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The effects of potential organic apple fruit thinners on gas exchange and growth of model apple trees: A model plant study of transient photosynthetic inhibitors and their effect on physiology and growth

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The effects of potential organic apple fruit thinners on gas exchange and growth of model apple trees: A model plant study of transient photosynthetic inhibitors and their effect on physiology and growth

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ABSTRACT

Few fruit thinners have been certified for organic fruit growers. Previous studies have shown that herbicides or shade are capable of reducing photosynthesis and are effective fruit-thinning techniques, although impractical. This project evaluated use of a model plant system of vegetative apple trees grown under controlled conditions to study photosynthetic inhibitors, which could be used as potential organic thinning agents. Various concentrations of osmotics, salts, and oils (lime-sulfur, potassium bisulfite, potassium bicarbonate, sodium chloride, soybean oil) were applied to actively growing apple trees and showed a reduced trend on the rate of apple tree photosynthetic assimilation (Pn), evapotranspiration (Et), and stomatal conductance (gs). From two studies, it was observed that treatments of 2% lime-sulfur (LS) + 2% soybean oil (SO), 4% SO, 8% LS, 5% potassium bicarbonate ($KHCO_3$), and 5% potassium bisulfite ($KHSO_4$) all significantly reduced Pn. The 4% LS + 2% SO, 4% LS + 4% SO, 0.5% sodium chloride (NaCl), and 2% NaCl did not significantly reduce Pn. The response of Et was significantly reduced by 2% LS + 2% SO, 5% $KHCO_3$, and 4% SO. In a second study, trees had reduced Pn, Et, and gs after the application of 4% LS + 4% SO, 2% NaCl, 5% $KHCO_3$, and 5% $KHSO_4$. Stem weight, total plant weight, average leaf weight, and leaf surface area of the treated plants, although reduced, were not significantly so when compared to the control 20 d after treatment.

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MEET THE STUDENT-AUTHOR

Jason D. McAfee

I graduated from Harrison High School in 1997. I began a career at the University of Arkansas in 1998. I did not enter the Horticulture Department until the following year. Since I have been in this department, I have found numerous opportunities in the area of plant science.

As an undergraduate in the Department of Horticulture, I decided to pursue my M.S. degree in the area of fruit crops. To give me some experience in the research field, I was fortunate to receive some grant money through the Mitchener Family Undergraduate Research Award. Dr. Curt Rom advised and encouraged me to do this research project to help prepare me and give me experience for graduate school. I have learned that research can be a very tedious task at times, but continuous persistence can be rewarding in the end.

I am proud to say this research won first place for the undergraduate presentation at the 63rd Annual Meeting of the Southern Regional American Society for Horticultural Science at Mobile, Ala. I would like to express my thanks and appreciation to Dr. Curt Rom for his cooperation and support.

INTRODUCTION

Fruit thinning is a technique essential to apple production that ensures fruit quality by maximizing fruit size and sustaining the tree's potential to annually bear marketable fruit. A number of chemical treatments are available to conventional apple growers but few are currently registered or recommended to certified organic growers. Organic growers typically rely on mechanical removal of excessive fruitlets by hand labor, which is very expensive. In order to test potential organic fruit-thinning treatments and develop reliable, economical thinning technologies, it is necessary to create a model system to test naturally occurring and organically certifiable compounds.

Over the past four decades, research has demonstrated the value and appropriate timing of thinning techniques to maximize fruit size and flower bud development for the following year's crop. Early studies showed the correlation between factors such as shade and the reduction in photosynthesis and how they affect fruit growth (Heinecke, 1966). Currently, fruit thinning is accomplished through synthetic plant-growth regulators, herbicides, and caustic chemicals or by mechanical means (hand removal of flowers or fruitlets). Due to the expense of hand removal of flowers and fruitlets, most fruit-thinning research has focused on chemical methods of application. Past studies have shown that herbicides such as terbacil and increased shade are good fruit-thinning techniques (Byers et al.,1990). Furthermore, the primary focus of research has been on chemical treatments for conventional orchards. Several of these chemical products have been registered for fruit-thinning purposes. However, none of these chemicals are certified for organic fruit producers.

