# PHYTOTOXICITY OF SOIL APPLIED PARAQUAT

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*Summary.* Tomato seedlings (*Lycopersicon esculentum*) variety UC 134 were grown in a greenhouse in pots containing 250 g of either low or high clay soil. At the 4 to 5 true leaf stage, paraquat was applied using a technique which avoided contact with the aerial parts of the plant. Treatments were applied in five arithmetic increments in the ranges 0 to 1 x $10^3$ and 0 to 3.2 x $10^3$ ppmw respectively, for the low and the high clay soil.

Toxicity was evident, but sub-lethal, at the lowest treatment rate used on each soil. When equal amounts of herbicide were applied to both soils, toxicity was less on the soil of higher clay content. The two highest treatment rates applied to each soil killed the seedlings within three days.

Development of the toxicity was characterised by symptoms which were identical to those which had developed in mature commercial crops of tomatoes within seven days following an inter-row application of paraquat, nominally at 300 g $ha^{-1}$. However, in this experiment a treatment equivalent to 200 kg $ha^{-1}$ was needed to cause symptoms of similar severity on the soil containing less clay. An explanation for this large discrepancy is proposed.

## INTRODUCTION

Paraquat is phytotoxic when added to nutrient solutions (Damanakis *et al.* 1970). This appears to be at variance with its use as a herbicide both shortly before sowing and for inter-row weeding in established row and vegetable crops. However, the commercial success of these practices is well known (Riley 1980). Experimentally they are supported by data which show that paraquat is photochemically and microbially degraded (Calderbank and Tomlinson 1968) and that its residues in soil are relatively unavailable for uptake by plant roots, because the residues are adsorbed onto clay minerals and organic fractions (Burns *et al.* 1973a, 1973b; Burns and Hayes 1974). Literature on these topics was reviewed by Riley (1980) and is also among the contents of a recent monograph on the bipyridinium herbicides (Summers 1980).

Nonetheless, it appears that soil applied paraquat may be toxic to tomatoes. John Toth observed oily lesions on the upper, green stems of mature plants in two commercial crops. These developed after a directed, inter-row herbicide application of approximately 300 g paraquat $ha^{-1}$. In both cases, the soil was a loamy sand and the weather conditions were cool and rainy for several days preceding and following the herbicide application.

The following pot experiment was designed to test whether paraquat applied to low and high clay soils would be toxic to tomatoes, and to compare the symptoms of toxicity, if any developed, with those which had previously been observed in farmers' crops.

## MATERIALS AND METHODS

Surface soil (0 to 10 cm) was collected from Yarramundi (Soil 1) and Breeza (Soil 2) in New South Wales (Table 1). Each soil was well mixed with superphosphate and ammonium and potassium sulfates, to provide adequate nutrition. After steam-air sterilization, 250 g of air-dry soil was placed into undrained polystyrene drinking cups.

Table 1. Soil characteristics

| Soil No. | Description | pH | Wilting point (%) | Field capacity (%) | Saturation (%) | Organic matter (% w/w) | Clay (% w/w) | Silt (% w/w) | Sand (% w/w) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Loamy sand | 6.0 | 4.4 | 12.7 | 31.9 | 1.7 | 5.7 | 33.9 | 60.4 |
| 2 | Black cracking clay | 7.4 | 29.0 | 45.1 | 81.8 | 2.5 | 66.3 | 23.5 | 10.2 |

Fifteen tomato seeds were sown per pot. Soil moisture was automatically maintained just above field capacity (Table 1) using the following technique : two lengths of hemp twine were pushed one-third of the way down into the soil on diametrically opposite sides of each pot. The free ends of the strings were dipped into a container of tap water at bench level, then the pots were placed on a stand above the bench. The height difference between the soil and water surfaces was 19 cm and 11 cm respectively for the Yarramundi and the Breeza soil.

When the plants had two true leaves they were thinned to five per pot. At the 4 to 5 true leaf stage, herbicide was applied in water through the hemp wicks. The applied concentrations were 0, 0.2, 0.4, 0.6, 0.8 and $1.0 \times 10^{-3}$ ppmw and 0, 0.64, 1.28, 1.92, 2.56, $3.2 \times 10^{-3}$ ppmw paraquat (in air dry soil) for the Yarramundi and Breeza soil respectively. Herbicide treatments were replicated eight times.

The pots had been moved through a series of randomly selected locations in the greenhouse prior to imposing the herbicide treatments and this procedure was continued for the duration of the experiment. During this period, plants were examined daily for symptom development and on the seventh day, the tops were collected and weighed.

$\text{Log}_{10}$ transformation of the fresh weights was necessary to normalise the variance. Least squares regression techniques were used to derive the relationship between $\log_{10}$ fresh weight of tops and the herbicide treatment level (Figure 1).

