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Single and split nitrogen dose in wheat yield indicators

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Key words:
Triticum aestivum
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temperature
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ABSTRACT

Single or split nitrogen (N) supply can maximize the expression of wheat yield indicators. The objective of the study was to evaluate the greater N use efficiency on wheat yield indicators by the single and split N supply under favorable and unfavorable year conditions to the crop in succession system of high and reduced residual N release. The study was conducted in 2014 and 2015, in a randomized complete block design with four replicates in a 4 x 3 factorial, for N-fertilizer doses (0, 30, 60, 120 kg ha^{-1}) and supply forms [full dose (100%) in the phenological stage V_3 (third expanded leaf); split dose (70 and 30%) in the phenological stages V_3/V_6 (third and sixth expanded leaves, respectively) and; split dose (70 and 30%) in the phenological stages V_3/R_1 (third expanded leaf and early grain filling)], respectively, in soybean/wheat and maize/wheat cultivation systems. The highest N use efficiency for wheat yield was obtained with the single dose supply in favorable year of temperature and rainfall and with the split dose in the V_3/V_6 stages in unfavorable year, regardless of the succession system of high and reduced residual N release.

Palavras-chave:
Triticum aestivum
ureia
N-residual
temperatura
precipitação

Dose única e fracionada do nitrogênio nos indicadores de produtividade do trigo

RESUMO

O fornecimento único ou fracionado do nitrogênio pode maximizar a expressão dos indicadores de produtividade do trigo. Objetivou-se no estudo avaliar a maior eficiência de uso do nitrogênio sobre os indicadores de produtividade do trigo pelo fornecimento único e fracionado do nutriente em condição de ano favorável e desfavorável ao cultivo, em sistema de sucessão de alta e reduzida liberação de N-residual. O estudo foi conduzido em 2014 e 2015, em delineamento experimental de blocos casualizados com quatro repetições em fatorial 4 x 3, para doses de N-fertilizante (0, 30, 60, 120 kg ha^{-1}) e formas de fornecimento [dose única (100%) no estádio fenológico V_3 (terceira folha expandida); fracionada (70 e 30%) no estádio fenológico V_3/V_6 (terceira e sexta folha expandida) e; fracionada (70 e 30%) no estádio fenológico V_3/R_1 (terceira folha expandida e início do enchimento de grãos)], respectivamente, no sistema de sucessão soja/trigo e milho/trigo. A maior eficiência do nitrogênio à produtividade do trigo é obtida no fornecimento em dose única em ano favorável de cultivo e com o fracionamento no estádio V_3/V_6 em ano desfavorável, independente do sistema de sucessão de alta e reduzida liberação de N-residual.

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Introduction

Wheat is the main winter crop in Southern Brazil and the state of Rio Grande do Sul is responsible for 36% of the national production (CONAB, 2016). In favorable years for cultivation, under adequate management, profitability is easily obtained. On the other hand, restrictive climatic conditions compromise the development and limit the use efficiency of nitrogen (N), the main nutrient for the elaboration of the yield indicators (Ferrari et al., 2016; Silva et al., 2016). Besides increasing the costs, N losses through leaching or volatilization turn the nutrient into a pollutant, generating the need for technologies that improve N use efficiency by the plant, regardless of the cultivation condition (Benin et al., 2012; Mantai et al., 2016).

According to the recommendation of cultivation, N fertilization should be applied at sowing and as top-dressing (between the beginning of tillering and beginning of elongation), moments in which the wheat crop needs greater supply of the nutrient (Arenhardt et al., 2015; Cunha et al., 2016). However, greater efficiency with top-dressing N application is directly dependent on adequate soil moisture, a condition not always obtained at the moment of fertilization (Silva et al., 2016). Studies indicated that split N supply can reduce its losses by using partial doses in moments suitable for fertilization (Brezolin et al, 2016; Ferrari et al., 2016). Thus, the complex relationships between plant, climate and management must be considered in the definition of efficient managements for N supply in the elaboration of yield.

The objective of the study was to evaluate the greater N use efficiency on wheat yield indicators through the single and split application of the nutrient under favorable and unfavorable year conditions to the crop and succession system of high and reduced residual N release.

