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Forage production dynamics of winter annual grasses sown on different dates

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ABSTRACT - This experiment was carried out from April to September 2008 with the objective of evaluating the forage production dynamics of winter annual grasses (*Avena strigosa* Schereb cv. IAPAR-61; *Lolium multiflorum* Lam cv. Comum; *Avena strigosa* cv. Comum; *Avena sativa* cv. IPR 126; and *Triticum aestivum* L cv. BRS Tarumã) on four sowing dates (April 4th, April 24th, May 14th and June 3rd). A completely randomized blocks with four replications was used. It was evaluated number of days and production at the first cutting, total production, number of cuts and density of plants and tillers. There is a strong interaction among cultivars and sowing dates for all analyzed variables and this indicates opportunities of choosing multiple combinations among cultivar and sowing dates to manipulate forage production aiming at easing forage gaps. The late season oats (IPR 126 and IAPAR 61) present high production and forage distribution capacities, especially if sown until mid-April.

Key Words: annual-ryegrass, black oat, forage budget, forage production, white oat

Dinâmica de produção de forragem de gramíneas anuais de inverno semeadas em diferentes épocas

RESUMO - Este trabalho foi realizado no período de abril a setembro de 2008 com objetivo de avaliar a dinâmica da produção de forrageiras anuais de estação fria (*Avena strigosa* Schereb cv. IAPAR-61; *Lolium multiflorum* Lam cv. Comum; *Avena strigosa* cv. Comum; *Avena sativa* cv. IPR 126; e *Triticum aestivum* L cv. BRS Tarumã) em quatro épocas de semeadura (4 e 24 de abril, 14 de maio e 3 de junho). O delineamento experimental empregado foi o de blocos ao acaso, com quatro repetições. Foram avaliados o número de dias e a produção ao primeiro corte, a produção total, o número de cortes e a densidade de plantas e perfilhos. Existe forte interação entre cultivares e épocas de semeadura para todas as variáveis analisadas e isso indica oportunidades de escolha de múltiplas combinações entre cultivar e época de semeadura para manipular a produção de forragem no intuito de amenizar vazios forrageiros. As aveias de ciclo longo (IPR 126 e IAPAR 61) são materiais com alta capacidade de produção e distribuição de forragem, especialmente se semeadas até meados de abril.

Palavras-chave: aveia-branca, aveia-preta, azevém, produção de forragem, vazio forrageiro

Introduction

The weather changes in southwestern Paraná during the cool-season often cause decreased row crop productivity.

The use of grain production land to forage production grazing the plants, besides being an option of income to farmers in between harvests, also became diverse the farm income, because these activities, conducted alone, are not sustainable in long-term. In a given time, the economic environment is favorable either to grain production or animal production (Flores et al., 2008a).

Dairy production is the primary economical activity of small farms in southwestern Paraná (IPARDES, 2008). In this region, small landholders predominate instead of large farming operations. The area is characterized by highly fertile soils and good environmental conditions capable of supporting ruminant production in a grass-fed system. However, very often, farmers are not benefitted from using the natural traits of the region and feed their animals with silage, hay or concentrate simply due to the absence of a forage budget and knowledge of forage species and management options adapted to the region.

From this standpoint, the herbage production dynamics is a key indicator of the distribution of herbage production across the growing season, and determines how intense the lack of supply forage would be at a given time. The production dynamics also has a large influence

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on total cost and animal production, and it can subsequently drives the decisions made related to the forage budget.

Considering these points, an evaluation of the effect of planting date on production of various species and cultivars, based on the hypothesis that the forage supply could be either made earlier or extended, would help make decisions about specific cultivar and planting date combinations.

Based on this context, the objective of this study was to evaluate the forage production dynamics of annual cool-season grasses planted across four dates.

Material and Methods

This trial was carried out from April 4th to December 18th of 2008, at the Estação Experimental da Universidade Tecnológica Federal do Paraná, Dois Vizinhos campus (25° 4´57" South and 53° 03´41" West), 534 m altitude in southwestern Paraná, located on the third plateau of Paraná. The climate is classified as mesothermic humid (Cfa) according to the Koepen classification (Maak, 1968). Mean monthly rainfall is 177 mm/month, and the average temperature of the coldest month is below 14.7ºC. Mean monthly temperature during the hottest month is above 25.2°C, illustrating hot summers and frost during the winter months.

