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The effect of nitrogen dose on the yield indicators of oats

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Studies on the effect of nitrogen dose on the yield indicators of oats can help cultivation recommendations. This study aims to study the simulation of the productivity indicators of oats based on optimal dose of nitrogen on grain yield expression, under the agricultural stand conditions of high and low availability of nitrogen and favorable and unfavorable weather conditions. Studies were conducted in 2011 and 2012 years, in a complete randomized block design with four replications in a 2 x 4 factorial arrangement to cultivars (Barbarasul and Brisasul) and nitrogen doses (0, 30, 60 and 120 kg ha^{-1}) in the soybean/oat and corn/oat succession system. In each succession system, two experiments were conducted, one for quantifying the production of biomass and another to estimate grain yield. The use of nitrogen introduced quadratic regression model on the grain yield and harvest index, showed linear behavior in the biological yield and straw in the two crop succession system. The difference of this behavior is caused by the biological, straw and also by year favorable or unfavorable. The simulation of the nitrogen optimal dose for the production of grain confirms major efficiency of Brisasul cultivar in the expression of grain yield indicators.

Key words: *Avena sativa* L., crop succession, nitrogen rates, yield indicators, simulation.

INTRODUCTION

Climatic changes on the planet have provided a new challenge in the world agricultural production, where breeding of more productive and tolerant to stresses cultivars (Araus et al., 2008), and efficiency in the use of

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light and nutrients (Oliveira et al., 2011) are required. In this context, the improper management of nitrogen, which efficiency depends on the quality of fertilizer, cultivation techniques, utilization of genetic efficiency and edaphoclimatic conditions become reasons for the low grain production of oat (Silva et al., 2006; Veloso et al., 2009; Costa et al., 2013). Increasing the nitrogen dose and the optimal application time under favorable climatic conditions shows significant effects on grain yield (Dencic et al., 2011; Flores et al., 2012). However, in unfavorable years of cultivation, utilization efficiency may be compromised, reducing productivity and increasing production costs, besides the nitrogen losses by volatilization and leaching generating environmental pollution (Benin et al., 2012; Silva et al., 2015).

The biological yield (grain yield + straw yield) is closely related to the processes of photosynthesis and respiration during the vegetative and reproductive stages (Demétrio et al., 2012). The relationship between grain and biological yields allows the determination of the harvest index, important parameter in defining the rate with which photo assimilates are transported to straw and grains (Silva et al., 2012). Studies of Demétrio et al. (2008), show that these traits are influenced by genotype, cultivation technique, water and nutrients availability, and edaphoclimatic conditions, which highlights the importance of these variables on the efficiency of nitrogen uptake and utilization (Silva et al., 2015). Thus, the studies of nitrogen use efficiency based on grain yield indicators can help towards the recommendations on better adjusted technologies, economically satisfactory, lower impact on the environment and decisive conditions in the search for more sustainable agricultural biosystems (Parry et al., 2011; Prando et al., 2013).

The objective of this study was the simulation of the productivity indicators of oats based on optimal dose of nitrogen on grain yield expression, under the agricultural stand conditions of high and low availability of nitrogen and favorable and unfavorable weather conditions.

