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Nitrogen management at sowing and topdressing with the time of supply in the main biotype of oats grown in southern Brazil

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Abstract

Adjusting the nitrogen dose at sowing and topdressing with the time of application can improve nutrient management and increase oat productivity. The objective of the study is the most efficient and sustainable management of nitrogen use in the adjusted combination of nutrient dose at sowing and for topdressing with the moment of application on the productivity of biomass and oat grains, considering the main systems of cereal succession in southern Brazil.. The experiment was conducted in the years 2015, 2016 and 2017, in Augusto Pestana, RS, Brazil. The design was a randomized block with four replications, in a 4 x 4 factorial model, consisted of four doses of nitrogen at sowing time (0, 10, 30 and 60 kg ha^{-1}), and topdressing dose by the total supplied of 70 and 100 kg ha^{-1} in succession system soybeans / oats and corn / oats, respectively, in the expectation of grain yield of 4000 kg ha^{-1}, with the supply for topdressing considering four application times (0, 10, 30 and 60 days after emergence). The most efficient and sustainable management of nitrogen use for biomass and oat grains productivity occurs with the total supply of the covered nutrient around 30 days after emergence, regardless of the condition of the agricultural year and succession system.

Introduction

The oats productivity potential is related with the genetic features of the cultivars and their interaction with meteorological conditions and management technologies. Among the management technologies, the dose and period of N-fertilizer supply are fundamental to increase productivity (Mantai et al., 2015; Silva et al., 2016). Nitrogen is the nutrient most absorbed and directly linked to productivity, due to the insufficient amount made available by the soil, it needs an exogenous supply in the form of nitrogen fertilizers (Silva et al., 2015; Marolli et al., 2018). The definition of the total dose to be applied depends on the organic matter content of the soil, the succession system and the expected productivity (Siqueira Neto et al., 2010; Silva et al., 2016). In cereals such as wheat and oats, the total dose provided considers its use for sowing and topdressing (Arenhardt et al., 2015; Mantai et al., 2016).
The most significant volumes are applied for topdressing, where the best conditions of soil moisture and air temperature are not always obtained, causing losses in productivity, with economic and environmental losses (Marolli et al., 2017; Costa et al., 2018). In the search for greater efficiency, studies on corn and beans have shown benefits of nitrogen fertilization in total dose or in greater quantity at the time of sowing (Brugnera, et al., 2003; Moreira et al., 2013). The most propitious moment for topdressing falls only on the phenology of the plant linked to the period of greatest lack of nutrient in the formation of production components. Therefore, the technical indications recommend as the fertilization time between the beginning of the tillering until the beginning of the elongation, an interval around 30 to 60 days after the emergence of the plants (Arenhardt et al., 2015; Marolli et al., 2017). The fertilization time for topdressing can be better adjusted by observing the weather conditions for anticipation or delay in application, in the interval of greatest demand for the nutrient by the plant. Fertilizing at sowing to protect nitrogen from sunlight and high air temperature, also keeps the nutrient closer to the roots, which would enable greater use efficiency on productivity (Mantai et al., 2016; Marolli et al., 2017). The objective of the study is the most efficient and sustainable management of nitrogen use in the adjusted combination of nutrient dose at sowing and for topdressing

with the moment of application on the productivity of biomass and oat grains, considering the main systems of cereal succession in Brazil in favorable and unfavorable agriculture years for growing.

