SHORT-TERM PARAQUAT EFFECTS ON PARAQUAT-RESISTANT HORSEWEED, *CONYZA CANADENSIS* CRONQ.

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Summary. The mechanism of paraquat resistance and the mode of action of paraquat were studied in susceptible and paraquat-atrazine co-resistant biotypes of horseweed, *Conyza canadensis*. Fast induction measurement of chlorophyll fluorescence was used in these investigations. Short-term dark treatments with paraquat confirmed that paraquat entered the chloroplasts of the resistant as well as the susceptible plants. Sunlight plus dark combinations in paraquat treatments suggest a key role of light not only in the primary action of paraquat but also in the recovery process in resistant plants.

INTRODUCTION

Paraquat has been used for many years as a broad-spectrum non-selective herbicide. Resistance to paraquat has developed but the exact mechanism of resistance is still unclear (2,5,12). Paraquat accepts electrons from PS I, possibly at ferredoxin. Several hypotheses for mechanisms of paraquat resistance have been proposed. These include adsorption of paraquat to lignified structures; lack of penetration due to increased epicuticular wax; binding of paraquat to cell walls; restriction of paraquat movement into the chloroplast; an alteration in the redox potential of the PS I primary electron acceptor; detoxification of the superoxide anion radical by an elevated level of total or chloroplast superoxide dismutase, ascorbate peroxidase, and glutathione reductase; or that resistant plants are able to prevent paraquat from entering the symplast (1,3,4,5,8,10,13,14). Transient characteristics of the initial effects of paraquat on horseweed (5,7,9,11,13) suggests that paraquat enters the chloroplasts of both the resistant and susceptible biotypes. Our aim was to further investigate the transient effects of paraquat action on susceptible and resistant plants with respect to the role of light.

METHODS

Whole plants were treated with 1 kg/ha paraquat (active ingredient) as 1% (v/v) tap-water solution of *Gramoxone*® (250 g/l dichloride salt) in sunlight (30 W/m^2). Inhibition of photosynthetic O_2 evolution and variable fluorescence (F_v) was monitored in a continuous daylight treatment. Fluorescence induction kinetics were recorded according to Szigeti *et al.* (11), and O_2 evolution was measured according to Walker and Osmond (15) with a Hansatech LD3 leaf disc electrode.

In another experiment, after a 1, 2 or 3 hr light treatment, the plants were placed in the dark for a further 5, 4 or 3 hr, respectively. In a separate experiment, whole plants were dark adapted for 1 hr and excised leaves were dipped in 1% (v/v) solution of commercial paraquat (see above) for 5 sec in dark. Fluorescence induction kinetics were observed after an additional 5 min dark period in the sample compartment of the instrument.

RESULTS AND DISCUSSION

Paraquat treatment of susceptible plants completely inhibited photosynthetic activity (Fig. 1). In addition paraquat treatment of resistant horseweed showed a large initial inhibition of both photosynthetic O_2 evolution and fluorescence induction. The effects of paraquat on photosynthetic CO_2 fixation showed a similar trend (5,6,11,13).

In addition it was found that after a short-term (5 min) dark treatment with paraquat there was about a 25% fluorescence quenching in both biotypes. This is additional evidence that paraquat had penetrated into the chloroplasts of the resistant plant.

