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Kaolin Particle Film Product Applications Before Harvest Begins May Not Improve Marketable Yields of Fresh Tomatoes

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Additional index words. *Lycopersicon esculentum*, foliage, fruit, Surround

Summary. **Drip-irrigated, stake-and-weave supported tomato (*Lycopersicon esculentum*) plots were established in 2005 and 2006. All plots (except controls) were treated with a kaolin particle film product (Surround WP) mixed at 0.5 lb/gal of water and applied with a pressurized hand sprayer. Sprays began after transplanting and were repeated as needed to maintain a particle film on the foliage. Sprays were discontinued either at anthesis, at first green fruit 5 cm in diameter, or at first colored fruit harvest. Multiple hand harvests were made as fruit matured. In 2005, all kaolin treatments reduced marketable fruit number and weight, whereas in 2006 there were no significant effects. Cull fruit weight and average weight per marketable fruit were unaffected by treatments during either year. Results indicate that when applied before harvest begins, Surround may not improve marketable yields of fresh tomatoes.**

Kaolin is a naturally occurring, chemically inert clay mineral. Kaolin particle film applications have been used to reduce negative impacts of environmental stresses on crop plants, to suppress diseases, and to protect crops from insect pests. The development of particle film technology and its initial applications have been reviewed (Glenn and Puterka, 2005).

Tomato production in the south–central United States is constrained by environmental stresses, diseases, and pests. Foliar applications of kaolin materials have been reported to reduce leaf and fruit tissue temperatures and to improve water use efficiency in some tree fruit crops (Glenn et al., 2001, 2002; Jifon and Syvertsen, 2003). Rao (1985) reported that under nonirrigated conditions, a single spray of 5% kaolinite improved the water status and yield of tomato plants compared with control plants sprayed with distilled water only. In contrast, Russo and Díaz-Pérez (2005) found that use of a kaolin particle film product had no effect on pepper (*Capsicum annuum*) leaf transpiration or fruit yield.

The kaolin particle film product Surround WP (Engelhard Corp., Iselin, NJ) is labeled for reduction of heat stress and sunburn on several crops, including tomato, but the application periods for tomato are not well defined. There also are concerns about using the product on full-size tomato fruits. The white coating interferes with determination of color change (the key index of tomato fruit maturity), and the coating can be difficult to wash off. The Surround label recommends discontinuing applications on fresh market pepper and eggplant (*Solanum melongena*) after fruit reach 25% of final size, presumably because of the difficulty in cleaning the fruits.

A potential tomato disease problem is beet curly top virus (BCTV), a curtovirus that is transmitted by the beet leafhopper (*Circulifer tenellus*). Beet curly top virus typically is a sporadic disease of Oklahoma tomato crops; but in 2003, a devastating outbreak caused significant economic losses. The leafhopper is less likely to enter a shaded, closed plant canopy, making young plants particularly

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.4047	acre(s)	ha	2.4711
29.5735	fl oz	mL	0.0338
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
0.1198	lb/gal	$kg \cdot L^{-1}$	8.3454
28.3495	oz	g	0.0353
70.0532	oz/acre	$g \cdot ha^{-1}$	0.0143
1	ppm	$mg \cdot L^{-1}$	1
2.2417	ton/acre	$Mg \cdot ha^{-1}$	0.4461
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

susceptible to BCTV (Romney, 1943). There are no effective materials specifically labeled to control BCTV on tomato. However, Creamer et al. (2005) found that kaolin treatments (using Surround) suppressed BCTV on chile pepper in New Mexico. Others have cautioned that the use of kaolin particle films for insect control may also have plant developmental effects that can impact crop management decisions (Tworkoski et al., 2002).

Our research was designed to provide information concerning appropriate preharvest application periods for Surround on fresh market tomatoes. A secondary objective was to determine whether Surround was useful in suppressing BCTV when used to protect young tomato plants.

