PHYTOTOXICITY AND PLANT-BACK – CRITICAL ISSUES IN THE AUSTRALIAN STRAWBERRY INDUSTRY

S.W. Mattner*, I.J. Porter, R.K. Gounder and A.L. Shanks
VDPI, PMB 15, FGDC, Vic, Australia, 3156, scott.mattner@dpi.vic.gov.au

Adoption of alternative fumigants by the Australian strawberry runner industry has lagged behind the strawberry fruit industry. One of the reasons for this has been the occurrence of phytotoxicity in runner trials with alternative fumigants (particularly with Telone C-35 and MITC-based fumigants), which led the industry to apply for a critical-use-exemption from the MB phase-out. This paper reports on plant-back trials in the strawberry runner and fruit industries and highlights the differences in fumigant phytotoxicity between the two production systems.

Phytotoxicity in commercial scale-up trials in the runner industry

A commercial scale-up trial was established at Toolangi, Vic (37º32'S, 145º28'E) in a clay soil to assess the comparative efficacy of Telone C-35 (TC-35), chloropicrin (Pic) and MB for soil disinfestation and strawberry runner production. Fumigants were applied in July, 2001 (winter) at a rate of 50g/m² and strawberries planted in October, 2001 (spring), 16 weeks after fumigation. One month after planting there was a high mortality rate of mother plants in plots treated with TC-35, but not in MB or Pic-treated plots. Those plants that did survive in TC-35 plots appeared stunted, nitrogen deficient and produced no stolons. Roots appeared black, 'burnt off', and new roots were emerging from the crowns above the soil surface. At final harvest (May, 2002 (fall)) yields of strawberry runners in TC-35 plots were 22% lower than yields in MB and Pic-treated plots (Fig 1).

The results from this trial were atypical of five previous experiments conducted at the same location, where fumigation with TC-35 produced runner yields equivalent to those with MB. The reduction in yields in TC-35 plots in this trial was not attributable to ammonium toxicity, or its failure to control pathogens and weeds. Rather, the symptoms appeared most consistent with fumigant-induced phytotoxicity. Fumigation in this trial occurred late in the season under cool, wet conditions (air temperatures averaged 5-15ºC and rainfall totalled 210mm during the 16 wk plant-back period) and this would have contributed to the retention of fumigant residues in soil. However, environmental conditions were not beyond the range encountered during the normal fumigation season in runner producing areas (April-June) or in previous trials. Another possible reason for the extended phytotoxicity of TC-35 in this trial was that it had been stored in-cylinder for a long period (ie up to 5 years), which might have affected its residual properties.

Plant-back trial in the strawberry runner industry

To address the issue phytotoxicity, a plant-back trial was conducted in an adjacent field to the commercial scale-up trial. Plots were fumigated in June, 2002 with: TC-35 (old) stored in-cylinder for over 5 years (50g/m²); a freshly mixed formulation of TC-35 (new) (50g/m²); MB:Pic 70:30 (50g/m²); Pic (17.5g/m²); Telone (32.5g/m²); and an untreated control. Strawberries were 'planted back' into plots at 0, 1, 2, 4, 8, and 16

weeks after fumigation. The trial was conducted as a randomised split-plot design with three blocks.

Runners were harvested in April 2003, 6-10 months after planting. Yields (runners/m²) were expressed as a percentage of those in untreated plots to minimize the confounding factor of variable seasonal effects at the different plant-back times, and because untreated plots contained no fumigant residues and thus formed a reference yield. Additionally, relative yields were $\log_{10}$ transformed to restore homogeneity of variance across different plant-back treatments. The following exponential function was fitted using non-linear regression to Log Relative Yield data for each fumigant:

$$Y_r = Y_m + B(S^P) \quad \text{.....(1)}$$

where, Y_r is the Log Relative Yield; Y_m is the theoretical maximum Y_r attainable; B is a parameter defining Y_r when $P = 0$; S is the rate of increase of Y_r; and P is the plant-back time in weeks. The fitted function was used to calculate the required plant-back time for each fumigant (P_{opt}), under the conditions of the trial. P_{opt} was defined as the plant-back (P) where $Y_r = 95\% Y_m$ (Fig 2).

Results showed that fumigation with TC-35 has the potential to produce runner yields equivalent to that with MB because Y_m values (the theoretical maximum yield) for both fumigants were similar (Table 1 & Fig 3a). However, TC-35 had a longer plant-back requirement (P_{opt}) than MB under the conditions of this experiment. Furthermore, TC-35 stored in-cylinder (TC-35 (old)) was more phytotoxic to strawberry runners than a freshly prepared formulation of TC-35 (TC-35 (new)), having double the plant-back requirement (Table 1 & Fig 3a). The reason for this is still under investigation, but partially explains the extended period of phytotoxicity in the commercial scale-up trial.

