Synthetic and organic fungicide control of apple scab: 2009 field trial

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I. Introduction

Apple scab, caused by the fungal pathogen *Venturia inaequalis*, is a significant fruit and foliar disease worldwide (Jones and Sundin 2006). Apples grown in regions of California characterized by spring precipitation are subject to infection. Initial pathogen colonization of green tissue occurs when water stimulates ascospore release from pseudothecia located in overwintering plant litter, followed by dispersal to leaves, flowers or fruit (Jones and Sundin 2006). Asexually-produced conidia from the primary sites of infection on the host can also colonize new tissue if spores are transported in the air or by water splash (Jones and Sundin 2006).

In California, periodic applications of synthetic or organic fungicides from approximately March to June are required to control the disease; the timing of fungicide applications is dependent on season to season patterns in precipitation (Gubler 2006). Based on research in other apple producing regions, additional control measures such as post-harvest fungicide applications at the time of leaf fall to reduce inoculum for the following growing season (Beresford et al. 2008), leaf litter removal (Gomez et al. 2007) or use of cultivar mixtures in an orchard (Didelot et al. 2007) may effectively reduce disease impacts.

We conducted a field experiment near Camino, El Dorado County, California (elevation 3200 ft) to test the effects of several registered and experimental fungicides on control of scab in mature Red Delicious apple trees. Four applications were made from late March (green tip) to early May 2009 (post-bloom). We compared disease levels obtained on fruits and foliage in untreated and water-treated trees with disease control exhibited by several soft chemistry (paraffinic oil, tea tree oil, copper sulfate pentahydrate, monopotassium phosphate) and synthetic materials (flutriafol, kresoxim-methyl, mancozeb). Yield was also assessed at fruit maturity (late September 2009) on selected treatments.

II. Materials and Methods

A. Trial layout

Experimental unit	1 tree = 1 plot		
Row and tree spacing	18 ft (row) and 18 ft (tree)	Plot unit area	324 ft^2
Area/treatment	1620 ft^2 or 0.0372 acre/treatment (5 replicate trees = 1 treatment)		
Fungicide applications	A green tip Tu 23 March 150 gallons/acre 5.6 gallons/5 replicates B red bud Tu 7 April 150 gallons/acre 5.6 gallons/5 replicates C full bloom Th 23 April 200 gallons/acre 7.4 gallons/5 replicates D petal fall Th 7 May 200 gallons/acre 7.4 gallons/5 replicates		

•	•	•	•	•	•	•	•	•
•	•	OKD	LG	G	KD	YKS	OS	•
•	GS	GS	RD	LG	YS	GS	BS	
•	LG	KD	PS	BS	OKD	YRD	RKC	•
•	RD	OKD	KD	LG	YKS		•	
•	KD	G	YKS	RD	RKC	•	•	•
•	YS	GS	OS	YS	YRD	KD	RKC	•
•	YRD	PS	G	RKC	OS	GS	YKS	•
•	G	YKS	BS	YS	LG	PS	G	
•	RD	OS	YRD	RKC	YRD	BS	YS	
•	OKD	PS	RD	•	OKD			
•	BS	OS						
•	PS							
•								

• = untreated tree

B. Experimental treatments

Flag	Product(s)	Applications	FP[1]/Acre	FP/Treatment
YKS	Unsprayed control	none	none	none
PS	Water control	ABCD	water only	5.6 gal (at 150 gallons) 7.4 gal (at 200 gallons)
G	Sovran (kresoxim-methyl)	ABCD	4 oz	4.2 g
RD	JMS Stylet-oil (paraffinic oil)	ABCD	2%	424 ml (at 150 gallons) 560 ml (at 200 gallons)
YS	OM2 (paraffinic oil with adjuvant)	ABCD	2%	424 ml (at 150 gallons) 560 ml (at 200 gallons)
OKD	Nutrol fertilizer (mono potassium phosphate)	ABCD	12.6 lb	213 g
OS	Nutrol fertilizer + Sovran	ABCD	12.6 lb + 2 oz	213 g + 2.1 g
YRD	Timorex Gold (tea tree oil)	ABCD	0.6%	127 ml (at 150 gallons) 168 ml (at 200 gallons)
GS	Sovran alt[2] Timorex Gold	AC BD	4 oz alt 0.6%	4.2 g alt 127 ml (at 150 gallons) 168 ml (at 200 gallons)
RKC	Phyton 016-B (copper sulfate pentahydrate)	ABCD	40 fl oz	44 ml
BS	Topguard (flutriafol)	ABCD	13 fl oz	14.3 ml
LG	Topguard + Dithane (mancozeb) (2x) then Topguard (2x)	AB CD	13 fl oz + 48 oz then 13 fl oz	14.3 ml + 50.6 g then 14.3 ml
KD	Topguard + Sovran	ABCD	13 fl oz + 2 oz	14.3 ml + 2.1 g