The soil is classified as Dystrophic Red Nitosol (Bhering et al., 2008). Initial characterization of the soil presented the following values: pH (CaCl) = 5.4; Organic matter = 29.48 g dm^{-3}; P = 7.08 mg dm^{-3}; K = 0.18 cmol$_c$ dm^{-3}; Cu = 5.01 mg dm^{-3}; Fe = 86.97 mg dm^{-3}; Zn = 3.61 mg dm^{-3}; 213.50 mg dm^{-3}; Al^{+3} = 0.00 cmol$_c$ dm^{-3}; H + Al = 3.68 cmol$_c$ dm^{-3}; Ca = 5.87 cmol$_c$ dm^{-3}; Mg = 3.93 cmol$_c$ dm^{-3} and; V = 73.6 %.

The experimental area has been used since 1998 under conservation tillage under a crop-rotation of soybean and corn during the summer, and black oat as green manure or wheat for grain production during the winter. After the soybean harvest, the area was prepared by using rotary tilling and fertilized according to CQFS (2004). There was no need to lime the area and fertilizer was broadcasted manually using 15 kg/ha of N, 75 kg/ha of P_2O_5 and 45 kg/ha of K_2O on each sowing date. The nitrogen fertilization top dressing was 60 kg/ha of N, using urea in three applications (30, 45 and 60 days after each sowing date).

The treatments were arranged in 4 × 5 factorial (four sowing dates and five cultivars). Treatments were arranged in a completely randomized block design with four replicates. The sowing dates were April 4th, April 24th, May 14th and June 3rd, 2008. The forage species/cultivars evaluated were *Avena sativa* cv. IPR 126 (white oat, 60 kg/ha), *Avena strigosa* Schreb cv. IAPAR 61 IBIPORÃ (black oat, 60 kg/ha); *Avena strigosa* cv. Common (black oat, 60 kg/ha); *Lolium multiflorum* Lam. cv. Common (annual ryegrass, 35 kg/ha) and *Triticum aestivum* L. cv. BRS Tarumã (wheat, 140 kg/ha).

It was used 9-m^2 (3 m × 3 m) and a 2-m alley between blocks. The total experimental area was 1,200 m^2. Weed control and harvest management of oats were made according to the recommendations of Comissão Sul-Brasileira de Pesquisa de Aveia (1995). Environmental factors such as moisture and temperature were recorded at each sowing event. Both seeds and fertilizer were incorporated to a 2-cm depth using a rake.

Clipping regime starting was variable among treatments and herbage mass production was obtained by harvesting 0.25 m^2 quadrats when plants reached the target clipping height. Clipping occurred when plants reached an average height of 30 cm, 25 cm and 30 cm for oats, ryegrass and wheat, respectively. Forage were clipped to a 7 cm stubble height and samples were dried in a forced-air oven (55°C) for 96 hours then weighed to obtain herbage production for each clipping event. Total herbage production was calculated as the total herbage mass from counting all clipping events. Immediately after sampling, plots were staged by mowing at the same sample height.

The time between the sowing date and first cut was called “days to first cut” (DFC). Plant and tiller density was evaluated by manual counting at the first cut of each cultivar using a 0.16 × 0.20 m frame.

Data were analyzed by using ANOVA to identify possible sowing date×cultivar interactions, and possible differences among sowing date and cultivars. Overall treatments means were compared through a Duncan’s multiple range test (1%). The SANEST program (Zonta & Machado, 1984) was used.

Results and Discussion

A significant interaction was observed ($P<0.05$) between forage treatments and sowing date for all variables, indicating great opportunity in terms of choices of combination between cultivar and sowing date.

The length of period between sowing date and the first harvest (or grazing) defined how long the lack of forage supply would be in the fall.