Results and discussion

In 2015, rainfall was similar to the historical average of the last 25 years (Table 2). More expressive values of precipitation were observed at the beginning of the growing cycle, mainly after fertilization at 10 and 30 days after emergence. The nitrogen supply at 60 days after emergence was in a condition of reduced soil moisture (Figure 1A). Although fertilization expects grain yield to be around 4000 kg ha^{-1}, the weather conditions presented with the yield results indicated an intermediate year (IY) condition for oat growing.
In 2016, rainfall was lower in relation to the historical average, however, with an adequate distribution throughout the cycle. Temperatures were milder and with some stability during growing (Table 2). The moment of nitrogen application at 10 and 30 days after emergence was in conditions of soil moisture due to rains that occurred before the fertilization (Figure 1B). The adequate distribution of rainfall with milder temperatures during the cycle promoted an average grain yield similar to the desired expectation of 4000 kg ha^{-1}, justifying a favorable year (FY) for growing. In 2017, the volume of rainfall was below the historical average (Table 2) and with irregular distribution (Figure 1C). Higher and unstable temperatures were also observed throughout the cycle compared to the other years of evaluation. Fertilization at 10 and 30 days after emergence was in conditions of severe soil moisture restriction for a long period without precipitation, with the exception of fertilization performed at 60 days after emergence (Figure 1C). The high temperatures together with reduced soil moisture during fertilization promoted grain yield of 1979 kg ha^{-1}, well below the expectation of 4000 kg ha^{-1}, justifying an unfavorable year (UY) for growing.
Of all segments of the economy, agriculture is the one that is most dependent on meteorological variables, generating fluctuations in production over the years. Rainfall stands out as one of the main elements responsible for these variations (Marolli et al., 2017). Temperature also influences productivity, acting as a catalyst for biological processes, which is why plants require a minimum and maximum temperature for normal physiological activities (Tonin et al., 2014). In oats, the favorable climate is described as that of milder temperatures and radiation that favors the tillering and filling of grains, without the occurrence of rain in large quantities and intensity, however, with adequate distribution to maintain the moisture stored in the soil (Arenhardt et al., 2015). In the supply of nitrogen, the occurrence of rainfall after fertilization reduces the efficiency of utilization by the plant due to the losses of the nutrient by leaching. Elevated temperatures and reduced soil moisture also reduce efficiency due to volatilization losses (Scremin et al., 2017). These conditions justify the development of strategies to promote more sustainable management.
In Table 3, in the soybean/oat system, in the absence of nitrogen at sowing and total supply for topdressing (70 kg ha^{-1}), the intermediate (2015) and favorable (2016) years for growing showed a higher rate of biomass productivity (b_1x), total and grain biomass when the nutrient was provided 30 days after emergence. The unfavorable year (2017) indicated the need to anticipate fertilization for topdressing, with a higher rate of biomass, total biomass and grain productivity at 10 days after emergence.
In Table 3, the use of 10 kg ha^{-1} of nitrogen at sowing combined with 60 kg ha^{-1} for topdressing and 30 kg ha^{-1} at sowing and 40 kg ha^{-1} for topdressing, in the total dose of 70 kg ha^{-1}, indicated the highest rates of biomass productivity, total biomass and grain yield with nitrogen supply at 30 days after emergence, be it an intermediate (2015) and favorable (2016) year of growing. In the unfavorable year (2017), sowing fertilizer with 10 and 30 kg ha^{-1} of nitrogen also indicated the need to anticipate application 10 days after emergence, with a higher rate of biomass productivity, total biomass and grain yield.
In Table 3, in the use of 60 kg ha^{-1} of nitrogen at sowing and 10 kg ha^{-1} for topdressing for a total dose of 70 kg ha^{-1} of the nutrient, the intermediate year (2015) of growing showed greater grain productivity when the nutrient was supplied at 30 days after emergence, although the rate of productivity and the total biomass productivity did not change under the conditions of fertilization at sowing. In a favorable year (2016), the supply of nitrogen for topdressing at 10, 30 and 60 days after emergence did not change the productivity of total biomass and grains, although the biomass productivity rate was more expressive with fertilization at 30 days after the emergence. In an unfavorable year (2017), none of the top dressing conditions promoted significant results in changing the productivity rate of biomass, total biomass and grains. In general, in Table 3 in the soybean/oat system, regardless of the condition of the agricultural year, a trend of reduction in grain yield is observed as the nitrogen doses at sowing increase with a reduction in topdressing. Therefore, the partitioning of the fertilizer dose at sowing and topdressing to contemplate the total nitrogen dose of 70 kg ha^{-1} for grain yield expectations of 4000 kg ha^{-1}, significantly alter the expression of oat productivity indicators.
In Table 4, in the corn/oat system, the condition without using nitrogen at sowing with total dose in topdressing (100 kg ha^{-1}) showed in the intermediate (2015), favorable (2016) and unfavorable (2017) years of growing the higher productivity of total biomass and grains, when supplied at 10 and 30 days after emergence. Although the biomass productivity rate was higher with the application of the nutrient at 30 days after emergence. In addition, regardless of the condition of the agricultural year, higher productivity of biomass and grains was observed with base fertilization in 10, 30 and 60 kg ha^{-1}, changing the topdressing dose by 90, 70 and 40 kg ha^{-1}, respectively, when provided 10 and 30 days after the emergence. In this system, regardless of the nitrogen dose at sowing, the best times of topdressing were at 10 and 30 days after emergence. Therefore, suggesting the possibility of earlier fertilization and a longer interval for nutrient supply when under more restrictive conditions of N-residual.
In general, in Table 4, there is also a tendency to reduce productivity as nitrogen doses at sowing increase and in topdressing decreases, in the total supply of 100 kg ha^{-1} of the nutrient in the expectation of grain productivity of 4000 kg ha^{-1}. This condition was similar to that obtained in the soybean/oat system (Table 3). In this way, only the total nitrogen dose is not decisive on the expected productivity, and it is necessary to establish a better adjustment between the nutrient dose at sowing and topdressing with the

