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Management of *Pratylenchus penetrans* and *Verticilllium* symptoms in strawberry
Gestion des symptômes causés par le *Pratylenchus penetrans* et le *Verticilllium* chez la fraise

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Résumé de l'article

Nous avons mesuré, en conditions naturelles, l'effet d'une seule rotation avec du maïs, des cultures crucifères (canola suivi de la moutarde blanche) utilisées comme engrais vert, de l'avoine et du millet perlé fourager sur la densité de *Pratylenchus penetrans* et son impact sur le dommage est les pertes causés par le *Verticillium dahliae* dans une plantation de fraises l'année suivante. Les plus faibles densités de *P. penetrans* ont été enregistrées après le millet perlé fourager et l'engrais vert des crucifères; dans les deux cas, les densités enregistrées se trouvaient sous le seuil d'infestation reconnu pour la fraise, c'est-à-dire 500 *P. penetrans* kg^{-1} sol. L'engrais vert des plantes crucifères et le millet perlé fourager ont réduit l'incidence de la flétrissure verticillienne et augmenté la croissance des plants de fraise. À l'automne, le nombre de couronnes et le nombre de jeunes plants étaient significativement plus élevés après le millet perlé fourager et les plantes crucifères qu'après le maïs. Les symptômes de flétrissure les plus élevés et la plus faible croissance des fraises ont été observés dans les parcelles qui avait précédemment été plantées avec du maïs; ces parcelles abritaient également les populations de *P. penetrans* les plus élevées au printemps. Ces résultats supportent l'interaction positive entre le *P. penetrans* et le *V. dahliae*, laquelle se fait sentir de façon encore plus significative chez les cultivars sensibles comme le 'Jewell'.

Management of *Pratylenchus penetrans* and *Verticilllium* symptoms in strawberry

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Under field conditions, the effect of a single rotation with corn, cruciferous crops (canola followed by white mustard) as green manure, oats, and forage pearl millet was measured on the density of *Pratylenchus penetrans* and its impact on damage and losses caused by *Verticillium dahliae* in a strawberry plantation the following year. The lowest density of *P. penetrans* was recorded following forage pearl millet and green cruciferous manure, and in both cases, it was below the known pest threshold in strawberry of 500 *P. penetrans* kg^{-1} soil. Both green manure of cruciferous plants and forage pearl millet reduced the incidence of Verticillium wilt and increased the growth of strawberry plants. In the fall, the number of crowns and the number of daughter plants were significantly higher following forage pearl millet or cruciferous plants than corn. The highest wilt symptoms and the lowest strawberry growth were observed in plots previously planted with corn, which also harboured the highest spring populations of *P. penetrans*. Those results support a positive interaction between *P. penetrans* and *V. dahliae*, even more importantly so on susceptible cultivard such as 'Jewell'.

Keywords: Field conditions, *Pratylenchus penetrans*, *Verticillium dahliae*, strawberry

[Gestion des symptômes causés par le *Pratylenchus penetrans* et le *Verticilllium* chez la fraise]

Nous avons mesuré, en conditions naturelles, l'effet d'une seule rotation avec du maïs, des cultures crucifères (canola suivi de la moutarde blanche) utilisées comme engrais vert, de l'avoine et du millet perlé fourager sur la densité de *Pratylenchus penetrans* et son impact sur le dommage est les pertes causés par le *Verticillium dahliae* dans une plantation de fraises l'année suivante. Les plus faibles densités de *P. penetrans* ont été enregistrées après le millet perlé fourager et l'engrais vert des crucifères; dans les deux cas, les densités enregistrées se trouvaient sous le seuil d'infestation reconnu pour la fraise, c'est-à-dire 500 *P. penetrans* kg^{-1} sol. L'engrais vert des plantes crucifères et le millet perlé fourager ont réduit l'incidence de la flétrissure verticillienne et augmenté la croissance des plants de fraise. À l'automne, le nombre de couronnes et le nombre de jeunes plants étaient significativement plus élevés après le millet perlé fourager et les plantes crucifères qu'après le maïs. Les symptômes de flétrissure les plus élevés et la plus faible croissance des fraises ont été observés dans les parcelles qui avait précédemment été plantées avec du maïs; ces parcelles abritaient également les populations de *P. penetrans* les plus élevées au printemps. Ces résultats supportent l'interaction positive entre le *P. penetrans* et le *V. dahliae*, laquelle se fait sentir de façon encore plus significative chez les cultivars sensibles comme le 'Jewell'.

Mots-clés : Conditions naturelles, fraise, *Pratylenchus penetrans*, *Verticillium dahliae*

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In Quebec, the root lesion nematode, *Pratylenchus penetrans* (Cobb) Filipjev and Schuurmans-Stekoven, is a common and dominant species in small fruit crops, including strawberry (*Fragaria* spp.) (Bélair and Khanizadeh 1994). The pathogenicity of *P. penetrans* on strawberry plants has been demonstrated under both controlled and field conditions (Morgan 1964; Townshend 1963; Townshend *et al.* 1966). The root lesion nematode has been shown to increase the symptoms and damage caused by Verticillium wilt (*Verticillium dahliae* Kleb.) (McKinley and Talboys 1979). This is even more drastic on cv. Jewell (*F. ananassa* Duch.), which is highly susceptible to Verticillium wilt (Maas *et al.* 1989). The withdrawal of numerous soil fumigants from the market, including dichloropropene, and the raising environmental awareness of growers generated the need for alternative management strategies for *P. penetrans* and Verticillium wilt in strawberry production. The purpose of this study was to monitor the impact of crop rotation on the management of root lesion density and its incidence on Verticillium wilt in a strawberry plantation.

