SHORT COMMUNICATION

Performance of steers fed on pasture receiving different seeding rates of vetch in an integrated crop-livestock system

Douglas Vonz[1], Luís F. G. Menezes[1], Wagner Paris[1], Fernando Kuss[1], Magali F. Silveira[1], Tiago Venturini[2], Fernanda Stanqueviski[1] and Bruna Boito[3]

[1] Universidade Tecnológica Federal do Paraná, Câmpus Dois Vizinhos, Dois Vizinhos, Paraná, Brazil. [2] Universidade do Oeste do Paraná, Câmpus Marechal Cândido Rondon, Marechal Candido Rondon, Paraná, Brazil. [3] Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil.

Abstract

Aim of study: To evaluate the performance of beef calves fed black oat and Italian ryegrass pasture seeded with several different seeding rates (SR) of common vetch in a crop-livestock integrated system.

Area of study: The experiment was carried out in Dois Vizinhos city, Paraná, Brazil.

Material and methods: An area of 8.3 ha was used, which was divided into 11 paddocks, 0.75 ha each. Nellore calves (n = 22), 7 ± 2 months old and with initial body weight of 134 ± 27 kg were used for the tests. The experimental design was completely randomised. Vetch (*Vicia sativa* L., 'Amethyst') SR treatments included 0, 15, 30, and 45 kg ha-1, in a mixture with black oat (*Avena strigosa* Schreb. 'IPR 61' and Italian ryegrass (*Lolium multiflorum* Lam.) pastures.

Main results: There was no effect of SR on pasture productivity parameters. The increase in vetch seed in the seed mixture resulted in an increase in crude protein and neutral detergent fibre, but decreased in vitro digestibility of vetch. However, these changes did not affect the nutritional value of the pasture. Vetch SR of 30 kg ha^{-1} or higher allowed greater share of the legume in the pasture, thereby enhancing greater individual animal performance

Research highlights: Vetch SR of 30 kg ha^{-1} or higher allowed greater share of the legume in the pasture, thereby enhancing greater individual animal performance.

Additional key words: animal production; forage; Italian ryegrass; oat

Abbreviations used: ADG (average daily gain); AFM (available forage mass); CP (crude protein); DAR (daily accumulation rate); DM (dry matter); FA (forage allowance); FM (forage mass); IVDMD (in vitro digestibility); L (linear); LW (live weight); NDF (neutral detergent fibre); Q (quadratic); SR (seeding rate); SRa (stocking rate).

Introduction

Livestock production based on forage is limited mainly by the variation in forage quality, and the availability of a continuous and consistent supply throughout the year. Inclusion of legume species increases pasture nutritional value and soil fertility through biological nitrogen (N) fixation (Lüscher *et al.*, 2014), enhancing soil organic matter content for following crops.

In pasture mixtures, the two main routes for legume mediated N supply to the associated grasses are grazing – with return of legume N to the soil in excreta – and through senescence and mineralisation of the legume itself (Dubeux Jr. *et al.*, 2007). N is considered the most important mineral nutrient for plants, because it increases the biomass of forage and the amount of protein, through increased chlorophyll and amino acids. N fertilization of forage plants is most commonly accomplished

by chemical fertilisers. However, in the case of intensive cattle-raising systems, direct expenses on fertilisers may represent more than half of the total production cost. The use of legumes in combination with grasses can be a cost saving alternative strategy through biological N fixation.

Moreover, the use of legumes in pasture mixture promotes an increase in animal production by increasing the quantity and nutritional value of the forage offered (Beck *et al.*, 2016). This improved nutritional value results from the high levels of crude protein (CP) and high digestibility of legumes (Lüscher *et al.*, 2014). Studies on the inclusion of legumes in pastoral systems are of great importance, because besides the benefits of biological N fixation, there is also the benefit of higher protein intake by animals, turning plant protein into animal protein, in addition to economic aspects. On the other hand, Dierking *et al.* (2010) suggested that a pasture of higher quality is not always the most effective alternative for the best animal performance, since the increasing degradability of dietary protein leads to a greater production of ruminal ammonia, thus resulting in higher N loss through urine and feces (Agle *et al.*, 2010). Consequently, the net energy storage for maintenance, growth, and fat reserves are lower due to the excess of protein in the diet, resulting in lower animal performance (Wright, 2013). The black oat (*Avena strigosa* Schreb.) and Italian ryegrass (Lolium multiflorum Lam.) mixed with vetch (*Vicia sativa* L.) are species of good nutritional quality, with high digestibility and high content of degradable N, which can be lost and excreted via urine if it is not adequately supplied in the diet (Lazzarotto *et al.*, 2019).