Notes: [1]FP = formulated product. [2]alt = alternated with.

Note: The treatments described in this report were conducted for experimental purposes only and crops treated in a similar manner may not be suitable for commercial or other use.

C. Fungicide application history

A	24 March 2009	Green tip 	150 gallons/acre (=5.6 gallons/5 trees)	Applications made to all treatments except the unsprayed control.
B	7 April 2009	Most plants at red bud or approaching red bud; a very few flowers present 	150 gallons/acre (=5.6 gallons/5 trees)	Applications made to all treatments except the unsprayed control.
C	23 April 2009	Plants at full bloom 	200 gallons/acre (=7.4 gallons/5 trees)	Applications made to all treatments except the unsprayed control. Dithane was not included with Topguard in treatment "LG" because of full bloom and bee activity.
D	7 May 2009	Petal fall 	200 gallons/acre (=7.4 gallons/5 trees)	Applications made to all treatments except the unsprayed control. Dithane was not included with Topguard in treatment "LG" because of bee activity.

D. Disease and yield evaluation and statistical analysis

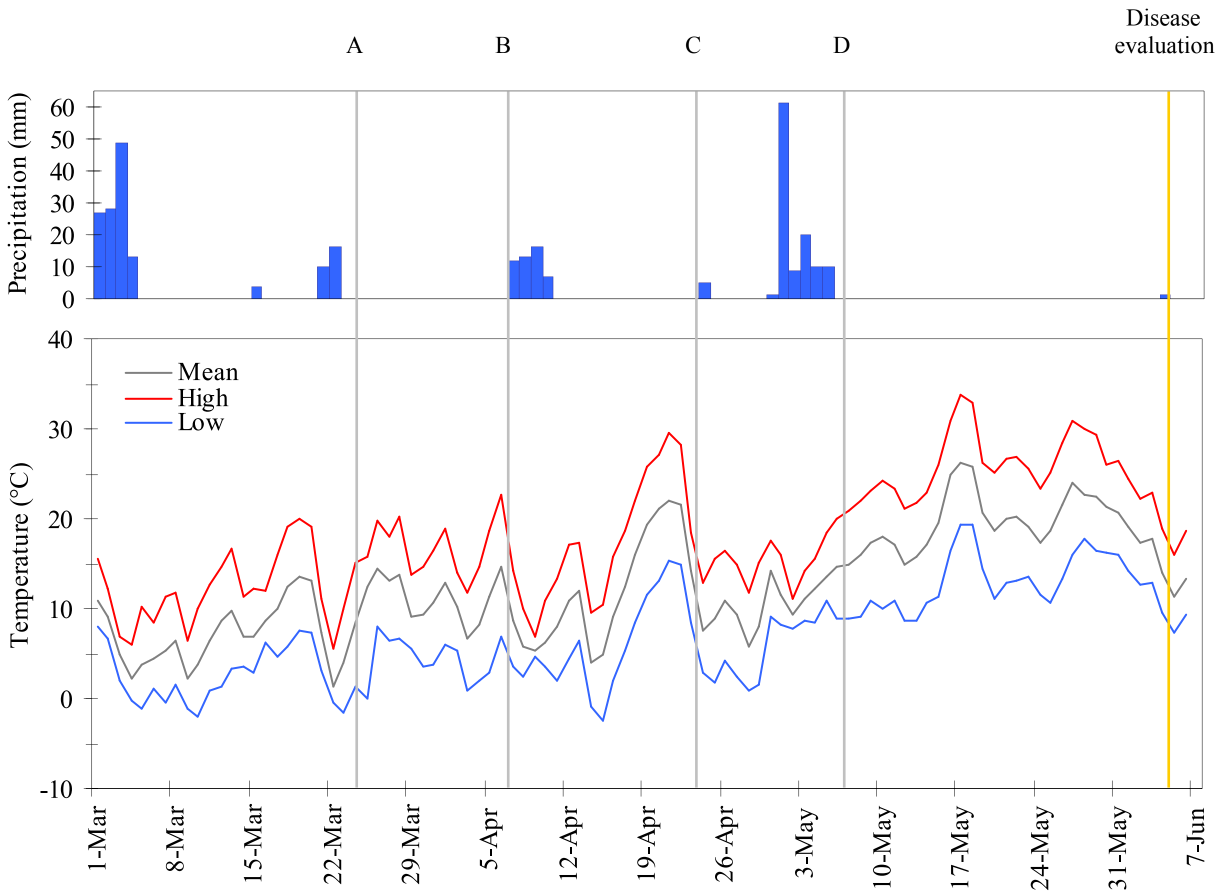
Disease was assessed on 5 June 2009 when fruits were large enough to observe scab lesions. Up to 60 (usually 40) fruits and leaves were randomly selected from each tree. The number of lesions was scored for each fruit or leaf; estimated counts were made when the boundaries of individual lesions could not be easily distinguished. Disease incidence per replicate tree was determined as the proportion of fruits or leaves that were infected by at least one lesion. Disease severity for each plot was obtained as the mean density of lesions on fruit or leaves. Data are presented as treatment means with 90% confidence intervals (CI) where CI = SE * $t_{(0.95,\, n-1)}$, SE = the standard error of the mean, and t is the threshold value from Student's t distribution (Rao 1998).

