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Dry matter production, chemical composition and nutrient accumulation in winter crops

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Some winter crops sown in no-tillage system can represent an important alternative to nutrient cycling. The objective of this work was to evaluate the production of dry matter (DM) and accumulation of nutrients for winter cultivation in the West of Paraná. The experimental design was a randomized block, with four treatments and six replications. The treatments were represented by four different winter crops (oat IPR 126, crambe FMS Brilhante, radish common cultivar and wheat BRS Taruma), and the DM, the contents of C, N, P, K, Ca, Mg and C/N ratio in DM and nutrients accumulation were determied The dry matter production was higher for radish with 4.929,14 kg ha^{-1}. The different winter crops used influenced the contents of C, N and C/N ratio. The other studied characteristics were not influenced. Among the four winter cultivation the radish presented larger production of dry matter. The chemical composition was influenced by the cultivations, the contents of C, N and C/N ratio, consequently in the contribution differentiated in the area. The winter cultivation in the studied conditions influences the accumulation of magnesium.

Key words: Nutrient cycling, decomposition, mineralization.

INTRODUCTION

The winter crops sowed in no-tillage system, have ability to absorb nutrients in subsurface layers, and, then releasing them in the surface layers through decomposition and mineralization of the residue (Torres et al., 2008), and contribute to the efficient use of fertilizers in annual crops succession (Calegari, 2004; Carvalho et al., 2004). These species help in soil conservation, the largest aggregation of particles and for

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Table 1. Chemical characteristics of the soil (0 - 10; 10 - 20 cm), in the experimental area, prior to deployment of winter crop, in Marechal Cândido Rondon.

Layer	P	MO	pH	H+Al	Al^{3+}	K^+	Ca^{2+}	MG^{2+}	SB	CTC	V
cm	mg dm^{-3}	g dm^{-3}	$CaCl_2$	-------------------------$cmol_c$ dm^{-3}-----------------------------							%
0-10	24.49	32.64	4.55	9.40	0.46	0.53	4.56	1.54	6.63	16.02	41.66
10 - 20	25.86	32.64	4.65	8.62	0.34	0.44	5.32	1.67	7.42	16.04	46.32

the protection of the soil surface to the direct impact of the rains (Pacheco et al., 2011).

In addition, winter crops are recommended for prolonging the period of pasture use, as well as increasing the quality and increasing the contribution of biomass, allowing the pasture to supports a greater number of animals (Santos, 2003), promote recovery and the maintenance of soil quality, since they are used as cover crops with the objective of maintaining and increasing the organic matter contents (Kliemann et al., 2006). These can still provide grain production for human and animal consumption (Bortolini et al., 2004), increased sustainability of agricultural systems (Boer et al., 2007), and optimize land use, the infrastructure and workforce allow in diversifying and verticalizar in production (Mello et al., 2004).

The cultivations commonly cultivated are the white oats, oats, rye, the barley, triticale and wheat. These cultivations can also be used as dual-purpose species, producing fodder early and even grains, with low cost, contributing to greater stability in production (Bortolini et al., 2004). Crambe and radish cultivations as winter crops in the western region of Paraná are not yet frequent.

Magalhães et al. (2000) evaluated the relationship between dry mass production and the export of nutrients in soils situated in the cerrado vegetation with several years of use which observed that the production of dry matter, the nutrient contents of the aerial part, and the quantities exported varied with the amount of years of soil use by the forage. The amount of nutrients in plant biomass with high C/N ratio, which release slow and gradual nutrients over time, may reduce the cost of fertilizer use in the next crop for the best use of nutrients contained in decomposing biomass.

The presence of nutrient in the dry biomass of the plants results in less loss due to erosion and leaching, than being directly in the soil, thus, knowing the levels that is important for the management of these nutrients within the cycles of cultivation (Pittelkow et al., 2012). Therefore, the objective of this work was to evaluate the dry matter production and the nutrient contents in cover crops as the oats IPR 126, crambe FMS Brilliant, common radish and BRS Tarumã wheat, grown in Eutrophic Red Latosol (LVe).

MATERIALS AND METHODS

The study was conducted at the Experimental Farm "Professor Antonio Carlos dos Santos Person " (latitude 24°33 ' 22' ' S and longitude 54°03' 24 ' ' W , with an altitude of approximately 400 m) at the Universidade Estadual do Oeste do Paraná - *Campus* Marechal Cândido Rondon in Eutrophic Red Latosol (LVe) (Embrapa, 2013). Table 1 described the chemical and physical characteristics of the area before the experiment. Due to the low V% (percentage of saturation of bases) liming was performed 30 days before sowing at a dosage of 2 Mg ha^{-1} (large 80 %) to raise up to 70%.

