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WEED SCIENCE

Cotton Response to Temperature and Pyrithiobac

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INTERPRETIVE SUMMARY

Staple herbicide (active ingredient pyrithiobac, from DuPont Agricultural Products Co.) was registered in 1996 for postemergence application to cotton. It controls many troublesome dicot weeds such as smooth pigweed, redroot pigweed, Palmer amaranth, most morningglory species, common cocklebur, Pennsylvania smartweed, ladysthumb, velvetleaf, prickly sida, hemp sesbania, coffee senna, and devil's-claw. It can be applied postemergence over-the-top of cotton, which is a distinct advantage compared with postemergence-directed applications on small cotton.

Cotton is usually tolerant of Staple applied postemergence. Chlorosis of terminal leaves is commonly observed but the effect is transient. Adverse effects have not been observed on yield, maturity, or lint quality in most studies. In a few cases, however, Staple has caused moderate to severe cotton injury. Empirical evidence suggests that the potential for injury is greater when cool temperatures occur during or near the time of Staple application. The objective of our study was to evaluate cotton response to Staple applied postemergence as influenced by temperature.

The experiment was conducted in controlled-environment growth chambers. Cotton cv. Deltapine 51 was grown at 88/75 °F (day/night, 14-h day length) until it reached the two-leaf stage. It was then subjected to four temperature regimes that included all combinations of warm (88/75 °F) and cool (70/46 °F) temperatures for 5 d before and after application of Staple at 1.2 and 2.4 oz of product per acre (0.064 and 0.128 lb a.i./acre). These rates are one and two times the recommended rate for postemergence application. At 5 d after Staple application, all plants were returned to the warm regime and grown for an additional 9 d.

Staple and temperature regimes affected cotton independently as indicated by the lack of a Staple rate-by-temperature regime interaction for all parameters evaluated. Staple caused visible chlorosis and reduced leaf chlorophyll content 4 to 5 d after treatment. The chlorosis disappeared by 10 d after treatment. Staple had no effect on cotton height, shoot dry weight, number of main stem nodes, or number of squares 14 d after treatment. Cool temperatures reduced cotton height and shoot dry weight 14 d after Staple application. Cotton height and shoot dry weight response to cool temperatures depended on length, but not time of exposure. Results were similar when the exposure occurred either 5 d before or 5 d after Staple application, but exposure for 10 d reduced both growth parameters more than a 5-d exposure. Exposure to cool temperatures reduced square production, with exposure for 5 d prior to Staple application having a greater impact than exposure for 5 d after application. Exposure to cool temperatures for 5 d before Staple application or 5 d before and after Staple application increased the nodal position of the first sympodium. The number of main stem nodes was reduced only on plants exposed to the cool temperatures for 5 d before and after Staple application. Lack of a temperature regime by Staple interaction suggests greater Staple injury under cool conditions as occasionally observed in the field may be due to a combination of stress factors.

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ABSTRACT

Cotton (*Gossypium hirsutum* L.) normally has good tolerance to pyrithiobac {2–chloro–6–[(4,6–dimethoxy–2–pyrimidinyl)thio] benzoic acid, sodium salt] applied postemergence. Occasionally, though, moderate-to-severe injury has been observed in the field. Empirical evidence suggests this injury is related to cool temperatures during or near the time of application. A growth

chamber experiment studied the effect of temperature on cotton cv. Deltapine 51's response to pyrithiobac applied postemergence. Cotton was grown at 31/24 °C (day/night), except for exposure to cool temperatures (21/8 °C) for 5 d before, 5 d after, or 5 d before *and* after pyrithiobac application. Pyrithiobac caused visible chlorosis and reduced leaf chlorophyll content 4 to 5 d after treatment but had no effect on other parameters. Cool temperatures reduced cotton height and shoot dry weight 14 d after pyrithiobac application, with reductions dependent upon length but not time of exposure. Results were similar when exposure occurred either 5 d before or 5 d after application, but exposure for 10 d caused greater reductions. Exposure to cool temperatures reduced square production, with exposure for 5 d before pyrithiobac application having a greater impact than exposure for 5 d after application. Exposure to cool temperatures for 5 d before or 5 d after pyrithiobac application increased nodal position of the first sympodium. The number of main stem nodes was reduced only on plants exposed to cool temperatures for 10 d. Lack of a temperature-by-pyrithiobac interaction suggests that the damage occasionally observed in the field under cool conditions may be due to a combination of stress factors.

