

## Evaluation of *N*-(1-alkoxy-2,2,2-trichloroethyl)-2-hydroxybenzamides for Clubroot Control in Chinese Cabbage

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### ABSTRACT

Ohmori, K., Nakagawa, T., and Koike, K. 1986. Evaluation of *N*-(1-alkoxy-2,2,2-trichloroethyl)-2-hydroxybenzamides for clubroot control in Chinese cabbage. *Plant Disease* 70:51-53.

Ten *N*-(1-alkoxy-2,2,2-trichloroethyl)-2-hydroxybenzamides were tested in the greenhouse against *Plasmodiophora brassicae*, causal agent of clubroot of Chinese cabbage. C<sub>4</sub>, C<sub>5</sub>, and C<sub>6</sub> derivatives of the alkoxy group gave better clubroot control than the standard PCNB. The most effective derivative, *N*-(1-butoxy-2,2,2-trichloroethyl)-2-hydroxybenzamide (trichlamide), was field-tested. Clubroot control on Chinese cabbage with preplant broadcast soil treatment of trichlamide at 30 kg a.i./ha was equal to that obtained with standard PCNB treatment (50 kg a.i./ha). Yield increase was associated with decrease in disease severity.

Clubroot, caused by *Plasmodiophora brassicae* Woron., is a disease of world-wide importance in crucifer production (2,5). In Japan, many fields are continuously cropped to cruciferous crops. This increases soil infestation of *P. brassicae* and causes severe losses in Chinese cabbage (*Brassica campestris* subsp. *pekinensis*), cabbage (*B. oleracea* var. *capitata*), table turnip (*B. campestris* var. *rapifera*), and other minor crucifers (10).

Cultural procedures recommended for control of clubroot are sanitation (removal and burning of infected plants), liming to raise soil pH to neutral or

slightly alkaline reactions, improvement of drainage, and crop rotation (10). Use of a variety of cruciferous hosts resistant to clubroot has been only partially successful. Although marked differences among Chinese cabbage cultivars have been observed on lightly infested sites, these differences have not been observed on heavily infested sites (4). Use of resistant cultivars of cabbage has been largely unsuccessful because of the occurrence of numerous biological races of the organism (9).

PCNB (20% dust incorporated into soil) has been the standard commercial method of clubroot control for cruciferous crops in Japan (6). The standard rates of PCNB used are 40–50 kg a.i./ha as a broadcast treatment. This treatment is effective for 10–12 mo (6). Environmental concern regarding the accumulation of PCNB and its technical impurity, hexachlorobenzene, in soil (6,7) and the restriction of PCNB leaves growers with no satisfactory fungicide for control of

clubroot on cruciferous crops except Chinese cabbage and cabbage in Japan.

The urgent need for a replacement chemical prompted research aimed at finding a new effective soil fungicide for clubroot disease control on a range of cruciferous crops (10). This paper describes a technique for screening chemicals against *P. brassicae* in the greenhouse and reports on the efficacy of *N*-(1-alkoxy-2,2,2-trichloroethyl)-2-hydroxybenzamides (Fig. 1) for clubroot control on Chinese cabbage in the greenhouse and in the field.

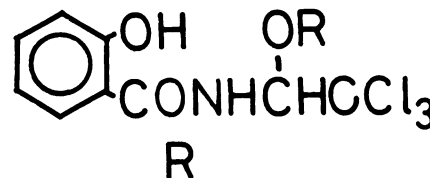


Fig. 1. Chemical structure of *N*-(1-alkoxy-2,2,2-trichloroethyl)-2-hydroxybenzamides (R: CH<sub>3</sub>, C<sub>2</sub>H<sub>5</sub>, n-C<sub>3</sub>H<sub>7</sub>, n-C<sub>4</sub>H<sub>9</sub>, n-C<sub>5</sub>H<sub>11</sub>, n-C<sub>6</sub>H<sub>13</sub>, n-C<sub>7</sub>H<sub>15</sub>, n-C<sub>8</sub>H<sub>17</sub>, n-C<sub>9</sub>H<sub>19</sub>, n-C<sub>10</sub>H<sub>21</sub>).