The area of conducting the experiment has a history in which for a period of four years, traditionally, the winter corn were grown (for silage production) in the off season and soybeans in the summer crop. These crops were always performed under the no-tillage system. The local climate, classified according to Koppen, is Cfa, subtropical humid mesothermal dry winter with rainfall were distributed throughout the year and in hot summers. The average temperatures of the quarter more cold vary between 17 and 18°C, and the quarter more hot between 28 and 29°C in its turn, the annual temperature ranged between 22 and 23°C. The total average annual precipitation normal pluvial for the region vary from 1600 to 1800 mm. with quarter, more humid presented totals which is between 400 to 500 mm (IAPAR, 2006). The climate data of the experimental period were obtained in automatic climatological station of the University of Paraná, distant approximately 100 m of the experimental area and are presented in Figure 1.

The experiment started in autumn-winter of 2012 and the area has been desiccated in 30 days before sowing, using glyphosate-isopropylamine salt in the dose of 3.0 L ha^{-1} with a volume of 250 L ha^{-1}. The experimental design used was a randomized block and the treatments consisted of 4 different winter crops (IPR 126 oats, Brillante FMS crambe, radish common cultivar and BRS Tarumã wheat) and 6 blocks. Winter crops were sown in the day 19/04/12, with drill seeder, coupled to the tractor on direct sowing system on maize straw. 60 kg ha^{-1} of oats` seed, 15 kg $ha^{-1}$ of crambe` seed, 15 kg ha^{-1} of radish` seeds and 90 kg $ha^{-1}$ of wheat` seeds, with 0.17 m between lines were used. The fertilizer for growing oats, f. radish, fodder wheat and radish, was performed according to CQFSRS/SC (2004). For the correction of soil fertility 200 kgha-1 formulated 8-20-20 (N, P_2O_5 and K_2O, respectively) were used. The fertilization in coverage was carried out using 90 kg ha^{-1} of N as urea.

Sampling for the determination of dry matter and nutrient contents by plants was performed 90 days after sowing of winter crops, in this period the crambe and the radish were at the maturation stage, the oats in the flowering stage and the wheat at the breeding stage. With the aid of a metallic square cast with a known area (0.25 m²) which was randomly released in each plot, all plant material contained inside was collected. After the collection, the material was submitted to drying in an oven with forced ventilation of air under a temperature of 55°C for 72 h, with subsequent weighing for determination of the dry matter.

After drying, the samples were crushed in the mill type Willey, with sieve of 20 meshes, for the determination of concentrations of total C, N, P, K, Ca and Mg. The C was obtained from the determination of organic matter in muffle as described by Silva and Queiroz (2006). To estimate the concentration of C in the samples the concentration of organic matter was divided by 1.72 as

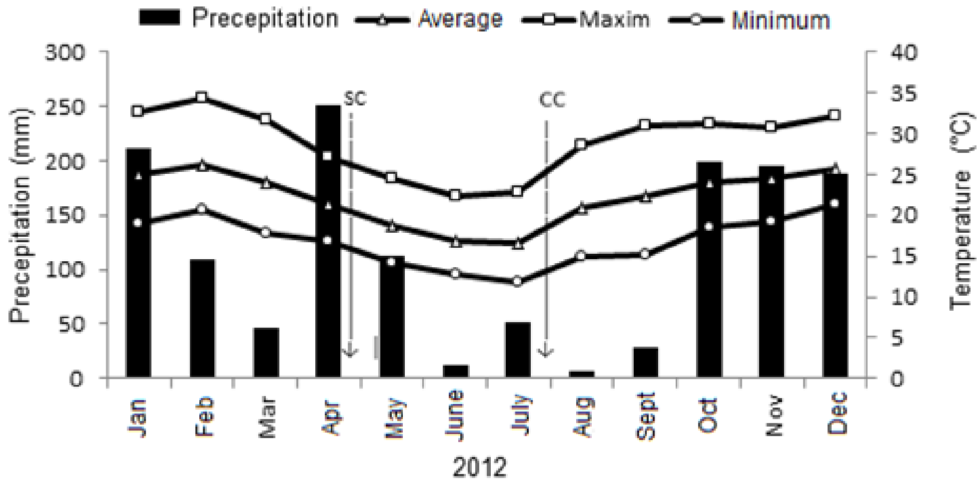

Figure 1. Monthly average temperatures maximum, minimum and average and precipitation accumulated during the months of the experimental period. SC: Seeding of winter crops. CC: collection of the winter crops. (Source: Automatic climatological station of the Nucleus of Experimental Stations of UNIOESTE, Marechal Cândido Rondon-PR).