Materials and methods

Studies were conducted at the Oklahoma Vegetable Research Station, Bixby, OK. The soil was a Severn very fine sandy loam [coarse-silty, mixed (calcareous), thermic Typic Udifluvent]. No plastic mulches were used. Weeds were controlled with a broadcast preplant-incorporated application of trifluralin (Treflan; Helena Chemical Co., Collierville, TN) at 560 $g \cdot ha^{-1}$ supplemented by hoeing and machine cultivation. Foliar insecticides used included permethrin (Pounce; FMC Corp., Philadelphia, PA) at 225 $g \cdot ha^{-1}$, esfenvalerate (Asana; DuPont, Wilmington, DE) at 34 $g \cdot ha^{-1}$, and methomyl (Lannate; DuPont) at 560 $g \cdot ha^{-1}$. Azoxystrobin (Quadris; Syngenta Crop Protection, Greensboro, NC) at 113 $g \cdot ha^{-1}$ and copper hydroxide at 1.73 $kg \cdot ha^{-1}$ were used for foliar disease control. Plant water requirements were met with rainfall supplemented by surface drip irrigation.

The cultivar Florida 47 was used. Seeds were sown in peat-lite mix in pressed peat pots in a greenhouse on 11 Mar. 2005 and 17 Mar. 2006. Transplants were set in the field by hand. Each transplant received ≈240 mL starter solution providing 1079 $mg \cdot L^{-1}$ nitrogen (N), 941 $mg \cdot L^{-1}$ phosphorus (P), 895 $mg \cdot L^{-1}$ potassium (K), and 300 $mg \cdot L^{-1}$ diazinon (Diazinon AG500; Helena Chemical Co.).

The design was a randomized complete block with four replications. Treatments in both years were applications of Surround that began after transplanting and were repeated as needed to maintain a particle film on the foliage. Surround was mixed at 0.5 lb/gal water (the label-recommended rate) and applied with an agitated, pressurized hand sprayer through a flat fan nozzle tip until the foliage was thoroughly coated. Sprays were discontinued either at anthesis, at first green fruit 5 cm in diameter, or at first colored fruit harvest. Surround treatments were compared with a water-only control during both years, and also with an untreated control in 2006.

Plots were 3.6 m long and consisted of single rows 1.8 m apart. Plants within rows were 60 cm apart with six plants per plot. Plants were supported as they grew by using the stake-and-weave method (McCraw et al., 2004). Plants were pruned one time (just before the first string was installed) by removing all suckers up to the one below the first flower cluster.

Selective hand harvest of fruits expressing any red–pink color (breakers or more mature) was done twice per week. Fruits were separated into marketable and cull categories (U.S. Department of Agriculture, 1991) and weighed. Cull fruits were further classified by predominant reason for culling as follows: blossom-end rot, cracked, misshapen, sunburned, insect damaged, colored while still too small (typically with a diameter ≤ 2 cm), and a miscellaneous category for the remainder.

Cultural practices

2005. Trifluralin was applied on 14 Apr. The soil was further prepared with a broadcast preplant- incorporated application of urea to supply 62 $kg \cdot ha^{-1}$ N on 18 Apr. Adequate P and K were available from fertilization of previous trials. Transplants were set in the field on 19 Apr. The first stake-and-weave support string was installed on 16 May. Plants were sidedressed with urea to supply 56 $kg \cdot ha^{-1}$ N on 24 May. Permethrin was applied on 3 June, before harvests began. A total of 10 harvests were made beginning on 20 June and ending on 22 July. Esfenvalerate was applied on 20 June after the initial harvest. An additional application of permethrin plus azoxystrobin was made on 13 July.

The first application of Surround was made on 19 Apr. Other dates of application were 26 Apr.; 3, 9, and 16 May (16 May = final spray for the discontinued-at-anthesis treatment); 24 May; 1 and 7 June (7 June = final spray for the discontinued-at-first-5-cm-green-fruit treatment); and 14 and 20 June (20 June = final spray for the discontinued-at-first-colored-fruit-harvest treatment).

2006. Trifluralin and urea to supply 56 $kg \cdot ha^{-1}$ N were broadcast and incorporated on 17 Apr. Adequate P and K were available from fertilization of previous trials. Transplants were set in the field on 20 Apr. The first stake-and-weave support string was installed on 22 May. Plants were sidedressed with urea to supply 56 $kg \cdot ha^{-1}$ N on 22 May. Permethrin was applied on 18 May, before harvests began. A total of 14 harvests were made beginning on 26 June and ending on 10 Aug. Applications of esfenvalerate plus azoxystrobin were made on 3 and 17 July. An application of methomyl plus copper hydroxide was made on 24 July, and an application of esfenvalerate plus copper hydroxide was made on 3 Aug.

