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The effect of deficiency of molybdenum and boron on trifluralin damage in cauliflowers

R. A. Drew and J. M. Bain

Summary

A nutrient solution was developed for aerated hydroponic culture of cauliflowers. Plants were grown in modifications of this solution to induce molybdenum and boron deficiency and then given a foliar spray of trifluralin. Symptoms of damage were observed and recorded. Interveinal chlorosis, which is normally associated with molybdenum deficiency was more severe after trifluralin application. Similarly, leaf cupping, and heart deformity are symptoms of deficiencies of both molybdenum and boron and were associated with trifluralin damage. Both molybdenum deficiency and trifluralin damage reduced shoot and root growth and interacted in terms of their effect on leaf area and leaf thickness.

INTRODUCTION

Herbicide damage has occurred in some cases when growers have applied trifluralin as a pre-emergent spray over transplanted cabbage and cauliflower seedlings on krasnozem soils in the Redlands district of south-east Queensland. The symptoms of damage that were observed resembled those caused by deficiencies of molybdenum and boron (Purvis and Carolus 1964; Hewitt 1956). These crops have a high demand for molybdenum. The availability of molybdenum is reduced by low pH values of these krasnozem soils. Thus it is a recommended practice in the Redlands district to spray *Brassica* crops with molybdenum and boron at the seedling stage, and after transplanting to the field. A survey of grower cultural practices revealed that many were omitting one or both of these sprays.

There are no reports in the literature of interaction between trifluralin damage and nutrient deficiency and there is little published data on the effect of trifluralin on the leaves and shoots of plants. Seeley and Bing (1978) report stunted and abnormal leaves and bracts in glasshouse grown poinsettias due to volatilisation of trifluralin which had been applied for weed control. Hess (1977), working with *Chlamydomonas* demonstrated that trifluralin inhibits cell division. The majority of reports of trifuluralin damage to plants relate to the root system. Inhibition of lateral root formation by trifluralin has been demonstrated with cotton (Gordon and Frans 1977) and some legume species (O'Donovan and Prendeville 1976). Suppression of nodulation on the roots of soybeans was recorded by Parker and Dowler (1976). In a study on the effect of trifluralin and resultant cytological and morphological changes in the roots of broad beans, Vavercova and Vancova (1973) reported considerable disruption of cell division in the root tips resulting in death of lateral roots.

The present paper investigates the damage caused by a foliar application of trifluralin to cauliflower plants which were supplied with adequate or deficient levels of molybdenum and boron.

MATERIALS AND METHODS

The experiments were carried out in a glasshouse at Redlands Horticultural Research Station in south-east Queensland. Seeds of cauliflower, cv. Snowball Y, were germinated in an inert medium of black plastic beads in a plastic seedling tray. They were watered daily with half-strength Arnon and Hoagland (1940) nutrient solution without boron and molybdenum.

When the seedlings were 25 mm high (about two weeks after planting) they were transferred to aerated solution culture. The experiment comprised 96 seedlings planted individually in 2.5 L polyvinyl chloride containers (including 36 for guard plants), each with 2 L of solution added. The solution was aerated through 1 mm diameter plastic tubes with air which had been passed through a 3 micron filter to remove trace element contamination. Each container was covered with a sealed lid, and all 96 were covered with black plastic film, the upper side of which was coated with a silver reflective surface to reduce absorption of solar radiation. The seedlings, held in place by high density polyurethane foam were suspended with their roots through a hole in the centre of the lid. A second hole, stoppered by a bark cork, was used for observation and maintenance.

The solution used was a modification of Arnon and Hoagland's (Table 1) without molybdenum and boron, with the treatment variations described in Table 2. To ensure that nutrients other than molybdenum and boron were adequate, nutrient solutions were completely replaced at weekly intervals. The experiment was a balanced factorial with five replicates of three levels of molybdenum, two levels of boron, and plus and nil trifluralin treatments. Plants were grown in solution for six weeks before a foliar application of trifluralin was applied to selected treatments. Concentration of the applied spray was 1% of the proprietary compound Treflan® containing 400 g/L trifluralin.

Table 1. Nutrient solution used for aerated solution culture of cauliflowers

Compound	Molarity
KNO_3	7.52 mmol/L
$Ca(NO_3)_2$	3.00 mmol/L
$NH_4H_2PO_4$	1.50 mmol/L
$MgSO_4.7H_2O$	1.46 mmol/L
Sequestrene* (6% Fe W/W)	9.13 µmol/L
$MnSO_4.4H_2O$	12.57 µmol/L
$CuSo_4.4H_2O$	0.48 µmol/L
$ZnSO_4.7H_2O$	0.76 µmol/L
H_3BO_3	46.24 µmol/L
$(NH_4)_6Mo_70_{24}$	0.16 µmol/L

* Piece of A.R. Iron wire was added to each container.

