Nitrogen efficiency in oat yield through the biopolymer hydrogel

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A B S T R A C T

The retainers of water in the soil can favor nitrogen (N) use efficiency in oat yield. The aim of the study was to determine if the conditions of use of the biopolymer hydrogel increase the fertilizer-N use efficiency in oat yield in succession systems of high and low residual-N release. In each succession system (soybean/oat, corn/oat), two experiments were conducted in 2014 and 2015, one to quantify biomass yield and the other to estimate grain yield and lodging. The design was randomized blocks with four replicates in a 4 x 4 factorial scheme for hydrogel doses (0, 30, 60 and 120 kg ha⁻¹), added in the furrow with the seed, and N fertilizer doses (0, 30, 60 and 120 kg ha⁻¹) applied in the fourth-expanded-leaf stage. The use of hydrogel increases N use efficiency in oat yield, especially under the conditions of 30 to 60 kg ha⁻¹ of biopolymer; however, this effect is dependent on the succession system and on weather conditions.

Eficiência do nitrogênio na produtividade da aveia pelo biopolímero hidrogel

R E S U M O

Os hidroretentores de água no solo podem favorecer a eficiência de uso do nitrogênio na produtividade da aveia. O objetivo do estudo foi determinar se as condições de uso do biopolímero hidrogel aumentam a eficiência de aproveitamento do N-fertilizante na produtividade da aveia em sistemas de sucessão de alta e reduzida liberação de residual-N. Em cada sistema de sucessão (soja/aveia; milho/aveia), dois experimentos foram conduzidos em 2014 e 2015, um para quantificar a taxa de produtividade de biomassa e outro na estimativa da produtividade de grãos e o acamamento. O delineamento foi de blocos casualizados com quatro repetições em fatorial 4 x 4, para doses de hidrogel (0, 30, 60 e 120 kg ha⁻¹), adicionado no sulco junto à semente e doses de N-fertilizante (0, 30, 60 e 120 kg ha⁻¹), aplicado no estádio de 4ª folha expandida. O uso de hidrogel aumentou a eficiência de aproveitamento do nitrogênio na produtividade da aveia, principalmente nas condições de 30 e 60 kg ha⁻¹ do biopolímero; porém, este efeito é dependente do sistema de sucessão e condições meteorológicas.

Introduction

Oat is an extremely nutritious cereal increasingly used in the food industry, especially in the form of flakes (Alves & Kist, 2010; Mantai et al., 2016). Rio Grande do Sul is the state with largest cultivation area, 196.8 thousand hectares, and mean yield of 2 t ha^{-1} (CONAB, 2016). The use of fertilizer-N is essential to maximizing the yield and quality of grains required by the industry (Mantai et al., 2015). Although the use of fertilizer-N increases oat biomass and grain yield in favorable years, high doses may lead to lodging, compromising grain production and quality (Arenhardt et al., 2015). In unfavorable years, yield losses can occur through leaching or volatilization of the nutrient, increasing costs and generating environmental pollution (Flores et al., 2013; Krüger et al., 2014). Arenhardt et al. (2015) comment that the adequate volume and distribution of rainfall with lower temperatures represent conditions of favorable years for oat cultivation.

The maximum use efficiency of the nutrient by the plant is determined by the maintenance of soil moisture, with expressive effects on the increase of yield (Borges et al., 2014; Silva et al., 2015). In this context, the use of water retainers can favor the maintenance of moisture in the soil, because it contributes to retaining water and gradually releasing it to the plants (Oliveira et al., 2004; Moghadam et al., 2011), which can improve the fertilizer-N use, potentiating the yield and reducing risks of losses of the nutrient. Hydrogels are biodegradable, three-dimensional polymer networks that retain water in their structure, forming a gel capable of hydrating and releasing water for a long period (Sartore et al., 2013; Guilherme et al., 2015).

This study aimed to determine if the conditions of use of the polymer hydrogel increase the fertilizer-N use efficiency in oat yield in succession systems of high and reduced residual-N release.

