ALTERNATIVES FUMIGANTS FOR THE CONTROL OF SOIL PESTS: STRAWBERRY AS A MODEL SYSTEM

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Introduction: Soil fumigation with methyl bromide plus chloropicrin is a standard practice in strawberry nurseries and fruiting fields to ensure pest free planting stocks at the nurseries and disease free plants at the fruiting fields. With the phase out of methyl bromide by the year 2005 as a soil fumigant, the strawberry industry is facing an urgent priority to find an alternative fumigation system. Few fumigant alternatives to methyl bromide are currently available and a little information is known about the effectiveness of such fumigants in strawberry nurseries and fruiting fields for the control of pests and weeds. The residual effects of nursery fumigation on subsequent plant health and vigor are also important in the fruiting field. Objectives of this research are to evaluate the on-site and nursery carryover effects of alternative fumigants on strawberry fruit production.

Materials and Methods: the effectiveness of alternative fumigants were compared to methyl bromide in two consecutive years (2000 and 2001) in a low elevation nursery (LEN) at Ballico CA and three years (2000-to-2002) in high elevation nurseries (HEN) at Susanville and MacDoel CA for strawberry (var.Camarosa) runner plant production. Similarly, on-site and nursery carryover efficacy of alternative fumigants was compared in the fruiting fields in 2000 to 2003 at Oxnard and Watsonville. In all nurseries, flat fumigation was done, while bed fumigation was carried out in the fruiting fields. Experimental design was a randomized complete block with four replications. At Ballico and Susanville, the treatments were methyl bromide plus chloropicrin (MBPic 57:43) at the rate of 450 kg ha^{-1}, methyl iodide plus chloropicrin (MIPic 50:50) at the rate of 392 kg ha^{-1} and a non-fumigated control (NF). At MacDoel, the treatments were methyl bromide plus chloropicrin (MBPic 57:43) at the rate of 450 kg ha^{-1}, methyl iodide plus chloropicrin (MIPic 50:50) at the rate of 392 kg ha^{-1}, Telone C35 (300 L ha^{-1}) followed by Basamid (280 kg ha^{-1}), Chloropicrin (336 kg ha^{-1}) followed by Basamid (280 kg ha^{-1}) and a non-fumigated control (NF). Fumigations were applied in the fall for planting of the mother plants the following spring at MacDoel. Marketable planting stocks from HEN were used to plant fruiting fields at Watsonville and Oxnard. At the fruiting fields, the treatments were methyl bromide plus chloropicrin (MBPic 67:33) at the rate of 392 kg ha^{-1} and chloropicrin (Pic) alone at the rate of 224 kg ha^{-1}. Plants from each HEN treatment were transplanted into plots at the fruiting fields treated with either MBPic or Pic. Standard commercial practices were followed during the growing season. At Watsonville, strawberries were harvested from March/April to August and at Oxnard, berries were harvested from January to June in each year. Cumulative fruit yield was

determined per plant basis. Data were analyzed using the SAS GLM procedure. The fumigation treatments in fruiting yield were nested to the previous HEN fumigation treatments.

Results and Discussion

Fruiting yield at Watsonville: in 2000-01, cumulative marketable and total strawberry fruit yield was significantly greater under on-site Pic treatments than under MBPic treatments (7% and 5% increase, respectively) (Table 1.). Surprisingly, Susanville HEN fumigants had negative carryover effects on fruit yield. In 2001-02, however, fruit yield was significantly greater under the on-site MBPic treatment than in Pic treatment alone (Table 2). MacDoel HEN fumigants had positive carryover effects on marketable fruit yield when the treatment was Pic fb Basamid. In 2002-03, marketable fruit yield was increased (9%) in on-site Pic treatments compared to MBPic treatments. In contrast, non-marketable fruit yield was significantly greater (4%) under MBPic than under Pic (Table 3). MacDoel HEN, fumigants had significant carryover effects on fruit yield at Watsonville. There was no interaction between MacDoel and Watsonville fumigants indicating that the effects of MacDoel and Watsonville fumigants were essentially additive. These results suggest that application of Pic fb Basamid at the HEN increased runner plant production, which eventually improved fruit yield with Pic in the fruiting field. Pic could be a viable alternative to MBPic.

Fruiting yield at Oxnard: in 2001-02, overall fruit yield was less than the 2002-03 yield. The on-site fumigants MBPic had significantly greater marketable and total fruit yield than Pic. However, MacDoel HEN fumigants had no carryover effects on fruiting yield (Table 4.). In 2002-03, on-site fumigation with MBPic resulted in significantly increased (4%) non-marketable fruit yield but marketable and total yield remained similar both under MBPic and Pic alone treatments (Table 5). MacDoel HEN fumigants did not show any carryover effects in the Oxnard fruiting yield. These results suggest that Pic alone could be an alternative fumigant to MBPic.

Table 1. Fruit yields of strawberry at Watsonville in 2001. The Susanville column indicates the source of the plants in the nursery in 2000, and Watsonville column indicates the fumigation in the fruiting field. The Watsonville trial was nested within Susanville.

