Chemical Control of Clubroot

results from cooperative work between California Exten

chemicals applied in setting water controlled soil-borne fungus disease

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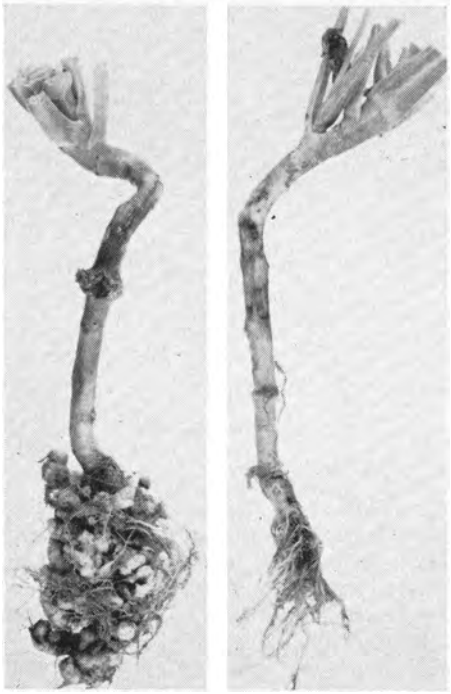
San Mateo County producers of cabbage, broccoli, and Brussels sprouts have incurred large financial losses—in the past several years—because of the clubroot disease of crucifer plants.

The clubroot disease caused by the soil-borne fungus — *Plasmodiophora brassicae*—has not been found in California, outside of San Francisco and San Mateo counties.

However, clubroot disease has been known in Europe for more than a century and in the United States for many years, where it is a major problem in certain areas, particularly in the Pacific Northwest. In 1938, the disease was found—for the first time in California—infecting large acreages of cabbage and cauliflower in southern San Francisco County and northern San Mateo County in the vicinity of Colma and Daly City.

During 1945 and 1946, clubroot was introduced into the Half Moon Bay area, probably on diseased transplants brought in from near Colma.

A young Brussels sprout plant infected with clubroot disease is at the left. A healthy plant is on the right.



There is concern among Brussels sprout growers in the central coastal counties of Santa Cruz, southern San Mateo, Monterey, and San Luis Obispo, because of the ease with which the disease is spread.

The clubroot fungus can persist in the soil for many years as resting spores. During favorable periods of temperature, moisture, and soil conditions, the resting spore germinates and produces a motile swarm spore. These motile spores invade a plant through root hairs, young roots, or wounded tissue. Infection may take place on seedlings in seedbeds or transplants in the field. Large, swollen growths—clubs—develop in the root system as a result of root cell invasion. These clubbed roots soon rot and the root system is destroyed. As a result of root infection, the tops of plants wilt and droop. Wilting of the tops of the plant is particularly noticeable on warm days. Early infection may cause death of the plant before a crop is produced. Later infection generally leads to reduced growth, lowered quality, and poor yields.

The rotting and breaking down of infected clubs releases enormous numbers of spores into the soil. A spectacular spread of the disease was observed in a Brussels sprouts planting in Half Moon Bay, where only a few diseased plants were found in a 20-acre field one season and—two years later—almost the entire planting was infected.

Because each spore is capable of inciting infection, the causal fungus can be introduced easily into clean soil by diseased plants from infested seedbeds or fields; by the movement of soil by water or wind; on plants, farm equipment, hoofs of animals, and so forth.

Where infection has occurred, a 3-to-5-year rotation interval out of susceptible crucifer crops—such as broccoli, cabbage, cauliflower, Brussels sprouts—has been of benefit but will not free the soil of fungus; it will only reduce the amount of the fungus. A satisfactory crop might possibly be obtained after such a rotation.

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Clubroot, a soil-borne fungus disease, threatene industry. Control was achieved on 250 acres in grated three-phase research program carried ou

This research program and the results obtai Station and Extension Service of combining fo instance, members of the University of Califo thology, Agricultural Engineering, and Vegetabl co-ordinated effort toward development of an e ment, and adaptation of equipment to apply ch sistant strain of seed.

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resistance to clubroot of breeding project i

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Development of a strain of Brussels sprouts resistant to the fungus causing clubroot disease was started because the use of chemical treatments at the time of transplanting does not provide a permanent solution for the problem.

Roots of plants grown on soil i Left: resistant plant of the bad Brussels sprouts; nor

Applications of $HgCl_2$—mercuric chloride — and PCNB — pentachloronitrobenzene—have been spectacularly successful in restraining the clubroot organism sufficiently to permit the growing of a good crop, but if acceptable lines of resistant sprouts could be bred, the problem could be solved without the need for such treatments. The breeding program necessary for this objective requires a number of years because the plants must be bred for several successive generations. The chemical treatments therefore have great value in providing an immediate and effective stop-gap control. Furthermore, it is of the utmost importance that the problem be attacked from both angles and that the work on both aspects be carefully integrated.

