Decomposition of *Arachis pintoi* and *Hyparrhenia rufa* litters in monoculture and intercropped systems under lowland soil[1]

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Abstract – Tropical grasslands under lowland soils are generally underutilized and the litter of forage legumes may be used to recover these degraded pastures. The objective of this work was to study the dynamics of litter decomposition of *Arachis pintoi* (pinto peanut), *Hyparrhenia rufa* (thatching grass) and a mixture of both species in a lowland soil. These treatments were analyzed in three areas: grass monoculture, legume monoculture and legume intercropped with the grass during the dry and wet seasons. Litter bags containing the legume, grass or a mixture of both species were incubated to estimate the decomposition rate and microorganism colonization. Decomposition constants (K) and litter half-lives ($T_{1/2}$) were estimated by an exponential model whereas number of microorganisms in specific media were determined by plate dilution. The decomposition rate, release of nutrients and microorganisms number, especially bacteria, increased when pinto peanut was added to thatching grass, influenced by favorable lignin/N and C/N ratios in legume litter. When pinto peanut litter was incubated in the grass plots, 50% N and P was released within about 135 days in the dry season and in the wet season, the equivalent release occurred within 20 days. These results indicate that *A. pintoi* has a great potential for nutrient recycling via litter and can be used to recover degraded areas.

Index terms: forage, microorganisms, pinto peanuts, soil organic matter, thatching grass.

Decomposição da serrapilheira de *Arachis pintoi* e *Hyparrhenia rufa* em sistemas de monocultura e consórcio sob solo de várzea

Resumo – Pastagens tropicais sobre solos de várzea são geralmente subutilizadas. A serrapilheira de leguminosas forrageiras pode ser usada para a recuperação destas pastagens. O objetivo deste trabalho foi estudar a dinâmica de decomposição de *Arachis pintoi* (arachis), *Hyparrhenia rufa* (capim jaraguá) e da mistura destas espécies, em solo de várzea. Estes tratamentos foram analisados em três áreas: monocultivo da gramínea; monocultivo da leguminosa e no consórcio entre as espécies durante as estações seca e chuvosa. Sacos de decomposição contendo a serrapilheira da leguminosa ou da mistura das espécies foram incubados para estimar a taxa de decomposição e colonização microbiana. A taxa de decomposição e o tempo de meia-vida ($T_{1/2}$) foram estimados por um modelo exponencial, e o número de microrganismos foi determinado por meio de diluição em placas em meios específicos. A liberação de nutrientes, a taxa de decomposição, e o número de microrganismos, especialmente bactérias, aumentaram quando arachis foi adicionado ao capim jaraguá, com influência da relação favorável de lignina/N e C/N do resto desta cultura. Quando arachis foi incubado em parcelas de monocultivo da gramínea, 50% do total de N e P foi liberado em 135 dias na estação seca e em 20 dias na estação chuvosa. Estes resultados indicam que *A. pintoi* tem um grande potencial para ciclagem de nutrientes e pode ser uma estratégia na recuperação de áreas degradadas.

Termos para indexação: forrageiras, microrganismo, arachis, matéria orgânica do solo, capim jaraguá.

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Introduction

The grasslands of Brazilian lowlands frequently suffer from pasture deterioration and degradation due mainly to frequent inundation (Ferguson, 1992). The causes of this degradation include low aeration, overgrazing, occasional attacks from pests and diseases and especially N and P deficiencies (Macedo, 1995; Thomas, 1995). In these cases, recent evidence has shown that the return of plant nutrients to the soil via litter is a very important process (Thomas, 1992).

The litter of forage legumes may be used to recover the soil, protecting it from erosion, increasing N mineralization efficiency, decreasing C/N ratios and adding P to soils. On the other hand, recycling via litter of forage legumes to improve the physical, chemical and biological properties of soils would yield better results if legume species were chosen in such a way as to allow a degree of synchrony between supply and uptake by growing plants (Thomas & Asakawa, 1993; Myers et al., 1997).