MATERIALS AND METHODS

The field experiments with oats were conducted in Augusto Pestana, RS, Brazil (28° 26' 30'' South latitude and 54° 00' 58'' West longitude), in 2011 and 2012 years. The soil of the area is classified as Oxisol Distroferric Typical and the climate, according to Köppen classification (Kuinchtner and Buriol, 2011), is temperate humid with hot summer, without dry season. Soil analysis ten days before oats sowings identified the following chemical characteristics of the local: i) crop succession corn/oat (pH = 6.5; P = 34.4 mg dm^{-3}; K = 262 mg dm^{-3}; Organic Matter = 3.5%; Al = 0.0 $cmol_c$ dm^{-3}; Ca = 6.6 $cmol_c$ dm^{-3} e Mg = 3.4 $cmol_c$ dm^{-3}) and ii) crop succession soybean/oat (pH = 6.2; P = 33.9 mg dm^{-3}; K = 200 mg dm^{-3} Organic Matter = 3.4%; Al = 0.0 $cmol_c$ dm^{-3}; Ca = 6.5 $cmol_c$ dm^{-3} e Mg = 2.5 $cmol_c$ dm^{-3}). In both experimental years, oats was sown in optimal time, that is, in the first week of June with seeder-fertilizer. Each plot consisted of 5 rows of 5 m length with 0.20 m line space, forming the experimental unit of 5 m^2. During the vegetation period, oats was protected from diseases by FOLICUR® CE tebuconazole fungicide applications at the dose of 0.75 l ha^{-1} and from weeds control by ALLY® metsulfuron-methyl herbicide, at the dose of 2.4 g ha^{-1} of the active ingredient and manual weeding when necessary.

At the time of oat sowing, NPK formulation was used (5-20-20), with nitrogen base of 10 kg ha^{-1} (except in the standard experimental unit) and 60 and 50 kg ha^{-1} of P_2O_5 and K_2O applied, respectively, based on the levels of organic matter, P and K in the soil to expect grain yield of about of 3 t ha^{-1}. The rest of the nitrogen to contemplate the remaining doses was applied in coverage with urea (45% N), in four oat leaf stage.

The experimental design was randomized blocks with four repetitions, in factorial scheme 4 × 2 to doses of N-fertilizer (0, 30, 60, 120 kg ha^{-1}) and oat cultivars (Barbarasul and Brisasul), respectively, totaling 64 experimental units for crop succession. Therefore, in each crop succession (corn/oat and soybean/oat system), two experiments were conducted to quantify the total biomass production and the other targeting exclusively to estimate grain yield. For that purpose, oats were harvested manually from three central rows of each plot at the maturity stage (grain moisture about 22%). Then threshed with a stationary thresher and dried to the 13% grain moisture, in addition to weighing to estimate the grain yield (GY, kg per ha^{-1}). The grain yield from each plot was determined and then recalculated to Kg per ha, the same for the other parameters.

In the experiments for the total biomass estimations, plant material was cut close to the soil, from the collection of a linear meter of the three central rows of each plot. Green biomass samples were dried in forced air oven at 65°C and weight for biological yield (BY, kg per ha^{-1}). Straw yield (SY, kg per ha^{-1}) was calculated by subtraction BY - GY and the harvest index (HI, kg per kg^{-1}) according to $\frac{GY}{BY}$ equation.

The homogeneity and normality was checked by Bartlett and Lilliefors test, after the analysis of variance which was performed to detect the main and interaction effects. The weather conditions and values average of grain yield were used to characterize the years in favorable and unfavorable. It was performed to the adjustment equations of degree two $GY = b_0 \pm b_1 x \pm b_2 x^2$ for the estimation of maximum technical efficiency ($MTE = -\frac{b_1}{2b_2}$) of grain yield. Equations that describe the biological yield, straw yield and harvest index to simulate this parameters in the use of ideal dose of nitrogen by grain yield were obtain. All analyzes were performed using the GENES software (Cruz, 2006).

In 2011, there was more pluviometric precipitation before N-fertilization (Figure 1). Maximum temperatures observed at the beginning of oat development were higher in 2012. From the fertilization, variations of temperature not shown marked change to oat crop (Figure 1). In Table 2, the minimum were not below 5°C in the months of May and June. The maximum temperature, even in the hottest months of the cycle, does not exceed 27°C. In 2011, expressive yield indicators of oat (Table 1) showed that total accumulated pluviometric precipitation was similar to the average precipitation over 25 years (Table 2). Moreover, the reduced expression of these parameters in 2012 indicated smaller rainfall compared to the historical average. Based in these results (Table 2), the 2011 year was classified as favorable (FY) and 2012 as unfavorable year (UY) for the oat production.