Table 1. Conditions of nitrogen supply at sowing and topdressing of oats in succession systems.

Nitrogen at sowing (kg ha^{-1})	Nitrogen for topdressing (kg ha^{-1})	Total Nitrogen (kg ha^{-1})	Productivity Expectation (kg ha^{-1})
Soybean/oat system			
0	70		
10	60	70	4000
30	40		
60	10		
Corn/oat system			
0	100		
10	90	100	4000
30	70		
60	40		

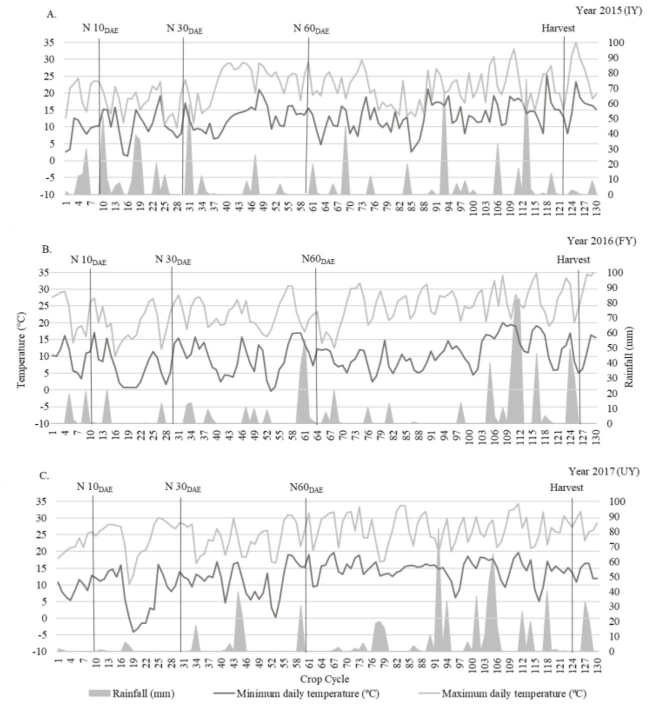

Fig 1. Data of rainfall and minimum and maximum daily temperature in the oat crop cycle. (A) 2015 agricultural year; (B) 2016 agricultural year; (C) 2017 agricultural year.

Table 2. Weather conditions and grain yield in the oat crop cycle.

Month	Temperature (°C)			Rainfall (mm)		GY (Kg ha^{-1})	Class
	Min	Max	Average	25 years*	Occurred		
2015							
June	9.56	21.47	15.52	162.5	228.3		
July	10.5	20.59	15.55	135.1	211.5		
August	13.3	24.8	19.05	138.2	86.8	3283	IY
September	12.73	19.93	16.33	167.4	127.3		
October	16.7	25.2	20.95	156.5	161.8		
Total	-	-	-	909.4	815,7		
2016							
June	4.7	19.3	12.00	162.5	65.6		
July	8.5	21.55	15.03	135.1	80.5		
August	9.4	22.5	15.95	138.2	160.0	3925	FY
September	8.44	23.82	16.13	167.4	56.3		
October	13.3	25.8	19.55	156.5	325.8		
Total	-	-	-	909.4	688.2		
2017							
June	10.7	21.8	16.25	162.5	146.3		
July	8.3	24.42	16.36	135.1	10.7		
August	11.4	23.7	17.55	138.2	117.8	1979	UY
September	15.36	27.07	21.22	167.4	161.5		
October	14.7	27.8	21.25	156,5	304,0		
Total	-	-	-	909.4	740.3		

