Biomass and nutrient cycling by winter cover crops

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10.1590/0034-737X201663060010

ABSTRACT

Cover crops are of fundamental importance for the sustainability of the no-tillage system, to ensure soil coverage and to provide benefits for the subsequent crop. The objective of this study was to evaluate the production of biomass and the content and accumulation of nutrients by winter cover crops. The experimental design used in the experiment was a randomized complete block with four replications and six treatments: oilseed radish, vetch, black oats, vetch + black oats, vetch + oilseed radish and fallow. Black oat, oilseed radish in single cultivation and black oat + vetch and vetch + oilseed radish intercroppings showed higher dry matter production. Vetch + oilseed radish intercropping demonstrates higher performance regarding cycling of nutrients, with higher accumulations of N, P, K, Ca, Mg, S, Cu, Zn, Fe, Na and B.

Key words: legumes; grasses; macronutrients; micronutrients.

RESUMO

Biomassa e ciclagem de nutrientes por plantas de cobertura de inverno

Culturas de cobertura são fundamentais para a sustentabilidade do sistema plantio direto por garantir a cobertura do solo e por proporcionar benefícios para a cultura subsequente. O presente trabalho teve o objetivo de avaliar a produção de biomassa, o teor e acúmulo de nutrientes por plantas de cobertura de inverno. O delineamento experimental foi o de blocos casualizados, com seis tratamentos: nabo forrageiro, ervilhaca, aveia preta, ervilhaca + aveia preta, ervilhaca + nabo forrageiro e pousio, com quatro repetições. O cultivo solteiro de aveia preta, nabo forrageiro e o consórcio de aveia preta + ervilhaca e ervilhaca + nabo forrageiro apresentam maior produção de matéria seca. O consórcio ervilhaca + nabo forrageiro demonstra desempenho superior quanto à ciclagem dos nutrientes, com maiores acúmulos de N, P, K, Ca, Mg, S, Cu, Zn, Fe, Na e B.

Palavras-chave: leguminosas; gramíneas; macronutrientes; micronutrientes.

Submitted on November 28th, 2014 and accepted on June 02th, 2016.

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INTRODUCTION

In southern Brazil, as the so-called "modern" technologies have expanded in agriculture, cover crops and green manures had been left out. Although studies on this subjected have resumptined, there is still much to do in terms of studies and dissemination of those practices such as the search for more efficient and adapted species to those production systems. Soil protection and cycling and/or biological fixation of nitrogen, both in winter and in summer or between harvest seasons will allow the construction of a production system that prioritizes the concepts of sustainability, minimizing production costs, characterized as no-tillage cropping system.

Among the plants used as green manure, legumes present the advantage of symbiotically associating themselves with the nitrogen fixing micro-organisms, thus increasing levels of that macronutrient in the straw (Perin *et al*., 2004). Furthermore, the grasses are able to accumulate large amounts of green matter (Barradas, 2010) with a high C/ N ratio and slower decomposition rate in relation to the legumes, favoring the maintenance of straw on the soil surface for a longer period of time, acting as a regulator of temperature and soil moisture, as well as reducing the risk of erosion. Regarding grasses intercropped with legumes, nutrient uptake and mineralization rates are higher due to the presence of legumes, thus the straw of these plants is more interesting for the composition of a crop rotation system or as contribution to nutrition in agro-ecological systems. The capacity of those species to cycle the available nitrogen in soil and/or to fix atmospheric nitrogen, the high nitrogen demand of grasses and the high cost of nitrogen fertilizers contribute to the inclusion of these species in rotation with corn (Giacomini *et al*., 2004). Thus, green manures are of great importance to agriculture because they promote a more rapid cycling of nutrients promoting their use by the following crop, particularly of those elements with leaching potential such as nitrogen and exchangeable cations, or of those that may be relatively easy retained in weathered soils, such as phosphorus (Rodrigues *et al*., 2012).

