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Simulation of oat grain (*Avena sativa*) using its panicle components and nitrogen fertilizer

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Nitrogen fertilizer management modifies oat (*Avena sativa*) panicle components and its grain yield. The work aims to study the potential of the variables of oat (*A. sativa*) panicle with N-fertilizer, and to simulatate its grain yield using multiple linear regression in succession systems of high and reduced N-residual release. The study was done in 2013 and 2014. The experiment was done in a complete randomized block of 4×2 factorial design, with four replications. The treatments include: nitrogen fertilizer of four doses (0, 30, 60 and 120 kg ha^{-1}), oat (*A. sativa*) cultivars at two levels (Barbarasul and Brisasul) and succession system at two levels (soybean/oat (*A. sativa*) and corn/oat (*A. sativa*). The multiple linear models were efficient in the harvest index of panicle of soybean/oat (*A. sativa*) system, regardless of the dose evaluated. However, at high doses, the number of grain per panicle was included. In the corn/oat (*Avena sativa*) system, the harvest index of panicle, the number of grains and spikelets panicle were adjusted based on the model. The multiple linear regression efficiently simulates N-fertilizer to affect the grain yield of oat (*Avena sativa*) and one or more potential variables of panicle in the succession systems.

Key words: Inflorescence, succession system, stepwise, multiple linear regression.

INTRODUCTION

Oat (*Avena sativa*) is an excellent culture of diverse functions in agriculture: it is used in feed and food as source of protein and fiber (Crestani et al., 2012; Hawerroth et al., 2014). The grain yield of oat (*A. sativa*) is affected by genetic characteristics of the cultivars, environmtal conditions and the management technologies of oat (*A. sativa*) (Benin et al., 2012; Mantai et al., 2015). Flores et al. (2012) claimed that the

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management of nitrogen fertilizer in grasses is one of the technologies that can increase grain yield. Study conducted by Frey (1959) and Jat et al. (2015) has shown that the application of nitrogen fertilizer in oat (*Avena sativa*) led to a greater number of panicles and grains per panicle. Kolchinski and Schuch (2003) mention that this nutrient has a strong influence on the number of oat (*A. sativa*) grains that can be produced.

Research by Wang et al. (2009) showed that using different levels of fertilizer in oat (*Avena sativa*) increased the number of its spikelets, length and the panicle mass. Furthermore, nitrogen fertilizer use efficiency in this species was different based on the type of succession system (Mantai et al., 2015). This indicates the need for more efficient cultivars during the uptake and use of N-fertilizer on the conditions of N-residual harnessing by the type of vegetation cover (Nascimento et al., 2012). Silva et al. (2015) found that the amount of nitrogen fertilizer in the corn/wheat system exerted changes in the spike components. These authors observed that in soybean/wheat, the amount of nitrogen fertilizer led to changes in the spike length and number of fertile and sterile spikelets. That way, the relationship between inflorescence oat (*A. sativa*) components with the management of nitrogen fertilizer can lead to the construction of efficient simulation models in expectation of grain yield (Cover et al., 2011).

In the multiple linear regression models, it is possible to combine several factors to estimate grain yield (Chai et al., 2012; Dalchiavon et al., 2014; Godoy et al., 2015). Dalchiavon et al. (2012) estimate the grain yield of rice by multiple regressions, incorporating the total number of spikelets, fertile and infertile panicle. Leilah and Khateeb (2005) also used this model to predict the grain yield of wheat under drought conditions, selecting the variable mass of grains per spike, harvest index, biological yield, number of spikes per square meter and spike length. Godoy et al. (2015) analyzed soil attributes to explain the grain yield in rice with copper nutrients, nitrogen fertilizer, iron and acid phosphatase. Thus, the use of efficient models that integrate components of the plant and its management can contribute to the predictability of agricultural harvest and crop planning, as well as allowing productivity analysis in the survey of agro-livestock activity assurance programs.

The objective of this study is to define potential variables linked to oat (*Avena sativa*) panicle with the N-fertilizer, to simulate grain yield using multiple linear regression in succession systems of high and reduced N-residual release.