RESULTS AND DISCUSSION

In soybean/oat crop succession system (Table 1), nitrogen rates indicate change on the yield indicators of oat, regardless of year of cultivation. Genetic differences were observed for grain yield and harvest index in 2011.

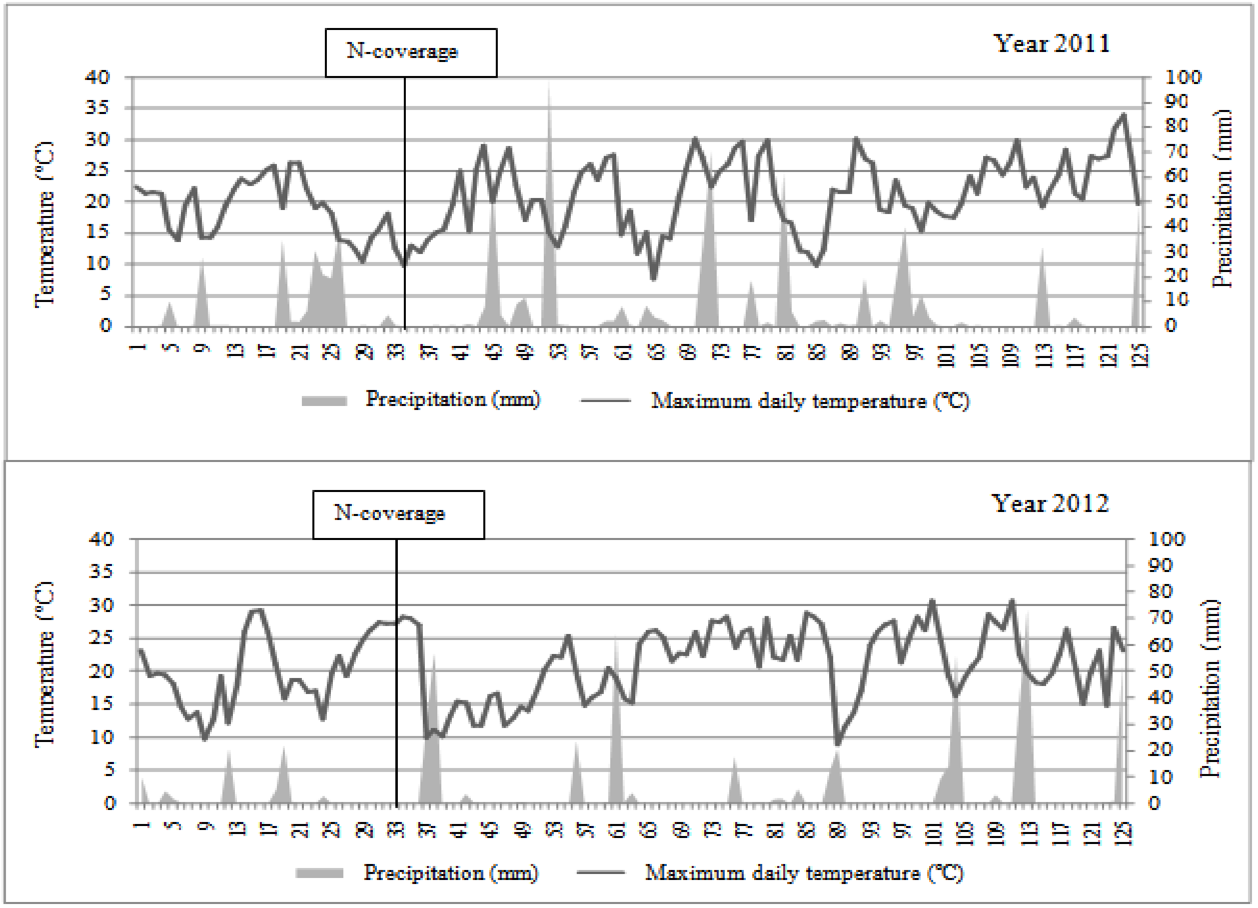

Figure 1. Pluviometric precipitation and maximum temperature in oats cycle.