Material and Methods

The experiment was carried out at the field, in the 2014 and 2015 agricultural years in the municipality of Augusto Pestana, RS, Brazil (28° 26' 30" S; 54° 00' 58" W). The soil of the experimental area is classified as typic dystroferric Red Latosol and the climate of the region, according to Köppen's classification, is Cfa, with hot summer without dry season. In the study, soil analysis was made ten days before sowing and the following chemical characteristics were identified in the average of the years (Tedesco et al., 1995): i) maize/wheat system - pH = 6.5, P = 34.4 mg dm^{-3}, K = 262 mg dm^{-3}, OM = 3.5%, Al = 0.0 $cmol_c$ dm^{-3}, Ca = 6.6 $cmol_c$ dm^{-3} and Mg = 3.4 $cmol_c$ dm^{-3}; and; ii) soybean/wheat system - pH = 6.2, P = 33.9 mg dm^{-3}, K = 200 mg dm^{-3}, OM = 3.4%, Al = 0.0 $cmol_c$ dm^{-3}, Ca = 6.5 $cmol_c$ dm^{-3} and Mg = 2.5 $cmol_c$ dm^{-3}. Sowing was performed using a seeder-fertilizer machine, composing plots with five 5-m-long rows spaced by 0.20 m, to form the experimental unit of 5 m^2. At sowing, fertilizations with 30 and 15 kg ha^{-1} of P_2O_5 and K_2O, respectively, were applied based on the contents of P and K in the soil for an expected grain yield 3 t ha^{-1}, and N fertilization was applied at planting as 10 kg ha^{-1} in the form of urea (except in the standard experimental unit) and the rest was applied to contemplate the doses proposed in the study. The seeds were subjected to tests of germination and vigor at the laboratory, to correct plant density to the desired value of 400 viable seeds m^{-2}. The fungicide Tebuconazole was applied at the dose of 0.75 L ha^{-1} and weeds were controlled with the herbicide metsulfuron-methyl at dose of 4 g ha^{-1}. The experiment used the wheat cultivar 'BRS Guamirim', with small size, early cycle, resistance to lodging, commercially classified as bread wheat and of high productive potential, representing the standard biotype desired by the wheat producers in Southern Brazil.

In each cultivation condition of high and reduced residual N release (soybean/wheat and maize/wheat systems), two experiments were conducted, one to quantify biomass yield and the other to estimate grain yield. Therefore, in the four experiments, the design was randomized complete blocks with four replicates in 4 x 3 factorial scheme, for N-fertilizer doses (0, 30, 60 and 120 kg ha^{-1}) and forms of N supply [single application (100%) in the phenological stage V_3 (third expanded leaf); split application (70 and 30%) in the phenological stages V_3/V_6 (third and sixth expanded leaves) and split application (70 and 30%) in the phenological stages V_3/R_1 (third expanded leaf and early grain filling)], totaling 192 experimental units. The experiments to estimate biomass and grain yields were manually harvested by cutting the three central rows of each plot, in the stage close to the harvest point (125 days), with grain moisture of 15%. Plots intended for grain harvest were threshed with stationary threshing machine, taken to the laboratory to correct grain moisture to 13% and weighed to estimate grain yield (GY, kg ha^{-1}). Plots intended for biomass analysis were dried in a forced-air oven at temperature of 65 °C until constant weight and weighed to estimate biomass yield (BY, kg ha^{-1}). The obtained values of total biomass yield and grain yield were used to estimate straw yield (SY, kg ha^{-1}) through the difference BY-GY and harvest index (HI, kg kg^{-1}) through the relationship GY/BY.

After meeting the assumptions of homogeneity and normality via Bartlett's test, analysis of variance was made to detect main and interaction effects. Based on these data, the linear equation ($Y = b_0 \pm b_1x$) and quadratic equation ($Y = b_0 \pm b_1x \pm b_2x^2$) were fitted as a function of N doses in each supply condition (single and split dose). Biomass, grain, straw yields and harvest index were estimated based on the N dose indicated for expected grain yield of 3 t ha^{-1}, considering the organic matter content in the soil and the crop in succession, according to the recommendation of cultivation. Therefore, the soybean/wheat and maize/wheat systems considered the total N doses of 60 and 90 kg ha^{-1} added in the crop cycle, respectively. In addition, Scott-Knott tests were applied to compare the means relative to the different N supply conditions, regardless of the total N dose applied as top-dressing. The program Genes was used for these analyses.

