Pest Management Grants Final Report

Contract No. 97-0231

Evaluation of Alternatives to Methyl Bromide in Strawberry Production

Frank V. Sances, Ph.D.
Alliance for Alternative Agriculture

May 6, 1999

Prepared for California Department of Pesticide Regulation

Disclaimer

The statements and conclusions in this report are those of the Alliance for Alternative Agriculture and not necessarily those of the California Department of Pesticide Regulation. The mention of commercial products, their source, or their use in connection with material reported herein is not to be construed as actual or implied endorsement of such products.

Acknowledgments

This report was submitted in fulfillment of contract no. 97-0231, *Evaluation of Alternatives to Methyl Bromide in Strawberry Production* by Alliance for Alternative Agriculture under the partial sponsorship of the California Department of Pesticide Regulation. Work was completed as of May 3, 1999.

Table of Contents

Abstract

Studies were conducted in 1998 on Camerosa strawberries planted with organic soil amendments and greenhouse grown plug transplants as alternatives to methyl bromide fumigation. These were compared to conventional strawberry production using bare root plants and methyl bromide fumigation. Neither compost alone at high rates or soil inoculation with vassicular arbuscular michoriza (VAM) increased strawberry production to levels approaching conventional practice on this well conditioned soil. Strawberry plug plant technology, however, in non fumigated soil out performed the conventional technology of bare root transplants in methyl bromide/chloropicrin fumigated soil. These data demonstrate that strawberry plug plant technology, adapted to California conditions, offers growers an alternative to methyl bromide fumigation in the nursery, as well as compensating for yield reductions with poor or non fumigated soil in the fruiting field. Further studies are underway in 1999 and 2000 to incorporate this technology with fully organic and conventional production systems at our research facility on the central California coast.

Executive Summary

This research project tested the benefits of high rates of compost and inoculation with vesicular-arbuscular-michorriza in soil on strawberry growth and yields. These alternative organic technologies were compared to conventional grower practice using bare root strawberry transplants planted into methyl bromide/chloropicrin treated soil. The compost increased production with bare rooted transplants, but only at the high rate of 112 mT/ha (50 U.S.T/ac). The yield increase at the high compost rate could have either been the result of added nutrients such as nitrogen, or from indirect effects from suppression of pathogenic organisms by biological control. Plug plants on the other hand, performed superior to all bare root treatments in all soil conditioning treatments studied. These differences were quite evident in the field, and were confirmed through measurements of plant length and diameter. Plug plants grown in non-fumigated soil numerically out produced conventional bare root plants in fumigated soil. The potential for grower utilization of this technology is assured, since the production of disease free planting stock and yield compensation in the fruiting field is of immediate concern in a post-methyl bromide era.

Research Report

Introduction

Recent awareness of reductions atmospheric ozone has given rise to significant efforts to develop alternatives to potential ozone depleting substances such as methyl bromide. In the research sector, both conventional and nontraditional (organic) methods are being investigated for many field, post harvest, and structural pest control uses. In California, methyl bromide is used extensively for pre-plant soil fumigation, alone, or in combination with chloropicrin to eliminate weeds and soil borne disease organisms. It is particularly important to strawberry production, where more than 99% of all strawberry acreage is fumigated with this compound (Calif. Strawberry Commission 1998). Although ozone protection has served as a catalyst for present research into alternatives to methyl bromide, advocates of sustainable agriculture have long held that the practice of soil sterilization leads to long term degradation of the soil (Mortvedt, Buxton, and Mikelson 1987. In strawberry production, however, the economic realities which most growers face require that they maximize short term yields through intense planting bed preparation, which includes the use of methyl bromide/chloropicrin applied under plastic mulch. In this system, soil fumigation also produces a significant growth response with many strawberry cultivars. This phenomenon accelerates growth and markedly increases plant productivity. Currently, it is only through these pest control attributes, and the resulting plant responses, that strawberry production is economically feasible in our state.