Although, the genetic differences on the yield indicators of oat in 2012 did not show differences, however, the interaction genotype *versus* doses confirm differences on nitrogen use by cultivars, condition similar to the previous year. In crop succession corn/oat system (Table 1), the nitrogen levels were also shown on the yield indicators of oat regardless of the year of analysis. In this condition, genetic differences were more evident, except for grain yield in 2011 which did not differed. The mean difference in general between the years in crop succession soybean/oat system were significant, with 2011 surpassing 2012 in 0.7, 3 and 2.5 t ha^{-1} grain yield, biological and straw, respectively.

In corn/oat crop succession system, even with lower average soybean/oat condition, also identified differences between the years, highlighting 2011 as the most favorable, with higher values of 0.2, 1.2 e 1 t ha^{-1} grain yield, biological and straw, respectively. There is the reduction of the harvest index in the years that were more effective for biomass production and grain, independent succession system. Therefore, the increase in grain yield in favorable years does not follow the same way the expression of the biological yield, leading to reduced harvest index by higher biomass straw. These results confirm in oat, in general, the biological yield and straw must show linear behavior and grain yield and harvest index with quadratic trend. The genetic differences edaphoclimatic conditions and different management in crops affect the use of nitrogen (Dencic et al., 2011; Viola et al., 2013).

The cultivation of cereals such as wheat and oats on the residue of soybeans and corn as a fore crops, show different development, mainly by differences in N-residual availability and their interaction with the nitrogen supplied in coverage (Wendling et al., 2007; Mantai et al., 2015). Studies with oat in different succession systems indicated a greater magnitude of alteration in the biological yield and grain than on income of straw and harvest index (Schaedler et al., 2009; Silva et al., 2015). Moreover, the quadratic trend in the expression of grain yield and oat harvest index has been observed (Mantai et al., 2015; Silva et al., 2015).

The cultivation soybean/wheat or soybean/oat crop succession compared to corn/wheat crop succession increased grain yield with the same fertilizer due to the greater availability of N-residual in favorable years (Bredemeier et al., 2013; Mantai et al., 2015). It is noteworthy that the set of favorable year effect (2011)

Table 1. Summary of variance analysis of N-fertilizer on the yield indicators of oat cultivars and of mean comparison between cultivation years in biosystems of high and reduced of N-residual release.

Source of variation	DF	Mean Square – Physiologic parameters			
		GY (kg ha^{-1})	BY (kg ha^{-1})	SY (kg ha^{-1})	HI (kg kg^{-1})
		Soybean/oat system			
		2011			
Block	3	44194	182552	152819	0.00038
Dose (D)	3	1352671*	5715876*	3681997*	0.00672*
Cultivar (C)	1	1303305*	212063^{ns}	463925^{ns}	0.00845*
D x G	3	225638*	1946987*	1128018*	0.00111*
Error	21	29097	244796	154992	0.00012
CV (%)		7.81	11.89	10.54	6.29
Mean		3621 ^{a}	10725 ^{a}	7104 ^{a}	0.33 ^{b}
		2012			
Block	3	27547	9658	28167	0.00035
Dose (D)	3	345496*	10229110*	9124200*	0.01989*
Cultivar (C)	1	220^{ns}	361675^{ns}	343827^{ns}	0.00015^{ns}
D x G	3	29279*	1323114*	994165*	0.00111*
Error	21	18421	128323	76005	0.00019
CV (%)		6.74	8.62	6.38	5.43
Mean		2920 ^{b}	7368 ^{b}	4447 ^{b}	0.40 ^{a}
		Corn/oat system			
		2011			
Block	3	64143	541745	245360	0.00006
Dose (D)	3	1468904*	13310303*	6722848*	0.00388*
Cultivar (C)	1	21218^{ns}	4166662*	4781005*	0.01445*
D x G	3	128645*	2708766*	1729137*	0.00096*
Error	21	17827	179581	111029	0.00014
CV (%)		9.12	12.47	9.49	7.82
Mean		2606 ^{a}	7735 ^{a}	5129 ^{a}	0.34 ^{b}
		2012			
Block	3	41989	342191	161748	0.00014
Dose (D)	3	4683712*	26277787*	9589247*	0.01212*
Cultivar (C)	1	1060332*	3603270*	8571870*	0.08303*
D x G	3	36261*	524507*	385751*	0.00183*
Error	21	8481	104874	81369	0.0002
CV (%)		8. 64	10.08	13.85	9.87
Mean		2403 ^{b}	6464 ^{b}	4050 ^{b}	0.37 ^{a}

