Effects of Lime Sulfur and Fish Oil on Apple Pollen Tube Growth and Fruit Set

Constance Walker, University of Guelph, Guelph, Ontario

Introduction

Most apple (*Malus domestica* Borkh.) have a natural tendency to over-fruit (Schmidt & Elfving, 2007) and will retain a heavy crop load throughout the growing season after an abundant bloom -producing small, low quality fruit and inhibiting flower bud induction; resulting in biennial bearing of fruit (Stopar, 2008). Managing crop load by chemical thinning improves the size, quality and colour of the fruit, increases return bloom (Yoder et al, 2009) and minimizes the costs of hand-thinning labor (Schmidt & Elfving, 2007).

The combination of lime sulfur (LS) and fish oil (FO) developed by an organic grower Harold Ostenson, (Washington Tree Fruit Research Commission, 2010) for use as an apple thinning agent has demonstrated observable efficacy in reducing fruit set in recent field tests and trials (McFerson, 2008; Noordijk and Schupp, 2003; Schupp, 2006). However, the mode of action of this combination is not well understood (McArtney et al, 2006). Research suggests that LS and FO may reduce fruit set by inhibiting photosynthesis in apple leaves and decreasing assimilate carbohydrate supply (Noordijk and Schupp, 2003; McArtney et al, 2006). In addition further thinning effects may be caused by inhibiting pollen germination, pollen tube growth in the style and fertilization (Yoder et al, 2009).

Objective

To determine the effects of Lime Sulfur (LS) and Fish Oil (FO) on pollen tube growth and fruit set in apples.

Material and Methods

To investigate the effects of LS and FO on pollen tube growth and fruit set in apples, two refereed research studies were selected: Experiment 1. (Yoder et al, 2009); Experiment 2. (McArtney et al, 2006). Both studies conducted in-field experimentation using low pressure applications of 2% Liquid Lime Sulfur and 2% Emulsified Fish Oil (Crocker's Fish Oil, Inc. Quincy, WA) to apple blossoms during the bloom period.

Applications of LS and FO were applied to 'Golden Delicious' apple trees at 0,4,24 and 48 hours after hand pollination in Experiment 1, to determine the timing effect on pollen tube growth and fruit set. Whereas, three repeat applications of LS and FO were applied alone or in combination to 'Braeburn' apple during the bloom period at 4 day intervals, to determine the interaction effects of LS and FO on pollen tube growth and fruit set. Differences in experimental design and analysis are summarized in Table 1. below.

Table 1. Experimental Design and Analysis Comparison between Experiments 1 and 2

	EXPERIMENT 1	EXPERIMENT 2
Location	Washington, USA	Nelson, New Zealand
Subject	10 yr. old Golden Delicious/M.27	5 yr. old Braeburn/M.9
Sample Size	12 trees (3 trees/block);	4 trees
Design	Randomized complete block design	2x2 Factorial Design Single guarded tree plots
Replications	4	6
LS and FO treatment	0, 4, 24, 48 hours after hand pollination	3 repeat applications (4 day interval) starting at late balloon stage
Statistical Analysis	Statistical Analysis Systems Software for PC: Analysis of variance, Duncan's multiple range test, regression analysis	2x2 Factorial design analysis

Pollen tube growth was determined in both studies using adapted and modified methods of Embree and Foster (1999). Flowers were harvested after LS and FO spray applications in Experiment 1 (48 hours) and Experiment 2 (5 days) to allow for sufficient pollen tube growth. Pollen germination and tube growth on the stigmatic surface, number of pollen tubes penetrating through the stigma, average tube of the longest tube pollen tubes in the styles and mean style length and number of pollen tubes penetrating the style were recorded in Experiment 1. Experiment 2 reported the percentage of flowers with less than 10 pollen tubes/flower, and the percentage of flowers with 0 pollen tubes/flower.

Fruit set was evaluated in both experiments by performing flower cluster counts at bloom, followed by fruit counts. Fruit set was reported as percentage of fruit per 100 flower clusters. The first experiment evaluated 15 flowers/per tree. Final count was determined 35 days after hand-pollination and treatment. Two sample limbs bearing 40-60 clusters were tagged and evaluated for each tree in Experiment 2, at bloom, 39 days after bloom (initial fruit set count), and 71 days after bloom (final fruit set count).