The research presented in the following report was conducted by the Alliance for Alternative Agriculture, a non-profit California corporation with Pacific Ag Research, an agricultural technology company that has developed conventional and alternative fruit and vegetable production methods since 1980. All field research plots were maintained at the Alliance Farm near San Luis Obispo, California. Among many vegetable and fruit production projects, the Alliance conducts extensive field studies on chemical and biological controls for soil-borne pathogens as substitutes for methyl bromide. The Alliance group disseminates this information through technical symposia and workshops for California pest control advisors, growers and the general public. The Alliance maintains offices, laboratory and farm facilities in San Luis Obispo, California and Yuma, Arizona, for research and development projects in coastal California the arid southwest.

The project reported here was funded with a grant from the California Department of Pesticide Regulation. Our current methyl bromide alternatives research emphasis for 1999-2000 continues this project with a focus on strawberry plug plant technology and comparisons of conventional, biorational and organic farming systems.

Materials and Methods

<u>Land preparation</u>

Prior to planting, the field of this study had been composted and cover cropped for two years. Previous to 1995, it had been fallow for three years, before which it was cultivated in various cole crops and lettuce for approximately 10 years. The pre-plant soil conditioning program implemented prior to this study year included a broadcast application of compost before each *Phacelia* cover crop at 22.7 metric tons per hectare. The first cover crop in the annual series was *Phacelia* seeded at a rate of 9 kg/ha in August 1996, and the following year in September 1997. This was incorporated to a depth of approx. 20 cm and by disking and cross disking, followed by a seeding of vetch, oat, rye, bell bean and sugar pea cover crop mix, at 90 kg/ha in November 1996, and the following year in December 1997. Hairy vetch was planted following incorporation of the mixed cover crop at 28 kg/ha in April 1996 and 1997. The final hairy vetch cover crop was incorporated to a depth of approx. 40 cm. It had flowered and produced viable seed prior to this incorporation in late September 1997.

The field was cross-disked and listed to form raised planting beds at 1 m spacing, and 40-45 cm in height. Replicated plots were established by marking off discrete sections of planting beds of 10 m each. Each series of treatments were replicated 4 times, creating 13 treatment plots per replicate for a total of 52 experimental plots. On plots receiving compost treatments, compost was measured (fresh weight) for the area equivalent of 56 T/ha (25 US tons/ac) and 112 T/ha (50 US tons/ac) and distributed uniformly on planting bed surfaces. This was then incorporated into the planting beds to approx. 4 cm in depth with garden rakes. Plots receiving methyl bromide fumigation had 67/33 shank applied methyl bromide/chloropicrin injected under black plastic mulch at a rate of 393 kg/ha. Depending on treatment requirements, plots receiving plug and bare root plants were either planted normally or inoculated with Vesicular-arbuscular mycorrhizae by dipping them separately into the formulation immediately prior to planting. In addition to these soil treatments, all plots were fertilized with controlled release fertilizer (Scotts Co. Osmocoat long term strawberry mix, 19-6-12 at 1182 kg/ha product) and fitted with drip irrigation tape at 5 cm depth.

Following planting, plots were overhead irrigated to set plants, and drip irrigated thereafter until harvest. All pest control inputs were performed as required with conventional pesticides applied as needed to control *Botrytis* and spidermites.

Data Collection

Harvest data were collected from March 10 through June 22. All fruit produced in experimental plots were harvested and separated by quality. Following quality separation, fruit were counted and weighed to obtain an estimate of size (gm/fruit).

Plant growth and harvest data were summarized for the season and analyzed by analysis of variance. Mean separation was performed by Duncan's new multiple range test at P=0.05.

Results

<u>Agronomic effects</u>

Weeding requirements

Data are presented for plot weeding requirements by experimental treatment in Table 1. While previous studies by these authors have shown significant reductions in weeding requirements with preplant soil fumigation, these plantings utilized opaque plastic mulch, and therefore, weed populations had minimal impact on growing costs between fumigated and non fumigated soil. Although all soil treatments had statistically similar hand weeding requirements, numerically, the methyl bromide standard and broccoli mulch treatments had the lowest maintenance costs. The cover cropping with *Phacelia* and Vetch had produced abundant seed that created relatively high weeding requirements in all plots. In addition to these, grasses and groundsel, were also abundant in the non-fumigated plots. In the methyl bromide fumigated plot, *Malva* was most prevalent weed present. By commercial standards, all plots were high in weed pressure, which resulted in higher than normal weeding requirements for opaque plastic culture.