Susanville	Watsonville	Marketable	Nonmarketable	Total
		----------grams per plant----------		
Control	Pic	1525.7	645.7	2171.6
MBPic	Pic	1436.2	619.0	2055.2
MIPic	Pic	1386.9	614.7	2001.6
Control	MBPic	1385.9	639.7	2025.6
MBPic	MBPic	1329.8	617.0	1946.8
MIPic	MBPic	1318.2	601.7	1919.9
Anova		----------P values----------		
Susanville		0.016*	0.187	0.008**
Watsonville		0.001**	0.655	0.003**
Susanville(Watsonville)		0.614	0.959	0.770

Table 2. Fruit yields of strawberry at Watsonville in 2002. MacDoel column indicates the source of the plants in the nursery in 2001, and Watsonville column indicates the fumigation in the fruiting field. The Watsonville trial was nested within MacDoel.

MacDoel	Watsonville	Marketable	Nonmarketable	Total
		----------grams per plant----------		
Control	Pic	1301.7	535.6	1837.3
MBPic	Pic	1235.8	550.9	1786.6
MIPic	Pic	1278.2	525.0	1803.3
Pic fb Basamid	Pic	1388.4	575.1	1963.4
C35 fb Basamid	Pic	1346.4	553.3	1899.7
Control	MBPic	1520.3	600.1	2120.4
MBPic	MBPic	1474.0	596.3	2070.3
MIPic	MBPic	1526.8	625.0	2151.8
Pic fb Basamid	MBPic	1634.5	640.6	2275.1
C35 fb Basamid	MBPic	1434.1	634.0	2068.1
Anova		----------P values----------		
MacDoel		0.04*	0.24	0.07
Watsonville		<0.0001**	<0.0001**	<0.0001**
MacDoel(Watsonville)		0.47	0.74	0.73

Table 3. Fruit yields of strawberry at Watsonville in 2003. MacDoel column indicates the source of the plants in the nursery in 2002, and the Watsonville column indicates the fumigation in the fruiting field. The Watsonville trial was nested within MacDoel.

MacDoel	Watsonville	Marketable	Nonmarketable	Total
		----------grams per plant----------		
Control	Pic	1270.2	1092.5	2362.7
MBPic	Pic	1244.2	1070.5	2314.7
MIPic	Pic	1153.7	992.9	2146.6
Pic fb Basamid	Pic	1324.6	1059.4	2384.0
C35 fb Basamid	Pic	1220.2	1069.7	2289.9
Control	MBPic	1177.2	1216.1	2393.3
MBPic	MBPic	1132.2	1179.8	2311.9
MIPic	MBPic	1050.8	1106.2	2157.0
Pic fb Basamid	MBPic	1166.9	1249.2	2416.0
C35 fb Basamid	MBPic	1111.0	1176.9	2287.9
Anova		----------P values----------		
MacDoel		0.001**	0.003**	0.0001**
Watsonville		<0.0001**	<0.0001**	0.70
MacDoel(Watsonville)		0.92	0.60	0.99

Table 4. Fruit yields of strawberry at Oxnard in 2002. The MacDoel column indicates the source of the plants in the nursery in 2001, and the Oxnard column indicates the fumigation in the fruiting field. The Oxnard field trial was nested within MacDoel.

MacDoel	Oxnard	Marketable	Nonmarketable	Total
		----------grams per plant----------		
Control	Pic	520.4	99.2	619.7
MBPic	Pic	517.5	89.8	607.3
MIPic	Pic	527.1	99.8	626.9
Pic fb Basamid	Pic	524.9	96.2	621.2
C35 fb Basamid	Pic	544.9	96.0	640.8
Control	MBPic	569.9	91.5	661.4
MBPic	MBPic	585.3	90.6	675.93
MIPic	MBPic	579.4	97.9	677.24
Pic fb Basamid	MBPic	582.4	94.6	677.03
C35 fb Basamid	MBPic	575.4	90.0	665.4
Anova		----------P values----------		
MacDoel		0.79	0.23	0.78
Oxnard		<0.0001**	0.17	<0.0001**
MacDoel(Oxnard)		0.60	0.80	0.49

Table 5. Fruit yields of strawberry at Oxnard in 2003. The MacDoel column indicates the source of the plants in the nursery in 2002, and the Oxnard column indicates the fumigation in the fruiting field. The Oxnard field trial was nested within MacDoel.

MacDoel	Oxnard	Marketable	Nonmarketable	Total
		----------grams per plant----------		
Control	Pic	1208.1	267.8	1475.9
MBPic	Pic	1184.8	262.5	1447.3
MIPic	Pic	1156.4	256.2	1412.6
Pic fb Basamid	Pic	1207.9	277.5	1485.4
C35 fb Basamid	Pic	1152.4	275.2	1427.6
Control	MBPic	1192.8	270.4	1463.2
MBPic	MBPic	1210.3	277.0	1487.3
MIPic	MBPic	1189.2	280.9	1470.1
Pic fb Basamid	MBPic	1202.8	281.4	1484.2
C35 fb Basamid	MBPic	1214.2	287.5	1501.6
Anova		----------P values----------		
MacDoel		0.60	0.20	0.55
Oxnard		0.17	0.01**	0.051
MacDoel(Oxnard)		0.46	0.53	0.36