Decomposition and nutrient release patterns of organic materials are determined by the organic constituents and nutrient content of the material, the decomposer organisms present, and the environmental conditions (Swift, 1976; Palm & Sanchez, 1991; Heal et al., 1997). Soil microflora, including fungi, bacteria and actinomycetes, is responsible for the biochemical processes involved in decomposition of plant residues and nutrient (N, P, S) release (Smith, 1994; Wardle et al., 1999).

The forage legume *Arachis pintoi* has been suggested as one of the best alternatives for pastures on poorly drained soils and pasture subjected to excessive grazing. This legume has faster rates of decomposition and a greater release of nutrients (Thomas, 1993). In order to develop a management of grasslands under lowland soils, knowledge of the decomposition characteristics and nutrient release is required.

The objective of this work was to study the decomposition and nutrient release rates of *Arachis pintoi* and *Hyparrhenia rufa* litters, both as single and mixed-species, in monoculture and intercropped systems under a lowland soil, during dry and wet seasons.

Material and Methods

The experiments were carried out on pastures established since 1993 in a lowland soil at Santa Rita Experimental farm, Sete Lagoas, MG, Brazil, situated at 732 m above sea level, 19°38' S, 45° W, during the dry (March to July, 1999) and wet (October 1999 to February 2000) seasons. The average temperature during the day throughout the experimental period was 18°C during dry season and 26°C during wet season, and mean annual rainfall was 55 mm during dry season and 1,350 mm during wet season. The soil was a hydromorphic clay (Gleissolo), clay texture (72% clay, 19% silt, 9% sand), with mean values of pH 5.1, 36% aluminum saturation, 10.1 g kg^{-1} organic C, 9 mg dm^{-3} available P (Mehlich-1), 1.5 mg dm^{-3} total N, 1.67 cmol$_c$ kg^{-1} Ca, 0.39 cmol$_c$ kg^{-1} Mg and 0.58 cmol$_c$ kg^{-1} K.

Litter decomposition rates and microorganism colonization were determined using 1.5 mm mesh nylon litter bags containing 15 g of three different plant residues (*Arachis pintoi* (pinto peanut) litter, *Hyparrhenia rufa* (thatching grass) litter, and a mixture of both litters at a 1:1 ratio). The litter bags were placed on the soil surface and covered with a layer of litter from the appropriate species for 120 days in the dry season and 80 days during the wet season in pasture plots. Bags were emptied at 20 day intervals, the material was dried at 60°C to constant weight and analyzed for total P (Sarruge & Haag, 1974), and Kjeldahl digestion was performed to determine total N (Oliveira, 1986). Ash free dry weight and total C was determined after combustion at 500°C for three hours (Wesemael, 1993). Lignin and cellulose contents were determined by the acid detergent fiber method (Soest, 1963).

Decay rate constant (K), and half life (T$_{1/2}$) were calculated from percent remaining dry weight using the single negative exponential decay function according to Olson (1963). The same model was used to calculate the decay rate constant of N and P (KN, KP) and the half-lives of N and P release (T$_{1/2}$N, T$_{1/2}$P).

The microbial populations of the residues were assessed using a residue washing technique (Chang & Hudson, 1967). The residues were diluted and incorporated into specific medium for each group of microorganisms (Parkinson et al., 1971).

The experimental design was a randomized complete block in a scheme of subdivided plot, with three replications comprising the following plots: monocultive stand of pasture of grass, monocultive stand of legume and intercropped stand of legume plus grass. The split plots consisted of bags containing three different litters. The split plots consisted of different harvest times for the whole period of the experiment. The plot x split plot interaction corresponds to the environment of bag incubation and bag content (plot/litter bag), for a total of nine treatments: pinto peanut/pinto peanut, pinto peanut/mixture, pinto peanut/grass, mix/pinto peanut, mix/mixture litter, mix/grass, grass/pinto peanut, grass/mixture, grass/grass.

