academicJournals

Vol. 10(48), pp. 4322-4330, 26 November, 2015
DOI: 10.5897/AJAR2015.10038
Article Number: 126CDF056169
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

The nitrogen supply in wheat cultivation dependent on weather conditions and succession system in southern Brazil

Emilio Ghisleni Arenhardt[1]*, José Antonio Gonzalez da Silva[2], Ewerton Gewehr[3], Antonio Costa de Oliveira[3], Manuel Osorio Binelo[4], Antonio Carlos Valdiero[4], Maria Eduarda Gzergorczick[2] and Andressa Raquel Cyzeski de Lima[2]

[1]Department of Crop Plants, Federal University of Rio Grande do Sul, Avenue Bento Gonçalves 7712, Zip Code: 91540-000, Porto Alegre, RS, Brazil.
[2]Department of Agrarian Studies, Regional Northwest University of Rio Grande do Sul, Comércio Street, Number 3000, Zip Code: 98700-000 Ijuí, RS, Brazil.
[3]Faculty of Agronomy Eliseu Maciel, Federal University of Pelotas, Center for Genomics and Plant Breeding, Zip Code: 96001-970, P. O. Box 354, Pelotas, Rio Grande do Sul, Brazil.
[4]Department of Exact Sciences and Engineering, Regional University of the Northwest of Rio Grande do Sul, Street Lulu Ingelfritz 480, Zip Code: 98700-000, Ijuí, RS, Brazil.

Received 16 June, 2015; Accepted 6 October, 2015

High wheat yields, besides the genetic potential and edaphoclimatic conditions, are obtained by proper management and nitrogen use. The objective of the study was to define the most appropriate time for N-fertilizer application, considering the range of greatest wheat requirements, dependent on the succession system type and the predictability of favorable and unfavorable years. The study was carried out in the 2008 to 2012 years, in Augusto Pestana, Rio Grande do Sul, Brazil. The experimental design was randomized blocks with four replications, with N-fertilizer application at 0, 10, 30 and 60 days after emergence, considering the corn/wheat and soybean/wheat succession system. The study found that the best time for nitrogen fertilizer application on wheat is mostly influenced by the year of cultivation and is less influenced by the succession system type. The appropriate time for the N-fertilizer application in favorable years of cultivation was about 45 days after emergence. In unfavorable years, it must be anticipated. Regardless of the cultivation year and the succession system type, the N-fertilization at 30 days after emergence evidenced the highest means as the most stabile grain yield.

Key words: Wheat *Triticum aestivum*, N-fertilizer time, optimization.

INTRODUCTION

In a globalized market, achieving self-sufficiency and competitiveness of Brazilian wheat is decisive. Therefore, the development of more productive cultivars, which are tolerant and efficient in the use of light and nutrients is

*Corresponding author. E-mail: emilio.arenhardt@yahoo.com.br.

desired (Freo et al., 2011). Besides the weather conditions, nitrogen management is essential to increase grain yield (Flores et al., 2012). The amount of fertilizer and the appropriate application time should also be taken into account due to the possibility that high doses and too early or too late applications might not be exploited at its most (Silva et al., 2005; Ma et al., 2010). In this context, the importance of nitrogen fertilization should be highlighted, not only for the costs associated to it, but also because it's efficient use is the key to sustainable production (Costa et al., 2013).

The N-fertilizer dose in wheat is based on the soil organic matter content, on the fore crop, and on the expected grain yield (Siqueira Neto et al., 2010). On the other hand, the appropriate time for nitrogen topdressing is defined by the plant phenology, according to the period of greatest deficiency of the nutrient during plant development and formation of yield components (Bredemeier et al., 2013). The periods when wheat mostly requires nitrogen is from the emergence until the sixth leaf stage (Yano et al., 2005). If applied in the early stages, the fertilizer promotes the maximum number of spikelet and grains per spike; if applied in final stages, it can increase the number of culms per area (Teixeira Filho et al., 2010). In Brazil, the technical recommendations for wheat production as the proper time of fertilization indicate the period between the beginning of tillering (V_3 stage; code 13 in BBCH scale) and the beginning of elongation (V_6 stage; code 16 in BBCH scale), that is, about 30 to 60 days after emergence stage, especially between the 30th and 45th day (Reunião da Comissão Brasileira de Pesquisa de Trigo e Triticale, 2013). It must be highlighted that the period between the beginning of tillering and elongation in wheat is indeed a large interval for the decision of the appropriate time of fertilizer application. This raises the need to consider factors other than just most favorable conditions of soil moisture, which would help in the definition of the more adjusted time of nitrogen supply, resulting in better efficiency in the nutrient use, and better grain yield.

