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Original article

Dissipation and persistence of major herbicides applied in transgenic and non-transgenic canola production in Quebec

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ABSTRACT

After soybeans, canola is the second most important oilseed crop in Canada, with more than 99% of the canola cultivation consisting of herbicide resistant (HR) varieties. The expansion in HR canola cultivation has led to the increasing use of the same herbicides for weed control which has resulted in a growing concern about their impact on the environment. The present study was conducted to investigate the dissipation and transport of the herbicides, glyphosate and glufosinate, in soil used for the transgenic production of canola and a comparison was made with the herbicide, trifluralin, used in non-transgenic canola. Commercially grown HR transgenic canola varieties and a conventional canola variety were planted in a randomized complete block design. The plots planted with Roundup Ready and Liberty Link cultivars were treated with glyphosate and glufosinate, respectively, at the 2–3 leaf stage and at the rosette stage in each replication. On conventional canola plots, trifluralin was incorporated into soil a day before planting. Soil samples were collected from two depths, 0–0.15 m and 0.15–0.30 m, at different time intervals (1, 7 and 20 days) after the application of the herbicide. Analysis of the soil samples was done by HPLC (high performance liquid chromatography) to determine the residual amounts of herbicide in the soil. Glufosinate was found to be the least persistent herbicide, while trifluralin persisted the longest. The overall order of persistence was Trifluralin > Glyphosate > Glufosinate. Trifluralin was found at lower depths (0.15–0.30 cm) at 7 and 20 days after the herbicide application, with higher residual concentrations than the other herbicides used in the HR canola.

1. Introduction

Canola (*Brassica napus* L.) is one of the most important crops in Canada. Globally, after soybeans (*Glycine max* (L.) Mill), it ranks second for its oilseed production [30]. The production of herbicide-resistant (HR) canola is expanding in Canada because of its higher yield, net profits and superior weed management [17]. Roundup Ready (RR), resistant to the herbicide glyphosate, and Liberty Link (LL), resistant to herbicide glufosinate, are two trade names for HR canola, which are used in large quantities for cultivation in Canada [5]. Of the total amount of pesticides (4.17 Gg yr^{-1}, as an active ingredient) presently sold in Quebec, 59.6% are herbicides, 16.9% fungicides and 12.5% insecticides [15]. Extensive use of herbicides has resulted in a decline in price, which leads farmers to apply an overdose of herbicides for weed control [29]. However, some herbicides, such as glyphosate, possess a high adsorption coefficient [7,11,35]. As a result, glyphosate stays in the upper soil-surface due to its high adsorption [18] and this can pose a threat to surface water-bodies through surface-runoff [2]. During a 2 year experiment on the transport of glyphosate and glufosinate [23], observed that these herbicides may cause surface water pollution. The field dissipation half-life of trifluralin was 55.3 days in plots growing oilseed rape [34], and [27] found trifluralin in deeper soil layers. Some laboratory experiments showed that the glyphosate compound could be mobile in certain soils [6,28]. Although these herbicides have been extensively studied in laboratory conditions, only limited information on their fate and transport is available from field studies. Thus, the aim of the present work was to evaluate the environmental dissipation and transport of herbicides used in the cultivation of herbicide-resistant canola. Also the dissipation rate of trifluralin in non-transgenic canola was studied for comparison.

Abbreviations: a.i., active ingredient; RR, roundup-ready; LL, liberty-link; LC, liquid chromatography.

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2. Materials and methods

2.1. Canola lines and herbicide applications

Field trials were conducted in 2010 at the Emile A. Lods Agronomy Research Centre, McGill University, Ste. – Anne-de-Bellevue, QC. Two Roundup Ready (45H28, 45H29) and two Liberty Link (5030, 5040) canola varieties, along with Avalanche, the conventional canola variety, were planted in a randomized complete block design (RCBD). An equal number of plots *i.e.*, 2 (6 m × 2 m) were assigned for the application of the pesticide at the 2-3 leaf stage or at the rosette stage in each replication. Plots with RR and LL cultivars were sprayed with glyphosate [Roundup Transorb®, Monsanto Canada, 1.25 L ha^{-1} (450 g active ingredient (a.i.) ha^{-1})] and glufosinate ammonium [Liberty 200 SN, Bayer crop Science Canada, 2 L ha^{-1} (400 g (a.i). ha^{-1})], respectively. The conventional canola variety, Avalanche, was treated with trifluralin [Rival EC, Nufarm Agriculture Inc., Canada, 1.6 L ha^{-1} (800 g (a.i.) ha^{-1})] (Fig. 1). Glyphosate and glufosinate herbicides were sprayed as post-emergent herbicides using a tractor sprayer, whereas trifluralin was applied, as a pre-plant herbicide, a day before sowing the canola. The trifluralin was spread as a water emulsion using a spray boom in front of the tractor, it was incorporated at a depth of 50–60 mm by pulling a disk harrow with the same tractor to prevent its rapid volatilization [16].