Results and Discussion

Data of rainfall and maximum temperature along the wheat crop cycle are presented in Figure 1. In 2014 (Figure 1A), high temperatures occurred in the early development, without rainfalls in previous days and after fertilization. This fact leads to greater N loss through volatilization, resulting in lower development of tillers and ears per area.

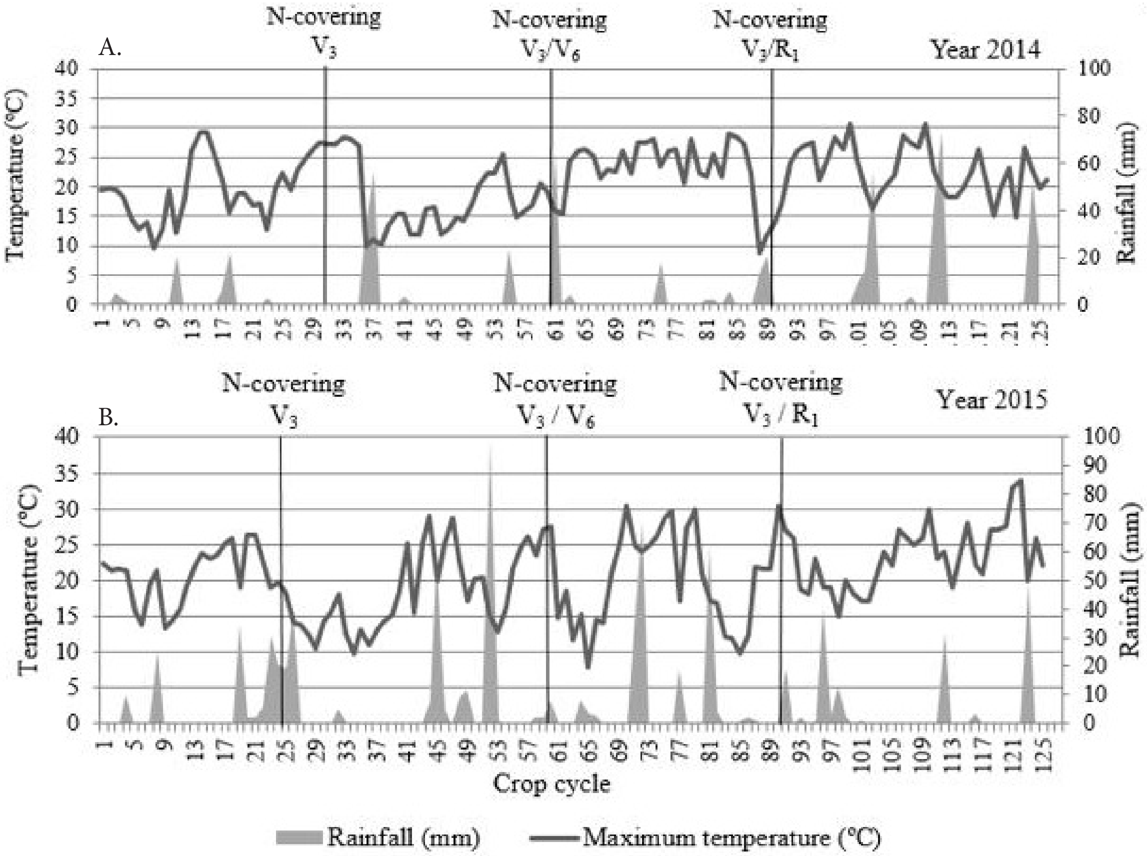
N-fertilizer application in the phenological stage V_6 was followed by high rainfall volume, which favored N loss through leaching. These factors along with the mean yields (Tables 1 and 2) qualify 2014 as unfavorable year (UY) for cultivation. In 2015 (Figure 1B), the occurrence of rainfalls in days preceding N-fertilizer application led to soil moisture favorable for N management. In addition, lower temperatures in the vegetative cycle favored tiller production and distribution of photoassimilates for yield. This fact, combined with the mean yields in the year, characterize 2015 as favorable year (FY) for wheat cultivation.

