CHEMICAL AND NON CHEMICAL ALTERNATIVES TO METHYL BROMIDE IN THE AREA OF VALENCIA

Vicent Cebolla*[1], Rafael Bartual[1], Alfonso Giner[5], Julia Busto[1], F.Pomares[1], S. Zaragoza[1], J.J. Tuset[1], P. Caballero[1], M. Mut[1], B. Cases[1], MD de Miguel[4], P. Fombuena[5], J.V. Maroto[3], A. Miguel[2], J.L. Porcuna[2].

[1]Instituto Valenciano de Investigaciones Agrarias (IVIA). Moncada (Valencia) Spain. [2]Conselleria Agricultura. Generalitat Valenciana. [3]Universidad Politécnica de Valencia. [4]Universidad Politécnica de Madrid. [5]Cooperativa Valsur

1- Introduction

Methyl bromide (MB) is used principally as a soil fumigant to control a wide spectrum of soil borne diseases, pests and weeds. Because of its versatility and low cost, so far there is no single chemical alternative that can replace MB in all of its many uses as a soil fumigant. Despite of it, research efforts should be conducted to find new chemical alternatives before its phase out in 2005 because the possibilities of keeping the use of MB as critical for some crops will be very restrictive presumably.

The Spanish Agricultural Department has been funding since 1997 a research project to provide new alternatives to MB as a fumigant for soil disinfestation in strawberry crops for the main strawberry production regions in the country. In the case of the area of Valencia, the Agriculture Department of Generalitat Valenciana (Regional Government) gives an additional financial support to carry out trials with strawberries among other crops.

Strawberry industry is very important in our country from the economic and social point of views. In fact Spain is the second country in the world in strawberry production for fresh consumption, right after the United States. Most of the land cultivated of strawberries is disinfested using MB as a standard cultural technique before planting to avoid disease incidence. Its beneficial effect on the crop in absence of a characterised pathogen is very appreciated by farmers in general, and by strawberry growers in particular.

Distribution of MB in Spain has been already reduced in a 25 % since 1998, according to the schedule approved by EU, and it will continue descending up to the phase out on January the 1st of 2005. Meanwhile, the dosage reduction to adapt to the MB phase out and treatments without MB has to be studied. Therefore, our country is specially interested in supporting this research project to find alternatives to MB.

In order to focus this problem for each particular region in an appropriate way, we must take into account the specific climatic and soil conditions, as well as the size of rural property, to provide feasible alternatives to MB. The area of Valencia shows a Mediterranean climate, loam to clay soils with low drainage and poor organic matter content, and small plot size.

We consider that some of the requirements to consider a treatment as an alternative to the use of MB are: (a) the feasibility of repeating the treatment and crop in the same land several consecutive years without loses in fruit quality and yield; (b) its long-term effect; (c) the occasional occurrence of harmful side effects.

We are considering in this work two examples in strawberries among all the experiments carried out. The former, in “La Canal”, considers two consecutive years repeating treatment and crop on the same plot, the latter in ”Bolbaite Nou” only for the first year and includes some complementary chemical treatments.

2- Material and methods

2-1 The experiment, in “La Canal”, has the aim to compare the behaviour of treatments reducing MB dosage by using VIF tarp (3); fresh manure at large rates (15Kg/m^2) (7) and moderate rates (5Kg/m^2) combined with Solarization (4); Metham-Na at standard dosages (140g/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 for improved Solarization treatment was 5 weeks.

Manure composition was 75% sheep and 25% chicken for Solarization improved treatment and Manure itself. Manure was buried with deeply ploughing followed by irrigation once in the former and three times in the latter.

The experimental design consisted in a two years crop with a complete randomised block with three replicates originally (1st year). The treatments were repeated on the same plots for a second year but one

of the replicates had to be removed. In order to be close to the reality, single plots were established with a large size (400 to 600 m^2). No important pathogens were detected in the soil or plants, nevertheless soil fatigue was observed, due possibly to a fungal complex in which *Fusarium* spp. participates as a main component.

Some small pieces of roots infested by *Fusarium* were buried at 10 and 30 cm depth before application, and recovered on Komada selective media after the treatment served to monitor the effect on inoculum. Plant failure was registered two weeks after planting date by counting the dead plants. 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 by time of removing weeds plus cleaning the plants, expressed in minutes per plant (min/plant).