Days to first cut (DFC) (Table 1) were 81 days on average for the five cultivars. Values of 81, 68, 81 and 70 days were observed for the first, second and third sowing date, respectively.

Table 1 - Number of days to first cut (NDC1) of annual winter grasses on different sowing dates

Forage	Sowing date: April 4th	April 24th	May 14th	June 3rd	Mean
Oat IPR 126[1]	69C	60C	83A	70B	70.5
Oat IAPAR 61[2]	61C	54C	80A	66B	65
Common black oat[5]	61C	52C	62B	62B	59
Common ryegrass[3]	84B	78B	91A	70B	81
Tarumã wheat[4]	131A	96A	91A	83A	100
Mean	81	68	81	70	
CV = 7.20%					

Values followed by same small letters, in the same column, do not differ significantly at 1% Duncan test
[1] $y = 66.850000 + 0.130000$ ($P=0.04156$; $r^2=0.1246$).
[2] $y = 59.025000 + 0.2075000x$ ($P=0.00283$; $r^2=0.2420$).
[3] $y = 81.312500 + 0.4093750x-0.00921875x^2$ ($P=0.01232$; $r^2=0.3985$).
[4] $y = 129.387500 - 1.7493750x + 0.01671875x^2$ ($P=0.00018$; $r^2=0.9613$).
[5] $P>0.05$.

Technically, the environmental conditions were better for plants sown in April when recorded values were 19.8°C and 219.4 mm for temperature and rainfall, respectively, in comparison to the other sowing dates. However, for all cultivars evaluated, the April 24th sowing date presented less DFC due to good environmental conditions for plants establishment and early growing. The weather in a planting time earlier than April 24th is most likely too hot for C_3 grasses, especially under a Cfa climate. On average for all species, the sowing date of April 4th in relation to April 24th took 13 days longer to reach the first harvest and the difference time between those two sowing date is 20 days. Results illustrate that with an early April planting date, in comparison to the recommended time (second half of April), it is possible to use the pasture a week earlier. This means that there will be one less week during the fall in which forage supply will be inadequate. The decision to plant earlier depends on several factors including economic issues, environmental and production system traits.

A comparison between sowing date to individual cultivars was made by using a regression analysis. A positive linear relationship was observed for IPR 126 and IAPAR 61, suggesting these cultivars present forage production earlier than the sowing date. Black oat was less affected by sowing date, and did not fit in any regression model. However, common ryegrass illustrated negative quadratic relationship, mainly due to a greater number of days to the first cut on the May 14th sowing date. Tarumã wheat illustrated a positive quadratic relationship, indicating that it is not a genotype adapted to sowing before May.

Besides the first sowing date, oats presented earlier forages in terms of forage production, followed by ryegrass and dual purpose wheat which took 131 days to reach the target cutting height, probably due to its adaptation to a more subtropical, temperate climate (Nelson et al., 1997).

No differences were observed between black and white oats for DFC, each one taking about 64 days to the first cutting. Thus, these cultivars may provide forage through mid-June, and subsequently significantly decrease the lack of forage in the fall. These forage species are highly productive early in the season when they are well fertilized and there is no occurrence of drought. Under these conditions, the first grazing or cutting can be made from 40 to 45 days after planting (Muehlmann et al., 2003).

Average NDC1 of five forage species sowed at April 24th was lower than when sowed on April 4th (Table 1), but no differences were observed among forage species within sowing date, indicating earlier forage production of the oats (55 days), followed by ryegrass (78 days) and finally Tarumã wheat (96 days). Flores et al. (2008b) counted 124 days to first harvest in the ryegrass plots when sowed in April, much longer than the period in this trial.

On the third sowing date, the genotypes evaluated were cut for the first time in mid-August, taking 81 days on average to reach the target clipping height. Black oat was harvested first, taking 62 days to be cut. This observation is in agreement with Floss et al. (2008) who stated that oats (IPR 126, IAPAR 61 and common oat) sowed on May 11th were first harvested 72 days after sowing. Cecato et al. (1998) also noticed this trend in several oat cultivars, including IAPAR 61 and common black oat, which took up to 60 days to the first cutting. The amount of time to the first cut can be headed by low rainfall and temperature occurring in May, which led to a low herbage accumulation rate. A similar situation was observed by Flaresso et al. (2001). When black oat was sown in March and April, it took up to 52 days to the first utilization and 66 days to the first cut when sowing was made in May and June.