Data obtained from the weather station located at the Regional Institute for Rural Development / IRDeR / UNIJUÍ in 2015, 2016 and 2017. FY - Favorable year; IY - Intermediate year; UY - Unfavorable year; GY - Grain yield; Min - minimum temperature; Max - Maximum temperature; * Rainfall in the months from May to October of the last 25 years. Sowing (2015): 06/09; Sowing (2016): 06/21; Sowing (2017): 06/22

Table 3. Estimation of the biomass rate (b_1x), total biomass and grain yield in nitrogen doses at sowing and topdressing in the soybean/oat system.

NS (dias)	2015 (IY) b_1x	R^2	BP (kg ha^{-1})	GY (kg ha^{-1})	2016 (FY) b_1x	R^2	BP (kg ha^{-1})	GY (kg ha^{-1})	2017 (UY) b_1x	R^2	BP (kg ha^{-1})	GY (kg ha^{-1})
N base (0 kg ha^{-1})												
0	62x	99	5771 c	2015 b	87x	99	8051 b	2649 b	50x	96	4624 b	1420 c
10	87x	99	8530 b	3224 a	105x	99	10969 a	3730 a	73x	98	6870 a	2495 a
30	110x	98	11228 a	3525 a	111x	99	11192 a	4055 a	68x	99	6422 a	2006 b
60	79x	99	7681 b	2329 b	97x	99	9073 b	2873 b	55x	97	5334 b	1862 b
N base (10 kg ha^{-1})												
0	72x	99	6717 d	2059 c	92x	99	8586 d	2846 b	55x	94	5071 b	1504 c
10	92x	99	8669 b	3093 b	85x	98	10349 b	3494 a	69x	97	6537 a	2274 a
30	113x	99	10561 a	3440 a	123x	98	11445 a	3795 a	67x	96	6325 a	1951 b
60	84x	99	7888 c	2313 c	101x	95	9415 c	3072 b	58x	99	5288 b	1886 b
N base (30 kg ha^{-1})												
0	91x	96	8612 b	2104 c	104x	98	10004 a	3035 c	56x	98	5118 b	1722 c
10	100x	99	9290 b	2825 b	113x	95	10666 a	3374 b	62x	95	5929 a	2200 a
30	118x	99	10602 a	3393 a	118x	96	11118 a	3611 a	60x	97	5887 a	1941 b
60	94x	99	8194 b	2354 c	110x	98	10585 a	3338 b	63x	95	5874 a	1900 b
N base (60 kg ha^{-1})												
0	88x	97	8268 b	2369 b	107x	96	9817 a	2840 b	67x	98	5492 a	1778 a
10	98x	99	9344 a	2690 b	114x	99	9898 a	3207 a	65x	99	5721 a	1912 a
30	98x	99	9244 a	3137 a	121x	99	10361 a	3375 a	65x	94	5828 a	1881 a
60	103x	99	9335 a	2409 b	112x	98	10275 a	3235 a	67x	96	5879 a	1830 a

NS - Nitrogen season; GY - Grain yield; BP - Total biomass productivity; IY - Intermediate year; FY - Favorable year; UY - Unfavorable year; R^2 - Coefficient of determination; b_1x - Slope parameter of the line that indicates the productivity rate of biomass produced in kg ha^{-1} each day; Averages followed by the same letters constitute a statistically homogeneous group per nitrogen dose by the Skott & Knott test at 5% probability of error

Table 4. Estimation of the biomass rate (b_1x), total biomass productivity and grain yield at nitrogen doses at sowing and topdressing in the corn/oat system.