The wide variation of grain yield is associated with the great variability in weather conditions, making the agricultural year the biggest contributing factor for the production instability (Storck et al., 2014). The years of favorable and unfavorable weather alter the nitrogen availability and its efficient use by the plant (Espindula et al., 2010). Also, it should be noted that nitrate leaching increases when N-fertilizer application is followed by excessive rain (Coelho et al., 2014), and ammonia volatilization is favored when applied in hot and dry periods (Ma et al., 2010). The type of vegetative cover also influences the losses by leaching or volatilization, and the nitrogen use efficiency (Ma et al., 2010; Viola et al., 2013). Therefore, the biochemical composition of residues affects the choice of proper dose and time of nitrogen supply, taking into account the nutrient release rate into the soil and the decomposing tissues (Siqueira Neto et al., 2010).

It is already known in the literature that weather conditions and cultivation techniques modify the nitrogen use efficiency. This justifies that the interactions between the succession system type and weather conditions and the periods of wheat greatest deficiency of nitrogen in wheat should be considered in the choice of the most appropriate period for application of N-fertilizer.

The objective of this study was to define the most appropriate period of N-fertilizer application according to wheat greatest requirement of the nutrient, dependent on the succession system type and on the predictability of weather favorable and unfavorable years.

MATERIALS AND METHODS

The experiments were carried out in the 2008 and 2012 years in the city of Augusto Pestana, RS, Brazil (lat. 28°26'30''S; long. 54°00'58''W, at 298 m asl). The soil is classified as Oxisol Distroferric Typical (Santos et al., 2006) and the climate, according to Köppen classification is Cfa with hot summer without dry season. The experiment was carried out in the same area during the five years, and it had had direct seeding for more than twenty years. The soil analysis carried out before sowings allowed to identify the following chemical characteristics: in corn/wheat succession system: Argil = 52%; Organic Matter = 2.9%; pH = 6.2; P = 40.8 mg dm^{-3}; K = 239.7 mg dm^{-3}; Al = 0.0 cmol$_c$ dm^{-3}; Ca = 6.5 cmol$_c$ dm^{-3} and Mg = 2.5 cmol$_c$ dm^{-3}; and in soybean/wheat rotation: Argil = 54%; Organic Matter = 3.2%; pH = 6.5; P = 26.9 mg dm^{-3}; K = 179.5 mg dm^{-3}; Al = 0.0 cmol$_c$ dm^{-3}; Ca = 6.3 cmol$_c$ dm^{-3} and Mg = 2.7 cmol$_c$ dm^{-3}. Sowings were carried out between May 15th and June 30^{th,} with a seeder-fertilizer. Each experimental field was formed of 5 m rows, spaced 0.20 m apart, composing the experimental unit of 5 m^2. Seeds underwent germination and vigor test in laboratory in order to correct the desired density of 330 viable seeds m^{-2} of the bread wheat cultivar BRS Guamirim, which has early cycle and short stature. During vegetation period, wheat plants were protected against diseases by tebuconazole fungicide applications of commercial name FOLICUR 200 EC® (Bayer CropScience Ltda, São Paulo, Brazil), at a dose of 0.75 l ha^{-1}. Moreover, weed control was carried out with metsulfuron-methyl herbicide, at a dose of 4 g ha^{-1}.

Wheat sowings basic fertilization (NPK) was applied in the rates of 80 kg ha^{-1} of P_2O_5, 60 kg ha^{-1} of K_2O and 10 kg ha^{-1} of nitrogen. The remaining part of nitrogen fertilization was applied in coverage in order to achieve an expected yield of 3 t ha^{-1} of wheat for each succession system. Therefore, 50 and 80 kg ha^{-1} nitrogen doses were applied in the soybean/wheat and in the corn/wheat succession systems, respectively. The experiments were set up in a randomized blocks experimental design with four replications, with N-fertilizer application (urea) at 0 (standard condition), 10, 30 and 60 days after emergence (DAE) of wheat plants. It should be noted that the periods of fertilization of 10, 30 and 60 DAE characterize the phenological stages of the wheat development V_1 (first expanded leaf), V_3 (third expanded leaf = early tillering) and V_6 (sixth expanded leaf = end of tillering and early elongation), respectively. Wheat was harvested at ripening (code 87 in BBCH scale). Grain yield was determined based in plants harvested manually from three central rows of each plot, which were then threshed with a stationary harvester. Grains were dried for humidity of 13% and weighed.

The obtained data on yield per hectare were subjected to analysis of variance for detection of interaction and for means

Table 1. Summary of the analysis of variance of times nitrogen application in wheat, in the different years and succession system.