The first application of Surround was made on 24 Apr. Other dates of application were 4, 9, 15, and 22 May (22 May = final spray for the discontinued-at-anthesis treatment); 30 May; 5 and 13 June (13 June = final spray for the discontinued-at-first-5-cm-green-fruit treatment); and 19 and 26 June (26 June = final spray for the discontinued-at-first-colored-fruit-harvest treatment).

Data analysis

Data were subjected to analysis of variance procedures using SAS (SAS Institute Inc., Cary, NC). Data were analyzed separately by year. When treatment main effects were significant, means were separated by Duncan's multiple range test ($P \leq 0.05$). Treatment means also were compared with control means by Dunnett's test ($P \leq 0.05$).

Results and discussion

In 2005, all Surround treatments reduced marketable fruit number and weight relative to the water-only control, whereas in 2006 there were no significant effects of treatments on marketable fruit production (Table 1). Total fruit weight also was reduced relative to the water-only control by

Table 1. Yields from 'Florida 47' tomato plants in response to treatments with the kaolin particle film product Surround WP (Engelhard Corp., Iselin, NJ), Bixby, OK, 2005 and 2006[z].

	Marketable fruit									
	(1000/ha)[y]		(Mg·ha^{-1})[y]		Avg wt (g/fruit)[y]		Cull fruit (Mg·ha^{-1})		Total fruit (Mg·ha^{-1})	
Treatment	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Untreated control	—	112	—	20.2	—	181	—	10.2	—	30.5
Water-only control	83 a[x]	121	17.6 a	21.7	211	179	9.6	9.8	27.1 a	31.5
Kaolin to anthesis	49 b	120	10.4 b	21.4	211	178	9.4	10.1	19.8 b	31.4
Kaolin to green fruit	44 b	117	9.4 b	21.5	214	184	10.2	9.3	19.6 b	30.8
Kaolin to first harvest	54 b	122	11.4 b	22.7	210	189	10.8	9.8	22.3 ab	32.5
Significance	**	NS	**	NS	NS	NS	NS	NS	*	NS

[z]During each year, plants began receiving sprays of Surround at 0.5 lb/gal after transplanting. Sprays continued until the end point indicated. Total sprays applied during each year were five (to anthesis), eight (to first green fruit), or 10 (to first harvest).
[y]1000 fruit/ha = 404.7 fruit/acre; 1 Mg·ha^{-1} = 0.4461 ton/acre; 1 g = 0.0353 oz.
[x]Mean separation in columns by Duncan's multiple range test ($P \leq 0.05$). For 2005 data, in columns, kaolin treatment means not followed by an "a" also differ from the water-only control by Dunnett's test ($P \leq 0.05$).
[ns,*,**]Nonsignificant or significant by F test at $P \leq 0.05$ or 0.01 respectively.

two of three Surround treatments in 2005. Variables unaffected by treatments in either year included average weight per marketable fruit (Table 1), total cull fruit weight (Table 1), and numbers of fruits in the various cull categories (data not presented).

Five Surround applications between the time of field transplanting and anthesis were sufficient to produce negative effects in 2005 (Table 1), indicating that the negative effects occurred early during plant development. Effects also were not cumulative, as 10 Surround applications were no worse (nor any better) than five applications. Makus (2000) reported that Surround applications delayed tomato fruit development but did not affect marketable yields relative to an untreated control. We believe that weather conditions contributed to the different effects of Surround during the 2 years of our study (Figs. 1 and 2). In 2006, there were six rain events of ≥ 20 mm each between 23 Apr. and 11 May (Fig. 2). This meant that residues from several of the initial Surround sprays were washed off the plants very shortly after application. There also were 4 d between field transplanting and the first Surround application in 2006, whereas in 2005 plants received their initial Surround application on the day of field transplanting.