Table 2. Concentrations of molybdenum and boron added as treatments

Treatment	Concentration µmol/L
Molybdenum added	nil
as $(NH_4)_6Mo_7O_{24}$	0.158
	0.316
Boron added as	0.46
H_3BO_3	46.24

Two weeks after spraying, the plants were harvested. At this stage, visual ratings were made of chlorosis, leaf cupping, and heart deformity. Leaf thickness and leaf area of the fourth oldest leaf of each plant were measured. Dry weights of shoots and roots of individual plants were recorded. Standard plant tissue analysis techniques were used to determine the levels of N, P, K, Ca, Mg, Mn, Cu, Fe, Zn, Na, B, Cl and nitrate present in the shoots.

Analyses of variance were performed on shoot and root dry weight, shoot to root ratio, leaf area and leaf thickness.

RESULTS

Symptoms of molybdenum deficiency were apparent on all plants from the nil molybdenum treatment. However, visual symptoms of deficiency were slight on plants grown in solutions containing the lower concentration of ammonium molybdate, and were absent on those from high molybdenum solutions. Interveinal chlorosis was directly related to molybdenum deficiency, with plants grown in solutions containing no molybdenum displaying the most severe symptoms. However, in all cases, more severe chlorosis was observed on plants sprayed with trifluralin, compared with those on corresponding unsprayed treatments. Whiptail symptoms which are characteristic of severe molybdenum deficiency were present in three of the five replicates of plants which were grown without molybdenum and sprayed with trifluralin, but did not occur in any other treatment. With plants grown in solutions containing the highest levels of molybdenum, no chlorosis was observed. However, plants grown on corresponding treatments with a trifluralin spray developed interveinal chlorosis typical of molybdenum deficiency.

Boron deficiency symptoms were observed on all plants grown in solutions containing the lower concentration of boric acid, but not on those containing the higher concentration. All boron deficient plants and all plants treated with trifluralin developed some leaf cupping. All six treatments sprayed with trifluralin exhibited more severe leaf cupping than corresponding nutritional treatments without trifluralin.

Heart deformity was defined as damage to the apical growing point and surounding small leaves. This symptom was present in every plant that had been sprayed with trifluralin and in one boron deficient plant that had not been sprayed.

Trifluralin application and molybdenum deficiency significantly reduced both shoot and root dry weights (Tables 3 and 4), but no significant interactions were measured. There were no significant effects of the treatments on shoot to root ratio.

Table 3. Effects of molybdenum concentration in solution on dry weight of shoots and roots

Growth index	Concentration of $(NH_4)_6Mo_7O_{24}$ µmol/L			l.s.d.
	0	0.158	0.316	*P*=0.05
Shoot dry weight (g)	4.8	8.4	7.6	2.4
Root dry weight (g)	0.45	0.76	0.70	0.23

Table 4. Effects of trifluralin application to leaves on dry weight of shoots and roots

Growth index	Trifluralin spray concentration		l.s.d.
	0	400 g/L	*P*=0.05
Shoot dry weight (g)	8.3	5.5	1.9
Root dry weight (g)	0.77	0.50	0.18

There was a significant interaction between molybdenum and trifluralin in their effect on leaf area (Table 5). Molybdenum deficiency did not affect leaf area (Table 5) in the absence of trifluralin, however, plants grown in solutions with no molybdenum and sprayed with trifluralin had significantly smaller leaves than those produced by plants in other treatments. There was a significant interaction between molybdenum concentration and trifluralin application in terms of their effect on leaf thickness (Table 6). Leaves were thicker in treatments where trifluralin was applied to plants receiving molybdenum in their nutrient solutions. Plant tissue analyses showed that all elements studied were present at satisfactory levels for normal growth except boron which was low in plants grown in the low boron solutions. No determinations were performed for molybdenum.

Table 5. The interaction between molybdenum concentration in solution and trifluralin spray in terms of their effect on leaf area (sq cm)

Trifluralin concentration	Concentration of $(NH_4)_6Mo_70_{24}$ µmol/L			Mean
	0	0.158	0.316	
nil	192.7	227.2	198.3	206.1
400 g/L	122.7	218.2	200.0	180.3
Mean	157.7	222.7	199.2	

l.s.d. (P=0.05) 40.7 for all comparisons within the body of the table.

Table 6. The interaction between molybdenum concentration in solution and trifluralin application in terms of their effect on leaf thickness (mm)

Trifluralin concentration	Concentration of $(NH_4)_6Mo_70_{24}$ µmol/L		
	0	0.158	0.316
nil	0.83	0.76	0.79
400 g/L	0.82	0.95	0.94

l.s.d. (P=0.05) 0.11 for all comparisons within the body of the table.