Weed management programs in non-transgenic cotton have relied on soil-applied herbicides to control annual monocot and dicot weeds (Wilcut et al., 1995). However, soil-applied herbicides seldom adequately control weeds season long (Batts and York, 1997; Culpepper and York, 1997). Consequently, postemergence or postemergence-directed herbicides are routinely used in conjunction with soil-applied herbicides (Buchanan, 1992; Wilcut et al., 1995). Various herbicides can be applied postemergence-directed if a height differential exists between cotton and weeds (Wilcut et al., 1997). Growers, however, prefer to apply herbicides postemergence, especially on small cotton (Wilcut et al., 1996). Directing herbicides to small cotton is a slow and tedious job requiring specialized equipment and a height differential between cotton and weeds which might not always be available.

Several graminicides can be applied postemergence to control grassy weeds without adversely affecting cotton (Wilcut et al., 1996). Fluometuron {*N*,*N*–dimethyl–*N*'–[3–(trifluoromethyl)phenyl]urea}, MSMA (monosodium methanearsonate), and DSMA (disodium methanearsonate) can be applied postemergence to control dicot weeds. However, postemergence-directed application is preferred because over-the-top application of these herbicides can injure cotton, delay maturity, and reduce yield (Byrd and York, 1987; Guthrie and York, 1989; Snipes and Byrd, 1994).

Pyrithiobac, a pyrimidinyl carboxy herbicide, was registered in 1996 for postemerence application to cotton (Reinhart, 1996). It controls many of the troublesome dicot weeds found in cotton, including pigweed species (*Amaranthus* spp.), most annual morningglory species (*Ipomoea* spp.), common cocklebur (*Xanthium strumarium*), smartweed species (*Polygonum* spp.), velvetleaf (*Abutilon theophrasti*), prickly sida (*Sida spinosa*), hemp sesbania (*Sesbania exaltata*), coffee senna (*Cassia occidentalis*), and devil's-claw (*Proboscidea louisianica*) (Dotray et al., 1996; Elkins et al., 1995; Jordan et al., 1993c,d,e; Keeton et al., 1996; Murdock et al., 1995). Cotton is usually tolerant of pyrithiobac applied postemergence. Chlorosis of terminal leaves is commonly observed, but the effect is transient and adverse effects on yield, maturity, and lint quality have not been observed in most studies (Allen and Snipes, 1995; Allen et al. , 1997; Culpepper and York, 1997; Dotray et al., 1996; Jordan et al., 1993a,b). However, significant injury has occasionally been observed in field experiments and in growers' fields (Harrison et al., l996; Keeling et al., 1993).

Smith et al. (1996) suggested cotton tolerance to pyrithiobac was related to environmental conditions. Severe injury, including leaf necrosis and defoliation, has sometimes been observed in North Carolina (authors, unpublished data). Empirical evidence suggests the potential for injury is greater when cool temperatures occur during or near the time of pyrithiobac application. The pyrithiobac manufacturer cautions users that cool temperatures and other stresses may increase cotton's sensitivity to the herbicide (Staple Herbicide label, DuPont Agricultural Products Co.). The objective of our study was to evaluate cotton response to pyrithiobac applied postemergence as influenced by temperature.