During early fall (28-30 September), several weeks following release of Red Delicious for harvest, fruits were collected from selected treatments to examine fungicide effects on fruit yield. Approximately 20 fruits were randomly selected per tree and weighed fresh within about 24 hr of collection. Mass was determined on a per fruit basis since trees were variable in size across the trial and a large percentage of fruits had already dropped from the trees.

III. Results

Climatic conditions. During the spring of 2009, several major precipitation events were conducive to the release and dispersal of *Venturia* ascospores (Figure 1). The most significant of these events occurred on 21-22 March at green tip (26 mm), 7-10 April at red bud (48 mm), and 30 April - 5 May at about late bloom (111 mm).

Figure 1. Daily precipitation and temperatures at the CIMIS weather station in Camino, California (http://wwwcimis.water.ca.gov/). Dates of fungicide applications (A-D) are indicated by light grey bands across the figure.



Disease incidence and severity. Disease incidence was high at the time of evaluation, with many treatments showing >90% disease incidence on fruits and 50-70% incidence on leaves (Figures 2,3). Sovran (alone or with Topguard or Nutrol fertilizer) and Topguard + Dithane tended to give the greatest degree of control (Figure 3). Disease severity was also markedly lower than untreated or water-treated trees in all treatments containing Sovran and trees treated with Topguard + Dithane (Figure 4). Although treatment with JMS Stylet-oil, Phyton 016-B or Topguard (13 fl oz/acre) gave some reduction in fruit scab severity relative to water treated trees, disease was not reduced enough generally to give fruit of marketable quality.

Figure 2. Representative fruits at the time of disease evaluation (5 June). (A) Heavily-infected fruit in the water control, (B) Sovran-treated fruit.