Plant growth and development

Plant development among treatments was compared through vigor assessments recorded on a numerical scale of 0-5 (Table 1). A rating of 5 represents maximum vigor at the time of evaluation. Differences were generally small between plots receiving soil conditioning treatments, but plant vigor in the organic treatments were somewhat higher than that of the chemical treatments, although these differences were not statistically significant at P=0.05. It should be noted however, that the organic plots received additional nitrogen and other nutrients from the compost applied prior to planting which was not compensated for in plots receiving conventional practice. Any increase in vigor could thus be attributed to either an increase in nutritional health of plants as a result of applied nutrients directly from the compost, or indirect effects of the increased microbial activity on soil nutrition or pathogen suppression. Further, soil conditioning treatments with plug plants were consistently more vigorous than identical treatments planted with bare root plants. Among the bare root treatments, the methyl bromide standard and broccoli mulch were visibly more vigorous than all other treatments. Plots receiving only VAM inoculation were similar to the untreated control. Again, these differences, although visible during the study across the plots, were not statistically significant (P=0.05).

Plant height and diameter data midseason were also evaluated among soil and plant conditioning treatments (Table 1). As with the plant vigor data above, the differences among treatments were slight. Nevertheless, in this case plant heights were statistically different from each other. Tallest plants were recorded from bare root plants with the methyl bromide standard numerically tallest among them. In contrast, plug plants tended to be more prostrate in growth habits. Further, plant diameter tended to be larger in each plug plant soil conditioning treatment over its bare root counterpar . For example, of the six paired comparisons of soil treatments receiving both bare root plants and plug plants, plug plant data were larger in five of the six cases. The exception being plug plants grown in soil mulched with broccoli. It is thus apparent that the plug plant growth form differs across several soil conditioning treatments, producing a lower, broader plant than conventional bare root technology.

Soil Foodweb

Several components of the soil food web were assayed mid-season, but the three most meaningful parameters are presented in Table 2 (Appendix). These include total fungal biomass, total bacterial biomass, and the ratio of these parameters to one another. While untreated soil was similar in both bacterial and fungal biomass, soil treated with methyl bromide had similar fungal biomass levels to untreated soil, but differed numerically in bacterial activity. These differences are slight (11.4%), and on this analyzed raw data (not transformed mathematically), are not statistically significant. However, this trend should be noted and compared to future data from fumigated soils. Fungal biomass was significantly affected by the addition of compost to soil, but results were not consistent among treatments. The differences in fungal biomass values were greatest in the bare root organic soil amendments, where increased soil fungal populations were evident in these plots. This was particularly true of the high rate of compost, where a 63% increase in total fungal biomass was recorded. Other data with plug plants were more variable, but tended to have higher fungal populations in plots receiving soil amendments. Data for the ratio between bacterial and fungal biomass also differed significantly among treatments.

Plant Productivity

Seasonal data for harvest among soil conditioning and plant treatments are shown in Table 3 (Appendix). Data between replicates were highly variable, however, treatment means followed trends from previous studies by these authors. Although not statistically significant, plug plants numerically yielded more than bare root plants in all soil treatments except the methyl bromide standard. In this case, the methyl bromide standard yielded numerically higher than the untreated broccoli mulch and low rate of compost plots. However, all other soil treatments using plug plants had higher seasonal yields. This trend includes untreated soil compared to the methyl bromide standard. Among treatments with conventional bare root plants, the 50 Tons/A compost numerically produced more flats per acre than any other treatment at 1892 flats/A. This was still lower than the methyl bromide standard, at 2224 flats/A.

Discussion

Data presented above indicate that soil conditioning practices immediately prior to planting in healthy, composted and cover cropped soil have minimal benefit to plant development. The soil foodweb levels at the onset of this study were already high in microorganism activity at the time of planting. Additional biomass in the form of compost, or VAM inoculate, probably were insufficient to increase this activity further. The 112 T/ha compost level had some effect on bare root plants, however, the amount of additional nitrogen in this treatment probably created a highly fertile rhizosphere, which enhanced plant growth and resulted in slightly increased yields. In contrast, owing to their increased vigor, plug plants showed almost no effect from this high rate of compost application.