Cold stored plants of cv. *Pajaro* were planted in two-row bed at 30cm apart in the 1st year while cv. *Camarosa* was used at 35cm apart in the 2nd year of experimentation. Two parameters were used for estimating plant vigour i.e. plant diameter and plant height, both expressed in centimetres (cm).

Yield was individually registered for each of the three categories (1st Quality, 2nd quality and debris) and expressed in grams per plant (g/plant). Earliness was considered as the yield harvested before 1st of May. Quality of the yield was measured as average 1st quality fruit weight, expressed in grams per fruit (g/fruit). Sample size was 20 fruits randomly chosen in each picking. Commercial yield and percentage of 2nd fruit quality on commercial yield were registered too.

2.2 the experiment "Bolbaite Nou" included four treatments: Non-treated control (1); fumigation with MB at the standard rate of 60g/m^2 (2); Telone (a well known nematocide) application at the dosage of 18 g/m^2) followed by Metham-Na application at the rate of 108g/m^2 (3); and Telone C35 (a mixture with 65% of Telone and 35% of Chloropicrine) at the dosage of 28g/m^2.

The application of MB was done according to the usual cold technique, covering the plot with polyethylene sheet. Tarping period was 5 days. Concerning treatment 3, the correspondent single plots were moistened by a drip irrigation system until soil moisture achieved the appropriate level to proceed to the application of Telone II immediately afterwards. The following day Metham-Na was applied using the same irrigation system at the indicated dosage. In the same way the treatment based on Telone C35 was applied when soil moisture had the appropriate level to proceed to it.

Cold stored plants of *cv. Camarosa* were planted in late summer in a two-row bed. The distances between plants within the same row and between beds were 35 cm and 1.1 m, respectively.

A sample of plants picked from the previous strawberry crop was analysed to detect possible presence of fungal pathogens in order to know the health status of the soil previous to planting. No important pathogens were detected in the plants although soil fatigue was observed, due possibly to a fungal complex in which *Fusarium* spp. participates as a main component.

Plant vigour was qualitatively estimated according to a scale ranging from 1 (low vigour) to 5 (maximum vigour). This evaluation was done in the mid-harvesting period. Chi-square test was done to perform the hypothesis test to determine whether or not to reject the idea that plant vigour and treatments are independent. Effect on inoculum, control of weeds, yield, earliness and fruit quality was studied like in the first experiment.

The experimental design was a completely randomised design (CRD) with three replication in one location. Single plot size was established in a relatively large dimensions (300m^2) to have a good approach to reality.

Duncan's Multiple Range Test was used, for statistical comparisons among treatments for the different quantitative traits under study, in both experiments.

3- Results

3.1- Results on survival of *Fusarium* spp from small pieces of roots in "La Canal" (Table 1.1) show that control and Manure treatments do not destroy inocula independently of the depth of sampling. However MB and improved Solarization treatments are effective on surface but not in depth. Only standard MB treatment eliminates completely the inoculum. However Solarization combined with manure is promising in this aspect too.

Results concerning plant failure (Table 1.2) show that mortality level of plants is quite low, except in the case of manure treatment, which is significantly higher than the rest of treatments in both years.

Plant size (Table 1.2), both in diameter and height, show two homogeneous groups, the best including MB treatments, improved Solarization and Metham-Na in the 1st year. In the other group Control and Manure treatments show the smaller plants. The 2nd year Metham-Na loses efficacy and Manure treatment plants are significantly smaller than Control ones. The general pattern in vigour offers a similar trend with independence of the variety we planted. Plant failure and small plant size in Manure treatment could be due to phytotoxicity caused by excess of manure.

The effect of weeds (Table 1.2) was significantly higher in Manure and Control treatments in the 1st year only. From the point of view of weed control, any other treatment has a similar effect compared with MB treatments in both years of experiments.

Results concerning earliness (Table 1.3) are not fully representative because of excessive cold temperature in winter 98-99. In fact cv. *Camarosa* is well known to be an earlier type than cv. *Pajaro*. However the results of second year are the opposite of this for that reason. Taking into account the results of the 1st year only, there is a slight trend to increase earliness in the improved Solarization treatments

Although the yield is not comparable from one year to the other because of the change of variety, parameters related with yield and fruit size show similar pattern. Results of total and commercial yield (Table 1.3) show the same pattern both years. MB and improved Solarization treatments do not differ in these traits significantly in the 1st year. Solarization combined with Metham-Na loses efficacy in the 2nd year if we compare results with those obtained with MB treatments and Solarization combined with manure. In fact it differs with standard MB treatment significantly while it did not the 1st year. In both years Metham-Na treatment was placed in an intermediate position and the worse results were got with the Control and Manure treatments. First quality fruit yield show the same pattern than total and commercial yield in the 1st year, but the second year results are better in those treatments based on the application of MB.

