 c	17.9 d	19.1 ab	58.7 cd
Auger Control	20.2 cd	19.5 cd	18.0 ab	57.1 d
P value	**<0.001**	**<0.0001**	**0.0046**	**<0.0001**

[1] Strip applications were 11- feet wide and length of plot. Aluminum phosphide was incorporated with backhoe, and other treatments were applied with a 24" liquid injection auger.

Table 6. Effects on disease severity of various non-fumigant treatments compared to Telone C35 row strip near Ballico, CA. Different letters indicate statistically significant difference (Steel-Dwass All Pairs $p < 0.05$).

Treatment	Disease Rating 2011 (0-5 , 0=healthy, 5=dead)	Disease Rating 2012 (0-5 , 0=healthy, 5=dead)	Disease Rating 2013 (0-5 , 0=healthy, 5=dead)
C35 tree row strip[1]	0.2 a	0.2 a	0.3 a
Backhoe incorporated AlP	0.2 a	0.7 b	0.9 b
Backhoe	0.2 a	0.9 bc	0.9 b
Brassica seed meal	0.1 a	1.1 cd	1.5 bc
Untreated	0.5 ab	1.2 d	1.5 bc
Soilguard	0.4 b	1.4 d	1.8 c
Auger Control	0.1 a	1.1 cd	1.8 c
P value	**0.0019**	**<0.0001**	**<0.05**

[1] Strip applications were 11- feet wide and length of plot. Aluminum phosphide was incorporated with backhoe, and other treatments were applied with a 24" liquid injection auger.

Table 7. Nematode counts from various treatments taken after two years of growth at the Ballico non-fumigant trial. Sampling performed in 2013. No significant differences among treatments were observed (Steel-Dwass All Pairs of ln (count+1), p>0.05.

Treatment	Root Knot	Ring	Lesion	Stubby Root	Pin	Free composite
	----- nematodes/500g soil -----					
Telone C35 row strip	2.3	31.1	4	39.1	0	25.7
Untreated	23.4	85.7	142.9	19.4	0	29.4
Backhoe	22.9	30.9	35.4	28	0	27.3

Table 8. Pre-plant soil treatment effects on Nonpareil variety tree growth and disease severity in a 2011 almond replant trial near Winton, CA comparing steam and chemical fumigants. Different letters indicate statistically significant difference (ANOVA, Tukey-Kramer HSD p < 0.05).

Treatment						
Fumigant	Rate (lb/A)	2012 change in trunk diameter (mm)	2013 change in trunk diameter (mm)	Total change in trunk diameter (mm)	Disease Rating 2012 (0-5 , 0=healthy, 5=dead)	Disease Rating 2013 (0-5 , 0=healthy, 5=dead)
Telone C35 row strip[1]	540	37.2 a	29.5 ab	66.7 a	0.6 ab	0.1 a
Telone C35 tree spot	340	36.3 a	30.5 a	66.8 a	0.4 ab	0.2 a
Chloropicrin tree spot	340	34.8 ab	29.5 ab	64.3 a	0.4 ab	0.1 a
Telone C35 tree spot	540	33.4 abc	32.3 a	65.7 a	0.3 a	0.1 a
Telone II strip	340	33.1 abc	30.3 a	63.4 a	0.5 ab	0.2 a
Telone II broadcast	340	30.0 bc	33.8 a	63.9 a	0.4 ab	0.0 a
Steam	0	30.4 bc	23.9 b	54.3 b	0.7 b	0.9 b
Untreated	0	28.7 c	28.1 ab	56.7 b	0.8 b	0.9 b
P value		**<0.0001**	**<0.0001**	**<0.0001**	**0.049**	**<0.0001**

Table 9. Nematode counts from various treatments taken after two years of growth at the Winton fumigant trial. Sampling performed in 2013. No significant differences among treatments were observed (Steel-Dwass All Pairs of ln (count+1), p>0.05).

Treatment		Root Knot	Ring	Lesion	Stubby Root	Pin	Free Composite
Fumigant	**Rate (lb/A)**	**----- nematodes/500g soil -----**					
Telone C35 row strip[1]	540	0	0	38.4	0	1.6	27.6
Telone C35 low tree spot	340	0	57.6	4	3.2	87.2	120.8
Chloropicrin tree spot	340	0	12.8	14.4	14	28.8	10.2
Telone C35 high tree spot	540	0	8.0	19.2	22.8	4.8	88.6
Telone II row strip	340	0	19.2	1.6	6.4	0.8	18.6
Telone II broadcast	340	0	16.8	0	9.6	0	5.6
Steam	0	0	106.4	84.8	36	0	11.8
Untreated	0	0	106.4	22.4	36.8	0	84.8

[1] Strip and broadcast applications were 11- and 22- feet wide and length of plot, tree spots applications were 6-feet wide and 6-feet long centered on the tree spot.

Table 10. Comparison of the effects of various non-fumigant treatments and Telone C35 in near Winton, CA. Different letters indicate statistically significant difference (ANOVA, Tukey-Kramer HSD p < 0.05).