NS (dias)	2015 (IY) b_1x	R^2	BP (kg ha^{-1})	GY (kg ha^{-1})	2016 (FY) b_1x	R^2	BP (kg ha^{-1})	GY (kg ha^{-1})	2017 (UY) b_1x	R^2	BP (kg ha^{-1})	GY (kg ha^{-1})
N base 0 (kg ha^{-1})												
0	64x	96	5893 c	1793 c	75x	99	7916 c	2274 c	38x	98	3585 c	1062 b
10	92x	99	8649 a	3591 a	103x	95	10292 a	4220 a	52x	97	5887 a	2304 a
30	107x	95	8653 a	3363 a	106x	96	10481 a	4072 a	55x	98	5929 a	2113 a
60	87x	97	6271 b	2394 b	98x	99	8846 b	2687 b	47x	95	4739 b	1357 b
N base (10 kg ha^{-1})												
0	71x	94	6460 c	1983 c	84x	95	7653 c	2500 c	41x	96	3796c	1078 c
10	93x	98	8620 a	3278 a	114x	97	10550 a	3878 a	64x	99	5996 a	2129 a
30	112x	97	9350 a	3409 a	118x	96	10829 a	3779 a	57x	98	5640 a	2001 a
60	90x	99	7280 b	2388 b	101x	99	9194 b	2783 b	49x	97	4437 b	1351 b
N base (30 kg ha^{-1})												
0	82x	95	7595 b	2287 b	101x	99	8586 b	3076 b	46x	95	4782 b	1129 c
10	95x	98	8741 a	3038 a	107x	96	9945 a	3235 a	57x	94	5505 a	1973 a
30	114x	96	8961 a	3414 a	112x	99	10406 a	3366 a	61x	98	5540 a	1765 a
60	97x	95	7635 b	2442 b	107x	98	9082 b	3009 b	53x	98	4851 b	1384 c
N base (60 kg ha^{-1})												
0	80x	99	7384 b	2330 b	105x	97	9366 a	2779 b	55x	97	4723 a	1048 c
10	92x	94	8392 a	2769 a	110x	95	9363 a	3121 a	64x	98	4856 a	1646 a
30	96x	98	8709 a	3022 a	114x	94	9770 a	2967 a	48x	95	4430 a	1591 a
60	94x	97	8618 a	2330 b	101x	96	9121 a	2754 b	45x	99	4176 a	1226 b

NS - Nitrogen season; GY - Grain yield; BP - Total biomass productivity; IY - Intermediate year; FY - Favorable year; UY - Unfavorable year; R^2 - Coefficient of determination; b_1x - Slope parameter of the line that indicates the productivity rate of biomass produced in kg ha^{-1} each day; Averages followed by the same letters constitute a statistically homogeneous group per nitrogen dose by the Skott & Knott test at 5% probability of error

Table 5. Parameters of the regression equation and estimation of the ideal time of nitrogen supply for topdressing to the productivity of oat grains in soybean/oat system.

N Base	SV	MS (GY)	Equation $GY = b_0 \pm b_1x \pm b_2x^2$	P (b_ix^n)	R^2	Ideal time (days)	GY_E (kg ha^{-1})
2015 (IY)							
0	L	324^{ns}	-	ns			
	Q	5752937*	$2153 + 98.14x - 1.59x^2$	*	93	31	4234
10	L	172^{ns}	-	ns			
	Q	4826134*	$2159 + 89.85x - 1.46x^2$	*	95	30	3946
30	L	36813^{ns}	-	ns			
	Q	3825677*	$2115 + 81.97x - 1.30x^2$	*	99	32	3406
60	L	360^{ns}	-	ns			
	Q	1478141*	$2334 + 49.85x - 0.81x^2$	*	98	31	3111
2016 (FY)							
0	L	3388^{ns}	-	ns			
	Q	5172880*	$2759 + 92.24x - 1.51x^2$	*	95	31	4167
10	L	16548^{ns}	-	ns			

	Q	2092366*	$2896 + 60.47x - 0.96x^2$	*	97	31	3848
30	L	134399*	$3240 + 4.0x$	*	20		
	Q	527551*	$3053 + 33.66x - 0.53x^2$	*	98	32	3643
60	L	231420*	$3033 + 5.25x$	*	36		
	Q	363292*	$2878 + 29.86x - 0.46x^2$	*	94	32	3435
2017 (UY)							
0	L	9610^{ns}	-	ns			
	Q	779579*	$1693 + 37.13x - 0.59x^2$	*	33	31	2277
10	L	31300^{ns}	-	ns			
	Q	383873*	$1696 + 27.23x - 0.41x^2$	*	34	33	2148
30	L	55^{ns}	-	ns			
	Q	119665*	$1850 + 14.21x - 0.23x^2$	*	25	31	2069
60	L	220^{ns}	-	ns			
	Q	24768*	$1806 + 6.59x - 0.10x^2$	*	60	33	1915

