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TIP-BURN OF LETTUCE IN RELATION TO CALCIUM NUTRITION

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SUMMARY

The calcium content of plants was increased by high concentrations of calcium in the nutrient solution or by calcium foliar sprays. However, only the foliar spray treatments prevented the occurrence of tip-burn. After head formation had commenced, the foliar spray treatments ceased to be effective, as they could no longer be applied directly to the young leaves.

Tip-burn of lettuce appears to be the result of a deficiency of calcium in the young leaves.

I. INTRODUCTION

Tip-burn of lettuce has been reported to be associated with unfavourable moisture relationships (Newell 1925; Andersen 1946; Canova 1956), over-fertilization (Grainger 1952), soil salinity (Clay and Davidson 1958), boron deficiency (Greer 1945) and supplementary lighting during propagation (Sheard 1961). Hume (1964) concluded that the occurrence of the disorder is influenced by all factors that affect absorption of water and transpiration from the leaves. That such a divergent range of factors has been associated with the occurrence of tip-burn was considered by Andersen (1946) to indicate the presence of some physiological disorder in the plant accompanying the associated factors, rather than the factors themselves.

A number of these factors have also been reported to influence the occurrence of black-heart in celery, which Geraldson (1954) found to result from a deficiency of calcium in the growing tip. The similarity of the two disorders has been proposed by Chupp and Scherf (1960), who suggested similar control measures, using calcium or strontium foliar sprays. However, Jenkins (1959) found that applications of lime to soil and calcium foliar sprays were ineffective in controlling tip-burn of lettuce.

The investigations reported here were carried out under glasshouse conditions to study the effect of calcium nutrition on the occurrence and severity of tip-burn of lettuce.

II. MATERIALS AND METHODS

General.—The variety Pennlake was used in these investigations. The plants were grown in sand culture, using the nutrient solution described by Hoagland and Arnon (1950). Calcium foliar sprays and nutrient solution treatments were commenced 3 weeks after germination. All plants were harvested 36 days after germination at the 15-16-leaf stage, prior to the commencement of head formation.

In the first experiment three concentrations of calcium were supplied in the nutrient solutions and calcium chloride foliar sprays were applied three times weekly until harvest. Two plant plots of each treatment were included in a 3 x 2 factorial design, which was replicated four times.

Calcium nitrate foliar sprays only were used in the second experiment. Ten replications of single plant plots were used in a randomized block design.

Sand cultures.—The plants were grown in 3-l pots of medium-grade quartz sand. Nutrient solutions to contain calcium concentrations of 34, 194 and 268 p.p.m. while maintaining the ratio of other nutrient ions constant, and a total concentration of 30 mg ions per litre, were prepared after the method of Steiner (1961). The pH of each solution was 5·8. Nutrient solutions were applied twice weekly, and every other day the water lost by evapotranspiration was replaced by weighing. The pots were thoroughly leached once a week.

Foliar sprays.—The concentration of both the calcium chloride and the calcium nitrate sprays was 0·04M with added surfactant. The sprays were applied three times weekly to completely wet the plants without run-off.

Evaluation of tip-burn.—A quantitative estimate of the severity of tip-burn was obtained by measuring the length of affected tissue on each leaf margin. The number of leaves which were affected was also recorded.

Plant analyses.—Recently mature leaves and whole plants were washed in 0·1N hydrochloric acid containing surfactant and rinsed three times in distilled water. The tissues were dried at 65°C. Samples were ashed at 550°C and analysed for calcium, using the method of Williams and Twine (1960).

III. RESULTS AND DISCUSSION

Plant weight.—The mean oven-dry weights of plants grown in nutrient solutions with calcium concentrations of 34, 194 and 268 p.p.m. were 3·9, 4·0 and 4·3 respectively (Table 1). Although these dry-weight values do not vary significantly, a trend towards the production of larger plants at higher calcium concentrations is indicated.

