Available online at www.sciencedirect.com

SCIENCE DIRECT®

Soil & Tillage Research 85 (2006) 94–106

Soil & Tillage Research

www.elsevier.com/locate/still

Effect of reduced tillage on weeds and soil organisms in winter wheat and summer maize cropping on Humic Andosols in Central Japan

T. Nakamoto *, J. Yamagishi, F. Miura

Laboratory of Plant Science for Sustainable Agriculture, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo 113-8657, Japan

Received 10 March 2004; received in revised form 22 December 2004; accepted 22 December 2004

Abstract

Although reduced tillage (RT) may preserve soil biota and improve the productivity and sustainability of arable lands in temperate regions, the extension of RT is limited by difficulties in controlling weeds. We studied the effect of RT without herbicide application on weed communities and soil biota in a 1-year 2-crop rotation system with winter wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) on Andosols in Japan. RT of the surface 3 cm and conventional moldboard plowing (CT) were conducted before seeding twice per year. For the first 3 years, from autumn 1997 to spring 2000, one field was managed with RT and another with CT. For the second 3 years, from autumn 2000 to spring 2003, RT and CT were conducted in two replicated plots in each field. Weed communities and soil biota were studied in the last 2 years. Dominant weed species in winter wheat cropping were Italian ryegrass (*Lolium multiflorum* Lam.) in 2002 and common vetch (*Vicia angustifolia* L.) in 2003, and their biomass was high where RT or CT was continuously conducted. Switching of tillage methods, from RT to CT or vice versa, reduced the biomass of winter weeds. In summer maize cropping, several annual and perennial weed species tended to increase under RT in the second 3 years. However, redroot pigweed (*Amaranthus retroflexus* L.), the most dominant weed in 2002 and 2003, responded to tillage inconsistently and its biomass was not always increased by RT. Species diversity of winter weeds was decreased by CT conducted in the first 3 years, and that of summer weeds was decreased by CT conducted in the second 3 years. The seedbank in the 0–10-cm soil layer under recent RT was large (7200–16 300 seeds m^{-2}) compared with that under CT (2900–7300 seeds m^{-2}). The microbial substrate-induced respiration (SIR) and the population densities of nematodes and mites were higher under RT in the second 3 years and were not affected by previous tillage practices. Both were highly correlated with soil total nitrogen. The positive effect of RT on these soil organisms was primarily attributable to the accumulation of organic matter in soil, but not to plant cover as a result of incomplete weed control by RT. Occasional adoption of RT in current CT systems may be effective at enriching soil organisms with little risk of weed infestation.

Keywords: Andosols; Reduced tillage; Soil biota; Weed ecology

* Corresponding author. Tel.: +81 3 5841 7505; fax: +81 3 5841 8041.
E-mail address: atomo@mail.ecc.u-tokyo.ac.jp (T. Nakamoto).

0167-1987/$ – see front matter
doi:10.1016/j.still.2004.12.004

1. Introduction

A disadvantage of reduced tillage (RT) is the difficulty in controlling weeds. Unless weed control strategies, such as residue management, cover cropping, and crop rotation, are successfully incorporated in RT systems, herbicide application may be the only practical way to eliminate weeds from the field. Therefore, the use of herbicides is likely to be greater under RT, in particular under a no-tillage system, than under conventional tillage (CT). A better understanding of weed ecology under RT systems is essential to promoting weed control strategies that could reduce herbicide application to a level not exceeding that under CT and thereby reduce environmental problems.

Density of weed populations may increase under RT (Cardina et al., 1991; Spandl et al., 1999) because weed seeds tend to accumulate in the topsoil layer under conditions that favor germination by some species (Buhler, 1995). The composition of weed communities is also affected by tillage. It is generally recognized that perennial weeds increase in RT systems because vegetative propagules, such as rhizomes and stolons, are less disturbed than in CT systems. RT often favors annual grasses and discourages annual dicotyledonous species (Froud-Williams et al., 1981; Gill and Arshad, 1995). However, generalizations are limited, because the effect of tillage on annual weeds is species-specific (Buhler, 1992), and the same species may respond differently when soil properties and other site characteristics vary. A study conducted in Saskatchewan, Canada, showed that changes in weed communities were more influenced by location and year than by tillage systems (Derksen et al., 1993). Due to difficulties in distinguishing fluctuational and successional changes in weed species composition (Swanton et al., 1993), little is known about the mechanisms that determine changes. On the other hand, changes in weed community composition due to tillage systems have been assessed with indices related to species diversity. Increased soil disturbance decreased the number of weed species and species diversity in maize cropping in Ohio, USA (Cardina et al., 1991). The relative contributions to the size and diversity of weed flora were greater by common species under CT and by rare species in less intensive tillage systems in spring crops in Canada (Gill and Arshad, 1995).

Advantages of RT include soil water conservation, soil erosion control (Griffith et al., 1986), and less use of fossil fuels. Additionally, in humid temperate regions, RT systems may help reduce environmental problems, such as soil degradation and decline in biodiversity, related to intensive cropping (Abivardi et al., 1998). The high amount of crop residues typical of these regions and the reduced soil disturbance may preserve living organisms in the soil. Internal regulatory functions of soil biota, such as nutrient cycling, soil structure preservation, and population control of undesirable organisms, are important factors supporting ecosystem preservation and productivity in arable fields. It should be noted here that weeds themselves affect soil microbes and fauna (Wardle, 1995). Under limited use of herbicides, high weed biomass in RT systems, although low enough to have no effect on crop yield, may encourage beneficial soil organisms. Therefore, simultaneous studies on weeds and soil biota are necessary to weigh the advantages and disadvantages of RT. There have been, however, few studies on both weeds and soil biota in RT systems (Garrett et al., 2001).

About half of the fields used for upland cropping in Japan are covered by Andosols, humus-rich soils derived from volcanic ash. Since these soils have a high proportion of pore space and low bulk density, intensive cultivation increases the risk of wind and water erosion and often has a negative impact on soil organisms (Nakamura, 1988). Although RT should be efficient at preserving Andosols, it is not widely used, partly because of difficulties in weed control and the potential risks of excessive herbicide application. Information on the effects of RT on both crop yields and agroecosystems is necessary.

The present study was initiated to clarify the effect of RT on weed communities and soil biota in a winter wheat–maize double cropping system in central Japan. The objectives of this study were: (1) to evaluate the effect of RT on both density of weed populations and composition of weed communities, with special attention to the potential risk of weed infestation under RT systems without the use of herbicides; (2) to characterize the possible benefits to soil organisms from RT; and (3) to develop a sophisticated use of RT