
Microbial Biomass and Diversity in Roundup-Ready Corn Rhizosphere

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Abstract

The effects of Roundup-Ready (RR) corn, grown in monoculture or in rotation with canola, on microbial biomass and diversity in corn rhizosphere were investigated at Lethbridge from 2002 to 2004. In monoculture, weeds in RR corn or conventional corn were controlled by applying either Roundup or other herbicides. In rotations, RR corn rotated with RR canola or Liberty-Link (LL) canola was compared with conventional corn rotated with conventional canola. Microbiological properties in corn rhizosphere were measured at tasseling stage. In monoculture, RR corn affected microbial biomass only in 2003, when application of Roundup increased microbial biomass in RR corn rhizosphere, but not in conventional corn rhizosphere. The diversity of bacteria in RR corn rhizosphere was greater than that in conventional corn rhizosphere, regardless of Roundup application, only in 2002. RR corn in rotation did not affect microbial biomass or bacterial diversity. Therefore, RR corn affected microbial biomass or diversity in only one of three years when it was grown in monoculture, but there were no effects when corn was grown in rotation with canola. When effects were significant, the rhizosphere of RR corn had greater microbial biomass or diversity than that of conventional corn.

Introduction

Genetically-modified (transgenic) crops have been in commercial use in Canada since 1995, when herbicide-resistant canola was introduced (Beckie et al. 2006). Use of herbicide-resistant crops has encouraged adoption of reduced tillage practices, which reduce soil degradation (Ammann 2005; Cerdeira and Duke 2006). However, growing these crops can have non-target effects on other flora and fauna. These crops can affect soil microorganisms due to differences in the amount and composition of root exudates (Saxena et al. 2002), gene transfer from the transgenic crop (de Vries et al. 2004), and effects of management practices for transgenic crops, e.g., pesticide applications (Sessitsch et al. 2004), tillage, and fertilizer application (Motavalli et al. 2004). These crops can also affect soil microorganisms due to differences in the amounts and composition of decomposing crop residues (Saxena and Stotsky 2001; Hopkins and Gregorich 2005). The objective of this study was to evaluate the effects of growing Roundup-Ready (RR) corn on soil microbial biomass and diversity in the rhizosphere of corn.

Methodology

From 2000, RR corn and conventional corn were grown in monoculture with or without their respective pesticides at Agriculture and Agri-Food Canada Research Centre, Lethbridge, AB. RR corn was also grown in rotation with RR canola and LL canola, and equivalent rotations consisting of conventional crops were included as controls. The following list contains the treatments, which were replicated four times:-

1. RR corn in monoculture [Roundup (glyphosate) applied].
2. RR corn in monoculture (no Roundup).
3. Conventional corn (herbicides applied - atrazine, bromoxynil, nicosulfuron, EPTC or MCPA as required).
4. Conventional corn (no herbicides).
5. RR canola – RR corn – RR canola – Bt corn (transgenic cultivars in rotation).
6. Canola – corn – canola – corn (conventional cultivars in rotation).

At tasseling growth stage of corn from 2002 to 2004, rhizosphere soil was sampled by excavating plants from 0.5 m row length at four different locations in a plot, shaking off loose soil, and carefully collecting (by brushing) soil adhering to plant roots. The soil was sieved through a 2 mm sieve and stored at 4° C until required for analysis.

Soil MBC was measured using the substrate-induced respiration (SIR) method (Horwath and Paul 1994). Functional bacterial diversity was evaluated by the Biolog™ method (Zak et al. 1994), which tests the ability of a microbial community to utilize different C substrates contained in a microplate. On the basis of the patterns of utilization of the substrates by the bacteria from each soil, Shannon index (H') of functional diversity was calculated as follows (Magurran 1988; Zak et al. 1994), using PC-ORD software (McCune and Mefford 1997):-

$$H' = -\sum p_i (\ln p_i)$$

where p_i = Ratio of activity (i.e., optical density reading) on the i th substrate to the sum of activities on all substrates.

Data from Treatments 1 to 4 were analysed as a 2 x 2 factorial, i.e., two RR traits (RR vs. conventional corn) and two Roundup applications (Roundup vs. not Roundup). Data from rotation treatments (Trt 5, RR corn vs. Trt 6, conventional corn) were analysed separately.

Results

Microbial biomass C

In monoculture, RR corn affected microbial biomass C only in 2003 (Table 1), when application of Roundup increased microbial biomass in RR corn rhizosphere, but not in conventional corn rhizosphere (Fig. 1). In rotation, RR corn did not affect microbial biomass C in any year (Table 1).

Table 1. Summary of Effects of Roundup-Ready (RR) Corn on Microbial Biomass C in Corn Rhizosphere. Corn was Grown either in Monoculture or in Rotation with Canola.

Treatment	P > F		
	2002	2003	2004
<i>Monoculture</i>			
RR trait	0.263	0.057	0.567
Roundup	0.331	0.348	0.155
Interaction	0.365	0.039* (Fig. 1)	0.593
<i>Rotation</i>			
	0.261	0.802	0.221

