BIOMASS DECOMPOSITION AND NUTRIENT RELEASE FROM BLACK OAT AND HAIRY VETCH RESIDUES DEPOSITED IN A VINEYARD[1]

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SUMMARY

A significant quantity of nutrients in vineyards may return to the soil each year through decomposition of residues from cover plants. This study aimed to evaluate biomass decomposition and nutrient release from residues of black oats and hairy vetch deposited in the vines rows, with and without plastic shelter, and in the between-row areas throughout the vegetative and productive cycle of the plants. The study was conducted in a commercial vineyard in Bento Gonçalves, RS, Brazil, from October 2008 to February 2009. Black oat (*Avena strigosa*) and hairy vetch (*Vicia villosa*) residues were collected, subjected to chemical (C, N, P, K, Ca, and Mg) and biochemical (cellulose - Cel, hemicellulose - Hem, and lignin - Lig content) analyses, and placed in litter bags, which were deposited in vines rows without plastic shelter (VPRWS), in vines rows with plastic shelter (VPRS), and in the between-row areas (BR). We collected the residues at 0, 33, 58, 76, and 110 days after deposition of the litter bags, prepared the material, and subjected it

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to analysis of total N, P, K, Ca, and Mg content. The VPRS contained the largest quantities and percentages of dry matter and residual nutrients (except for Ca) in black oat residues from October to February, which coincides with the period from flowering up to grape harvest. This practice led to greater protection of the soil surface, avoiding surface runoff of the solution derived from between the rows, but it retarded nutrient cycling. The rate of biomass decomposition and nutrient release from hairy vetch residues from October to February was not affected by the position of deposition of the residues in the vineyard, which may especially be attributed to the lower values of the C/N and Lig/N ratios. Regardless of the type of residue, black oat or hairy vetch, the greatest decomposition and nutrient release mainly occurred up to 33 days after deposition of the residues on the soil surface, which coincided with the flowering of the grapevines, which is one of the phenological stages of greatest demand for nutrients.

Index terms: cover crops, nutrient cycling, plastic shelter, *Vitis sp.*

RESUMO: *DECOMPOSIÇÃO E LIBERAÇÃO DE NUTRIENTES DE RESÍDUOS DE AVEIA- PRETA E ERVILHACA EM VINHEDO*

*Em áreas de vinhedos, uma significativa quantidade de nutrientes pode retornar anualmente ao solo durante a decomposição de resíduos de espécies de plantas de cobertura. Este trabalho objetivou avaliar a decomposição e liberação de nutrientes de resíduos de aveia-preta e ervilhaca depositados nas linhas de plantio de videiras sem e com cobertura plástica e nas entrelinhas. Este estudo foi conduzido em um vinhedo comercial em Bento Gonçalves, RS, no período de outubro de 2008 a fevereiro de 2009. Resíduos de aveia-preta (*Avena strigosa*) e ervilhaca (*Vicia villosa*) foram coletados, submetidos a análises químicas (C, N, P, K, Ca e Mg) e bioquímicas (cellulose - Cel, hemicellulose - Hem e lignina - Lig) e acondicionados em bolsas de decomposição, que foram depositadas em linhas de plantio sem cobertura plástica (LPSCP), linhas de plantio com cobertura plástica (LPCCP) e entrelinha (EL). Em 0, 33, 58, 76 e 110 dias depois da deposição das bolsas de decomposição, os resíduos foram coletados, preparados e submetidos à análise dos teores totais de N, P, K, Ca e Mg. As maiores quantidades e porcentagens de matéria seca e nutrientes remanescentes, com exceção do Ca, em resíduos de aveia-preta, no período de outubro até fevereiro, que coincide do florescimento até a colheita da uva, foram observadas na LPCCP, o que promoveu maior proteção da superfície do solo, evitando o escoamento superficial de solução derivada das entrelinhas; entretanto, retardou a ciclagem de nutrientes. A taxa de decomposição e liberação de nutrientes de resíduos de ervilhaca, de outubro até fevereiro, não foi influenciada pela posição de deposição dos resíduos no vinhedo, o que pode ser atribuído, especialmente, aos menores valores de relação C/N e Lig/N. Independentemente do tipo de resíduo, aveia-preta ou ervilhaca, a maior taxa de decomposição e liberação de nutrientes aconteceu, especialmente, até os 33 dias após a deposição dos resíduos na superfície do solo, o que coincidiu com o florescimento das videiras, que é um dos estágios fenológicos de maior demanda de nutrientes.*

*Termos de indexação: plantas de cobertura, ciclagem de nutrientes, cobertura plástica, V*itis sp.

INTRODUCTION

Most of the vineyards in the South of Brazil are established on soils on rolling or rugged land. Therefore, to dissipate the kinetic energy of raindrops, minimize transfer of the soil solution and particles through surface runoff, and promote cycling of nutrients, volunteer plant species are maintained between the rows of the vineyards, or winter cover crop species are sown, among which are hairy vetch (*Vicia villosa*) and black oats (*Avena strigosa*). The shoots of these species are cut throughout the cycle and the residues are deposited on the soil surface between the plant rows. However, part of the residues may also be deposited on the grapevine plant rows where the weeds and soil cover crops are desiccated to avoid competition for water and nutrients. In contrast, in vineyards with table grape and wine varieties, a plastic shelter over the plant rows has been used, among other things, to decrease rainfall on plant shoots, which restricts free water on grape leaves and fruit, minimizing infection from fungal leaf diseases and, consequently, ensuring production and quality grapes (Chavarria et al., 2007, 2009; Chavarria & Santos, 2009). Nevertheless, the rainwater that falls on the plastic shelter over the grapevine plant row is directed to the area between the rows. Thus, the plant row normally has less water available in the soil, which may decrease nutrient uptake (Chavarria et al., 2009) and also reduce soil microbial activity (Gama-Rodrigues et al., 2007), retarding decomposition and nutrient release from residues of soil cover plants which are deposited on the grapevine row. If this occurs, the residues remain for a longer time on the soil surface, which is desirable, because this may minimize sediment runoff from between the rows. However, nutrient cycling may be retarded and this may even affect nutrient availability to the grapevines.