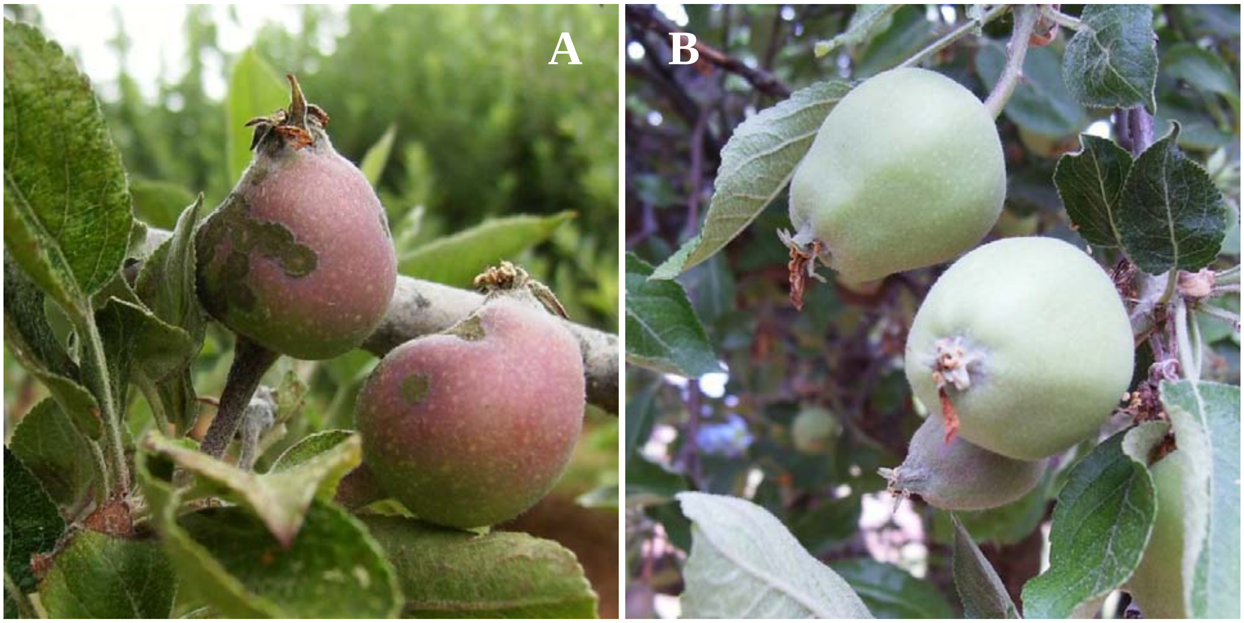


Figure 3. Apple scab disease incidence in late spring 2009 (means ± 90% confidence intervals).