Source of variation	DF	Mean square	
		Grain yield (kg ha^{-1})	
		Corn/wheat succession system	Soybean/wheat succession system
Block	3	43558	105077
Days after emergence	3	3374337*	2058141*
Year	4	3783418*	15555800*
Days after emergence x Year	12	433321*	112229*
Error	57	41745	57978
Total	79		
Overall mean		2236	2658
Coefficient of variation (%)		9.14	9.06

* = Significant at 5% confidence level by the F test; DF = Degrees of freedom.

grouping by the Scott & Knott model. Mean grain yield values along with information of temperature and pluviometric precipitation in the wheat vegetation period were used as criteria for classification of favorable and unfavorable years. Wheat yield stability was estimated according to Wrick (1965) and Eberhart and Russell (1966) models. The Wricke model, named ecovalence (ωi), was estimated according to the equation: $\omega_i = \sum_{j=1}^{n}(eN)_{ij}^{2}$, with the Nitrogen time $(eN)_{ij} = Y_{ij} - Y_i - Y_j - Y$, where Y_{ij} is the mean of time "i" in the environment "j"; Y_i is the mean of time "i" for all environments; Y_j is the mean of the environment "j" for all times; and $Y = m_i$ is the overall mean. According to this methodology, it is considered stable when reduced values of ωi or ωi (%) are observed. The Eberhart & Russell model is based on the linear regression: $Y_{ij} = B0_i + B1_i I_j + S^2_{ij} + E_{ij}$, where Y_{ij} is the mean time "i" in the environment "j"; $B0_i$ is the overall mean of the time "i"; $B1_i$ is the linear regression coefficient, whose estimate represents the response of the time "i" to the variation of the environment "j"; I_j is the codified environmental index; S^2_{ij} is the regression deviation; and E_{ij} is the experimental error expectation. The stability of the time of N-fertilizer application was obtained by the S^2_{ij} parameter. An indicator was considered stable when $S^2_{ij} = 0$, and unstable when $S^2_{ij} \neq 0$. Furthermore, regression equations were applied in order to define the study years (as favorable or unfavorable), and the most appropriate time of N-fertilizer application dependent on the succession system (soybean/wheat; corn/wheat). The statistical analyses were carried out with the aid of the GENES program (Cruz, 2006).

RESULTS AND DISCUSSION

Table 1 shows the analysis of variance, the interaction of N-fertilizer application time with the year of cultivation was detected, regardless the succession system. Therefore, the best time for the application was dependent on the year of cultivation, and the magnitude of the mean square shows major change in soybean/wheat succession system. The interaction between weather and the use of nitrogen in wheat results in variations from year to year in grain yield, being the availability of water the most decisive factor (Benin et al., 2012). The type of residuals coverage also affects the efficiency of fertilizer harnessing (Nascimento et al., 2012). In wheat, the use of leguminous plants has reduced the demand and the losses of nitrogen (Pinnow et al., 2013). The cultivation of wheat in succession to sunnhemp, the species of high rate of N-residual release, also promotes high yield, reduces the demand for fertilizers, and the losses of N by leaching and volatilization, and the total cost of the tillage (Nunes et al., 2011). Although the best use of fertilizer depends on the weather conditions and the succession system, genetic differences among cultivars also influence the rate of nitrogen uptake (Wamser and Mundstock, 2007). Besides the cultivars which have high grain yield those which are more efficient in fertilizer use, and are tolerant to environmental stresses have been continuously used (Oliveira et al., 2011).

Table 2 presents the corn/wheat succession system, the higher grain yield in the overall mean was obtained in the years of 2008 and 2011, which had values closer to the expected of 3 t ha^{-1}. Likewise, in the soybean/wheat succession system, 2008 and 2011 were the years with greater contribution to yield, surpassing the expectation of desired yield. It should be noted that in the years favorable for wheat cultivation in corn/wheat succession system, N-fertilizer applications were applied at 30 and 60 days after emergence (DAE). In the soybean/wheat succession system, this condition was also detected in 2008; however, the year of 2011 favored the application at 10 DAE along with the other times tested, except for the control treatment without fertilization.

The combined effect of years suitable for wheat cultivation (2008 and 2011) with the succession system of high N-residual release considerably contributed to increase grain yield. On the other hand, the unfavorable years nullified the benefits of soybean/wheat succession system (Table 2). Variations in temperature were not so high to the point of damaging the culture of wheat, except for particular conditions in 2009, in June and July, with minimum below 5°C (Table 3). Daily maximum

Table 2. Mean values of times of N-fertilizer application on wheat in the different years and succession system.