MATERIALS AND METHODS

The experiment was conducted in controlled environment chambers at the North Carolina State University Phytotron. Pots measuring 15 cm in

diam. were filled with a mixture of fine gravel and a commercial blend of peat moss and vermiculite based on the original "Cornell mix" (Boodley and Sheldrake, 1972). Cotton cv. Deltapine 51 was planted, and seedlings were thinned to one per pot 7 d after planting. At 7 and 17 d after planting, 10 mL per pot of a 26 g L^{-1} commercial greenhouse fertilizer (Peters Professional All Purpose 20-20-20 from W. R. Grace & Co.) were added.

The cotton was grown for 20 d at 31/24 °C (day/night; 14/10 h) until it reached the two-leaf stage. It was then exposed to four temperature regimes during the 5-d period before and after pyrithiobac application. This was accomplished by rotating plants between two identical chambers set at 31/24 °C and 21/8 °C (hereafter referred to as warm and cool, respectively). The four temperature regimes were warm/warm, cool/warm, warm/cool, and cool/cool (5 d before pyrithiobac application/5 d after pyrithiobac application). On the sixth day, all plants were returned to the warm chamber and allowed to grow for an additional 9 d. Light intensity (510 μE m^{-2} s^{-1} in a 14-h photoperiod) and relative humidity (60–70%) were held constant throughout the experiment.

The sodium salt of pyrithiobac was applied at 0, 70, or 140 g a.i. ha^{-1} using a spray chamber equipped with an 8001E flat fan nozzle (TeeJet Spray Nozzles from Spraying Systems Co.) and calibrated to deliver 400 L ha^{-1} at 160 kPa. A nonionic surfactant (X-77 Spreader, alkylarylpolyoxyethylene glycols, free fatty acids, and isopropanol from Valent USA Corp.) at 0.25% (v/v) was included with the pyrithiobac. The recommended rate of pyrithiobac for postemergence application is 70 g ha^{-1} (Staple Herbicide label, DuPont Agricultural Products Co.). Cotton exposed to cool and warm temperatures for 5 d before pyrithiobac application was 9.6 cm tall with two to three leaves and 13.3 cm tall with three to four leaves, respectively, at time of herbicide application. The experimental design was completely randomized with treatments replicated 10 times. Five replicates were used for chlorophyll determination and the remaining replicates were used for other evaluations. The experiment was repeated once.

Plant height was recorded 5, 8, 10, and 14 d after pyrithiobac application. The number of squares and main stem nodes, nodal position of the first sympodium, and shoot dry weight were determined 14 d after herbicide application. Percent chlorosis relative to the non-treated cotton in the warm/warm regime was estimated visually 3, 5, 8, 10, and 14 d after pyrithiobac application. Total chlorophyll content in the youngest leaf with a diameter of 2 cm or greater was determined 4 d after herbicide application according to Moran (1982). Five to 10 disks (9.5 mm diam.), depending upon size of the leaf, were removed using a cork borer. Leaf disks were weighed and then placed in test tubes containing 7.5 ml of *N*,*N*–dimethylformamide. Samples were stored in complete darkness at 4 °C for 60 h before centrifugation at 1200 × g for 2 min. Absorbance values at 647 and 664 nm were determined spectrophotometrically. Total chlorophyll content per unit fresh weight was calculated using extinction coefficients determined according to Moran (1982).

Data from the repeated experiment were pooled and subjected to analysis of variance with partitioning for a four by three (temperature regime by pyrithiobac rate) factorial arrangement. Means were separated by the appropriate Fisher's Protected LSD Test at $P = 0.05$. Non-transformed data from the visual estimates of chlorosis are presented because arcsine square root transformation did not affect conclusions.

RESULTS AND DISCUSSION

Pyrithiobac and temperature regimes affected cotton independently as indicated by the lack of a pyrithiobac rate-by-temperature regime interaction for all evaluated parameters. Main effects of pyrithiobac rates were noted for leaf chlorophyll content 4 d after pyrithiobac application and for cotton chlorosis 3, 5, and 8 d after application but not for cotton height, shoot dry weight, number of main stem nodes, square production, or nodal position of the first sympodium.