The field experiment was conducted at the MP Vaillancourt Farm on Île d'Orléans, Quebec. The soil was sandy loam with a coarse texture (44% sand, 33% silt, 23% clay). In 2005, the following crop treatments were performed: corn (*Zea* spp.), canola (*Brassica napus* L.) cv. Hyola followed by white mustard (*Sinapsis alba* L.) cv. Caliente, oats (*Avena* spp.) (positive control), and forage pearl millet (*Pennisetum glaucum* L.) hyb. CFPM 101. On May 15, 2005 oats, canola and white mustard were seeded at a rate of 100, 6, and 15 kg ha^{-1}, respectively. Forage millet was sown on June 15, 2005 at a rate of 10 kg ha^{-1}. Each plot was 5.2 m wide and 20 m long. The experimental design was a complete randomized block with six replicates. The cruciferous plots were plowed up as follows: canola (late flowering stage, early silica formation) at the end of July and white mustard during the first week of October. In spring 2006, all plots were rototilled and 1.5-m plant beds were made in the middle of each plot. Strawberry plants cv. Jewel were transplanted in double rows (30-cm rows, 40 cm between the rows) in early May 2006. A 1.5-m band of oats between the blocks and plots was planted and mowed as necessary between the plots to ensure vegetation cover on the ground. Total mineral fertilization was carried out according to the reference grids of the different crops in the *Fertilization Reference Guide* (CRAAQ 2003). Weeds were mechanically and manually controlled. Soil samples for nematode counts were taken on June 15 and September 15, 2006. Verticillium wilt symptoms were assessed on August 28, 2006 using the following index: Verticillium wilt (1 = dead plant, 5 = normal). Canopy/strawberry growth was monitored by counting the total number of crowns and daughter plants per 3-m row on October 11, 2006.

On June 15, 2006, nematode populations (*P. penetrans*) were significantly higher in plots grown in corn or oats the previous year (ANOVA: $p = 0.05$) (Table 1). The lowest nematode density was found in previous forage pearl millet and cruciferous crops. Nematode density recorded for both sampling dates generally was below 500 *P. penetrans* kg^{-1} soil, which is the known pest threshold for strawberry (Tremblay and Baker 1990). Nematodes had an impact on Verticillium disease symptom expression and plant stunting. Green manure of cruciferous plants and forage pearl millet reduced the incidence of Verticillium wilt and increased the growth of strawberry plants (Table 1). In October, the number of crowns and daughter plants was significantly higher following forage pearl millet or cruciferous than corn. The highest wilt symptoms and the lowest strawberry growth were observed in previous corn plots, which also harboured the highest spring populations of *P. penetrans*. These results support a positive interaction between *P. penetrans* and *V. dahliae*, and more importantly on susceptible cultivars such as Jewell (McKinley and Talboys 1979). It also supports the idea that the management of *P. penetrans* density will have an impact on Verticillium wilt symptoms and damage. Sakuma *et al.* (2011) concluded that *B. juncea* L. as green manure could decrease damage caused by the root lesion nematode to subsequent crops although it had no effect on population, thus suggesting it could be used to improve soil conditions rather than be used as a control method. In two subsequent field trials in the same strawberry production area, the same *Brassica* green manure treatments failed to reduce *P. penetrans* density and had no significant impact on Verticillium wilt symptoms (G. Bélair, unpublished

Table 1. Effect of cropping on *P. penetrans* density, Verticillium wilt symptoms and canopy growth of strawberry cv. Jewel in 2006.

Crop treatment (2005)	*Pratylenchus penetrans*		Wilt[a]	Canopy
	15 June (kg^{-1} soil)	15 September (kg^{-1} soil)	28 August (1-5)	1 October (3-m row)
Oats*	328 ab	292 a	3.5[ns]	21.3 ab
Canola + White mustard	106 b	37 b	3.9	30.0 a
Corn	524 a	169 ab	3.0	12.7 b
Pearl millet	72 b	58 b	4.0	37.8 a

* Values within the same column followed by the same letter are not significantly different (ANOVA: $p \leq 0.05$; Tukey's test: a) Wilt = Verticillium wilt index (1 = dead plant, 5 = normal); b) Canopy = total number of daughter plants and crowns per 3-m row); ns: values not significantly different (ANOVA: $p > 0.05$).

data). Because *Brassica* crops are also very good hosts for *P. penetrans*, this nematode multiplies on their root system before the plants are chopped and plowed under (Bélair *et al.* 2012). In Quebec, this procedure is performed from mid- to late July for the first crop, and from mid- to late October for the second crop. Further field trials are needed to confirm the efficacy of *Brassica* green manure for controlling Verticillium wilt and for improving growth in strawberry plants. Previously, forage pearl millet cv. CFPM 101 was shown to decrease *P. penetrans* density and increase potato yield in Quebec (Bélair *et al.* 2005). Thus, the results from the current trial would support the cropping of forage pearl millet as an alternative management strategy to control *P. penetrans* in the strawberry production system. Also, it is suggested to avoid corn as a rotation crop in strawberry fields with a history of Verticillium wilt problems. With the highest count of *P. penetrans* at strawberry planting, this crop generated the highest wilt symptoms and the lowest strawberry growth, even lower than oats, our standard positive host.

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