* = Significant at the 5% level of probability the test F; ^{ns} = not significant; Means followed by the same letter in the column in the culture system does not differ between the years by Tukey model in 5% probability of error; CV = coefficient of variation; DF = Degrees of freedom; GY = grain yield; BY = biological yield; SY = Straw yield; HI = Harvest index.

with the N-residual biosystem greater release (soybean/oat) allowed increasing grain yield around 3.6 t per ha^{-1} (Table 1). Years of favorable and unfavorable climate change to nitrogen availability and use of efficiency by the plant (Espindula et al., 2010). Benin et al. (2012), observed in wheat greater response to grain yield by nitrogen when the rains were not limiting. The strong variation of grain yield is associated with greater variability of cultivation conditions, and the agricultural year being the largest contributing factor to the instability of production (Storck et al., 2014). This conditions support the use of more productive cultivars, tolerant to stresses and efficient in the use of light and nutrients (Araus et al., 2008; Oliveira et al., 2011).

The genotype *versus* nitrogen dose interaction tested in biosystems signal the breakdown of equations for each genotype in both the favorable and unfavorable cultivation years. In Table 3, the soybean/oat crop succession system, the Barbarasul genotype showed grain yield of expression and harvest index with quadratic

Table 2. Temperature and precipitation data in the months and years of oat cultivation.

Year	Month	Temperature (ºC)			Precipitation (mm)		Class
		Minimum	Maximum	Mean	Mean 25 year*	Occurred	
2011	May	10.5	22.7	16.6	149.7	100.5	FY
	June	7.9	18.4	13.15	162.5	191	
	July	8.3	19.2	13.75	135.1	200.8	
	August	9.3	20.4	14.85	138.2	223.8	
	September	9.5	23.7	16.6	167.4	46.5	
	October	12.2	25.1	18.65	156.5	211.3	
	Total	-	-	-	909.4	973.9	
2012	May	11.1	24.5	17.8	149.7	20.3	UY
	June	9.3	20.7	14.5	162.5	59.4	
	July	7.4	17.5	12.4	135.1	176.6	
	August	12.9	23.4	18.1	138.2	61.4	
	September	12.0	23	17.5	167.4	194.6	
	October	15.0	25.5	20.2	156.5	286.6	
	Total	-	-	-	909.4	798.9	

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

Table 3. Regression equation and significance parameters to estimate the optimal dose of nitrogen in the simulation of the physiological characters in the production of soybean/oat system.

