c) Dichlone in mixture with nabam-zinc sulfate tends to nullify the adverse effect of the latter.

Data on fruit rot, caused by *Botrytis* and *Rhizoctonia*, were obtained (Fig. 2). Some materials appeared to be effective against only one of the organisms, some against both and others against neither. The nabam plus metal salts fell in the last-named category. Dichlone appeared to be effective against *Botrytis* but ineffective against *Rhizoctonia*. Thiram, Tennam, Vancide 51 and ferbam appeared to reduce disease caused by both organisms.

It is emphasized at this point that the above is the result of one year's work, and that confirmation of these findings is essential before final conclusions can be drawn. In the meantime, however, it might well pay the grower to re-evaluate his spray program in the light of the evidence presented here. The writers are not prepared to make official recommendations at the present time, but would be glad to discuss the problem with the growers at their request.

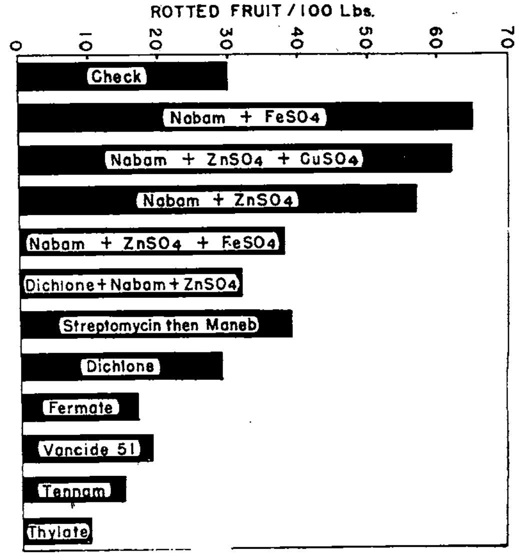

Fig. 2. Effect of various fungicide sprays on fruit rot. Chart shows number of rotted tomatoes per 100 pounds of ungraded tomatoes. Average of 4 replications.

EVALUATION OF CONTROL METHODS FOR BLACKHEART OF CELERY AND BLOSSOM-END ROT OF TOMATOES

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During the past several years, recommended control methods using calcium (1,2) for blossom-end rot of tomatoes and blackheart of celery have been used by growers in a number of states and countries as well as in Florida. Experiments have been continued in the greenhouse for the purpose of determining the fundamental factor or factors causing these physiological disorders, so that the efficiency and effectiveness of the control method may be improved by a better understanding of the fundamental causal factors. The purpose of this paper is to point out and evaluate the major fundamental causes of the disorders so that application of proper measures can be regulated according to the evaluated and expected effects of the varied and often interrelated factors.

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METHODS AND RESULTS

From previous experiments it has been concluded that a deficiency of calcium is a fundamental factor causing blossom-end rot and blackheart (1,2). Greenhouse experiments with nutrient cultures were conducted this past year to study the effect of low calcium ratios, boron levels and excessive soluble salts on the calcium nutrition of celery, tomato and pepper.

Single tomato (STEP 250), celery (Pascal) or pepper (California Wonder) plants were grown in 2-gallon crocks containing an aerated nutrient solution which was changed once weekly. Results given in Tables 1, 2 and 3 are from replicated experiments conducted during the fall of 1955. Similar results were obtained during the 1956 spring season. The calcium was determined on oven dry plant tissue samples, using a flame photometer for the analysis. Tomatoes grown in solutions containing normal calcium ratios were compared to those grown in solutions containing low calcium ratios. Results of these experiments are presented in Table 1.

Recorded responses of pepper and celery grown in solutions where calcium ratios, boron levels and soluble salt levels were compared are presented in Tables 2 and 3.

Discussion

From the data presented in Tables 1, 2 and 3, it is evident that excessive soluble magnesium, potassium, sodium or ammonium salts or a deficiency of soluble calcium salts (low calcium ratio) cause a decreased calcium uptake and an increased prevalence and severity of blossom-end rot and blackheart. On an equivalent basis ammonium affects the calcium nutrition most severely while sodium has the least effect.

