Effect of Soil Amendment on Clubroot of Crucifers

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摘　　要

楊慶鴻、謝文瑞（1985）土壤添加物對十字花科蔬菜根瘤病之防治效果　（國立中興大學）

在土壤中添加 0.5%及 1 %的 S—H 混合物可有效抑制青江白菜根瘤病的發生，將 S—H 混合物之各成份以不同組合方式測試，發現蚵殼粉加礦灰及單獨使用礦灰皆具有幾乎與 S—H 混合物相同的防病效果。礦灰中含有 CaO、MgO、Al_2O_3、FeO 及 SiO_2 等成份，分別單獨使用前三者皆可降低青江白菜根瘤病根毛感染率。在田間試驗中，土壤添加礦灰、碳酸鈣及 S—H 混合物都可明顯抑制根瘤病的發生。由上述結果顯示土壤添加物中的鈣離子可能是防治根瘤病的最主要成份。

（關鍵字：十字花科蔬菜，根瘤病，土壤添加物，防治）

ABSTRACT

Amendment of soil with S-H mixture at 0.5 and 1% greatly reduced the incidence of clubroot disease on the cultivar Green-Petiole Pai-Tsai of *Brassica chinensis*. Among various combinations of the components of S-H mixture tested, oyster-shell powder plus mineral ash and mineral ash alone were almost as effective as S-H mixture in reducing clubroot disease. Mineral ash contained CaO, MgO, Al_2O_3, FeO and SiO_2. The first three, when applied singlely, greatly reduced the root hair infection of Green-Petiole Pai-Tsai. In the field, mineral ash, calcium carbonate and S-H mixture markedly reduced the incidence of clubroot disease. The above results suggest that calcium at the concentration present in the tested soil amendments is the most active component in controlling the disease.

(Key words: cruciferous vegetables, clubroot, soil amendments, control)

INTRODUCTION

Clubroot caused by *Plasmodiophora brassicae* Wor. has become serious in both the northern and central parts of Taiwan in recent years[8]. Mustard, Szechuan mustard, Pak-Choi, Chinese cabbage and rapeseed suffered considerable losses when grown in the infested field. The recommended control measures include liming of soil, the use of a wide range of chemicals and soil fumigation[1,3,4,5,17]. Although some soil sterilants and fungicides offer an adequate disease control, the values of the host crops do not usually justify adoption of a chemical means[1,17]. Lime appears to be effective in controlling clubroot when it is applied at a high rate. Its use is easy and inexpensive in comparison with other control chemicals[5]. However, the application of large quantities of lime in soil may often result in a reduced availability of some trace elements such as boron, iron and maganese[12]. Of the various methods commonly recommended for clubroot control[7], none is considered economical and has been used by farmers in Taiwan. We, therefore, investigated the possibility of controlling the disease with soil amendments.

MATERIALS AND METHODS

Test of soil amendments

The S-H mixture consisting of 4.4% bagasse, 8.4% rice husks, 4.25% oyster-shell powder, 1.01% potassium nitrate, 13.16% calcium superphosphate, 8.25% urea and 60.5% mineral ash has been found effective in preventing watermelon wilt caused by *Fusarium oxysporum* f. sp. *niveum* when mixed with infested soil at 1%[16]. This mixture was incorporated into the *Plasmodiophora brassicae* infested soil at 0.5% or 1% for test against clubroot disease. Each six Kg of sandy soil (pH 4.6) mixed with S-H mixture was placed in a plastic flat ($35 \times 27 \times 8.5$cm). To each flat was added 150 ml suspension of *P. brassicae* resting spores (4×10^7 spores/ml). Seeds of Green-Petiole Pai-Tsai of *Brassica chinensis* were sown in treated soil as well as in control soil. Data were collected after 37 days. The various components of the S-H mixture were also tested to determine if they are effective in reducing clubroot disease incidence.

A field trial was conducted to compare mineral ash and calcium carbonate with S-H mixture to control clubroot. The soil was sandy loam (pH 5.0). To an area of 1 m^2 was applied one Kg of S-H mixture, mineral ash or calcium carbonate. About 2,000 seeds of Green-Petiole Pai-Tsai were sown in each plot (8×4m). After thinning made one week later, 1,000 seedlings remained and 600 plants were examined for the presence of clubbed roots for each plot. The treatments were replicated five times and observations made after 48 days.

