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ABSTRACT

Tomato (Lycopersicon esculentum Mill. 'Heinz 1350') transplants were conditioned by reducing temperature, watering, fertilization, and increasing light. These "hardened" transplants and unhardened transplants were treated with 0.56 kg ai/ha metribuzin (4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)one) at the 5, 6, or 7 leaf stage. Hardened plants at all leaf stages and the most mature unhardened plants (7 leaf stage) sustained least injury. Hardened plants contained a lower percent nitrogen and higher carbon: nitrogen ratio than unhardened plants. Plants showed a trend towards decreasing percent N and increasing carbon: nitrogen ratio, as well as towards decreasing injury, with hardening and maturity. Percent nitrogen at treatment time was negatively correlated with survival and carbon: nitrogen ratio was positively correlated with survival.

INTRODUCTION

Postemergence applications of metribuzin at rates appropriate for weed control have produced injury to tomato transplants in many cases. Investigators have attempted to link injury with plant size and maturity (5, 9, 13, 30, 34, 37). Increased plant size or maturity has conferred tolerance in some cases, but not in others. An attempt was made in this study to identify the possible relationship between plant size and/or maturity and tolerance to metribuzin under controlled conditions.

Since carbohydrates (3, 12, 24, 36) and nitrogen (2, 6, 14, 15, 16, 17, 18, 19, 22, 28, 32, 33, 35, 41) have been implicated in metribuzin mode of action and injury, an attempt was made to deter-

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mine whether the status of carbon and nitrogen in plants at the time of treatment was associated with tolerance.

MATERIALS AND METHODS

'Heinz 1350' tomatoes were seeded in vermiculite and transplanted to a peat-vermiculite mixture in 10 cm plastic pots 2 weeks later. One week after transplanting, when plants had reached the 2 leaf stage, they were moved from the 16.5 C (minimum temperature) greenhouse to growth chambers.

One-half the plants were subjected to a hardening regime of reduced temperature (20.5 C), reduced watering (only at wilt), reduced fertilization (quarter-strength Hoagland solution at alternate waterings), and increased light intensity (3000 footcandles). The remaining half of the plants, unhardened, were grown with 25.5 C days and 19 C nights, watered daily, fertilized every other day with half-strength Hoagland solution, and provided 1500 footcandles. All plants were grown in a 17 hour light and a 7 hour dark regime.

All plants were treated with 0.56 kg ai/ha metribuzin upon reaching the appropriate developmental stage--5, 6, or 7 leaf stage. Metribuzin was applied by means of a compressed air knapsack sprayer calibrated to deliver 167 l/ha at 0.075 kg/cm^2 pressure.

The randomized complete block design contained six treatments and six replicates. The treatments consisted of herbicide application to six plant types: 1) unhardened 5-leaf, 2) hardened 5-leaf, 3) unhardened 6-leaf, 4) hardened 6-leaf, 5) unhardened 7-leaf, and 6) hardened 7-leaf.

Injury ratings (0=no injury, 10=complete kill) were taken 5 days and 10 days after treatment. Tissue samples were collected just prior to herbicide application. Samples were taken from the end leaflets of middle rank leaves, oven dried, and ground in a Wiley mill with 40 mesh screen. An elemental analysis for percent carbon, nitrogen, and hydrogen was performed by Baron Consulting Co., Milford, Ct., using a Perkin-Elmer elemental analyzer with thermal conductivity sensors with carbon dioxide and water traps. The combusted samples were converted to carbon dioxide, water, and nitrogen gas and elemental percentages recorded. For statistical analysis, percentages were transformed by means of an arcsin transformation.

RESULTS AND DISCUSSION

The hardening regime was not intended actually to harden transplants, but to condition them using the techniques of hardening. The growth rate of plants designated for hardening was slowed with higher light intensity, lower temperature, reduced watering, and reduced fertilization. Unhardened plants, or plants not so conditioned, reach the designated physiological stages for treatment before the hardened plants (Table 1). Unhardened plants in two of three pairs were taller than hardened plants of the same physiological age (Table 1). Slow-growing plants have been noted to be generally more tolerant of herbicides than fast-growing counterparts (12, 25).

Table 1. Height of 5, 6, and 7 leaf stage tomato plants at time of metribuzin application

Physiological stage	Unhardened		Hardened	
	Average height	Treatment date	Average height	Treatment date
	-cm-		-cm-	
5 leaf	11.3	9/29	12.7	10/4
6 leaf	17.4	10/4	15.4	10/7
7 leaf	21.2	10/7	17.2	10/10

Injury ratings 5 days after treatment revealed highly significant differences among treatments. Unhardened plants treated with metribuzin at the 5 or 6 leaf stage had similar injury ratings (5.8 and 6.2, respectively) which were significantly higher than those in all other treatments (Table 2). Hardened plants at all leaf stages were similar and less injured, as were the unhardened plants at the

7 leaf stage (0.2 to 1.8 rating range) (Table 2).

