

The use of Vapam as a soil fumigant for clubroot [*Plasmodiophora brassicae*] control in canola

K. A. Zuzak¹, S. F. Hwang², G. D. Turnbull², V. Manolii¹ and S. E. Strelkov¹

¹Department of Agricultural, Food and Nutritional Science, 410 Agriculture/ Forestry Centre, University of Alberta, Edmonton, AB T6G 2P5, Canada

²Crop Diversification Centre North, Alberta Agriculture and Rural Development, 17 507 Fort Road N.W., Edmonton, AB T5Y 6H3, Canada.

Key Words: canola, clubroot, *Plasmodiophora brassicae*, soil fumigation

Abstract

Clubroot is an important soilborne disease of canola in Alberta, Canada, which is caused by the obligate parasite *Plasmodiophora brassicae*. In recent year, clubroot has spread throughout central Alberta, with isolated infestations also identified into southern Alberta and Saskatchewan. Soil fumigation could prove to be an effective tool to eradicate localized clubroot infestations and new infection foci. Soil-applied Vapam is a liquid metam sodium solution used to control weeds, nematodes, insects and soil-borne diseases in crops. We analyzed the efficacy of various concentration rates of Vapam for the control of clubroot of canola at two heavily infested field locations in Edmonton, Alberta. A clubroot-susceptible canola cultivar was grown in soil treated with Vapam, with plants subsequently assessed for disease severity, plant weight and height, and gall weight. Preliminary results from one of the field locations suggest that Vapam may effectively reduce clubroot severity at certain concentrations. Next year, the same sites will be sown to the same canola cultivar to assess the residual effects of the Vapam treatments. In addition, new field sites will also be included in order to replicate the initial experiment using the same concentrations of Vapam.

Introduction

Clubroot is a soilborne disease of crucifers caused by *Plasmodiophora brassicae*. *P.brassicae* is an obligate parasite, meaning that it cannot grow and reproduce in the absence of a living host organism. Potential hosts for this parasite include members of the family Brassicaceae, including cultivated crop species such as canola (*Brassica rapa* and *Brassica napus*), mustards, and cruciferous vegetables, as well as weeds such as stinkweed (*Thlaspi arvense*), shepherd's purse (*Capsella bursa-pastoris*), and volunteer plants (Dixon 2009a, Dixon 2009b, Hwang *et al.* 2012).

Soil becomes infested with clubroot when *P.brassicae* resting spores are released from decomposing host root tissue. These resting spores can also be dispersed to uninfected plants through the movement of infested soil and water (Dixon 2009b, Kageyama and Asano 2009), or perhaps even by wind-borne dust (Rennie *et al.* 2012). Clubroot resting spores exhibit extreme longevity, which contributes to the severity of this disease. The half-life of resting spores has been estimated to be 3.6 to 4.4 years, while they can survive in the soil for nearly 20 years (Wallenhammar 1996, Dixon 2009a, Hwang *et al.* 2013).

Plants infected with *P.brassicae* exhibit external symptoms such as a stunted growth habit, premature and uneven ripening, and the characteristic galled roots. There can also be severe yield and quality decreases associated with clubroot infection, while the land value is depressed (Dixon 2009a). In canola, the plant produces fewer seeds with lower oil quality. Clubroot is proving to be a serious concern for farmers as it spreads to new areas. Brassica crops are becoming increasingly important for both dietary and industrial applications, so more hectares are being grown, most of which are sown to varieties that are susceptible to clubroot (Dixon 2009a).

In the Canadian canola crop, clubroot was not reported until 2003, when a dozen infested fields were identified in central Alberta. Previous reports of clubroot in Alberta were restricted to home and market gardens, so this marked the first cases of clubroot in canola (Strelkov *et al.* 2006). More canola being grown requires more equipment use, which is providing a serious challenge to clubroot management. Resting spore movement by soil, water, and wind means that machinery provides an ideal method of transportation from field to field, facilitating spread across borders and into previously uninfested regions (Dixon 2009a). An increase in canola hectareage paired with the continued clubroot spread helps to account for an increase from 12 to 1064 in confirmed clubroot-infested fields in the province of Alberta between its initial discovery in 2003 and 2012. The year 2011 also marked the confirmation of the first cases of clubroot in Saskatchewan (Tewari *et al.* 2005, Strelkov *et al.* 2012, Strelkov *et al.* 2013).