Material and Methods

The experiments were carried out under field conditions in 2014 and 2015, in the municipality of Augusto Pestana-RS, Brazil (28° 26' 30" S; 54° 00' 58" W). The soil of the experimental area was classified as typic dystroferric Red Latosol and the climate of the region, according to Köppen's classification, is Cfa (humid subtropical), with rainfalls well distributed along the year and the mean temperature of the hottest month above 22 ºC. Ten days before sowing, soil analysis was performed to determine the following chemical characteristics (Tedesco et al., 1995): i) corn/oat system (pH = 6.5; P = 34.4 mg dm^{-3}; K = 262 mg dm^{-3}; OM = 2.9%; Al = 0 cmol$_c$ dm^{-3}; Ca = 6.6 cmol$_c$ dm^{-3} and Mg = 3.4 cmol$_c$ dm^{-3}) and; ii) soybean/oat system (pH = 6.2; P = 33.9 mg dm^{-3}; K = 200 mg dm^{-3}; OM = 3.0%; Al = 0 cmol$_c$ dm^{-3}; Ca = 6.5 cmol$_c$ dm^{-3} and Mg = 2.5 cmol$_c$ dm^{-3}). Regardless of agricultural year, sowing was performed in the third week of June, according to the recommendation of cultivation for the species, in residual cover of high and reduced C/N ratio, corn/oat and soybean/oat system, respectively. The sowing process used a seeder-fertilizer in the composition of the plot with five

5-m-long rows spaced by 0.18 m, forming an experimental unit of 4.5 m^2. The population density was 400 viable seeds m^{-2}. During the study, the fungicide Tebuconazole was applied at the dose of 0.75 L ha^{-1}. Weeds were controlled with the herbicide metsulfuron-methyl at the dose of 4 g ha^{-1} and manual weedings, always when necessary. In the experiments, 45 and 30 kg ha^{-1} of P$_2$O$_5$ and K$_2$O were applied at sowing, based on the contents of P and K in the soil for the expected grain yield of 3 t ha^{-1}, respectively, and 10 kg ha^{-1} of N as basal application, except in the control experimental unit, with absence of N. Therefore, basal fertilization consisted in the N-P-K formulation of 10-20-20. The rest of the N was applied as top-dressing in the fourth-expanded-leaf stage. The different doses of granular hydrogel of the biopolymer were applied together with the oat seeds, being in the soil at the same depth and cultivation row, approximately 3 cm deep.

In each cultivation condition of high and reduced residual-N release (corn/oat and soybean/oat systems), two experiments were conducted, one to quantify biomass yield (BY, kg ha^{-1}) through the cuts performed every 30 days until physiological maturity and the other to estimate grain yield (GY, kg ha^{-1}) and lodging (LD, %). Hence, the four experiments were set in a randomized block design with four replicates, in a 4 x 4 factorial scheme corresponding to four hydrogel doses (0, 30, 60 and 120 kg ha^{-1}) and four fertilizer-N doses (source: urea) (0, 30, 60 and 120 kg ha^{-1}), using the white oat cultivar 'URS-Corona'.

Lodging was visually estimated and expressed in percentage, in the stage close to grain harvest, following the methodology proposed by Moes & Stobbe (1991). Grain yield was obtained by the cut of three central rows of each plot in the harvest maturity stage, with grain moisture around 22%. Plants were threshed with stationary threshing machine and sent to the laboratory for the correction of grain moisture to 13% and weighing, to estimate grain yield (GY, kg ha^{-1}). In the experiments intended for quantifying biomass yield (BY kg ha^{-1}) along the development of the plants, the vegetal material was harvested close to the soil, through the collection of one linear meter of the three central rows of each plot, in the periods of 30, 60, 90 and 120 days after emergence, totaling four cuts. The samples of fresh biomass were dried in an oven at temperature of 65 ºC.

After meeting the assumptions of homogeneity and normality through the Bartlet tests, analysis of variance was used to detect the main effects and the effects of interaction. Linear equations (BY = $b_0 \pm b_1x$) were used to estimate the biomass yield of oat and the Scott-Knott method was used to compare the mean values of grain yield and lodging. Quadratic equations (Y = $b_0 \pm b_1x \pm b_2x^2$) were used to estimate the fertilizer-N dose ideal for maximum grain yield (N$_{ideal}$ = -b_1/2b_2), with simulation of lodging, under the conditions of the use of hydrogel in the cultivation systems. The computer program Genes was used for these determinations.