The present increase in market demand for organically grown food has increased the need for science-based technologies that are certifiable organic alternatives to conventional methods and hand labors. It was proposed that some certified organic spray materials may cause a transient suppression or inhibition of photosynthesis. The reduction of carbohydrate supply caused by this suppression would result in strong inter-fruit competition for metabolites whereby smaller or developmentally delayed fruit would not compete and therefore abort. A model plant test under a controlled environment of treatment effects on photosynthesis and vegetative growth may indicate the usefulness of such materials for fruit thinning in the field. The objective of this project was to study the effects of potential organic thinning agents on gas exchange and growth of vegetative apple trees as a model system.

MATERIALS AND METHODS

Study 1 (February – March, 2002).

'Golden Delicious'/M.7a nursery stock trees (approximately 0.5-0.75 cm diameter) were potted in 7.6 L pots with a soil medium consisting of a Sunshine SB500 mix (35-45% bark, Canadian sphagnum peat moss, vermiculite, perlite, dolomitic limestone, gypsum, starter nutrient charge, and wetting agent) at the University of Arkansas Agricultural Research and Extension Center, Fayetteville, in January, 2002. At potting, trees were cut 2.5 cm above the graft union and subsequently new growth was trained to single shoot and all lateral buds were removed. Plants were grown in a greenhouse with temperatures of 25-30/18-20°C (day/night). Trees were watered as needed and fertilized with a weekly Peters' soluble 10N-4.4P-8.3K fertilizer. Pests were controlled by chemical treatments only if found present from scouting.

Trees were divided into six replications of 10 single-tree experimental unit treatments. When shoots were approximately 20 cm in height (Feburary, 2002) treatments were applied one time for the study. Treatments included: 1) 4% soybean oil (SO); 2) 2% lime-sulfur (LS) + 2% SO; 3) 4% LS + 2% SO; 4) 4% LS + 4% SO; 5) 0.5% sodium chloride (NaCl); 6) 2% NaCl; 7) 5% potassium bicarbonate ($KHCO_3$); 8) 5% potassium bisulfate ($KHSO_4$); 9) 8% LS; and 10) untreated control. Treatments were applied once with 1 L spray bottles until leaves were dripping. Trees were placed in a completely randomized design in the greenhouse.

Study 2 (November – December, 2002).

M.111 EMLA clonal apple-rootstock liners (0.30-0.50 cm diameter) were planted in 4.1 L pots with Sunshine SB500 mix and grown in a greenhouse (as described previously) in late August, 2002. After planting, liners were cut 2.5 cm above the soil leaving two buds exposed. Plants were grown as single shoots and managed as described above. Treatments included: 1) LS 4% + SO 4%; 2) 2% NaCl; 3) 5% $KHCO_3$; 4) 5% ($KHSO_4$); and 5) untreated control. The trees were placed in a completely randomized design with five single-tree experimental unit replications of each treatment.

Measurement Variables. A CIRAS-1 differential CO_2/H_2O infra-red gas analyzer with integral cuvette air-supply unit and Parkinson leaf cuvette with an automatic light control was used for the measurements of photosynthetic assimilation (Pn), internal CO_2 (Ci), evapotranspiration (Et), conductance (gs), leaf temperature (T), relative humidity (RH), and photosynthetically active radiation (PAR) in each study. The chamber of the leaf cuvette measured a leaf surface area of 2.5 cm^2. The leaf chamber conditions were set for 50% RH, 350 ppm CO_2. Light saturation of PAR for all measurements averaged >1000 mmol/m^2/s and a temperature of 25°C.

Each tree was labeled at the fifth and seventh leaf for continued measurement of the same leaves. In Study 1, leaves were measured on -1, 1, 4, 8, 15, and 22 d after treatment. In Study 2, leaves were measured on -1, 1, 3, 10, and 20 d after treatment. Following measurements, trees were cut off at the graft union. Leaves were divided between treated and newly emerged. Growth measurements were recorded for the stem dry weight (oven dried), total plant dry weight (oven dried), total leaf surface area, and average leaf area. The growth and treatment measurements were based on a previous, similar study using shade treatments (Barden, 1977). The various treatments used in the two studies represented a range of solution-pH and electrical conductivity (EC) characteristics (Table 1). The statistical analysis for this study was done using JMP-IN software and an LSD student's t-test.