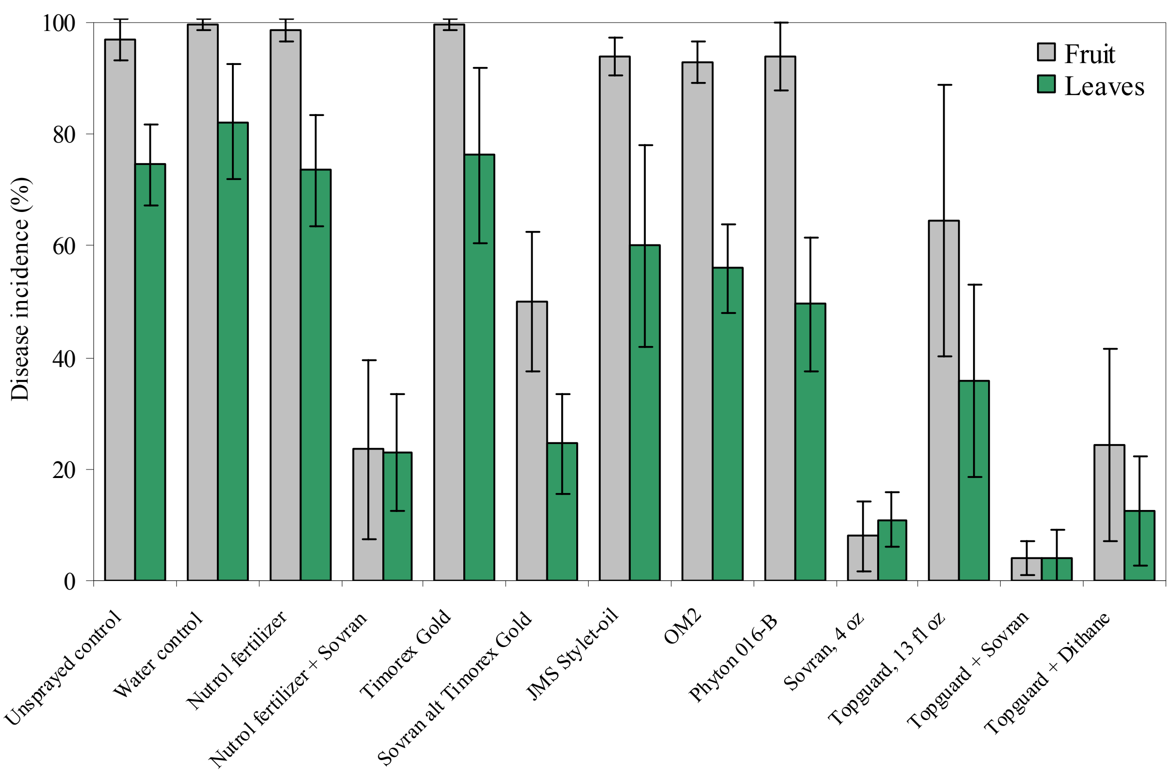
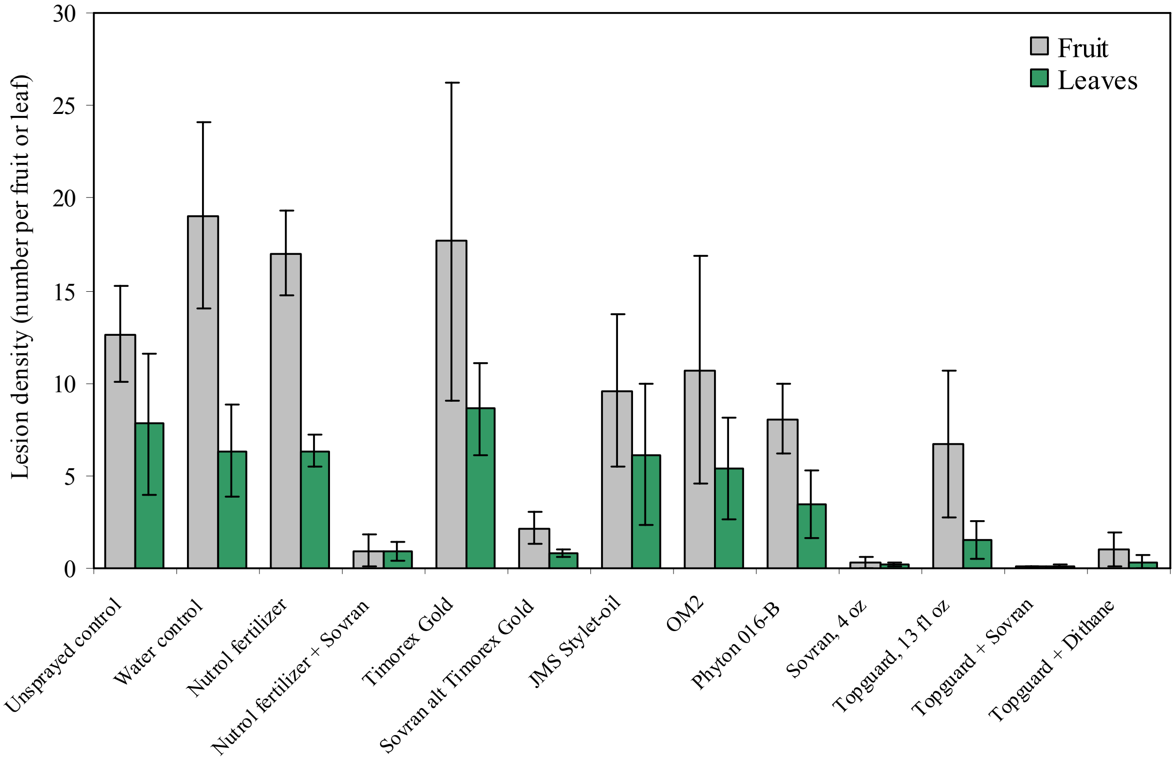


Figure 4. Disease severity (lesion density) in late spring 2009 (means ± 90% confidence intervals).