Seeding rates (SR) directly influences plant population, productivity of tillers and, consequently, the production of pasture. Oftentimes in farms, SR is increased prior to the entry of the animals into the pasture, thus, reducing autumn forage deficits. Commonly recommended SR of common vetch range from 30 to 40 kg ha^{-1} (Balbinot Junior *et al.*, 2011). However, these recommendations are not based on research findings, but on practical experience. Most studies on the vetch crop have tested it as a cover crop (Chiamolera *et al.*, 2013). Thus, there is a need to increase the research efforts related to determining vetch – and other legumes – optimum SR.

The aim of the study was to identify the best common vetch SR over a mixed pasture of Italian ryegrass and black oat, through the performance of grazing beef calves in a crop-livestock integrated system.

Material and methods

This work is part of a research project approved by the Animal Use Ethics Committee at the Federal Technological University of Paraná (CEUA-UTFPR) Protocol: 2013-008. The experiment was carried out in Dois Vi-

zinhos city, Paraná, Brazil, third plateau at an altitude of 520 m; located at 25°44'' S and 54°04'' W, where, according to the Köppen-Geiger classification, climate is humid-subtropical-mesothermic (Cfa). The soil is classified as a typical distroferric nitossol of clayey texture.

Chemical analysis of the soil in the experimental area was conducted by the pertinent corrective measures, showing the results: organic matter = 36.2 mg dm^{-3}; pH = 4.70; P = 4.60 mg dm^{-3}; K = 70.4 mg dm^{-3}; Ca = 4.10 cmolc dm^{-3}; Mg = 3.70 cmolc dm^{-3}; Al = 0.15 cmolc dm^{-3}; base saturation = 59.9%. Base fertilization consisted in the application of 300 kg ha^{-1} 08-20-10 (N-P-K) at planting, followed by N fertilization with 150 kg ha^{-1} urea, split into three applications; the first at the start of tillering and two more 28-days apart, after the first one.

The experimental area was 8.3 ha divided into 11 paddocks. In each paddock a drinking fountain was available with running water and mineral salt 'ad libitum'. The experiment was laid in a completely randomised design with four treatments and three replications (data analysed for the control treatment came from two replications only, since the third replication was excluded because of incorrect seeding). Vetch 'Amethyst' SR treatments included 0, 15, 30, and 45 kg ha^{-1}, in a mixture with black oat 'IPR 61' and Italian ryegrass pastures, at SRs of 40 and 30 kg ha^{-1}, respectively. The three species were broadcast, one at a time (25 May, 2012), by means of a seed spreader; followed by harrowing to cover the seed.

Twenty-two Nellore calves averaging 134 ± 27 kg of initial weight and 7 ± 2 months of age were used as experimental animals, through the technique of *put and take* (Mott & Lucas, 1952) for 86 days, with 10 days of adaptation (not included in the results).

Two animals were randomly assigned to each treatment-paddock, where they remained throughout the experimental period. Each group of animals was chosen so that each treatment had similar initial weight and age. There were also ten additional spare animals available when required for a 'put-and-take' system to maintain the target grazing pressure, these are called the 'regulator' animals.

Forage allowance (FA) was used as a criterion for the entry or exit of regulator animals of similar weight and age, which remained in an adjacent area grazing on an oat and Italian ryegrass pasture. The FA (kg dry matter/100 kg live weight) was obtained by the following equation:

$$FA = [(AFM + (DAR * days) / days] / SRa * 100,$$

where AFM is the available forage mass (kg DM ha^{-1}), DAR is the daily accumulation rate (kg DM ha^{-1}), days is the experimental period interval and SRa is the stocking rate (kg LW ha^{-1}). The recommended FA was 15 kg DM per 100 kg LW, which aimed at maintaining a forage residue at the end of the experiment for direct planting of summer crops.

