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ABSTRACT

Tomato (Lycopersicon esculentum Mill., 'Heinz 1350') transplants were provided either abundant N or limited N fertilization in the greenhouse, at field setting, and before herbicide application. Herbicide treatment consisted of 0.56 kg ai/ha metribuzin (4 amino-6-tert-butyl-3-(methylthio-as-triazin-5(4H)-one). Metribuzin treated plants supplied abundant N had significantly greater stand reduction than those supplied limited N. In response to herbicide treatment, percent N in the plant tissues rose more and the C:N ratio fell more in plants given limited N fertilization (low N) than in plants given abundant N (high N). However, low N plants retained a lower percent N and higher C:N ratio. Damaged tissue in both high and low N plants was associated with a higher percent N and lower C:N ratio than was undamaged tissue.

In growth chamber experiments with hardened and unhardened plants grown with high (10 mM) or low (1 mM) nitrate, low N and hardening were associated with tolerance to metribuzin treatment. Percent N increased more in metribuzin treated, hardened plants and low N plants. The C:N ratio fell more with low N and hardening. However, with metribuzin treated plants, final (48 h data) percent N was higher in high N plants and C:N ratio was lower in high N plants. The plant status at time of herbicide application (high percent N, low C:N ratio) was associated with injury, whereas the magnitude of N increase and C:N ratio decreases was not.

Additional index words. Herbicide injury, hardening, C:N ratio.

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INTRODUCTION

Metribuzin has caused injury to tomato transplants when used postemergence at rates appropriate for weed control. Injury has been attributed to time of application, plant size, and environmental conditions.

It has been demonstrated that triazines can increase N (4, 6, 8, 9, 22) and that N itself is implicated in the herbicidal mode of action (1, 4, 7, 11, 12, 13, 23, 24). A field experiment was established to determine the effect of abundant N and limited N fertilization upon uptake and injury.

Earlier work had indicated that plants grown with limited N fertilization or hardened plants were more tolerant of metribuzin (19). Growth chamber experiments were subsequently established to determine the response of hardened and unhardened

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transplants grown with high (10 mM) or low (1 mM) nitrate to metribuzin treatment. The low (1 mM) nitrate was suboptimal. Data consisted of foliage injury ratings and changes in percent N and in C:N ratio.

MATERIALS AND METHODS

Field experiment: 'Heinz 1350' tomatoes were seeded in vermiculite in a 16.5 C (minimum temperature) greenhouse July 7, transplanted to peat-vermiculite mix in 5.5 cm peat pots on July 23, field set on August 13, 1976. Transplants were divided into two groups 2 weeks before field setting. One group was watered daily and fertilized with 20-20-20 soluble fertilizer providing 473 ppmw N every third watering. The nitrogen source provided 14.4% N as ammonium and 5.6% as nitrate. These were designated "high N" plants. The second group of transplants was watered daily, but fertilized only once a week. These were designated "low N" plants.

All transplants were field set on August 13 when transplants had six true leaves. The high N plants averaged 23 cm tall and were watered in with 250 ml of a 20-20-20 fertilizer solution at field setting. The low N plants averaged 20 cm and received only water at planting.

Plants were set in a Woodbridge fine sandy loam with pH 6.2 and 3% organic matter content. Rows were 3 m long and 1 m apart. Each row contained five plants.

On August 16 the high N plants were sidedressed with ammonium nitrate at 75 kg/ha. The low N plants were not sidedressed. On August 18 all tomato plants were treated with 0.56 kg ai/ha metribuzin. The herbicide was applied over transplants from a compressed air sprayer calibrated to deliver 374 L/ha at 2.81 kg/cm^2 pressure. At the time of herbicide application high N plants averaged 28 cm and low N plants averaged 23 cm, in height.

Plants were set in a randomized complete block design with two treatments and six replicates. The treatments were 1) metribuzin and high N and 2) metribuzin and low N. Injury was rated three times between August 23 and 31 using a 0 to 10 scale with 0=no injury and 10=complete kill.