N - Nitrogen; SV - Source of variation; GY - Grain yield (kg ha^{-1}); MS - Mean square; L - Linear equation; Q - Quadratic equation; R² - Coefficient of determination; P (b_ix^n) - Probability of the slope parameter; IY - Intermediate year; FY - Favorable year; UY - Unfavorable year; * Significance of the slope parameter at 5% probability of error by t test; ns - Not significant at 5% probability of error; EGY - Estimated grain yield.

Table 6. Parameters of the regression equation and estimation of the ideal time of nitrogen supply for topdressing to the productivity of oat grains in corn/oat system

N Base	SV	MS (GY)	Equation $GY = b_0 \pm b_1x \pm b_2x^2$	P (b_ix^n)	R^2	Ideal time (days)	GY_E (kg ha^{-1})
2015 (AI)							
0	L	6858^{ns}	-	ns			
	Q	6059501*	$2132 + 101.43x - 1.64x^2$	*	71	31	3700
10	L	6607^{ns}	-	ns			
	Q	4979422*	$2170 + 92.01x - 1.48x^2$	*	87	31	3600
30	L	81^{ns}	-	ns			
	Q	3249982*	$2335 + 73.52x - 1.20x^2$	*	98	31	3460
60	L	4960^{ns}	-	ns			
	Q	1300585*	$2314 + 45.80x - 0.76x^2$	*	99	30	3004
2016 (AF)							
0	L	63277^{ns}	-	ns			
	Q	8999902*	$2613 + 119.76x - 1.99x^2$	*	78	30	4415
10	L	36687^{ns}	-	ns			
	Q	4580490*	$2739 + 85.31x - 1.42x^2$	*	79	30	4020
30	L	20586^{ns}	-	ns			
	Q	288166*	$3073 + 20.36x - 0.36x^2$	*	99	28	3360
60	L	4770^{ns}	-	ns			
	Q	112101*	$2863 + 12.92x - 0.22x^2$	*	44	29	3052
2017 (AD)							
0	L	17806^{ns}	-	ns			
	Q	3047486*	$1298 + 69.83x - 1.16x^2$	*	72	30	2349
10	L	4770^{ns}	-	ns			
	Q	2279688*	$1271 + 60.90x - 1.00x^2$	*	74	30	2198
30	L	2190^{ns}	-	ns			
	Q	772301*	$1325 + 35.38x - 0.58x^2$	*	48	31	1864
60	L	2^{ns}	-	ns			
	Q	752648*	$1156 + 35.41x - 0.58x^2$	*	75	31	1696

N - Nitrogen; SV - Source of variation; GY - Grain yield (kg ha^{-1}); MS - Mean square; L - Linear equation; Q - Quadratic equation; R² - Coefficient of determination; P (b_ix^n) - Probability of the slope parameter; IY - Intermediate year; FY - Favorable year; UY - Unfavorable year; * Significance of the slope parameter at 5% probability of error by t test; ns - Not significant at 5% probability of error; EGY - Estimated grain yield.

moment of application, considering the plant requirements and adequate weather conditions for the best use.

Mantai et al. (2015) observed a higher productivity rate of biomass and total oat biomass in the use of nitrogen under favorable weather conditions for growing. In this condition, the maximum efficiency of the nutrient in the preparation of grains was obtained with 66 kg ha^{-1}, with productivity of 3874 kg ha^{-1}, supplied at 30 days after emergence. In an unfavorable year, in the same fertilization period, maximum efficiency was achieved with 92 kg ha^{-1}, with grain yield of 3172 kg ha^{-1}. According to the authors, the lower efficiency of nitrogen use was due to reduced soil moisture and higher temperatures at the time of fertilization. In irrigated wheat, Teixeira Filho et al. (2010) verified the viability of total nitrogen supply at sowing, however, not differing from the traditional application of sowing and topdressing in the search for greater efficiency in productivity. Ercoli et al. (2013) observed in upland wheat greater efficiency of nitrogen to grain yield with the application of 30 kg ha^{-1} of the nutrient at the time of sowing and the remainder of the total dose for topdressing. Kaefer et al. (2015) observed in canola an increase in the efficiency of nitrogen utilization for the preparation of grains by parceling, with one third at sowing and two thirds for topdressing (40 and 80 kg ha^{-1}) applied at the true fourth leaf stage. Despite the interdependence of nitrogen doses at sowing and topdressing in beans, Moreira et al. (2013) observed increases in grain yield with the addition of higher doses at sowing, increasing the number of pods per plant with up to 120 kg ha^{-1}.