Forage mass (FM) was estimated by the double-sampling method (Wilm *et al.*, 1944), using a square of 0.25 m² for 20 visual evaluations (5 cuttings) of the pasture. The cuttings were done to ground level. Samples were homogenized and split into two sub-samples, one part for determining dry matter (DM) concentration after drying at 55 oC in an oven with forced air circulation for 72 hours and the other part for botanical composition of leaf blades and stems of grasses. Common vetch was separated into whole vetch plant, dead material, and weeds. The forage accumulation rate per day was measured using two exclusion cages per paddock. The cages were posi¬tioned at representative points of the average sward height, with similar mass and morphological composition. The forage masses, inside and outside the cage, were obtained within the 0.25 m² square, by cutting to the ground level. This evaluation was performed every 28 days. After each cutting, the cages were moved to other points of the paddocks, following the same methodology. The forage accumulation (DM kg ha⁻¹) was obtained by the difference between the forage mass inside the cage in the current period and outside the cage in the previous period. To estimate the forage accumulation rate per day (kg ha⁻¹ d⁻¹), the total was divided by the number of days in each period.

The SRa recorded during the experimental period was obtained by averaging weight of experimental animals and adding regulator animals average weight multiplied by the number of days in which they remained within the paddock. The resulting value was divided by the number of grazing days and expressed as LW (kg ha⁻¹).

To determine average daily gain (ADG), animals remained on solid diet and water fasting for 12 to 14 hours. The ADG was then calculated as the increase in LW of the experimental animals divided by the number of days between weightings (76 days). With ADG information from experimental animals, LW gain per hectare was calculated. The animals were weighed individually at the beginning and end of the experiment (determination of the ADG), as well as at each experimental period (2 of 28 days and the last of 20 days).

The nutritional value and botanical composition of the pastures were assessed in composite samples cut close to the soil surface by the double sampling technique (Wilm *et al.*, 1944). Analyses were performed at the Food Analysis Laboratory of the Federal Technological University of Paraná, Câmpus Dois Vizinhos. Total N was determined by the Kjeldahl method (AOAC, 2005), neutral detergent fibre (NDF) was estimated according to the method by Van Soest *et al.* (1991) adapted to the use of the Ankom 200 fibre digester (Ankom Technology, NY, USA). Finally, *in vitro* dry matter digestibility (IVDMD) was determined according to Tilley & Terry (1963), after adapting their method for use of the artificial rumen (Holden, 1999) developed by Ankom Technologies®.

Data were subjected to analysis of variance and the F test using PROC Mixed in SAS vers. 9.2). The study of polynomial regression was performed using the following model:

$$Y_{ijk} = \beta_0 + \beta_1 X_i + \beta_2 X_i^2 + \varepsilon_{ijk}$$

where Y_{ijk} is the dependent variable, βs corresponds to the regression coefficients, X_i represents the independent variables, and εijk is the residual random error.

Results and discussion

Average forage mass obtained over the experimental period was 1957 ± 607 kg of DM ha⁻¹ (Table 1) and it was not affected by SR. Despite the increasing SR, DAR and SRa did not differ significantly. A successful pasture formation is critical to ensure high production in grazing systems. Thus, in addition to uniform seed distribution, recommended seed rates should ensure high productivity. According to Mott (1984), forage mass in temperate pastures should range between 1,200 and 1,600 kg DM ha⁻¹ in order to allow maximum animal performance. However, in crop-livestock integrated systems, we must also consider residual straw for No-tillage management of the successor crop. In addition, the increase in SR did not influence the botanical composition of the grasses (Table 1), that is, the increase in the contribution by the vetch did not affect the development of black oat or Italian ryegrass. Similarly, Lithourgidis (2006) reported that total forage yields of mixtures of vetch with oat were not affected by SR. However, these authors observed an effect on the yield of mixed black oat relative to single black oat when SR was 65:35 (vetch:oat), compared to a ratio of 55:45. In the present study the SR was in a ratio of 40:60 (vetch:grasses) at the highest SR. In this mixture, Italian ryegrass production was expected to increase, but there was an evident dominance by oat (leaf + stem) in the pasture. The proportion of Italian ryegrass in the mixture was lower than that of oat as a result of a longer life cycle and slower development. When used in mixtures, Italian ryegrass showed a slow development at the beginning, but later it increased its production in spring with the higher temperatures. However, the lack of rain in August and the subsequent ending of our experiments in September severely limited the contribution of Italian ryegrass to the productivity of the pasture.