Days after emergence (DAE)	Corn/wheat succession system - Year				
	2008	2009	2010	2011	2012
0	A 1605^{c}	A 1604^{a}	A 1425^{b}	A 1717^{c}	A 1571^{b}
10	A 2671^{b}	C 1721^{a}	B 2015^{a}	A 2527^{b}	B 2134^{a}
30	A 3043^{a}	B 1919^{a}	B 2157^{a}	A 3204^{a}	B 2181^{a}
60	A 3268^{a}	B 1869^{a}	B 1815^{a}	A 3215^{a}	B 2042^{a}
Overall Mean	2647^{b+}	1779^{a+}	1853^{a+}	2666^{b+}	1982^{a+}
Days after emergence (DAE)	**Soybean/wheat succession system - Year**				
	2008	**2009**	**2010**	**2011**	**2012**
0	A 3160^{c}	C 1553^{b}	C 1301^{c}	B 2672^{b}	C 1672^{b}
10	A 3607^{b}	B 2050^{a}	C 1508^{c}	A 3389^{a}	B 2138^{a}
30	A 4079^{a}	C 2057^{a}	C 2257^{a}	B 3661^{a}	C 2213^{a}
60	A 4037^{a}	C 2105^{a}	D 1758^{b}	B 3334^{a}	C 2209^{a}
Overall Mean	3721^{a+}	1941^{a+}	1706^{a+}	3264^{a+}	2058^{a+}

Means followed by the same capital letter on the line, small letters in the column and with $^{+}$ sign represents the overall mean of each year between succession system, do not differ significantly by Scott & Knott test with 5% confidence level; DAE = days after emergence.

temperatures, even in the warmer months of the cycle, did not exceed the month average of 27°C. It stands out that, in the years which favored grain yield (Table 2), the total cumulative of pluviometric precipitation was similar to the average precipitation along the previous 25 years (Table 3). On the other hand, reduced grain yield was obtained in the years with precipitation excess (2009) and precipitation restriction (2010 and 2012), when compared to the long-term average. The analysis of the mean values of grain yield with the conditions of temperature and precipitation allowed to classify 2008 and 2011 as favorable years (FY) and 2009, 2010 and 2012 as unfavorable years (UY) to wheat cultivation (Table 3). The agronomic efficiency of nitrogen fertilization strongly depends on weather conditions (Battisti et al., 2013). Benin et al. (2012) observed that wheat was more responsive to grain yield increase by nitrogen fertilization when the precipitation was not a limiting factor. However, under favorable weather conditions, the use of high rates of nitrogen is not always the most appropriate strategy. The increase of grain yield can be achieved by improvements of the utilization efficiency of the fertilizer by the plant (Tavares et al., 2014).

The environmental variations, for being decisive in the time of fertilization, highlight the demand for high means with stability in wheat grain yield. This is a condition that qualifies the estimate of general means with the stability parameters in the five years of study at each fertilization time (Table 4). The use of N-fertilizer in the corn/wheat succession system indicates that the highest values of grain yield were obtained as a result of N applications at 30 and 60 DAE. At these development stages, the combination of high means with the lowest ecovalence value, and S^2_{ij} = 0 in the promotion of the greatest stability, was obtained with fertilization at 30 DAE. In the soybean/wheat succession system, the highest values of grain yield were also obtained with fertilization at 30 and 60 DAE. The greater N-residual condition enabled the high productivity with stability at the treatment of N fertilization at 60 DAE. This result confirms the effect of N-fertilizer application in cases under more restrictive conditions of N-residual release. On the other hand, the appropriate release of nitrogen contained in the tissues of soybean allows the possibility of nitrogen application delay under conditions of the soybean/wheat succession system. In the joint analysis involving succession systems (Table 4), the most stabile grain yield was correlated with fertilization at 30 DAE. Presented studies confirmed the previous results of Nascimento et al. (2012) and Benin et al. (2012), that plant residue decompose type affected the efficiency of nitrogen fertilization of

Table 3. Temperature and precipitation data in the months and years of wheat cultivation.

Year	Month	Temperature (ºC)			Precipitation (mm)		Class
		Minimum	Maximum	Mean	Mean 25 year*	Occurred	
	May	8.7	22.5	15.6	149.7	83.8	
	June	7.4	18.1	12.7	162.5	231.2	
	July	11.4	23.1	17.2	135.1	60.8	
2008	August	10.1	21.2	15.6	138.2	128.0	FY
	September	9.1	21.9	15.5	167.4	72.4	
	October	14.5	25.5	20.0	156.5	390.8	
	Total	-	-	-	909.4	967.0	
	May	10.7	24.4	17.5	149.7	189.0	
	June	4.6	17.9	11.2	162.5	55.6	
	July	4.3	17.5	10.9	135.1	137.2	
2009	August	10.1	23.0	16.5	138.2	268.2	UY
	September	9.8	21.9	15.8	167.4	348.0	
	October	11.7	26.7	19.2	156.5	126.9	
	Total	-	-	-	909.4	1124.9	
	May	8.0	13.8	10.9	149.7	149.7	
	June	8.5	14.5	11.5	162.5	119.8	
	July	7.7	16.9	12.3	135.1	225.3	
2010	August	7.2	18.1	12.6	138.2	41.7	UY
	September	8.4	24.9	16.6	167.4	145.1	
	October	11.8	25.6	18.7	156.5	109.4	
	Total	-	-	-	909.4	791.0	
	May	10.5	22.7	16.6	149.7	100.5	
	June	7.9	18.4	13.1	162.5	191.0	
	July	8.3	19.2	13.7	135.1	200.8	
2011	August	9.3	20.4	14.8	138.2	223.8	FY
	September	9.5	23.7	16.6	167.4	46.5	
	October	12.2	25.1	18.6	156.5	211.3	
	Total	-	-	-	909.4	973.9	
	May	11.1	24.5	17.8	149.7	20.3	
	June	9.3	19.7	14.5	162.5	59.4	
	July	7.4	17.5	12.4	135.1	176.6	
2012	August	12.9	23.4	18.1	138.2	61.4	UY
	September	12.0	23.0	17.5	167.4	194.6	
	October	15.0	25.5	20.2	156.5	286.6	
	Total	-	-	-	909.4	798,9	