Variable	Mean square	Equation ($Y=b0\pm b1x\pm b2x^2$)	P (b_i)	R^2	N/MTE (kg ha^{-1})	Y_E
		Barbarasul 2011 (FY)				
GY	1724526*	$2997 + 26.5x - 0.20x^2$	*	0.95	66	3875
BY	2154331*	$10210 + 8.27x$	ns	0.92		10210
SY	1703510*	$7210 - 18.10x + 0.20x^2$	*	0.99		6887
HI	0.01520*	$0.29 + 0.002x - 0.000019x^2$	*	0.04		0.34
		2012 (UY)				
GY	192484*	$2668 + 11.05x - 0.06x^2$	*	0.97	92	3176
BY	21562772*	$6101 + 26.16x$	*	0.86		8507
SY	17624335*	$3309 + 23.65x$	*	0.77		5485
HI	0.02103*	$0.40 + 0.0019x - 0.00002x^2$	*	0.99		0.4
		Brisasul 2011 (FY)				
GY	1746813*	$3202 + 30.44x - 0.20x^2$	*	0.84	76	4360
BY	17032950*	$9586 + 23.25x$	*	0.82		11353
SY	10835333*	$6010 + 18.54x$	*	0.98		7419
HI	0.003507*	$0.35 + 0.0008x - 0.000009x^2$	*	0.92		0.36
		2012 (UY)				
GY	501201*	$2636 + 15.34x - 0.11x^2$	*	0.79	70	3171
BY	8465599*	$6401 + 16.39x$	*	0.86		7548
SY	6935548*	$3565 + 14.83x$	*	0.91		4603
HI	0.005556*	$0.41 + 0.0008x - 0.00001x^2$	*	0.99		0.42

Y_E = Expected value from the ideal dose of N on grain yield; P(b_i) = Slope parameter of the trend line; * = Significance of the slope parameter to 5% of probability; R^2 = Coefficient of determination; N/MTE = Nitrogen dose for maximum technical efficiency of grain yield; GY = grain yield; BY= biological yield; SY = Straw yield; HI = Harvest index; FY = Favorable year; UY = Unfavorable year.

trend, and the biological yield linear behavior, independent of the agricultural year. Brisasul genotype cultivated after the soybean as a fore crop (Table 3) showed the same response of nitrogen in grain, biological yield and harvest index, in both years. It is noteworthy that, although the Barbarasul genotype indicate this system in unfavorable condition of growing a linear trend, similar to Brisasul in 2011 and 2012, the favorable agricultural year is revealed in straw yield as a quadratic trend. The results indicate quadratic behavior in grain yield and harvest index and the trend of linearity by biological yield, however, the interactions genotype *versus* favorable and unfavorable year seem to bring more dynamism to instability in straw yield.

The favorable year (2011) in soybean/oat crop succession in Barbarasul indicated maximum nitrogen use efficiency for grain yield with 66 kg ha^{-1}. In unfavorable year maximum, efficiency was obtained with 92 kg ha^{-1}, including, the grain yield reducing drastically compared to the previous year. In the simulation of biological yield, the difference between the years was intensified, primarily by strong change in straw yield (Table 3). It is noteworthy that the observed reduction in harvest index in the favorable year does not express the efficiency obtained for the productivity of grain due to lowest use of nitrogen in comparison with 2012.

Therefore, a condition reports inefficiency of these parameters to indicate more genotypes adjusted to reduced fertilizer in comparing crop years. In Brisasul cultivar, it showed the same management conditions (Table 3), but favorable and unfavorable cultivation year, the use of nitrogen to the maximum grain yield showed similar result with 76 and 70 kg ha^{-1} fertilizer. Furthermore, in the favorable year grain, biomass and straw yields of barbarasul cultivar increased.

Therefore, identifying the brisasul behavior of higher agronomic efficiency to the preparation of both biomass and grain was reported. This fact is evidenced in the more restrictive cultivation year, because, it showed similarity in grain yield, why the use of nitrogen by Barbarasul demanded an increase by 20 kg per hectare. This is in agreement with the results obtained in the adjusted model for simulating the harvest index. The use of the optimal dose, confirms the higher grain yield efficiency of this cultivar, independent of the agricultural year. Besides genetic efficiency of each cultivar, the largest nitrogen utilization is directly linked to environmental stimuli such as photoperiod, temperature, radiation and water availability (Almeida et al., 2011).