The data were submitted to normalization and analysis of variance, analysis of correlation and the means were compared by the Tukey test at 5% significance level (MSTATc program, Michigan State University, MI, USA).

Results and Discussion

Initial quality of legume (*A. pintoi*) litter and grass (*H. rufa*) and the mixture of both species are shown in Table 1. During both seasons, the concentrations of N and P of the legume were higher than those of the grass, at dry and wet season. The C/N ratio of the grass litter was the highest, followed by the mix-

ture of litter and legume. The lignin/N ratio and cellulose contents were higher for grass.

Decomposition constants (K) and litter half-lives ($T_{1/2}$) were similar during the dry season (Table 2). However, significant differences were observed among the treatments in the wet season, probably due to favorable conditions for decomposition, such as high soil humidity and high temperatures. The decomposition constant and dry matter weight loss of the thatching grass were increased when pinto peanut litter was present, especially in grass monoculture stands during the wet season. Probably this fact was influenced by the lower initial C/N ratio of this legume and the higher microbial activity found in these litters (Table 3). It is known that litter decomposition depends on the initial values of the C/N and lignin/N ratios, and the cellulose contents (Entry & Backman, 1995; Wardle & Lavelle, 1997; Tian, 1998). The K values agree with those reported by Thomas & Asakawa (1993) in Colombian soils (sa-

Table 1. Initial litter composition of *Arachis pintoi* (peanut), *Hyparrhenia rufa* (grass) and mixture (peanut + grass) during dry and wet season in litter bags with 15 g of plant residue in each bag.

Season	C/N	Lignin/N	N	P	Lignin	Cellulose
			--- (mg/litter bag) ---		----------- (%)----------	
			Arachis pintoi			
Dry	38.7	3.74	368.5	61.0	9.2	27.3
Wet	36.3	1.97	393.0	61.0	5.2	20.4
			Mixture			
Dry	62.6	5.28	221.7	41.2	7.5	33.4
Wet	61.3	4.07	227.5	41.3	6.2	30.2
			Hyparrhenia rufa			
Dry	180.2	12.86	74.95	21.5	5.8	39.6
Wet	222.4	17.61	61.5	21.5	7.2	39.5

Table 2. Decomposition rate (K), half time decomposition ($T_{1/2}$), in litter of *Arachis pintoi* (peanut), *Hyparrhenia rufa* (grass) and mixture (peanut + grass), in single and mix plots after incubation for 160 and 80 days during the dry and wet seasons, respectively[1].

Treatment	K (day⁻¹)		$T_{1/2}$ (days)	
(plot/litter bag)	Dry	Wet	Dry	Wet
Peanut/peanut	0.0028	0.0334a	245.51	20.76c
Peanut/mixture	0.0022	0.0233ab	318.04	29.68c
Peanut/grass	0.0022	0.0104cd	320.47	66.81a
Mixture/peanut	0.0022	0.0271ab	320.88	25.61c
Mixture/mixture	0.0025	0.0184bc	274.72	37.68bc
Mixture/grass	0.0016	0.0110cd	429.07	62.78ab
Grass/peanut	0.0025	0.0340a	272.17	20.38c
Grass/mixture	0.0021	0.0205b	337.87	33.83c
Grass/grass	0.0018	0.0083d	376.15	83.44a

[1]Means followed by the same letter in each column did not differ significantly at 5% probability level by the Tukey test; the coefficients of variation for the decomposition rate and for the half time decomposition, both in the wet season, were 11.4% and 20.89%, respectively.

vannas) and were a little lower than those found in Brazilian "cerrado" soils (Oliveira et al., 2002). Differences found among lowland soil (72% clay, 19% silt, 9% sand) results and Brazilian "cerrado" soils (a red yellow latossol with 55% clay, 11% silt, 34% sand) may be related to soil texture. Lowland soils have high clay level, with low drainage and aeration capacity and tendency to flooding. The high clay values also favor the aggregate of organic matter to clay, limiting microbial access to organic substrate, resulting in slower decomposition speed (Heal et al., 1997). Similarly Groffman et al. (1996) suggest that soil texture is an important controller of changes in microbial activity in studies of grass decomposition in two soils with different textures (a silt loam, with 75-95% silt plus clay, a loamy sand with 15-40% silt plus clay and a coarse-silty, with 55-85% silt plus clay).