Results and Discussion

In the years 2014 and 2015, the rainfalls were 952 and 817 mm, respectively. These volumes are close to the historical

average of the last 20 years (900 mm), but with different distribution. In 2014, a large volume of rainfall occurred from half of the cycle to the maturation (Figure 1A), a condition that led to periods of lower insolation in the phase of elongation and grain filling. In 2015, the largest volume of rainfall occurred from emergence to 43 days of development, with subsequent regular rainfalls of lower volumes (Figure 1B). Rainfall periods along the cycle reduce the light use efficiency in the photosynthesis and, in the stage of filling and maturation, interfere with grain yield and quality (Arenhardt et al., 2015). These conditions led to the higher grain yield obtained in 2015.

In the analysis of the source of variation year, N dose and hydrogel dose, the main effects and interaction effects were significant. In Table 1, in the soybean/oat system in 2014, the use of 30 kg ha^{-1} of hydrogel caused greater biomass yield per day and grain yield at the highest dose of fertilizer-N. The highest mean of grain yield (2775 kg ha^{-1}), regardless of the N use condition, was also obtained with 30 kg ha^{-1} of the biopolymer. In 2015 (Table 1), the higher biomass yield per day and grain yield was also obtained with 30 kg ha^{-1} of hydrogel at the highest fertilizer-N dose (120 kg ha^{-1}). The highest mean of grain yield, regardless of the N dose, was obtained with the doses of 30 and 60 kg ha^{-1} of hydrogel and 3416 and 3518 kg ha^{-1}, respectively. Although higher biomass and grain yields occurred in 2015 favored by the meteorological conditions (Figure 1), reflexes on the increase of plant lodging

were intensified, especially at higher doses of fertilizer-N, a condition that compromises harvest and decrease grain quality. It should be pointed out that the condition of high residual-N release, as in the soybean/oat system along with the interaction with the fertilizer, tends to lead to greater plant lodging.

In Table 2, in the corn/oat system, the biomass yield per day and grain yield were incremented by the increase in the dose of fertilizer-N, regardless of the hydrogel dose and agricultural year. There were reduced values of lodging in this succession system, especially in 2014, in which the increase of fertilizer-N did not lead to alteration. In 2014, grain yield was not altered using hydrogel. On the other hand, in the absence of hydrogel with the highest dose of fertilizer-N, grain yield was equal to 2780 kg ha^{-1}, but the use of the biopolymer with 60 kg ha^{-1} at the highest dose of fertilizer-N incremented grain yield to 3237 kg ha^{-1} (Table 2). In 2015, regardless of the dose of fertilizer-N, the use of hydrogel did not alter grain yield; however, high doses of fertilizer-N increased the biomass and grain yields, along with the lodging percentage, a fact also observed in the year 2014. It should be highlighted that, in the condition of reduced release of residual-N, in corn/oat system, there is a strong contribution to the reduction of plant lodging, which, in this perspective, qualifies this succession system.