Tissue samples were taken immediately before herbicide treatment and at first data-taking. Samples were collected from the outer leaflets of middle rank leaves, oven dried, and ground in a Wiley mill with 0.425 mm screen. An elemental analysis for percent C, N, and H was performed using a Perkin-Elmer elemental analyzer with thermal conductivity sensors with carbon dioxide and water traps.[1] The combusted samples were converted to carbon dioxide, water, and nitrogen gas and elemental percentages calculated.

Growth chamber experiments: 'Heinz 1350' tomatoes were seeded in vermiculite. These were transferred to modified Hoagland nutrient solutions (Appendix 1) in aerated 1.1 L opaque plastic jars when they reached the 2 leaf stage. One-half of the plants were grown in solution containing 1 mM nitrate ("low N" plants). The other half were grown in solution containing 10 mM nitrate ("high N" plants). Solutions were changed weekly after the first 2 weeks and at treatment. The plants were further subdivided between two growth chambers. One-half the high N plants and one-half the low N plants were grown under hardening conditions: 20.5 C (reduced temperature) and a light intensity of 22,000 lux. The remaining plants, 1 mM and 10 mM, were not hardened. These were grown at 26 C day and 19 C night temperatures and 13,000 lux. Relative humidity was maintained at 70% in both chambers. Plants received 17 h of light and 7 h of dark.

Plants were treated with 0.56 kg ai/ha metribuzin when they reached the 6 leaf stage. Herbicide was applied by means of a compressed air knapsack sprayer calibrated to deliver 374 L/ha at 2.81 kg/cm^2 pressure.

The split-split plot design assigned hardened or unhardened

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1. Performed by Baron Consulting Co., Milford, CT.

plants to the main treatment, 1 mM or 10 mM nitrate to subplots, and metribuzin or no metribuzin to subsubplots. There were four replicates of each treatment. The experiment was repeated to confirm results.

Injury ratings (0=no injury, 10=complete kill) were taken 2 and 7 days after herbicide treatment. Tissue from the outer leaflets of middle rank leaves was collected immediately before metribuzin application and 48 h following. Samples were analyzed for percent C, N, and H as described above.

RESULTS AND DISCUSSION

<u>Field experiment:</u> At 5 and 14 days after herbicide treatment there were no significant differences in foliage injury between the treatments. There was, however, a significant difference in stand reduction. Metribuzin treatment of tomatoes grown under high N resulted in a 20% stand reduction as compared to a 7% stand reduction for similarly treated plants grown under low N.

It is possible that abundant N encouraged growth and placed demands for photosynthates and energy which the injured plants could not supply quickly enough. Alternatively, abundant N may have caused an accumulation of toxic N products (14).

At treatment high N plants contained a greater percent N and lower C:N ratio than did low N plants. All plants, high and low N, were treated with metribuzin and exhibited an increase in percent N and a decrease in C:N ratio (Figures 1 and 2).

Plants grown with abundant N showed a small increase in percent N between treatment and first data-taking (Figure 1). Percent N increased more dramatically in plants grown with low N. Despite a greater increase in the plants grown with low N, these plants contained a smaller percent N 5 days after treatment than plants grown with high N (Figure 1). The high initial and final percent N in plant tissue in high N plants was