When evaluating the effect of cover crops on maize grown in no-tillage system, Bonjorno *et al*. (2010) demonstrated the economic viability of agro-ecological management of no-till corn following different winter cover crops. Because of its ability to fix atmospheric nitrogen and the high rate of decomposition of crop residues, vetch is able to provide significant amounts of nitrogen to corn in succession (Heinrichs *et al*., 2001; Aita *et al*., 2001). However, black oat affect the supply of nutrients and productivity of grains (Aita *et al*., 2001) since it accumulates lower amount of nitrogen in the green matter, and releases it slowly after its management. Considering the role played by soil cover crops plants in agriculture, particularly during the winter period, it is highlighted the importance of carrying out studies that quantify the production and the supply of nutrients in dry matter. The objective of this study was to evaluate the production of green matter, dry matter, the content and the accumulation of nutrients in the aboveground part of plants used in winter cover crops.

MATERIAL AND METHODS

The experiment was carried out in the experimental area of the Universidade de Cruz Alta (UNICRUZ) in the municipality of Cruz Alta, Rio Grande do Sul, 28°38'19"S, 53°36'2"W, and altitude of 452 m. According to Köppen classification, the weather is subtropical Cfa with uniform rainfall over the year. The soil is classified as clayey Red Oxisol (Embrapa, 2013), with the following characteristics in the 0-20 cm layer: clay: 48%; Water pH = 5.2; Organic Matter = 2.9%; Phosphorus = 3.7 mg dm^{-3}; Potassium =116 mg dm^{-3}; Aluminum = 1.8 $cmol_c$ dm^{-3}, Calcium = 2.9 $cmol_c$ dm^{-3}, Magnesium = 1.5 $cmol_c$ dm^{-3}, Aluminum + Hydrogen = 8.7 $cmol_c$ dm^{-3} and base saturation = 35%.

The experimental design was a randomized block with six treatments and four replications, where treatments consisted of different winter cover crop plants in single or intercropped systems, as follows: oilseed radish (*Raphanus sativus* var *oleiformis*), Vetch (*Vicia sativa*), black oat (*Avena strigosa*), vetch + black oat, vetch + oilseed radish and fallow (spontaneous vegetation). During fallow, the following weeds were more frequent: *Conyza* spp, *Bidens pilosa*, *Ipomoea* spp. and *Lolium multiflorum*. Plots consisted of a 24 m^2 area and sowing was carried in the broadcast system in May, with no additional fertilization.

Fresh matter production was determined by weighing the aboveground part of the plants after harvest and dry matter was quantified by drying the material in an oven at 65 °C until constant mass, expressing the results in kg ha^{-1}. Samples of the dry matter of the plants were ground in a Wiley mill, then packed in containers with 100 g and sent to the Soil and Plant Tissue Analysis Laboratory at the Universidade Federal do Rio Grande do Sul to determine the nutrient content, according to the methodology described by Tedesco *et al*. (1995). Accumulations of macro and micronutrients were obtained by multiplying the production of dry mass by the nutrient content of each treatment. Statistical analyzes were performed with the aid of the statistical program Sisvar (Ferreira, 2011).

RESULTS AND DISCUSSION

No difference was found in the dry and fresh matter production of cover crops (Table 1), and the fresh matter production ranged from 5,507 kg ha^{-1} to 9,248 kg ha^{-1}.

According to Lima *et al*. (2001), fresh matter demonstrates high variability, probably due to the oscillation that occurs in the water content of the plants in the interval between sampling and weighing, which may cause variable underestimation of the results. Fallow showed the lowest production of fresh matter, significantly differing from the cover species in single and intercropping cultivation systems.

Crops of black oats, oilseed radish and black oat + vetch and vetch + oilseed radish intercropping presented the highest dry matter accumulation. The dry matter of black oat, oilseed radish, vetch, black oat + vetch and vetch + oilseed radish were lower than those obtained by Carvalho *et al*. (2007). The authors report the production of 4,632 kg ha^{-1}, 2,468 kg ha^{-1}, 2,839 kg ha^{-1}, 4,564 kg ha^{-1}, 2,850 kg ha^{-1} for black oats, oilseed radish, vetch, black oats + vetch and vetch + oilseed radish, respectively.

