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Validation of a Methyl Bromide Alternative Program for Fresh-Market Tomato

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Abstract: With methyl bromide (MBr) phase-out, extensive research has been conducted to find a suitable replacement. Although a great deal of data from small-plot trials has been reported, there have been few studies in commercial conditions. Therefore, large-scale field validations were conducted during spring 2004 in two fresh-market tomato (*Lycopersicon esculentum*) farms in Florida to compare the effect of an alternative fumigant and herbicide program to MBr on soilborne pests and fresh-market tomato growth and yield. Two treatments were compared: a) in-bed applied MBr + chloropicrin (Pic) at a rate of 390 lb/acre; and b) a combined fumigation program consisting of in-bed applied 1,3-dichloropropene (1,3-D) + Pic (65/35 v/v) at 245 L ha^{-1}, followed by tank-mixed preplant incorporated napropamide + trifluralin at 2.25 + 0.55 kg ha^{-1}, respectively, and later injected with in-bed Pic at 170 kg ha^{-1}. Tomato yield and nutsedge (*Cyperus* spp.) control data demonstrated that the proposed alternative fumigation program is an effective replacement for MBr + Pic.

Key words: *Lycopersicon esculentum*, *cyperus*, nutsedge, 1,3-dichloropropene, chloropicrin, napropamide, trifluralin

INTRODUCTION

During the last decade, a great deal of research has been conducted to identify suitable alternatives for MBr fumigation in mulched-vegetables. Among the potential replacements for MBr, the combination of 1,3-D + Pic, has shown to be among the leading alternatives for soilborne pest management in tomato (*Lycopersicon esculentum*). However, nutsedge (*Cyperus* spp.) control continues to be a major challenge for tomato production (Gilreath and Santos, 2005a; Noling and Gilreath, 2001). This weed has the ability to penetrate polyethylene mulch and interfere with the crop for essential factors, such as light, nutrients, water, and space (Holm *et al*., 1977; Gilreath and Santos, 2005b).

Currently in Florida, there are few herbicides labeled for nutsedge control in fresh-market tomato (Stall and Gilreath, 2002; Maynard, 2003). Previous research has demonstrated that the use of the herbicide pebulate alone or in combination with other herbicides can complement 1,3-D + Pic activity and improve nutsedge control in tomato (Gilreath and Santos, 2004; Gilreath *et al*., 2004). Unfortunately, although pebulate had acceptable efficacy against nutsedge, it required careful application procedures to avoid crop injury and it is no longer available for the crop. Therefore, other herbicide options must be explored.

Most commercial application implements deliver fumigants in-bed prior to mulching (Gilreath *et al*., 2001). For this procedure, a great deal of hand labor is required and personnel must wear protective equipment to avoid fumigant exposure, which is uncomfortable and cumbersome. To improve safety, field machinery has been developed to deliver 1,3-D + Pic broadcast (Noling and Gilreath, 2001). The Mirusso-Avenger Yetter coulter (Yetter Manufacturing, Colchester, Illinois, USA) reduces the need for extensive personnel protective equipment and reduces fumigant volatilization (Gilreath *et al*., 2002). One possible disadvantage of this methodology is that it might allow fumigants, such as Pic, to volatilize quickly from the soil because the beds are left usually uncovered for several days after application. To correct this drawback and based on routine field observations, it is proposed that additional Pic should be injected in the soil when planting beds are firmly pressed and covered with mulch. However, further trials are needed to determine if this practice would improve soilborne pest control and tomato yield.

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During 2004, the US accounted for almost 10% of the worldwide tomato production, with a gross value of almost $1.350 million (FAO, 2005; USDA, 2005). In spite of the importance of tomato, few reports of commercial large-scale validations of MBr alternatives are found in the literature. This situation has hindered adoption of alternative fumigant programs by growers. It is hypothesized that there is at least one alternative fumigant and herbicide program to replace MBr for polyethylene-mulched tomato production. Therefore, the objective of this study was to compare the effect of a soilborne pest control program composed of broadcast 1,3-D + Pic, preplant incorporated napropamide + trifluralin, and in-bed injections of Pic with MBr + Pic in large validation fields.