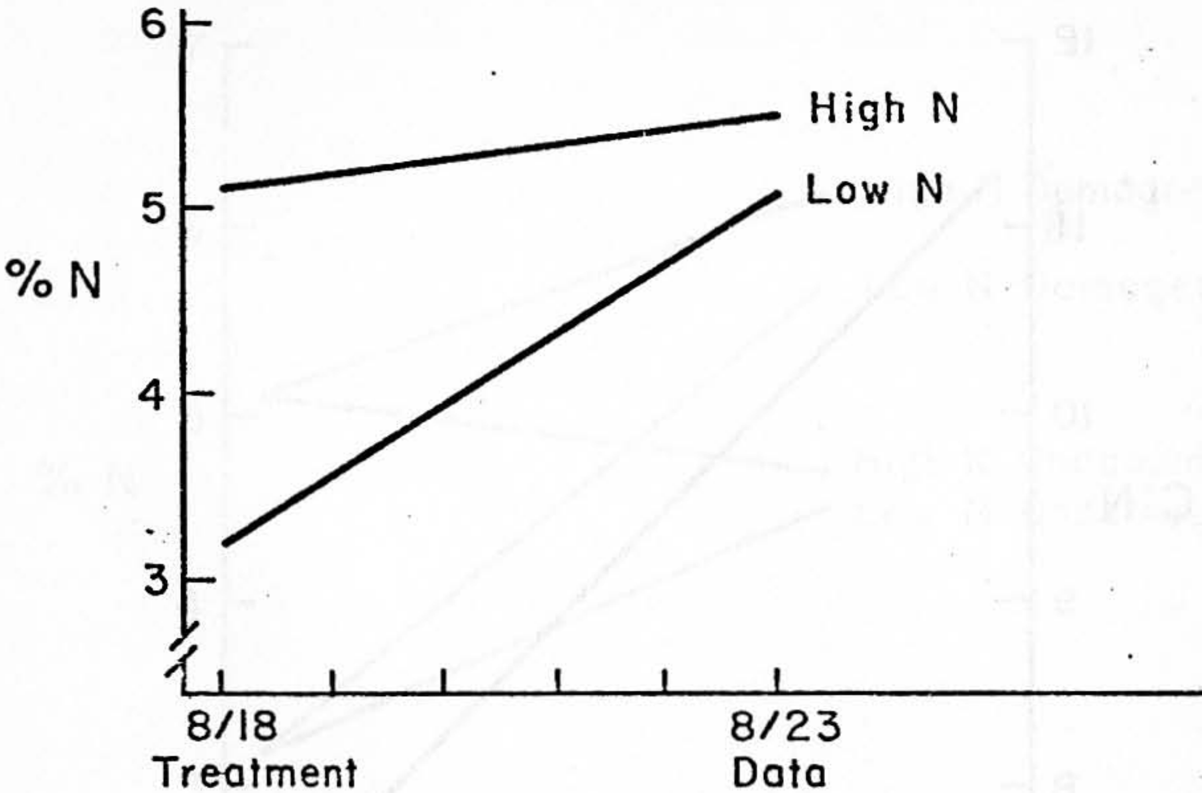

Figure 1. Field Summer 1976 High N-Low N. % N in tomato leaf tissue of plants supplied low or high N fertilization and treated with metribuzin.

associated with stand reduction. The great increase in percent N in low N plants was not associated with stand reduction.

The ratio of C to N was higher in low N plants than in high N plants at treatment (Figure 2) and remained higher 5 days after treatment. However, the ratio fell more sharply in low N plants than in high N plants (Figure 2).

In this experiment, low percent N and high C:N ratio at treatment, produced as a result of low N fertilization, were associated with less stand reduction. It is possible that in high N plants C constituents may be depleted by any herbicide-induced increase in percent N and N metabolism (2, 5, 6, 27). In low N plants, C constituents may be adequate for increased N metabolism.

Figures 3 and 4 indicate percent N and C:N ratio in leaf tissue of damaged and undamaged plants. Whether from high or low N plants, the average percent N after treatment was higher