A statistically significant difference was found for the nutrient content in the dry matter of cover crops, except for iron (Tables 2 and 3). The content of nitrogen was higher in the vetch grown in single cultivation, a higher result than that reported by (Bettiol *et al*., 2015) in a study with Brachiaria (*Urochloa sp.*) and its intercropping with gray velvet bean, *Canavalia ensiformis*, *Crotolaria juncea* and *Cajanus cajan.* Increases in the content of phosphorus were observed in fallow, in the single cultivation of vetch and in vetch intercropped with oilseed radish. That accumulation of phosphorus is higher than that found in the first year of *Mucuna aterrima* (3.15 g kg^{-1}) and lower than that found in the second year (4.80 g kg^{-1}) by Silva *et al*. (2014). In relation to potassium, the highest values for the nutrient content were obtained in the single cultivation of vetch, oilseed radish and in black oats + vetch and vetch + oilseed radish intercropping, which did not differ statistically from the fallow. This result is higher than that found by (Bettiol *et al*., 2015) for *Brachiaria decumbens* (18.31g kg^{-1}) and its intercropping with: *Mucuna cinereum* (19.51 g kg^{-1}), *Canavalia ensiformis* (20.06 g kg^{-1}), *Crotalaria juncea* (20.08g kg^{-1}) and *Cajanus cajan* (18.44 g kg^{-1}).

The highest magnesium content was provided by oilseed radish and was higher than that found for *Crotalaria juncea* (4.0 g kg^{-1}) by Silva *et al*. (2014). Oilseed radish grown in single cultivation also responded for the highest contents of sulfur and calcium. These results differ from those reported by Silva *et al*. (2010), who found higher sulfur and calcium contents in pearl millet (2.5 g kg^{-1}) and in *Crotalaria juncea* (8.9 g kg^{-1}). As for the copper content, single cultivation of vetch and fallow showed the highest levels, while for zinc and boron, the highest levels were found in the cultivation of vetch, oilseed radish and its intercropping; however, for zinc, it did not differ statistically from fallow. According to Faquin (2001), dicotyledonous absorb more amounts of boron than monocotyledonous. The manganese content was high in single cultivation of black oat and black oat intercropped with vetch. These results differ from those observed by Teixeira *et al*. (2008), who found no difference in the content of manganese in the single cultivation of *Canavalia ensiformis*, *Cajanus cajan*, pearl millet and their intercrops. As for sodium, the highest values were found in the intercropping.

Higher accumulations of nitrogen and sodium were observed in vetch intercropped with oilseed radish. Although it did not present higher nitrogen content, the greater accumulation of nutrients in the vetch + oilseed radish intercropping may be attributed to a higher production of dry matter in relation to single cultivation of vetch. Nitrogen accumulation was higher than that observed by Silva *et al*. (2007) in vetch + oilseed radish intercropping, which was 50 kg ha^{-1}. In addition, the nitrogen accumulation in this study was higher than that found by Silva *et al*. (2014) for pearl millet, *Crotalaria juncea* and *Cajanus cajan* grown in 2010 and 2011, and lower than the accumulation of *Mucuna aterrima* (361 kg ha^{-1} and 357 kg ha^{-1}) in two years of cultivation, respectively. Although vetch presents higher nitrogen content in the present study in relation to the nutrient content in *Mucuna aterrima* (30.4 g kg^{-1} and 29.5 g kg^{-1}) of the previous mentioned study, the largest production of dry matter provided the high nitrogen accumulation in *Mucuna aterrima*. Giacomini *et al*. (2003) found higher nitrogen accumulation in the first year of oilseed radish crop (101 kg ha^{-1}), which decreased in the following years (67 kg ha^{-1} and 63 kg ha^{-1}). The highest

Table 1: Production of aboveground dry and fresh matter of winter cover crops

Cover Crop	Fresh matter	Dry matter
	kg ha^{-1}	
Fallow	1,721.00 b	456.50 c
Vetch	5,507.00 a	2,100.60 b
Black oat	6,929.50 a	2,742.80 a
Oilseed radish	8,623.10 a	2,736.60 a
Black oat + Vetch	8,374.00 a	2,907.30 a
Vetch + oilseed radish	9,248.00 a	2,743.50 a
CV (%)	30.44	16.62

Groups of means not followed by the same letter in the column are different by the Scott Knott's test at 5% of probability.

accumulation in the first year was because of the higher availability of nitrogen in the soil, where oilseed radish succeeded soybean cultivation and in the following years, the decrease occurred because oilseed radish was sown after corn cultivation.