High levels of N fertilization, despite maximizing production, can favor plant lodging, in addition to other environmental damages and increase in the production costs (Ma et al., 2010;
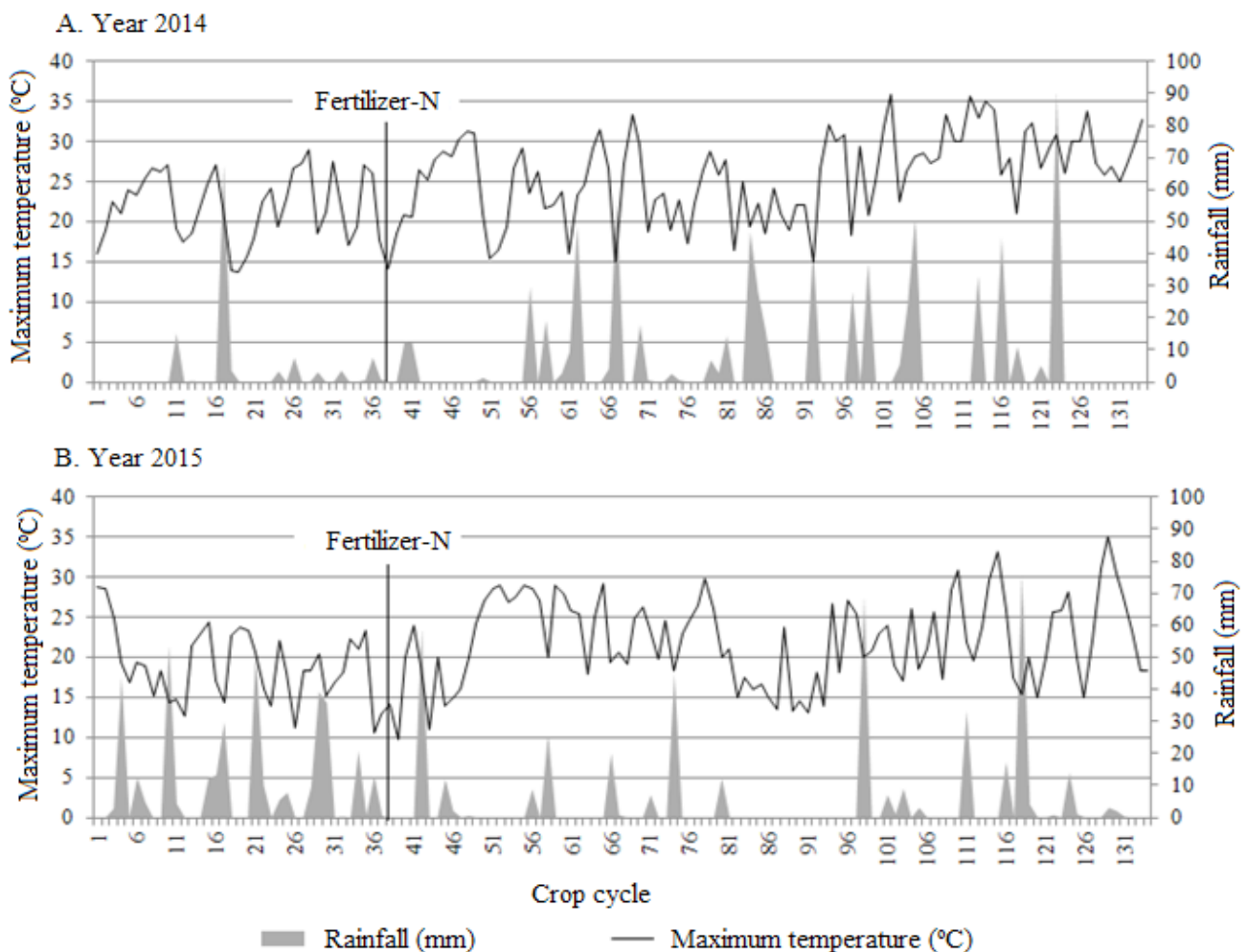

Figure 1. Rainfall and maximum temperature in the oat cycle

Table 1. Biomass yield per day, grain yield and lodging of oat plants under doses of hydrogel and nitrogen in the soybean/oat system

Hydrogel	Nitrogen (kg ha⁻¹)	BY = $b_0 \pm b_ix$	R^2	P (b_ix)	GY (kg ha⁻¹)	X GY$_H$ (kg ha⁻¹)	LD (%)
Year 2014							
0	0	-585 + 48x	0.91	*	1999 b		4 c
	30	-1279 + 85x	0.86	*	2748 a	2565 B	8 c
	60	-1433 + 104x	0.91	*	2874 a		43 b
	120	-1560 + 116x	0.88	*	2640 a		52 a
30	0	-766 + 55x	0.91	*	2172 b		8 c
	30	-1308 + 81x	0.90	*	2893 a	2775 A	9 c
	60	-1213 + 98x	0.91	*	2970 a		37 b
	120	-1977 + 134x	0.91	*	3065 a		53 a
60	0	-851 + 58x	0.91	*	2036 d		3 d
	30	-1299 + 85x	0.90	*	2783 b	2596 B	23 c
	60	-1234 + 98x	0.93	*	2948 a		43 b
	120	-1712 + 118x	0.89	*	2615 c		57 a
120	0	-1175 + 69x	0.89	*	2000 c		4 d
	30	-1391 + 95x	0.89	*	2485 b	2519 B	33 c
	60	-1394 + 114x	0.92	*	2786 a		57 b
	120	-1578 + 120x	0.93	*	2807 a		79 a
Year 2015							
0	0	-1605 + 79x	0.82	*	2442 c		10 c
	30	-1826 + 96x	0.84	*	3321 b	3330 B	40 b
	60	-1832 + 108x	0.90	*	3810 a		76 a
	120	-2204 + 126x	0.91	*	3745 a		83 a
30	0	-1879 + 89x	0.81	*	2482 c		4 d
	30	-1812 + 102x	0.88	*	3319 b	3416 A	35 c
	60	-2143 + 122x	0.88	*	3996 a		72 b
	120	- 2019 + 130x	0.91	*	3868 a		93 a
60	0	-1600 + 80x	0.85	*	2847 d		9 d
	30	-1451 + 87x	0.91	*	3493 c	3518 A	33 c
	60	-1899 + 109x	0.90	*	4057 a		72 b
	120	-1840 + 117x	0.91	*	3677 b		88 a
120	0	-1457 + 74x	0.85	*	2141 c		7 c
	30	-1427 + 92x	0.93	*	3452 b	3207 B	40 b
	60	-1702 + 109x	0.91	*	3644 a		78 a
	120	-2206 + 125x	0.90	*	3591 a		86 a