Throughout decomposition of the residues deposited on the soil surface, organic carbon (OC) is used as an energy source by the microbial population, part of it being released in the form of CO_2 to the atmosphere. Part of the nutrients contained in the residues, such as N, P, K, Ca, and Mg, are released to the soil, increasing their availability, and they may be taken up by the grapevine during its cycle. However, residue decomposition and, consequently, nutrient release is dependent on the edaphic and climatic conditions, such as temperature, moisture, pH values, and oxygen and nutrient contents in the soil (Paul & Clark 1989; Trinsoutrot et al., 2000; Agehara & Warncke, 2005; Cabrera et al., 2005), as well as on the chemical composition of the plant matter, especially on lignin and cellulose contents and on the values of ratios such as C/N, lignin/N, and lignin/P (Trinsoutrot et al., 2000; Giacomini et al., 2003; Carvalho et al., 2009; Matos et al., 2011; Marcelo et al., 2012). In general, residues with greater lignin content and values of the C/N and lignin/N ratio, like those of black oats, are decomposed and release nutrients to the soil in a slower and more gradual way (Giacomini et al., 2003; Brunetto et al., 2005; Crusciol et al., 2008). In comparison, decomposition and nutrient release is faster and more intense in those residues with high N and less lignin content and lower values of the C/N and lignin/N ratio, like hairy vetch (Aita & Giacomini 2003; Doneda et al., 2012); and most nutrients in the residues may be released in the first 30 days after deposition (DAD) on the soil surface (Aita & Giacomini, 2003; Doneda et al., 2012).

In the South of Brazil, various studies have been performed to evaluate biomass decomposition and nutrient release from residues of soil cover plants, alone or intercropped, especially mixing grasses and legumes within a no-tillage system of annual grain crops (Giacomini et al., 2003; Aita et al., 2004). However, studies evaluating biomass decomposition and nutrient release from volunteer species, and particularly from grasses and legumes, in vineyards are scarce for traditional grape-growing regions of the world (Nikolaidou et al., 2010). In the South of Brazil, there are no studies evaluating biomass decomposition and nutrient release from residues deposited in different positions of the vineyard, with and without plastic shelter. This study aimed to evaluate biomass decomposition and nutrient release from residues of black oats and hairy vetch deposited in the vines rows, with and without plastic shelter, and in the between-row areas throughout the vegetative and productive cycle of the plants.

MATERIALS AND METHODS

Characterization of the study area

The experiment was conducted from October 2008 to February 2009, corresponding to the flowering period up to grape maturity. The experiment was set up in a commercial vineyard (Latitude 29° 09' 44" S and Longitude 51° 31' 50" W) in Bento Gonçalves, RS, Brazil. The experimental vineyard was established in 2004 using seedlings of the Niagara Rosada cultivar, with Paulsen 1103 rootstock. The vines were planted at a density of 3,333 plants per hectare (2.5 × 1.20 m) and trained in an overhead trellis system. Climate in the region is the subtropical Cfa type. The coldest months are June and July, with a mean low temperature of 8 °C and a mean high temperature of 17 °C. The hottest months are January and February, with a mean low temperature of 17 °C and mean high temperature of 26 °C. The rainfall and temperature data obtained while carrying out the experiment are shown in figure 1. The soil was classified as a Neossolo Litólico (Entisol) (Embrapa, 2006). In the 0-20 cm layer before setting up the experiment, the soil contained 220 g kg^{-1} of clay, 29.0 g kg^{-1} of organic matter, and pH in water of 5.9; 14.2 mg kg^{-1} of available P and 145 mg kg^{-1} of exchangeable K (extracted by Mehlich-1); 9.2 $cmol_c$ kg^{-1} of Ca^{2+}, 1.8 $cmol_c$ kg^{-1} of Mg^{2+}, and 1.8 $cmol_c$ of Al^{3+} (extracted by 1 mol L^{-1} KCl); and 17.7 $cmol_c$ of $CEC_{pH7.0}$.

Black oats was sown in seven between-row areas of the vineyard and hairy vetch in another seven between-row areas in May 2008 at the rate of 120 and 40 kg ha^{-1} of black oat and hairy vetch seed, respectively. Seeds were deposited on the soil surface without incorporation. After sowing, volunteer plants,

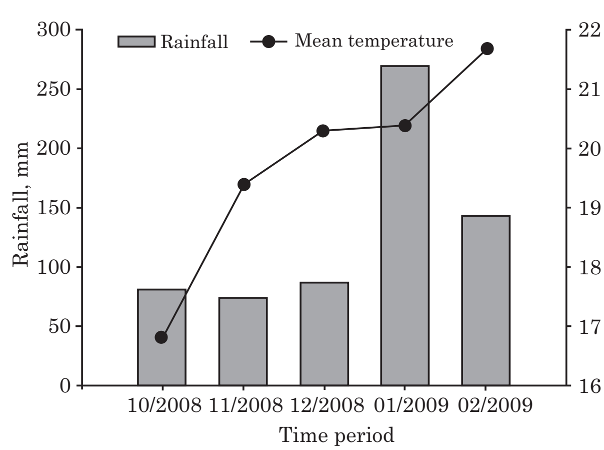

Figure 1. Mean monthly temperature and rainfall values observed while carrying out the experiment.

such as beggar-ticks (*Bidens pilosa* L.), papuã (*Brachiaria plantaginia*) and hairy crabgrass (*Digitalia sanguinalis*), were cut for the purpose of covering the seeds of the two cover crops.

