Applied Soil Ecology 89 (2015) 85–92

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Short-term effects of soil amendment with meadowfoam seed meal on soil microbial composition and function

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ARTICLE INFO

Article history:
Received 3 March 2014
Received in revised form 9 January 2015
Accepted 10 January 2015
Available online 24 January 2015

Keywords:
Limnanthes alba
Ecoplate
Basal respiration
Microbial biomass
Enzymatic activity

ABSTRACT

Meadowfoam (*Limnanthes alba* Hartw. *ex* Benth) seed meal (MSM), a by-product of meadowfoam oil extraction, has a secondary metabolite known as glucosinolate glucolimnanthin. MSM applied as a soil amendment has been reported to have herbicidal and fertilizer properties. Experiments were conducted over 28 days to evaluate short-term effects of a MSM application on soil microbial communities. MSM was applied to soil as either a full or a split application. In addition to MSM and untreated control treatments, urea was used as a N source to account for the fertilizer effect of the seed meal. Urea was applied either as a full or a split rate on the same schedule as MSM. Soil microbial activities were not different between the full and the split rate applications of MSM. After day 7 following MSM application, carbon-source utilization of microbial communities of MSM was different from the urea and control treatments. Microbial communities in MSM treatments utilized complex carbon sources to a relatively greater degree than microbial communities in urea or control treatments. The C and N inputs from MSM increased the gross metabolic activity of the mixed microbial population. Basal respiration was stimulated and microbes reallocated carbon input to biomass and enzyme production. Within 7 and 14 days after MSM application, the reallocation occurred quickly and microbial biomass increased by at least 80% for C and 95% for N compared to the untreated control. In the short-term, MSM treatments affected nutrient dynamics, and the soil microbial structure and function. The effects of MSM application on the composition of bacterial and fungal communities warrant additional study.

1. Introduction

Meadowfoam (*Limnanthes alba* Hartw. ex Benth.) is a member of the *Limnanthaceae* family, which is native to southern Oregon and northern California, USA. Meadowfoam is grown as a winter annual crop in the Willamette Valley of Oregon. The oil extracted from meadowfoam seed possesses unique unsaturated long-chain 20:1, 22:1, and 22:2 fatty acids (Knapp and Crane, 1995) with oxidative stability. Meadowfoam oil is used in a wide range of cosmetic and personal care products. About 70% of the biomass of harvested seed remains after oil extraction. At present, this by-product, known as meadowfoam seed meal (MSM), has little value.

MSM contains 2–4% of a plant secondary metabolite known as the glucosinolate glucolimnanthin (GLN). GLN breakdown products have been reported to have herbicidal activity (Intanon, 2013; Intanon et al., 2014; Stevens et al., 2009). Intanon et al. (2014) suggested that the herbicidal effect of MSM is transient, lasting a maximum of 6 days after seed meal incorporation. To extend the herbicidal effect from glucosinolate-containing seed meal throughout a crop growing season, Rice et al. (2007) recommended reapplication of the material. This application scenario would reflect the use of herbicides that are applied sequentially. However, reapplication of glucosinolate-containing seed meal could increase late-season weed biomass due to the fertilizer effect and increase in plant-available nitrogen (N) (Intanon, 2013).

Soil incorporation of glucosinolate-containing seed meal has been suggested to preserve glucosinolate bioactivity (Gimsing and Kirkegaard, 2009; Matthiessen and Kirkegaard, 2006). Soil amended with MSM has been reported to enhance plant growth (Linderman et al., 2007) and suppress weeds (Stevens et al., 2009; Vaughn et al., 2006). Few papers refer to the effect of seed meals on soil respiration and biochemical properties (Galvez et al., 2012; Wang et al., 2012; Zaccardelli et al., 2013), and there are no data on the impact of MSM application on soil microbial community characteristics.

Changes in soil microbial composition and function can be measured using multiple parameters. For example, carbon (C) flux measurement via respiration, or CO_2 evolution, is a traditional index that measures the gross metabolic activity of mixed

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http://dx.doi.org/10.1016/j.apsoil.2015.01.009
0929-1393/

microbial populations (Stotzky, 1997). Microbial biomass size is an important indicator of soil quality and plant nutrient dynamics for short and long term studies (Insam, 2001).

Community-level physiological profiling (CLPP) and specific enzyme activity provide information about soil microbial community structure and function (Garland and Mills, 1991; Insam, 2001; Sinsabaugh et al., 1991). Extracellular enzymes catalyze the initial steps of decomposition and nutrient mineralization (Sinsabaugh et al., 2005). Extracellular enzymes are necessary to break down macromolecules, such as cellulose, hemicelluloses or lignin, whereas intracellular enzymes break down smaller molecules such as sugars or amino acids (Insam, 2001). Extracellular enzyme activities (EEA) respond quickly to the changes in soil management practices (Paz-Ferreiro et al., 2009) and are sensitive indicators of ecological changes (Wallenstein and Weintraub, 2008).