Arenhardt et al. (2015) point out that rainfall volume and distribution combined with air temperature are potential variables in the classification of favorable and unfavorable years for wheat cultivation. Espindula et al. (2010) comment that climatic variation influences N use by the plant. Favorable climate for wheat is determined by mild temperatures without the occurrence of rainfalls in large amounts and intensity (Valério et al., 2009). The excess of rainfalls after fertilization causes N loss through ammonia leaching (Ercoli et al., 2013). High temperatures promote reductions in yield and biomass accumulation due to the increase in respiration rate and N loss through volatilization, contributing to the events related to global warming (Mandal et al., 2016).

In the soybean/wheat system in the unfavorable year (2014), regardless of N fertilization dose, the highest mean grain yield was obtained in the split application in V_3/V_6 (Table 1). Although the mean values of straw yield and harvest index are similar between the N supply forms, the joint expression of straw and grain through the biological yield was also favored by the split application in V_3/V_6, a contribution from the higher grain production under such condition. The equations obtained by the N doses in each supply condition, either linear or quadratic, indicated significant slope parameter (b_ix), qualifying the effectiveness of these equations on the inferences to be formulated. Therefore, the simulation with the N dose of 60 kg ha^{-1} in soybean/wheat system for an expected grain yield of 3 t ha^{-1} led to value closer to this expected yield in the V_3/V_6 condition. The indicated dose also promoted greater contribution to biological yield and harvest index.

In the favorable year (2015), the mean values of grain yield, regardless of N doses, were more expressive in the application of single N dose in the phenological stage V_3 (Table 1). It should be highlighted that the mean values of the other yield indicators qualify the N supply in single dose and split dose in V_3/V_6, except for straw yield, which did not show alteration. In the simulation with the N dose of 60 kg ha^{-1} for expected yield of 3 t ha^{-1}, the condition of favorable agricultural year promoted values higher than this expected yield. However, the most expressive contribution of grain yield was obtained with the N supply in single dose, which also occurred for the expression of the biological yield.

The presented results indicate that the expected grain yield based on N dose is dependent on the weather conditions of the



V_3 - Full nitrogen dose (100%) at stage of third expanded leaf; V_3/V_6 - Split nitrogen dose (70 and 30%) at stages of third and sixth expanded leaves; V_3/R_1 - Split nitrogen dose (70 and 30%) at stages of third expanded leaf and early grain filling
Source: Weather Station of the Rural Development Regional Institute

Figure 1. Rainfall and maximum temperature along the wheat crop cycle and the moments of nitrogen application in year 2014 (A) and 2015 (B)

Table 1. Mean and regression with the estimation of biological, grain and straw yields and harvest index according to the form of nitrogen supply in the soybean/wheat system in 2014 unfavorable year and in 2015 favorable year

Variable	N supply	Mean	Fitted equation ($Y = b_0 \pm b_1x \pm b_2x^2$)	P (b_ix)	R^2 %	Y_E ($N = 60$ kg ha^{-1})
			2014 (UY)			
GY	V_3	2327 b	$1856 + 8.97x$	*	92	2394 b
	V_3/V_6	2573 a	$1788 + 20.30x - 0.10x^2$	*	85	2657 a
	V_3/R_1	2343 b	$1655 + 18.40x - 0.11x^2$	*	99	2363 b
BY	V_3	6366 b	$5845 + 9.92x$	*	90	6440 b
	V_3/V_6	6960 a	$6403 + 10.05x$	*	77	7006 a
	V_3/R_1	6407 b	$5900 + 9.66x$	*	94	6479 b
SY	V_3	4038 a	$4234 - 16.04x + 0.13x^2$	*	80	3739 a
	V_3/V_6	4387 a	$4356 - 10.40x + 0.05x^2$	*	72	3912 a
	V_3/R_1	4064 a	$4207 - 10.52x + 0.086x^2$	*	83	3885 a
HI	V_3	0.36 a	$0.28 + 0.0024x - 0.000015x^2$	*	88	0.37 b
	V_3/V_6	0.37 a	$0.28 + 0.0028x - 0.000015x^2$	*	92	0.39 a
	V_3/R_1	0.36 a	$0.28 + 0.0022x - 0.000015x^2$	*	95	0.36 b
			2015 (FY)			
GY	V_3	3534 a	$2278 + 23.91x$	*	97	3712 a
	V_3/V_6	3371 b	$2127 + 22.68x$	*	97	3488 b
	V_3/R_1	3115 c	$1938 + 22.41x$	*	96	3282 c
BY	V_3	8376 a	$6702 + 31.88x$	*	98	8614 a
	V_3/V_6	8135 a	$6202 + 30.05x$	*	98	8005 b
	V_3/R_1	7746 b	$6075 + 31.82x$	*	97	7984 b
SY	V_3	4842 a	$4423 + 7.97x$	*	94	4901 a
	V_3/V_6	4774 a	$4207 + 10.79x$	*	95	4854 a
	V_3/R_1	4631 a	$4137 + 9.40x$	*	99	4701 a
HI	V_3	0.41 a	$0.31 + 0.003x - 0.000014x^2$	*	99	0.43 a
	V_3/V_6	0.41 a	$0.31 + 0.003x - 0.000014x^2$	*	99	0.43 a
	V_3/R_1	0.39 b	$0.32 + 0.00125x$	*	89	0.39 b