## RESULTS AND DISCUSSION

Paraquat was toxic to the tomato seedlings and as expected, the toxicity was less in the Breeza soil which had a higher clay content (Figure 1).

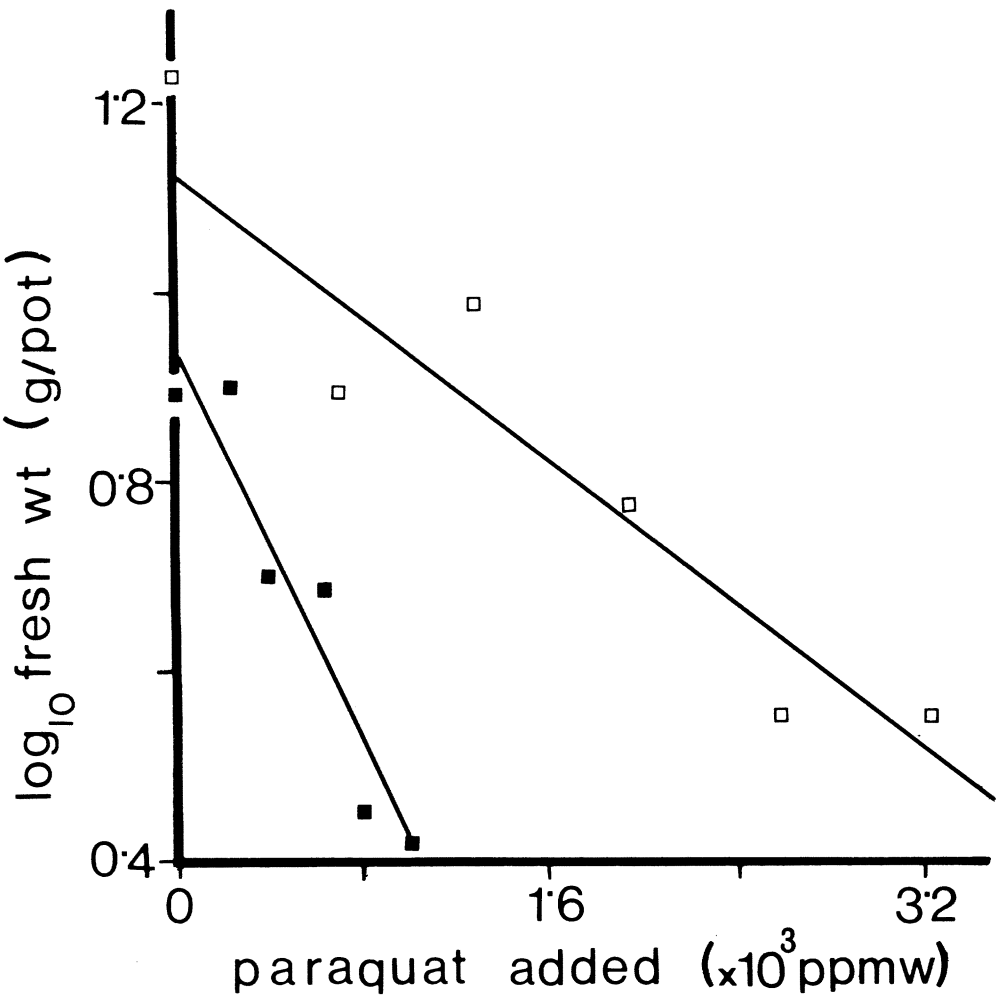


Figure 1. Fresh weight of tomato tops seven days after paraquat had been applied to the soils in which they were growing (Yarramundi(■) and Breeza (□)).

For each soil, onset of toxicity occurred sooner as treatment rate increased. Even the lowest rate caused oily lesions on the green parts of the stem within four days. This was followed by acropetal development of

extensive leaf yellowing and some necrosis. The leaf symptoms developed outward from the veins. Higher treatment rates caused more extensive necrosis, to the extent that the second highest and highest rates killed all plants within three days and two days respectively.

The symptoms of sub-lethal toxicity were identical to those previously seen in farmers' crops. The occasional occurrence of toxicities in crops growing on sandy soils has been reported previously (Gleeson 1964), but in this experiment and in others not reported here, the herbicide application needed to induce toxicity was at least one hundred times the levels used commercially (about 0.5 kg $ha^{-1}$, which is equivalent to 0.5 ppmw in the surface 7.5 cm of soil).

Three reasons are advanced to account for the much greater availability of paraquat to the affected commercial crops. First, the soils were of lower clay content; secondly, the environment favoured superficial root development; and thirdly, herbicide application was followed by light rain which would have moved paraquat into the root zone and protected it from rapid photo-decomposition. Under the circumstances, uptake from spray solutions containing several thousand ppmw of paraquat could have been enhanced to the point where damage occurred, since less than two ppmw in nutrient solutions is toxic to plants of many species (Damanakis *et al.* 1970; Summers 1980).

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