Results

Pollen Tube Growth

Experiment 1

Yoder et al. (2009) found pollen tube growth in styles to be inhibited by application of LS and FO 4 or 24 hours after hand pollination. The number of pollen tubes growing to the base of the style was found to be 0.0 in both applications made 4 or 24 hours after pollination. No significant difference was found between the control and applications made at 48 hours. Treatments made at 48 hours after hand pollination had 16.2 pollen tubes growing to the base, where as the control was found to have 17.4. Progression of the pollen tubes in style samples (seen as fluorescent chartreuse) at the indicated times are shown in Figure 1 below.

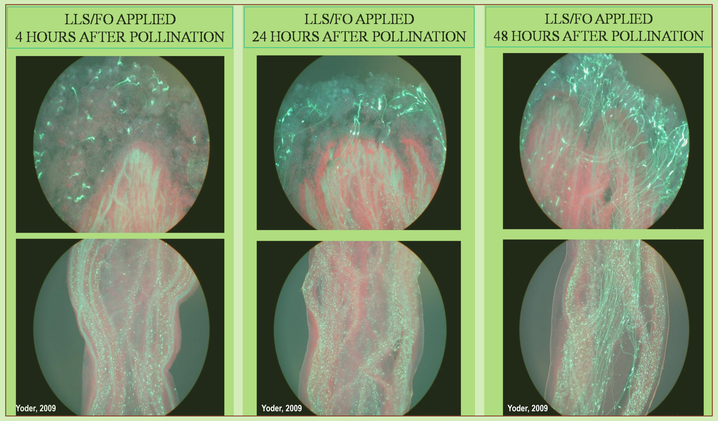

Figure 1. Progression of apple pollen tubes into styles after application of 2% Lime Sulfur and Fish Oil spray 4, 24 and 48 hours after hand pollination.

Experiment 2

McArtney et al. (2006) found that LS significantly affected pollen tube growth. No significant interaction was found between the combination of LS and FO on pollen tube growth using a 2X2 factorial analysis. The proportion of flowers, with less than 10 tubes/flower and 0 tubes/flower was found to be 82% and 48% respectively when LS was used as a treatment. The proportion of flowers with less than 10 tubes/flower and 0 tubes/flower in the control was found to be 5% and 4%. Table 2 below summarizes the findings of McArtney et al. (2006).

Table 2. Summarization of Experiment 2 Results; Main effects of LS and FO during bloom. Back transformed weighted means presented. Adapted from McArtney et al. (2009).

Main Effects	Flowers with limited pollen tube no. (%)		Fruit set (fruit/100 clusters)	
	<10 tubes/flower	0 tubes/flower	Initial set	Final set
Lime sulfur				
No lime sulfur	5	4	66.4	58.9
Lime sulfur	82	48	40.5	38.8
Fish oil				
No fish oil applied	33	16	59.8	54.2
Fish oil	41	26	47.1	43.4
Significance (P>F)				
Lime sulfur	<0.0001	<0.001	<0.0001	<0.0001
Fish Oil	0.52	0.29	0.006	0.015
Interaction	0.80	0.29	0.36	0.84

Fruit Set

Experiment 1

No Fruit Set occurred (0 % fruit set) when LS and FO was applied 4 or 24 hours after hand pollination. LS and FO applied 48 hours after hand pollination had a fruit set of 76.0%. Results for the control are inconclusive.

Experiment 2

No significant interaction was found between LS and FO on fruit set. LS had a greater effect on both initial and final fruit set reducing it by 39% and 34%. FO was found to reduce initial and final fruit set by approximately 20%. Findings are reported in Table 2 above.

Discussion

Blossom sprays are considered to be superior to post bloom sprays, as earlier application has a greater effect on fruit size and return bloom (Yoder et al. 2009). The exact mode of action of LS and FO as a bloom thinning agent, is still unclear as it has been shown that LS and FO inhibit leaf photosynthesis which may lead to reduced fruit set. Previous research found differences in LS and FO thinning efficacy between trials in Western and Eastern USA, and had suggested that the amount of sunshine received impacted photosynthetic recovery rates; affecting thinning efficacy (Schmidt and Elfving, 2007).These findings suggested that over thinning could result in area that typically experienced cloudy weather during the bloom period, as Pn recovery rates, were slower to recover. However, findings in Experiment 1 strongly suggest that LS and FO causes flower and fruit abscission primarily by inhibition of pollen germination, pollen tube growth in the style and fertilization, when applied over the bloom period, as the application of LS and FO had no effect on fruit set, 48 hours after pollination (Yoder et al, 2009).