Table 2. Effect of hardening and leaf stage upon injury in tomatoes treated with metribuzin.

Treatment	Mean injury			
	5 days after treatment		10 days after treatment	
Unhardened 5 leaf	5.8[1]	a[2]	9.7	a
Unhardened 6 leaf	6.2	a	10.0	a
Unhardened 7 leaf	1.8	b	4.6	b
Hardened 5 leaf	0.0	b	0.3	c
Hardened 6 leaf	1.3	b	1.3	c
Hardened 7 leaf	0.2	b	0.2	c

[1]Rated 0 to 10 scale with 0=no effect, 10=complete kill.

[2]Duncan's multiple range test: values within a column followed by the same letter are not significantly different at 0.01% level.

Injury ratings 10 days after treatment fell into three groups: 1) unhardened 5 and 6 leaf plants with most injury (9.7 and 10.0 ratings, respectively), 2) unhardened 7 leaf plants with intermediate injury (4.6 rating), and 3) all hardened plants (5, 6, and 7 leaf) with little injury (0.3, 1.3, and 0.2 ratings, respectively) (Table 2).

At both 5 and 10 day observations, hardening was responsible for significant decreases in injury. Unhardened plants with 7 leaves, i.e., the most mature and largest of the unhardened plants, resembled the hardened plants most in response. In unhardened plants, maturity was a factor in reducing injury. In hardened treatments, plants were equally tolerant of metribuzin at the 5, 6, and 7 leaf stages. Maturity of unhardened plants and hardening of plants were associated with tolerance.

Hardening generally alters carbon and nitrogen relationships since it retards plant growth. Carbonaceous constituents are normally increased and nitrogenous constituents reduced as a result of hardening (4, 7, 20, 21, 26, 27, 29, 31, 39, 40). In all cases in this study, the hardened plants had a lower percent nitrogen and higher carbon nitrogen ratio than unhardened counterparts (Table 3). Applications of triazine herbicides to plants have been associated with increases in the concentration of nitrogen containing substances (6, 8, 10, 11, 15, 28, 38) and reduction in concentration of carbon containing substances (1, 7, 23, 31, 41). The status of the hardened plant (low carbon, high nitrogen) could, theoretically, prove advantageous.

The changes in percent carbon, and nitrogen, and the carbon nitrogen ratio with maturity in the six treatments were not clear-cut (Table 3). Percent carbon showed no consistent pattern. Although percent nitrogen did not fall consistently with maturity, there was a marked trend towards decreasing percent nitrogen with age and hardening (6.5% to 3.5%). Decreasing percent nitrogen was associated with decreasing injury. Despite inconsistencies, hardening and maturity were associated with increasing carbon:nitrogen ratio (6.5 units to 11.9 units). Increasing carbon:nitrogen ratio was associated also with decreasing injury.

Table 3. Percent C and N and the C:N ratio in hardened and unhardened tomato plants at the 5, 6, or 7 leaf stage immediately before metribuzin application

Physiologic stage	Carbon		Nitrogen		C:N	
	U[1]	H[1]	U	H	U	H
5 leaf	42.0	42.0	6.5	5.0	6.5	8.4
6 leaf	40.1	40.2	6.5	5.6	6.2	7.3
7 leaf	38.4	41.2	5.9	3.5	6.5	11.9

[1] U=unhardened and H=hardened.

Percent carbon at treatment was not significantly correlated with injury or survival (Table 4). However, percent nitrogen was significantly correlated with injury (+0.80) and with survival (-0.89). Thus, increasing percent nitrogen paralleled increasing injury and decreasing survival. Ratio of carbon to nitrogen was also significantly correlated with survival (+0.75). Increasing carbon: nitrogen ratio paralleled increasing survival.

Table 4. Correlations between percent carbon and nitrogen and the C:N ratio at the time of metribuzin application and both injury and survival of tomato plants.

	% C	% N	C:N
Injury	+0.02	+0.80*	-0.66
Survival	+0.12	-0.89**	+0.75*

* and ** indicate significance at the 0.10 and 0.05 levels, respectively.

In summary, the percent nitrogen in plant tissue at the time of treatment strongly correlates with survival of metribuzin treated tomato plants. The C:N ratio showed a similar correlation with survival, but this may be nothing more than a reflection of the strong nitrogen correlation. The percent carbon at treatment did not correlate with either injury or survival.

Hardening proved to be more important than physiologic age in determining the tolerance of tomatoes to metribuzin application. Even the smallest of the hardened plants (4 leaf stage) were as tolerant of metribuzin as the most mature unhardened plants. This suggests that hardening, or conditioning using hardening principles, might be a practical technique for the production of transplants tolerant of postemergence metribuzin application.

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