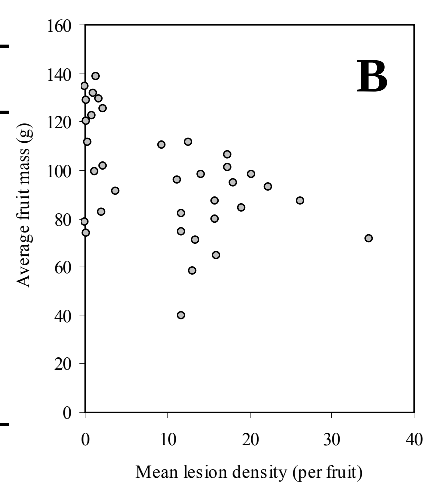


Fruit yield. Of the seven treatments evaluated, fruit wet weight was greatest in Sovran and Sovran + Nutrol-treated trees (Figure 5). Trees treated with Nutrol or Timorex Gold alone did not show a marked increase in fruit mass; Sovran alternated with Timorex Gold gave intermediate results.

Figure 5. (A) Fruit yield, measured as per fruit mass, in selected treatments (means ± 1 S.E.; n = 5). Different letters indicate significantly different groups of means (Fisher's LSD test at $\alpha = 0.10$). (B) Bivariate plot of yield versus fruit severity with each tree as a replicate ($r^2 = 0.24$; n = 35).

A. Fruit yield in selected treatments.

Treatment and application rate (per acre)	Average mass per fruit (g)	Change relative to water control (%)
Unsprayed control	76.8 ± 13.1 [a]	-
Water control	85.3 ± 2.2 [ab]	-
Sovran, 4 oz	114.4 ± 10.8 [cd]	+ 34.1
Nutrol fertilizer, 12.6 lb	86.9 ± 8.1 [ab]	+ 1.9
Nutrol fertilizer, 12.6 lb + Sovran, 2 oz	118.9 ± 10.5 [d]	+ 39.4
Timorex Gold, 0.6%	92.9 ± 6.6 [abc]	+ 8.9
Sovran, 4 oz alt Timorex Gold 0.6%	101.0 ± 7.9 [bcd]	+ 18.4



IV. Acknowledgements

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V. References

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VI. Appendix 1: Products tested

Product	Active ingredient(s) and concentration	Class	Manufacturer	OMRI
Dithane 75 DF Rainshield	mancozeb (75%)	carbamate	Dow Agrosciences LLC	NO
JMS Stylet-oil	paraffinic oil (97.1%)	mineral oil	JMS Flower Farms	YES
Nutrol fertilizer	phosphate (51.5%), potash (34%)	fertilizer	Rotem BKG	NO
OM2	paraffinic oil with OE-444 (an oil-based adjuvant, 2%)	mineral oil	OE-444: DuGassa/Goldschmidt	NO
Phyton 016-B	copper sulfate pentahydrate (21.4%)	inorganic/organic	Phyton Corporation	NO
Sovran	kresoxim-methyl (50%)	strobilurin	BASF Corporation	NO
Timorex Gold	oil derived from the tea tree, *Melaleuca alterniflora* (23.8%)	mineral oil	Biomor Israel, LTD	NO
Topguard 1.04 SC	flutriafol (12%)	dimethylase inhibitor	Cheminova A/S	NO

Appendix 1 references: (1) Adaskaveg, et al. 2008. Efficacy and timing of fungicides, bactericides and biologicals for deciduous tree fruit, nut, strawberry, and vine crops 2008, available at http://plantpathology.ucdavis.edu/ext/gubler/fungtrials2008/file/IPMFungicidetables2-14-08.pdf, (2) http://www.omri.org/index.html, (3) Janousek et al. 2008. Grape powdery mildew trials, available at http://plantpathology.ucdavis.edu/ext/gubler/fungtrials2008/file/Grape_PM_2008_web_report.pdf, (4) Janousek et al. 2008. Apple scab trial, available at: http://plantpathology.ucdavis.edu/ext/gubler/fungtrials2008/file/Apple_scab_2008_web_report.pdf, (5) various sources including product labels and/or MSDS, product websites, and personal communications.