Agriculture, Ecosystems and Environment 190 (2014) 37–42

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Does cattle grazing of dual-purpose wheat accelerate the rate of stubble decomposition and nutrients released?

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ARTICLE INFO

Article history:
Received 4 March 2013
Received in revised form
27 December 2013
Accepted 10 January 2014
Available online 7 February 2014

Keywords:
Decomposition
Dual-purpose wheat
Grazing
Litter bag
No tillage
Soybean

ABSTRACT

Decomposition and nutrient release of winter annual forages in integrated crop-livestock systems could be affected by the resultant alterations in structure and quality of residues caused by grazing, but little information is available to test this hypothesis. Information on residue dynamics is needed to synchronize nutrient release from cover-crop litter to cash-crop nutrient demand and to overcome potential deficiencies with appropriate fertilization strategies. We evaluated the influence of different grazing period lengths (0, 21, 42, 63, 85, and 105 days) of dual-purpose wheat (*Triticum aestivum* L.) pasture on the release rate of N, P, K, Ca, and Mg from decomposing wheat straw in a field experiment at the Agronomic Institute of Paraná, Brazil. Wheat litter decomposition and nutrient release were assessed with litter bags placed at the soil surface in a completely randomized design with seven collection periods (0, 15, 35, 63, 98, 139, and 196 days) during the subsequent growth of soybean [*Glycine max* (L.) Merr.]. Wheat residue decomposition and nutrient release followed an exponential function with time. Enhanced decomposition of wheat residue with previous grazing did occur, but the influence was relatively small (range of 6–11% greater release, except for 4% inhibition of K). In integrated crop-livestock systems, the effect of residual forage mass at the cessation of the grazing season (structure) would have much greater impact on nutrient cycling than composition of plant litter (quality). Nutrient cycling via animal excrement was not investigated, but was considered another significant mechanism for enhanced nutrient cycling with integrated crop-livestock systems. Grazing of wheat tended to have negative consequences on soybean grain yield, declining 9 kg ha^{-1} for every day of grazing (i.e. 19% lower yield at 105 days of grazing compared with no grazing). Minor changes in nutrient release dynamics can be expected with grazing of winter cover crops, but these changes are important for managing nutrients in integrated crop-livestock systems.

1. Introduction

Minimum- or no-tillage planting systems are largely used in agricultural systems of southern Brazil, where fall/winter cover cropping with black oat (*Avena strigosa*) is typical. Although cover crops are rich in nutrients (mainly N) and could serve as a biological source of fertility, little is known of cover crop decomposition and subsequent nutrient release to a succeeding crop in this region. Knowledge of the synchrony of nutrient release with subsequent crop demand is needed so that supplemental inorganic fertilizer can be applied if needed.

Cover crop cultivation does not result in immediate economic return to the farmer. In the Brazilian subtropics, 13 million ha of summer crops, mainly soybean (*Glycine max*), corn (*Zea mays*), and rice (*Oryza sativa*), are cultivated, but only 4.4 million ha are double-cropped with economically profitable winter crops, such as wheat (*Triticum aestivum*), white oat (*Avena sativa*), canola (*Brassica napus*), and rye (*Secale cereale*). Therefore, nearly 9 million ha are unproductive during the fall/winter season. Winter cover crops could provide needed forage for ruminant herds, which often have

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[1] Assistantship from CAPES.

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http://dx.doi.org/10.1016/j.agee.2014.01.011

feed deficit in winter due to the majority of pastures as warm-season C4 grasses (Moraes et al., 2012).

Switching from typical black oat as cover crop to dual-purpose wheat as cover crop could provide multiple benefits, including quality feed for ruminants, potential wheat grain harvest, and additional profit for farmers. Such a system of including wheat in the rotation would allow greater production from grain and livestock gain, as well as hopefully maintaining soil conservation benefits from no tillage and winter cover cropping.

One of the main reasons farmers in the Brazilian subtropics may resist adoption of an integrated crop-livestock system is the concern that grazing could negatively affect the succeeding cash crop. However, Moraes et al. (2012) recently reviewed 23 studies carried out in the Brazilian subtropics and found that grain yield of crops succeeding winter pastures was actually greater compared to ungrazed controls.

When cover crops are grazed, little or no fertilizer may be used to avoid input costs. In this case, nutrient cycling from plant litter and animal feces are important nutrient sources for the pasture (Dubeux et al., 2007) and the succeeding grain crops. However many factors affect litter decomposition and nutrient release dynamics, such as chemical and physical characteristics of the residue (Anderson, 1991; Cornelissen and Thompson, 1997), climatic characteristics (Semmartin et al., 2004), soil microbial activity and photo-oxidation potential (Austin and Vivanco, 2006), initial N concentration of leaves and residue (Parton et al., 2007), and soil microbial populations (Smith and Bradford, 2003).

Additionally, grazing may affect nutrient cycling in crop-pasture systems. Frequent defoliation may accelerate net N mineralization rate of residue, thereby increasing N availability to growing plants (Holland and Detling, 1990; Dubeux et al., 2006). Grazing may enhance N availability in soil and plants, but may also improve residue quality returning to the soil (Shariff et al., 1994), as well as by the urine and feces added onto the soil (Dubeux et al., 2007). Defoliation intensity of grazing may also affect the quality and quantity of residues and nutrient recycling in feces and urine, causing changes in residue decomposition and nutrient release (Dutta and Agrawal, 2001; Dubeux et al., 2006).