Common ryegrass sown in May presented 91 days of NDC1, according to results from Flaresso et al. (2001), who observed reduction of the period to first cut when sowing dates were postponed along winter months in Vale do Itajaí region (SC). When sowing common ryegrass in March and April, the period required to the first cutting was 99 days and 87 days when sown in May and June. On the other hand, common ryegrass populations established in May in subtropical climate region needed 51 days to be first harvest. These differences are justified by genotypic variability and their interaction with the local environment. The same cultivar sown on similar dates can perform differently.

On the fourth and last sowing date, there were no observed differences among IPR 126, IAPAR 61, common black oat, common ryegrass forage species, which all took on average 67 days to the first cutting. Tarumã wheat was cut with 83 days of growth (late August). On sowing dates from the middle of May to beginning of June, both first cuttings were during the winter, extending to the end of August for IPR 126, common ryegrass and Tarumã wheat cultivars. Noro et al. (2003) obtained longer vegetative growth period using annual ryegrass, with the peak occurring during August when sown on April 26th. In general, Tarumã wheat shows potential as a late season forage production option and oats, especially common black oat, as an early season forage production option across all sowing dates.

Forage production at the first cut (Table 2), indicates the forage availability in the fall, a season widely characterized by a lack of forage supply. Although height defined the time of cutting and cutting height was fixed, differences in forage production between cuts and species occur due to structural modification in the canopy, e.g. tiller population density, leaf/stem ratio and dead material accumulation.

At the first sowing date, the highest forage production was obtained with oat IPR 126 (3,730 kg DM/ha), with no difference in relation to Tarumã wheat, and the lowest was obtained in oat IAPAR 61 (2,440 kg DM/ha). Technical recommendations of sowing dates for Paraná state for oat IAPAR 61 is from March to April, and from April to May for oat IPR 126 (IAPAR, 2005). However, by considering the forage production at the first cut for the oat IPR 126 in the present study, it could be sown earlier than official recommendation. At the second sowing date, ryegrass stood out by producing 5,650 kg DM/ha, probably due to better adaptation to the climatic conditions during this time of the year. Tarumã wheat performed 2,640 kg DM/ha, decreasing its production in relation to the first sowing date.

There was a reduction in forage production when plots were sown on May 14th (Third date), except for Tarumã wheat which increased its forage yield; however, no significant differences were observed among the five species. Machado et al. (2006) evaluated block common oat, IAPAR 61, IPR 126, rye and common annual ryegrass sown in May and fertilized with nitrogen just after each cut. In the study, no significant differences were observed in total herbage production and production at the first cutting among cultivars. At the fourth sowing date, IPR 126, black common oat, common ryegrass and Tarumã wheat did not present differences in their forage yield and IAPAR 61 presented the lowest production.

Observing the ryegrass forage production among sowing dates, it can be seen that the yield at the first cut was the highest one (4,050 kg DM/ha) and for IAPAR 61 the lowest yield (2,765 kg/ha), probably due to morphological differences leading to distinct canopy bulk densities. Ryegrass even cut when it reach lower height (25 cm) comparing to oats (30 cm) presented higher herbage amount in that harvest. Cecato et al. (1998), when evaluating cultivars and entries of oat, found 2,482 kg DM/ha at first cut for common black oat, and 2,521 kg/ha for IAPAR 61.