RESULTS AND DISCUSSION

Study 1.

Treatments of the 4% SO and 2% LS + 2% SO significantly reduced Pn at 1 and 4 d after treatment (DAT). Treatments of 5% $KHCO_3$, 5% $KHSO_4$, and 8% LS significantly decreased Pn 4 DAT. Three different treatment combinations of LS and SO treatments were introduced to compare differences in concentration. The lowest concentration (2% LS and 2% SO) was the only one to show a significant decrease in Pn when compared to the higher concentrations (Fig. 1A). Treatments of 5% $KHCO_3$, 5% $KHSO_4$, 4% SO, 8% LS, and 2% LS + 2% SO significantly decreased Et 4 DAT (Fig. 1B). Treatments of 5% $KHCO_3$, 5% $KHSO_4$, 4% SO, 8% LS, and 2% LS + 2% SO significantly decreased gs 4 DAT (Fig. 1C).

Study 2.

Treatments of 5% $KHSO_4$, 5% $KHCO_3$, and 2% NaCl significantly reduced Pn 20 DAT (Fig. 2A). Treatments of 5% $KHSO_4$ and 5% $KHCO_3$ significantly reduced Et (Fig. 2B). A treatment of 5% $KHSO_4$ significantly reduced gs 10 DAT. A treatment of 5% $KHCO_3$ significantly reduced gs 20 DAT (Fig. 2C). Stem weight, total plant weight, average leaf weight, and leaf surface area of the treated plants, although reduced, were not significant when compared to the control 20 DAT.

The treatment of $KHSO_4$ had the greatest decrease in Pn out of all treatments. The gs was reduced following treatment. As an acidic salt, this treatment potentially decreased the number of stomates present on the leaf's surface, which resulted in a decrease of Pn, Et, and gs. The leaves exhibited necrotic burn. This damage appeared as small burned lesions randomly distributed all over the leaves. A 5% concentration of $KHSO_4$ has a pH of 1.1 and a high EC of 333 mV (Table 1); this caustic nature is presumed to be the cause of the necrosis.

The LS treatments have the potential to act as a caustic agent for fruit-thinning purposes. This compound has a pH in the range of 10-11 and a low EC measured at -246, acting as a strong base. When applied as a thinning agent, it is capable of stressing the leaves of the tree due to osmotic tension on stomatal and epidermal cells therefore lowering Pn, Et, and gs.

A treatment of SO may potentially cover and plug stomates. This can slow the Pn of the leaves and results in a lower Et. An SO application on the tree may cover stomatal pores on the leaf surface of the plant. This may decrease the plant's photosynthesis and transpiration and further decrease the amount of carbohydrates available for cell division resulting in fruit abortion (Weller and Ferree, 1978).

This model plant study was a successful method for studying photosynthetic inhibitors under a controlled environment. In both studies, osmotics, salts, and oils reduced Pn, Et, and gs in model vegetative apple trees. Future studies will need an increase in replications to show more significance between treatments and control. The next step is to study each individual photosynthetic inhibitor for differential effects among various concentrations. Once concentration effects have been measured, it will be necessary to apply these photosynthetic inhibitors in the orchard during the post-bloom period. This will show the true potential of these inhibitors as fruit-thinning agents.

ACKNOWLEDGMENTS

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Table 1. Characteristics of spray solutions used in studying effects on apple leaf gas exchange.

Treatment	pH	EC (mV)[2]
Control H_20	6.9	15
Potassium bisulfate 5%	1.1	333
Potassium bicarbonate 5%	8.3	-71
Sodium chloride 0.5%	4.7	140
Sodium chloride 2%	4.9	124
Lime-sulfur 8%	11.3	-246
Soybean oil 4%	9.5	-145
Lime-sulfur 2% + soybean oil 2%	10.4	-198
Lime-sulfur 4% + soybean oil 2%	10.8	-219
Lime-sulfur 4% + soybean oil 4%	10.9	-224

[2] EC = electrical conductivity; mV = millivolts.