V_3 - Collar formed on the 3rd leaf of the main stem; V_3/V_6 - Collar formed on 6th leaf of the main stem and V_3/R_1 - Ear differentiation; BY - Biological yield; GY - Grain yield; SY - Straw yield; HI - Harvest index; UY - Unfavorable year; FY - Favorable year; P(b_ix) - Parameter that measures the significance of the line; R^2 - Coefficient of determination; Y_E - Estimated value for nitrogen fertilization dose of 60 kg ha^{-1}

cultivation year. Additionally, there is different contribution to the yield indicators for the N supply in single and split doses by the condition of the cultivation year. In a system with reduced C/N ratio, such as the soybean/wheat succession, N supply in split dose at V_3/V_6 in the unfavorable year, and in single dose at V_3 in the favorable year are recommended under this cultivation condition.

Nitrogen is one of the nutrients most required by the wheat crop and is mostly not supplied in ideal quantity and period to guarantee high yield and good quality of the final product (Todeschini et al., 2016). The definition of the N dose in wheat depends on organic matter content in the soil, previous crop and expected yield (Siqueira Neto et al., 2010). However, N management to obtain the desired expected yield depends on the weather conditions of the cultivation year (Arenhardt et al., 2015). Studies have demonstrated that the split N application under unfavorable condition for cultivation results in higher N use by the plant, reducing its losses to the environment with increase of yield (Brezolin et al., 2016; Ferrari et al., 2016). The use of leguminous species as source of residual N in cereals such as wheat and oat has also favored crop yield with reduction in the use of N-fertilizer (Pinnow et al., 2013; Mantai et al., 2016). Although the greater absorption of N-fertilizer in the vegetative period promotes significant increments in biomass production, the use efficiency is defined by the capacity of transformation into biomass and grains, conditioning the expression of the harvest index (Viana & Kiehl, 2010; Todeschini et al., 2016).

In the maize/wheat system in the unfavorable year (2014), regardless of the N fertilization dose, the highest mean value of grain yield was obtained in the split application at V_3/V_6 (Table 2). The mean values of biological and straw yields were similar between the different forms of N supply, without alteration of the harvest index in the conditions V_3 and V_3/V_6. The equations obtained for the maize/wheat system (Table 2) through the N doses in each supply condition, either linear or quadratic, also indicated a significant slope parameter (b_ix), qualifying these equations on the obtained inferences. Thus, in the simulation with the N dose of 90 kg ha^{-1} in maize/wheat system for expected grain yield of 3 t ha^{-1}, the value closest to this expected yield was obtained in the condition V_3/V_6, a result similar to that for the soybean/wheat system. It worth highlighting that the simulation of straw yield was not altered by the forms of N supply, a condition that favored greater expression of the harvest index in the use of split dose at V_3/V_6 due to the higher grain production, although the biological yield is similar in the supply at V_3 and V_3/V_6.