Herbage production of IPR 126 at the first cut presented quadratic and positive adjustment according to sowing

Table 2 - Forage production (kg DM/ha) at the first cut of annual winter grasses on different sowing dates

	Sowing date				
Forage	April 4th	April 24th	May 14th	June 3rd	Mean
Oat IPR 126[1]	3,730A	3,430B	2,920A	3,800A	3,470
Oat IAPAR 61[2]	2,440B	3,780B	2,800A	2,040B	2,765
Common black oat[5]	3,040AB	2,880B	2,800A	3,480A	3,050
Common ryegrass[3]	3,300A	5,650A	3,850A	3,400A	4,050
Tarumã wheat[4]	3,200A	2,640B	3,800A	3,000AB	3,160
Mean	3,142	3,676	3,234	3,144	
CV = 17.24 %					

Values followed by same capital letters, in the same column, do not differ significantly by Duncan test at 1%.
[1] $y = 0.381000 - 0.0045750x + 0.00007375x^2$ ($P = 0.04802$; $r^2 = 0.7337$).
[2] $y = 0.256700 + 0.0067850x - 0.000131225x^2$ ($P = 0.00166$; $r^2 = 0.8060$).
[3] $y = 0.357500 + 0.0097500x - 0.00017500x^2$ ($P = 0.0001$; $r^2 = 0.5781$).
[4] $P>0.05$

dates. Both IAPAR 61 and ryegrass performed in quadratic and negative way. Results illustrate that from 26 to 28 days after April 4th (April 30th and May 2nd, respectively) would be the estimated date when the highest herbage production would be observed at first cut. Common black oat and Tarumã wheat were less influenced by sowing date, and did not illustrate significant adjustment according to the regression analysis.

According to forage production (Table 3) at first sowing date, IAPAR 61 and IPR 126 were the highest (16,067 and 14,762 kg DM/ha, respectively), followed by common black oat and common ryegrass (11,960 and 9,930 kg DM/ha, respectively) and Tarumã wheat had the lowest yield (5,160 kg DM/ha). In the same system, in the Castrolanda, PR region, comparing ten genotypes of oat under 30 cm (height target for the cut moment) and 7 cm (stubble height) regime, yield for IAPAR 61 and IPR 126 were 7,454 and 8,337 kg DM/ha, respectively (Almeida et al., 2006), which were values much lower than the ones found in this trial.

Sowing time recommendations for the temperate climate region for grazing use is from March 15th to April 15th, allowing production from 2,000 to 6,000 kg DM/ha (Kichel & Miranda, 2000). In this experiment, the highest forage production was obtained when sowing date was from April 4th to April 24th.

When sown on April 24th, IPR 126 presented the highest forage production (20,190 kg DM/ha), overcoming IAPAR 61 (16,755 kg DM/ha) and common black oat (11,420 kg DM/ha). The high production obtained at this sowing date can be explained by the optimal weather conditions. Neto et al. (2000) noticed increased productivity in white oat in relation to the length of vegetative growth and grain yield. A genotype × environment interaction was also observed in several years. The average forage production was 8,178 kg DM/ha in 85 days of vegetative growth.

Ryegrass production declined from 9,930 to 8,490 kg DM/ha suggesting that ryegrass could be planted earlier to reach higher herbage yield. In research using ryegrass carried out on Planalto Médio in the state of Rio Grande do Sul (Cfa climate), forage production ranged from 9,000 and 11,000 kg DM/ha when clipped to a 7 cm stubble height when the canopy reached 30 to 35 cm height (Noro et al., 2003). According to Flaresso et al. (2001), common ryegrass forage production was 30% higher when sown in April than in May and June, under Cfa climate conditions and cut regime of 28 days often fertilizing with nitrogen right after every harvest.

Tarumã wheat had an increase in herbage production from 5,160 to 7,470 kg DM/ha, from the first to second sowing date, indicating that the best management to increase herbage production is to postpone the sowing date up to April 24th or May14th. This cultivar, released by EMBRAPA, is recommended for cold regions and it should be sown from middle April to May to obtain good forage production distribution during winter and fall (Wendt et al., 2006), which may explain low forage production anticipating sowing date, especially under Cfa climate.

Mean of wheat forage yield reaches 3,000 kg DM/ha when sowed between April and May, allowing grazing in June, July and August (Del Duca & Fontaneli, 2006). On nine sowing dates using wheat genotypes, it was obtained 6,010 kg DM/ha, on average, when it was sowed on the second half of April and 5,496 kg DM/ha in the beginning of May sowing date (Del Duca et al., 2002).