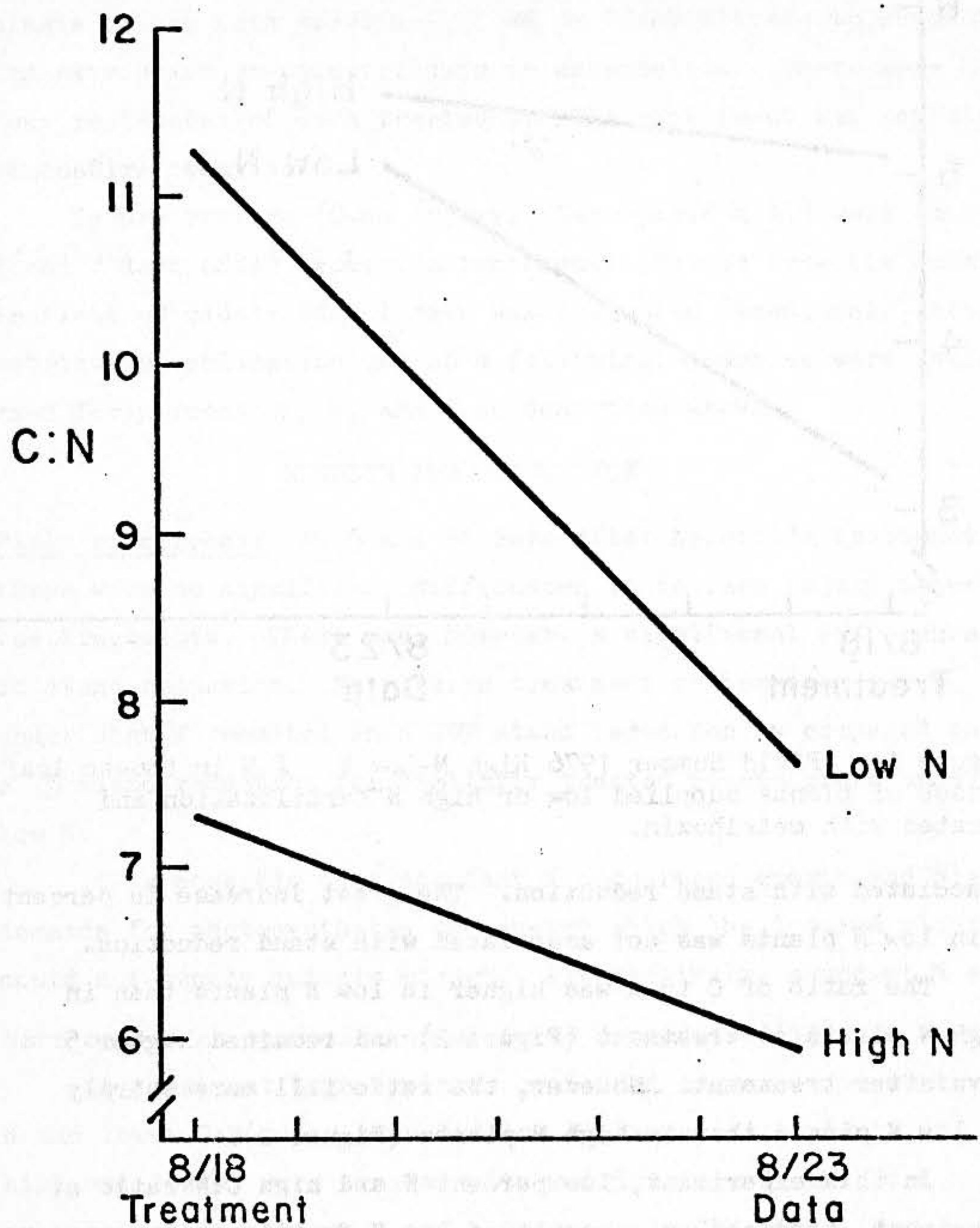

Figure 2. Field Summer 1976 High N-low N. C:N ratio in tomato leaf tissue of plants supplied low or high N fertilization and treated with metribuzin.

in damaged plants than in undamaged plants (Figure 3). The C:N ratio in high or low N plants after treatment was lower in damaged than in undamaged leaves (Figure 4). Damaged tissue was associated with higher percent N and lower C:N ratio than undamaged tissue.