The highest accumulations of phosphorus and iron were found in single crops and intercropping of cover crops plants, which differed only from fallow. Pittelkow *et al*. (2012) found higher values for phosphorus accumulation (44.40 kg ha^{-1}) in the cultivation of Brachiaria (*Urochloa sp*.). Giacomini *et al*. (2003) found higher phosphorus accumulation in the single cultivation of oilseed radish and vetch, differing from black oats, and, according to the authors, this result is due to the greater accumulation of this nutrient in legumes in comparison to grasses. The accumulated amounts of phosphorus in the cover crops were higher than that recorded by Barros *et al*. (2013) in *Canavalia ensiformis*, *Mucuna aterrima*,

Table 2: Macronutrient content and accumulation of the aerial part of winter cover crops

Cover crops	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur
	Content (g kg^{-1})					
Fallow	26.00 b*	4.50 a	40.25 a	8.35 c	3.07 c	3.12 b
Black oat	11.50 d	3.62 b	27.25 b	3.62 d	2.02 d	1.20 c
Vetch	34.25 a	4.40 a	43.75 a	8.27 c	2.92 c	2.10 c
Oilseed radish	22.25 c	3.45 b	39.00 a	16.50 a	5.02 a	4.87 a
Oat + Vetch	20.25 c	3.65 b	36.00 a	6.30 c	2.47 d	1.80 c
Vetch + Oilseed radish	28.75 b	4.35 a	42.00 a	12.00 b	3.87 b	3.37 b
CV %	17.25	6.97	7.80	16.96	10.27	19.83
Cover crops	**Nitrogen**	**Phosphorus**	**Potassium**	**Calcium**	**Magnesium**	**Sulphur**
	Accumulation (kg ha^{-1})					
Fallow	44.75 c	7.75 b	69.00 c	14.25 c	5.25 c	5.25 c
Black oat	79.75 c	25.00 a	188.75 b	25.00 c	13.75 b	8.25 c
Vetch	188.75 b	24.25 a	240.75 b	45.50 b	16.00 b	11.50 b
Oilseed radish	192.00 b	29.75 a	336.50 a	142.25 a	43.25 a	42.00 a
Oat + Vetch	169.50 b	30.50 a	301.50 a	52.50 b	20.75 b	15.25 b
Vetch + Oilseed radish	266.0 a	40.25 a	388.50 a	111.00 a	35.75 a	31.00 a
CV %	13.75	13.26	13.89	16.85	15.36	16.36

Group of means not followed by the same letter in the column do not differ by the Scott Knott test at 5% probability. Nutrient accumulation data transformed by square root of Y + 0.5 - SQRT (Y + 0.5).

Table 3: Micronutrient content and accumulation of the aerial part of winter cover crops