Synchronization of N mineralization with crop growth is needed to sustain high production while minimizing environmental impacts, such as greenhouse gas emissions and nitrate leaching (Borgen et al., 2010). Grazing may provide an opportunity to better synchronize nutrient release from cover crop residues with nutrient demands of succeeding grain crops. The N mineralization-immobilization process during crop residue and green manure decomposition requires an accounting of plant residue qualities, but also a better understanding of the process in the simplest way possible.

Sartor (2012) observed that after grazing of cover crops fertilized with N in an integrated crop-livestock system, the residual effect of N fertilization was enhanced by grazing. Assmann et al. (2003) and Sandini et al. (2011) observed that in a cover crop fertilized with 300 kg N ha^{-1} and grazed during the winter, the succeeding maize crop did not respond to additional N topdressing. This indicates that there is potential to improve winter forage production for livestock grazing using fall/winter-applied N fertilizer and then eliminate fertilizer application for summer grain culture. It is likely that livestock consumption of winter forage would enhance herbage decomposition and subsequent nutrient release.

With greater complexity of the soil-plant-animal system in integrated crop-livestock systems, nutrient cycling is one of the most important issues to understand to improve overall system efficiency. Therefore, we conducted an experiment to evaluate N, P, K, Ca, and Mg release rates from dual-purpose wheat stubble decomposition under different lengths of grazing period during the winter. In addition, nutrient effects on subsequent soybean yield were evaluated during the same decomposition season. We hypothesized that quality of litter would be greater with increasing grazing days of wheat due to younger residual shoot growth, the effect of which would lead to faster release of nutrients from dual-purpose wheat.

2. Material and methods

2.1. Grazing experiment

The grazing experiment was conducted from April to November 2007 at the Instituto Agronômico do Paraná, in Pato Branco, PR, Brazil (26° 07' S; 52° 39' W; 700 masl). The soil is classified as Red Dystrophic Oxisol with clay texture (EMBRAPA, 1999). Prior to experiment initiation, 10 sub-samples were collected from the 0–20 cm depth of soil. Soil chemical characteristics were: pH ($CaCl_2$) = 5.0; organic matter = 66 g kg^{-1}; P = 9 mg kg^{-1}; K = 0.9 cmol$_c$ kg^{-1}; Al = 0.0 cmol$_c$ kg^{-1}; Ca = 7.3 cmol$_c$ kg^{-1}; Mg = 3.4 cmol$_c$ kg^{-1}; CEC = 16.6 cmol$_c$ kg^{-1}; base saturation = 68%.

No-tillage was used in the experimental area since 1995. Previous crops were soybean or corn in summer and small grains in winter. The integrated crop-livestock system was initiated in 2003 by grazing of winter oat.

The first experimental phase was established on 30 April 2007 with dual-purpose wheat (*Triticum vulgare*) using no tillage. The wheat cultivar was BRS-Tarumã, classified as bread wheat for baking and pasta, and released by Embrapa Trigo.

Fertilization practices were guided by soil chemical analyses and also based on the recommendation of the Brazilian Commission for Chemical and Soil Fertility (CQFS/RS-SC, 2004). Wheat was fertilized with 20 kg N ha^{-1}, 70 kg P_2O_5 ha^{-1}, and 40 kg K_2O ha^{-1} at sowing. Three topdressing applications of urea were made at key wheat vegetative growth stages and based on weather conditions on May 5 (45 kg N ha^{-1}), June 25 (22 kg N ha^{-1}), and August 8 (18 kg N ha^{-1}).

This experimental phase was conducted as a randomized complete block design with two replicates. Six grazing period durations on dual-purpose wheat were evaluated: 0, 21, 42, 63, 84, and 105 days of grazing. Grazing started 71 days after wheat sowing on July 10 in all plots, except those remaining ungrazed. Livestock grazed until July 31, August 21, September 11, October 2 and October 23 according to grazing periods. Livestock were 10-month-old steers of the Brazilian race Purunã (¼ Aberdeen Angus, ¼ Canchim, ¼ Caracu, ¼ Charolais) with initial body weight of 163 kg. There were two tester steers of similar age and weight assigned to each plot. Grazing was continuous with put-and-take stocking (Mott and Lucas, 1952) to maintain canopy height of ~25 cm, based on Del Duca et al. (2000) recommendations. Sward height was measured weekly using a sward stick. Distance from soil level to the height where the marker was touched by the topmost leaf was measured at 50 places in every plot.

The total area was 4.5 ha, which was divided into 10 experimental units (plots) of 0.38 ha each. In addition, two ungrazed control plots of 0.0012 ha each were also evaluated for a total of 12 experimental units. Wheat was harvested for grain on 13 November 2007, with soybean sown on the same day. Wheat stubble mass was evaluated immediately before soybean sowing. From each plot, six forage samples of 0.25 m^2 were cut at soil level. Samples were dried by a forced-air oven (55 °C) to a constant weight to determine forage mass in kg ha^{-1} of dry matter (DM).