Test of mineral salts

Mineral ash contained in the S-H mixture had the following composition: SiO_2, 31%; CaO, 44%; MgO, 1.7%; Al_2O_3, 18% and FeO, 1%. The effects of the various components on infection of root hairs by *P. brassicae* were tested experimentally, $AlCl_3$, $CaCl_2$, $FeCl_3 \cdot 6\,H_2O$, $MgCl_2 \cdot 6\,H_2O$ and H_2SiO_3 were used at quantities so that the concentrations of each cation in the soil was corresponding to mineral ash applied at 0.5% and 1%.

Sixty grams of infested sandy loam soil at pH 5.6 was mixed with each of the test mineral salts separately and placed in a polyethylene container (8×6cm). Forty seeds were sown in each container. Four containers were used in each treatment. After one week, seedlings were gently removed from soil. Washed roots were immersed in 0.6% aceto-carmine solution [2] for two days, and then examined under a microscope for the presence of *P. brassicae* zoosporangia in root hairs. Four roots (2.5 cm long) were examined for each treatment.

RESULTS

Effect of soil amendment on clubroot

The infested soil amended with S-H mixture at 1% raised soil pH from 4.6 to 6.0. Amendment of soil with the mixture greatly reduced the incidence of clubroot disease (Table 1). None of the plants grown in soil amended with 1% S-H mixture had clubbed roots. Amendment of soil with S-H mixture at 0.5% also reduced the disease incidence from 34.6% in nonamended soil to 1.4% in amended soil.

Table 1. Effect of soil amendment with S-H mixture on incidence of clubroot on *Brassica chinensis* cultivar Green-Petiole Pai-Tsai

Amendment	No. of plants with clubbed roots/ No. of plants examined				Total	Plants infected (%)
	Rep. I	Rep. II	Rep. III	Rep. IV		
1% S-H mixture	0/47	0/44	0/47	0/29	0/167	0
0.5% S-H mixture	2/57	0/52	1/57	0/56	3/222	1.4
None	26/65	15/55	23/64	18/53	82/237	34.6

Table 2. Effect of components of S-H mixture on incidence of clubroot in *Brassica chinensis* cultivar Green-Petiole Pai-Tsai

Amendment	Conc. (%)	No. diseased plants/ No. plants examined	Plants infected (%)
S-H mixture	1	1/64	1.6 a[1]
Rice husks+urea+ oyster-shell powder	0.21	47/94	50.0 c
Urea+mineral ash	0.69	8/79	10.2 a
Oyster-shell powder+ mineral ash	0.65	1/163	0.6 a
Urea+calcium superphospate	0.22	17/62	27.4 b
Potassium nitrate+ calcium suphosphate	0.14	33/144	29.0 b
None		64/139	46.0 c

1) Within the column, values followed by the same letter do not differ significantly (P=0.05) according to Duncan's new multiple range test.

Among various combinations of the components of S-H mixture tested, oyster-shell powder plus mineral ash and urea plus mineral ash were almost as effective as S-H mixture in reducing disease incidence (Table 2). Since the combination of rice husks, urea and oyster-shell powder was not effective in suppressing clubroot, mineral ash appeared to be the major active component of S-H mixture.

In the field trial, calcium carbonate, mineral ash and S-H mixture were effective in reducing disease incidence of clubroot and increased the plant weight significantly (Table 3). At the rate of 10 t/ha, calcium carbonate, mineral ash and

Table 3. Efect of S-H mixture, mineral ash and calcium carbonate on incidence of clubroot on *Brassica chinensis* cultivar Green-Petiole Pai-Tsai in the field

Amendment[1)]	No. of diseased plants/No. of plants examined[3)]	Plants infected (%)	Plant weight (kg/3000 plants)
S-H mixture[2)]	638/3000	21.3 a[4)]	290.7 a
Mineral ash	605/3000	20.2 a	244.7 a
Calcium carbonate	435/3000	14.5 a	272.3 a
None	935/3000	31.4 b	184.4 b

1) About 1 kg of S-H mixture, mineral ash or calcium carbonate was incorporated into an 1 m^2 area.
2) S-H mixture minus urea.
3) Number of plants investigated in five replications in each treatment.
4) Means followed by the same letter in a column are not significantly different, P=0.05, by Duncan's multiple range test.