The growth and yield responses of plug plants were similar among soil conditioning treatments. The increased vigor and yield were also consistent with other studies by the authors (Sances and Ingham,1995, 1996, 1997). In non fumigated soil, plug plant technology produced 61.4% greater yield than bare root technology. This plant production method seems particularly well suited to the Camarosa cultivar, where yields from Camerosa plugs in non-fumigated soil were similar to bare root technology in fumigated soil (2561 vs. 2224 flats per acre respectively). The mechanism for this yield enhancement was evident in the field prior to first harvest. It was observed that plug plants initiate root and shoot development faster and exhibit less transplant shock than bare root plants of similar genetics and conditioning.

Summary and Conclusions

These data agree with previous studies by these authors in California comparing bare root and plug plant technologies in various soil environments. At least with the Camerosa and Chandler varieties, properly grown plug plants perform well in both fumigated and non-fumigated soils. In some cases as occurred here, the increased productivity with this technology can make up yield deficiencies created by pathogenic organisms in non-fumigated soil. That is, plug plants grown in non fumigated soil can demonstrate equivalent yields to bare root plants grown in methyl bromide fumigated soil. It should be emphasized, however, that the soil used in these studies was cover cropped and composted for two years prior to planting with these experimental treatments. While fumigation had significant effects to bare root plants by increasing yields, other commercial fields in the state may have higher pathogen pressure and thus greater impact on both strawberry plant types. In these soils, plug plants will likely perform well, but whether or not the yield increases will surpass conventional technology using bare root plants and methyl bromide fumigation remains to be seen.

Amending soil through VAM inoculation and the addition of compost had minimal effect on plant performance in this study. This was likely the result of the previous year's composting and cover cropping of this field, which would have encouraged soil VAM populations and overall food web complexity. The addition of more organic matter and beneficial organisms in this third year were negligible in relation to that naturally occurring from previous years' soil conditioning programs. The exception was the slight increase in yield from the high rate of compost with bare-root plants. As previously stated, this was likely attributable to additional nutrients compared to non-composted or minimally amended soil.

Further studies are underway at our research center on the Central Coast with large block comparisons comparing plug plants in non-fumigated soil with conventional technology. Further, a hybrid production system is also being evaluated for feasibility using alternative soil fumigation with Telone/chloropicrin, together with plug plants in a third comparison production system. In addition to yields, comparisons of economic feasibility will be made since plug plant production is considerably more expensive than conventional bare root technology. The results from these studies will be reported following termination of harvest in June 2000.

Appendix

Table 1.

	Treatments	Plant Parameters				Yield	
		Weeding $/hectare	vigor 0-5 scale	height cm	diameter cm	Harvest flats/hectare	Size grams/berry
Bare Root	Untreated	4536 a	3.06 a	8.36 abc	22.13 a	3921 a	26.44 a
	Broccoli Mulch	3645 a	3.74 a	9.06 ab	25.56 a	4466 a	26.65 a
	Compost 25 Tons/A	4056 a	3.39 a	8.48 abc	24.23 a	4130 a	26.43 a
	Compost 50 Tons/A	5125 a	3.35 a	8.67 abc	24.48 a	4673 a	27.08 a
	VAM Innoculant	4774 a	2.96 a	8.48 abc	22.06 a	4276 a	27.43 a
	VAM Innoculant+Compost	3912 a	3.11 a	8.22 abc	22.86 a	3863 a	25.87 a
	Methyl Bromide	4925 a	3.64 a	9.99 a	24.81 a	5493 a	26.51 a
Plug Plants	Untreated	5211 a	3.63 a	7.62 bc	24.16 a	6325 a	25.44 a
	Broccoli Mulch	3991 a	3.61 a	7.43 bc	21.75 a	5678 a	25.87 a
	Compost 25 Tons/A	4515 a	3.12 a	7.05 bc	25.69 a	6504 a	27.08 a
	Compost 50 Tons/A	5767 a	3.82 a	7.78 bc	25.62 a	6355 a	24.59 a
	VAM Innoculant	5519 a	3.56 a	7.21 bc	25.56 a	6226 a	24.8 a
	VAM Innoculant+Compost	5167 a	3.6 a	6.9 c	24.83 a	5010 a	25.87 a

Means followed by the same letter do not significantly differ (P=.05, Duncan's new MRT)

Table 2.