DISCUSSION

Preliminary experiments were carried out in which cauliflower plants were grown in Arnon and Hoagland (1940) solution. Plant tissue analyses showed these plants to be very low in calcium, low in manganese and phosphorus, and high in magnesium and zinc. Low calcium to magnesium ratios were also evidenced by necrotic leaf spots, and interveinal chlorosis indicated molybdenum deficiency. These factors led to the development of an improved solution for cauliflower culture (Table 1).

The level of molybdenum required was double that of Arnon and Hoagland (1940) solution to prevent the occurrence of any deficiency symptoms in the control treatment. No significant differences occurred for any of the quantitative measurements (Tables 3 to 6) between plants grown on solutions containing the low level of molybdenum compared with the higher level, even though some interveinal chlorosis occurred at the lower level. Thus nil molybdenum was required in solution to produce symptoms severe enough to be associated with measurable responses.

The results indicate a relationship between molybdenum and boron deficiency and trifluralin damage in cauliflowers; damage being more severe when the plants are deficient in these trace elements. The effect of trifluralin on molybdenum deficient plants was clearly indicated by markedly increased interveinal chlorosis which is a characteristic symptom of molybdenum deficiency (Hewitt 1956).

Trifluralin spray on the foliage caused more severe symptoms than corresponding unsprayed treatments at all molybdenum levels.

Leaf cupping may be caused by molybdenum or boron deficiency (Purvis and Carolus 1964). In the present experiment leaf cupping appeared to be related to boron deficiency as it did not occur at any level of molybdenum when boron was present in solution at the higher concentration. The presence of more severe leaf cupping in all plants sprayed with trifluralin was evidence of the additive effect of trifluralin damage and boron deficiency.

Damage to the growing point of plants is caused by boron deficiency (Purvis and Carolus 1964) and is a common field symptom of boron deficiency in cauliflowers. Damage to the smaller heart leaves has been attributed to boron deficiency (Dearborn *et al.* 1936), and molybdenum deficiency (Hewitt 1956). Trifluralin causes considerable disruption of cell division in the growing points of roots (Vavercova and Vancova 1973). In our experiment, damage to the growing point and surrounding young leaves was caused by trifluralin, showing it to affect shoot as well as root apices. In the absence of trifluralin, this symptom was observed in only one boron deficient plant, probably because the boron deficiency was not severe enough to induce it more generally.

The additive effect of molybdenum deficiency and trifluralin damage was evidenced by the reduced weights of shoots and roots (Tables 3 and 4). As root absorbed trifluralin can seriously reduce root growth (Gordon and Frans 1977; O'Donovan and Prindeville 1976), it was noteworthy that foliar applied trifluralin did not affect shoot to root ratio. This is consistent with the findings of Brouwer and De Wit (1969) who experimented with *Phaseolus vulgaris* seedlings and found a constant distribution pattern of the dry matter produced between the leaves and roots. They found that a rapid restoration in shoot to root ratios occurred after partial removal of either shoots or roots.

The reduction in weight of molybdenum deficient plants is consistent with the report of Purvis and Carolus (1964) that retarded growth is a symptom of molybdenum deficiency. Leaf area and leaf thickness were measured also as criteria of plant growth. Trifluralin application did not effect leaf thickness when applied to molybdenum deficient plants (Table 6), however, this comparison was made using leaves which were quite different in area. When comparisons were made using leaves which were not significantly different in area, leaf thickening was a characteristic symptom of trifluralin damage.

Trifluralin belongs to the dinitroanaline group of herbicides, which are known to reduce protein synthesis (Probst and Tepe 1969). Klepper (1974) has shown that a wide range of herbicides interfere in the normal process of nitrite reduction, resulting in nitrite accumulation. Klepper states that free nitrite within the plant can help to explain the initial symptoms of herbicide injury, abnormal metabolism and death of plants. Molybdenum deficiency also interferes with nitrogen metabolism and this may explain the enhancement of some effects of trifluralin in molybdenum deficient plants.

In a field trial, trifluralin damage was more severe when the soil was not limed (R. A. Drew and J. M. Bain, unpub. data 1980). Liming krasnozem soils in the Redlands district increases pH and makes molybdenum more readily available to the plant.

Herbicides which perform well during initial testing under carefully controlled conditions often perform less consistently when tested on growers properties, resulting in poor weed control properties or damage to crops. There is a tendency to explain this inconsistency as being due to climatic and environmental factors. The results reported here indicate the need for good crop nutrition and management when applying herbicides and could explain some of the variable results when herbicide treatments are subjected to wider useage.

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The authors are officers of Horticulture Branch, Queensland Department of Primary Industries stationed at Redlands Horticulture Research Station, Cleveland, Q. 4163.