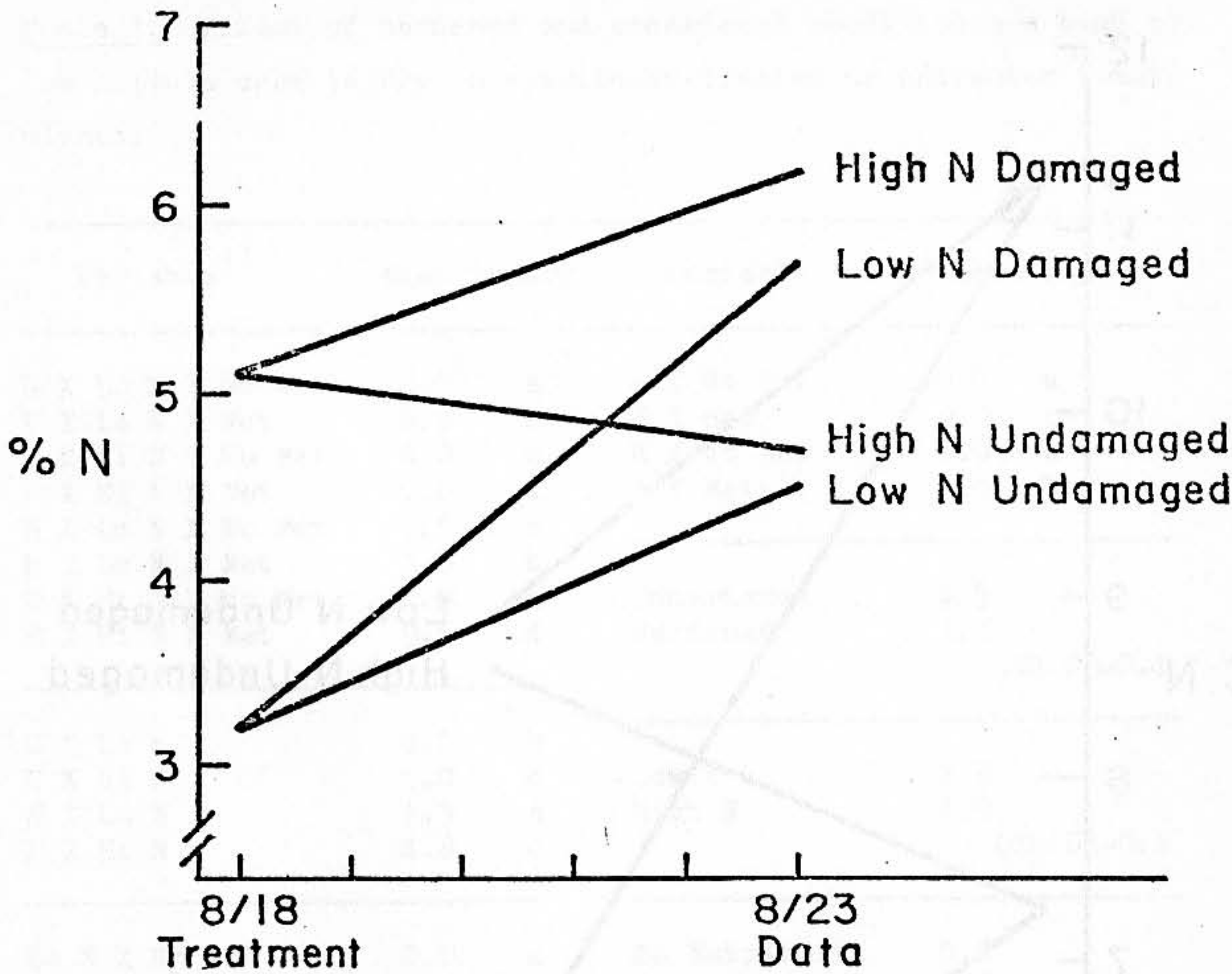

Figure 3. Field Summer 1976 High N-low N. % N in damaged and undamaged tomato leaf tissue of plants given high or low N fertilization and treated with Metribuzin.

Growth chamber experiment: The three-way interaction among hardening, N level, and metribuzin treatment accounted for significant differences in injury to tomatoes (Table 1). The greatest injury was caused by the combined applications of high N and metribuzin to hardened or unhardened plants. The combined effects of low N, metribuzin, and the unhardened condition accounted for significantly less injury. Finally, the combination of low N, metribuzin and the hardened condition accounted for still significantly less injury. Tomatoes not treated with metribuzin showed no injury.

