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OZONE AFFECTS COMPETITION BETWEEN COTTON AND NUTSEDGE

D.A. Grantz
Department of Botany and Plant Sciences
University of California at Riverside
Anil Shrestha
University of California, Statewide IPM Program
Kearney Agricultural Center
Parlier, CA

Abstract

Cotton production in the San Joaquin Valley and elsewhere is threatened by new and increasingly recalcitrant weeds, and by increasing ozone air pollution. Interactions are not well understood. In field exposure chambers with potted plants we found that plant growth was reduced in both cotton and yellow nutsedge when plants grown alone were exposed to high concentrations of ozone. When the two species are grown together the effect is compounded, particularly near ambient ozone concentrations. As tropospheric ozone levels increase, yield of cotton will be reduced due to oxidant damage and competitiveness of cotton with respect to weedy species will decline. Greater use of herbicides may result unless more ozone resistant cotton cultivars are developed.

Introduction

Ozone air pollution (O_3) reduces yields of adapted upland *(Gossypium hirsutum* L.) cotton cultivars by about 20% in the San Joaquin Valley (SJV) of California (Grantz & McCool 1992; Olszyk *et al.* 1993; Oshima *et al.* 1979; Temple *et al.* 1988a). Pima (G. *barbadense* L.) cotton cultivars are impacted even more (Grantz & McCool 1992; Olszyk *et al.* 1993). Ozone affects cotton through direct oxidant damage to physiological processes and ultimately to yield (Gimeno et al., 1995; Grantz, 2003).

Cotton production in the SJV is also challenged by competition from weeds. Weed control is a major cost in cotton production, with herbicide application to 60% of California cotton acreage (DPR, 2002). Herbicide application is becoming increasingly restricted (Szmedra, 1997), but prevents an approximate 60% loss of productivity in SJV cotton (NCFAP, 2000). A total of 413,418 lbs of Glyphosate (Round-up) was applied to 412,540 acres of the 690,000 acres of cotton planted in CA for weed control in 2002 (DPR, 2000).

Yellow nutsedge (*Cyperus esculentus* L.) is one of the world's most problematic weeds (Holm et al., 1991), particularly well-adapted to irrigated field and row crops (Holm et al., 1991; Mulligan and Junkins, 1976) including cotton under SJV conditions.

Much of the cotton acreage in the SJV is subject to increasing concentrations of O_3. Little is known of crop-weed interactions under elevated O_3 (Fuhrer and Booker, 2003; Ziska, 2002). The ability of nutsedge to compete with cotton under elevated O_3 has not been explored.

Materials and Methods

Plant Material

Cotton (cv. Pima S6) was grown from seed in 9-l tapered plastic pots (Treepot; Hummert International, Earth City, MO), filled with 6-40 mesh sintered clay (Quicksor, A & M Products, Taft, CA).

Yellow nutsedge seedlings, approximately 6 cm tall with 2-3 leaf blades were collected from field sites near Parlier, California. Seedlings were washed to remove soil, trimmed if necessary to a single tuber, and transplanted to pots containing cotton on July 18, 2003. Several seedlings were planted to each pot, and thinned five days later to desired densities of 1, 2, or 3 plants pot^{-1}. Additional pots contained only a cotton plant or only a nutsedge seedling.

Pots were randomly assigned to an Open Top Chamber (OTC) for exposure to one of three different concentrations of ozone. The pots were automatically irrigated to run-through up to three times a day as required by the weather. A complete fertilizer (Miracle Gro; Scotts Miracle-Gro Products Inc., Port Washington, NY) was applied at 1.3 g l^{-1} weekly.

Ozone Exposure

Experiments were conducted in the OTC (3.1 m diameter x 2.4 m height; Heagle et al., 1973) exposure facility at the University of California, Kearney Agricultural Center, Parlier, CA (103 msl, 36.598 N 119.503 W). Ozone was generated by corona discharge (Model G22; Pacific Ozone Technology, Brentwood, CA) from oxygen (Model AS-12; AirSep Corporation, Buffalo, NY). The daily timecourse of O_3 concentration was regulated in a single OTC using a dedicated O_3 monitor (Model 49C, Thermo Environmental Instruments, Franklin, MA) interfaced to a computer for feedback control, as described previously (Grantz et al., 2003). The low O_3 (LO3) regime was charcoal filtered (CF) and was nominally O_3-free (actua 12 hm = 15.9 ppb). The medium O_3 (MO3) regime approximated the diurnal profile and maximal concentration observed on exceptionally polluted days at this location (actual 12 hm = 80.6 ppb). The high O_3 (HO3) regime was approximately 1.9-fold greater than the MO3 at each time point (actual 12 hm = 153.6 ppb).

Experimental Design

The experiment was arranged as a split plot with four replications. Ozone regime (LO3, MO3, HO3) was the main plot and nutsedge density (0, 1, 2, 3 plant pot^{-1}) was the subplot. Each individual pot was an experimental unit, with four replicates of each subplot. Data were analyzed using PROC GLM (SAS Institute, 1990). Additional single degree of freedom contrasts were conducted of biomass parameters in both species grown with and without competition.