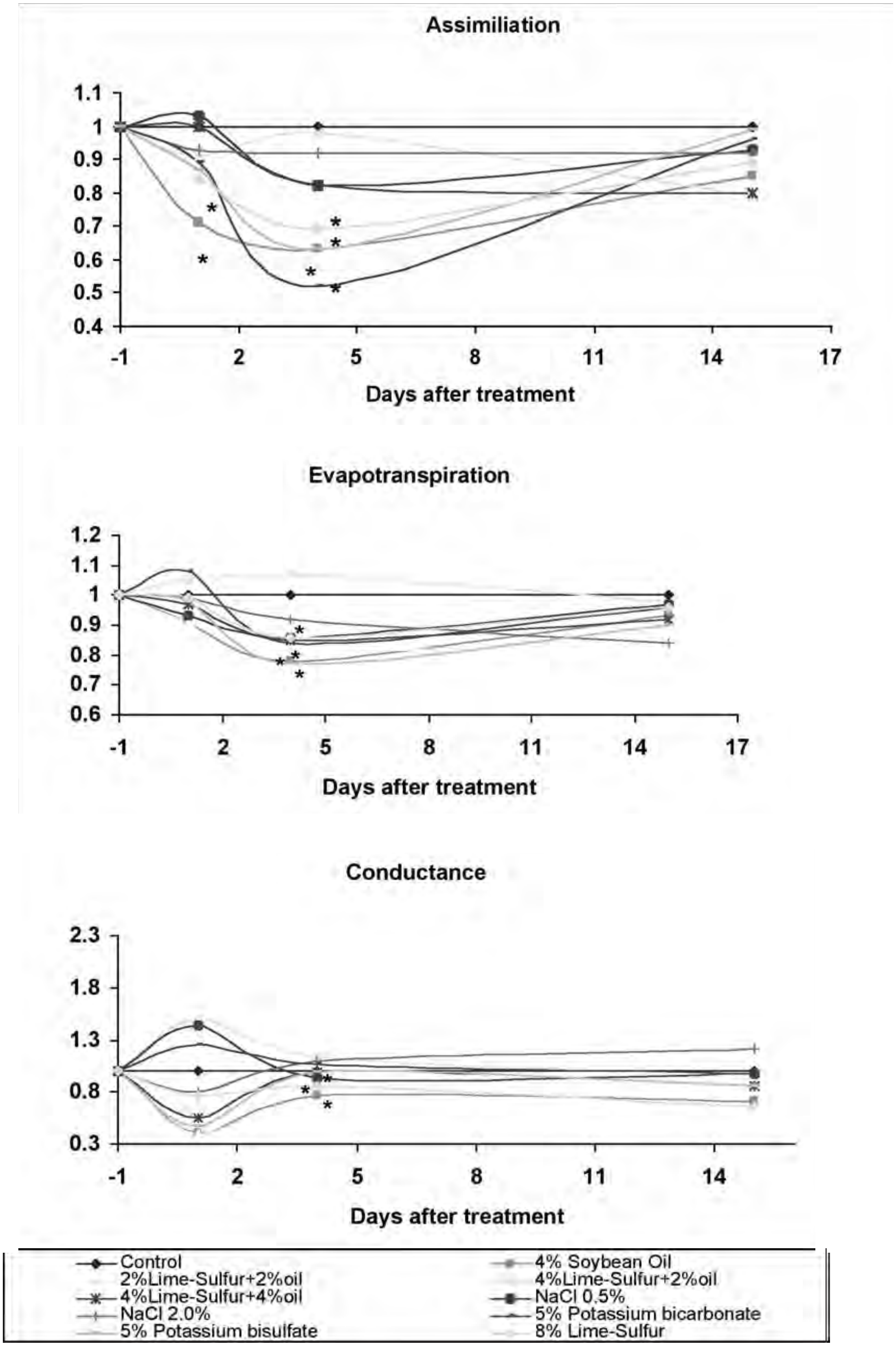

Fig. 1. Pn (A), Et (B), and gs (C) in response to various treatments of organic thinning chemicals, Fayetteville, Ark., February – March, 2002. Mean separation by LSD (P≤0.05, n = 10).