In general, in the wet period, the half-lives of decomposition in mixed litters and pinto peanuts litter were less than 50% of those of grass litter, probably due to higher temperatures and rainfall that can positively influence the rates of decomposition (Palm & Sanchez, 1991; Thomas, 1995) by affecting microbial decomposition (Swift et al., 1979; Okeke & Omaliko, 1992). During the initial period of the wet season the bacterial population was increased, probably contributing to the higher K values (Tables 2 and 3). The fungal population showed few changes in most treatments. The bacterial population increased after 120 days in the dry season and was markedly reduced after 80 days in the wet season, with exception of the treatments, grass/mixture and grass/grass. This was probably due to the intense flooding that occurred during the final period of the wet season, contributing to the low aeration of this soil. Fungal populations are more intimately associated with litter and soil (Wardle et al., 1999), and consequently are less susceptible to seasonal variation and low aeration (Cornejo et al., 1994) than bacteria during decomposition (Wardle et al., 1999). The cellulolytic populations were generally decreased after 80 days in the wet season and phosphate-solubilizing microorganisms were present in higher numbers in *A. pintoi* and mixed litters in the wet season in grass plots. The mixture of different substrates can favor the diversity of microorganisms. In "cerrado" soils (Oliveira et al., 2002) with the same litters, phosphate solubilizing microorganisms were also higher in pinto peanut litter in all plots. This observation confirms the affinity of these microorganisms for *A. pintoi* litter, which contains high

Table 3. Number of colonies forming unite/g of dry litter of the microbial populations in litter bags with *Arachis pintoi* (peanut) litter, *Hyparrhenia rufa* (grass) litter, mixture (peanut + grass) litter, in single and intercropped plots during the dry and wet seasons[1].

Treatment (plot/litter bag)	Time[2]	Fungi		Bacteria		P. solubilizing		Cellulolitic	
		Dry ($x10^7$)	Wet ($x10^8$)	Dry ($x10^7$)	Wet ($x10^8$)	Dry ($x10^7$)	Wet ($x10^8$)	Dry ($x10^4$)	Wet ($x10^4$)
Peanut/peanut	Initial	1.7c	0.43	94cdef	843.3de	0.6	7.330bcd	4.0ij	4.0d
	Final	4.3abc	0.33	407a	1.7f	6.0	0.330d	160.0a	2.0ef
Peanut/mixture	Initial	4.3abc	0.83	167cd	1,080.0bcd	1.0	3.670d	30.0d	2.0ef
	Final	8.3a	0.67	477a	7.3f	3.4	0.330d	25.0e	0.011h
Peanut/grass	Initial	3.1bc	0.30	18ef	1,306.7ab	2.4	1.000cd	17.5f	1.7efg
	Final	3.1bc	0.33	83def	6.3f	0.7	0.001d	30.0d	0.0008h
Mixture/peanut	Initial	0.7c	0.37	27ef	996.7cd	0.1	7.670cd	1.7j	15.0b
	Final	3.7abc	0.33	110cdef	53.0f	1.2	3.330cd	175.0f	0.2h
Mixture/mixture	Initial	2.0c	0.37	36ef	1,570.0a	0.2	17.000cd	2.0j	2.5e
	Final	3.7abc	0.67	173bcd	21.7f	1.3	0.001d	7.0hi	0.8fgh
Mixture/grass	Initial	8.0ab	0.17	11f	693.7e	0.1	1.670cd	3.0ij	13.0c
	Final	1.3c	0.01	53ef	4.3f	1.3	8.000d	20.0f	0.0017h
Grass/peanut	Initial	4.0abc	0.40	192bc	1,273.3bc	0.5	1 6.670b	14.0g	30.0a
	Final	4.0abc	1.33	270b	12.0f	2.9	43.330a	90.0b	0.007h
Grass/mixture	Initial	1.7c	0.10	109cdef	636.7e	0.5	4.330cd	35.0c	3.0de
	Final	1.0c	1.40	47ef	99.3f	1.5	39.300a	9.5h	0.2h
Grass/grass	Initial	3.3abc	0.77	22ef	690.0e	4.4	7.000cd	35.0c	2.0ef
	Final	7.7ab	1.33	113cde	23.0f	0.9	0.001d	1.7j	0.5gh
CV (%)		18.9	ns	23.88	30.01	ns	30.61	20.02	16.73