Excess total salts also can cause a calcium deficiency and have frequently been associated with blossom-end rot and blackheart, even when the measurable calcium ratio is considered normal or adequate. Conclusions as to how excess salts cause a calcium deficiency have not been reached. It is logical to expect, however, that as salt concentrations increase, the proportion of soluble calcium salts tends to decrease. Also due to a relative activity effect, the 'effective' concentrations of calcium salts tend to decrease with increasing total salt (2). Such effects may explain, at least in part, the results obtained.

A deficiency of boron, accentuated by the high calcium levels, was associated with a thin-walled pepper which in turn appeared more susceptible to sunburn. Cracked stem of celery was similarly associated with the boron deficiency and appeared only at the higher calcium level. It should be noted that the calcium sprays prevented development of cracked stem, but might be explained on the basis of boron being a contaminant. By previous experiments, it was concluded that boron sprays or various boron levels in the nutrient solution would not control blackheart. However, a deficiency of boron could affect the calcium uptake by the plant or movement within the plant. In these experiments, a deficiency of boron does appear to increase slightly the incidence of blackheart but would generally be considered of minor importance. From the evidence obtained it would seem that if the boron deficiency was severe enough to cause a calcium deficiency, severe cracked stem would also result. Cracked stem is generally not found in fields where blackheart is a problem. However, the accentuating of a boron deficiency by high calcium levels could be of major importance.

All of the factors most frequently associated with outbreaks of blossom-end rot or blackheart during the past 50 years can be placed according to the mechanism by which they affect calcium nutrition into two major categories; (A) low calcium ratios; and (B) excess salts.

Unfavorable moisture relationships have been associated more often with blossom-end

Table 1. Effect on tomato yields, incidence of blossom-end rot and calcium content when potassium, sodium, ammonium or magnesium replaced equivalent amounts of calcium in the nutrient culture*

Calcium ratio		Not sprayed					+ $CaCl_2$ sprays			
ppm Ca/ ppm Salts	Cation partially replacing Ca	Marketable fruit		Blossom-end rot		% Ca leaves	Marketable fruit		Blossom-end Rot	
		Number	Wt. (gms.)	No.	%		Number	Wt. (gms.)	No.	%
150/1000		33	5092	0	0	1.35	26	3288	0	0
50/1000	K	9	516	6	40	.80	24	2594	0	0
50/1000	Na	21	2824	4	16	.95	38	4686	0	0
50/1000	NH_4**	1	135	3	75	.47	38	5726	6	13
50/1000	Mg	14	1676	4	22	.67	48	5532	0	0

*Yield figures given in all tables are summation results of 2 replicates; percentages are averages.

**Unsprayed plants receiving this treatment wilted severely after 2 day period of cloudy weather. Sprayed plants did not wilt.

rot and blackheart than any other factor. The role of moisture is considered as secondary in that it facilitates the operation of the primary factors (2). Movement of moisture in and out of the 'effective' root zone moves with it the salts that affect calcium nutrition. Salts, during dry weather or as a result of fertilizer top dressings, accumulate in the surface soil and rainfall moves these salts downward into the 'effective' root zone, decreasing the calcium ratio and often increasing total salt concentration in that zone. Insufficient soil moisture as well as addition and accumulation of fertilizers can cause excessive concentrations of salts. Excessive soil moisture favors the accumulation of ammonium salts which on an equivalent basis (compared with the other cations) causes the most severe calcium deficiencies (Table 1).

Excess soluble salt (1, 2, 4, 5) and excess of certain nutrients such as nitrogen and potash (1, 2, 3) have frequently been associated with the prevalence and severity of blackheart and blossom-end rot. Additions of lime or superphosphate have sometimes been associated with a reduction of the incidence (1, 2). These factors would be considered primary in that they directly affect the calcium ratio or total salt concentration.