In Table 5, with the regression equation in the soybean/oat system, it was found that regardless of the condition of the agricultural year and nitrogen dose at sowing, grain productivity according to the time of supply shows quadratic behavior.

In table 5, under the different fertilization conditions, the total dose delivered of 70 kg ha^{-1} for grain yield expectations of 4000 kg ha^{-1}, regardless of the agricultural year classification, shows a greater expression of grain yield when supplied at 30 days after the emergence. The inclusion of the ideal season in the regression model shows, by simulation, a reduction in grain yield by increasing the nitrogen dose at sowing and a reduction for topdressing, regardless of the condition of the growing year.

In Table 6, of the regression equation in the corn/oat system, regardless of the condition of the agricultural year and nitrogen dose at sowing, the behavior of grain yield according to the time of supply of the nutrient for topdressing also indicates quadratic behavior, similar to soybean/oat system (Table 5).

In Table 6, the corn/oat system, the grain yield expectation of 4000 kg ha^{-1} with the total nitrogen dose of 100 kg ha^{-1}, shows greater productivity efficiency when nitrogen was supplied at 30 days after emergence. The inclusion of the ideal season in the regression equation also shows by simulation a reduction in grain yield by increasing the nitrogen dose at sowing and a reduction in topdressing. The results presented show the perspective of increasing the productivity of oat grains with the minimum dose or absence of nitrogen at sowing, since the topdressing dose is increased, depending on the time of application around 30 days after emergence. Therefore, the results observed in the two succession systems, regardless of the condition of classification of agricultural year, show security for the dissemination of results and in the technical recommendation.

In oat, the use of nitrogen fertilizer is necessary due to its low content in the soil during the growing cycle (Mantai et al., 2017). The correct dose and timing of application of the nutrient is decisive for increasing productivity (Flores et al., 2012). However, the efficiency of nitrogen use is dependent on adequate conditions of air temperature and soil moisture during supply (Scremin et al., 2017). The definition of the dose of N-fertilizer in wheat and oat is defined according to the organic matter content of the soil, the previous crop and the productivity expectation and the time for topdressing fertilization on the phenology during the period of greatest nutrient deficiency (Bredemeier et al., 2013). From the emergence, the emission of the sixth leaf is the time when the oat plants demand more nitrogen (Mantai et al., 2015). If applied in the initial stages, it favors the maximum number of spikelets and grains in the inflorescence, when applied in the final stages, it can increase the number of stems per area (Teixeira Filho et al., 2010). The technical indications for the growing of oats and wheat in Brazil recommend as a fertilization time between the beginning of the tillering (stage V3) and the beginning of elongation (stage V6), an interval around 30 to 60 days after the emergence of the seedling. According to these authors, the period between the beginning of the tillering and the elongation shows a large interval in the decision of the appropriate moment of application, necessitating, besides the most favorable conditions of soil moisture, other elements in dimensioning the most adjusted season. In this perspective, Silva et al. (2016) report that nitrogen doses at sowing and topdressing and the timing of application would also be dependent on the predecessor crop, expected productivity, history of use of the area and weather conditions during management. In wheat, the season of nitrogen fertilization showed great influence of the year of cultivation, however, of little change by the succession system. In years favorable to growing, the time of fertilization with N-fertilizer proved to be adequate 45 days after emergence. In unfavorable years, the most adjusted application time was 35 days after the emergence (Arenhardt et al., 2015). The results presented show that the definition of the nitrogen dose at sowing at the appropriate time of application are important strategies in optimizing the nutrient for productivity, improving biological and environmental indicators.