In the maize/wheat system in the favorable year (2015), the mean values of grain yield, regardless of N doses, were more expressive with the N supply in single dose in the phenological stage V_3 (Table 2). Although there is similarity between the mean values of biological yield in V_3 and V_3/V_6, and without alteration of straw yield due to the forms of N supply, the greater expression of the harvest index in V_3 brings the contribution from grain yield. In the simulation with the N dose of 90 kg ha^{-1} for expected yield of 3 t ha^{-1}, the condition of favorable agricultural year also led to values higher than this expected yield, a fact also evidenced in the soybean/wheat system. The most expressive contribution of grain yield was obtained with the N supply in single dose, leading to greater expression of the harvest index in this condition, because straw

Table 2. Mean and regression with the estimation of biological, grain and straw yields and harvest index according to the form of nitrogen supply in the maize/wheat system in 2014 unfavorable year and in 2015 favorable year

Variable	N supply	Mean	Fitted equation ($Y = b_0 \pm b_1x \pm b_2x^2$)	P (b_1x)	R^2 %	Y_E ($N = 90$ kg ha^{-1})
			2014 (UY)			
GY	V_3	2603 b	$1159 + 15.70x$	*	99	2572 b
	V_3/V_6	2825 a	$973 + 33.88x - 0.14x^2$	*	99	2888 a
	V_3/R_1	2370 c	$1070 + 13.82x$	*	98	2314 c
BY	V_3	7104 a	$4014 + 76.79x - 0.41x^2$	*	98	7620 a
	V_3/V_6	7204 a	$4396 + 59.40x - 0.27x^2$	*	99	7555 a
	V_3/R_1	6954 a	$4504 + 26.02x$	*	99	6845 b
SY	V_3	4350 a	$3127 + 46.20x - 0.29x^2$	*	90	4936 a
	V_3/V_6	4578 a	$3433 + 29.98x - 0.15x^2$	*	95	4916 a
	V_3/R_1	4183 a	$3475 + 12.85x$	*	91	4631 a
HI	V_3	0.37 a	$0.234 + 0.0012x$	*	89	0.34 b
	V_3/V_6	0.39 a	$0.22 + 0.003x - 0.000013x^2$	*	94	0.38 a
	V_3/R_1	0.34 b	$0.21 + 0.0028x - 0.000015x^2$	*	95	0.34 b
			2015 (FY)			
GY	V_3	3534 a	$1304 + 47.30x - 0.21x^2$	*	94	3860 a
	V_3/V_6	3271 b	$1471 + 21.9x$	*	95	3442 b
	V_3/R_1	3015 c	$1520 + 16.19x$	*	95	2977 c
BY	V_3	8376 a	$4424 + 87.32x - 0.40x^2$	*	97	9042 a
	V_3/V_6	8145 a	$4650 + 81.27x - 0.36x^2$	*	97	9048 a
	V_3/R_1	7846 b	$5302 + 67.37x - 0.35x^2$	*	90	8530 b
SY	V_3	4842 a	$3119 + 39.92x - 0.18x^2$	*	99	5253 a
	V_3/V_6	4774 a	$3415 + 42.99x - 0.23x^2$	*	87	5421 a
	V_3/R_1	4783 a	$3842 + 47.01x - 0.32x^2$	*	86	5480 a
HI	V_3	0.42 a	$0.28 + 0.003x - 0.000016x^2$	*	81	0.42 a
	V_3/V_6	0.40 b	$0.28 + 0.0012x$	*	92	0.38 b
	V_3/R_1	0.38 c	$0.261 + 0.001x$	*	95	0.35 c

V_3 - Collar formed on the 3rd leaf of the main stem; V_3/V_6 - Collar formed on 6th leaf of the main stem and V_3/R_1 - Ear differentiation; BY - Biological yield; GY - Grain yield; SY - Straw yield; HI - Harvest index; UY - Unfavorable year; FY - Favorable year; P(b_1x) - Parameter that measures the significance of the line; R^2 - Coefficient of determination; Y_E - Estimated value for nitrogen fertilization dose of 60 kg ha^{-1}

yield was not altered by the form of N supply and the biological yield was similar in the conditions V_3 and V_3/V_6.

The results in the maize/wheat system were similar to those of the soybean/wheat system, indicating that higher N use efficiency was obtained with the split application in the stages V_3/V_6 in unfavorable year and single application under favorable condition for cultivation. In the different conditions analyzed, the use of split dose in the stages V_3/R_1 did not promote benefits in N use for the elaboration of the yield indicators, a condition that, despite not leading to increase of yield, can contribute to the technological and chemical quality of the grains through the N supply in the grain filling stage.