Pooled across temperature regimes, pyrithiobac at 70 and 140 g ha^{-1} reduced leaf chlorophyll content 12 and 23%, respectively (LSD 0.05 = 4; data not shown). Similarly, pyrithiobac caused 15 to 20% and 18 to 21% chlorosis 3 and 5 d after application, respectively (Fig. 1). Greater chlorosis was noted with the higher rate of pyrithiobac 3 d after application but not at 5 or 8 d after

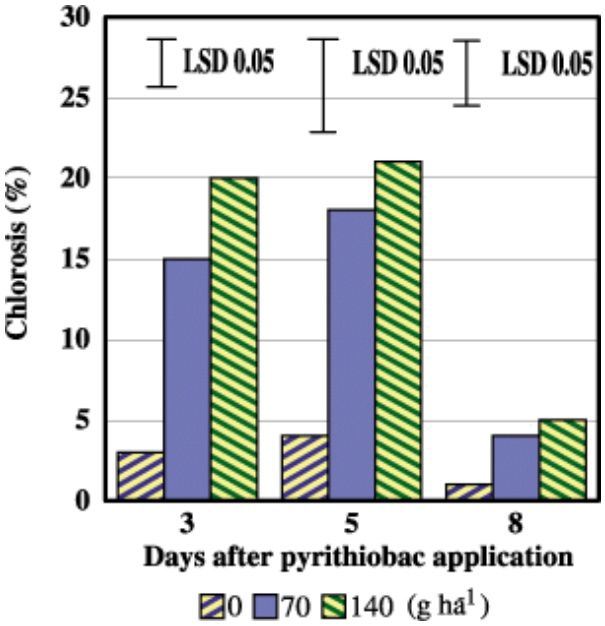

Fig. 1. Main effect of pyrithiobac rates on cotton chlorosis.

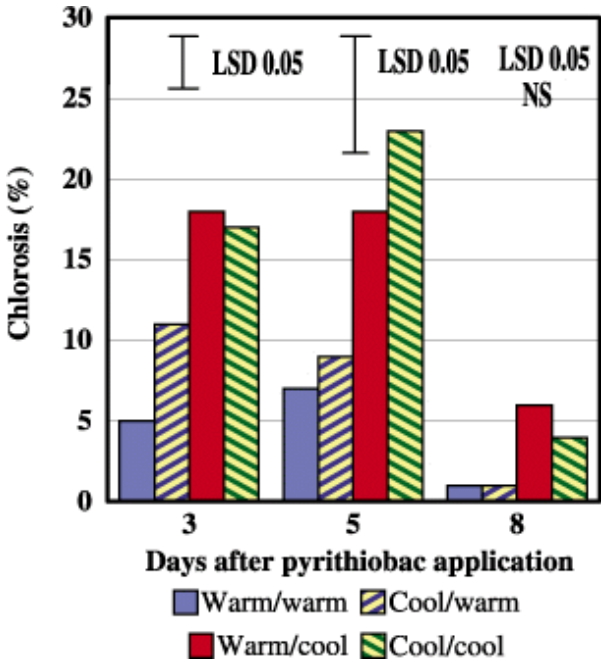

Fig. 2. Main effect of temperature regimes on cotton chlorosis.

application. Cotton recovered quickly, and only 4 to 5% chlorosis was noted 8 d after pyrithiobac application. No chlorosis was noted at 10 or 14 d (data not shown). These results are similar to previous reports of transient chlorosis but no lasting effect of pyrithiobac on cotton (Allen and Snipes, 1995; Allen et al., 1997; Culpepper and York, 1997; Dotray et al. 1996; Jordan et al. 1993b).