The interaction of hardening and N level (H x N) was significant due to the increased injury of unhardened low N

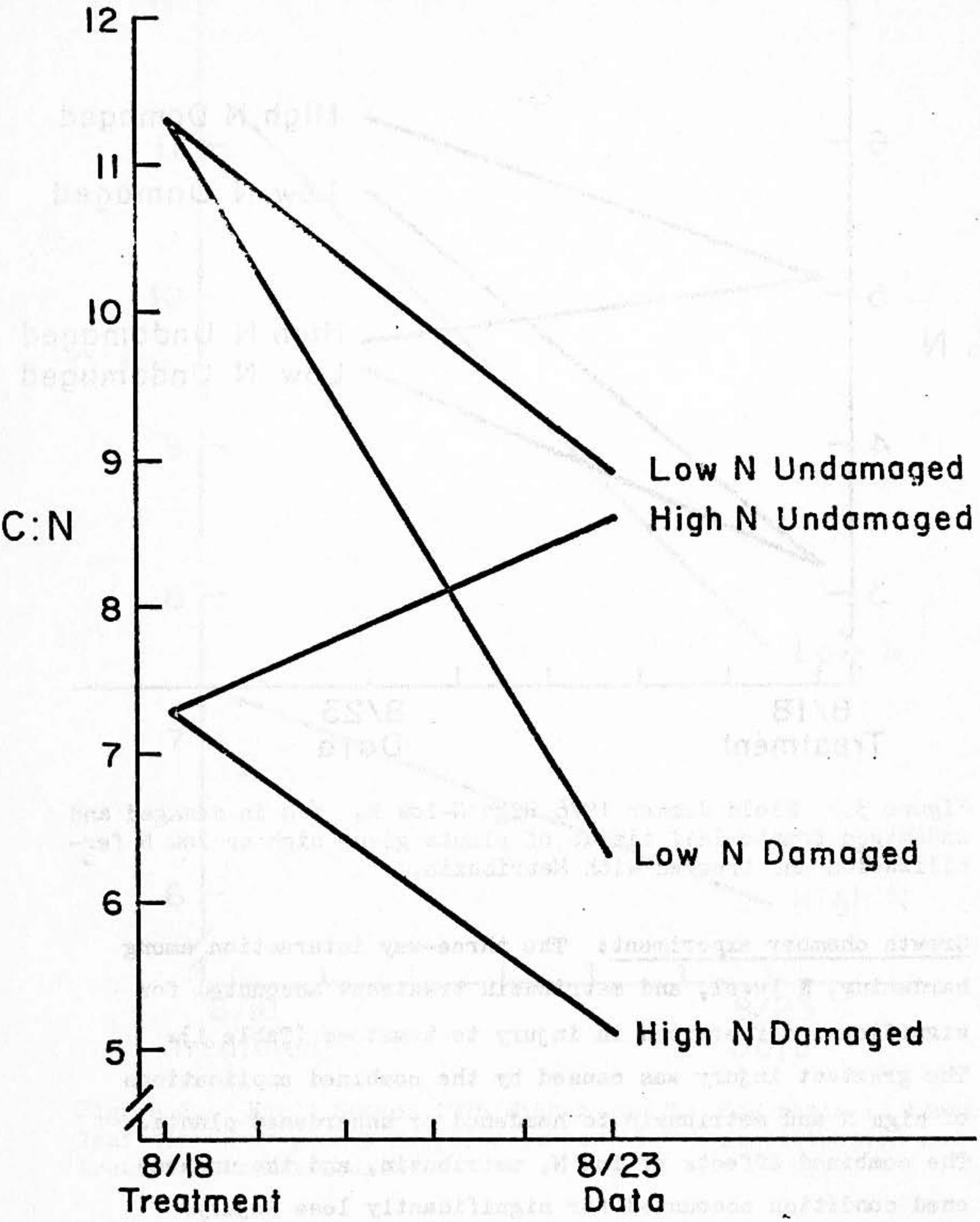

Figure 4. Field Summer 1976 High N-low N. C:N ratio in damaged and undamaged tomato leaf tissue of plants given high or low N fertilization and treated with metribuzin.

Table 1. Effect of hardened and unhardened condition and high or low nitrate upon injury in metribuzin-treated or untreated tomato plants.

