Fig. 1. Plant collapses from infection of *Plasmodiophora brassicae* (club root).

CLUB ROOT CO
using Lime for

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Club root, incited by *Plasmodiophora brassicae* (Woronin), is one of the most serious diseases of plants of the crucifer family and is a threat to crop production wherever it occurs. In heavily infested soil, it is capable of destroying a crop before it reaches market maturity.

Club root was first reported in California in the San Francisco Bay area in 1938 by an agricultural inspector at Colma, who indicated that the disease first appeared in 1931. Since that time, club root has spread to San Mateo, Santa Cruz and northern Monterey counties, primarily by movement of infected plants and soil. The extensive use of transplants in the central coast area of California is probably responsible for much of the spread that has taken place. Once introduced into a field, club root will persist in soil for many years, even though no host plants are grown.

In the early stages of infection, the plants may appear normal. As the disease progresses and the plant matures, infected roots become enlarged and deformed into "clubs" which eventually decay. As decay progresses, the plant ceases growth, wilts, and eventually dies. High soil moisture favors a rapid build-up of this disease. Resistance to club root is known but has not been transferred into a commercially acceptable variety of Brussels sprouts.

Control measures consist of crop rotation, fumigation with high rates of 1,3d, incorporation of PCNB into the soil at transplanting, fumigation of transplant beds with a mixture of chloropicrin and methyl bromide, and the use of disease-free transplants. All of these methods of control offer some disadvantages. They are expensive, only partially effective, or time consuming.

TABLE 1. pH LEVELS OF SOIL AS AFFECTED BY ADDITIONS OF LIME

Tons lime/acre		Soil pH		
1973	1974	7/26/73	9/25/73	9/10/74
0	0	6.3	6.4	6.1
2.5	2.5	6.5	6.8	6.8
5.0	5.0	6.6	7.0	7.2
10.0	10.0	6.7	7.1	7.3

It was observed before the middle of the 19th century that applications to the soil of materials such as lime reduced or prevented the disease. Liming soils has become a control practice in many areas; however, in some cases it is not consistently effective.

In 1967 observation trials using lime were established in three Brussels sprout fields and in one cabbage field, each with a history of club root disease. The soils were light in texture, requiring 2 to 6 tons of lime to bring pH above 7.2. The cabbage field pH was maintained above 7.2 by applying 1 1/2 to 2 tons of lime per acre every 2 to 3 years. No club root has been detected in the cabbage field, even though there have been seven crops of cabbage and one crop of Brussels sprouts produced on this soil. Club root was observed in only one of the Brussels sprout fields in small isolated areas. Soil analysis revealed the pH was 6.9 to 7.0 in these areas, compared with 7.2 or above in the adjoining disease-free areas.

In 1972 a soil known to have severe club root for over 15 years was selected for an experimental site. The soil composition was 54 percent clay, 29 percent silt, and 17 percent sand with a saturation percentage of 56. The pH of the soil varied from 6.1 to 6.3. The lime requirement was calculated to be approximately 15 tons per acre to bring the pH level to 7.3. The area was divided into four plots; lime was added to the plots at the rates of 0, 2.5, 5, and 10 tons per acre, respectively. Each quantity was rototilled into the soil in the spring of 1973 prior to planting. In the fall of 1973 after harvest of the Brussels sprouts, the land was plowed 12 to 14 inches deep. In the spring of 1974, lime was again applied to the plots—at the rate of 0, 2.5, 5, and 10 tons per acre—and incorporated into the soil

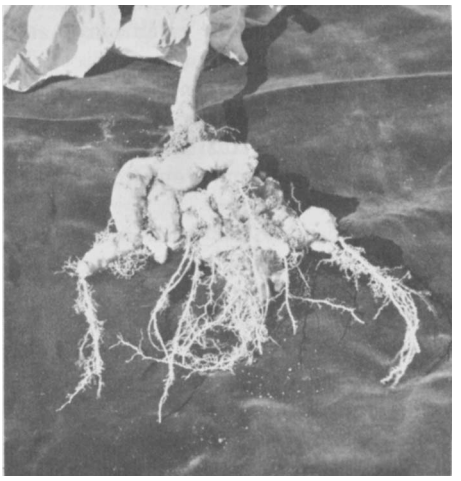

Fig. 2. Typical root enlargements caused by *Plasmodiophora brassicae* (club root).

NTROL IN BRUSSELS SPROUTS
pH Adjustment

by disking six times, bringing totals to 0, 5, 10, and 20 tons of lime per acre. The 1974 crop was then planted. Soil samples were taken during the middle and at the end of each crop growing period.

1,3d was applied at the rate of 30 gallons per acre before planting the 1973 crop. In 1974 1,3d was applied at the effective nematicidal rate of 15 gallons per acre. The lime was applied twice to avoid any adverse effects on the nutrient status of the soil that might result from one single heavy application. However, the grower applied 15 to 18 tons of lime in a single application to the surrounding field with no apparent adverse effects.

Table 1 indicates the changes in soil pH that occurred with the additions of the lime. Only in the 10 and 20 ton per acre treatments was the pH adjusted to the desired 7.2 or above level.

Table 2 contains the 1973 yield and disease rating. The high rate of 1,3d application suppressed disease development until late in the growing period. However, the less lime added per acre, the greater the level of disease and the lower the yield.

Table 3 summarizes results obtained during the 1974 growing season. Excellent control of club root was obtained in plots which had received a total of 10 and 20 tons of lime over the 2-year period. Some control of club root was evident in plots receiving a total of 5 tons of lime per acre. The addition of lime resulted in a significant increase in yield of sprouts when compared with plots receiving no lime. There were no significant differences in yield between treatments receiving the various rates of lime.

In Santa Cruz and Monterey counties this soil pH was one of the most difficult to adjust because of its high buffering capacity. High lime applications caused no adverse effect on plant growth in any of the trial areas or commercial field applications.

Different soil types vary considerably in their response to efforts to alter the pH with lime applications. Therefore, it is advisable for any grower wishing to attempt this procedure to engage the services of a soils laboratory to determine initial pH and the amounts of lime required to bring the pH to the desired level, and to monitor the actual changes taking place after the application. Periodic monitoring of the pH in subsequent years is advisable to determine the stability of the change.

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TABLE 2. YIELD OF BRUSSELS SPROUTS AND CLUB ROOT RATING IN 1973

Tons lime/acre	Lbs. sprouts/plant	% Plants with various club root ratings* 0	1	2	3	4
0	1.6 a**	40	15	20	20	5
2.5	1.8 a b	60	10	10	14	6
5.0	1.9 a b	84	8	6	0	2
10.0	2.1 b	77	17	2	4	0

* 0 = no detectable disease; 4 = plants collapsed.
** Means followed by the same letter are not significantly different at the 1 percent level.

TABLE 3. YIELD OF BRUSSELS SPROUTS AND CLUB ROOT RATING IN 1974

Tons lime/acre/ application	Total tons lime/acre	Lbs. sprouts/plant	% Plants with various club root ratings* 0	1	2	3	4
0	0	0.5 a**	10	0	20	35	35
2.5	5.0	1.2 b	30	18	35	17	0
5.0	10.0	1.5 b	78	12	10	0	0
10.0	20.0	1.5 b	90	5	5	0	0

* 0 = no detectable disease; 4 = plants collapsed.
** Means followed by the same letter are not significantly different at the 1 percent level.