Treatments	2/23/98 total fungal biomass ugm/gm	total bacterial biomass ugm/gm	active fungi:active ratio
Bare Root/Untreated	21.6 ab	156.57 a	1.68 a
Bare Root/Broccoli Mulch	31.57 ab	160.9 a	1.09 ab
Bare Root/Compost 25 Tons/A	24.78 ab	161.63 a	1.67 a
Bare Root/Compost 50 Tons/A	35.21 a	191.1 a	1.41 ab
Bare Root/VAM Innoculant	22.34 ab	164.43 a	1.26 ab
Bare Root/Compost/VAM Innoculant	18.4 a	174.73 a	0.82 ab
Methyl Bromide Standard	23.15 ab	174.88 a	1.64 ab
Plug Plant/Untreated	22.59 ab	155.02 a	1.52 ab
Plug Plant/Broccoli Mulch	18.74 ab	176.85 a	1.43 ab
Plug Plant/Compost 25 Tons/A	19.01 ab	173.33 a	1.13 ab
Plug Plant/Compost 50 Tons/A	26.52 ab	171.47 a	0.79 b
Plug Plant/VAM Innoculant	28.55 ab	162.22 a	1.46 ab
Plug Plant/Compost/VAM Innoculant	26.03 ab	166.9 a	1.12 ab

Means followed by the same letter do not significantly differ (P=.05, Duncan's new MRT)

Table 3.

Various experimental soil treatments compared to the Methyl Bromide Standard. Flats/acre are U.S. No. 1 fruit are averages obtained from 4 replicate plots per treatment. These means are non-transformed values (raw) "Yield Increase"

	Marketable Strawberry Flats/Acre		
Treatment	Conventional Bare Root *(flats/A)*	Alternative Plug Plants *(flats/A)*	Yield Increase *(%)*
1 Untreated	1587	2561	61.4
2 Broccoli Mulch	1808	2299	27.2
3 Compost @ 25 T/A	1672	2633	57.5
4 Compost @ 50 T/A	1892	2573	36.0
5 VAM Inoculation	1731	2521	45.6
6 Compost+Inoc.	1564	2029	29.7
7 Methyl Bromide Standard	2224	n/a	n/a

indicates percent change in yield of the new technology plug plants as compared to conventional bare root plants. *Spring 1998, San Luis Obispo, CA*

Figure 1

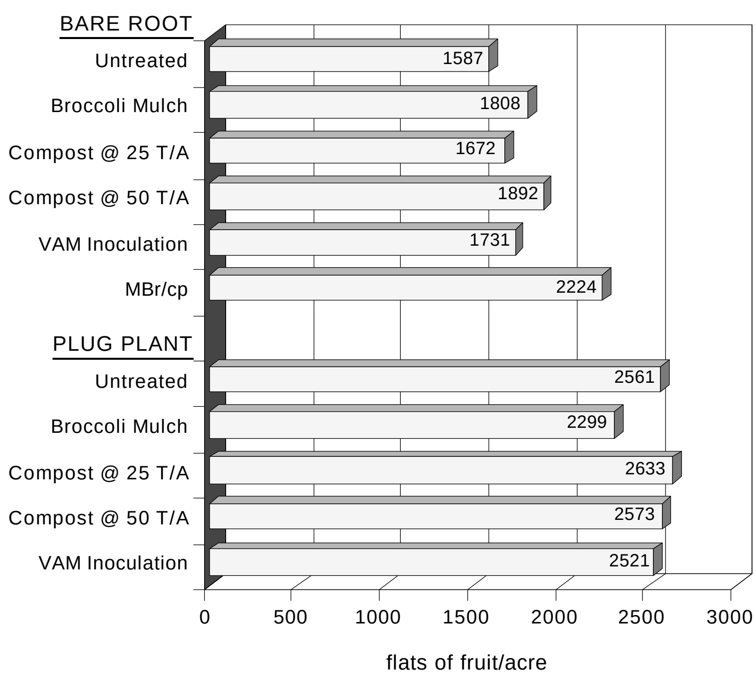

Figure 1. Average seasonal yields from organic soil amendments and alternative strawberry transplants, compared to conventional production that relies on methyl bromide/chloropicrin fumigation and bare root transplants. *Spring 1998, San Luis Obispo, CA.*