Table 4. Effect of mineral amendments on the root hair infection by *Plasmodiophora brassicae* on *Brassica chinensis* cultivar Green-Petiole Pai-Tsai

Cation (mineral)	Cation conc. added (ug/g)	No. of root hairs infected per plant[1)]	Soil pH
Al ($AlCl_3$)	150	0.3	4.9
	75	3.4	5.4
Ca ($CaCl_2$)	1000	0.9	5.5
	500	4.4	5.6
Fe ($FeCl_3 \cdot 6H_2O$)	100	108.7	5.4
	50	113.4	5.5
Mg ($MgCl_2 \cdot 6H_2O$)	200	10.6	5.7
	100	23.4	5.6
Si (H_2SiO_3)	2000	38.8	5.7
	1000	39.6	5.7
None		82.3	5.6

1) All values are mean of zoosporangia formed root hairs of 16 plantlets examined.

S-H mixture reduced the disease incidence from 31.4% to 14.5%, 20.2% and 21.3 %, respectively. Also the average plant weight of 3,0000 plants in 5 replicates increased by 47.7%, 32.7% and 57.7%, respectively.

Effect of mineral salts on root hair infection

There was no significant pH change of the soil when $AlCl_3$, $CaCl_2$, $FeCl_3.6\ H_2O$, $MgCl_2.6\ H_2O$, or H_2SiO_3 was added individually to the soil at the test concentration. The number of infected root hairs per root decreased from 82 in non-treated soil to less than 11 when soil was amended with 150 and 75 ppm of Al^{+++}, 1,000 and 500 ppm of Ca^{++}, or 200 ppm of Mg^{++}. However, 100 and 50 ppm of Fe^{+++} had no effect in reducing root hair infection (Table 4).

DISCUSSION

Application of mineral ash to soil, in combination with urea or oyster shell powder, was as effective as S-H mixture in controlling clubroot. This suggests that mineral ash was the active component of the mixture. Further supporting evidence came from the observation that deletion of mineral ash from S-H mixture rendered the latter ineffective in clubroot control, as seen in the greenhouse tests result with the combination of rice husks, urea and oyster shell powder (Table 2). The explanation is further supported by results which showed that mineral ash alone was as effective as S-H mixture in reducing root hair infection and clubroot in field trials.

Ko and Hora[11] reported that Al^{+++} at 0.65 ppm inhibited ascospore germination of *Neurospora tetrasperma*. Lewis[13] also showed that addition of Al^{+++}, Ca^{++}, Cu^{++} and Zn^{+++} at 50 and 100 ppm to soil significantly reduced root rot of peas caused by *Aphanomyces euteiches*. The mineral ash in our experiments consisted of SiO_2, CaO, MgO, Al_2O_3 and FeO. Among the cations, Al^{+++}, Ca^{++}, Mg^{++} and Si^{++++} appeared to be responsible for the suppression of root hair infection. However, because calcium carbonate alone at 1% was as effective as S-H mixture at the same concentration in reducing root hair infection and incidence of clubroot disease, we believe that Ca^{++} is the most important active component in mineral ash in controlling clubroot disease.

Liming the soil before planting has been the oldest practice used widely for the control of clubroot[10]. Using high rate of lime at 20 t/ha and raising soil pH up to 7.2 were effective in suppressing clubroot[5,10]. Carbonates of Na^+, K^+, Ca^{++}, Ba^{++}, $Mg^{++}$and and Al^{+++} raised soil pH from 6.6 to 7.2 and reduced the number of root hair infection by *Plasmodiophora brassicae*, while chloride of these cations did not raise soil pH and did not reduce the number of infected root hair considerably[15]. Our results showed that root hair infection decreased significantly when soil was amended with $CaCl_2$, $AlCl_3$, $MgCl_2.6\ H_2O$ or H_2SiO_3. However, soil pH did not change noticeably (Table 4). Fletcher et al reported[5] that soil amended with $CaSO_4$ (20 t/ha) reduced clubroot incidence, while the soil pH also was reduced from 7.0 to 6.6. Hamilton and Crête[6] reported that the increase in calcium ion concentration and in soil pH decreased the incidence of clubroot. At a low soil pH, calcium ion may be lost easily, resulting in Ca^{++} deficiency in the