2.2. Soil sampling for herbicide residue analysis

Soil samples were collected from two depths (0–0.15 m and 0.15–0.30 m). Sampling was done with two augers, one for each soil depth; these were thoroughly cleaned by dipping in a 70% bleach solution and between each sampling activity, then dried with brown paper. Samples (150–200 g) were collected from two different points within each plot and then mixed together in a bag to get a representative sample at each depth. Soil samples from each plot were placed in Ziploc™ bags which were sealed and taken to the laboratory where they were stored at −20 °C until analysis. Soil samples were collected on the day prior to the herbicide application (0 day), and at days 1, 7 and 20, thereafter (Table 1). Physical and chemical properties are depicted in Table 2.

Adsorption of glyphosate was evaluated by carrying out a batch sorption study. Only glyphosate was considered for this study due to the concern raised by [18] that glyphosate mostly stays in the top 2 mm of the soil profile. Hence this concern becomes important for our study because glyphosate can be more prone to surface runoff. The adsorption isotherm was appraised by using Freundlich's adsorption equation as described by [22]:

$$S = K_f \times C_f^n$$

Where S is the amount of pesticide adsorbed in mg Kg^{-1} of the adsorbent; C is the equilibrium solution concentration (mg L^{-1}); K_f is the adsorption coefficient and n_f is the Freundlich exponent.

Table 1
Soil sampling days for the field location.

Herbicide	Sampling time		Time after application (days)
	2-3 Leaf stage	Rosette stage	
Glyphosate	21-Jun-11	08-Jul-11	1
	27-Jun-11	15-Jul-11	7
	10-Jul-11	28-Jul-11	20
Glufosinate	21-Jun-11	08-Jul-11	1
	27-Jun-11	15-Jul-11	7
	10-Jul-11	28-Jul-11	20
#Trifluralin	Pre-incorporated (Sampling-Days)		Time after Application (days)
	01-Jun-11		1
	07-Jun-11		7
	20-Jun-11		20

#Trifluralin, a soil-incorporated pre-emergence herbicide, was not applied at 2-3 leaf stage or rosette stage Note: For all the three herbicides, soil samples at 0 day were taken on 31-May-11.

2.3. Reagents

Glyphosate and glufosinate analytical standards (99% purity) were purchased from Sigma Aldrich (St. Louis, MO), whereas the trifluralin analytical standard (99.9% purity) was purchased from Supelco (Bellefonte, PA). These were used for the preparation of stock solutions to run calibration curves for each herbicide. The physico-chemical characteristics of these herbicides are presented in Table 3. A Microsorb-MV 100-5 Amino 250 × 4.6 mm column was purchased from Agilent Technologies (Santa Clara, CA) and a Nova Pak C18, 300 × 3.9 mm column from Waters (Milford, MA). All solvents and other chemicals used in this study were HPLC-grade. The water used during the solution preparation and the analysis was obtained from a Milli-Q (Billerica, MA) system (resistivity > 18 MΩ cm).

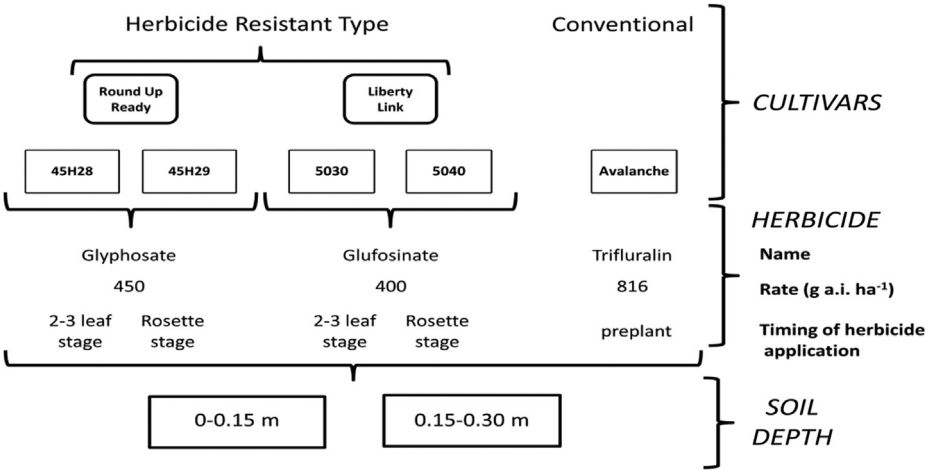

Fig. 1. Treatment assignments and sampling procedure for the field site.