* = Mean of pluviometric precipitation obtained based on the months from May to October 1982-2007; Class = classification suggested by the authors; FY = favorable year; UY = unfavorable year.

the culture in succession. Furthermore, growing wheat after soybeans, when compared to corn/wheat succession system, greatly increases grain yield with the same fertilization due to the greater availability of N-residual (Bredemeier et al., 2013).

The predictions of the optimal time of N-fertilizer application for the conditions of favorable and unfavorable year of cultivation, and the regression equations that indicate the need for early or late applications are presented in Table 5. It is noteworthy that in the different succession systems, only favorable years (2008 and 2011) showed significant linear trend for

Table 4. Stability parameters on grain yield dependent on the application time of N-fertilizer in succession system by the Wricke model and Eberhart & Russell model.

Days after emergence (DAE)	Mean of grain yield (kg ha^{-1})	Ecovalence ωi	Ecovalence ωi (%)	Regression S^2_{ij}	Regression R^2 (%)
Corn/wheat succession system					
0	1587^c	2075079	53.3	1767^{ns}	44.2
10	2233^b	197904	5.0	9170^{ns}	93.3
30	2580^a	333655	8.5	-773^{ns}	98.4
60	2541^a	1293254	33.2	-718^{ns}	99.0
Soybean/wheat crop roation					
0	2171^c	132556	13.2	-12538^{ns}	99.8
10	2638^b	312704	30.9	23843^{ns}	97.5
30	3013^a	389679	38.6	34180*	96.8
60	2808^a	175121	17.3	-283^{ns}	99.2
Joint analysis (corn/wheat + soybean/wheat)					
0	1879^c	2417195	45.5	64592*	84.9
10	2436^b	513000	9.7	8590^{ns}	96.8
30	2796^a	724178	13.6	15105^{ns}	96.4
60	2675^a	1660146	31.2	43993*	93.7

Means followed by the same letter in the column do not differ at 5% confidence level (by the Scott & Knott test); DAE= days after emergence; Ecovalence (ωi) = Wricke; Regression = Eberhart & Russell; * significant at 5% confidence level by the F test; ^{ns} not significant by F test; S^2_{ij} = deviations from regression; R^2 = coefficient of determination by the *F* test (Ho: S^2_{ij} = 0).

grain yield. Under corn/wheat rotation, in the favorable years (2008 and 2011), the best time for fertilization in coverage was at 44 and 45 DAE. In the years considered as unfavorable (2009, 2010 and 2012), the demand for anticipation of the time of fertilization is evident, with the best weather condition around 34 and 35 DAE, that is, an anticipation of 10 to 11 days (Table 5). In the soybean/wheat succession system (Table 5) this trend was also observed, showing the best time of fertilization in coverage at 48 DAE in favorable years, and around 39 and 40 DAE, in unfavorable years, that is, an anticipation of 8 to 9 days. The succession system presented less correlation to the ideal time of fertilization (3 to 5 days) compared to the effect of the year of cultivation. These results demonstrate that the year of cultivation is decisive for better nitrogen use, considering the ideal time of fertilization for grain yield. The use of residual N in the soybean/wheat succession system provided considerable benefits to the grain yield of wheat. The additive effects of weather conditions in a favorable year in this succession system and the best time of nitrogen supply enables grain yield superior to 4 t ha^{-1} (Table 5).