Soil fumigants have traditionally been sought after to control soilborne pests and pathogens in high-value crops, such as vegetables (Papiernik *et al.* 2004). Soil fumigants have several common characteristics that make them particularly effective, including relatively high vapour pressures, low boiling points, and high air-water partitioning coefficients (Papiernik *et al.* 2004). We are particularly interested in the soil fumigant Vapam or metam sodium (“metham sodium” in some literature), which has low adsorption to soil and a comparatively slow diffusion within soil. It also possesses a high rate of decomposition at high soil temperatures, and a relatively greater partition into water from air relative to some other fumigants (Smelt & Leistra 1974). These factors make Vapam a good candidate to assess as a soil fumigant for clubroot control.

Vapam is converted into an array of degradation products in the soil, including methyl isothiocyanate (MITC), carbon disulfide, carbonyl sulfide and hydrogen sulfide (Smelt & Leistra 1974, Saeed *et al.* 2000, Triky-Dotan *et al.* 2010). MITC is water soluble and toxic, with a relatively high vapour pressure (Saeed *et al.* 2000). It is this compound that is thought to have toxic effects on soilborne pests such as fungi, nematodes, weeds, and some soil arthropods (Smelt & Leistra 1974, Triky-Dotan 2010).

This project is focused on assessing and developing new methods to eradicate or effectively control localized clubroot infestations, with the aim of preventing the establishment of *P. brassicae* in regions that are currently free of the pathogen.

Materials and Methods

Mini-plots were established in 2012 at two naturally infested field locations in Edmonton. The plots were 1.4m × 1.4m and arranged in a randomized complete block design. Vapam HL was applied at each of 5 concentrations (10%, 25%, 50%, 100%, and 200% of label rate), with

treatments replicated four times at each of the two locations. Controls consisted of plots watered without the addition of Vapam and were also replicated four times at each of the two locations.

After the soil was treated with the appropriate concentration of Vapam, each mini-plot was covered with a black plastic tarp (approximately 1.2m × 1.2m), the edges of which were trenched in the soil to secure the covering and prevent volatilization. The tarps remained on the mini-plots for 48 to 72 hours and were then removed. After a minimum of two days without the tarps, canola was seeded into the treated soil. Each mini-plot was hand-seeded with four rows of 20 seeds each at a depth of 2cm, with the seeds spaced about 5 cm apart. Row spacing was approximately 25 to 30 cm. Meter sticks were pre-marked in 5cm increments to ensure uniform seed placement.

The plants were grown for approximately 8 weeks after seeding, when they were dug from the soil, washed with water, and rated for clubroot symptom development on a 0 to 3 scale, as per Kuginuki *et al.* (1999). All plants within each mini-plot were assessed for clubroot severity and individual disease ratings were used to calculate an index of disease according to Horiuchi and Hori (1980) as modified by Strelkov *et al.* (2006). Measurements taken on plants also included fresh and dry gall weights, fresh and dry stem weights, stem heights and pod counts per plant.

Results and Discussion

Although the results are from a single field season and still very preliminary, some trends could be discerned among the parameters measured. At one field site, there was a reduction in the index of disease (clubroot severity) as the concentration of soil-applied Vapam was increased, up to the label rate. Past the label rate, the reduction in index of disease was not as pronounced. Increasing concentrations of Vapam had a less pronounced effect on clubroot incidence. Trends were less clear at the second field site where the indices of disease were quite variable across treatments.

These differences in the apparent efficacy of Vapam at the two field sites could reflect differences in seeding date, environmental factors, as well as differences between the field locations themselves. The plots in the first field were sown approximately three weeks prior to those in the second field. Thus, the clubroot cycle would have been initiated earlier in the season and the timing of critical events in disease development would have occurred under different environmental conditions. In addition, differences in the amount and distribution of *P.brassiccae* inoculum in the two fields may have led to differences in the intensity and evenness of disease pressure. In order to evaluate this possibility, the inoculum loads in soil samples collected prior to and after the experiments will be measured by quantitative PCR.

The 2013 growing season will provide an opportunity to examine any potential residual effects of Vapam on clubroot of canola. The same plots will be sown with the same cultivar of canola without a pre-planting application of Vapam to determine if differences in clubroot severity will be distinguishable after one year. To further assess the efficacy of Vapam as a soil fumigant, the 2012 experiment will also be repeated at newly established mini-plots located on different locations within the same naturally infested fields.

The promising preliminary results obtained at one of the field locations in 2012 suggests that Vapam has good potential as a soil fumigant for the control of clubroot of canola. The additional

experiments in 2013 should help to determine the magnitude and consistency of this potential. If the promising preliminary results are confirmed, then Vapam may serve as a useful tool to reduce the severity of localized *P.brassicae* infestations.