The use of harvest index while indicating the efficiency of the photo assimilates conversion for the production of straw and grains, but cannot identify cultivars more efficient, because an expressive grain yield also requires an appropriate minimum of expression of leaves and stems (Silva et al., 2015). Oliveira et al. (2011), comment the importance of detecting the genetic differences among cultivars in the production of straw and grains, because, confer gains that qualify economic performance and the benefits of high biomass are directed to the soil. Emphasizes on the viability of the tillage system is directly dependent on the volume and quality of biomass on soil (Silva et al., 2006). Schaedler et al. (2009), studying the genetic variability of yield indicators of oat, observed harvest index between 0.33 and 0.45. The results found by these authors, conforms with the result obtained in this study, that the use of optimal dose of nitrogen directed to grain yield is between 0.34 to 0.42.

In corn/oat crop succession system, the Barbarasul cultivar evidenced grain yield and harvest index quadratic, and the behavior of the biological yield and linear straw (Table 4). This behavior of indicators of oat production occurred during favorable or unfavorable condition year of cultivation. Therefore, showing adjusted results obtained on theses parameters. In Brisasul cultivar, in corn/oat crop succession system (Table 4), the use of nitrogen in the expression of grain yield and harvest index showed a quadratic behavior, independent of the year. On the other hand, the biological yield and straw indicated quadratic adjustment of expression in the year 2011 (favorable crop), but linearity observed in the more restrictive year (2012). These results evidenced that crop succession system slower the release of N-residual, part of the nitrogen applied as fertilizer has been used in microbial action in straw, especially in the favorable year, provided that the best volume and distribution of rainfall is observed (Figure 1 and Table 2), giving better benefit to the biological activity.

Thus, greater action of microorganisms in straw degradation leads to greater competition in nitrogen use, hypothesis which can elucidate the stability of nutrient absorption oats obtained by this system. Although, it has not been quantified, visible differences in degradation time straw in a year indicated in 2012, still in the oat harvest period, was observe volume of corn straw on the soil cover. Moreover, in 2011 (favorable year), the intensified degradation process did not permit visualization of straw after oats harvest. In general, independent of the year, the quadratic behavior in the expression of grain yield and harvest index was similar among cultivars and years of study, whereas differences of the year in corn/oat crop succession system major instability of the biological yield and straw (Table 4).

This similar condition was also obtained in soybean/oat crop succession system by instability of expression biomass straw (Table 3). The favorable year (2011) in corn/oat cropping succession system showed in Barbarasul maximum nitrogen use for grain yield with 96 kg ha^{-1}, with similarity when compared to unfavorable year with maximum use to 93 kg ha^{-1}. Although, the simulations using of the optimal dose in this cultivar, evidence similar expression to the grain yield, and favorable year indicated higher nitrogen contribution in the expression of biological yield and straw in relation with harvest index.

Table 4. Regression equation and significance parameters to estimate the optimal dose of nitrogen in the simulation of the physiological characters in the production of corn/oat system.

Variable	Mean square	Equation ($Y=b0\pm b1x\pm b2x^2$)	P (b_i)	R^2	N/MTE (kg ha^{-1})	Y_E
			Barbarasul 2011 (FY)			
GY	727753*	$1942 + 25.17x - 0.13x^2$	*	0.99	96	3160
BY	34905064*	$5627 + 33.28x$	*	0.99		8822
SY	19259724*	$3444 + 24.72x$	*	0.97		5817
HI	0.009118*	$0.35 + 0.002x - 0.000014x^2$	*	0.99		0.41
			2012 (UY)			
GY	1817920*	$1178 + 39.06x - 0.21x^2$	*	0.99	93	2994
BY	34526115*	$5061 + 33.10x$	*	0.87		8193
SY	12977790*	$3502 + 20.29x$	*	0.93		5389
HI	0.135586*	$0.26 + 0.002x - 0.000016x^2$	*	0.98		0.31
			Brisasul 2011 (FY)			
GY	1259308*	$2061 + 25.71x - 0.17x^2$	*	0.99	76	3033
BY	6027717*	$6635 + 62.45x - 0.38x^2$	*	0.97		9186
SY	1778050*	$4573 + 36.74x - 0.20x^2$	*	0.95		6210
HI	0.001755*	$0.30 + 0.00076x - 0.000006x^2$	*	0.88		0.32
			2012 (UY)			
GY	1758868*	$1560 + 38.42x - 0.20x^2$	*	0.95	96	3405
BY	35868825*	$4357 + 33.74x$	*	0.88		7759
SY	14087486*	$2423 + 21.14x$	*	0.89		4452
HI	0.020574*	$0.38 + 0.002x - 0.00002x^2$	*	0.96		0.39