Table 2. Calculated F values of the dry matter chemical composition of different winter crops, managed under no-tillage system

Source of variation	DF	Dry Matter	K	Ca	MG	P	C	N	Ratio C/N
Crops	3	5.71*	0.65	1.28	1.30	0.89	18.64*	69.20*	14.62*
Block	5	1.17	0.34	0.58	2.29	0.32	0.25	4.15	1.52
Error	15	-	-	-	-	-	-	-	-
CV (%)	-	21.71	35.22	49.68	42.39	37.25	11.20	5.75	14.45

*Significant at 5% probability by the F test, respectively. CV: Coefficient of variation.

recommended by Peixoto et al. (2007). The N was determined by sulfuric digestion and distillation in Kjeldal semi-micro system, while for macronutrient determination, nitroperchloric digestion was carried out, with subsequent reading in an atomic absorption spectrophotometer (Embrapa, 2009).

The accumulation values of N, P, K, Ca and Mg in the aerial part of the plant were obtained by multiplying their concentration in the tissue in the production of DM, being expressed in kg ha^{-1}. The data obtained were submitted to statistical analysis using the SISVAR program (Ferreira, 2011), and the averages compared by the Tukey test at 5% level of probability.

RESULTS AND DISCUSSION

According to the results, there was a significant difference ($p < 0.05$) in the dry matter production of winter crops, as well as changes in carbon (C), nitrogen (N) and relation C/N between the studied cultivation. However, the values of potassium (K), calcium (Ca), magnesium (MG) and phosphorus (P) were not influenced ($p > 0.05$) by treatments (Table 2).

Production of dry matter

For DM there was a significant difference between the studied crops, which radish provided higher dry matter yield than wheat, but similar to oats and crambe (Table 3). The results for the radish are very close to those found by Lima et al. (2007), evaluating the behavior of radish (*Raphanus sativus* L.), found that at the stage of flowering, this culture presented 5,480.5 kg ha^{-1} of dry matter, consisting of a desirable property for a green manure.

The highest production of radish in relation to the wheat due to the cycle of the crops is because the radish has a shorter cycle, presenting its peak production and accumulation of DM earlier in relation to the wheat of double purpose that has a longer cycle. Crusciol et al. (2005) verified the production of 2,938 kg ha^{-1} of dry matter in the aerial part of radish, cultivate Siletina, when the seeding density was 20 kg ha^{-1}. This value was lower than that found in the present study, in which the seeding density was 15 kg ha-1 of fodder radish.

According to Calegari (1998), the radish presents average yield of 3,000 kg ha^{-1} of shoot dry matter, and, even in areas without fertilization, this value may vary between 2,000 and 6,000 kg ha-1 of dry matter in the stage of flowering. Heinz et al. (2011) found the production of dry matter of the aerial part 5.586kg ha^{-1}

Table 3. Production and chemical composition of dry matter, of different winter crops, managed under no-tillage system.

Crops	DM (Kg ha^{-1})	C (g kg^{-1})	N (g kg^{-1})	Ratio C/N	K (g kg^{-1})	Ca (g kg^{-1})	MG (g kg^{-1})	P (g kg^{-1})
Oats	A	112.90^{b}	18.43d	6.16^{b}	20.54	5.23	1.40	0.54
Crambe	3951^{ab}	153.10^{ab}	26.19^{b}	5.86^{b}	22.29	7.08	1.52	0.56
Radish	4929^{a}	185.35^{a}	22.28c	8.46^{a}	16.83	6.17	1.71	0.41
Wheat BRS	2893^{b}	149.09^{ab}	29.23^{a}	5.11^{b}	21.06	4.06	1.04	0.57
Average	4014	150.11	24.03	6.4	20.18	5.64	1.42	0.52

*Medium followed by the same lowercase letter in the column do not differ statistically by the Turkey test (5%).

and 2.688kg ha^{-1} for the radish and the crambe, respectively, observing a 52% higher biomass production of the radish in relation to the crambe on the day of the management. The difference in the dry matter production observed between these works can be attributed to the climatic conditions, soil conditions, the cultivars used or the stage at which the plants were managed.

Nutrients concentration

The values obtained for the total concentration of N in the plants showed significant differences between the four studied crops, among which the N content of the wheat crop was higher (Table 3). The N content of the aerial part of this grass reached 29.23 g kg^{-1}, followed by the crambe with an accumulation of 26.19 g kg^{-1}, radish with 22.28 g kg^{-1} and finally the oat with 18, 43 g kg^{-1}. The oats, despite having a smaller amount of N than the other crops (Borket et al., 2003), may also contain reasonable quantities of N due to the amount of total N contained in biomass as well as the radish by efficiency in nutrient cycling of N in the soil (Aita et al., 2001).