Cover crops	Copper	Zinc	Iron	Manganese	Sodium	Boron
	Content (g kg^{-1})					
Fallow	9.50 a*	30.25 a	672.75 a	122.5 b	47.25 b	13.00 b
Black oat	6.00 c	18.25 b	561.00 a	241.00 a	76.00 b	2.50 c
Vetch	11.00 a	33.50 a	802.75 a	100.75 b	77.50 b	20.25 a
Oilseed radish	5.75 c	28.00 a	554.25 a	85.50 b	78.75 b	18.75 a
Black oat + Vetch	7.75 b	23.50 b	657.25 a	261.00 a	95.00 a	10.75 b
Vetch + Oilseed radish	8.25 b	29.50 a	456.00 a	97.75 b	118.25 a	22.00 a
CV %	14.64	13.45	34.79	23.23	25.98	26.60
Cover crops	**Copper**	**Zinc**	**Iron**	**Manganese**	**Sodium**	**Boron**
	Accumulation (g ha^{-1})					
Fallow	16.25 c*	52.00 c	1,157.50 b	210.50 d	81.50 d	22.50 c
Black oat	41.50 b	126.25 b	3,887.50 a	1,670.00 b	526.50 c	17.50 c
Vetch	60.50 a	184.75 a	4,420.75 a	554.75 c	427.00 c	111.50 b
Oilseed radish	49.75 b	241.50 a	4,779.50 a	737.50 c	679.00 c	161.75 a
Black oat + Vetch	65.00 a	197.00 a	5,504.00 a	2,185.75 a	795.50 b	89.75 b
Vetch + Oilseed radish	76.50 a	272.75 a	4,217.00 a	904.25 c	1,093.50 a	203.25 a
CV %	12.51	13.90	13.37	12.29	13.66	15.43

Stizolobium deeringiznum and sorghum where the accumulation in these species ranged from (2.66 kg ha^{-1} to 11.33 kg ha^{-1}) at different cultivation spacings (25 cm and 50 cm). Larger accumulated amounts of potassium were observed in the cultivation of forage turnip and in both evaluated intercropping. According to Teodoro *et al*. (2011), the potassium accumulation capacity presented by legumes accredits them as a good alternative for the increase of this element in the production system and, in the case of this study, it contributed to the composition of intercrops. The values observed for the potassium accumulation are higher than those found by Giacomini *et al*. (2003). The authors found average accumulation of potassium in the cultivation of oilseed radish (99 kg ha^{-1}). They also noted that, on the average of three years of cultivation, the treatments consisting of intercropped species: 15% black oat + 85% vetch; 30% black oat + 70% vetch; 45% black oat + 55% vetch and 30% black oat + 70% oilseed radish and oilseed radish in single cultivation did not differ from each other, corroborating the results of this study.

For calcium, magnesium and sulfur, cultivation of oilseed radish and oilseed radish intercropped with vetch showed the highest accumulation of these nutrients. Silva *et al*. (2010) found higher accumulation of calcium in crotalaria (71.10 kg ha^{-1}) and pearl millet (56.60 kg ha^{-1}) and magnesium (47.40 kg ha^{-1}) and sulfur (35.00 kg ha^{-1}) in pearl millet. These results are inferior to the accumulation of calcium and sulfur, and higher than magnesium accumulation in this study. However, the accumulated values for calcium and magnesium are higher than those observed by Pacheco *et al*. (2013) for the species *Urochloa ruziziensis*, *Urochloa brizantha*, *Pennisetum glaucum*, *Urochloa ruziziensis* + *Cajanus cajan*. On the other hand, the observed accumulation of magnesium is lower than those obtained by Silva *et al*. (2014) for *Crotalaria juncea* grown in the second year of the crop (50 kg ha^{-1}) and higher than the accumulation of pearl millet, *Mucuna aterrima* and *Cajanus cajan* and pearl millet + *Crotalaria juncea* intercrop. As for sulfur, the same authors observed higher accumulation in *Mucuna aterrima* (58 kg ha^{-1}) and pearl millet + *Mucuna aterrima* intercrop (60 kg ha^{-1}). Those results are higher than those observed in this study.

The largest accumulations of copper were found in vetch crops and its intercropping, and for zinc in the crops of vetch, oilseed radish and in the intercopprings. The largest manganese accumulation was found in black oat + vetch intercropping and for boron, in the single cultivation of oilseed radish and oilseed radish + vetch intercropping. Likewise, Barros *et al*. (2013) found higher accumulations of zinc, boron and copper in legumes than in summer grasses.

CONCLUSIONS

Black oat, oilseed radish and black oat + vetch and vetch + oilseed radish intercropping present the highest dry matter production.

Vetch intercropped with oilseed radish presents the highest accumulation of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, copper, zinc, iron, sodium and boron.

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