Acknowledgement

This study was conducted with funding from the Canola Agronomic Research Program, the Canadian Agricultural Adaptation Program (Agriculture and Food Council) and the Clubroot Risk Mitigation Initiative (AAFC/CCC). This work was also supported by the plant pathology lab at the University of Alberta and the Crop Diversification Centre North.

References

- Dixon, G.R. (2009a). The occurrence and economic impact of *Plasmodiophora brassicae* and clubroot disease. *J. Plant Growth Regul.* 28, 194-202.
- Dixon, G.R. (2009b). *Plasmodiophora brassicae* in its environment. *J. Plant Growth Regul.* 28, 212-228.
- Hwang, S.F., Ahmed, H.U., Zhou, Q., Rashid, A., Strelkov, S.E., Gossen, B.D., Peng, G. and Turnbull, G.D. (2013). Effect of susceptible and resistant canola plants on *Plasmodiophora brassicae* resting spore populations in soil. *Plant Pathol.* 62, 404-412.
- Hwang, S.F., Ahmed, H.U., Zhou, Q., Strelkov, S.E., Gossen, B.D., Peng, G. and Turnbull, G.D. (2012). Assessment of the impact of resistant and susceptible canola on *Plasmodiophora brassicae* inoculum potential. *Plant Pathol.* 61, 945-952.
- Kageyama, K. and Asano, T. (2009). Life cycle of *Plasmodiophora brassicae*. *J. Plant Growth Regul.* 28, 203-211.
- Kuginuki, Y., Hiroaki, Y., and Hirai, M. (1999). Variation in virulence of *Plasmodiophora brassicae* in Japan tested with clubroot-resistant cultivars of Chinese cabbage (*Brassica rapa* L. spp. *Pekinensis*). *Eur. J. Plant Pathol.* 105, 327-332.
- Papiernik, S.K., Yates, S.R., Dungan, R.S., Lesch, S.M., Zheng, W. and Guo, M. (2004). Effect of surface tarp on emissions and distribution of drip-applied fumigants. *Environ. Sci. Technol.* 38, 4254-4262.
- Rennie, D.C., Turkington, T.K., Leboldus, J.M., Howard, R.J., Kutcher, H.R. and Strelkov, S.E. (2012). Dust monitoring for clubroot [*Plasmodiophora brassicae*] in Alberta. *Can. J. Plant Pathol.* 35, 99-132.
- Saeed, I. A. M., Rouse, D. I. and Harkin, J. M. (2000). Methyl isothiocyanate volatilization from fields treated with metam-sodium. *Pest Management Science.* 56, 813-817.
- Smelt, J. H. and Leistra, M. (1974). Conversion of metham-sodium to methyl isothiocyanate and basic data on the behaviour of methyl isothiocyanate in soil. *Pestic. Sci.* 5, 401-407.

Strelkov, S.E., Hwang, S.F, Howard, R.J., Hartman, M. and Turkington, T.K. (2011). Progress towards the Sustainable Management of Clubroot [*Plasmodiophora brassicae*] of Canola on the Canadian Prairies. *Prairie Soils and Crops* 4,114-121. [<http://www.prairiesoilsandcrops.ca>].

Strelkov, S.E., Manolii, V.P., Liu, J., Jurke, C., Rennie, D.C., Orchard, D., Hwang, S.F., and Laflamme, P. (2012). The occurrence of clubroot on canola in Alberta in 2011. *Can. Plant Dis. Surv.* 92, 1-157.

Strelkov, S.E., Manolii, V.P., Rennie, D.C., Manolii, E.V., Fu, H., Strelkov, I.S., S.F. Hwang, Howard, R.J., and Harding, M.W. (2013). The occurrence of clubroot on canola in Alberta in 2012. *Can. Plant Dis. Surv.* 93 (in press).

Strelkov, S.E., Tewari, J.P., and Smith-Degenhardt, E. (2006). Characterization of *Plasmodiophora brassicae* populations from Alberta, Canada. *Can. J. Plant Pathol.* 28, 467-474.

Tewari, J.P., Strelkov, S.E., Orchard, D., Hartman, M., Lange, R.M., and Turkington, T.K. (2005). Identification of clubroot of crucifers on canola (*Brassica napus*) in Alberta. *Can. J. Plant Pathol.*, 27, 143-144.

Triky-Dotan, S., Ofek, M., Austerweil, M., Steiner, B., Minz, D., Katan, J. and Gamliel, A. (2010). Microbial aspects of accelerated degradation of metam sodium in soil. *Phytopathology* 100, 367-375.

Wallenhammar, A.C. (1996). Prevalence of *Plasmodiophora brassicae* in a spring oilseed rape growing area in central Sweden and factors influencing soil infestation levels. *Plant Pathol.* 45, 710-719.