From stand point of view of fruit size (Table 1.4) no treatment offers any possibility to replace MB treatments. This situation occurs in both years. Results of 2nd fruit quality indicate that MB treatments offer the lower rates although they do not show significant differences with improved Solarization treatments in both years. Then the only treatment that gives similar results than standard MB in yield, earliness, and fruit quality is the MB 30g/m^2 with VIF sheet. This treatment allows following the EU regulations of reducing consumption up to the MB phase out.

With respect to Solarization combined with Metham-Na at the dosage used in this research, results were not promising after two consecutive years of application on the same plot. Maybe this lack of effectiveness could be corrected by increasing the dosages of this fumigant or improving the application system.

3.2- Results on survival of *Fusarium* spp. from pieces of roots in "Bolbaite Nou" (Table 2.1) show that the control treatment does not destroy inoculum, independently of the depth of sampling. On another hand treatments (3) and (4) reduce the amount of fungal structures although Telone C35 and Telone II+ Metham-Na at in a different way. The former is more effective in the upper layers while the later is better in deeper ones. Anyway the better results were achieved with the application of MB in this aspect.

Statistical analysis of plant failure (Table 2.1) shows that there is no significant difference among treatments including the control. To the contrary Chi-square test for plant vigour show that there is a dependence between treatments and plant vigour, since P-value (0.138) is less than 0.05 at the 95% confidence level. Obviously, all of the treatments show higher plant vigour when compared with the control. There is a slight increase in plant vigour when MB is applied.

The incidence of weeds, (Table 2.1) was significantly higher ($P<0.05$) in the case of control when compared with the rest of all treatments. Standard MB treatment is the most effective one from the weed control stand point of view although there is not significant difference with Telone C35.

Results of commercial and 1st quality fruit yield (Table 2.2) show that all treatments differ significantly from the control. The standard MB and Telone C35 treatment are similar, the former being significantly different from Telone + Metham-Na. When total yield is considered, MB treatment is highly significant different with the rest of them. However, earliness is similar in all treatments except for the control, which was significantly superior to them. The low magnitude of the values for early yield are due to the unusual cold temperatures that were registered in winter 1998-1999 causing a substantial loss of earliness.

First quality average fruit weight was our references on quality of the production. Statistical analysis for fruit weight (Table 2.2) show that standard MB and Telone C35 offered similar fruit weight and all of the

treatment are significantly different from the control. Once again, standard MB and Telone C35 are the better treatment in this aspect

4- Conclusions

As a conclusion, from "La Canal" results, we can say that some treatments can replace MB in the yield and plant vigour aspect. To the contrary none of the treatments considered under study, except VIF treatment, could be an alternative to standard MB from the stand point of view of fruit size. Particularly Solarization combined with manure, in a general context, could be a possible alternative, specially in small farms where manure supplies are available and make it economically feasible.

Although we are aware that results of just one year of research in "Bolbaite Nou" are not enough to arrive to final conclusions, there is a hope that new chemicals or combinations between them could be alternatives to MB. In fact Telone C35 is the only treatment that can be considered as effective as MB in productive traits as well as fruit quality, weeds costs, and vigour.

If Telone C35 keeps the same results in all other experiments, could be considered as an alternative to MB in strawberry crops in our area. This research must be pursued to examine its long-term effect.

As a matter of fact some of the treatments are as good as MB in some of the experiments, but MB treatments are always among the best ones. More research is needed in order to increase the reliability of the alternatives before the phase out of MB.

Table 1.1. Survival rate of *Fusarium* spp. in root pieces at two depths after disinfestation in "La Canal" experiment.

	Depth	
	10cm	30cm
1 Control	100	100
2 Br60PE	0	0
3 Br30VIF	5	50
4 Sol+Manure 5	5	10
5 Sol+Metham	0	55
6 Metham-Na	10	75
7 Manure 15	100	100

Table 1.2. Removing weeds plus cleaning plants time (min/plant) and plant failure after planting and plant vigour at mid season in "La Canal" experiment.