In the last week of September 2008, with the aid of a 0.5 × 0.5 m (0.25 m^2) metal frame, sample shoots of the two cover crops were cut at ground level, dried in a forced air circulation laboratory oven at 65 °C until constant weight, and weighed for quantification of dry matter production. In the first week of October 2008, using a 0.5 × 0.5 m (0.25 m^2) metal frame, shoots of each cover crop were once more cut at ground level. The fresh matter of the shoots was homogenized separately for each species, and then part was set aside to be added to the litter bags. The other part was dried in a forced air circulation laboratory oven at 65 °C until constant weight, passed through a Willey type mill and sieve with a 40 mesh screen, and set aside for analyses of total and soluble nutrients, cellulose, hemicellulose, and lignin content (Table 1).

Experimental design, treatments, and deposition of litter bags

A randomized block experimental design with a 3 × 2 factorial arrangement was used in a split-plot in time system, with three replications. The factors assessed consisted of placement of the residues (in the vine plant row with plastic shelter - VPRS, in the vine plant row without plastic shelter - VPRWS, and in the between-row areas - BR), and the species used (black oats and hairy vetch). Split-plots were set up for five time periods (0, 33, 58, 76, and 110 days after deposition of the residues) for collection of the litter bags. The period of 0, 33, 58, 76, and 110 days after deposition (DAD) of the residues on the soil correspond approximately to flowering, end of flowering, berry filling, maturation, and grape harvest.

Part of the fresh matter of the shoots of the two cover crop species were placed in litter bags. The litter bags were created with 1 mm mesh nylon fabric and dimensions of 0.4 × 0.4 m, occupying an area of 0.16 m^2. A total of 24 litter bags were deposited on the soil surface and in the projection of the grapevine canopy in the VPRS. The plastic shelter consisted of transparent woven plastic sheeting, waterproofed with low density polyethylene, with a thickness of 160 µm and width of 2.65 m; 24 litter bags were deposited in the VPRWS and 24 litter bags were deposited in the BR of grapevines without plastic shelter. The litter bags were held on the soil using iron bars to avoid possible displacement caused by wind. Each litter bag had 120.44 g of dry matter (DM) of black oats, equivalent to 845.48 g of fresh matter (which corresponds to 7527.5 kg ha^{-1} DM) or 31.63 g of DM of hairy vetch, equivalent to 210.48 g of fresh matter (which corresponds to 1977 kg ha^{-1} DM). Six litter bags with black oat residue and six litter bags with hairy vetch residue were collected for each time period. The residues were removed from each litter bag and, soon after, soil particles adhering to the residues were removed using a brush. The residues were washed immediately with distilled water, then washed with a 0.1 mol L^{-1} HCl solution for 2 min, and once more washed in distilled water. Soon afterwards, the residues were dried in a forced air circulation laboratory oven at 65 °C, weighed for determination of DM, passed through a Willey type mill and a sieve with a 40 mesh screen, and set aside for analyses.

Mineral nutrient analysis and extraction of cellulose, hemicellulose and lignin

In the residues deposited on the soil surface, the following factors were analyzed: total organic C, N, P, K, Ca, and Mg contents (Tedesco et al., 1995), and cellulose (Cel), hemicellulose (Hem), and lignin (Lig) contents (van Soest, 1963). The C/N, Cel/Lig, and Lig/N ratios were calculated. Total N, P, K, Ca, and Mg contents were analyzed (Tedesco et al., 1995) in the different collection time periods in the residues removed from the litter bags.

Statistical analysis

Decomposition of the DM of the residues and nutrient release were estimated by the variation of the initial quantity of DM and N, P, K, Ca, and Mg content in the residue in relation to the quantity and content remaining in the litter bags in each collection period. The results for the residual percentage of each variable were fitted by the exponential mathematical model described by Wieder & Lang (1982) and used by Thomas & Asakawa (1993), Torres et al. (2005), and Boer et al. (2007), $y = y_o^{\exp(-kt)}$, in which y = the quantity of DM or nutrient remaining after a period of time t, in days; y_o = the initial quantity of DM or nutrient; and k = the decomposition constant. Half-life ($t^{½}$ = 0.693/k) was calculated with the value of k (Paul & Clark, 1989); half-life expresses the period of time necessary for half of the residues to decompose

Table 1. Composition of the crop residues of black oats and hairy vetch placed in litter bags

Specie	Cel[1]	Lig	Hem	C	N	P	K	Ca	Mg	C/N	Cel/Lig	Lig/N
	g kg^{-1} of dry matter											
Black oats	462	91.2	278.4	439	16.5	7.8	2.8	2.3	0.8	26.6	5.1	55.3
Hairy vetch	284	75.7	101.2	425	38.3	5.2	3.1	1.9	0.7	11.0	3.8	19.8

[1] Cel: cellulose; Hem: hemicellulose; Lig: lignin.

and for half of the nutrients contained in the residues to be released.