On the third sowing date (May 14th), common black oat presented the highest forage production (11,170 kg DM/ha) and IPR 126 and IAPAR 61 production decreased significantly (7,500 and 7,882 kg DM/ha, respectively). Similar results were observed for IPR 126 with 10,848 kg DM/ha within 125 days from emergence to flowering (Primavesi et al., 2005).

Table 3 - Total forage production (kg DM/ha) of annual winter grasses on different sowing dates

	Sowing date				
Forage	April 4th	April 24th	May 14th	June 3rd	Mean
Oat IPR 126[1]	14,762A	20,190A	7,500B	7,780A	12,558
Oat IAPAR 61[2]	16,067A	16,755B	7,882B	3,780B	11,121
Common black oat[5]	11,960B	11,420C	11,170A	6,120AB	10,167
Common ryegrass[3]	9,930B	8,490D	6,557B	6,040B	7,754
Tarumã wheat[4]	5,160C	7,470D	6,520B	6,520A	6,417
Mean	11,575	12,869	7,926	6,048	
CV = 13.19 %					

Values followed by same capital letters, in the same column, do not differ significantly by Duncan test at 1%.
[1] $y = 1.631688 + 0.0024844x - 0.00032172x^2$ ($P = 0.00082$; $r^2 = 0.5667$).
[2] $y = 1.678400 - 0.0049050x - 0.00029938x^2$ ($P = 0.00140$; $r^2 = 0.9149$).
[3] $y = 1170550 + 0.0080275x - 0.00028188x^2$ ($P = 0.00215$; $r^2 = 0.941$).
[4] $y = 0.979475 - 0.0068013x$ ($P = 0.00023$; $r^2 = 0.9811$).
[5] $P>0.05$.

Ryegrass and Tarumã wheat diminished their production in relation to the two previous sowing dates (6,557 and 6,520 kg DM/ha, respectively) and no differences were observed between them. Lower rainfall index and lower temperature during May (64.2 mm and 16.5°C) decreased the yield and delayed the first cutting event. Pereira et al. (2008) evaluated forage production of 30 ryegrass populations sowing in the beginning of May. The first cutting was June 28th and the last one on October 6th, totaling 98 days of pasture utilization and obtaining forage production varying between 3,654 kg DM/ha and 8,544 kg DM/ha. According to these data, it was verified great genetic diversity of this species.

On the fourth sowing date, IPR 126 had the highest forage production (7,780 kg DM/ha), followed by common black oat and common ryegrass. IAPAR 61 and wheat performed worse on this sowing date (Table 3).

When comparing sowing dates, regardless of the forage species, higher forage production was observed on the second date (April 24th). When comparing forage species, regardless of the sowing date, higher production was observed for IPR 126. These results are similar to values from a 3-year study by Flaresso et al. (2001) in which on four sowing dates ranging from March to June, better yield and longer forage production period were found from sowing oats and ryegrass in April, when the average temperature was 18.4ºC. The ideal temperature for annual cool-season grasses ranges from 15 to 25°C (Monteiro et al., 2008).

Comparing all sowing dates within forage species, it was verified that IPR 126, IAPAR 61 and common black oat performed in negative quadratic way, in which maximum estimated yield would be reached respectively 4, 8 and 14 days from April 4th (April 8th, April 12th and April 18th, respectively). Ferolla et al. (2007) found significant interactions between sowing date (April, May and June), method used (mechanical harvest and grazing) and forage species (common black oat and triticale) under temperature and rainfall precipitation of 24°C and 1,023 mm yearly. These authors concluded that common black oat performs better when sown in May (3,426 kg DM/ha) and June (2,686 kg DM/ha), allowing three cuts in May and a higher leaf/stem ratio in June. Ryegrass forage production linearly declined according to sowing dates. The highest herbage production was achieved when it was sowed in April. On the other hand, Tarumã wheat was not affected by the sowing date for this variable.