Materials and methods

The work was developed in the field in the agricultural years of 2015, 2016 and 2017 in Augusto Pestana, RS, Brazil (28° 26 ’30’ ’south latitude and 54° 00’ 58 ’’ west longitude). The soil of the experimental area was classified as Typical Red Latosol (Oxisol) and the climate of the region, by the Köppen classification, of the Cfa type, with hot summer without dry season. Twenty days before sowing, soil analysis was carried out, determining the following chemical characteristics (Tedesco et al., 1995): i) soybean/oat system (pH = 6.2; P = 33.9 mg dm^{-3}; K = 200 mg dm^{-3}; OM = 3.0%; Al = 0 cmolcdm^{-3}; Ca = 6.5 cmolcdm^{-3} e Mg = 2.5 cmolcdm^{-3}) and corn/oat system (pH = 6,5; P = 34.4 mg dm^{-3}; K = 262 mg dm^{-3}; OM = 2.9%; Al = 0 cmolcdm^{-3}; Ca = 6.6 cmolcdm^{-3} and Mg = 3.4 cmolcdm^{-3}). Sowing was carried out in the third week of June with a seeder-fertilizer in the composition of the plot with 5 lines of 5 m in length and spacing between lines of 0.20 m, forming the experimental unit of 5 m^2. The population density used was 400 viable seeds m-2. During the execution of the study, applications of tebuconazole fungicide were performed at a dosage of 0.75 L ha^{-1}. Weed control was performed with metsulfuron-methyl herbicide at a dose of 4 g ha^{-1}. For sowing, 45 and 30 kg ha^{-1} of P_2O_5 and K_2O were applied, respectively, based on the levels of P and K in the soil for the expectation of grain yield of 4 t ha^{-1}.

In each growing system (soybean/oat; corn/oat), two experiments were conducted, one to quantify the biomass and total biomass productivity rate by the cuts made every 30 days until physiological maturity and, the other, to the estimate the grain yield (GY, kg ha^{-1}) with the use of the white oat cultivar URS Taura. This cultivar has a short cycle, reduced height and high productivity and industrial grain quality, representing the standard biotype grown on a commercial scale in Brazil. In the four experiments, the design was randomized blocks with four replications in a 4 x 4 factorial scheme, for four doses of nitrogen at sowing (0, 10, 30 and 60 kg ha-1), changing the topdressing dose by the total provided. 70 and 100 kg ha^{-1} in soybean/oat and corn/oat systems, respectively, in the expectation of grain yield of 4000 kg ha^{-1}, with the supply for topdressing in four application times (0, 10, 30 and 60 days after emergence), totaling 128 experimental units per succession system. The nitrogen doses at sowing and topdressing with the urea source were provided according to information in Table 1.

Grain productivity was obtained by cutting three central lines of each plot at harvest maturity, grain moisture close to 22%. They were tracked with a stationary harvester and directed to the laboratory to correct grain moisture to 13% and estimate grain yield (GY, kg ha-1). In the experiments to quantify the biomass productivity, the harvest of the plant material was close to the soil, by collecting a linear meter of the three central lines of each plot at 30, 60, 90 and 120 days after emergence, totaling four cuts. The samples were sent to a forced air oven at 65 °C, until reaching constant weight to estimate the biomass productivity rate ((b_1x, in kg ha^{-1} day^{-1}) and total biomass (BP, in kg ha^{-1}).

When meeting the assumptions of homogeneity and normality via the Bartlet test, analysis of variance was performed to detect the main and interaction effects. The linear equation was adjusted to obtain the slope (b_1x) in the estimation of the biomass productivity rate and comparison of averages over the total biomass and grain productivity by the Scott & Knott model. After the adjustment of the quadratic equation of grain yield (GY) was performed to obtain the coefficients of the model ($GY = b_0 \pm b_1x \pm b_2x^2$) in the estimation of the ideal time for supplying the nutrient for topdressing $\left(Ideal\ time = -\frac{b_1}{2b_2}\right)$ in each nitrogen dose condition at sowing, considering the expected grain yield of 4000 kg ha^{-1}.

Conclusions

The most efficient and sustainable management of nitrogen use to the productivity of biomass and oat grains occurs with the total supply of the nutrient for topdressing around 30 days after emergence, regardless of the condition of the agricultural year and succession system.

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