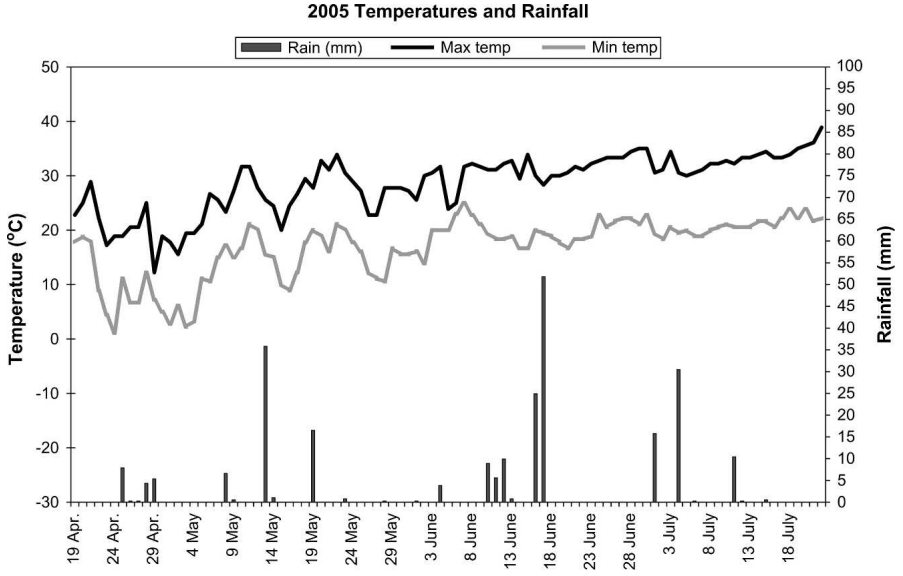

Fig. 1. Maximum (Max temp) and minimum (Min temp) daily air temperatures and daily rainfall totals at the Oklahoma Vegetable Research Station, Bixby, OK, during the 2005 experimental period. Tomatoes were transplanted to the field on 19 Apr. and the final harvest was on 22 July. 1 mm = 0.0394 inch; (1.8 × °C) + 32 = °F.

A physiological explanation for the negative effects of Surround cannot be determined from this study. There were no foliar symptoms and overall plant size was not obviously affected. Others (Glenn et al., 2001, 2003; Lombardini et al., 2005; Rosati et al., 2006) have reported that kaolin particle film applications did not increase (or even decreased) leaf assimilation when air temperatures were not elevated to stressful levels and crops were well irrigated. As a result, kaolin particle film applications in the absence of high-temperature and low-moisture stresses have at times resulted in no crop yield response (Lombardini et al., 2005) or in reduced productivity (Schupp et al., 2002; Tworkoski et al., 2002).

Although this study was not designed to measure insect-suppressive effects of Surround directly, the ideal would have been to avoid using other insecticides until harvest began. Pressure from Lepidoptera larvae [especially the tomato fruitworm (*Helicoverpa zea*)] necessitated the permethrin applications on 3 June 2005 and 18 May 2006.

Only one data plant was confirmed to have been infected with BCTV in 2005, and none were infected in 2006. Thus, we were unable to determine whether Surround sprays on young tomato plants

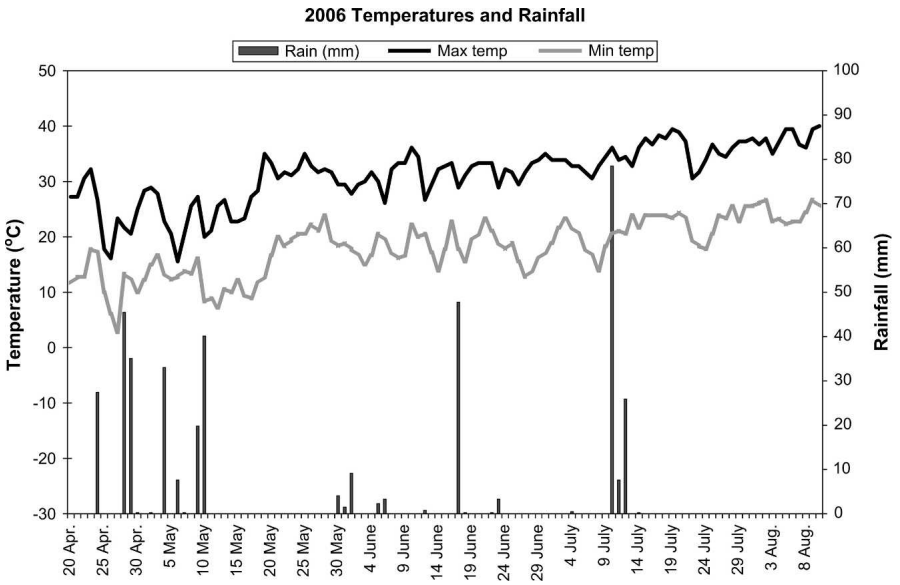

Fig. 2. Maximum (Max temp) and minimum (Min temp) daily air temperatures and daily rainfall totals at the Oklahoma Vegetable Research Station, Bixby, OK, during the 2006 experimental period. Tomatoes were transplanted to the field on 20 Apr. and the final harvest was on 10 Aug. 1 mm = 0.0394 inch; (1.8 × °C) + 32 = °F.

