FOUR YEARS RESEARCH ON IMPROVED SOIL SOLARIZATION AND OTHER ALTERNATIVES TO METHYL BROMIDE ON STRAWBERRY CROPS

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ABSTRACT

To develop alternatives to MB, it is necessary to study not only the efficacy of the treatments but also their long-term effects and the feasibility of repeating the treatment in the same field several years consecutively. A four year experiment was carried out in a strawberry field in which there were established seven treatments: non treated control; standard dosage application of MB (60g/m^2); half dosage application of MB (30g/m^2) using VIF tarp; moderate rates of manure (5kg/m^2) combined with solarization; reduced dosages of metam-sodium (MS) (35g/m^2) combined with solarization; MS at standard dosages (144g/m^2); and fresh manure at high rates (15kg/m^2). The solarization treatments were split in two sub-treatments in the last year, in such a way that a half of the solarization combined with manure treatment of the third year was replaced by solarization combined with MS and *vice versa*, so that the experiment had a total of 9 treatments. After four years of research, we can infer that improved solarization with manure offers the better possible alternative when data of the first two years are considered but there is a loss of efficacy if these treatments are uninterruptedly applied longer than two years. The replacement of MS for manure produced less marketable yield losses than the reverse replacement.

Keywords: methyl bromide, alternatives, solarization, metam-sodium, strawberry

INTRODUCTION

The strawberry industry is very important in Spain, ranking second in the world in strawberry production for fresh consumption right after the United States. Most of the land cultivated in strawberries is disinfested before planting using MB as a standard cultural technique to avoid disease incidence.

The MB consumption in Spain has been reduced by 50% since 1998, and it will continue declining up to the phase out in January 2005, according to the schedule approved by the EU. This means that there is an urgent need to find possible chemical and non-chemical alternatives to MB before that deadline.

As a consequence of the progressive importance that organic strawberry fruit production is acquiring in the European market, this cultural production system has to be included among the present and future studies; therefore, solarization by itself or even combined with fresh manure (Gamliel & Stapleton 1997) to increase the toxic effect of volatile compounds to control soil-borne pathogens, have to be taken under consideration. Furthermore, the fact that the soils of Valencia area are loam or clay ones with low drainage and they have a low organic mater content, offers an additional reason to examine the possibilities of these organic techniques as alternatives to MB. Also the possibility of reducing dosage of MB while keeping effectiveness was studied in our area by combining with solarization or using a VIF sheet (Cebolla *et al.* 1996) with a subsequent reduction of emissions to the atmosphere.

Chemical alternatives to MB, that are not harmful to the ozone layer, have been suggested by using fumigants such as MS at standard dosages or at low ones combined with solarization. Therefore, they have to be considered in this type of studies equally.

MATERIALS AND METHODS

The aim of this experiment was to compare the behaviour of treatments reducing MB dosage by using VIF tarp (3); fresh manure at large rates (15 kg/m^2) (7) and moderate rates (5 kg/m^2) combined with solarization (4); metam-sodium (MS) at standard dosages (140 g/m^2) (6) or reduced dosages (35g/m^2) combined with solarization (5). Non treated control (1) and standard dosage application of MB (60g/m^2) (2) were used as references. Tarping period for MB treatments was 5 days while the solarization treatments was 5 weeks. Manure

composition was 75% fresh sheep and 25% poultry for the solarization improved treatment (4) and for the manure treatment itself (7).

The ranges of the main characteristics of fresh sheep manure for treatments 4, 5' & 7 were 51.7 –52.3 for % dry matter; 58.5-67.9 for % total Organic Matter; 1.85-2.08 for % Total Nitrogen and 17.2-18.7 for C/N ratio; and for poultry manure the ranges were 54.2-81.2 for % dry matter; 51.3-70.3 for % total Organic Matter; 2.95-7.29 for % Total Nitrogen and 6.6-13.8 for C/N ratio.

The solarization treatments were split in two sub-treatments in the fourth year, in such a way that a half of the solarization combined with manure treatment(4) was replaced by solarization with MS (4') and a half of solarization combined with MS was replaced by solarization combined with manure (5') . Manure was buried with deeply ploughing followed by irrigation once in solarization treatments and three times in the manure (7).

The experimental design consisted of four years cropping with a complete randomised block with three replicates originally (first year). The treatments were repeated on the same plots for three additional years in two locations instead of three. Single plots were established with a large size (400 to 600m^2). Due to the large differences among the marketable yield variance and that of the control in successive years, the data were converted with logarithmic transformation for statistical analysis. Percentage data were converted with arcsin transformation for statistical analysis. Duncan's multiple range tests were done for statistical comparison among treatments.

Some small pieces of roots infested by *Fusarium* were buried at 10 and 30 cm of depth before treatments application, and recovered on Komada selective media (Komada 1975) after the treatment to monitor the effect on inoculum. Missing plants were replaced with new ones to keep the plant population.

The incidence of weeds in each treatment was monitored all along the growing season as the time of removing weeds plus cleaning the plants.

Cold stored plants of cv. Pajaro were planted in two-row bed at 30cm apart in the first and fourth years while cv. Camarosa was used at 35cm apart in the second and third years of experimentation. Two variables were used for estimating plant vigour: plant diameter and plant height.

Marketable yield (expressed in g/m^2) and percentage of second quality fruit yield over marketable yield were recorded.