Table 2. Effect of calcium ratios x boron levels and excess salt levels on the yields, incidence of blossom-end rot, sunburn and calcium content of pepper

Calcium ratio Ca/total salts	Boron ppm	Marketable Fruit Number	Marketable Fruit Wt. (gms.)	Blossom-end* rotted fruit	Sunburned* fruit	% Ca leaves	% Ca fruit
150/1000	0.5	8	1254	-	-	1.22	.17
50/1000	.5	4	553	++	-	.62	.13
150/1000	0	0	0	+	++++	.99	.20
50/1000	0	4	430	++	-	.56	.15
450/3000	.5	3	547	++	+	1.27	.12
150/3000	.5	0	0	+++++	-	.96	.16

*The incidence and severity of blossom-end rot and sunburn was determined by the number of fruit affected and the eventual severity. A - sign means non-occurrence and the number of + signs indicates increasing severity. (Fig. 1)

Table 3. Effect of calcium ratios x boron levels and excess salt levels on the yields, incidence of blackheart and cracked stem of celery

Calcium ratio C/Total Salts	Boron ppm	Unsprayed: Marketable Wt. (gms.)**	Unsprayed: Blackheart*	Unsprayed: Cracked Stem*	+ Ca Cl2 spray: Marketable Wt. (gms.)	+ Ca Cl2 spray: Blackheart	+ Ca Cl2 spray: Cracked Stem
150/1000	0.5	2160	-	-	2400	-	-
50/1000	.5	515	+++	-	2325	-	-
150/1000	0	990	+	++++	2520	-	-
50/1000	0	530	+++	-	2025	-	-
450/3000	.5	1305	++	-	1820	-	-
150/3000	.5	540	+++++	-	1900	-	-

*The incidence and severity of blackheart and cracked stem was determined by relative time of appearance and eventual severity at time of harvest. A - sign means non occurrence and the number of + signs indicates increasing severity.

**Those indicated as having blackheart were not marketable but weights were included for comparison.

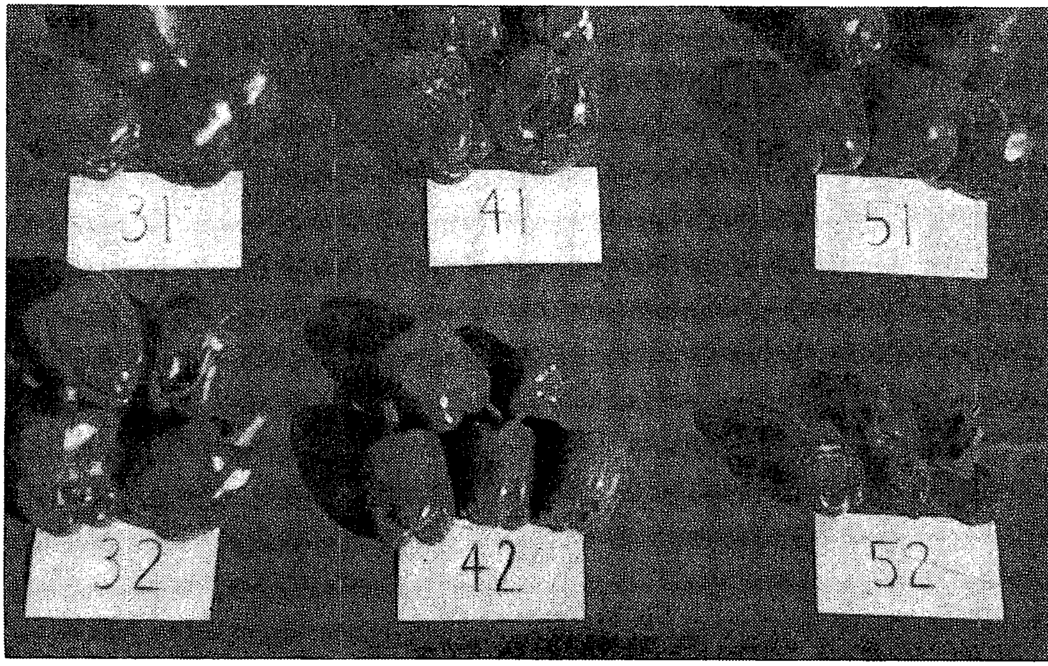

Fig. 1. Incidence and severity of blossom-end rot of peppers increase as calcium ratios decrease and total salts increase. Ratios indicate ppm calcium/ppm total salts supplied to the nutrient solution and are as follows:

Treatment No.	Ratio	Treatment No.	Ratio	Treatment No.	Ratio
31	150/1000	41	150/1000	51	450/3000
32	50/1000	42	50/1000	52	150/3000

Boron was omitted from No.'s. 41 and 42. Its absence was associated with a sunburn injury accentuated severely at the higher calcium ratio.

Rapid growth, another associated factor, would be considered as accentuating because it tends to increase the calcium requirement per unit of time.