TABLE 1

DRY-WEIGHT RESPONSE (IN GRAMS) OF PLANTS TO CALCIUM IN NUTRIENT SOLUTIONS AND FOLIAR SPRAYS

Ca^{++} (p.p.m.) in Nutrient Solution	$CaCl_2$ Foliar Sprays		Means
	Unsprayed	Sprayed	
34	4·0	3·7	3·9
194	4·4	3·7	4·0
268	4·6	4·0	4·3
Means ..	4·3	3·8	..
	Unsprayed > Sprayed		

The application of calcium chloride sprays three times weekly has resulted in a significant decrease in the mean oven-dry weight of plants from 4·3 to 3·8 g (Table 1). This decrease in plant dry-weight probably represents a phytotoxic reaction to the frequent calcium chloride foliar sprays. When calcium nitrate foliar sprays were used, there was no significant reduction in the dry-weight of plants (Table 2).

TABLE 2

EFFECT OF CALCIUM NITRATE FOLIAR SPRAYS ON PLANT DRY-WEIGHT AND TIP-BURN OCCURRENCE

Spray Treatment	Oven-dry Weight (g)	Mean Length of Leaf Margin with Tip-burn (cm)
Unsprayed ..	5·9	18·1
Sprayed	5·7	3·4
Mean difference ..	0·19 ± 0·4	14·7 ± 4·4
	Not significant	Significant (1%)

Symptoms.—Descriptions of tip-burn symptoms vary widely, but most recognize a brown marginal discoloration of older frame leaves and a browning of internal head leaves (Hume 1964). On frame leaves, a necrosis of terminal portions of veinlets is rapidly followed by browning or scorching of leaf margins. If this symptom develops while leaves are young, considerable distortion will occur as the leaves expand. This symptom is encountered in field-grown crops only under exceptional circumstances. The more commonly observed symptom occurs only on inner head leaves and is first noted as a terminal necrosis of veinlets together with necrotic spotting of interveinal tissue. These spots are usually 1-2 mm in diameter and may extend up to 3-5 cm in from the margin. Under favourable conditions the whole margin may eventually be involved. Secondary organisms frequently invade the injured tissue and produce wet rot or slimy conditions (Chupp and Scherf 1960).

In these experiments, plants suffering from tip-burn of inner head leaves were dissected in such a way as to expose the affected leaves. Within 24-28 hr, the affected leaf margins had dried out and assumed a similar appearance to the frame-leaf symptom. It would therefore appear that the two symptoms are of similar origin, but are modified in expression by their micro-environments.

Occurrence of tip-burn.—Jenkins (1959) used calcium chloride sprays at 4 lb/100 gal applied twice weekly during heading and recorded no reduction in the severity of tip-burn. Similar results were obtained when calcium sprays were first used in these investigations. However, it was observed that the severity of the frame-leaf symptoms appeared to be reduced.

The concentration of calcium in the nutrient solution has not significantly reduced the mean length of tip-burn per plant (Figure 1), or the percentage of affected leaves (Table 3). The length of marginal leaf scorch occurring on plants grown with nutrient solutions containing calcium concentrations of 34 and 268 p.p.m. was 9 and 7 cm respectively. Although these values do not vary significantly, they show a trend towards a reduction in the severity of tip-burn as the calcium concentration increases. However, it is indicated that very high calcium levels would be necessary in the root medium to satisfactorily reduce the severity of tip-burn.

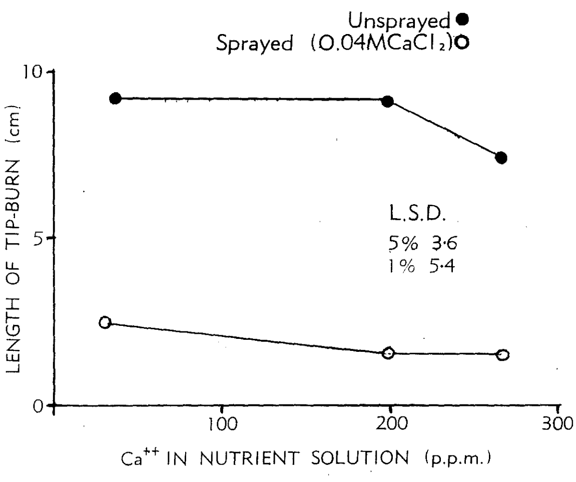

Fig. 1.—Mean length of tip-burn per plant.