As previously reported, the favorable and unfavorable conditions in the year of cultivation were predominantly defined by the pluviometric precipitation (Figure 1). The 2008 and 2011 years, considered as favorable, evidenced the occurrence of precipitation close to the nitrogen application time, with the exception of 2011, when the fertilizer was applied at 10 DAE. On the other hand, in the years 2009, 2010 and 2012, most of the times there was no occurrence of rainfall close to the nitrogen application time (Figure 1). Therefore, the nitrogen use efficiency is reinforced when the fertilizer was applied in the interval between 30 and 60 DAE, in periods near the occurrence of precipitation, regardless the succession system, as long as precipitation is not of high pluviometric volume. These results emphasize the importance of understanding the effect of year climatic conditions and management practices in wheat productivity. Stresses caused by deficiency or excess of water in the soil negatively affect the plant development, with direct effect on ultimate yield (Guarienti et al., 2005). The most efficient way to reduce these risks is the choice of proper cultivar, the sowing time (Silva et al., 2011), and the dose and time of nitrogen application.

Conclusions

The choice of the best time for nitrogen dressing on wheat was strongly influenced by the weather conditions distribution on the year of cultivation; however, it is less influenced by the succession system.

In favorable years for wheat cultivation, the best time for fertilization with N-fertilizer was around 45 days after emergence. In unfavorable years, the N-fertilizer should

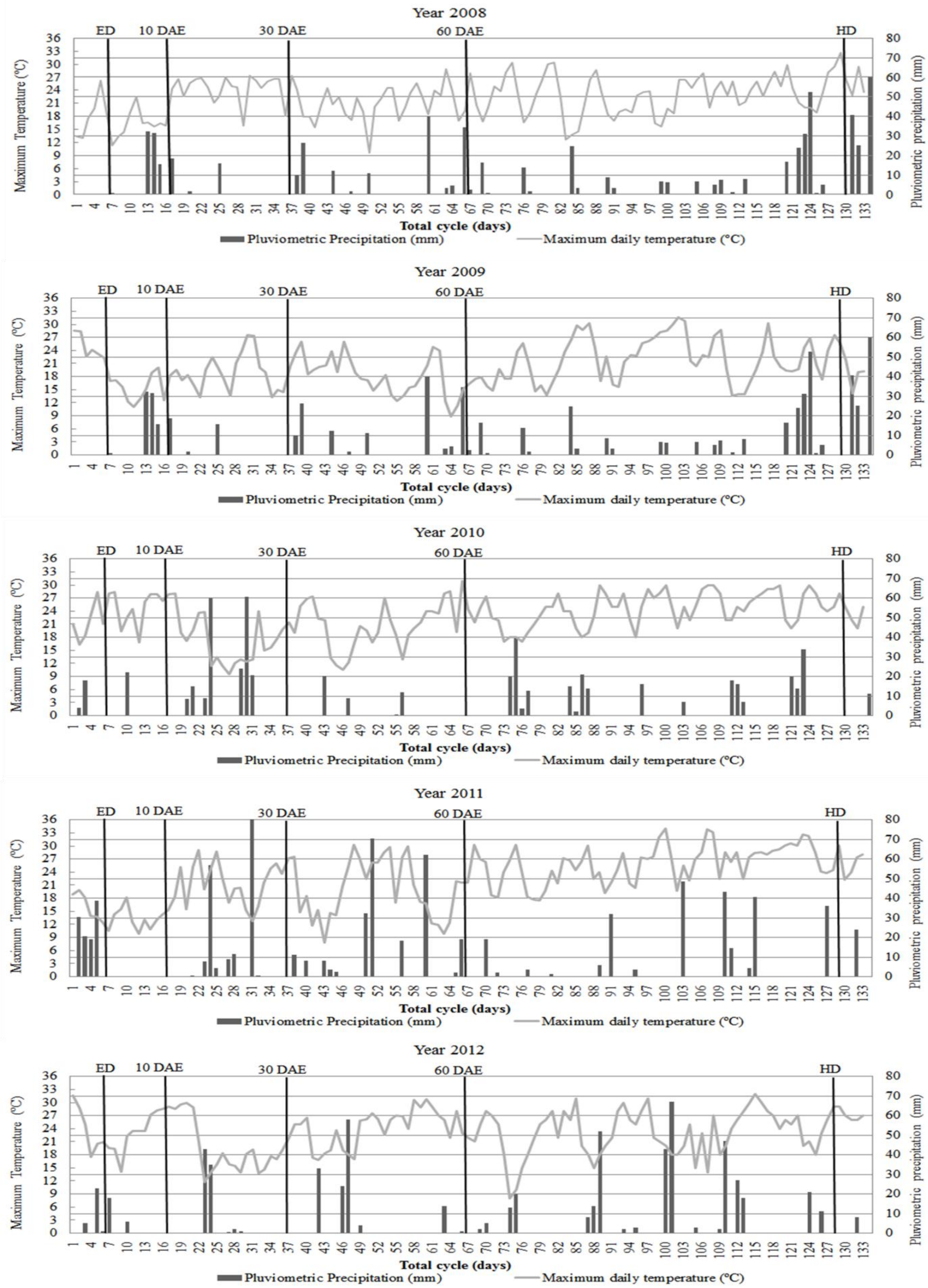

Figure 1. Climatological data of different years of study; ED = Emergence day; DAE = Days after emergence; HD = Harvest Day.