Variable[1]	Mean injury		Variable	Mean injury	
U X Lo N X No Met	0.0[2]	a[3]	U X No Met	0.0	a
U X Lo N X Met	8.0	c	U X Met	9.0	c
U X Hi N X No Met	0.0	a	H X No Met	0.0	a
U X Hi N X Met	10.0	d	H X Met	6.6	b
H X Lo N X No Met	0.0	a			
H X Lo N X Met	3.8	b			
H X Hi N X No Met	0.0	a	Unhardened	4.5	
H X Hi N X Met	9.5	d	Hardened	3.3	
				LSD.05=0.4	
U X Lo N	4.0	b			
U X Hi N	5.0	c	Low N	2.9	
H X Lo N	1.9	a	High N	4.9	
H X Hi N	4.8	c		LSD.05-0.4	
Lo N X No Met	0.0	a	No Metribuzin	0.0	
Lo N X Met	5.9	b	Metribuzin	7.8	
Hi N X No Met	0.0	a		LSD.05=0.4	
Hi N X Met	9.8	c			

1) U=unhardened and H=hardened. Lo N=1 mM nitrate and Hi N= 10 mM nitrate. Met=metribuzin and No Met=no metribuzin.

2) Rated 7 days after treatment using a 0 to 10 scale with 0=no effect and 10=complete kill.

3) Duncan's multiple range test: items followed by the same letter are not significantly different at .05.

plants over hardened low N plants and the increased injury of both hardened and unhardened high N plants over unhardened low N plants (Table 1). Unhardened low N plants sustained significantly more injury than hardened low N plants. Unhardened and hardened high N plants sustained significantly more injury.

The interaction of N level and metribuzin treatment (N x M) was significant (Table 1). Treatment of high N plants accounted for significantly more injury than did treatment of low N plants.

The interaction of hardening and metribuzin treatment (H x M) was also significant (Table 1). With no metribuzin, no injury occurred. Treatment of unhardened plants accounted for significantly more injury than did treatment of hardened plants.

Individual variables contributed to injury as they did in earlier experiments and in the two and three way interactions (Table 1). Unhardened plants were significantly more injured than hardened plants. High N plants were significantly more injured than low N plants. Metribuzin treated plants were significantly more injured than untreated plants.

Data were analyzed for the effect of metribuzin upon changes in percent N and C:N ratio from immediately before herbicide application to 48 h after in the four treatments. Significant differences among treatments emerged, but changes were not readily related to injury.

Significant changes in percent N resulted from metribuzin treatment and from the low nitrogen applications (Table 2). Although the percent change in N from the hardening treatment-N level—herbicide treatment interaction was not significant at the 5% level, it is interesting to note that the recorded change in percent N does not go along with the observed foliage injury (Table 1).

The treatment with the greatest increase in percent N (hardened, low N, metribuzin) was the metribuzin treatment with least tissue injury. Despite the great increase in percent N, this treatment also contained the lowest initial percent N and a lower final percent N than any of the high N plants.

Table 2. Changes in percent N in leaf tissue of hardened and unhardened tomato plants grown with high or low nitrate and treated or untreated with metribuzin.

Variables[1]	Change in % N	
U X Lo N X No Met	+0.5	c[2]
U X Lo N X Met	+1.4	d
U X Hi N X No Met	-1.1	a
U X Hi N X Met	+0.3	c
H X Lo N X No Met	+0.4	c
H X Lo N X Met	+2.4	e
H X Hi N X No Met	-0.3	b
H X Hi N X Met	+1.2	d
	LSD.10=0.5	
U X No Met	-0.3	a
U X Met	+0.8	b
H X No Met	+0.2	c
H X Met	+1.8	d
	LSD.10=0.5	

Variables	Change in % N
Unhardened	+0.3
Hardened	+1.0
	LSD.10=0.3
Low N	+1.2
High N	+0.1
	LSD.05=0.3
No Metribuzin	0.0
Metribuzin	+1.3
	LSD.05=0.3

[1] U=unhardened and H=hardened. Lo N=1 mM nitrate and Hi N=10 mM nitrate. Met=metribuzin treatment and No Met = no metribuzin treatment.

[2] Duncan's multiple range test: items followed by the same letter are not significantly different at the level indicated for LSD.