MATERIALS AND METHODS

The study was done in a field in 2013 and 2014 in Augusto Pestana City, RS, Brazil (28°26'30' 'South latitude and 54°00'58'' West longitude). The soil of the experimental area is classified as Distrofic Red Latosol, and the climate of the region, according to Köppen classification (Kuinchtner and Buriol, 2001), is Cfa type, with hot summer without dry season. Ten days before sowing, soil analysis was performed and the following chemical characteristics of the local crops were identified: i) corn/oat (*Avena sativa*) succession systems (pH = 6.5; P = 34.4 mg dm^{-3}; K = 262 mg dm^{-3}; organic matter = 3.5%; Al = 0.0 cmolc dm^{-3}; Ca = 6.6 cmolc dm^{-3} e Mg = 3.4 cmolc dm^{-3}) and ii) soybean/oat (*Avena sativa*) succession systems (pH = 6.2; P = 33.9 mg dm^{-3}; K = 200 mg dm^{-3}; organic matter = 3.4%; Al = 0.0 cmolc dm^{-3}; Ca = 6.5 cmolc dm^{-3} e Mg = 2.5 cmolc dm^{-3}). In both experimental years, the oat (*A. sativa*) was sown at the ideal time, that is, in the first week of June with seeder-fertilizer. Each plot consisted of 5 rows of 5 m length and row spacing was 0.20 m, forming the experimental unit of 5 m^2. During the study, tebuconazole fungicide named commercial FOLICUR® CE at a dose of 0.75 L ha^{-1}. Moreover, the weed control was performed with metsulfuron-methyl herbicide was applied, at a dose of 2.4 g ha$^{-1,}$ and weeding was done when necessary. In the experiments, during sowing, 60 and 50 kg ha^{-1} of P_2O_5 and K_2O were applied, respectively, based on the levels of P and K in the soil on the expected grain yield of about 3 t ha^{-1}, plus nitrogen fertilizer of 10 kg ha^{-1} (except in the standard experimental unit). The remainder was applied based on the contemplation of using N-fertilizer on the phenological stage. This is indicated with the four expanded leaves, using urea (45% N).

The experimental design used was randomized complete block with four replications, based on a factorial scheme of 4 × 2 for the N fertilizer doses (0, 30, 60 and 120 kg ha^{-1}) and oat (*Avena sativa*) cultivars (Barbarasul and Brisasul), respectively. There was a total of 32 experimental units for the succession system of high and reduced condition N-residual in corn/oat (*Avena sativa*) and soybean/oat (*A. sativa*), respectively. The grain yields were obtained by cutting three central rows of each plot during harvest at maturity stage. The grain moisture was 18%. The plants were threshed with a stationary harvester and directed to the laboratory to correct the humidity of grain to 13%, and weighed to estimate grain yield (GY, kg ha^{-1}). In the analysis of the panicle components (Figure 1), there was a random collection of 20 oat (*A. sativa*) panicles per experimental unit. They were directed to the laboratory to correct the grain moisture to 13%, and subsequent decomposition of inflorescence components. The followings were measured: panicle length (PL, cm), number spikelet per panicle (NSP, n), number of grains per panicle (NGP, n), panicle mass (PM, g), grain mass of panicle (GMP, g) and harvest index of panicle (HIP, g g^{-1}) given by the ratio of the mass grain panicle by panicle mass.

To meet the assumptions of normality and homogeneity via *Bartlett* test, analysis of variance was conducted for the detection of the main effects and interaction. Although there was an evidence of interaction (data not presented), regression analysis was obtained by cropping year to confirm differences in nitrogen fertilizer absorption capacity for oat (*Avena sativa*) in favorable and unfavorable cropping years, and jointly (2013 + 2014) to estimate the optimal dose of nutrient independent of the cropping year. It is noteworthy that in the equations, the average effect among the cultivars was considered, because inferences were generalized about the species and not cultivars. Therefore, the data were submitted to variance analysis of regression for the definition of the polynomial equation $y = b_0 \pm b_1 x \pm b_2 x^2$ and its parameters. From this, based on the model $x = -b_1 / 2b_2$, the maximum level of technical efficiency of nitrogen fertilizer used by oat (*Avena sativa*) was estimated in the maximum grain yields expected. In addition, analysis of the average of panicle components was done using Scott & Knott's grouping method. The next step is to select the potential variables for the multiple linear regression models via *stepwise* technique. This procedure builds iteratively a regression models sequence for adding and removing variables, selecting the one with highest relationship with the main variable (y). In this