A consistent supply of calcium from the soil solution is especially important because for all practical purposes, calcium within the plant is not readily trans-located from older plant tissue to younger. Therefore the soil supply must be constant as well as adequate at all times. Any combination of factors that causes the plant requirement for calcium to exceed the supply, whether it is of a temporary nature or a deficiency of longer duration, can be associated with the disorders.

Control Method

1. Primary objective—maintain to the best degree possible a favorable calcium ratio by supplying more soluble calcium salts and avoiding excesses, as much as possible, of soluble potassium, magnesium or ammonium salts as well as total soluble salts.

Most virgin sandy soils in Florida contain insufficient potentially soluble calcium. Calcium from the common liming materials is usually only slowly soluble. When liming materials containing magnesium are utilized, less calcium as well as greater amounts of a competitive salt are being supplied per unit of liming material. However, the more soluble magnesium, potassium or ammonium salts, supplied mainly from fertilizers and decomposing organic material, are potentially the main sources of competitive soluble salts. Amounts of nitrate or ammonium nitrogen can vary with the amount and rate of breakdown of organic matter as well as with amounts added in fertilizers. A high ammonium level is favored by low soil pH's and excessive soil moisture. (It is not recommended (1, 2) that the nitrate sources of nitrogen replace the ammonium, because excess nitrate can increase the calcium requirement). Superphosphate, gypsum, calcium nitrate, and calcium chloride are good sources of the more soluble calcium. Soils cropped for a number of years and receiving periodic additions of liming material and superphosphate gradually accumulate a good supply of potentially soluble calcium. The subsoil calcium, whether native or due to movement from that added to the top soil, is also important when considering the calcium supplying capacity of a soil.

2. Supplementary objective – periodically utilizing calcium sprays during the time when the plant requirement is expected to exceed the soil solution supply.

Timing is the key to successful use of calcium sprays for control of blossom-end rot and blackheart and is governed to a great extent by considerations discussed above. Calcium sprays should be applied within 24-48 hours after rains (especially if surface salts had accumulated) and have been leached into the 'effective' root zone. When excess salts are causing the disorders, sprays are the only successful means of supplying calcium. Soil amendments during the growing season are generally not recommended. Sprays should also be used during period of most rapid growth. Calcium sprays should always be considered as supplementary to that supplied from the soil solution and used accordingly; corrective–not curative.