Differences in obtained regression models clearly illustrate the forage cultivar and sowing date interaction, and bring information that could be used to make decisions about forage species mixtures to extend the growing season and ensure a more constant forage supply. According to Cecato et al. (1998), who evaluated 12 entries of oat, cultivar mixture may be used to have a longer period of forage production and higher forage production mainly when water plant demand was matched.

In relation to the number of cuts (Table 4), of the plots sowed at the first date, the three oat entries required a higher number of cuts. Similarly, Flaresso et al. (2001) sowed common black oat and ryegrass in March and April and obtained greater numbers of cuts and a longer period of pasture utilization in relation to plots sowed later.

At the second sowing date, the three oats performed better as well, especially the two improved cultivars (IAPAR 61 and IPR 126). At this sowing date, Tarumã wheat only required three cuts and was cut only twice on the other sowing dates. It can be concluded that the evaluated forage species perform better at the beginning of the growing season when sown under environmental conditions such as those which occurred in April. On the third sowing date, the reduction in the number of cuts was most evident for IPR 126 and IAPAR 61. Average of number of cuts for all five cultivars on this sowing date decreased to three, indicating that

Table 4 - Number of cuts performed on annual winter grasses on different sowing dates

Forage	Sowing date				Mean
	April 4th	April 24th	May 14th	June 3rd	
Oat IPR 126[1]	6A	5AB	3AB	3A	4
Oat IAPAR 61[2]	6A	6A	3AB	2A	4
Common black oat[5]	5A	4BC	4A	2A	4
Common ryegrass[3]	3B	2D	2B	2A	2
Oat IPR 126[1]	2B	3CD	2B	2A	2
Mean	4	4	3	2	
CV = 23.12 %					

Values followed by same capital letters, in the same column, do not differ significantly by Duncan test at 1%.
[1] y = 5.900000 - 0.0550000x (P = 0.00003; r² = 0.8963).
[2] y = 6.500000 - 0.0750000x (P = 0.00001; r² = 0.8824).
[3] y = 5.100000 - 0.0450000x (P = 0.00012; r² = 0.8526).
[4] P>0.05.

establishing these late-growing season forages from May is not ideal (Table 4). However, Reis et al. (1992) reached five cuts in common black oat sown at the end of May.

On the fourth sowing date, no significant differences were observed among forage species, although the number of cuts in common black oat decreased in relation to the previous dates. Pereira et al. (2008) evaluated 30 genotypes of common ryegrass, and when planted in May, seven harvests were obtained. Reduction in the number of cuts in almost all forage species probably is associated with environmental factors such as day length and temperature.

In relation to performance of each forage species across sowing dates, it was verified that oats presented a linear negative adjustment, indicating less number of cuts when sowing date is postponed. In contrast, ryegrass and Tarumã wheat were not influenced by sowing date, considering the number of cuts.

According to the information about the forage production dynamics presented so far, a mixture of forage species can be used to lengthen the herbage production period. However, forage species performance may be different when grown either alone or in association with other forage species.

A tendency of decreasing plant density was observed when sowing date was postponed, with the exception of common black oat (Table 5).

Nakagava et al. (2000) planted common black oat in June and counted 87.5 plants/m² less than Rosseto & Nakagava (2001), who obtained, on average, 126 plants/m². When sowing was carried out in the second half of May in Dois Vizinhos, Hastenpflug et al. (2007) obtained 221.3 plants of Tarumã wheat/m². These values were far higher than those obtained in this experiment, except for April 24th sowing date.

Comparisons among sowing date within forage species, through regression analysis, indicates linear negative adjustment for common ryegrass and IPR 126 oat, showing that any delay in sowing time from April 4th decreases plant population density. Tarumã wheat and IAPAR 61 presented quadratic negative adjustment, according to sowing dates. Dates that would promote highest plant population density, estimated by the mode, are April 25th and April 20th for Tarumã wheat and IAPAR 61, respectively. Common black oat was not influenced by sowing date for this variable.