Plant-back trial in the strawberry fruit industry

A similar plant-back trial to the one described above was established on a clay soil in the strawberry fruit industry at Main Ridge, Vic (38°24'S, 144°58'E) on May 1999. Fumigant treatments in this trial included MB:Pic 30:70, Pic and TC-35 applied at rates of 50g/m². Fruit was harvested throughout the growing season and Log Relative Yields fitted to the exponential function (1) as described above.

Yields in this trial had already begun to plateau after a plant-back period of just 1 week for each fumigant (Fig 3b) and thus the required plant-back (P_{opt}) under the conditions of this trial were much shorter than in the runner trial (Table 2). Y_m values for all fumigants were similar, highlighting the potential for alternative fumigants to produce fruit yields equivalent to those with MB.

Discussion/Conclusions

Generally, the plant-back periods required for alternative fumigants are longer and more variable than those for MB, and this is making phytotoxicity an important issue during the transition to MB alternatives. This is particularly the case for industries such as strawberry runners, whose production schedules force them to fumigate under marginal environmental conditions. The current trials suggest that fumigant-induced phytotoxicity in strawberries may be expressed more markedly in runner yields than fruit yields. This is probably due in part to the cooler soil temperatures where high-elevation runners are produced and to retained fumigant residues affecting early

vegetative growth more than later reproductive growth. Furthermore, in some instances, phytotoxicity might affect the physiology of plants whereby a small setback in early vegetative growth enhances reproductive yields later in the season.

Results from plant-back trials are increasing the confidence of strawberry growers in predicting when it is safe to plant their crops. Growers are beginning to accept that they may need to fumigate earlier in the season and are more aware of the importance of environmental conditions. This season, 30% of runner growers in Australia are trialing freshly prepared formulations of TC-35 in commercial trials.

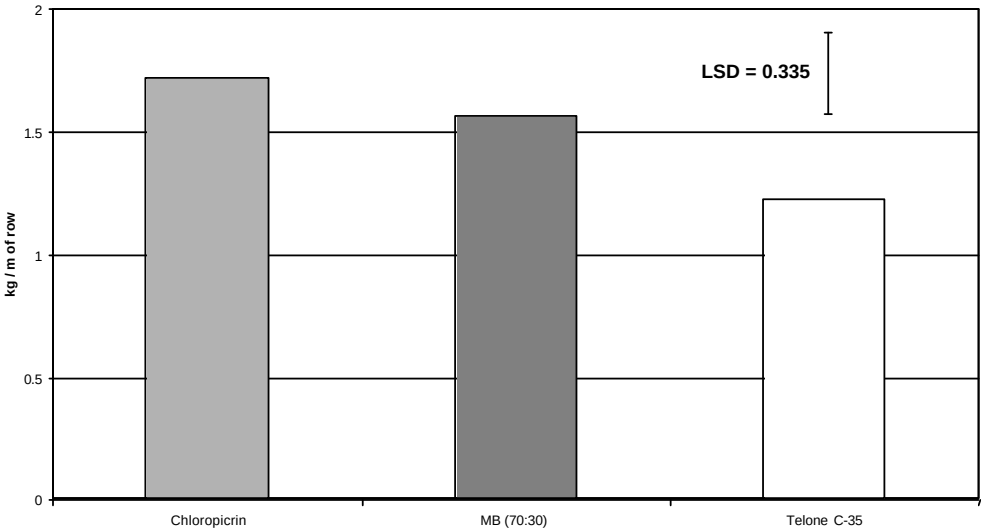

Figure 1. Strawberry runner yields from a commercial, scale-up trial at Toolangi, Vic. Strawberry plants in Telone C-35 plots were affected by fumigant-induced phytotoxicity and yielded 22% below those in MB and chloropicrin-treated plots.

