Fewer Whiteflies Found on CO₂-enriched Greenhouse Tomatoes with High C : N Ratios

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Abstract. Eight tomato (*Lycopersicon esculentum*) cultivars were grown for 16 weeks in greenhouses enriched for an average of 8.1 hours daily to 1000 µl CO₂/liter of air or in greenhouses maintained at ambient CO₂. Carbon dioxide enrichment significantly decreased the mean number of greenhouse whiteflies [*Trialeurodes vaporariorum* (Westward), Homoptera: Aleyrodidae] as measured by counts from commercial yellow sticky traps. The number of whiteflies present was negatively correlated with both seasonal foliar C : N ratio and percent C but positively correlated with percent N in the foliage. Thus, CO₂ enrichment apparently alters plant composition in such a way as to reduce significantly the population growth of greenhouse whiteflies.

Additional index words. *Lycopersicon esculentum*, *Trialeurodes vaporariorum*, carbon dioxide, carbon : nitrogen ratio

Carbon dioxide enrichment of greenhouse crops increases carbohydrate concentrations in foliage and can also result in increased C : N ratios due to reduced N concentrations (Madsen, 1968; Yelle et al., 1989). These changes in foliar composition may affect insect populations on leaves of plants grown at elevated CO₂ concentration. Decreased growth rates and increased mortality (Akey and Kimball, 1989; Fajer et al., 1989) as well as increased feeding (Johnson and Lincoln, 1990; Lincoln et al., 1986; Osbrink et al., 1987) have been found in insects feeding on leaves of plants grown at elevated CO₂ concentration. A preliminary study in 1988 showed fewer greenhouse whiteflies in a

greenhouse tomato crop grown at 1000 µl CO₂/liter air. Increased carbohydrate concentration in the foliage may have led to reduced whitefly populations. Therefore, further counts of whitefly populations from enriched and nonenriched greenhouses were conducted in Spring 1989 and whitefly counts correlated with foliar percent C (%C), percent N (%N), and C : N ratios.

Eight cultivars of greenhouse tomato were seeded and grown to transplant size in a

glasshouse in Raleigh, N.C., using standard water and fertilization practices. Seven-week-old seedlings were transplanted into 18.9-liter black polyethylene grow bags (Hydro-Gardens, Colorado Springs, Colo.) filled with soilless medium. Six plants of each cultivar were transplanted to each of four small, polyethylene-covered greenhouses in Raleigh. Two houses were enriched to 1000 µl CO₂/liter, and two houses remained at ambient CO₂ concentration (≈350 µl·liter⁻¹). Average hours of CO₂ enrichment were 8.1 per day. The plants were grown for 16 weeks.

Using drip irrigation, a modified Hoagland's nutrient solution was injected three times daily for a total of 1.5 liters, but watering was adjusted to crop evapotranspiration. Foliage was sampled for C and N in plants 10, 11, 13, 14, 15, 17, 19, 21, and 23 weeks old. Total C and N concentrations were determined by Perkin-Elmer CHN analyzer. A seasonal mean %N, %C, and C : N ratio was determined for each CO₂ × cultivar treatment.

One yellow 22 × 28 cm commercial sticky trap was hung in the upper canopy region of each of the eight plots per house. Fresh traps were hung at 18 weeks, then removed for counting and replaced at 21 weeks. At 23 weeks (termination of the entire study), all remaining traps were removed and insects counted from a 25-cm² area, randomly chosen from the lower half of each trap. This resulted in 32 whitefly counts per CO₂ treatment (2 count dates × 1 count per trap × 1 trap per plot × 8 plots per greenhouse ×

Table 1. Seasonal mean foliar %C, %N, C : N ratio, for eight cultivars of tomato grown for 16 weeks at 350 or 1000 µl CO₂/liter, and mean number of whiteflies per plot for plant age weeks 19-23.

CO ₂ (µl·liter ⁻¹)	Cultivar	%C	%N	C : N ratio	Whiteflies (no./plot)
350	Michigan-Ohio	32.8	3.19	10.5	217
	Laura	33.1	3.08	10.9	127
	B83.977	33.9	2.87	12.1	164
	TRVE12	34.4	2.85	12.6	197
	Hotset	32.3	3.41	9.6	202
	Caruso	33.1	2.96	11.4	313
	Dombito	31.7	2.88	11.3	220
	Perfecto	34.0	3.03	11.4	121
	Michigan-Ohio	34.5	2.43	14.6	117
	Laura	34.5	2.40	14.6	80
1000	B83.977	34.1	2.37	14.8	60
	TRVE13	34.4	2.51	14.3	38
	Hotset	32.5	3.09	10.8	200
	Caruso	33.1	2.57	13.1	113
	Dombito	33.2	2.46	13.9	136
	Perfecto	34.0	2.56	13.8	107
	LSD _{0.05}	0.8	0.17	0.7	85

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2 greenhouses per CO₂ treatment). Analysis of variance was performed to determine if whitefly counts differed. Correlation analysis was performed on the CO₂ treatment × cultivar means between whitefly counts and the average seasonal %C, %N, and C : N ratios. Whitefly management procedures were identical for all houses and consisted of one initial application of Methonyl 90 SP at recommended rates at 14 weeks, with no further treatment.

Whitefly counts decreased significantly with CO₂ enrichment (Table 1) but were not consistently affected by cultivar. These results differ from those of Butler et al. (1986), who found no difference in sweetpotato whitefly populations on cotton grown at elevated and ambient CO₂ concentrations. However, these authors grew the plants in open-topped chambers, and elevated CO₂ concentrations were only in the range of 355 to 776 µl CO₂/liter with considerable variation. The data presented here indicate that tomato plants grown at elevated CO₂ may not support as high a population of whiteflies as those grown at ambient CO₂. Mean whitefly counts were significantly negatively correlated with both seasonal C : N ratio ($r = -0.72$, $P = 0.001$) and %C ($r = -0.60$, $P = 0.01$). Mean whitefly count was positively correlated with %N ($r = 0.67$, $P = 0.004$). Reduced foliar N has been shown to limit development of many insects (Mattson, 1980; Minkenberg and Ottenheim, 1990). Since plants grown at elevated CO₂ concentrations have reduced foliar N, whiteflies feeding on these crops may suffer N deficiency resulting in reduced populations.

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