[1]Means followed by the same letter in each column did not differ significantly at 5% probability level by the Tukey test. [2]The final time was 160 and 80 days in the dry and wet season, respectively; numbers in parenthesis are the decimal of the number of colonies forming unite/g of dry litter.

P concentrations (Vasconcellos et al., 1997). On the other hand, these P-solubilizing microorganisms favor the release of P to soil solution.

Pinto peanut and mixed litters increased the release of nutrients, especially in the wet season (Table 4). However, immobilization of N was clearly observed on thatching grass litter in both seasons. The values of litter cellulose decomposition did not differ significantly among treatments. Higher nutrient concentrations in legume litters as compared to grass litters generally favor release of nutrients from legumes (Palm & Sanchez, 1991; Thomas, 1995; Ayarza et al., 1998). During the wet season, the N and P half lives were also low in the mixed litter, especially in the grass monoculture (Table 5). The addition of pinto peanut to thatching grass litter in grass monoculture reduced the time of N release from 829.2 to 31.9 days, during the wet season, and the time of P release, from 39.1 to 22.8 days. Furthermore, the mixture of litters can reduce the C/N and lignin/N ratios in grass (Palm & Sanchez, 1991; Handayanto et al., 1997). The existence of a synergistic effect of the legume litter on the decomposition of the grass litter has been reported (Thomas & Asakawa, 1993; Myers et al., 1997; Wardle et al., 1999). It is well established that the composition and

Table 4. Residual P (PR), N (NR) and cellulose (CR) in litters bags with *Arachis pintoi* (peanut) litter, *Hyparrhenia rufa* (grass) litter, mixture (peanut + grass) litter in single and intercropped plots after 160 and 80 days during dry and wet seasons, respectively. Values are expressed as percentage of the initial values[1].

Treatment (plot/litter bag)	PR		NR		CR	
	Dry	Wet	Dry	Wet	Dry	Wet
	------------------------------- (%) -------------------------------					
Peanut/peanut	62.91a	3.50d	46.59b	6.39b	96.61a	57.27a
Peanut/mixture	78.43a	9.76cd	61.03ab	14.86b	104.22a	32.60a
Peanut/grass	74.35a	31.93a	80.48ab	79.66a	82.70a	50.39a
Mixture/peanut	66.15a	5.94d	60.47ab	11.71b	116.36a	58.15a
Mixture/mixture	64.11a	11.38cd	52.76ab	21.00b	93.32a	48.04a
Mixture/grass	73.07a	27.12ab	83.12ab	75.76a	94.41a	57.45a
Grass/peanut	73.06a	3.22d	50.50ab	6.79b	88.17a	63.94a
Grass/mixture	73.61a	8.84cd	59.08ab	17.56b	99.65a	62.02a
Grass/grass	63.34a	23.93a	89.02a	99.23a	101.36a	58.09a

[1]Means followed by the same letter in each column did not differ significantly at 5% probability level, by the Tukey test; the coefficients of variation for PR in the wet season and for NR in the dry and wet seasons were 19.43%, 16.44% and 20.62%, respectively.

the activity of soil microflora depend on the quality of litter (Robertson & Morgan, 1996; Handayanto et al., 1997; Heal et al., 1997; Wardle & Lavelle, 1997; Wardle et al., 1999).