were useful in suppressing BCTV. The widespread economic loss to Oklahoma tomato crops incited by BCTV in 2003 may have been an aberration. The disease may be more sporadic, and preventative sprays strictly for BCTV control may not be justified. We demonstrated no yield benefit, and 1 year with a yield reduction, from Surround applications extending over various stages of preharvest crop development. Therefore, we would not recommend Surround applications as a prophylactic treatment before tomato harvest begins.

Literature cited

Creamer, R., S. Sanogo, O.A. El-Sebai, J. Carpenter, and R. Sanderson. 2005. Kaolin-based foliar reflectant affects physiology and incidence of beet curly top virus but not yield of chile pepper. HortScience 40:574–576.

Glenn, D.M., A. Erez, G.J. Puterka, and P. Gundrum. 2003. Particle films affect carbon assimilation and yield in 'Empire' apple. J. Amer. Soc. Hort. Sci. 128:356–362.

Glenn, D.M., E. Prado, A. Erez, J. McFerson, and G.J. Puterka. 2002. A reflective, processed-kaolin particle film affects fruit temperature, radiation reflection, and solar injury in apple. J. Amer. Soc. Hort. Sci. 127:188–193.

Glenn, D.M. and G.J. Puterka. 2005. Particle films: A new technology for agriculture. Hort. Rev. (Amer. Soc. Hort. Sci.) 31:1–44.

Glenn, D.M., G.J. Puterka, S.R. Drake, T.R. Unruh, A.L. Knight, P. Baherle, E. Prado, and T.A. Baugher. 2001. Particle film application influences apple leaf physiology, fruit yield, and fruit quality. J. Amer. Soc. Hort. Sci. 126:175–181.

Jifon, J.L. and J.P. Syvertsen. 2003. Kaolin particle film applications can increase photosynthesis and water use efficiency of 'Ruby Red' grapefruit leaves. J. Amer. Soc. Hort. Sci. 128:107–112.

Lombardini, L., M.K. Harris, and D.M. Glenn. 2005. Effects of particle film application on leaf gas exchange, water relations, nut yield, and insect populations in mature pecan trees. HortScience 40: 1376–1380.

Makus, D.J. 2000. Effect of pre-plant application of VAM and particle film applications on tomato in a supra-optimal, semi-arid environment. HortScience 35:442(abstr.).

McCraw, D., J. Motes, and R.J. Schatzer. 2004. Commercial production of fresh market tomatoes. F-6019. Coop. Ext. Serv., Okla. State Univ., Stillwater, OK.

Rao, N.K.S. 1985. The effects of anti-transpirants on leaf water status, stomatal resistance and yield in tomato. J. Hort. Sci. 60:89–92.

Romney, V.E. 1943. The beet leafhopper and its control on beets grown for seed in Arizona and New Mexico. U.S. Dept. Agr. Tech. Bul. 855. USDA, Washington, DC.

Rosati, A., S.G. Metcalf, R.P. Buchner, A.E. Fulton, and B.D. Lampinen. 2006. Physiological effects of kaolin applications in well-irrigated and water-stressed walnut and almond trees. Ann. Bot. (Lond.) 98:267–275.

Russo, V.M. and J.C. Díaz-Pérez. 2005. Kaolin-based particle film has no effect on physiological measurements, disease incidence or yield in peppers. HortScience 40:98–101.

Schupp, J.R., E. Fallahi, and I.J. Chun. 2002. Effect of particle film on fruit sunburn, maturity and quality of 'Fuji' and 'Honeycrisp' apples. HortTechnology 12:87–90.

Tworkoski, T.J., D.M. Glenn, and G.J. Puterka. 2002. Response of bean to applications of hydrophobic mineral particles. Can. J. Plant Sci. 82:217–219.

U.S. Department of Agriculture. 1991. United States standards for grades of fresh tomatoes. Agricultural Marketing Service, Washington, DC.