MATERIALS AND METHODS

Large-scale research trials were conducted during spring 2004 in two commercial tomato fields (Deseret Farms and Artesian Farms) located in Ruskin, Florida. The soil at these farms is a fine sand spodosol, with organic matter content <2% and pH between 6.3 and 6.5. The two selected experimental sites have history of heavy nematode, nutsedge, and soilborne disease infestations. Two treatments were used at both locations: a) in-bed applied MBr + Pic at a rate of 390 kg ha^{-1} and b) a combined fumigation program consisting of in-bed applied 1,3-D + Pic (65/35 v/v) at 245 L ha^{-1}, followed by tank-mixed preplant incorporated napropamide + trifluralin at 2.25 + 0.55 kg ha^{-1}, respectively, and later injected with in-bed Pic at 170 kg ha^{-1}. These treatments were arranged in a randomized complete block design with four replications. Experimental plots were 115 and 150 m^2 of planted rows, equivalent to 12 rows of 165 and 210 m each at Artesian and Deseret Farms, respectively. In-row and between-row spacing were 0.6 and 1.8 m, respectively, whereas finished planting beds were 2.33 and 2.75 m wide on top, and 0.2 m high.

Application of MBr + Pic was made with a standard nitrogen-pressurized fumigation rig. Three chisels per bed injected the fumigants 20 cm deep and 20 cm apart. Fumigant flow was controlled by a flowmeter, calibrated to deliver the specified quantity of fumigant. In the alternative fumigation program, broadcast injection of 1,3-D + Pic was made with a Mirusso-Avenger Yetter coulter rig that injected the fumigants at 20 cm below the soil surface. In Artesian and Deseret Farms, tank-mixed napropamide + trifluralin were broadcast-applied directly to the soil at 14 and 7 seven days after 1,3-D + Pic injection, respectively, with a tractor mounted three-nozzle boom with 8004 flat fan nozzles, calibrated to deliver approximately 280 L ha^{-1}, and pressurized to 240 kPa. Immediately after spraying, soil was rototilled 10 cm deep in each plot. In-bed Pic injection was made with the same standard fumigation rig used for MBr + Pic, at 1 and 6 days after herbicide application at Artesian and Deseret Farms, respectively. Immediately after application, two bands of starter fertilizer 10N-0P-20K at 340 kg ha^{-1} were applied 8 cm from the bed shoulders. Simultaneously, beds were pressed and covered with Pliant metallized with black stripe film (Pliant Corp., Schaumburg, Illinois, USA) at Artesian Farms, and Sunoco black mulch (Sunoco Chemicals, Philadelphia, Pennsylvania, USA) at Deseret Farms. One drip irrigation line (T-Tape, T-Systems International, San Diego, California, USA) with emitters 30 cm apart was installed in the bed centers at a depth of 10 cm. Irrigation flow was approximately 0.5 L m^{-1} min^{-1}. Five to six-week-old 'Florida 47' tomato seedlings were transplanted 22 days after treatment (DAT).

At the end of each cropping season, Fusarium wilt (*Fusarium oxysporum* f.sp. *lycopersici*) incidence was determined counting the number of plants with disease symptoms and dividing this number by the total number of plants in each plot. Likewise, nematode root-galling was assessed at the same time by extracting the roots of 20 tomato plants per experimental unit and rating gall formation using a 0 to 10 scale, where 10 indicates very heavily galled roots. Nutsedge densities emerged through the mulch in each experimental unit were counted at 42 and 83 DAT. Visual estimates of tomato plant vigor were made using a scale, where 100% represented optimum plant vigor and 0% indicated plant death. Tomato plant height was determined by sampling 20 plants per plot. These variables were measured at 42 and 83 DAT at Deseret Farms. Tomato fruits were harvested in the whole fields at 99 and 113 DAT at Artesian Farms, and at 103 DAT at Deseret Farms. Fruits were weighted and graded according to current market as extra-large, large, and medium (Sargent, 1997). Non-marketable fruit were discarded. The yields of these categories were added to obtain marketable fruit weight.

Disease incidence and tomato plant vigor data were transformed with arc sin prior to analysis. Similarly, nutsedge densities were transformed with $\log_{10}$ + 1. Treatment effect on tomato yield was determined with at-Student test at 5% significance level (SAS Institute, 2000).

RESULTS AND DISCUSSION

At Deseret Farms, the proportion of tomato plants infected with Fusarium wilt and root-knot nematode galling in both treatments was negligible, although there

Table 1: Comparison between an alternative fumigant and herbicide program and MBr + Pic on tomato plant vigor and height and nutsedge density at Deseret Farms, Ruskin, Florida, USA. Spring 2004

Treatment*	Rate per ha	Vigor** 42 DAT (%)	Height 42 DAT (cm)	Nutsedge density*** 42 DAT (plants m^{-2})	83 DAT
Mbr + Pic	390 kg	76	81.1	1.1	3.5
1,3-D + Pic					
napropamide + trifluralin					
Pic	245 L	89	79.9	24.7	47.3
	2.25 + 0.55 kg				
	170 kg				
Significance		*	NS	*	*