There was no correlation between mass (RM) and P release during the dry season (Table 6). During the wet season, significant correlations were observed for pinto peanut and mixed litters with r values

Table 5. Decay Rate Constant for N and P (KN, KP) and half-lives of N and P release ($T_{1/2}N$, $T_{1/2}P$) in litter bags with *Arachis pintoi* (peanut) litter, *Hyparrhenia rufa* (grass) litter, mixture (peanut + grass) litter in single and intercropped plots after 160 and 80 days during dry and wet seasons, respectively[1].

Treatment (plot/litter bag)	KN (days^{-1})		KP (days^{-1})		$T_{1/2}N$ (days)		$T_{1/2}P$ (days)	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Peanut/peanut	0.006a	0.036a	0.003a	0.044ab	112.0c	19.8c	180.1a	16.1d
Peanut/mixture	0.004a	0.025ab	0.002a	0.029ab	174.2c	29.1c	424.3a	23.8cd
Peanut/grass	0.001a	0.003c	0.002a	0.015b	557.8b	465.4b	318.0a	49.3a
Mixture/peanut	0.004a	0.031a	0.003a	0.038ab	167.2c	25.3c	204.5a	19.1d
Mixture/mixture	0.005a	0.020ab	0.003a	0.027ab	130.5c	36.2c	191.8a	25.5bcd
Mixture/grass	0.001a	0.003c	0.002a	0.016ab	886.7a	202.9b	268.3a	42.7ab
Grass/peanut	0.005a	0.036a	0.005a	0.045a	122.8c	20.2c	139.6a	15.8d
Grass/mixture	0.004a	0.022ab	0.003a	0.030ab	159.2c	31.9c	283.9a	22.8cd
Grass/grass	0.001a	0.0001d	0.004a	0.018ab	567.9b	829.2a	216.5a	39.1abc

[1]Means followed by the same letter in each column did not differ significantly at 5% probability level by the Tukey test.

Table 6. Pearson correlation coefficients of mass loss (RM) and P release (PR) during dry and wet seasons.

Treatment (plot/litter bag)	Dry	Wet
Peanut/peanut	-0.33[ns]	0.98[**]
Peanut/mixture	-0.50[ns]	0.79[**]
Peanut/grass	-0.14[ns]	0.42[ns]
Mixture/peanut	-0.30[ns]	0.98[**]
Mixture/mixture	-0.27[ns]	0.95[**]
Mixture/grass	0.41[ns]	0.63[*]
Grass/peanut	0.43[ns]	0.98[**]
Grass/mixture	-0.08[ns]	0.97[**]
Grass/grass	0.19[ns]	0.47[ns]

[ns]No-significant. * and **Significant at 5% and 1% probability level, respectively.

over 0.79. The P release probably was influenced for favorable conditions for P-solubilizing microorganisms activities. In pinto peanut and mixed litters, the efficient release of P coincided with that of N, showing the high potential for nutrient recycling by pinto peanut litter in lowland soil and may be used to recover degraded soils.

Conclusions

1. About 272.17 days are necessary for 50% of *Arachis pintoi* decomposition, during dry season and 20.38 days during wet season, under grass plots degraded; about 122.8 and 139.6 days are necessary for *A. pintoi* to release 50% of N and P, respectively, in the dry season, and 20.2 and 15.8 days in the wet season, under the same plots.

2. The content of cellulose, and the lignin/N and C/N rations influence the decomposition of the *A. pintoi* and *Hyparrhenia rufa* residues.

3. The decomposition rate and release of nutrients of the *H. rufa* litter are reduced 50% after the addition of *A. pintoi* litter and are influenced by favorable lignin/N and C/N ratios of pinto peanut litter.

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