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Contribution of nitrogen from agricultural residues of rye to '*Niagara Rosada*' grape nutrition

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ABSTRACT

Nitrogen from cover crop residues decomposing on the soil surface may contribute to '*Niagara Rosada*' grape nutrition. This study estimated the recovery of N from the decomposition of rye (*Secale cereale*) residues deposited on the soil surface in vineyards. Rye litter labeled with ^{15}N was applied in July 2008 on the soil surface of a '*Niagara Rosada*' grape (*Vitis labrusca*) vineyard in Bento Gonçalves in the southern region of Brazil. In January 2009 and 2010, '*Niagara Rosada*' grape plant organs were sampled, and in January 2010, soil samples were collected in different depths. Total N and ^{15}N were analyzed in the plant tissue and soil samples. The N derived from the rye litter added to the soil surface was mostly accumulated in the annual and perennial organs of the '*Niagara Rosada*' grape at a similar percentage. Most of the N contained in '*Niagara Rosada*' grape organs was derived from different N sources rather than rye litter. Thus, the N derived from rye litter apparently contributed little to '*Niagara Rosada*' grape nutrition in the short time period.

1. Introduction

Winter cover crop species, including rye (*Secale cereale*), may be sown and grown between grapevine rows. The purpose of this practice is to reduce weed growth, dissipate the kinetic energy of raindrops, and reduce runoff on the soil surface to increase both water infiltration into the soil profile and nutrient uptake by the grapevines. These nutrients are incorporated into the organic fractions of the plant tissue, which reduces leaching in the soil profile and consequently increases nutrient residence time in the vineyard (King and Berry, 2005; Stevens and Quinton, 2009; Ovalle et al., 2010; Steenwerth and Belina, 2010; Brunetto et al., 2011). The aboveground portions of the cover crop plants may either be cut or desiccated with herbicides, and the residues can then be deposited on the soil surface of the '*Niagara Rosada*' grape rows to discourage the growth of plants that may compete with the '*Niagara Rosada*' grape for water and nutrients (Celette et al., 2009; Brunetto et al., 2011).

Microorganisms use the organic carbon of the cover crop residues that are deposited on the soil surface between the rows of the '*Niagara Rosada*' grape plants as a source of energy, which releases CO_2 to the atmosphere. Nutrients, including nitrogen, that are contained in the plant tissue residues can be mineralized in the soil, increasing mineral forms, such as nitrate (NO_3^--N) and ammonium (NH_4^+-N), which may be taken up by the grapevines (Ovalle et al., 2010). Mineralized N derived from the decomposition of residues may be taken up by the '*Niagara Rosada*' grape, especially during the vegetative and productive period, and distributed primarily to annual organs, such as leaves, clusters and shoots (1 year old), which normally are an N sink because of the increase of dry matter (Glad et al., 1994; Schreiner and Scagel, 2006). Especially near grape harvest, most of the N contained in the annual plant organs may be distributed to the perennial organs, such as the cordon, stem, and especially the roots, where it accumulates preferentially in the form of amino acids or proteins, and in the next growth cycle, the N may once again be redistributed to

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the annual organs (Conradie, 1990, 1991; Bates et al., 2002; Brunetto et al., 2005, 2006a; Menino et al., 2007; Neto et al., 2008). If the decomposition of the residues contributes to grapevine nutrition, as reported in preliminary studies in California (United States of America) (Patrick et al., 2004; King and Berry, 2005), Chile (Ovalle et al., 2010) and the Emilia-Romagna region of Italy (Brunetto et al., 2011), the N inputs from other sources, such as fertilizers, may be reduced. However, in Brazil, especially in the south, which is the most important wine-growing region of Brazil, the synchronism between the decomposition of cover crop litter and the uptake of the released litter nutrients by '*Niagara Rosada*' grape throughout a subsequent growth cycle has not yet been studied. For this type of study, stable isotopes of nitrogen (^{15}N) have been used as tracers because they allow precise monitoring of the quantity of N from fertilizer or even from plant litter that is recovered and compartmentalized in the grapevine (Brunetto et al., 2006a,b, 2011).

The aim of this study was to evaluate the recovery of N derived from rye residues deposited on the soil surface of vineyards in '*Niagara Rosada*' grape plants.

2. Materials and methods

2.1. Labeling procedures

In April 2008, an untilled Typic Hapludalf soil sample (Soil Survey Staff, 2006) was collected, passed through a sieve, mixed with sand (10% of the total soil volume) and placed in amianthus asbestos boxes in a greenhouse, where rye seeds were sown. Two weeks after emergence of the plants, a urea solution, enriched with 5 at.% ^{15}N excess was applied to the amended soil. This application was repeated four times at weekly intervals, providing a total of 10 g N m^{-2}. The plants were watered daily, and weeds were eliminated weekly to prevent them from taking up ^{15}N. In July 2008, the stem of the rye plants was severed at ground level, and the above-ground plant parts were weighed for the determination of green weight. A sample was then removed and dried in a laboratory oven with forced-air circulation at 65 °C until constant weight. The dry matter (DM) was subsequently saved for chemical characterization, and the rest of the green matter was stored in reserve. The rye litter deposited on the soil surface contained 462.0 g kg^{-1} cellulose, 56.0 g kg^{-1} lignin, 349 g kg^{-1} total C, 41.0 g kg^{-1} total N, 2.37 at.% ^{15}N excess, 2.7 g kg^{-1} total P, 8.5 g kg^{-1} total K, 1.3 g kg^{-1} total Ca and 1.1 g kg^{-1} total Mg.