BY - Biomass yield; LD - Lodging; GY - Grain yield; XGY$_H$ - Mean of grain yield in the conditions of use of hydrogel; R^2 - Coefficient of determination; P (b_ix) - Probability of the line slope parameter; *Significant at 0.05 probability level by t-test
Means followed by the same lowercase letters in each hydrogel dose compare nitrogen doses and uppercase letters compare hydrogel doses constituting statistically homogeneous group by the Scott-Knott model at 0.05 probability level

Arenhardt et al., 2015). In rye, the use of hydrogel led to a significant increment in the biomass production at different levels of fertilization under water restriction (Nissen & Tapia, 1996). In canola, the use of the biopolymer increases the water storage capacity of the soil, favoring the vegetative period and oil quality in the grains (Moghadam et al., 2011).

To determine if the biopolymer hydrogel increases the fertilizer-N use efficiency, Tables 3 and 4 show the estimates of the optimal dose of the nutrient for maximum grain yield and expected lodging using the biopolymer. In Table 3, for the soybean/oat system in 2014, the maximum N use efficiency for grain yield was obtained with 75 kg ha⁻¹ in the absence of hydrogel, with expected yield of 2993 kg ha⁻¹ and lodging of 36%. For the use of hydrogel with 30 and 60 kg ha⁻¹, there were reductions in the N use to 73 and 71 kg ha⁻¹, respectively, generating expected yields of 3180 and 3017 kg ha⁻¹, respectively. At these doses of the biopolymer, the obtained values of lodging were similar to those of the standard dose. At the highest dose of hydrogel, there was a reduction in N use efficiency (84 kg ha⁻¹), indicating greater use of the nutrient with lower grain yield and high lodging. This fact indicates that the excess of hydrogel may substantially increase soil moisture, leading to greater vegetative growth and, consequently, plant lodging, interfering with the yield.

In 2015, in the soybean/oat system (Table 3), the maximum N use efficiency for grain yield without using hydrogel was obtained with 87 kg ha⁻¹, with expected yield of 3968 kg ha⁻¹ and lodging of 74%. The hydrogel dose of 60 kg ha⁻¹ led to reduction in the use of fertilizer-N to 80 kg ha⁻¹, with expected grain yield of 4084 kg ha⁻¹ and lodging percentage similar to those of the other biopolymer doses.

In Table 4, for the corn/oat system in 2014, the maximum N use efficiency for grain yield was obtained with 105 kg ha⁻¹ in the absence of hydrogel. This dose promoted expected grain yield of 2892 kg ha⁻¹ with lodging of 3%. In the use of 30 kg ha⁻¹ of hydrogel, the optimal dose of fertilizer-N was also obtained with 105 kg ha⁻¹. Although there was no reduction of fertilizer-N, there was an increment in grain yield to 3100 kg ha⁻¹. The hydrogel doses of 60 and 120 kg ha⁻¹ caused a linear response in the fertilizer-N use efficiency for grain yield. In 2015, the maximum N use efficiency for grain yield without using hydrogel was obtained with 90 kg ha⁻¹, and expected grain yield of 3520 kg ha⁻¹ and lodging of 33%. The hydrogel dose of 30 kg ha⁻¹ promoted increment in the use of the optimal dose of fertilizer-N, to 105 kg ha⁻¹, with increment in the expected grain yield to 3700 kg ha⁻¹. The hydrogel doses caused linearity in the N use for grain production, i.e., for being linear, the functions do not generate stability, as the quadratic functions

Table 2. Biomass yield per day, grain yield and lodging of oat plants under doses of hydrogel and nitrogen in the corn/oat system