At the first sowing date, common black oat and ryegrass had a higher tiller population density (Table 6), due to their

Table 5 - Plant density population (plant/m^2) of annual winter grasses on different sowing dates

	Sowing date				
Forage	April 4th	April 24th	May 14th	June 3rd	Mean
Oat IPR 126[1]	368B	384B	188C	196B	284
Oat IAPAR 61[2]	426A	506A	357B	171BC	365
Common black oat[5]	496A	588A	496A	568A	537
Common ryegrass[3]	400A	336B	172CD	156BC	266
Oat IPR 126[1]	112C	218C	80D	75C	121
Mean	360	406	259	233	
CV = 16.36 %					

Values followed by same capital letters, in the same column, do not differ significantly by Duncan test at 1%.
[1] y = 390.800000 – 3.560000x (P=0.00003; r² = 0.7452).
[2] y = 436.375000 + 5.4062500x – 0.16656250x² (P=0.00013; r² = 0.9700).
[3] y = 400.400000 – 4.4800000x (P=0.00001; r² = 0.9166).
[4] y = 130.950000 + 2.9475000x – 0.07x² (P = 0.03902; r² = 0.4662).
[5] P>0.05.

Table 6 - Tiller population density (tillers/m^2) of annual winter grasses on different sowing dates

	Sowing date				
Forage	April 4th	April 24th	May 14th	June 3rd	Mean
Oat IPR 126[1]	1,684B	1,684B	832C	976B	1,294
Oat IAPAR 61[2]	1,754B	1,488C	1,168BC	896B	1,326
Common black oat[5]	2,056A	2,004B	2,357A	1,436A	1,963
Common ryegrass[3]	2,224A	2,684A	1,320B	1,765A	1,998
Oat IPR 126[1]	1,728B	1,520C	1,130BC	1,580A	1,489
Mean	1,889	1,876	1,361	1,331	
CV = 12.14%					

Values followed by same capital letters, in the same column, do not differ significantly by Duncan test at 1%.
[1] y = 1740.400000 – 14.8800000x (P = 0.00002. r² = 0.71557).
[2] y = 1761.125000 – 14.4812500x (P = 0.00002; r² = 0.9988).
[3] y = 1972.012500 + 25.0631250x – 0.54328125x² (P = 0.00042; r² = 0.6819).
[4] y = 2409.250000 – 13.700000x (P = 0.00003; r² = 0.3626).
[5] y = 1778.987500 – 28.8131250x (P = 0.00327; r² = 0.7330).

morphology and smaller leaves and tiller in relation to other forage cultivars. Similarly, at the second sowing date, these materials had a higher tiller population density, the same of IPR 126 oat. On the third sowing date, common black oat maintained the highest tiller population density, and IPR 126 had the lowest density, decreasing its tiller population density in comparison to previous sowing dates. When sown on June 3rd, the two improved cultivars of oats presented the lowest tiller population density. In general, it was observed that these forage species had higher tillering ability when sown in April, except for Tarumã wheat, which certainly influenced the higher forage production at that sowing time (Table 3).

The tiller population density performance of each forage species under different sowing dates were linear negative when sowing date was postponed, except for common black oat which was adjusted to a quadratic negative model, which had an estimated highest tiller population density when sowing was done on April 27th.

Radiation level partially dictates tiller population density (Chapman & Lemaire, 1993). The highest rainfall occurred in April (219.4 mm), and temperature (19.8°C) probably influenced great plant tillering when plots were sowed at first and second sowing dates. A date in April for sowing can be recommended to encourage a high tiller population density and forage production. During May, less rainfall (64.2 mm) occurred. The reduction in tiller population density under less water supply is an indication of how susceptible plants are to water deficits (Bortolini et al., 2005).

Conclusions

Sowing dates strongly interfere with the forage production dynamics of annual cool-season grasses. The highest forage production, plant and tiller population densities and number of cuttings occurred when these pastures are planted until the end of April. The significant sowing date and forage material interaction for all variables evaluated indicates the need for knowledge on the correct combination between these two factors (forage cultivar/ species and sowing date) according to the forage demand on each farm. Oats, especially late growing season entries, are excellent options to provide forage during June and August, when long periods of forage production, earlier and high forage production are presented.

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