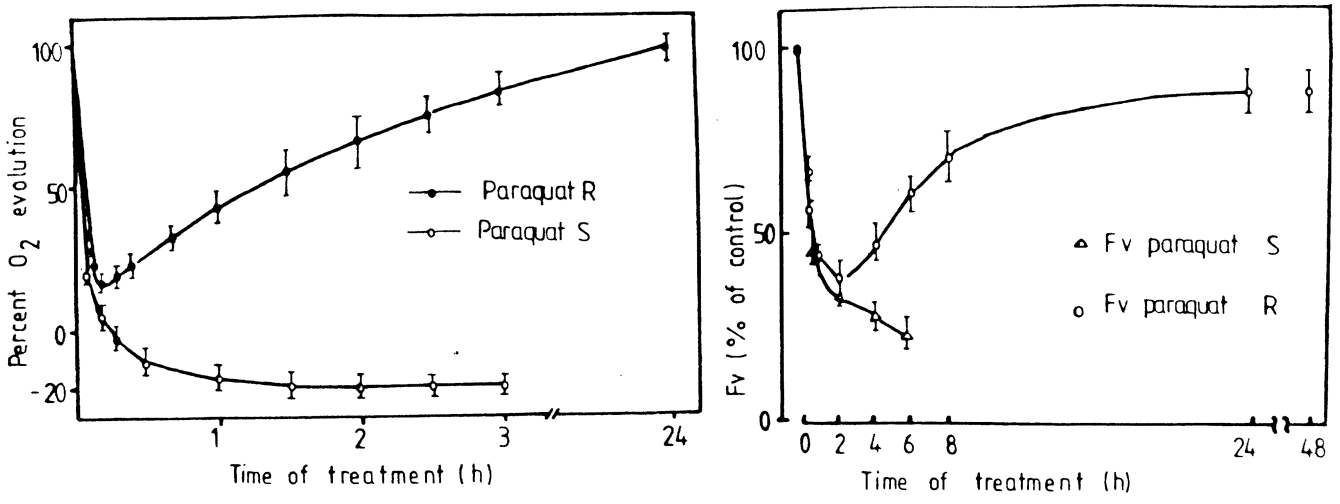

Figure 1. Time dependence of photosynthetic O2 evolution (1A) and variable fluorescence (1B) in horseweed treatment with paraquat in continuous daylight.

Continuation of the dark paraquat treatment for several hours results in a steady-state level of about 40% fluorescence quenching (Lehoczki, unpublished data) instead of a transient inhibition. This suggests a role of light in the initial recovery processes. Figure 2 shows the effect of different sunlight plus dark combinations on the recovery of F_v after paraquat treatment. There was no recovery in the dark period after 1 or 2 hr light treatments as F_v remained nearly constant at 30-40%, however after 3 hr sunlight a pronounced increase in F_v occurred in the dark (up to 55% of control) in resistant plants.

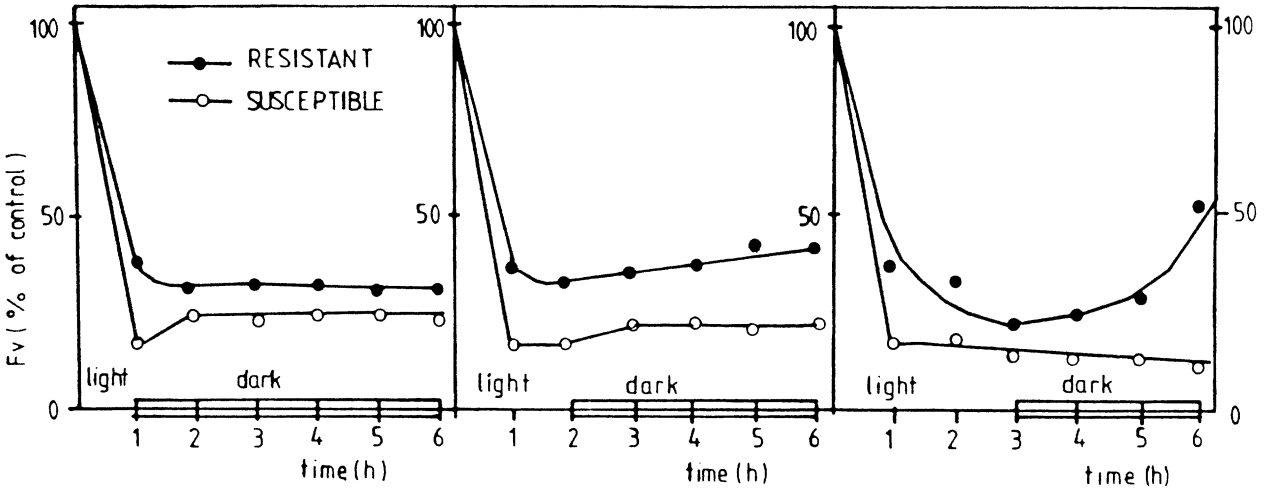

Figure 2. Time dependence of the effect of paraquat on variable fluorescence of horseweed exposed to daylight plus dark combinations

A slight increase in the F_v of susceptible plants in the dark after illumination may be due to a recovery from a photoinhibitory effect. Illumination for different time periods did not result in the same profile of the time course of variable fluorescence (F_v) suggesting that light plays an important role not only in the primary effect of paraquat but also in the resistance mechanism of horseweed. The recovery process apparently needs light, but after sufficient illumination (3 hr in our case) the recovery can continue in the dark.

The transient character of the paraquat inhibition in resistant horseweed plants may result from two opposite reactions. Electrons from PS I reduce paraquat initiating the generation of toxic oxygen radicals coupled with a light- and paraquat-induced elimination process whereby

paraquat activity at PS I is decreased. At present the possibility of metabolism of paraquat or a role of alternative pathways of electron transport cannot be excluded as resistance mechanisms. The results in Fig. 2 and in the long-term dark treatments indicate a role for light in any such process. Enzymatic protection against toxic oxygen radicals is not the main cause of paraquat resistance, as the paraquat-atrazine co-resistant horseweed plants showed no resistance against acifluorfen (12,13). However, such enzymatic processes may have a role in the initial phase of recovery by protecting the resistant plants against these radicals for a short period. The pronounced effect of light on the recovery of resistant plants may support our hypothesis of a role for the xanthophyll-epoxide cycle in the initial defence mechanism against paraquat.

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