Available online at www.sciencedirect.com
ScienceDirect
Soil & Tillage Research 90 (2006) 39–49
Soil & Tillage Research
www.elsevier.com/locate/still

Soil profile distributions of water and solutes following frequent high water inputs

W.M. Bandaranayake [a], M.A. Arshad [b,*]

[a] University of Florida, CREC IFAS, 700 Experimental Station Road, Lake Alfred, FL 33850, USA
[b] Department of Renewable Resources, University of Alberta, 751 General Services Building, Edmonton, Alta., Canada T6G 2H1

Received 17 September 2004; received in revised form 6 July 2005; accepted 2 August 2005

Abstract

Investigation of factors affecting leaching patterns under tilled and no-till soils are important for successful modelling of solute leaching. There can be various other factors that may offset an anticipated tillage effect on solute leaching. A study was conducted in a Donnelly silty loam (fine-loamy, mixed frigid Typic Cryoboralf) at Dawson Creek, British Columbia, Canada, to investigate how a reactive chemical (FD&C blue#1 dye) and a conservative tracer (bromide, Br^-) would leach in a no-till (NT) soil compared to a tilled (T), when high volume of water are provided discretely, at short time intervals. Three plots of 1.5 m × 1.5 m were prepared in each NT and T soil for flood irrigation. The chemicals were applied by spray using a knapsack sprayer. Soil cores were extracted from a maximum depth of 1.25 m using a truck mounted hydraulic soil sampler at 5, 19, and 55 days (S1, S2, and S3, respectively) after irrigating different amounts of water. These soil cores, sub-sampled at different depths, were analysed for water content, Br^- and dye concentrations. The analyses indicated that Br^- and dye moved in distinctive patterns in the two tillage systems. After irrigating with a total of 240 mm of ponded water in three applications over a period of 10 days, the centre of mass of the travel depth profiles for Br^- was 0.15 m in the NT and 0.26 m in the T plots; for the dye, 0.27 m in the NT and 0.17 m in the T plots. At soil core sampling times S1, S2, and S3, the average mass recovered for Br^- was 82%, 39%, and 27% in the NT and 78%, 50%, and 45% in the T plots. For the dye, mass recovery rates of 78%, 58%, and 22% were observed in the NT and 92%, 79% and 25% in the T plots. The increasing mass loss of Br^- observed with increasing net water inputs in the two tillage systems was more likely due to a lateral loss with water than due to a leaching below sampling depth. The increasing mass loss of dye over time in the two tillage systems was more likely due to a high rate of degradation than to a loss through a lateral or vertical flow.

Keywords: Canada; Cryosols; Bromide; Tracer dye; Canola; Solute transport; Tillage systems; Water quality; Agricultural chemicals

1. Introduction

In the northern region of Alberta and British Columbia (Peace River Region), a considerable extent

* Corresponding author. Tel.: +1 780 492 6921; fax: +1 780 492 4323.
E-mail address: charlie.arshad@ualberta.ca (M.A. Arshad).

0167-1987/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.still.2005.08.003

of land is under no-till (NT) cultivation, which is likely to increase more over the years due to the rising popularity of NT among farmers. Cropping systems in this area depend entirely on rainfall for water. As is the nature of rain-fed agriculture, the erratic rainfall patterns have often created problems for growing crops in this region. During five consecutive years (1989–1994), the rainfall was favourable during only 2 years. During the other 3 years, crops were adversely affected due to heavy or inadequate rains. The seasonal rainfall (May through August) during this 5-year period was 186 mm in the driest season and 403 mm in the wettest season. The 30-year average rainfall for the same period was 238 mm.

Contamination of groundwater with non-point source agrichemicals occurs mainly through preferential flow paths. Scientists have observed enhanced preferential flow under NT systems (Edwards et al., 1989; Isensee et al., 1990; Andreini and Steenhuis, 1990). The continuity of micro/macro-pores (Beven and Germann, 1982) from the soil surface in the NT, coupled with high intensity prolonged rainfall, can increase preferential flow in such soils (Isensee et al., 1990). In contrast, high amounts of crop residue and organic matter close to the soil surface in NT may reduce leaching potential of chemicals by a combination of factors such as interception, adsorption and biodegradation in the biologically active zone of the soil (Sauer and Daniel, 1987; Isensee and Sadeghi, 1993; Felsot et al., 1990; Seta et al., 1993).

The Br anion, though observed to have some anionic repulsion, has been used successfully as a tracer of water (Bowman and Rice, 1984; Butters et al., 1989; Starr and Glotfelty, 1990) and NO_3^- movement. Dyes have been used to stain macro-pore paths (Bouma et al., 1977, 1979; Omoti and Wild, 1979; Parlange et al., 1988), or as a substitute for certain pesticides (Andreini and Steenhuis, 1990), or as a tracer in pesticide transport studies (Bandaranayake, 1994). For example, when tested with an Ulm clay loam soil, the blue dye (number 1 food dye) produced a distribution coefficient (K_d) of 2.52 l kg^{-1} and a half life of 24 days (Bandaranayake, 1994).

The temporary flooding of a field soon after a heavy rain may closely resemble the standing water conditions of a field after being flood irrigated rather than being sprinkler irrigated (overhead supply). In modelling solute leaching, the method of water supply may be a crucial factor in chemical leaching in either tillage system. The objective of this study was to investigate the differences in soil profile distribution of water, Br^-, and a dye in the tilled and the no-till systems after flooding with different amounts of water at short time intervals.

2. Materials and methods

2.1. Plot preparation and chemical application

This study was conducted at Dawson Creek, BC, Canada, during the summer of 1994. The soil at this site was classified as a fine-loamy mixed frigid Typic Cryoboralf (Donnelly silty loam). The soil contained an average of 450 g silt, 220 g clay and 25 g organic C kg^{-1} soil in the 0 to 225 mm depth and 360 g silt, 305 g clay and 10 g organic C kg^{-1} soil in the 225–300 mm depth. It had a compact horizon at 100–150 mm depth with a bulk density of 1.37 Mg m^{-3} and was poorly drained. The soil had a pH of 5.5 (in 0.01 M $CaCl_2$).

The movement of Br^- and dye was studied using 1.5 m × 1.5 m plots (WXYZ in Fig. 1) replicated three times in NT and T soils. The no-till area had been under NT for a period of 16 consecutive years. Plots were prepared into basins for flood irrigation using 2.5-cm thick by 30-cm wide wooden frames, partially buried (to about 10 cm) to secure them firmly in the ground. Imported soil was mounded along the outside of the frame to prevent water from leaking underneath the boards. The 3-week-old (one inch tall) canola (*Brassica campestris* L.) plants within the study plots were clipped at ground level using scissors before applying chemicals. The background Br^- and the initial soil moisture content (ISM) were determined using soil cores, extracted from outside the plot areas in the T and NT soils. Potassium bromide (KBr) and FD&C blue dye#1 [disodium salt of ethyl[4-[*p*[ethyl(m-sulfobenzyl)amino]-*a*-(sulfophenyl) benzylidene]-2,5-cyclohexadien-1-ylidene](m-sulfobenzyl) ammonium hydroxide inner salt] (Warner Jenkins & Company[1]) were spray applied on 2 July 1994, at

[1] Trade names are used in this publication to provide specific information. Mention of a trade name does not constitute a guarantee or warranty of the product or equipment nor an endorsement over other similar products.