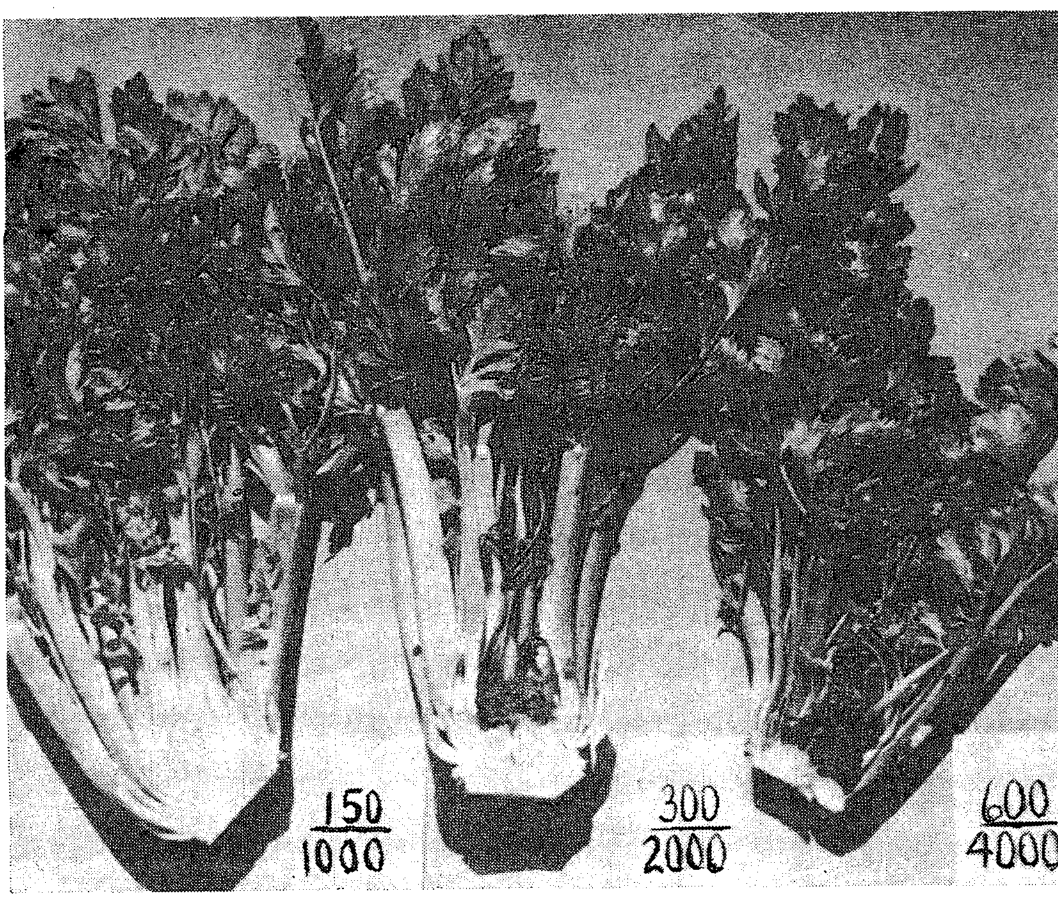

Fig. 2. Incidence and severity of blackheart of celery increase as salt concentrations increase even though the "apparent" calcium ratios remain constant. (Ratios indicate ppm calcium/ppm total salts supplied to the nutrient solution). Plants grown in similar solutions and receiving periodic calcium sprays did not develop blackheart.

The interrelated effects of the several contributing factors will be accentuated to the degree the primary objective (favorable calcium ratio) of the control method has been neglected and thus make the supplementary objective (calcium sprays) that much more difficult.

Points of Emphasis in Control of Blossom-end Rot of Tomatoes

1. Florida tomato soils often contain insufficient amounts of soluble calcium and application (preferably before planting) of such a material as gypsum is frequently recommended as a means of obtaining a more favorable calcium ratio.

2. Overall foliage sprays supply calcium to the leaves which probably allows more of the limited soil solution calcium to reach the fruit and thus prevent development of blossom-end rot. Although sprays are successfully used for control, they cannot be considered as the most efficient and successful way to supply calcium.

3. Depending on the causal factors, various combinations of the primary and supplementary objective of the control method are recommended to try to insure a constant and adequate supply of calcium at all times.

Points of Emphasis in Control of Blackheart of Celery

1. Blackheart in Florida has frequently associated with excessive soil salts. In such cases application of calcium to the soil during the growing season is generally not recommended. Gypsum may be recommended if leaching can be accomplished (generally between growing seasons). When possible, excess salts should be leached out, or preferably, not added to the point of excessiveness. Excessive salts have accumulated in certain muck soils and apparently do not leach out, even during the rainy season. Whenever excess salts (or low calcium ratios) are causing the calcium deficiency, calcium sprays can be used successfully for control of blackheart.

2. Calcium sprays must be supplied directly to the heart of the plant for control and is considered as an efficient way of supplying calcium because it is supplied directly to the portion of the plant that is calcium deficient.

3. In most cases, calcium sprays are recommended for control of blackheart because sprays can be completely successful regardless of the factors involved and even under conditions so severe that 100 percent of unsprayed plants would be affected.

Summary

All of the factors most *frequently* associated with the prevalence and severity of blossom-end rot of tomatoes and blackheart of celery, according to the mechanism by which they effect calcium nutrition, can be placed into two categories:

(a) Excessive soluble ammonium, potassium, magnesium or sodium salts or a deficiency of soluble calcium salts (low calcium ratio) cause a decreased calcium uptake and increased incidence of the physiological disorders.

(b) Excess total salts also can cause a calcium deficiency and has frequently been associated with the prevalence of these disorders even when the measurable calcium ratio is considered high or adequate. It was also found that a boron deficiency was accentuated by the higher calcium ratios.

A discussion and evaluation of the recommended control methods is based on the fundamental factors causing the calcium deficiency. The control method can be used most efficiently and effectively if the soil solution calcium is supplemented by calcium sprays to maintain a constant and adequate supply of calcium to meet the plant requirement.

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