Work on the breeding of resistant Brussels sprouts was initiated in 1952,

CLUBROOT DISEASE

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In San Mateo County, economic conditions are such that a long rotation out of Brussels sprouts would be difficult. Few other irrigated vegetables can be profitably raised in competition with other areas of the state. Sprouts are a specialty crop grown only in the central coast counties with the cool, moist climate necessary for high-quality sprouts.

A series of tests was initiated in 1951 to investigate possible chemical control in field plantings. After two years of trial and demonstration, seedbed fumigation with chloropicrin—tear gas—became a standard practice. Liming of soils was not found to be entirely satisfactory in San Mateo County soils.

Additional field experiments during 1951 and 1952 showed that a 1-to-2,000 $HgCl_2$—mercuric chloride—solution, about four ounces to 55 gallons of water, used as the setting water at transplanting time gave good control when the solution was applied by hand at the rate of one-half to three-fourths pint per transplant. On the basis of results obtained in the hand-treated test plots, over 250 acres of Brussels sprouts were treated with mercuric chloride in 1953 and 1954

Later, machine transplanters were developed to automatically set plants and inject a measured amount of the mercuric chloride solution into the soil around the stem and root.

Mercuric chloride treatment does not completely control clubroot disease but it will protect the main root and stem from attacks by the fungus. Therefore a satisfactory crop can be obtained where otherwise continued planting would not be possible.

Chemical Soil Treatment Control of Clubroot on Brussels Sprouts, 1954

Chemical concentration*	Pure chemical per acre (pounds)	Infection rating (0–4)	Yield: Per plot (pounds**)	Yield: Pounds per acre equivalent
1. Nontreated (water only)	..	2.14	14.83	5,980
2. $HgCl_2$ 1-2000	1.2	0.54	24.25	9,770
3. PCNB 1-1600	1.5	0.78	27.41	11,050
4. PCNB 1- 400	6.0	0.35	28.05	11,300
5. Captan 1-1600	1.5	1.36	20.67	8,330
6. Captan 1- 400	6.0	0.51	23.95	9,650

* Applied at the rate of 8 oz. per plant or 302.5 gal. per acre.
** Each plot equivalent to 1/403 acre.

Because mercuric chloride is very corrosive to equipment and extremely poisonous to humans, a series of tests was made during the 1954 season in an effort to find other—less hazardous—chemicals for control of clubroot.

In May 1954, an experimental plot was established near Half Moon Bay to compare the protective effects of mercuric chloride with two dosages each of captan and PCNB—pentachloronitrobenzene. Each plot consisted of 12 hand-planted and hand-treated plants, and the six treatments were each replicated six times in a Latin square arrangement. Observations were made throughout the season on the appearance and vigor of the plants. Yield was measured by three pickings at 3-to-4-week intervals.

Examination of the roots at the end of the experiment showed that most of the nontreated plants were severely infected with clubs and that the roots had been invaded by secondary organisms and completely destroyed. The captan-treated roots were severely clubbed, but secondary invasion of the main stem and root system had not occurred and the root systems were still intact. PCNB provided good control of infection on the main stem and root, although overgrowths were found on the branch roots some distance from the crown. The best protection was obtained with mercuric chloride, but some of the plants appeared less vigorous than those treated with PCNB.

All treatments significantly increased yield over that of nontreated plots, but the highest yield occurred with PCNB treatments.

Because PCNB provided club root control nearly equal to that from mercuric chloride but was less injurious to plants in dry soils—as well as being much less poisonous and noncorrosive to metals—it appears to offer advantages over the other fungicides tested and its use may soon supersede that of mercuric chloride.

In addition to the replicated hand-planted plots, several large field plantings were made with mechanical transplanters using a PCNB suspension as the setting water. All of the field plots were on land known to be infested with the clubroot disease. The 75% wettable powder of PCNB was used at a concentration of two, three, four, and eight pounds per 100 gallons of water, and each plant received three-fourths pint of the liquid. Clubroot disease control was obtained almost equally well at all concentrations. No injury was observed at higher levels except perhaps a slight stunting of plants early in the season.

On several plantings where PCNB and mercuric chloride solutions were used as the setting water, the soil had been treated with 2,000 to 3,000 pounds of Dolomite lime prior to planting. It was observed that the lime application in combination with PCNB and mercuric chloride treatment appeared to increase the degree of control. This will be investigated further.

Registration of PCNB has been recently completed by the Bureau of Chemistry, so it is expected that this chemical will be widely used for clubroot control in 1955.

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Control of clubroot by chemical soil drench. The row of Brussels sprouts left of the center was treated with PCNB 1-400 in the transplanting solution while the row to the right of the center was nontreated and shows the loss due to clubroot infection.

RESISTANCE

Continued from preceding page

producing a large quantity of seed, which was planted in an infected seedbed in 1954 in the same fashion as in tests of the preceding years. Since conditions in the seedbed did not prove satisfactory for the development of clubroot symptoms, it was not possible to select plants for resistance there, but it was necessary to transplant all seedlings to the field without advance knowledge of their resistance. In the field, however, conditions for infection were satisfactory as judged by the clubroot symptoms on susceptible control lines.

As expected, plants of this backcross generation segregated for resistance as