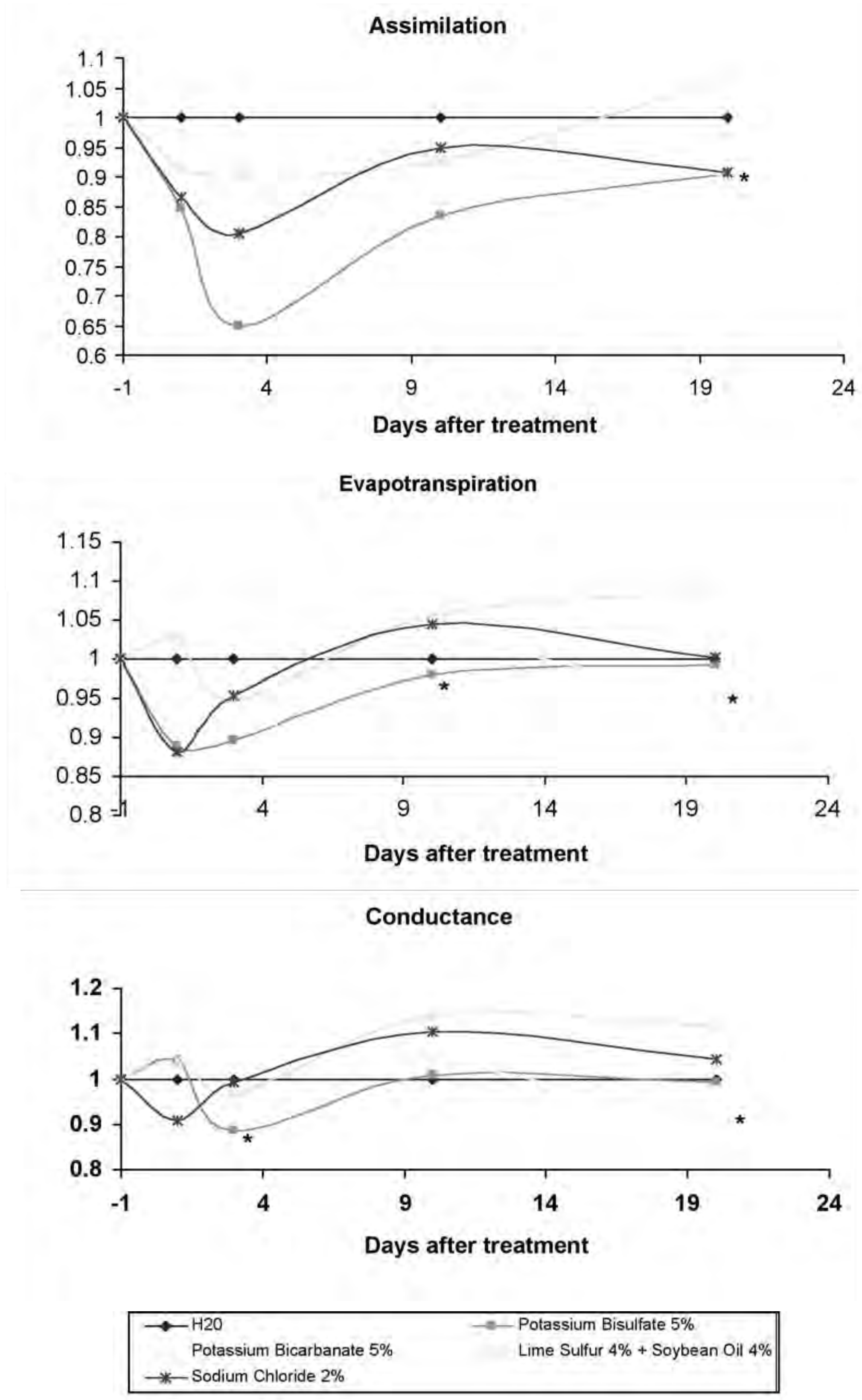

Fig. 2. Pn (A), Et (B), and gs (C) in response to various treatments of organic thinning chemicals, Fayetteville, Ark., November - December, 2002. Mean separation by LSD (P≤0.05, n = 5).