Hydrogel	Nitrogen (kg ha^{-1})	BY = $b_0 \pm b_i x$	R^2	P ($b_i x$)	GY (kg ha^{-1})	X GY$_H$ (kg ha^{-1})	LD (%)
				Year 2014			
0	0	-608 + 45x	0.84	*	1239 d		3 a
	30	-959 + 71x	0.74	*	2163 c	2163 A	2 a
	60	-1068 + 86x	0.75	*	2468 b		2 a
	120	-1304 + 102x	0.82	*	2780 a		2 a
30	0	-477 + 40x	0.92	*	1239 d		1 a
	30	-850 + 70x	0.91	*	2264 c	2297 A	1 a
	60	-876 + 81x	0.84	*	2657 b		1 a
	120	-1220 + 101x	0.91	*	3027 a		1 a
60	0	-783 + 54x	0.93	*	1593 d		1 a
	30	-812 + 64x	0.89	*	1989 c	2337 A	1 a
	60	-1078 + 87x	0.82	*	2530 b		1 a
	120	-1403 + 105x	0.80	*	3237 a		2 a
120	0	-618 + 40x	0.91	*	1295 d		1 a
	30	-767 + 54x	0.94	*	2008 c	2201 A	2 a
	60	-679 + 81x	0.86	*	2427 b		2 a
	120	-1179 + 111x	0.83	*	3072 a		2 a
				Year 2015			
0	0	-1204 + 64x	0.86	*	1863 c		1 d
	30	-1476 + 79x	0.87	*	2789 b	2849 A	15 c
	60	-1636 + 88x	0.88	*	3337 a		30 b
	120	-1780 + 101x	0.89	*	3407 a		40 a
30	0	-1389 + 70x	0.84	*	1766 d		1 c
	30	-1739 + 85x	0.83	*	2758 c	2874 A	7 c
	60	-1552 + 91x	0.91	*	3302 b		22 b
	120	-1770 + 102x	0.90	*	3669 a		48 a
60	0	-1623 + 79x	0.82	*	2189 d		5 c
	30	-1510 + 84x	0.89	*	2572 c	2883 A	7 c
	60	-1479 + 88x	0.91	*	3143 b		33 b
	120	-1928 + 114x	0.91	*	3627 a		52 a
120	0	-1247 + 67x	0.87	*	1973 d		2 c
	30	-1303 + 80x	0.92	*	2718 c	2847 A	9 c
	60	-1438 + 93x	0.89	*	3087 b		30 b
	120	-1921 + 111x	0.90	*	3608 a		62 a

BY - Biomass yield; LD - Lodging; GY - Grain yield; XGY$_H$ - Mean of grain yield in the conditions of use of hydrogel; R^2 - Coefficient of determination; P ($b_i x$) - Probability of the line slope parameter; *Significant at 0.05 probability level by t-test
Means followed by the same lowercase letters in each hydrogel dose compare nitrogen doses and uppercase letters compare hydrogel doses constituting statistically homogeneous group by the Scott-Knott model at 0.05 probability level

Table 3. Equation of the estimate of the nitrogen dose ideal for grain yield with expected lodging using hydrogel in the soybean/oat system

Hydrogel (kg ha^{-1})	Y = $b_0 \pm b_1 x \pm b_2 x^n$	R^2	P ($b_i x^n$)	N$_{ideal}$ (kg ha^{-1})	Y$_E$
			Year 2014		
0	GY = 2036 + 25.51x - 0.17x^2	0.96	*	75	2993
	LD = 3.95 + 0.43x	0.84	*		36
30	GY = 2224 + 21.5x − 0.15x^2	0.94	*	73	3180
	LD = 5.35 + 0.41x	0.89	*		35
60	GY = 2066 + 26.88x - 0.19x^2	0.98	*	71	3017
	LD = 8.4 + 0.44x	0.93	*		40
120	GY= 1999 + 21.9x - 0.13x^2	0.97	*	84	2859
	LD = 11.6 + 0.61x	0.93	*		63
			Year 2015		
0	GY = 2445 + 34.9x - 0.2x^2	0.99	*	87	3968
	LD = 20.45 + 0.61x	0.83	*		74
30	GY= 2454 + 37.71x - 0.22x^2	0.99	*	86	4070
	LD = 11.95 + 0.74x	0.92	*		76
60	GY= 2813 + 31.88x - 0.2x^2	0.98	*	80	4084
	LD = 15.4 + 0.67x	0.91	*		69
120	GY= 2220 + 41.57x - 0.25x^2	0.94	*	83	3949
	LD = 18.5 + 0.65x	0.83	*		72