Multiple experiments were conducted to examine the impact of MSM application on crop growth, weed control, and soil microbial communities (Intanon, 2013). In this study, the short-term effects of MSM application on soil microbial composition and function were investigated using multi-parameter approaches. We tested the hypothesis that soil respiration, microbial biomass C and N, soil enzyme activities, and community profiles would be affected by MSM application to soil.

2. Materials and methods

2.1. Experimental site and design

Field experiments were conducted at the Lewis-Brown Horticulture Research Farm, Oregon State University, near Corvallis, Oregon, USA (43°33′N, 123°12′W). The soil at this site is classified as a Malabon silty clay loam (Pachic Ultic Argixerolls) (Soil Survey Staff, 2010) with an organic matter content of 3.2% and pH of 6.5. Average air temperature for 28 days of the studies was recorded (Fig. 1A). Experimental plots were tilled to remove weeds followed by hand-weeding before starting the experiments. Two field experiments were conducted in different locations from July 9 to September 12, 2012, for the first experiment, and from August 1 to October 5, 2012, for the second experiment, using a randomized complete block design with four replications. There were five treatments, two amendment materials (urea and MSM) with two application methods (either full or split rate application), and one control treatment (non-amended).

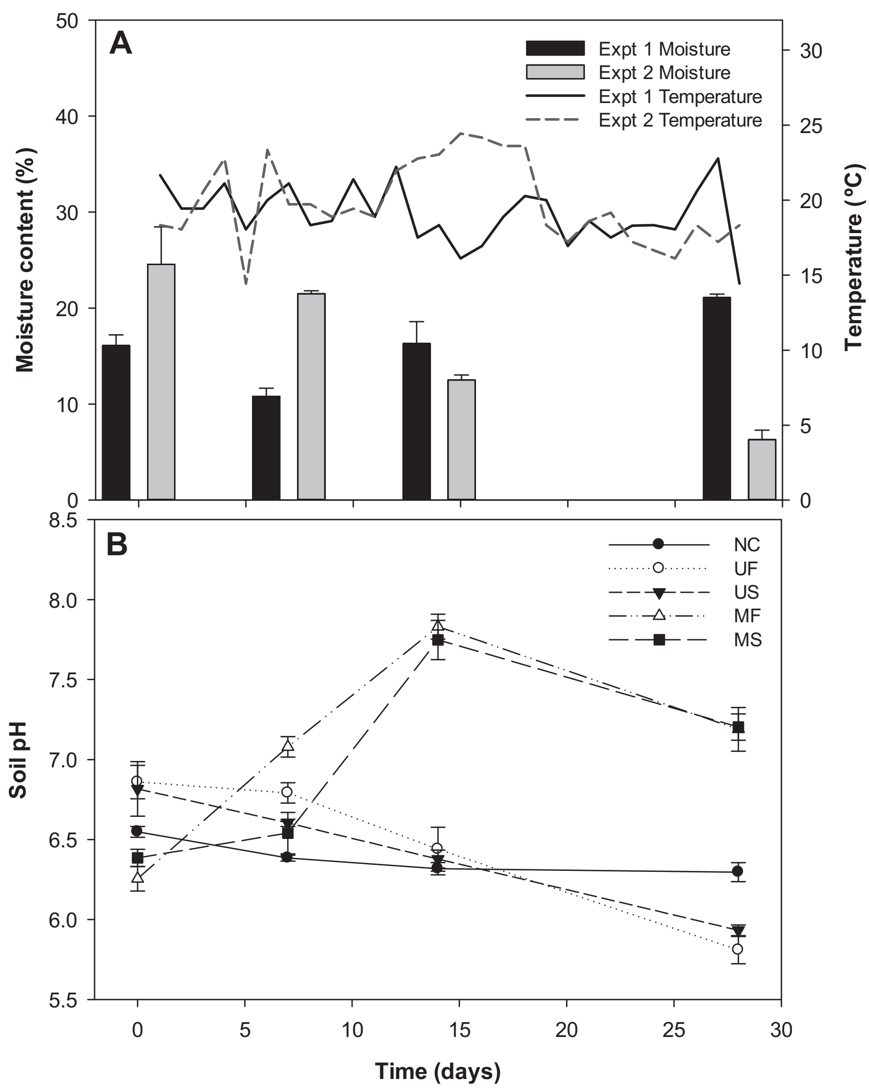

Fig. 1. Physicochemical data of soil moisture at 5 cm soil depth measured on 0, 7, 14, and 28 days after the initial meadowfoam seed meal and urea applications and average daily air temperature recorded in 2012 at a weather station located at Hyslop Field Laboratory, near Corvallis, Oregon, approximately 13 km from the study site (A) and soil pH at 5 cm depth combined from Experiments 1 and 2 (B).