Growth Measurements

Weekly measurements were taken of plant height in cotton. Both species were destructively harvested at 2 months after planting. Cotton plants were separated into leaves (laminae plus petioles) and stems. The number of leaves attached to the cotton plants at harvest was counted. Total leaf area was measured by a LI-3000 area meter (LI-COR). Leaf area of the nutsedge plants was not measured, Shoot biomass was stored at 4ºC until (1-2 days) then dried to constant weight in a forced-air oven at 70ºC.

Nutsedge tubers were separated from the root mass, counted, and dry weight determined. The cotton and nutsedge roots were intertwined in pots containing both species, so dried biomass of the combined root system was determined. As considerable sintered clay growth medium adhered to this root mass, each sample was combusted (Thermolyne Corp., Dubuque, IA) at 800ºC, leaving only the sintered clay medium and a negligible amount of ash. Total root biomass was then determined as the difference between the root dry weight and the ashed weight of the sintered clay.

The root:shoot biomass ratios for both species grown alone (without competition) were calculated.

Leaf area ratio (LAR) and specific leaf weight (SLW) of the cotton plants were calculated as total leaf area/total shoot dry weight and total leaf area/total leaf dry weight, respectively. Similarly, leaf weight ratio (LWR) was calculated as total leaf dry weight/total shoot dry weight.

Results and Discussion

Growth of cotton plants was negatively impacted by exposure to ozone. Plants were significantly shorter (Table 1) and produced significantly fewer leaves and less biomass (Table 1). This was observed in shoot (Fig. 1a; open circles) and root (Fig. 1b; open circles), particularly at the highest ozone exposure (HO3). Shoot biomass was reduced by about 80% at HO3. In these experiments, shoot biomass was not reduced at MO3, though root biomass declined by a modest amount at this exposure.

Growth of nutsedge, in the absence of competition from cotton was similarly affected (Table 1; Fig. 2a), with little impact (slight increase) on shoot biomass at MO3 but substantial inhibition at HO3, relative to LO3. Root biomass declined slightly from LO3 to MO3, and substantially at HO3 (Fig. 2b).

In cotton plants, with and without nutsedge, the biomass was reduced to the same extent (Figure 1a). While the interaction of O_3 x weed density was not significant (not shown) it is clear (Fig. 1a) that shoot biomass at near-ambient O_3 concentrations (MO3) was reduced to a much greater extent than in clean air (LO3). In contrast, at very high O_3 concentration (HO3), O_3 reduced cotton growth to such an extent that the presence of nutsedge had no further effect. The root biomass decreased in all pots containing cotton and nutsedge as the concentrations of ozone increased (Figure 1b).

Cotton grown with a single nutsedge plant (Fig. 1b; 1:1, pale grey symbols) exhibited combined root biomass that was equal at all ozone concentrations to the sum of the root biomass of the two species grown separately. However, under these conditions, shoot biomass of cotton (Fig. 2a; 1:1, pale grey symbols) was inhibited by a single plant of nutsedge.

Additional nutsedge plants contributed less than additively to combined root biomass (Fig. 1b) but had no further effect on shoot biomass of cotton at MO3 or HO3 (Fig. 1a).

The addition of 1 or 2 nutsedge plants to the pots of cotton grown alone had no effect on cotton plant biomass at LO3. Addition of a third nutsedge plant depressed shoot biomass of cotton by a small amount at LO3. However, cotton plants were not able to tolerate the addition of 1 nutsedge plant when exposed to MO3 or HO3 growing conditions. Cotton growth was hindered by ozone, and near ambient conditions was further impacted by competition with nutsedge. This indicates that cotton must be kept weed free to be grown in areas where ozone levels are increasing.

Plant growth is reduced in both cotton and nutsedge when either is exposed to high concentrations of ozone. When the two plants are grown together the effect is compounded, particularly near ambient air pollution conditions. As tropospheric ozone levels increase, yield of cotton will be reduced and competitiveness of cotton with respect to weedy species will decline. Greater use of herbicides may result unless more ozone resistant cotton cultivars are developed.

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Table 1. Analysis of variance of the effects of ozone exposure and competition on growth parameters in cotton and nutsedge.

ANOVA	**P-value**	
Source of variation	**Cotton**	**Nutsedge**
Plant height		
Ozone	0.0002	--
Weed presence	0.1033	--
Shoot biomass		
Ozone	0.0001	0.0181
Weed presence	0.0049	0.2042
Number of leaves		
Ozone	0.0001	--
Weed presence	0.0005	--
Leaf area		
Ozone	0.0002	--
Weed presence	0.0195	--
Root weight		
Ozone	0.0010	0.0381
Tuber number		
Ozone	--	0.2807
Weed presence	--	0.4451
Tuber weight		
Ozone	--	0.2194
Root:Shoot ratio		
Ozone	0.1101	--