### MATERIALS AND METHODS

**Test compounds.** Physical properties of the *N*-(1-alkoxy-2,2,2-trichloroethyl)-2-hydroxybenzamides are listed in Table 1. Each test compound was formulated as 10% dust including 90% clay by weight. PCNB (20% dust including 80% clay by weight) was used as a standard chemical.

**Greenhouse experiment.** An alluvial sandy loam, pH 5.8, naturally infested with *P. brassicae* was obtained from a

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field cropped to Chinese cabbage at Ohra Gun, Gunma Prefecture. Infested soil was divided into 1-kg lots to which 100 mg a.i. (about 83 kg a.i./ha broadcast) of test compounds was mixed well by hand in plastic bags. Holes 12 cm in diameter × 9 cm deep dug in ground beds in the greenhouse were filled with treated or untreated infested soil. Treatments were replicated three times. Ten seeds of Chinese cabbage cultivar Taibyo Rokujyunichi were sown in each hole. Air temperature of the greenhouse was 20–28 C with a daily mean of 24 C. Soil temperature was kept at 22 C with water (45 C) circulated in pipes buried 40 cm below soil line. Plots were misted automatically every 3 hr. Supplementary lighting was provided from 5:00 to 7:00 A.M. and from 5:00 to 7:00 P.M. each day with mercury vapor lamps (New Delux White HF 1000 XW, Mitsubishi Electric Co., Ltd., Tokyo). The experiment was terminated 30 days after sowing. Plants were washed free of soil and disease severity was assessed. The clubroot control activity of test compounds was evaluated by comparison with that of standard PCNB, where A = superior, B = equivalent, and C = inferior to PCNB.

**Field experiment.** Seedlings of Chinese cabbage cultivar Ohsho were raised in sterile soil in polyethylene pots for 5 wk before use. The experiment began on September 1979 at Ohra Gun. Treatments were replicated three times. Each plot was 3 × 9 m. C<sub>4</sub> derivative or PCNB was broadcast and incorporated into an alluvial sandy loam, pH 5.8, 12 cm deep with a cultivator at the rate of 81 or 135 g a.i. (about 30 or 50 kg a.i./ha) per plot, respectively. Fertilizer (16:14:16) was applied at 1,000 kg/ha at planting. An additional 500 kg was applied 1 mo later. Plants were set by hand 50 cm apart in rows on 60-cm centers. Acephate 5G insecticide and trifluralin 3G herbicide were applied at planting at 40 kg/ha. Random samples of 30 plants taken from the three center rows were examined at crop maturity (December 1979). Numbers of healthy and infected plants were recorded. Heads were individually weighed and roots were examined for clubroot severity. For each treatment, the disease index (DI) was calculated as follows:  $DI = (A \times 5 + B \times 4 + C \times 3 + D \times 2 + E \times 1 + F \times 0) / 5 \times (A + B + C + D + E + F)$ , where A = number of plants with severe clubbing on taproot, B = number

of plants with moderate clubbing on taproot, C = number of plants with severe clubbing on major lateral root, D = number of plants with clubbing on major lateral root, E = number of plants with clubbing on minor lateral root, and F = number of plants with normal roots.

## RESULTS AND DISCUSSION

In the greenhouse test, the C<sub>4</sub>–C<sub>6</sub> derivatives of *N*-(1-alkoxy-2,2,2-trichloroethyl)-2-hydroxybenzamides gave clubroot control superior to that obtained with the standard PCNB at about 83 kg/ha broadcast (100 mg a.i./kg of soil, incorporated) (Table 1). The C<sub>4</sub> derivative (trichlamide, NK-483) was the best of these. The other derivatives fell into two groups. The C<sub>1</sub>–C<sub>3</sub> and C<sub>10</sub> derivatives were less active than PCNB, whereas the C<sub>7</sub>–C<sub>9</sub> derivatives were equivalent to PCNB. Untreated controls were affected with serious root clubbing.