RESULTS

No important pathogens were detected in the soil or plants. Nevertheless, soil fatigue was observed, due possibly to the presence of a fungal complex in which *Fusarium* spp participates as a main component. Results on survival of *Fusarium* spp from small pieces of roots (Table 1) show that control and manure treatments do not destroy inocula, independently of the depth of sampling. VIF and improved solarization treatments are effective on the surface, but not as much as standard MB in depth. Only standard MB treatment eliminated completely the inoculum. However, solarization combined with manure (4) is promising in this aspect, too. The efficacy of solarization with MS has declined in the fourth year with respect to the first one. The sub-treatments (4' and 5') applied in the fourth year did not improve the fungicidal efficacy of the disinfestation.

Table 1. Survival percent of *Fusarium* after disinfestation, from biological probes.

Year	1998		1999		2000		2001	
Treatment	10cm	30cm	10cm	30cm	10cm	30cm	10cm	30cm
1 Control	100	100	100	100	100	100	100	100
2 MB60	0	0	0	0	0	0	0	90
3 MB30VIF	0	2.5	5	50	0	100	0	5
4 Sol.+Manure	0	22.5	5	10	0	60	0	20
4' SolMV							25	90

Year	1998		1999		2000		2001	
Treatment	10cm	30cm	10cm	30cm	10cm	30cm	10cm	30cm
5 Sol.+MS	12.5	50	0	55	0	50	20	45
5' SolVM							40	60
6 MS	12	40	10	75	0	50		
7 Manure 15	100	100	100	100				

Solarization combined with manure treatment (4) was similar to MB treatments in plant vigour the first two years while solarization combined with MS was similar to that one the first year only. In the following years MB treatments showed better plant vigour than the rest of them. Control and manure treatment (7), when it was applied, produced less vigorous plants. Plant failure and small plant size in manure treatment (7) could be due to phytotoxicity caused by excess manure.

The effect of weeds was significantly higher in manure and control. From the point of view of weed control, all other treatments had a similar effect as MB treatments along the experiment.

Results concerning earliness are not fully representative because of the variability in environmental conditions from one year to another (cold temperatures in winter 1998-99, severe drought in 1999-2000, and early high temperatures and drought in 2000-2001). Despite these abnormalities, there is a slight trend to increase earliness in the improved solarization treatments if we take into account the results in a global manner.

Results of marketable yield and percentage of second quality fruit yield are shown in Table 2. Duncan multiple range tests for marketable yield can offer us an approach about the efficacy of every treatment although they had to be done for each year independently because of the change of the variety and the large differences in climatic conditions from one year to other.

Table 2. Marketable yield and % of class 2 quality fruit yield over marketable along the four years.

	Marketable yield (g/m^2)				% Second quality fruit yield			
Treatment	1998	1999	2000	2001	1998	1999	2000	2001
1 Control	2325 c	2039 c	1150 c	603 d	16.2 c	23.1 b	27.7 e	20.5 c
2 MB60	3956 a	3835 a	2852 a	3076 a	8.5 a	14.6 a	12.3 a	10.9 a
3 MB30VIF	3735 a	3547ab	3123 a	3048 a	8.6 a	13.9 a	13.1 a	11.4 a
4 Sol.+Manure	4090 a	3011ab	2029 b	1553 bc	10.3 a	18.3 ab	21.0 d	19.0 bc
4' SolMV				1464 c				15.7 b
5 Sol.+MS	4028 a	2815 b	2014 b	1803 bc	9.7 a	18.9 ab	18.5 cd	16.5 b
5' SolVM				1973 b				17.0 bc
6 MS	3104 b	2131 c	1924 b		11.3 ab	23.3 b	19.5 cd	17.7 bc
7 Manure 15	2069 c	1003 d			15.1 c	34.2 c		

Regarding marketable yield, we can observe that the more stable treatments are those based on MB although all treatments seem to decline in productivity along the years.

Solarization with manure treatment does not differ significantly from MB treatments in the first two years. Nevertheless, it moves to a group of classification different from MB in the last two years. Solarization combined with MS belongs to the MB group of classification the first year only.

Results of MS treatment occupied an intermediate position while it was applied. Solarization improved with MS, even at reduced dosages works better than standard MS always. The worse results were obtained with the control (1) and manure (7) treatments. If we take into

account the results of marketable yield for 4, 4' , 5 and 5' treatments in the last year, we realise that the effect of replacing manure for MS (4') is worse than that one caused by the replacement of MS for manure (5'). In fact, differences between treatments 4 and 5 are not significant in the last year while differences between treatments 4' and 5' are significant. With respect to solarization combined with MS at the dosage used in this research, results were not promising after four consecutive years of application on the same plot. Maybe this lack of effectiveness could be corrected by increasing the dosage of this fumigant.

Regarding second quality fruit yield, results indicate that MB treatments offered the lower percentage and the higher stability as well. Improved solarization treatments remain at the same level as MB in this aspect in the first two years only. The worse treatments were manure and control.

CONCLUSIONS

After four years of research, we can infer that improved solarization with manure offers the better possible alternative when data of the first two years are considered but there is a loss of efficacy if these treatments are uninterruptedly applied longer than two years. The effect of replacing MS for manure had less marketable yield losses than the reverse replacement. The only treatment that gives similar results to standard MB in marketable yield, and fruit quality is the MB 30g/m^2 with VIF sheet. This treatment allows us to follow the EU regulations of reducing consumption of MB up to its phase out.

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