2.2. Description of the experiment

The experiment was carried out from July 2008 to January 2010 in an experimental vineyard of Embrapa Uva e Vinho in Bento Gonçalves (Latitude 29°09′44″ S and Longitude 51°31′50″ W) in the State of Rio Grande do Sul in southern Brazil on the '*Niagara Rosada*' grape (*Vitis labrusca*) grafted on Paulsen 1103 rootstock and grown at a density of 3033 plants per hectare using a trellis training system. The '*Niagara Rosada*' grapevines were six years old. The climate of the region, according to the Köppen classification, is Cfa subtropical, with the coldest months occurring in June and July, when the mean minimum temperature is 8 °C and the mean maximum temperature is 17 °C. The hottest months are January and February, with a mean minimum temperature of 17 °C and a mean maximum temperature of 26 °C. The mean annual rainfall is 1736 mm. The average rainfall, air and soil temperatures, and air humidity data throughout the experimental period are shown in Table 1. The soil was a Typic Hapludalf, with the characteristics described in Table 2. Within a 1.2 m wide strip centered along the '*Niagara Rosada*' grape row, the weeds were desiccated with a nonresidual herbicide, and between the plant rows, a mixture of *Lolium perenne*, *S. cereale* and *Paspalum notatum* was grown. During the experiment the '*Niagara Rosada*' grape received no applications of mineral N fertilizers. On July 1, 2008, 1038 g of rye green manure, the equivalent of 192.74 g of DM, was applied on an area of 0.96 m^2 (0.80 m × 1.20 m) on the soil surface around each grapevine plant. The amount of added DM corresponded to 2.0 Mg ha^{-1}, containing 41.0 g kg^{-1} N, which is equivalent to 82 kg of N ha^{-1} (labeled with 2.37 at.% ^{15}N excess). A nylon screen with a 5 mm aperture mesh was placed on the rye biomass to avoid possible losses caused by wind and animals. A completely randomized experimental design with five replications was used, and five other grapevines that received rye biomass without added ^{15}N served as controls.

In January 2009, at 28 weeks after depositing the rye biomass on the soil surface, eight clusters of grapes were collected at random from each '*Niagara Rosada*' grape. An established number of berries from the top, middle and lower part of each cluster were collected, frozen in liquid N, dried in a lyophilizer until reaching a constant weight and then adequately stored. The eight rachises were reserved. Three shoots (1 year old) and a fraction of a cordon with a length of 0.03 m were then collected at random from each '*Niagara Rosada*' grape and reserved. Soon afterwards, the leaves from each new shoot were collected and reserved. The leaves, the shoots and the rachises were dried at 65 °C until they reached a constant weight, ground and stored.

Table 1
Accumulated rainfall; mean air temperature; mean soil temperature (at the depth of 0.00–0.05 m); mean air relative humidity (RH) during the experimental period.

Years–months	Rainfall (mm)	Air temperature (°C)	Soil temperature (°C)	Air RH (%)
2009				
July	97.8	10.2	11.5	78
August	257.9	15.2	14.8	78
September	411.7	14.6	15.9	84
October	145.1	16.7	18.4	75
November	359.5	21.6	22.8	83
December	232.6	21.2	24.2	80
2010				
January	296.4	22.0	24.2	83
February	167.1	23.0	25.0	79
March	57.2	20.7	22.9	81
April	142.1	17.5	19.2	79
May	154.7	14.2	15.4	87
June	129.9	13.1	13.8	81
July	213.2	12.7	13.5	78
August	48.8	13.0	13.5	76
September	237.9	15.5	16.6	80
October	48.8	15.6	18.0	77
November	89.5	18.4	21.0	71
December	94.3	20.9	23.7	74
2011				
January	174.6	22.9	25.2	80

Table 2
Main physical and chemical characteristics of the soil in the experimental site at the depth of 0.00–0.20 m.

Attribute	Unit	0.00–0.20 m
Clay	g kg^{-1}	162
Silt	g kg^{-1}	558
Sand	g kg^{-1}	280
Organic matter	g kg^{-1}	218
Organic C	g kg^{-1}	126
pH in H_2O	–	6.00
Total N	mg kg^{-1}	2.500
Mineral N	mg kg^{-1}	20
Aluminum (exchangeable)	mg kg^{-1}	0.00
Magnesium (exchangeable)	mg kg^{-1}	413
Calcium (exchangeable)	mg kg^{-1}	1593
Phosphorus (availability)	mg kg^{-1}	33
Potassium (exchangeable)	mg kg^{-1}	246