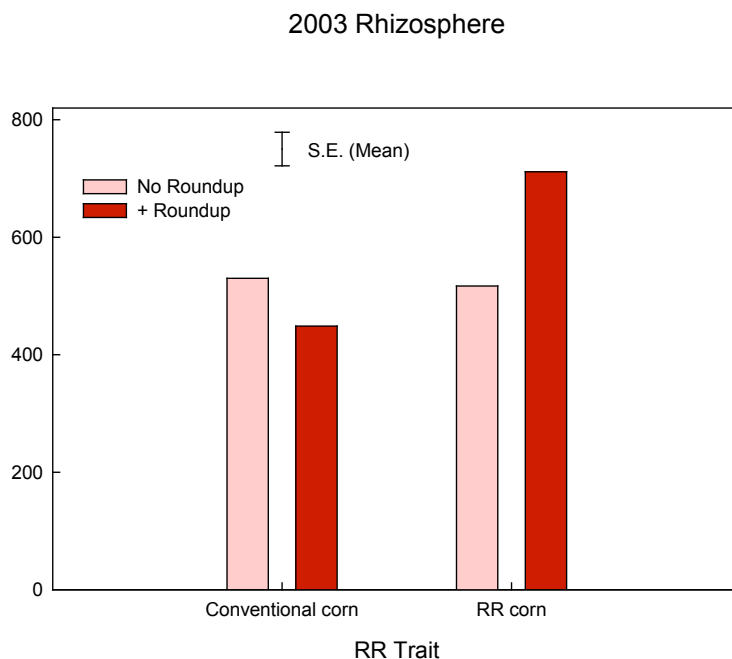


Figure 1. Microbial biomass C in the rhizosphere of RR corn and conventional corn grown in monoculture in 2003. RR = Roundup Ready, S.E. = standard error. Weeds in conventional corn “+ Roundup” treatment were controlled with atrazine, bromoxynil, nicosulfuron, EPTC or MCPA as required.

Functional diversity

The diversity of bacteria in RR corn rhizosphere was greater than that in conventional corn rhizosphere, regardless of Roundup application, only in 2002 (Table 2 and Fig. 2). In rotation, RR corn did not affect microbial biomass or bacterial diversity in any year (Table 2).

Table 2. Summary of Effects of Roundup-Ready (RR) Corn on the Functional Diversity of Bacteria in Corn Rhizosphere. Corn was Grown either in Monoculture or in Rotation with Canola.

Treatment	P > F		
	2002	2003	2004
<i>Monoculture</i>			
RR trait	0.013* (Fig. 2)	0.737	0.371
Roundup	0.482	0.487	0.493
Interaction	0.401	0.846	0.801
<i>Rotation</i>			
	0.843	0.074	0.953

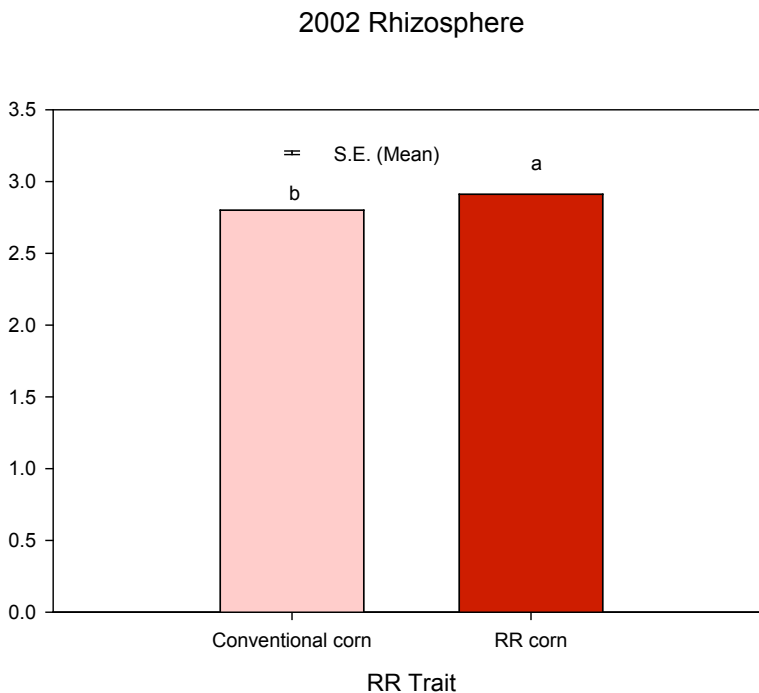


Figure 2. Functional diversity of bacteria in the rhizosphere of RR corn and conventional corn grown in monoculture in 2002. RR = Roundup Ready, S.E. = standard error.

Discussion

In the few cases that the Roundup-resistant trait or herbicide affected soil microorganisms in the rhizosphere of corn grown in monoculture, it increased microbial biomass or diversity. Haney et al. (2000) and Ratcliffe et al. (2006) also observed that Roundup applied at higher-than-recommended rates increased microbial biomass or activity. This increase may be due to soil microorganisms metabolizing (a) the carbon (and N and P) contained in Roundup, or (b) the carbon from decomposing weeds killed by the herbicide. In most other studies, Roundup applied at recommended rates has been observed to have no significant effects on soil microbial biomass

(Olson and Lindwall 1991; Haney et al. 2000; Lupwayi et al. 2004). In a Roundup-resistant corn-soybean cropping system, Liphadzi et al. (2005) also found no Roundup-related differences in soil microbial biomass. Shifts in bacterial community structure in the rhizosphere of herbicide-resistant canola varieties have been reported (Siciliano et al. 1998; Siciliano and Germida 1999; Dunfield and Germida 2001, 2003), but the changes did not persist into the following growing season (Dunfield and Germida, 2003).

There were no significant effects when corn was grown in rotation with canola, probably due to the reduced frequency of RR corn in rotation compared with corn in monoculture. The results reported here are from corn rhizosphere and may be different than effects in bulk soil.

Conclusions

RR corn affected microbial biomass C or diversity in only one of three years when it was grown in monoculture, but there were no effects when corn was grown in rotation with canola. When effects were significant, the rhizosphere of RR corn had greater microbial biomass or diversity than that of conventional corn.

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