The results of DM and nutrient content in each time period of collection of the litter bags were subjected to analysis of variance and, when significant, the mean values were compared by the Scott-Knott test at 5 %.

RESULTS AND DICUSSION

The residual DM of the black oat and hairy vetch residues in the vine plant row without plastic shelter (VPRWS), in the vine plant row with plastic shelter (VPRS), and in the between-row areas (BR) decreased over time (Tables 2 and 3; Figures 2 and 3). Black oats exhibited the greatest quantities of remaining residue in all the collection time periods in the VPRS (Table 2). The remaining quantity of residue of black oats in the VPRWS, VPRS, and BR at 33 DAD was 36, 13. and 21 %; but at 110 DAD, remaining residue was found to be approximately 10, 21, and 9 %, respectively, showing that decomposition in the environments with protection is less. Thus, the half-lives ($t^{1/2}$) calculated from these residues in the VPRWS, VPRS, and BR were 14.14, 31.50, and 19.25 days, respectively (Table 3). As for the hairy vetch residues, the residual quantity was similar in the three systems studied (Table 2), for, at 33 DAD, a remainder of 12, 15, and 10 % was observed in the VPRWS, VPRS, and BR; however, at 110 DAD, there was a remainder of 3, 5, and 4 %, respectively. The half-lives ($t^{1/2}$) calculated for these residues in the VPRWS, VPRS, and BR were 12.38, 13.86, and 11.00 days, respectively.

Microbial activity and the removal of soluble compounds by water is responsible for decomposition of the residues and consequent reduction in residual DM (Christensen et al., 1985; Musvoto et al., 2000). This may have been promoted by rising air and soil temperature and by rainfall in the period of the experiment (Figure 1) (Torres et al., 2005; Espíndola et al., 2006). The greater quantities and percentages of DM remaining, as well as $t^{1/2}$ values calculated for black oat residues deposited in the VPRS, as compared to the VPRWS and BR (Tables 2 and 3, Figures 2 and 3), probably occurred because the rainwater that fell on the plastic shelter was directed to the BR. Therefore, the soil of the VPRS exhibits lower water availability in comparison to the BR or even the VPRWS (Chavarria et al., 2009). Lower water availability in the soil reduces microbial activity and, consequently, the crop residue decomposition rate (Gama-Rodrigues et al., 2007). Thus, it is expected that grapevines grown in VPRS take up a smaller quantity of water and nutrients, as was diagnosed by Chavarria et al. (2009) through the lower nutrient content in the grapevine leaves. However, for the hairy vetch residues, the equal quantities and percentages of residual DM in the VPRWS, VPRS, and BR (Tables 2 and 3; Figures 2 and 3) may also be attributed to the smaller quantity of material contained in the litter bags deposited on the soil surface in relation to the litter bags of the black oats. Thus, there may have been a smaller surface of contact of the residues with the soil, hindering decomposition (Carneiro et al., 2008). Even so, the decomposition of the hairy vetch residues occurred more quickly in all the positions of the vineyard where it was deposited, which must have occurred because of its low C/N ratio (Table 1). Normally the residue decomposition rate on the soil surface is explained by the C/N ratio (Isaac et al., 2000; Hadas et al., 2004). In this study, the C/N ratio of the hairy vetch was 11.0 and of black oats, 26.6. Thus, as Moreira & Siqueira (2006) and Silva et al. (2008) report, residues with a C/N ratio less than 20 are more easily colonized by the microbial population because there is more N available. This increases the mineralization of components of the residue and, consequently, there is less residual DM (Chaves et al., 2004). The hairy vetch residues also have lower lignin content, which is reflected in lower values of the Cel/Lig and Lig/N ratio when compared to black oats (Table 1). In residues with lower lignin content, the cellulose of the cell wall has less mechanical protection against degradation (Vanlauwe et al., 1997).

The residual N of the black oat and hairy vetch residues in the VPRWS, VPRS, and BR decreased over time (Tables 2 and 3; Figures 2 and 3); but, for black oats, the greatest quantities of residual N in all the collection time periods were observed in the VPRS (Table 2), similar to that which occurred to the residues. In the black oat residue in the VPRWS, VPRS, and BR at 33 DAD, there was 12, 29, and 17 % of residual N, but at 110 DAD, approximately 8, 12, and 5 % of residual N. The greatest contents are always observed in the protected environments. The $t^{1/2}$ in the residues in the VPRWS, VPRS, and BR were 13.08, 23.10, and 15.40 days, respectively (Table 3). But for the hairy vetch residues, the quantity of residual N was the same in the VPRWS, VPRS, and BR (Table 2). At 33 DAD in the VPRWS, VPRS, and BR, there was 10, 12, and 8 % of residual N; however, at 110 DAD, approximately 2, 3, and 2 % of residual N was observed. The $t^{1/2}$ times in the residues in the VPRWS, VPRS, and BR were very similar, 10.88, 11.55, and 10.04 days, respectively; but, in any case, the protected environment retards decomposition of the plant matter and nutrient release.