Main effects of temperature regimes were noted for all parameters evaluated. Cool temperatures caused cotton chlorosis 3 and 5 d after herbicide application (Fig. 2). Greater chlorosis was noted on plants exposed to cool temperatures for 5 d after pyrithiobac application (warm/cool, 18%) as compared with those exposed to cool temperatures for 5 d before application (cool/warm, 9–11%). Chlorosis was similar on plants exposed to warm/cool and cool/cool regimes. Results from the chlorophyll extraction 4 d after pyrithiobac application were similar to the visual estimates of chlorosis except that a 10-d cool period had a greater effect than a 5-d cool period. Cool temperatures for 5 d before, 5 d after, and 5 d before plus 5 d after pyrithiobac application reduced chlorophyll content 14, 36, and 51%, respectively (LSD 0.05 = 4; data not shown). Total chlorophyll content in non-treated cotton grown in the warm/warm regime was 2.08 mg g^{-1} fresh weight.

Data for chlorosis and chlorophyll content appear to indicate cool temperatures after pyrithiobac application were more detrimental than cool temperatures prior to application. However, this was likely an artifact of the time of evaluation since chlorosis decreased rapidly upon return to warm temperatures. Temperature had no effect on chlorosis 8 d (Fig. 2) or 10 or 14 d after pyrithiobac application (data not shown). Chlorosis and chlorophyll content were not determined during the cool period prior to pyrithiobac application. However, it was generally observed that chlorosis at the end of the 5-d cool period prior to pyrithiobac application was similar to that observed at the end of the 5-d cool period following application.

Cool temperatures reduced cotton height at each evaluation (Fig. 3). However, the magnitude of the response was greatest 5 d after herbicide application and decreased with time. Response to cool temperatures depended on length of exposure but not time of exposure. Exposure to 5 d of cool temperatures reduced cotton height 16% at 5 d after pyrithiobac application, 10 to 11% after 8 d, 7 to 9% after 10 d, and 7% at 14 d after pyrithiobac application. Results were similar when the exposure occurred either 5 d before (cool/warm) or 5 d after application (warm/cool). Exposure to cool temperatures for 10 d (cool/cool) reduced cotton height 39% at 5 d after pyrithiobac application,

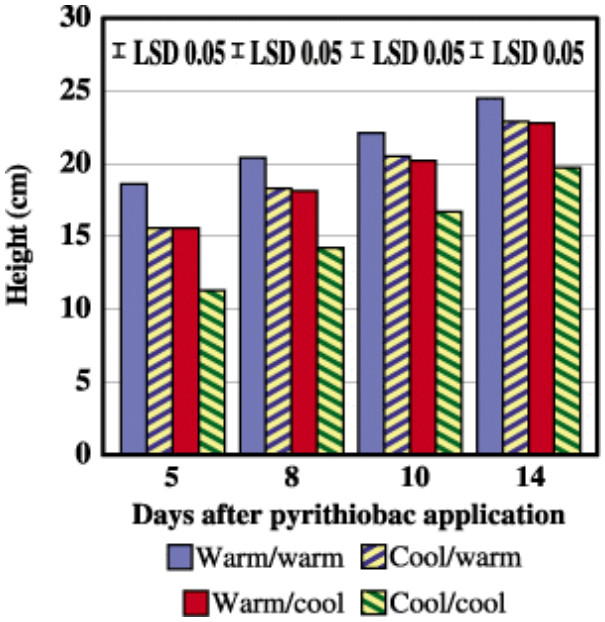

Fig. 3. Main effect of temperature regimes on cotton height.

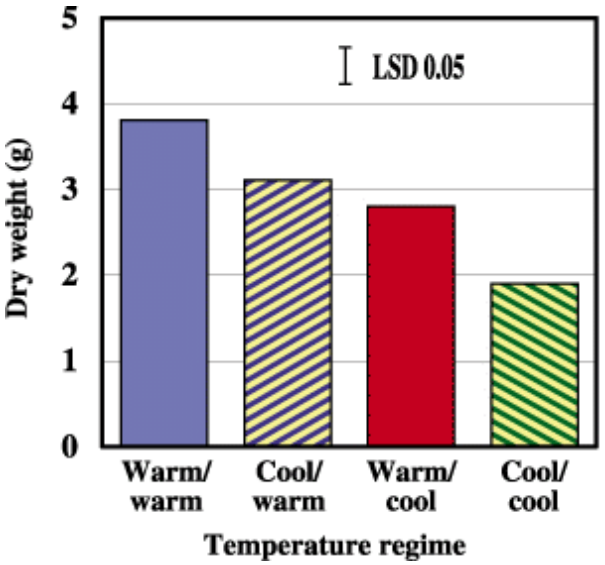

Fig. 4. Main effect of temperature regimes on cotton shoot dry weight 14 days after pyrithiobac application.