Treatment	2012 change in trunk diameter (mm)	2013 change in trunk diameter (mm)	Total change in trunk diameter (mm)	Disease Rating 2012 (0-5 , 0=healthy, 5=dead)	Disease Rating 2013 (0-5 , 0=healthy, 5=dead)
Telone C35 row strip[1]	33.5 a	30.6 a	64.0 a	0.6 b	0.2 a
Untreated	29.7 b	25.8 a	55.5 b	0.8 b	0.9 b
24” auger	28.4 ab	24.3 a	52.7 b	1.0 ab	1.0 b
Al Phosphide	28.3 b	27.5 a	55.8 b	0.8 b	1.0 b
Backhoe	28.0 b	27.2 a	55.2 b	0.7 b	1.0 b
Soilguard	27.2 b	27.2 a	54.4 b	0.5 b	0.6 b
Basamid	27.5 b	27.1 a	54.8 ab	1.5 a	1.1 b
P value	**0.0002**	**0.3433**	**<0.001**	**0.0047**	**0.0047**

[1] Strip applications were 11- feet wide and length of plot. Aluminum phosphide was incorporated with backhoe, and other treatments were applied with a 24” liquid injection auger.

Table 11. Nematode counts from various treatments taken after two years of growth at the Winton non-fumigant trial. Sampling performed in 2013. No significant differences among treatments were observed (Steel-Dwass All Pairs of ln (count+1), p>0.05).

Treatment	Root Knot	Ring	Lesion	Stubby Root	Pin	Free composite
	----- nematodes/500g soil -----					
Telone C35 row strip	0	4.5	0	6.6	2.9	7.3
Untreated	0	0	18	45.3	6.7	33.5
Backhoe	0	37.7	35.4	4.9	0.9	30.3

Table 12. Comparison of the effects of various fumigant treatments in Livingston, CA. Different letters indicate statistically significant difference (ANOVA, Tukey-Kramer HSD p < 0.05).

Treatment	2010 & 2011* change in trunk diameter (mm)	2012 change in trunk diameter (mm)	2013 change in trunk diameter (mm)	Total change in trunk diameter (mm)
Telone C35 row strip	40.2 a	25.3 ab	34.3 a	99.8 a
Telone C35 tree spot	41.4 a	22.9 b	29.6 c	93.9 a
Telone II strip	40.7 a	25.1 ab	31.0 bc	96.8 a
MeBr Strip	39.8 a	25.8 a	32.2 ab	97.7 a
Untreated	31.6 b	19.8 c	29.9 bc	81.3 b
P value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

* Change in diameter from 24 March 2010 to 5 March 2012

Table 13. Comparison of the effects on yield of various fumigant treatments in Livingston, CA. Different letters indicate statistically significant difference (log 10 yield) ANOVA, Tukey-Kramer HSD).

Treatment	2012 Yield (lbs/acre)	2013 Yield (lbs/care)	Cumulative Yield (lbs/care)
Telone C35 row strip	73.0 ab	210 a	284 a
Telone C35 tree spot	65.9 ab	210 a	275.9 a
Telone II strip	65.0 b	184 a	249 ab
MeBr Strip	84.0 a	235 a	319 a
Untreated	40.8 c	105 a	145.8 b
P value	**<0.05**	**<0.05**	**<0.05**

Table 14. Nematode counts from various treatments taken after two years of growth at the Livingston fumigant trial. Sampling performed in 2013. No significant differences among treatments were observed (Steel-Dwass All Pairs of ln (count+1), p>0.05).

Treatment	Root Knot	Ring	Lesion	Stubby Root	Pin	Free Composite
	----- nematodes/500g soil -----					
Telone C35 row strip	0	20	3	8	116.5	320.8
Telone C35 tree spot	0	1	10	1	18.5	7.8
Telone II strip	0	0	7	7	57	10.8
MeBr Strip	0	0	12	1	53.5	73.5
Untreated	0	109	18	10.5	24.5	20.3

Table 15. Comparisons of non-fumigant pre-plant treatments in Livingston, CA. Different letters indicate statistically significant difference (ANOVA, Tukey-Kramer HSD $p < 0.05$).

Treatment	2012 Change in Trunk Diameter	2013 Change in Trunk Diameter	Total Change in Trunk Diameter
Untreated	23.2 bc	32.2 c	55.4 c
24" steam injection[1]	26.4 b	32.7 bc	59.1 c
36" steam injection	25.2 bc	33.4 bc	58.6 c
24" auger	23.3 bc	35.7 bc	59.0 c
36" auger	21.8 c	37.8 bc	59.6 c
1% peroxide solution	24 bc	33.1 bc	57.1 c
Backhoe	23.9 bc	42.0 a	65.9 b
Yeast Extract	23.4 bc	40.6 abc	64.0 c
LCS compost tea	23.1 bc	32.8 bc	55.9 c
Basamid[2]	22 bc	-	-
Telone II strip[3]	33.8 a	44.1 a	77.9 a
P value	**<0.0001**	**<0.05**	**<0.05**

[1] Steam injections were raised to a temperature of at least 160°Frip applications were 11- feet wide and length of plot. Basimid was incorporated with 24" auger only as dry granular and other treatments were applied as slurry with a 24" liquid injection auger. [2]Applications of Basamid caused phytotoxicity due to lack of soil moisture and rain. Due to replanted trees, measurements were not taken in 2013. [3]Telone II was adjacent to plots and was included in analysis as a grower standard.

Figure 1: The liquid injection auger that has been used within the trials to inject and mix the product within the root zone.