Split N application has been recommended for promoting higher efficiency in N assimilation, especially when the weather conditions are not adequate for application (Sangoi et al., 2007; Mantai et al., 2016). For Bredemeier et al. (2013), the adequate moment for N-fertilizer application as top-dressing depends on plant phenology, determined by the period of highest demand for the nutrient, which reflects the period between the production of third and sixth leaves (Arenhardt et al., 2015). Brezolin et al. (2016), evaluating N doses and supply to the wheat crop in maize/wheat system of succession, observed effects more favorable to grain yield with the split N application in the stages V_3/V_6. In contrast, Sangoi et al. (2008) observed that early N application stimulates higher grain yield. Teixeira Filho et al. (2010) reported that N doses of up to 120 kg ha^{-1} increase biomass and grain yields in wheat, regardless of the application period and source of N. However, high doses do not guarantee yield, due to losses of the nutrient caused by unfavorable weather conditions.

Conclusion

The highest efficiency of nitrogen for wheat yield is obtained with the supply in single dose in favorable cultivation year and with the split application in the stage V_3/V_6 in unfavorable year, regardless of the system of succession of high and reduced residual N release.

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Literature Cited

Arenhardt E. G.; Silva, J. A. G. da; Gewehr, E.; Oliveira, A. C. de; Binelo, M. O.; Valdiero, A. C.; Gzergorczick, M. E.; Lima, A. R. C. de. The nitrogen supply in wheat cultivation dependent on weather conditions and succession system in southern Brazil. African Journal of Agricultural Research, v.10, p.4322-4330, 2015. https://doi.org/10.5897/AJAR2015.10038

Benin, G.; Bornhofen, E.; Beche, E.; Pagliosa, E. S.; Silva, C. L. da; Pinnow, C. Agronomic performance of wheat cultivars in response to nitrogen fertilization levels. Acta Scientiarum. Agronomy, v.34, p.275-283, 2012. https://doi.org/10.4025/actasciagron.v34i3.14468

Bredemeier, C.; Variani, C.; Almeida, D.; Rosa, A. T. Estimativa do potencial produtivo em trigo utilizando sensor óptico ativo para adubação nitrogenada em taxa variável. Ciência Rural, v.43, p.10-15, 2013. https://doi.org/10.1590/S0103-84782013005000080

Brezolin, A. P.; Silva, J. A. G. da; Frantz, F. C. R.; Binelo, M. O.; Valdiero, A. C.; Zimmer, C. M.; Mantai, R. D.; Marolli, A.; Scremin, O. S.; Mazurkievicz, G. The efficiency of wheat yields by nitrogen dose and fractionation. African Journal of Agricultural Research, v.11, p.3440-3449, 2016. https://doi.org/10.5897/AJAR2016.11249

CONAB - Companhia Nacional de Abastecimento. Acompanhamento da safra brasileira de grãos: Safra 2016/17 - Segundo levantamento. Brasília: CONAB, 2016. 156p.

Cunha, G. R. da; Caierão, E.; Rosa, A. C. Informações técnicas para trigo e triticale: Safra 2016. In: Reunião da Comissão Brasileira de Pesquisa de Trigo e Triticale. Passo Fundo: Biotrigo Génetica, 2016. 228p.

Ercoli, L.; Masoni, A.; Pampana, S.; Mariotti, M.; Arduini, I. As durum wheat productivity is affected by nitrogen fertilization management in Central Italy. European Journal of Agronomy, v.44, p.38-45, 2013. https://doi.org/10.1016/j.eja.2012.08.005

Espindula, M. C.; Rocha, V. S.; Souza, M. A. de; Grossi, J. A. S.; Souza L. T. de. Doses e formas de aplicação de nitrogênio no desenvolvimento e produção da cultura do trigo. Ciência e Agrotecnologia, v.34, p.1404-1411, 2010. https://doi.org/10.1590/S1413-70542010000600007

Ferrari, M.; Nardino, M.; Carvalho, I. R.; Szareski, V. J.; Pelegrin, A. J. de; Souza, V. Q. de. Manejos e fontes de nitrogênio nos componentes de afilhamento de trigo. Revista Brasileira de Ciências Agrárias, v.11, p.178-185, 2016. https://doi.org/10.5039/agraria.v11i3a5379