	Removing weeds time		Plant failure %		Plant Diameter (cm)		Plant Height (cm)	
	1998	1999	1998	1999	1998	1999	1998	1999
1 Control	0.40 bc	1.26 b	2.06 ab	5.21 a	22.4 b	24.8 bc	16.0 b	22.8 c
2 Br60PE	0.20 ab	0.83 a	0.66 a	2.98 a	26.6 a	29.5 a	23.8 a	30.1 a
3 Br30VIF	0.19 a	0.7 a	0.98 a	3.93 a	27.0 a	29.6 a	22.7 a	29.9 a
4 Sol+Manure 5	0.28 abc	0.79 a	3.54 ab	5.49 a	28.0 a	29.3 a	23.3 a	28.9 a
5 Sol+Metham	0.26 abc	0.81 ab	1.38 a	4.29 a	28.3 a	27.1 ab	22.7 a	27.4 ab
6 Metham-Na	0.23 ab	0.85 ab	1.65 a	4.11 a	25.2 ab	23.5 c	20.9 a	23.9 bc
7 Manure 15	0.44 c	1.03 ab	9.39 b	10.11 b	22.2 b	19.0 d	16.7 b	17.3 d

Table 1.3. Yield in the 1st and 2nd year of planting in "La Canal" experiment.

	Total yield		1st Quality yield		Early yield		Commercial yield	
	1998	1999	1998	1999	1998	1999	1998	1999
1 Control	335.9 c	438.5 c	271.2 c	321.8 d	112.4 cd	49.3 a	319.7 c	392.5 c
2 Br60PE	561.0 a	807.2 a	497.3 a	656.4 a	127.4 abc	40.0 ab	544.0 a	738.2 a
3 Br30VIF	531.3 a	738.0 ab	472.3 a	610.3 ab	117.5 bcd	36.4 ab	513.5 a	682.7 ab
4 Sol+Manure 5	585.1 a	635.6 b	507.2 a	497.2 bc	144.4 ab	21.7 b	562.4 a	579.5 ab
5 Sol+Metham	579.6 a	585.8 bc	501.3 a	456.5 cd	149.8 a	48.0 a	553.9 a	541.8 bc
6 Metham-Na	442.5 b	452.2 c	382.4 b	343.1 d	120.8 abc	27.6 ab	426.8 b	410.2 c
7 Manure 15	300.5 c	228.7 d	243.5 c	142.7 f	90.1 d	33.5 ab	284.5 c	193.1 d

Table 1.4. Fruit size of 1st quality and percentage of 2nd quality yield in "La Canal" experiment.

	Fruit size 1st Quality		2nd quality per cent	
	1998	1999	1998	1999
1 Control	17.6 c	17.3 b	16.2 c	23.1 b
2 Br60PE	19.4 a	19.5 a	8.5 a	14.6 a
3 Br30VIF	19.6 a	20.1 a	8.6 a	13.9 a
4 Sol+Manure 5	18.7 b	18.2 b	10.3 a	18.3 ab
5 Sol+Metham	18.6 b	18.2 b	9.7 a	18.9 ab
6 Metham-Na	18.6 b	17.7 b	11.3 ab	23.3 b
7 Manure 15	18.4 b	16.1 c	15.1 bc	34.2 c

Table 2.1. Plant failure after planting and plant vigour at mid season and Removing weeds plus cleaning plants time (min/plant) and survival rate of *Fusarium* spp in root pieces at two depths after disinfestation in the "Bolbaite Nou" experiment.

	Plant failure %	Plant Vigour (1-5)	Removing weeds time	Weeds %	Survival rate	
					10cm	30cm
1 Control	4.2 a	3.0	1.04 a	16.7 a	100	100
2 Br60PE	4.2 a	4.7	0.77 c	4.3 b	0	0
3 Telone+MethNa	5.8 a	4.0	0.88 b	4.3 b	13.3	6.6
4 Telone C35	6.2 a	4.3	0.84 bc	3.0 b	6.6	30

Table 2.2. Yield in the 1st year of planting in the "Bolbaite Nou" experiment.

	Total Yield	1st Quality Yield	Early yield	Commercial yield	Fruit size 1st Quality
1 Control	326.7 a	250.9 a	44.7 a	295.2 a	17.7 a
2 Br60PE	533.8 c	415.1 c	23.0 b	485.6 c	19.4 c
3 Telone+Meth-Na	417.8 b	316.3 b	28.0 b	279.9 b	18.7 b
4 Telone C35	464.1 b	368.8 bc	25.3 b	427.5 bc	19.2 bc