The reduction in the quantity and percentage of residual N in the cover plant residues implies an increase in mineral N in the soil (Aita et al., 2004). It should be noted that in this study, already at 33 DAD, most of the N of the black oat residues, and especially of the hairy vetch residues, was released to the soil. This resulted in an average addition of 103 kg ha^{-1} N through the black oats at 33 DAD, whereas the hairy vetch residue released 67 kg ha^{-1} N on average. The period of 33 DAD coincides with the flowering of the grapevines, and this is one of the phenological stages with greatest production of fine, white roots, which are responsible for greater water and nutrient uptake from the soil. Thus, it is expected that most of the N derived from the residues in decomposition may be taken up by the grapevines, which may be one of the possible explanations for the lack of response in berry yield in grapevines subjected to N fertilization, whether through use of urea or organic compost (Brunetto et al., 2009; 2012). Nitrogen acquisition through cover plants is not derived only from remobilization of soil N, but there is also the

Table 2. Quantity of dry matter, N, P, K, Ca and Mg in black oat and hairy vetch residues collected at different times in the vine plant row without plastic shelter (VPRWS), in the vine plant row with plastic shelter (VPRS), and in the between-row area (BR) in a Niagara cultivar vineyard

Residue	Position	Day after deposition of the litter bags on the soil surface				
		0	33	58	76	110
				Dry matter (kg ha^{-1})		
Black oats	VPRWS	7527.5 a	1017.5 c	942.5 c	779.4 b	757.5 b
	VPRS	7527.5 a	2728.1 a	1978.1 a	1641.8 a	1555.6 a
	BR	7527.5 a	1716.8 b	1420.6 b	883.8 b	695.0 b
Hairy vetch	VPRWS	2287.0 a	275.9 a	216.7 a	131.8 a	82.2 a
	VPRS	2287.0 a	337.7 a	243.9 a	185.5 a	123.0 a
	BR	2287.0 a	251.4 a	177.3 a	133.2 a	86.9 a
				N (kg ha^{-1})		
Black oats	VPRWS	124.2 a	13.2 c	11.2 c	9.1 b	8.7 b
	VPRS	124.2 a	30.3 a	21.0 a	15.4 a	13.1 a
	BR	124.2 a	18.3 b	14.1 b	7.7 c	5.9 c
Hairy vetch	VPRWS	75.7 a	8.1 a	5.7 a	3.4 a	2.1 a
	VPRS	75.7 a	9.4 a	5.7 a	3.4 a	2.1 a
	BR	75.7 a	6.8 a	4.7 a	3.2 a	1.4 a
				P (kg ha^{-1})		
Black oats	VPRWS	58.2 a	3.6 c	1.9 b	1.1 b	0.7 b
	VPRS	58.2 a	13.8 a	3.4 a	2.4 a	1.8 a
	BR	58.2 a	5.6 b	1.9 b	1.0 b	0.8 b
Hairy vetch	VPRWS	10.3 a	1.0 a	0.3 a	0.2 a	0.1 a
	VPRS	10.3 a	1.3 a	0.3 a	0.2 a	0.1 a
	BR	10.3 a	0.7 a	0.2 a	0.1 a	0.1 a
				K (kg ha^{-1})		
Black oats	VPRWS	21.1 a	1.3 b	0.8 b	0.6 b	0.5 b
	VPRS	21.1 a	5.5 a	3.8 a	2.3 a	1.8 a
	BR	21.1 a	1.4 b	1.2 b	0.8 b	0.4 b
Hairy vetch	VPRWS	6.1 a	0.3 a	0.2 a	0.1 a	0.1 a
	VPRS	6.1 a	0.5 a	0.3 a	0.2 a	0.1 a
	BR	6.1 a	0.2 a	0.2 a	0.1 a	0.1 a
				Ca (kg ha^{-1})		
Black oats	VPRWS	17.3 a	1.3 b	0.7 b	0.3 a	0.2 a
	VPRS	17.3 a	2.1 a	1.5 a	0.4 a	0.3 a
	BR	17.3 a	0.8 c	0.6 b	0.3 a	0.1 a
Hairy vetch	VPRWS	3.8 a	0.7 a	0.1 a	0.1 a	0.1 a
	VPRS	3.8 a	0.4 a	0.1 a	0.1 a	0.1 a
	BR	3.8 a	0.6 a	0.1 a	0.1 a	0.1 a
				Mg (kg ha^{-1})		
Black oats	VPRWS	6.0 a	0.4 b	0.3 b	0.3 b	0.2 b
	VPRS	6.0 a	1.1 a	0.8 a	0.5 a	0.4 a
	BR	6.0 a	0.4 b	0.2 b	0.2 b	0.1 b
Hairy vetch	VPRWS	1.38 a	0.1 a	0.1 a	0.1 a	0.1 a
	VPRS	1.38 a	0.2 a	0.1 a	0.1 a	0.1 a
	BR	1.38 a	0.1 b	0.1 a	0.1 a	0.1 a

Mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test at 5 %.

contribution of biological fixation, both symbiotic, as in hairy vetch, and asymbiotic, as in black oats (Franche et al., 2009).

The residual P of the black oat and hairy vetch residues, as well as all the other nutrients, decreased over time in the three systems evaluated (Tables 2 and 3; Figures 2 and 3). For the black oat residues, the greatest quantities of residual P in all the collection periods were also observed in the VPRS (Table 2), but already at 33 DAD, 6, 23, and 9 % of residual P was observed in the VPRWS, VPRS, and BR, and at 110 DAD, it was practically exhausted, with only 1, 3, and 1 % of residual P, respectively. The $t^{1/2}$ calculated were 8.56, 15.40, and 10.04 days, respectively (Table 3). As for the hairy vetch residues, the quantities of residual P at 33 DAD in the VPRWS, VPRS, and BR showed values of 6, 12, and 6 % of P, and at 110 DAD, less than 1 % remained. The $t^{1/2}$ calculated were 8.56, 10.83, and 8.56 days (Table 2).