30% at 8 d, 25% at 10 d, and 20% at 14 d after pyrithiobac application.

Trends in response to temperature regimes were similar with cotton height and shoot dry weight 14 d after pyrithiobac application. Shoot dry weight response to temperature regimes also depended on length of exposure, but not time of exposure, to the cool temperatures (Fig. 4). Exposure to cool temperatures for 5 d before or 5 d after pyrithiobac application reduced shoot dry weight 18 to 26% but exposure to cool temperatures for 10 d reduced dry weight 50%. The magnitude of the response to cool temperatures was greater for shoot dry weight than for plant height. Other researchers also noted that cool temperatures reduced shoot dry weight more than plant height (Flint et al., 1983).

Cool temperatures also reduced square production. At 14 d after pyrithiobac application, plants grown in the warm/warm regime had 3 squares per plant, those in the warm/cool had 2, those in the cool/warm had 1 square per plant, and those in the cool/cool regimes had only 0.4 squares per plant (LSD 0.05 = 0.3; data not shown).

This response to cool temperatures appeared to be primarily due to a delay in sympodium initiation and secondarily due to a reduction in main stem node formation. Twenty-nine of the 30 plants in the warm/warm regime and 27 of the 30 in the warm/cool regime had a sympodium on node six (data not shown). In contrast, only 17 of the 30 plants in the cool/warm regime and five of the 30 in the cool/cool regime had a sympodium on node six. Plants in the warm/warm regime had seven to eight main stem nodes (average 7.4; data not shown).

A 5-day cool period before or after pyrithiobac application did not affect the number of nodes (average 7.4 in warm/cool and 7.7 in cool/warm regimes), but exposure of plants to a 10-d cool period reduced the number of main stem nodes to six or seven (average 6.8; LSD 0.05 = 0.5). Gibson and Ray (1974) reported that nodal position of the first sympodium probably is determined between cotton emergence and appearance of the first true leaf. Our plants were not exposed to cool temperatures until the two-leaf stage and yet exposure to cool temperatures for 5 d before pyrithiobac application increased the nodal position of the first sympodium.

The adverse effects of cool temperatures on cotton growth and development in our experiment are similar to previous observations (Flint et al., 1983; Reddy et al., 1992). However, we did not observe that cool temperatures for 5 d before, 5 d after, or 5 d before plus 5 d after pyrithiobac application increased cotton injury by the herbicide. Harrison et al. (1996) grew cotton at temperatures of 25/23, 30/28, and 35/33 °C at soil moisture potentials of -0.03, -0.5, and -1.0 MPa. They reported that neither temperature nor soil moisture affected cotton injury by pyrithiobac at 140 or 420 g ha^{-1}. They speculated that their temperatures may

not have been low enough to influence cotton injury by pyrithiobac.

Pyrithiobac is most commonly applied postemergence in North Carolina during the last 10 d of May. The long-term average maximum and minimum temperatures in the central Coastal Plain of our state during this period are 29 and 16 °C, respectively (National Climatic Data Center, Asheville, NC). The average lowest maximum and minimum temperatures recorded during this period are 17 and 9 °C, respectively. Additionally, these cool periods seldom last more than 2 or 3 d. Hence, the cool temperatures in our experiment represent the extremes that would likely be encountered. The severe injury by pyrithiobac that is occasionally observed in the field may be due to a combination of stresses such as cool temperatures, wet soils, cloudy skies, high humidity, and early-season insect damage.

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