The combined effect of N level and metribuzin treatment accounted for a significant drop in C:N ratio in the treated plants grown with low N (Table 3). The combined effect of hardening and metribuzin treatment produced a significant reduction in C:N ratio in hardened treated plants as compared to all other plants (Table 3).

Individual variables—N level and metribuzin treatment—accounted for significant differences in C:N ratio changes

Table 3. Changes in C:N ratio in leaf tissue of hardened and unhardened tomato plants grown with high or low nitrate and treated or untreated with metribuzin.

Variables[1]	Change in C:N	
Lo N X No Met	-1.7	b[2]
Lo N X Met	-6.2	c
Hi N X No Met	+0.5	a
Hi N X Met	-0.9	ab
	LSD.05=1.7	
U X No Met	-0.1	a
U X Met	-1.9	b
H X No Met	-1.0	ab
H X Met	-5.2	c
	LSD.10=1.4	
Unhardened	-1.0	
Hardened	-3.1	
	LSD.10=1.0	
Lo N	-3.9	
Hi N	-0.2	
	LSD.05=1.2	
No Met	-0.6	
Met	-3.5	
	LSD.05=1.2	

[1] U=unhardened and H=hardened. Lo N=1 mM nitrate and Hi N=10 mM nitrate. Met=metribuzin treatment and No Met=no metribuzin treatment.

[2] Duncan's multiple range test: items followed by the same letter are not significantly different at level indicated for LSD.

(Table 3). Reductions in C:N ratio were associated with low N vs high N and with metribuzin treatment vs no treatment. The decreases in C:N ratio with low N and hardening in response to metribuzin were not associated with high levels of injury (Table 2). Despite greater reduction in hardened plants, these plants had higher average C:N ratio than unhardened plants at treatment. Low N plants had a higher average initial C:N ratio than high N plants.

Since the effect of triazine application is normally linked to carbohydrate depletion and N accumulation, (2, 5, 6, 10, 15, 16, 17, 20, 23, 25, 27) it seems possible that plants with a favorable N and C:N status could better tolerate treatment. It has been demonstrated that metribuzin injury in unhardened tomato plants grown with adequate N is associated with increasing N and decreasing C:N ratio (18).

Those plants subjected to a suboptimal growth environment—i.e., hardening and restricted N—sustained the least foliar injury with metribuzin treatment (Table 2) although they were associated with <u>greater</u> increases in percent N (Table 3) and reductions in C:N ratio (Figure 4). The great increase in percent N that is not associated with foliar injury is a unique response of triazine-treated plants grown under suboptimal conditions and/or treated with subherbicidal rates of herbicide (3, 12, 21, 26). It is likely that injury is consistently related to increases in percent N and decreases in C:N ratio when plants are grown under conditions supplying adequate N and favoring rapid growth.

In summary, when N was adequate or abundant, injury was associated with increasing percent N and decreasing C:N ratio. When N was suboptimal, increases in percent N and decreases in C:N ratio were not associated with injury. Injury was consistently related to conditions producing unhardened plants and to abundant N supply. The low level of N and high C:N ratio

in low N and hardened plants at treatment may be more significant in explaining tolerance than increases in N or decreases in C:N ratio.

APPENDIX 1

Nutrient Solutions Supplying 1 and 10 mM NO_3^-

	gm/L		gm/L
KNO_3	0.10	KCL_2	0.38
KCL	0.30	$Ca(NO_3)_2 \cdot 4H_2O$	1.18
$CaCl_2$	0.56	$MgSO_4 \cdot 7H_2O$	0.49
$MgSO_4 \cdot 7H_2O$	0.49	KH_2PO_4	0.14
KH_2PO_4	0.14	Fe chelate	0.10
Fe chelate	0.10		

Note: All solutions contain 1 ml/L micronutrient stock solution.

Micronutrient Stock Solution

	gm/l
H_3BO_4	2.86
$MnSO_4$	1.71
$ZnSO_4 \cdot 7H_2O$	0.22
$CuSO_4 \cdot 5H_2O$	0.08
$H_2MoO_4 \cdot H_2O$	0.09

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