The greater rate of P release from the residues must have occurred because most of the P in the plant tissue is found in the vacuole of the cell in the form of inorganic P and monoesters, which are soluble in water (Giacomini et al., 2003) and, for that reason, more easily released (Figure 1). The other water-soluble forms of residual P, such as diesters (nucleic acids, phospholipids, and phosphoproteins), are released by the action of the microbial population (Frossard et al., 1995; Giacomini et al., 2003). The greater quantity and percentage of residual P in the black oat residues deposited in the row with plastic shelter may be attributed to the greater quantity and residual percentage of DM (Tables 2 and 3). It should be highlighted that at 33 DAD, most of the P of the black oat residues is released to the soil, adding approximately 50 kg ha^{-1} P. The hairy vetch residues added an average of 9.25 kg ha^{-1} P. This P comes to be part of the labile fraction or is incorporated in other forms present in the soil.

Table 3. Parameters of the models fitted ($y = y_o e^{-kt}$) to the values of residual dry matter (DM), N, P, K, Ca, and Mg; the half-life time (t½) of each compartment, and R^2 values for the hairy vetch and black oat residues deposited in the vine plant row without plastic shelter (VPRWS), in the vine plant row with plastic shelter (VPRS), and in the between-row area (BR)

	Parameter of the decomposition equation							
	Hairy vetch				Black oats			
	y_o (1)	k (2)	t½	R^2	y_o	k	t½	R^2
	%	g g^{-1}	day		%	g g^{-1}	day	
				DM				
VPRWS	99.74	0.056*	12.38	0.99*	99.33	0.049*	14.14	0.96*
VPRS	99.56	0.050*	13.86	0.98*	99.68	0.022*	31.50	0.92*
BR	99.83	0.063*	11.00	0.99*	98.60	0.036*	19.25	0.96*
				N				
VPRWS	99.87	0.064*	10.83	0.99*	99.57	0.053*	13.08	0.97*
VPRS	99.85	0.060*	11.55	0.99*	99.28	0.030*	23.10	0.96*
BR	99.72	0.069*	10.04	0.99*	99.40	0.045*	15.40	0.98*
				P				
VPRWS	99.98	0.081*	8.56	0.99*	99.98	0.081*	8.56	0.99*
VPRS	99.99	0.064*	10.83	0.99*	100.06	0.045*	15.40	0.99*
BR	99.99	0.081*	8.56	0.99*	99.97	0.069*	10.04	0.99*
				K				
VPRWS	99.98	0.087*	7.97	0.99*	99.97	0.080*	8.66	0.99*
VPRS	99.95	0.073*	9.49	0.99*	99.02	0.035*	19.80	0.97*
BR	99.99	0.099*	7.00	0.99*	99.95	0.077*	9.00	0.99*
				Ca				
VPRWS	99.98	0.077*	9.00	0.99*	99.96	0.074*	9.37	0.99*
VPRS	99.97	0.066*	10.5	0.99*	99.87	0.059*	11.75	0.99*
BR	99.99	0.088*	7.88	0.99*	99.98	0.089*	7.79	0.99*
				Mg				
VPRWS	99.95	0.069*	10.04	0.99*	99.95	0.076*	9.12	0.99*
VPRS	99.96	0.068*	10.19	0.99*	99.44	0.044*	15.75	0.98*
BR	99.99	0.106*	6.54	0.99*	99.97	0.079*	8.77	0.99*

(1) Initial proportion of matter. (2) Decomposition constant. * significant at 5 % by the Scott-Knott test.

The decline of K in the black oat residues was also less pronounced in the VPRS (Tables 2 and 3; Figures 2 and 3), where 22 % of the total remained at 33 DAD, falling to 7 % at 110 DAD, a content which had already been reached in the other systems at 33 DAD. The $t^{1/2}$ calculated in the VPRWS, VPRS, and BR were 8.66, 19.80, and 9.00 days, respectively (Table 3). For the hairy vetch residues, the quantity of residual K was the same in the VPRWS, VPRS, and BR (Table 2). There was a rapid release, because at 33 DAD in the VPRWS, VPRS, and BR, there was 5, 7, and 3 % of residual K; however, at 110 DAD, residual K was practically nil. The $t^{1/2}$ calculated were less than 10 days (Table 2). This rapid release of K must have occurred because it is a cation that is not associated with any structural component in the plant tissue (Rosolem et al., 2003; Boer et al., 2007), and it is normally found in the soluble form in residues of cover plant species deposited on the soil surface (Giacomini et al., 2003).