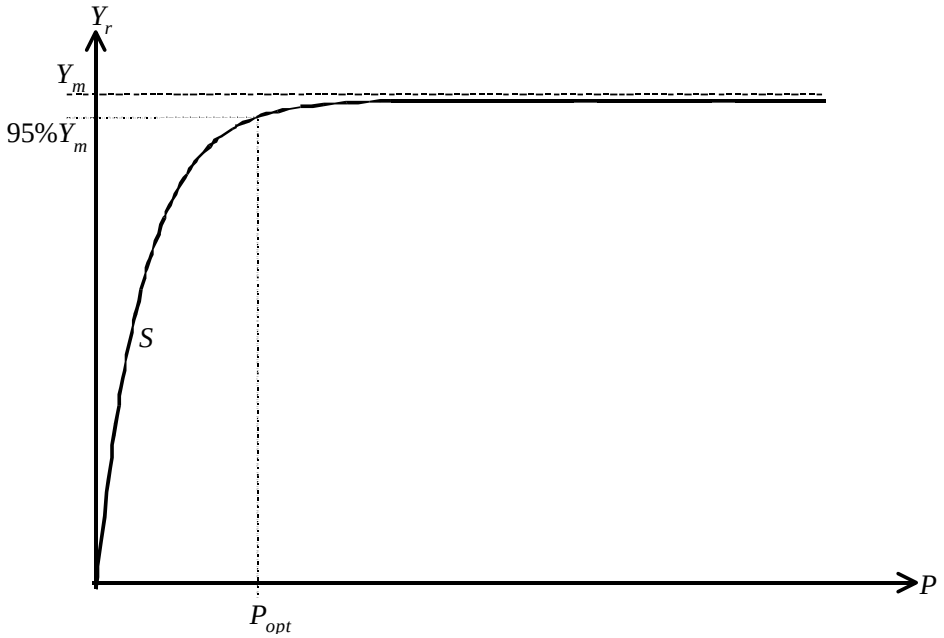

Figure 2. Exponential function (1) showing the relationship between Log_{10} Relative Yield (Y_r) and plant-back time (P). Y_m is the theoretical maximum Y_r attainable; and S is the rate of increase of Y_r. The required plant-back (P_{opt}) was defined as the P where Y_r = 95% Y_m.

Table 1. Parameters generated by fitting an exponential function (1) for different fumigants in a plant-back trial at Toolangi, Vic in strawberry runners. Y_m is the maximum theoretical Log Relative Yield (Y_r). S describes the rate of increase of Y_r. The required plant-back time (P_{opt}), **under the conditions of this trial**, was defined as the plant-back time where Y_r = 95% Y_m. Telone C-35 (old) was a formulation stored in-cylinder for over 5 years, while Telone C35 (new) was a freshly prepared formulation. Figures in parentheses are standard errors where p = 0.05.

Treatment	Y_m	S	Required plant back, P_{opt} (weeks)	R Square (%)
Telone C-35 (old)	3.25 (0.43)	0.79 (0.07)	12.96	77.6
Telone C-35 (new)	3.11 (0.22)	0.64 (0.07)	6.79	84.8
Chloropicrin	2.76 (0.16)	0.65 (0.06)	6.78	88.3
Telone	2.86 (0.28)	0.67 (0.09)	7.42	73.5
MB:Pic (70:30)	3.08 (0.16)	0.39 (0.07)	3.14	89.7

Table 2. Parameters generated by fitting an exponential function (1) for different fumigants in a plant-back trial at Main Ridge, Vic in strawberry fruit. Y_m is the maximum theoretical Log Relative Yield (Y_r). S describes the rate of increase of Y_r. The required plant-back time (P_{opt}), **under the conditions of this trial**, was defined as the plant-back time where Y_r = 95% Y_m. Figures in parentheses are standard errors where p = 0.05.

Treatment	Y_m	S	Required plant back, P_{opt} (weeks)	R Square (%)
Telone C-35	2.12 (0.02)	0.03 (0.02)	0.80	99.3
Chloropicrin	2.04 (0.03)	0.01 (0.02)	0.67	98.7
MB:Pic (30:70)	2.00 (0.02)	4×10^{-4}	0.38	99.2

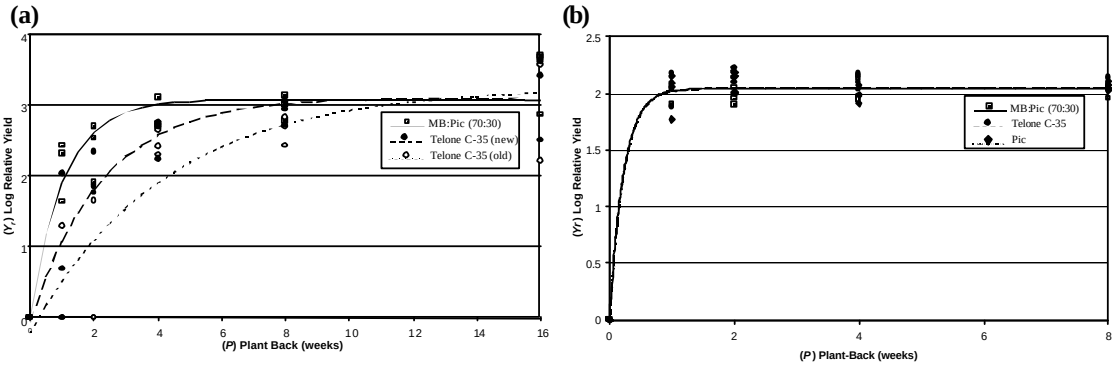

Figure 3. Raw data (data points) and fitted exponential functions (curves) for different fumigants in plant-back trials conducted in (a) strawberry runners and (b) strawberry fruit. The fitted functions for different fumigants in (b) are almost identical.