*Mbr = methyl bromide; Pic = chloropicrin; 1,3-D + Pic = 1,3-dichloropropene + Pic (65/35 v/v); NS = Non-Significant at 0.05; (*) = significant at 0.05; DAT = days after treatment. **Plant vigor obtained by using a percentage scale where 100% = optimum plant vigor and 0% = plant death. Data transformed with arc sine prior to analysis. ***Nutsedge density data transformed with $\log_{10} + 1$ prior to analysis

Table 2: Comparison between an alternative fumigant and herbicide program and MBr + Pic on marketable and per category tomato yield at Artesian and Deseret Farms, Ruskin, Florida, USA. Spring 2004

Treatment*	Rate per ha	Extra large ($t\ ha^{-1}$)	Large	Medium	Marketable
Artesian farms					
MBr + Pic	390 kg	198.7	26.7	46.6	272.0
1,3-D + Pic	245 L				
napropamide + trifluralin	2.25 + 0.55 kg	182.3	24.4	48.4	255.1
Pic	170 kg				
Significance		NS	NS	NS	NS
Deseret farms					
MBr + Pic	390 kg	225.1	107.7	54.7	387.5
1,3-D + Pic	245 L				
napropamide + trifluralin	2.25 + 0.55 kg	236.1	113.1	59.8	409.0
Pic	170 kg				
Significance		NS	NS	NS	NS

*Mbr = methyl bromide; Pic = chloropicrin; 1,3-D + Pic = 1,3-dichloropropene + Pic (65/35 v/v); NS = Non-Significant at 0.05

was disease and nematode pressure in nearby guard rows (data not shown). Tomato plant vigor at 42 DAT was higher with the alternative fumigation plus herbicide program (89%) than with MBr + Pic (76%), which indicated that the fumigant plus herbicide combination was not injurious to the crop (Table 1). At the same time, tomato plant height of the alternative fumigant and herbicide program was not different from the MBr + Pic treatment, with plants being approximately 80 cm tall.

With regard to nutsedge densities, the injection of MBr + Pic controlled the weed more effectively than the combination of 1,3-D + Pic, napropamide + trifluralin and Pic. At 42 and 83 DAT, nutsedge densities were less than 5 plants m^{-2} with Mbr + Pic, whereas 24.7 and 47.3 plants m^{-2} were present in the alternative fumigant and herbicide program, respectively (Table 1). These weed densities are still within commercially-acceptable levels for most tomato production systems. Previous studies have shown that significant tomato yield reductions occur when nutsedge densities exceed 50 plants m^{-2}, which indicates that both treatments were likely below the biological threshold for this weed in tomato (Gilreath and Santos, 2004).

At both locations, marketable fruit yield and weight per category were the same for both treatments. At Artesian Farms, marketable fruit yield ranged between 272.0 and 255.1 t ha^{-1}, with extra large fruits representing approximately 73% of the total weight (Table 2). This proportion was equal in both treatments, while large and medium fruits comprised about 10 and 17% of the total marketable fruit yield. At Deseret Farms, marketable fruit yield ranged between 387.5 and 409.0 t ha^{-1} (Table 2). The extra large fruit grade was 58% of the marketable yield, whereas the large and medium categories represented 28 and 14%, respectively. The differences in fruit grade partitioning in both locations may have been caused by differences in number and time of harvest. For instance, at Deseret Farms there was only one harvest at 107 DAT, which occurred eight days after the first harvest in Artesian Farms, likely allowing more time for medium-size fruits to enlarge their diameter, thus increasing the proportion of large tomato fruits.

The results indicated that the proposed alternative fumigant and herbicide program, composed of successive applications of in-bed applied 1,3-D + Pic, preplant incorporated napropamide + trifluralin, and in-bed injected Pic, can be considered as an effective replacement for MBr + Pic. In the past, the combined use of herbicides with fumigants for soilborne pest control in tomato has been recommended to growers as an alternative to MBr +

Pic injections (Noling and Gilreath, 2001). Previous research have also discussed the benefits of using the herbicide pebulate alone or in combination with napropamide to effectively control nutsedge (Gilreath and Santos, 2005a,b; Gilreath *et al.*, 2005). However, this herbicide no longer has a label for tomato in Florida. In spite of the non-availability of pebulate, these findings demonstrated that the combined fumigant and herbicide program composed of broadcast 1,3-D + Pic, preplant incorporated napropamide + trifluralin, and in-bed injections of Pic can be a suitable replacement for MBr in mulched tomato. Further research should concentrate ion finding a single herbicide that could replace the napropamide + trifluralin mix in the program. Also, more retentive mulches, such as metalized and virtually impermeable films, could be included to reduce 1,3-D and Pic rates and volatilization.

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