In the field experiment (Table 2), trichlamide at 30 kg a.i./ha gave clubroot control equal to that obtained with standard PCNB at 50 kg a.i./ha. Both compounds reduced the incidence and severity of infected plants, and neither had phytotoxic effects. Disease pressure was extremely high. Trichlamide has also been tested in the United Kingdom and proved effective on clubroot (1,3). Because the 30-kg a.i./ha rate (300 kg of 10% dust) is similar to the 50-kg a.i./ha rate of PCNB (250 kg of 20% dust), no problems in application are expected. Trichlamide is also known to be active against *Spongospora*, *Streptomyces*, and *Aphanomyces* (8). How residual activity compares with that of PCNB is currently unknown.

## ACKNOWLEDGMENTS

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**Table 1.** Physical properties and clubroot control activity of Chinese cabbage in greenhouse test of *N*-(1-alkoxy-2,2,2-trichloroethyl)-2-hydroxybenzamides

| Derivative                        | Melting point (C) | Refractive index at 25 C | Clubroot control activity <sup>2</sup> |
|-----------------------------------|-------------------|--------------------------|--|
| CH <sub>3</sub>                   | 117–118           | —                        | C                                      |
| C <sub>2</sub> H <sub>5</sub>     | 123–124           | —                        | C                                      |
| n-C <sub>3</sub> H <sub>7</sub>   | 121–121.5         | —                        | C                                      |
| n-C <sub>4</sub> H <sub>9</sub>   | 73–74             | —                        | A*                                     |
| n-C <sub>5</sub> H <sub>11</sub>  | 60–61             | —                        | A                                      |
| n-C <sub>6</sub> H <sub>13</sub>  | 73–74             | —                        | A                                      |
| n-C <sub>7</sub> H <sub>15</sub>  | 58–59             | —                        | B                                      |
| n-C <sub>8</sub> H <sub>17</sub>  | 47–48             | —                        | B                                      |
| n-C <sub>9</sub> H <sub>19</sub>  | —                 | 1.5110                   | B                                      |
| n-C <sub>10</sub> H <sub>21</sub> | —                 | 1.5122                   | C                                      |

<sup>2</sup> Clubroot control activity of test compounds was evaluated by comparison with that of standard PCNB, where A = superior, B = equivalent, and C = inferior to PCNB; A\* = most effective compound.

**Table 2.** Effect of trichlamide 10% dust on clubroot of Chinese cabbage in a field test

| Treatment <sup>w</sup>              | Rate (kg a.i./ha) | Infected plants (%) | Disease index <sup>x</sup> | Head weight (kg/plant) |
|-------------------------------------|-------------------|---------------------|----------------------------|------------------------|
| Trichlamide <sup>y</sup> (10% dust) | 30                | 42 a <sup>z</sup>   | 0.7 a                      | 4.0 a                  |
| Standard PCNB (20% dust)            | 50                | 52 b                | 1.2 a                      | 4.0 a                  |
| Untreated                           | —                 | 100 c               | 3.5 b                      | 2.6 b                  |

<sup>w</sup> Broadcast soil treatment.

<sup>x</sup> Disease index =  $(A \times 5 + B \times 4 + C \times 3 + D \times 2 + E \times 1 + F \times 0) / 5 \times (A + B + C + D + E + F)$ , where A = number of plants with severe clubbing on taproot, B = number of plants with moderate clubbing on taproot, C = number of plants with severe clubbing on major lateral root, D = number of plants with clubbing on major lateral root, E = number of plants with clubbing on minor lateral root, and F = number of plants with normal roots.

<sup>y</sup> Trichlamide = *N*-(1-butoxy-2,2,2-trichloroethyl)-2-hydroxybenzamide.

<sup>z</sup> Means in each column followed by the same letter do not differ significantly ( $P = 0.05$ ) according to Duncan's multiple range test.

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