There are only a few reports in the literature assessing vetch SR in a mixture with grasses under grazing conditions. However, we can attribute the linear growth of the vetch to the growth behaviour. Vetch developmental performance is characterized by having a high climbing potential. The legume has a high ability to overlap neighbouring plants (Balbinot Junior *et al.*, 2011). Overall,

Table 1. Forage mass (FM), daily accumulation rate (DAR), stocking rate (SRa) and botanical composition of black oat/Italian ryegrass mixture receiving different vetch seeding rate

Variable[1]	Common vetch seeding rate (kg ha⁻¹)				SEM[2]	p-value[3]	
	0	15	30	45		L	Q
FM (kg DM ha⁻¹)	2200	1890	1800	2020	252.5	0.693	0.289
DAR (kg DM ha⁻¹ day⁻¹)	42.9	43.4	48.6	48.9	8.16	0.521	0.982
SRa (kg live weight ha⁻¹)	945	800	900	880	71.8	0.931	0.489
Botanical composition							
Oat							
Leaf	290	235	210	235	24.6	0.140	0.096
Stem	385	330	310	385	44.9	0.920	0.146
Italian ryegrass							
Leaf	110	120	160	100	25.2	0.965	0.202
Stem	115	120	105	90	26.5	0.364	0.677
Inflorescence	85	75	125	105	6.6	0.702	0.944
Vetch	00	80	130	130	25.6	0.002[4]	0.146
Others	3.0	3.2	2.4	1.8	13.5	0.628	0.066
Dead material	85	75	55	50	13.4	0.057	0.865
Leaf:stem ratio	0.86	0.85	1.01	0.78	0.16	0.867	0.769

[1] DM = dry matter. [2] SEM = standard error of the mean. [3] L and Q = linear and quadratic effects. [4] Regression equation for participation of vetch = 25.0874 + 2.7380*SR; r^2= 0.256.

we found an increase in the vetch proportion for the higher SR, showing that botanical composition of the pasture is influenced by SR without necessarily affecting total productivity of a mixed pasture.

Variations in the nutritional value of pasture components were observed only for the vetch (Table 2). There was an increase in vetch CP and NDF contents at the highest legume SR tested. The increase in NDF resulted in a decrease in IVDMD. This fact can be explained by the higher tiller appearance rate (y=0.0321+0.0145*SR; r^2=0.76) shown by the vetch when it was sown in larger quantities, since higher tiller number means higher number of leaves per plant, whereby CP will increase. The higher rate of appearance and lower mortality of tillers (y= -0.0276+(0.0239*SR)-(0.0004*SR²); r^2 = 0.71) and, consequently, stronger competition for light, resulted in larger NDF contents due to elongation of the stem, *i.e.*, the structural support of the plant. Lithourgidis *et al.* (2006) reported similar results on an oat-vetch intercropping system.

The regression equation shows a linear response of ADG with increasing vetch SR (Table 3). However, analysis of the means revealed a trend for stabilization or decrease in growth, beginning at about 30 kg of SR. The increase in ADG is due to greater vetch share in the mix (Table 1) and better nutritional value (Table 2) when sown in larger quantities. At the lower SR treatments, animals may have been able to perform a more effective selection of oat and Italian ryegrass over the vetch, since they prefer grass to the legume (Rutter, 2006). In those paddocks

with a higher proportion (higher SR) of vetch, this selection was more difficult; thus, the nutritional quality of the consumed pasture would have been higher. Animals that remained on treatments including 30 or 45 kg ha⁻¹ of vetch showed average gains 23% higher than those experienced by animals that remained under treatments without any or with only 15 kg of the vetch. This led to a shortening of grazing time and, consequently, to a decrease in time to reach slaughter weight of these animals, which eventually would lead to an optimization of the grazing area. Hirai *et al.* (2015) observed what ADG and gain per area unit (kg ha⁻¹) were higher for animals growing in a mixture with vetch than in oat-only pastures.