Mandal, S.; Thangarajan, R.; Bolan, N. S.; Sarkar, B.; Khan, N.; Ok, Y. S.; Naidu, R. Biochar-induced concomitant decrease in ammonia volatilization and increase in nitrogen use efficiency by wheat. Chemosphere, v.142, p.120-127, 2016. https://doi.org/10.1016/j.chemosphere.2015.04.086

Mantai, R. D.; Silva, J. A. G. da; Arenhardt, E. G.; Sausen, A. T. Z. R.; Binello, M. O.; Bianchi, V.; Silva, D. R. da; Bandeira, L. M. The dynamics of relation oat panicle with grain yield by nitrogen. American Journal of Plant Sciences, v.7, p.17-27, 2016. https://doi.org/10.4236/ajps.2016.71003

Pinnow, C.; Benin, G.; Viola, R.; Silva, C. L. da; Gutkoski, L. C.; Cassol, L. C. Qualidade industrial do trigo em respostas à adubação verde e doses de nitrogênio. Bragantia, v.72, p.20-28, 2013. https://doi.org/10.1590/S0006-87052013005000019

Sangoi, L.; Almeida, M. L. de; Pucci, A. L. R.; Strieder, M.; Zanin, C. G.; Silva, L. C. da; Vieira, R. J. A aplicação precoce de nitrogênio em cobertura não aumenta o rendimento de grãos do trigo cultivado na presença do alumínio. Ciência Rural, v.38, p.912-920, 2008. https://doi.org/10.1590/S0103-84782008000400002

Sangoi, L.; Berns, A. C.; Almeida, M. L. de; Zanin, C. G.; Schweitzer, C. Características agronômicas de cultivares de trigo em resposta à época da adubação nitrogenada de cobertura. Ciência Rural, v.37, p.1564-1570, 2007. https://doi.org/10.1590/S0103-84782007000600010

Silva, J. A. G. da; Goi Neto, C. J.; Fernandes, S. B. V.; Mantai, R. D.; Scremin, O. B.; Pretto, R. Nitrogen efficiency in oats on grain yield with stability. Revista Brasileira de Engenharia Agrícola e Ambiental, v.20, p.1095-1100, 2016. https://doi.org/10.1590/1807-1929/agriambi.v20n12p1095-1100

Siqueira Neto, M.; Piccolo, M. de C.; Venzke Filho, S. de P.; Feigl, B. J.; Cerri, C. C. Mineralização e desnitrificação do nitrogênio no solo sob sistema plantio direto. Bragantia, v.69, p.923-936, 2010. https://doi.org/10.1590/S0006-87052010000400019

Tedesco, M. J.; Gianello, C.; Bissani, C. A.; Bohnen, H.; Volkweiss, S. J. Análise de solo, plantas e outros materiais. 2.ed. Porto Alegre: UFRGS, 1995. 174p. Boletim Técnico

Teixeira Filho, M. C. M.; Buzetti, S.; Andreotti, M.; Arf, O.; Benett, C. G. S. Doses, fontes e épocas de aplicação de nitrogênio em trigo irrigado em plantio direto. Pesquisa Agropecuária Brasileira, v.45, p.797-804, 2010. https://doi.org/10.1590/S0100-204X2010000800004

Todeschini, M. H.; Simionato, A. M.; Trevizan, D. M.; Bornhofen, E.; Finatto, T.; Storck, L.; Benin, G. Eficiência de uso do nitrogênio em cultivares modernas de trigo. Bragantia, v.75, p.351-361, 2016. https://doi.org/10.1590/1678-4499.385

Valério, I. P.; Carvalho, F. I. F. de; Oliveira, A. C. de; Benin, G.; Maia, L. C.; Silva, J. A. G; Schmidt, D. M.; Silveira, G. da. Fatores relacionados à produção e desenvolvimento de afilhos em trigo. Semina: Ciências Agrárias, v.30, p.1207-1218, 2009. https://doi.org/10.5433/1679-0359.2009v30n4Sup1p1207

Viana, E. M.; Kiehl, J. C. Doses de nitrogênio e potássio no crescimento do trigo. Bragantia, v.69, p.975-982, 2010. https://doi.org/10.1590/S0006-87052010000400024