Little academic research has been conducted to distinguish the interaction effects between LS and FO. Scientists suggested previously that use of FO in combination with LS increased thinning efficacy (McArtney, 2006). No significant interaction effect was found in Experiment 2. Although the study found that FO used alone did reduce fruit set by 20%. Research trials have been conducted using other vegetable and horticultural oils in combination with LS. A macroanalysis of over 200 trials in Washington by Washington Tree Fruit Research Commission has been reported as consistently outperforming conventional treatments such as ammonium thiosulfate (Schmidt and Elfving, 2007). Another study found that LS and FO applied as a post-bloom spray on cultivars McIntosh and Empire resulted in fruit russeting and leaf phytoxicity (Noorrdijk and Schupp, 2003).

Growth rate of the pollen tube into the style and number of pollen tubes penetrating the style; growing to the base has been found to increase with increasing temperatures and decrease with decreasing temperatures. Thus, application timing may be critical to the efficacy of a blossom thinning agent. Researchers Yoder et al. (2009) recommend that a better understanding of the effects of temperature on pollen tube growth in other cultivars is needed, and may be used to optimize timing and efficacy of bloom thinning sprays in apple production. Constructed models of pollen tube growth progression under determined temperature conditions as seen in Figure 2, may be used to explain thinning success or failure of LS and FO application (Yoder et al, 2009).

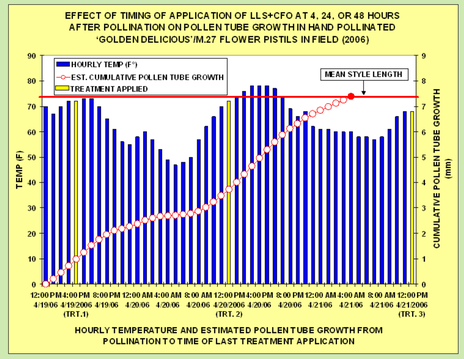

Figure 2. Predicted Pollen Tube Growth Curve Chart that may be used in future models to predict success or failure of LS and FO in bloom thinning programs; Source: Yoder, 2009

Summary

- Findings suggest that LS and FO cause flower and fruit abscission primarily by inhibiting pollen tube growth in the style and fertilization, when applied over the bloom period.
- Thinning efficacy of LS and FO may be reduced when applied after fertilization has occurred.
- Interaction effect between LS and FO was not significant.

References

McArtney, S., J. Palmer, S. Davies and S. Seymour. 2006. Effects of lime sulfur and fish oil on pollen tube growth, leaf photosynthesis and fruit set in apple. HortScience. 41 (2): 357-360.
McFerson, J. 2008. Chemical thinning of apple. Final project report to Washington Tree Fruit Commission.
Noorrdijk, H. and J. Schupp. 2003. Organic post-bloom apple thinning with fish oil and lime sulfur. HortScience. 38 (5) 690-691 (Abstract)
Schmidt, T.R. and R.C. Elfving. 2007. Crop load management of apple via induced plant stress. Journal of the American Pomological Society. 61 (4): 167-169
Schupp, J. 2006. Efficacy and physiological effect of oil/lime sulfur combinations. Final project report #AH-03-308 to Washington Tree Fruit Commission.
Stopar, M. 2008. Vegetable oil emulsions, NaCl, CH3COOH and CaSx as organically acceptable apple blossom thinning compounds. Europ.J.Hort.Sci., 73 (20): 55-61
Yoder, K., R. Yuan, L. Combs, R. Byers, J. McFerson and T. Schmidt. 2009. Effects of temperature and the combination of liquid lime sulfur and fish oil on pollen germination, pollen tube growth, and fruit set in apples. HortScience. 44 (5): 1277-1283.
Washington Tree Fruit Research Commission. 2010. Organic Fruit Production. Retrieved from http://organic.tfrec.wsu.edu/OrganicIFP/OrganicFruitProduction/Horticulture.html