Table 5. Regression equations and the ideal time estimate of nitrogen supply for wheat grain yield in the different years and succession system.

Year	Degree	Regression Model $GY = a \pm bx \pm cx^2$	R^2	P	The best time (DAE)	GY_E (kg ha^{-1})
Corn/wheat succession system						
2008-FY	1	2058 + 23.52x	0.71	*	45	3383
	2	1758 + 71.22x -0.78x^2	0.92	*		
2009-UY	1	1670 + 4.33 x	0.64	ns	35	1882
	2	1594 + 16.28x - 0.23x^2	0.99	*		
2010-UY	1	1752 + 4.02x	0.61	ns	34	2242
	2	1502 + 43.86x - 0.65 x^2	0.90	*		
2011-FY	1	2097 + 22.72x	0.72	*	44	3432
	2	1768 + 75.23x - 0.85x^2	0.99	*		
2012-UY	1	1894 + 4.65x	0.78	ns	34	2150
	2	1656 + 29.14x - 0.43x^2	0.89	*		
Soybean/wheat succession system						
2008-FY	1	3380 + 13.62x	0.70	*	48	4193
	2	3071 + 46.89x - 0.49x^2	0.99	*		
2009-UY	1	1769 + 6.86x	0.69	ns	40	2167
	2	1648 + 26.16x - 0.33x^2	0.77	*		
2010-UY	1	1495 + 8.41x	0.60	ns	39	2156
	2	1108 + 54.20x - 0.70x^2	0.91	*		
2011-FY	1	3057 + 18.28x	0.97	*	48	4092
	2	2754 + 56.52x - 0.59x^2	0.93	*		
2012-UY	1	2425 + 9.29x	0.69	ns	39	2042
	2	1163 + 45.95x 0.60x^2	0.91	*		

FY = Favorable year; UY = Unfavorable year; * significant at 5% confidence level by the *t* test; ^{ns} not significant by *t* test; Degree 1 and 2 = linear and quadratic regression, respectively; R^2 = coefficient of determination, in decimal; P = significance level; significant (*), or not significant (^{ns}); GY_E = Estimated grain yield from the best time in kg ha^{-1}.

be applied about 35 days after emergence. Regardless of the year of cultivation and succession system, N-fertilization at 30 days after emergence enables high stability of grain yield.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank CNPq, FAPERGS, UNIJUÍ and UFPel for contributing with the resources for the development of this research, and for the "Scientific and Technological Initiation" and "Research Productivity" scholarships.

REFERENCES

Battisti R, Sentelhas PC, Pilau FG, Wollmann CA (2013). Eficiência climática para as culturas da soja e do trigo no estado do Rio Grande do Sul em diferentes datas de semeadura. Ci. Rural. 43(3):390-396.

Benin G, Bornhofen E, Beche E, Pagliosa ES, Silva CL da, Pinnow C (2012). Agronomic performance of wheat cultivars in response to nitrogen fertilization levels. Acta Sci. Agro. 34(3):275-283.

Bredemeier C, Variani C, Almeida D, Rosa AT (2013). Estimativa do potencial produtivo em trigo utilizando sensor óptico ativo para adubação nitrogenada em taxa variável. Ci. Rural. 43(7):10-15.

Coelho EF, Costa FS, Silva ACP, Carvalho GC (2014). Concentração de nitrato no perfil do solo fertigado com diferentes concentrações de