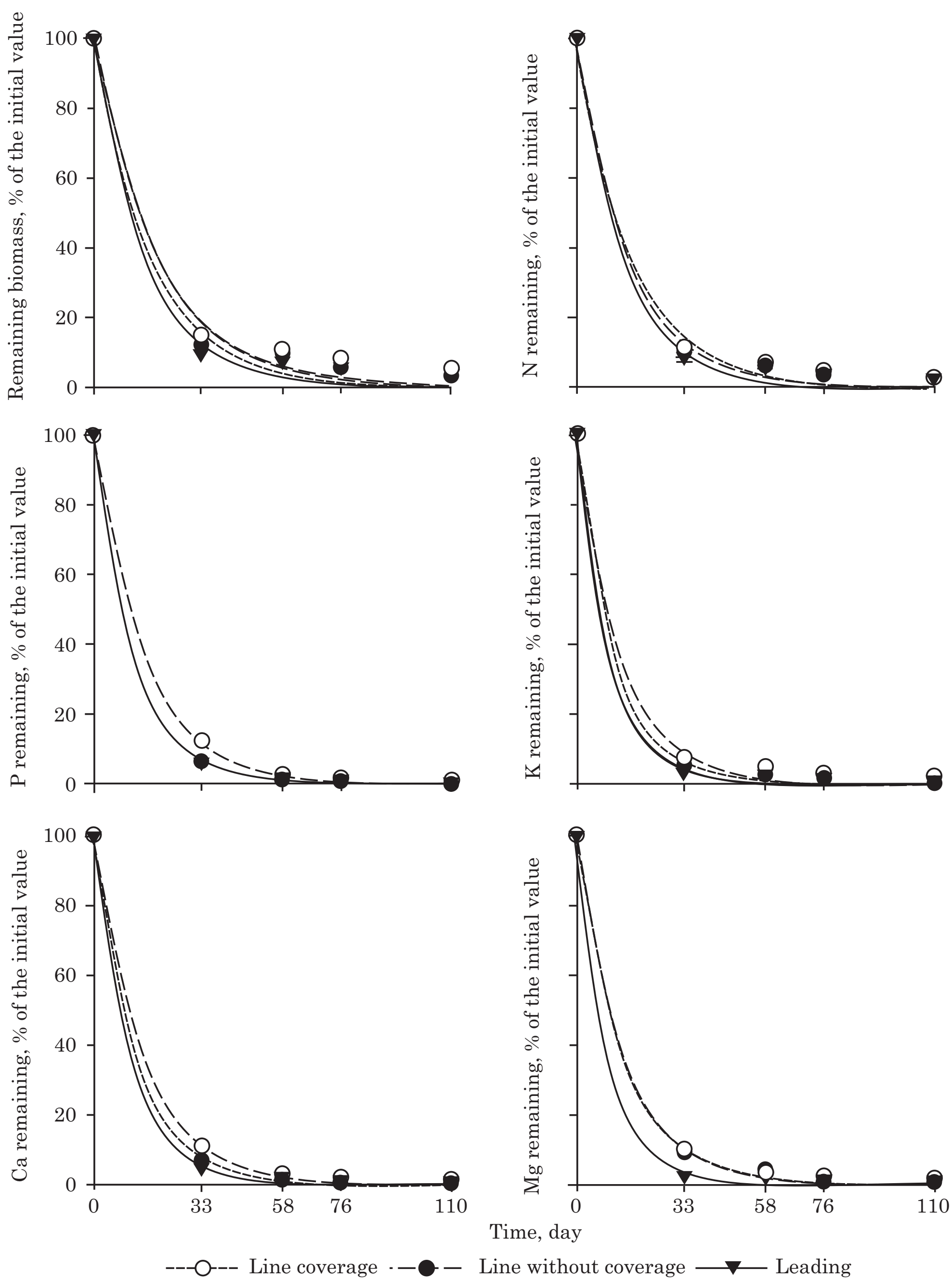

Figure 2. Remaining biomass, and N, P, K, Ca, and Mg remaining from hairy vetch in decomposition in the vine plant row without plastic shelter (VPRWS), in the vine plant row with plastic shelter (VPRS), and in the between-row area (BR). Values expressed as % of initial values. Vertical bars represent standard errors. The equations and significance of the adjustments are shown in table 3.

The quantities of Ca remaining at 33 DAD were also greater in the VPRS (Table 2) and reached 7, 12, and 5 % of initial Ca, and, at 110 DAD, there was 0.9, 1.8, and 0.8 % of residual Ca in the VPRWS, VPRS, and BR, respectively. The $t^{1/2}$ calculated were 9.37, 11.75, and 7.79 days, respectively (Table 3). In the hairy vetch residues, the quantities of residual Ca were similar percentage-wise to the quantities in black oats (Table 2) since at 33 DAD in the VPRWS, VPRS, and BR, there was 7, 11, and 6 % of residual Ca, and, at 110 DAD, there was approximately 0.56, 1.14, and 0.7 %. For that reason, the $t^{1/2}$ calculated were also close: 9.00, 10.50, and 7.88 days. In contrast, Mg in the black oat residue in the VPRWS, VPRS, and BR at 33 DAD showed slightly higher values than the values of Ca, with 6, 17, and 6 %, and, at 110 DAD, 2, 6, and 2 % were observed. The $t^{1/2}$ times calculated, consequently, follow the same trend, at 9.12, 15.75, and 8.77 days (Table 3). These same trends were observed for the hairy vetch residues (Tables 2 and 3; Figures 2 and 3).