soil. Continuous application of ammonium sulfate by Taiwan farmers in the past 30 years tends to decrease soil pH[14]. We suggest that application of mineral ash, calcium carbonate or S-H mixture at 1% will be an effective means in controlling clubroot of short-term cruciferous crops. Studies are underway to determine whether these soil amendments can also be effective in controlling clubroot disease of long-term crops, i.e. Chinese cabbage, mustard and Szechuan mustard.

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LITERATURE CITED

1. Alderson, W. C., R. L. Gabrielson, W. A. Haglund and A. S. Baker. 1976. Clubroot control in crucifers with hydrated lime and PCNB. Plant Dis. Reptr. 60:561-565.
2. Brooks, R. M., M. V. Bradley and T. I. Anderson. 1966. "Plant Microtechnique Manual". 5 th ed. 70pp. Department of Pomology, University of California, Davis, U. S. A.
3. Buczacki, S. T. 1973. Glasshouse evaluation of some systemic fungicides for control of clubroot of Brassicae. Ann. appl. Biol. 74:85-90.
4. Colhoun, J. 1954. Biological techniques for the evaluation of fungicides III. The evolution of a technique for the evaluation of soil fungicides for the control of clubroot disease of Brassicae. Ann. appl. Biol. 41:290-304.
5. Fletcher, J. T., M. J. Him, F. C. Archer and A. Brown. 1982. Effects of adding calcium and sodium salts to field soils on the incidence of clubroot. Ann. appl. Biol. 100:245-251.
6. Hamilton, H. A. and R. Crête. 1978. Influence of soil moisture, soil pH, and liming sources on the incidence of clubroot, the germination and growth of cabbage produced in mineral and organic soil under controlled conditions. Canadian Jour. of Pl. Sci. 58:45-53.
7. Horiuchi, S. 1981. Studies on the clubroot in recent years and the list of refernces on *Plasmodiophora brassica* Wor. 118 pp. Chiugoku Agr. Exp. Sta. (in Japanese)
8. Hsieh, W. H. and C. H. Yang. 1983. Effect of soil amendments on the root hair infection caused by *Plasmodiophora brassicae* Wor. in Green-Petiole Pai-Tsai. Plant Prot. Bull 25:302. (Abstr. in Chinese)
9. Hsieh, W. H. and C. H. Yang. 1984. Investigations on the clubroot and the susceptibility of crucifers in Taiwan. Plant Prot. Bull. 27:3-10.
10. Karling, J. 1968. "The Plasmodiophorales". 2nd ed. 256 pp. Hafner Publishing Company, New York and London.
11. Ko, W. H. and F. K. Hora. 1972. Identification of an Al ion as a soil fungitoxin. Soil Sci. 113:42-45.
12. Kou, K. S. 1983. "Soil Science". 801 pp. Chung-Kou Book Company, Yungho. (in Chinese)
13. Lewis, J. A. 1973. Effect of mineral salts on *Aphanomyces* root rot of pea. Phytopathology 63:989-993.
14. Lin, K. C. and S. Lian. 1960. An experiment on the effect of the continuous application of ammonium

sulfate, ammonium chloride, calcium ammonium nitrate and urea to rice. Agr. Res. 9:32-45. (in Chinese)

15. Samuel, G. and S. D. Garrett. 1954. The infected root-hair count for estimating the activity of *Plasmodiophora brassicae* Woron. in the soil. Ann. appl. Biol. 32:96-101.
16. Sun, S. K. and J. W. Huang. 1983. Effects of soil amendments on Fusarium wilt of watermelon. Plant Prot. Bull. 25:127-137.
17. White, J. G. and S. T. Buczacki. 1977. The control of clubroot by soil sterilization: A review. Ann. appl. Biol. 184:287-300.