Considering the levels of C found, there were significant differences between crops. The radish presented the highest values with 185.35 g kg^{-1}, differing from crambe and wheat, which presented intermediate values 153.10 and 149.09 g kg^{-1}, respectively and oats with 112.90 g kg $^{-1}$ (Table 3). The no-tillage system favors the sequestration of carbon by plants, since it increases the influx of C via organic material, which due to the minimal mobilization of the soil, shows slow and gradual decomposition, reducing the efflux of C from the ground to the atmosphere, determining the positive balance in the accumulation of C in the soil (Bayer et al., 2006).

For C/N ratio, the significant difference was found for radish in relation to other crops, and in 8.46 for the cultivation of radish. For the C/N ratio the significant difference was found for the radish in relation to the other crops, constituting in 8.46. The C/N ratio has been the most used feature in models to predict the availability of N in the soil during the decomposition of organic materials (Nicolardot et al., 2001). The leguminous have lower C/N ratio in the aerial part, forming a material that presents a C/N ratio lower than that of equilibrium (< 28/1), and is thus a material that during decomposition releases nitrogen to the crop deployed in succession on the crop residues (Diekow et al., 2005).

Radish, has a mean C/N ratio, in the range of 20 to 25 (Giacomoni et al., 2003), and, consequently, a high mineralization rate, comparable to that of leguminous (Amado et al., 2002). This species is also characterized by the behavior of a plant that recycles and provides nutrients, especially nitrogen (Aita and Giacomoni, 2003) and potassium (Giacomoni et al., 2003). In this study, the low value found for C/N ratio for the radish (8.46) is due to the time when the crop management was carried out.

The other chemical elements such as K, Ca, Mg and P studied, did not present significant differences among the crops. The highest concentration of potassium was obtained in the crambe crop with 22.29 g kg $^{-1}$, which also had the highest calcium concentration (7.08 g kg $^{-1}$). The magnesium was found in greater quantity in the culture of the radish that showed 1.71 g kg^{-1} of this nutrient. The phosphorus was found at higher concentrations in the wheat crop with 0.57 g kg^{-1} (Table 3).

Nutrient accumulation

For the accumulated values of the nutrients in the dry matter there was difference ($p < 0.05$) only for the values obtained of MG, already for the accumulation of C; N; K; Ca and P which has no difference (Table 4). In relation to magnesium the wheat crop accumulated a highest amount (9.15 kg ha^{-1}) when compared to the crambe (3.96 kg ha^{-1}) and the radish (4.31 kg ha^{-1}) and was similar to oats (5.50 kg ha^{-1}).

Kubo et al. (2007), with the objective of verifying the dry matter production and the nutrient accumulation by the crops of white oats, wheat and black oats verified that the greater accumulated amount of the nutrient phosphorus was in black oat with and without fertilization of N (9.71 and 10.95 kg ha^{-1}, respectively), which were higher significantly in wheat (0.76 kg ha^{-1}) and white oat (0.39 kg ha^{-1}). And for the potassium accumulated obtained the

Table 4. Accumulation of nutrients in dry matter, from different winter crops, managed under no-tillage system.

Crops	C (kg ha^{-1})	N (kg ha^{-1})	K (kg ha^{-1})	Ca (kg ha^{-1})	MG (kg ha^{-1})	P (kg ha^{-1})
Oats	614.62	114.74	80.11	24.99	5.50^{ab}	2.06
Crambe	595.54	81.10	78.60	17.87	3.96^{b}	1.71
Radish	571.26	92.24	80.59	20.14	4.31^{b}	2.13
Wheat BRS	630.08	91.11	81.23	30.46	9.15^{a}	2.34

*Medium followed by the same lowercase letter in the column does not differ statistically by the Tukey test (5%).

highest amount in black oat with N fertilizer (216 kg ha^{-1}) followed by black oat without fertilization of N (212 kg ha^{-1}) were significantly higher than in the white oats (48.38 kg ha^{-1}) and wheat (38.63 kg ha^{-1}).

The accumulation of N in this study although not significant, was higher in the culture of oats which presented 114.74 kg ha-1, differs from the results found by Monteiro et al., (2004), with the aim of assessing nutrient accumulation of species intercropped or grown alone which verified that in isolated cultivation, the amount of N accumulated by vetch in the three years was superior to that of oats and, in the second year alone, was superior to the radish. In the years evaluated, the accumulation of N by the aerial part of the leguminous reached 113, 91 and 63 kg ha^{-1} in 1998, 1999 and 2000, respectively, against 101, 67 and 63 kg ha $^{-1}$ in the radish and only 59, 57 e 42 kg ha^{-1} in oats.

Conclusions

Among the four winter crops the radish had higher dry matter production, crambe and oats showed intermediate production while wheat was the crop of lower production. The chemical composition was influenced by the cultures, in the C, N and C/N ratio, consequently in the differentiated contribution in the area.

Winter crops, under the conditions studied, influence the accumulation of magnesium.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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