fontes nitrogenadas. Ver. Bras. Eng. Agric. Amb. 18(3):263-269. http://dx.doi.org/10.1590/S1415-43662014000300004
Costa L, Zucareli C, Riede CR (2013). Parcelamento da adubação nitrogenada no desempenho produtivo de genótipos de trigo. Ver. Ci. Agro. 44(2):215-224.
Cruz CD (2006). Programa Genes: Biometria. Editora UFV. Viçosa (MG). P 382.
Eberhart SA, Russell WA (1966). Stability parameters for comparing varieties. Crop Sci. 6(1):36-40.
Espindula MC, Rocha VS, Souza MA de, Grossi JAS, Souza LT de (2010). Doses e formas de aplicação de nitrogênio no desenvolvimento e produção da cultura do trigo. Ci. Agro. 34(6):1404-1411.
Flores RA, Urquiaga SS, Alves BJR, Collier LS, Morais RF de, Prado RM (2012). Adubação nitrogenada e idade de corte na produção de matéria seca do capim-elefante no Cerrado. Rev. Bras. Eng. Agric. Amb. 16(12):1282-1288.
Freo JD, Rosso ND, Moraes LBD, Dias ARG, Elias MC, Gutkoski LC (2011). Physicochemical properties and silicon content in wheat flour treated with diatomaceous earth and conventionally stored. J. Stored Prod. Res. 47:316-320.
Guarienti EM, Ciacco CF, Cunha GR da, Del Duca LJA, Camargo CMO (2005). Efeitos da precipitação pluvial, da umidade relativa do ar e de excesso de déficit hídrico do solo no peso hectolitro, no peso de mil grãos e no rendimento de grãos de trigo. Ci. Tec. Alim. 25(3):412-418.
Ma BL, Wu TY, Tremblay N, Deen W, Mclaughlin NB, Morrison M, Stewart G (2010). On-farm assessment of the amount and timing of nitrogen fertilizer on ammonia volatilization. Agro. J. 102:131-144.
Nascimento FM, Bicudo SJ, Fernandes DM, Rodrigues JGL, Fernandes JC, Furtado MB (2012). Efeito da antecipação da adubação nitrogenada na cultura do milho em sistema de plantio direto. Rev. Bras. Ci. Agric. 7(1):1-8. 10.5039/agraria.v7i1a1013
Nunes AS, Souza LCF, Vitorino ACT, Mota LHS (2011). Adubos verdes e doses de nitrogênio em cobertura na cultura do trigo sob plantio direto. Semina Ci. Agric. 32(4):1375-1384.
Oliveira DM, Souza AM, Rocha VS, Assis JC (2011). Desempenho de genitores e populações segregantes de trigo sob estresse de calor. Bragantia 70(1):25-32.
Pinnow C, Benin G, Viola R, Silva CL da, Gutkoski LC, Cassol LC (2013). Qualidade industrial do trigo em resposta à adubação verde e doses de nitrogênio. Bragantia 72(1):20-28.
Reunião da Comissão Brasileira de Pesquisa de Trigo e Triticale (2013). Informações técnicas para trigo e triticale – safra 2013. Londrina, PR: Instituto Agronômico do Paraná (IAPAR) P 220.
Santos HG dos, Jacomine PKT, Anjos LHC dos, Oliveira VA de, Oliveira JB de, Coelho MR, Lumbreras JF, Cunha TJF (2006). Sistema brasileiro de classificação de solos. 2ª ed. Rio de Janeiro: Embrapa Solos, P 306.
Scott AJ, Knott M (1974). A cluster analysis method for grouping means in the analysis of variance. Biometrics 30:507-512.
Silva PRF da, Strieder ML, Coser RPS, Rambo L, Sangoi L, Argenta G, Forsthofer EL, Silva AA da (2005). Grain yield and kernel crude protein content increases of maize hybrids with late nitrogen side-dressing. Sci. Agric. 62(5):487-492.
Silva RR, Benin G, Silva GO da, Marchioro VS, Almeida JL de, Matei G (2011). Adaptabilidade e estabilidade de cultivares de trigo em diferentes épocas de semeadura, no Paraná. Pesq. Agro. Bras. 46(11):1439-1447.
Siqueira Neto M, Piccolo MC, Venzke Filho SP, Feigl BJ, Cerri CC (2010). Mineralização e desnitrificação do nitrogênio no solo sob sistema plantio direto. Bragantia 69(5):923-936.
Storck L, Cargnelutti Filho A, Guadagnin JP (2014). Análise conjunta de ensaios de cultivares de milho por classes de interação genótipo x ambiente. Pesq. Agro. Bras. 49(3):163-172.
Tavares LCV, Foloni JSS, Bassoi MC, Prete CEC (2014). Genótipos de trigo em diferentes densidades de semeadura. Pesq. Agro. Trop. 44(2):166-174.
Teixeira Filho MCM, Buzetti S, Andreotti M, Arf O, Benett CGS (2010). Doses, fontes e épocas de aplicação de nitrogênio em trigo irrigado em plantio direto. Pesq. Agro. Bras. 45(8):797-804.
Viola R, Benin G, Cassol LC, Pinnow C, Flores MF, Bornhofen E (2013). Adubação verde e nitrogenada na cultura do trigo em plantio direto. Bragantia 72(1):90-100.
Wamser AF, Mundstock CM (2007). Adubação nitrogenada em estádios fenológicos em cevada, cultivar “MN 698”. Ci. Rural 37(4):942-948.
Wricke G (1965). Zur Berechning der okovalenz bei sommerweizen und hafer. Zeitschrift für Pflanzenzüchtung 52:127-138.
Yano GT, Takahashi HW, Watanabe TS (2005). Avaliação de fontes de nitrogênio e épocas de aplicação em cobertura para o cultivo do trigo. Semina Ci. Agric. 26(2):141-148.