TABLE 3

PERCENTAGE OF LEAVES WITH TIP-BURN IN RELATION TO CALCIUM IN THE NUTRIENT SOLUTION AND FOLIAR SPRAYS

Ca^{++} (p.p.m.) in Nutrient Solution	$CaCl_2$ Foliar Spray	
	Unsprayed	Sprayed
34	19·1	1·6
194	16·6	1·6
268	17·1	0
	No significant difference	Not analysed

Calcium chloride foliar sprays have reduced both the mean length of tip-burn per plant (Figure 1) and the percentage of affected leaves (Table 3). Where the level of calcium supplied in the nutrient solution was low (34 p.p.m.) the sprays reduced the mean length of marginal leaf scorch from 9 to 1 cm per plant. At the two higher levels of calcium nutrition, the sprays prevented the occurrence of the disorder prior to head development.

Calcium nitrate (0·04M) foliar sprays were also found to reduce the incidence of tip-burn significantly (Table 2).

The wrapper leaves of several plants in which head development had commenced were removed to expose affected inner head leaves. It was observed that when calcium chloride sprays were applied to these plants the new leaves which developed were free from tip-burn.

These data indicate that calcium foliar sprays will prevent the occurrence of tip-burn provided that they are applied directly to the young leaves. Once head formation has commenced, the penetration of foliar sprays to inner head leaves is prevented by the wrapper leaves, and the sprays are thus rendered ineffective.

Plant analyses.—The concentration of calcium in whole plants and recently matured leaves is presented in Figure 2 and Table 4 respectively. Although the treatments have produced similar trends in both tissues, the concentrations recorded in whole plants are generally higher than those in single leaves. This is probably the result of calcium accumulation as tissues age. Both nutrient solution treatments and foliar sprays have produced significant increases in the calcium content of the tissues. The concentration of calcium in untreated whole plants was 6,732 p.p.m. This value was increased to 8,636 p.p.m. by increasing the concentration of calcium in the nutrient solution, to 9,752 p.p.m. by foliar sprays, and to 12,163 p.p.m. by both foliar sprays and nutrient solution treatments.

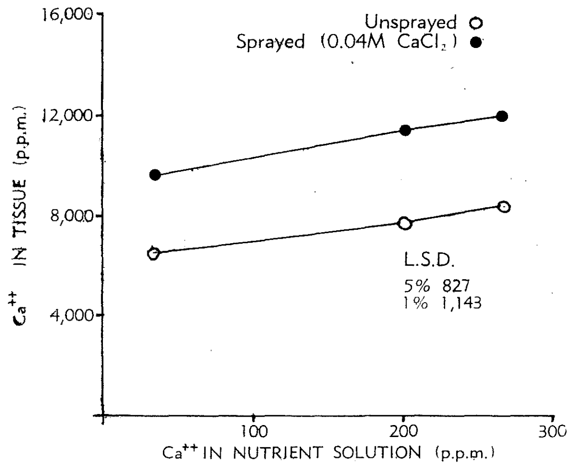

Fig. 2.—Mean calcium content of whole plants.

TABLE 4

CONCENTRATION OF CALCIUM (p.p.m.) IN RECENTLY MATURE LEAVES IN RELATION TO CALCIUM IN THE NUTRIENT SOLUTION AND FOLIAR SPRAYS

Ca^{++} (p.p.m.) in Nutrient Solution	$CaCl_2$ Foliar Sprays		Means
	Unsprayed	Sprayed	
34	4,079	6,118	5,009
194	4,486	7,456	5,971
268	4,927	7,923	6,425
Means ..	4,497	7,166	..

Foliar sprays: Sprayed $\gg$ Unsprayed
Nutrient solutions: 268 p.p.m. > 34 p.p.m.

Although the calcium content of plants was increased by either additional calcium in the nutrient solution or foliar sprays, only the latter satisfactorily controlled the tip-burn disorder, and then only when applied directly to the younger tissues. This indicated that tip-burn of lettuce is associated with low levels of calcium in young tissue. The wide range of factors, including unfavourable moisture relations, excess of total soluble salts, rapid growth and soil salinity, which have been associated with the occurrence of tip-burn were all considered by Geraldson (1957) in relation to the occurrence of celery blackheart to be possible causes of calcium deficiencies. As calcium is relatively immobile and is not readily redistributed in plant tissues, it must be obtained by young tissues *via* xylem from the root medium and factors which interfere with its availability will influence the occurrence of the disorder.

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