GY - Grain yield (kg ha^{-1}); LD - Lodging percentage (%); R^2 - Coefficient of determination; P($b_i x^n$) - Probability of the slope parameter; *Significant at 0.05 probability level by t-test; N$_{ideal}$ - Ideal dose of nitrogen estimated by the regression equation of grain yield; Y$_E$ - Estimated values

Table 4. Equation of the estimate of the nitrogen dose ideal for grain yield with expected lodging using hydrogel in the corn/oat system

Hydrogel (kg ha^{-1})	$Y = b_0 \pm b_1x \pm b_2x^n$	R^2	P (b_ix^n)	N_{ideal} (kg ha^{-1})	Y_E
	Year 2014				
0	GY = 1281 + 29.49x - 0.14x^2	0.98	*	105	2892
	LD = 2.4 - 0.0052x	0.69	*		3
30	GY = 1281 + 33.55x - 0.16x^2	0.99	*	105	3100
	LD = 0.95 + 0.0021x	0.77	ns		2
60	GY = 1610 + 13.85x	0.99	*	-	-
	LD = 1.1 + 0.007x	0.13	ns		
120	GY = 1451 + 14.27x	0.96	*	-	-
	LD = 1.35 - 0.08x	0.66	ns		
	Year 2015				
0	GY = 1900 + 36x - 0.2x^2	0.99	*	90	3520
	LD = 4.85 + 0.31x	0.93	*		33
30	GY = 1815 + 35.8x - 0.17x^2	0.99	*	105	3700
	LD = -1.75 + 0.40x	0.98	ns		41
60	GY = 2245 + 12.13x	0.97	*	-	-
	LD = 2.2 + 0.41x	0.93	ns		
120	GY = 2166 + 12.95x	0.97	*	-	-
	LD = -1.8 + 0.52x	0.98	ns		

GY - Grain yield (kg ha^{-1}); LD - Lodging percentage (%); R^2 - Coefficient of determination; P(b_ix^n) - Probability of the slope parameter; *Significant at 0.05 probability level by t-test; ns - Not significant at 0.05 probability level by t-test; N_{ideal} - Ideal dose of nitrogen estimated by the regression equation of grain yield; Y_E - Estimated values

do, in the increment of N doses. This fact was similar in both cultivation years.

The N use efficiency was obtained through equations as a function of the N doses in each condition of the biopolymer. Therefore, the results of Tables 3 and 4 indicate that, in the soybean/oat system, the highest yields with the lowest use of fertilizer-N were obtained at hydrogel doses of 30 and 60 kg ha^{-1}. On the other hand, in the corn/oat system, the highest efficiency was observed with 30 kg ha^{-1} of the biopolymer, leading to the highest estimate of yield using the optimal dose. The product hydrogel costs R$ 18.00 kg^{-1}; thus, a dose of 30 kg ha^{-1} of the biopolymer leads to a cost of R$ 540.00 ha^{-1}. Although the cost may seem high considering the reduced use of the technology in large scale, the biopolymer has a water retaining action in the soil of 3 to 4 years; therefore, the cost is diluted along the cultivation seasons. However, there are no studies on the use of hydrogel in cereals considering the actual conditions of cultivation, especially searching for the link with N use efficiency. Therefore, we highlight the innovative character of this study, for using the biopolymer aiming at higher N use efficiency in oat grain yield.

Studies conducted by Marques et al. (2012), with sugarcane, indicated that the hydrogel dose of 53 kg ha^{-1} increased the stalk mass yield, a value between the biopolymer doses that led to higher N use efficiency for oat yield in the present study. In the production of seedlings, Mews et al. (2015) observed that the use of the biopolymer increased the use of N fertilization, with ideal doses between 2 and 4 g kg^{-1} of substrate. In bell pepper, the increment of hydrogel doses led to greater development of the seedlings, linearly increasing the number of leaves and shoots of the plants (Marques & Bastos, 2010).

Conclusions

The use of hydrogel increases N use efficiency in oat yield, especially in the conditions of 30 and 60 kg ha^{-1} of the biopolymer; however, this effect is dependent on the succession system and on weather conditions.

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