Y_E = Expected value from the ideal dose of N on grain yield; P(b_i) = Slope parameter of the trend line; * = Significance of the slope parameter to 5% of probability; R^2 = Coefficient of determination; N/MTE = Nitrogen dose for maximum technical efficiency of grain yield; GY = grain yield; BY = biological yield; SY = Straw yield; HI = Harvest index; FY = Favorable year; UY = Unfavorable year.

Therefore, different from what occurred in the soybean/oat cropping succession system, the release condition of the N-residual by corn showed higher harvest index in the favorable year than in the more restrictive condition. This happened because although the values of the total biomass and straw have been incremented, there was also an increase in grain yield when using optimal dose. In the analysis, the Brisasul cultivar slow release of the N-residual biosystem (Table 4) favoring the growth conditions in 2011 showed dose adjusted to maximum grain yield with 76 kg ha^{-1}. There is reduction in fertilizer in comparison with the Barbarasul cultivar in the same crop year.

In 2012, there was greater restriction on oat cultivation, although nitrogen consumption show similarity between the two cultivars, grain yield was maximized by Brisasul cultivar, confirming its potential as an ecologically being a more sustainable genotype by higher grain yield by less use of fertilizer. The simulation parameters of production in Brisasul cultivar using the optimal dose in grain yield showed in 2011 high biological yield and straw, including, results obtained in the same year of Barbarasul cultivar.

Similar behavior was also obtained in these variables both in condition of high release of N-residual (soybean/oat) and cultivars (Table 3). The biochemical composition of plant residues affect the nitrogen release rate contained in the straw and the use of N-fertilizer by the plants due to competition with soil microorganisms (Siqueira et al., 2010; Nascimento et al., 2012). Moreover, water deficiency hinders the process involved in the use of fertilizer and residual nitrogen, showing that nitrogen to grain yield and biomass can be considerably increased with adequate moisture in the soil (Cazetta et al., 2008).

In wheat, the best results of nitrogen fertilization were obtained with nitrogen doses ranging from 70 to 120 kg ha^{-1} (Espindula et al., 2010; Teixeira Filho et al., 2010). Kolchinski and Schuch (2003), found in oat grain yield nitrogen of 75 kg ha^{-1}. Mantai et al. (2015), studying the nitrogen use efficiency in oat showed a linear behavior on biomass production rate with the increment of fertilizer, condition not always accompanied by the highest grain yield by evidence quadratic behavior. It is noteworthy that oats biomass and grain yields tend to be favored by crop succession system of smaller C/N ratio, generating cost savings and less environmental pollution by nitrogen fertilizers (Silva et al., 2006).

Studies realized by Silva et al. (2015), showed that the use of the analysis of the yield indicators was decisive in the most sustainable management system suggesting changes in population density in oat.

Conclusions

The use of N-fertilizer in oats presented quadratic response of grain yield and harvest index, however, linear behavior in the biological yield and straw in soybean/oat and corn/oats crop succession systems were obtained. Changes of the response were caused by the biological yield, straw and also by year of favorable or unfavorable cultivation. The simulation of the optimal dose of nitrogen for grain yield confirmed higher efficiency of Brisasul cultivar in the expression of yield indicators.

Conflict of Interest

The authors have not declared any conflict of interest.

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