Backgrounding is a phase of great importance in any fattening cattle production system, as it enables the producer to save time – provided a greater weight gain by the animals can be maintained during the shorter period. Well-reared herds reach the final phase heavier and, therefore, require less time to reach the time for slaughter; such reduction can generate important savings.

Despite the high available forage mass obtained in this study (1,978 kg DM) in order to maintain a forage residue for direct planting of a subsequent summer crop, it was possible to have a stocking rate near to 2 animal unit ha⁻¹. This provides weight gains above 300 kg ha⁻¹ in only 76 days of evaluation, even during a whole winter under severe water restriction. This showed that an adequate pasture management allows high animal production based exclusively on pasture. With the results found, we can conclude that vetch seeding rates of 30 kg ha⁻¹ or higher

Table 2. Chemical composition (g kg^{-1} of dry matter) of pasture of black oat/Italian ryegrass mixture receiving different vetch seeding rate

| Variable[1] | Common vetch seeding rate (kg ha^{-1}) | | | | SEM[2] | p-value[3] | |
	0	15	30	45		L	Q
Oat leaf							
CP	235	234	232	221	22.1	0.672	0.845
NDF	500	516	487	495	17.5	0.476	0.980
IVDMD	737	728	847	813	50.6	0.136	0.729
Oat stem							
CP	132	133	116	115	13.8	0.368	0.883
NDF	622	584	623	625	17.7	0.558	0.334
IVDMD	699	737	774	766	59.8	0.298	0.576
Italian ryegrass leaf							
CP	217	244	205	215	20.7	0.743	0.665
NDF	508	535	496	485	26.4	0.339	0.554
IVDMD	746	745	815	829	57.6	0.209	0.938
Italian ryegrass stem							
CP	112	125	117	112	17.9	0.781	0.688
NDF	613	550	566	592	25.5	0.948	0.119
IVDMD	690	729	758	754	56.4	0.314	0.510
Vetch							
CP	-	192	229	250	14.9	0.004[4]	0.058
NDF	-	416	413	445	27.8	0.002[5]	0.001
IVDMD	-	722	708	670	32.7	0.008[6]	<0.0001
Total pasture							
CP	134	135	119	122	13.9	0.401	0.934
NDF	547	546	553	547	37.3	0.953	0.943
IVDMD	825	795	776	805	19.6	0.586	0.986

[1] CP = crude protein; NDF = neutral detergent fibre; IVDMD = in vitro digestibility (IVDMD). [2] SEM = standard error of the mean. [3] L and Q = linear and quadratic effects. [4] CP = 59.14 + 4.89*SR, r^2 = 0.517. [5] NDF = 26.73 + 28.45*SR, r^2 = 0.840. [6] IVDMD = 41.25 + 52.18*SR, r^2 = 0.883.

Table 3. Initial live weight (IW), final live weight, average daily gain (ADG), and live weight gain (LWG) per hectare in cattle of black oat/Italian ryegrass mixture receiving different vetch seeding rates

| Variable | Common vetch seeding rate, (kg ha^{-1}) | | | | SEM[1] | p-value[2] | |
	0	15	30	45		L	Q
IW (kg)	135	135	140	135	-	-	-
Final live weight (kg)	185	195	200	200	19.04	0.237	0.761
ADG (kg)	0.690	0.700	0.815	0.860	0.06	0.059[3]	0.831
LWG							
kg ha^{-1} day^{-1}	4.08	3.42	4.29	4.34	0.46	0.394	0.712
kg ha^{-1}	314	264	330	334	35.9	0.454	0.771

[1] SEM= standard error of the mean. [2] L= linear; Q= quadratic. [3] Regression equation for ADG = 0.6664 - 0.00014429*IW + 0.00434SR; r^2=0.45.

allowed greater share of the legume in the pasture, thereby enhancing greater individual animal performance.

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