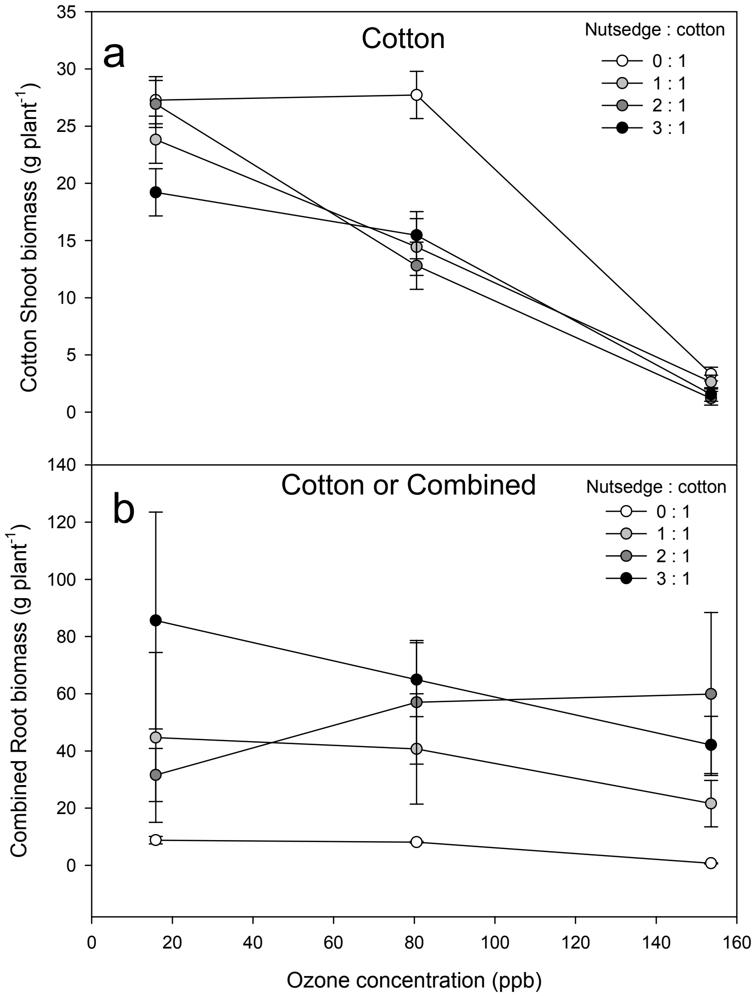

Figure 1. Effect of ozone exposure on (a) cotton shoot and (b) cotton or combined cotton plus nutsedge root biomass shown as means ± SE.

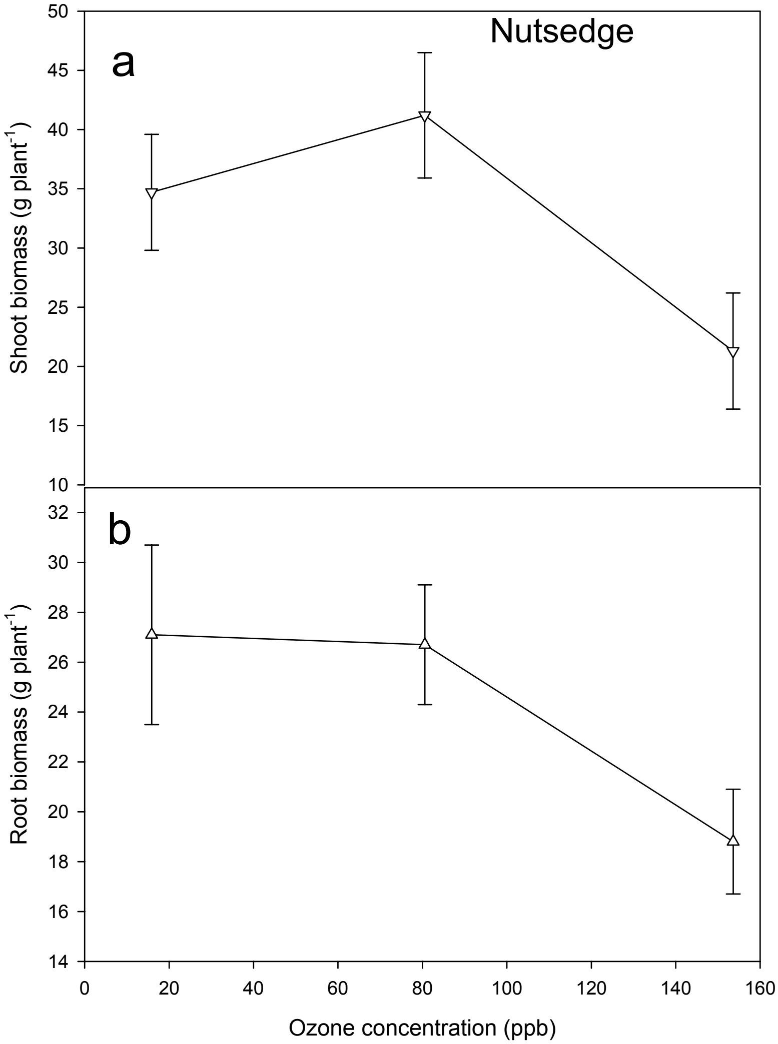

Figure 2. Effect of ozone exposure on (a) shoot and (b) root biomass of nut sedge grown alone, shown as means ± SE.