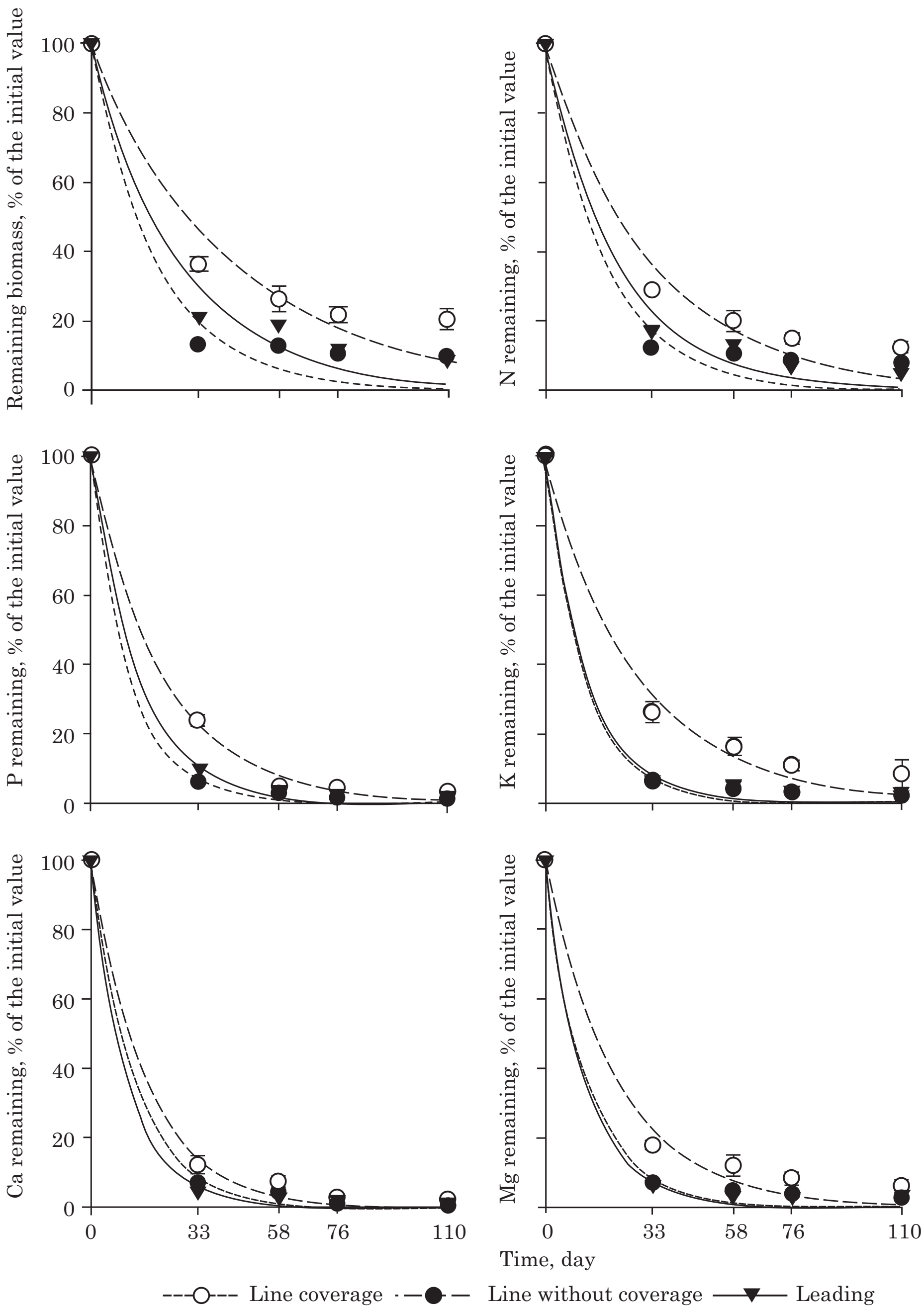

Figure 3. Remaining biomass, and N, P, K, Ca and Mg remaining from black oats in decomposition in the vine plant row without plastic shelter (VPRWS), in the vine plant row with plastic shelter (VPRS), and in the between-row area (BR). Values expressed as % of initial values. Vertical bars represent standard errors. The equations and significance of the adjustments are shown in table 3.

In general, decomposition kinetics of residues of cover crops, evaluated by residual percentages of dry matter, N, P, K, Ca, and Mg over time, was different among the species in regard to the place of deposition of residues (Figure 2 and 3). A greater proportion of residues and a lower rate of decomposition occurred for addition of the black oat residues after deposition in the different locations. This probably occurred because the black oat residues had a greater C/N ratio compared to hairy vetch residues (Table 1). The microbial processes of immobilization and mineralization of N, in large part, depend on the C/N ratio of the crop residues. Thus, based on this presupposition, Allison (1966) stated that organic residues with C/N values from 25 to 30 show balance between mineralization and immobilization. From this, it may be inferred that in treatments with the hairy vetch residues, there was predominance of mineralization, probably resulting in an increase in the amount of soil mineral N during decomposition. In contrast, the C/N ratio of the black oat residues suggests the occurrence of net immobilization of N during their decomposition on the soil.

As observed in these results (Tables 2 and 3; Figures 2 and 3), release of the nutrients contained in the residues of these plants exhibit a $t^{1/2}$ from 7 to 23 days, while decomposition or mineralization is from 11 to 23 days. It is less for the residues with a lower C/N ratio. Therefore, the nutrient release rate is greater than the mineralization rate of the residues. That occurs because most of the nutrients contained in the residues are not part of the structural constituents of the plants but are released to the extent that the cellular components most vulnerable to the microorganisms are decomposed (Crusciol et al., 2008; Serbin et al., 2009; Heinz et al., 2011). For that reason, in the first assessment at 33 DAD, the percent of nutrients remaining in the residues was always less than 20 % (Figures 2 and 3).

CONCLUSIONS

1. The greatest quantities and percentages of dry matter and residual nutrients, with the exception of Ca, in black oat residues was observed in the vine plant row with plastic shelter, which leads to greater protection of the soil surface.

2. The rate of decomposition and nutrient release from hairy vetch residues was not affected by the position of deposition of the residues in the vineyard.

3. Regardless of the type of residue, black oat or hairy vetch, the greatest rate of decomposition and nutrient release occurred especially at 33 days after deposition of the residues on the soil surface, which coincided with the period of flowering of the grapevines, which is one of the phenological stages with greatest demand for nutrients.

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