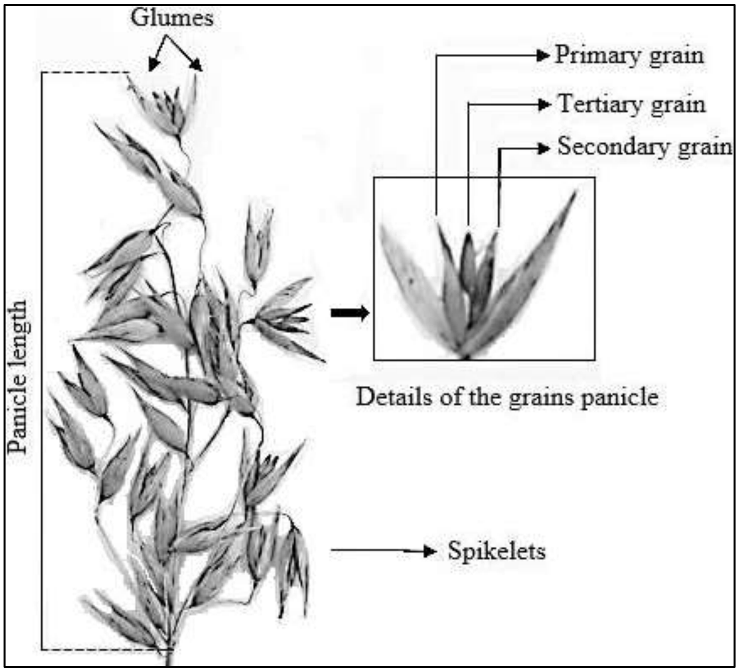

Figure 1. Inflorescence detail of oat (*Avena sativa*) type panicle.

study, it is represented by the grain yield, using the statistical partial *F* (Nunes et al., 2001), according to the model below:

$$F_j = \frac{SQ_R(\beta_j \mid \beta_1, \beta_o)}{MQ_E(x_j, x_1)} \quad (1)$$

Where SQ_R is the quadratic sum of regression and $MQ_E(x_j, x_1)$ is the average square error for the model containing the variables x_1 and x_j. The variables selected via *stepwise* were used to determine the multiple linear regression equation, which simulates the grain yield of oat (*Avena sativa*) from two or more variables,

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + \cdots + b_nx_n \quad (2)$$

Described in matrix form as,

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix}; \quad X = \begin{bmatrix} 1 & X_{11} & X_{21} & \cdots & X_{p1} \\ 1 & X_{21} & X_{22} & \cdots & X_{p2} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ 1 & X_{1n} & X_{2n} & \cdots & X_{pn} \end{bmatrix}; \quad \beta = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_n \end{bmatrix}; \quad \text{e} \quad \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix} \quad (3)$$

From these matrices, one obtains the value of the regression coefficients, being,

$$\hat{\beta} = (X'X)^{-1}X'Y \quad (4)$$

And the variance of the coefficients was obtained by covariance matrix of vector of the regression coefficients,

$$C\hat{o}v(\hat{\beta}) = (X'X)^{-1}\hat{\sigma}^2 \quad (5)$$

$$\hat{\sigma}^2 = \frac{(Y - X\hat{\beta})'(Y - X\hat{\beta})}{n - p - 1} \quad (6)$$

Being 'n' the number of equations and 'P' the number of parameters. The hypothesis testing is verified $H_0 : \beta_i = 0$ vs. $H_a : \beta_i \neq 0$ expressed by,

$$t = \frac{\hat{\beta}_i - \beta_i}{\sqrt{\hat{V}(\hat{\beta}_i)}} \quad (7)$$

The values of the optimal dose of nitrogen fertilizer were used in the multiple linear regression models. The average values of the oat (*A. sativa*) panicle components were validated by the *stepwise* technique, considering the combined effect of the year and cultivar. All analyses were performed using the Genes software versen 2005.5.0

RESULTS AND DISCUSSION

The analysis of variance, regression equation of grain yield of oat (*A sativa*) using N-fertilizer dose, the mean square of linear and quadratic equations were significant, regardless of the system and year of cultivation (Table 1). However, only the equation of degree two was employed to estimate the maximum technical nutrient use efficiency

Table 1. Summary of variance analysis the regression equation and its parameters with estimation of optimal nitrogen fertilizer dose and grain yield of oat (*A. sativa*).

Year	SV	MS (GY)	Equation: $GY=b_0 \pm b_1 x \pm b_2 x^2$	P (b_i)	R^2	N_{MTE} (Kg ha^{-1})	GY_{MTE} (Kg ha^{-1})
			Soybean/oat (*A. sativa*) system				
	L	508135*	3471.9 + 2.84 x	ns	0.13		
2013	Q	3471885*	3100 + 28.50 x - 0.21 x²	*	0.98	68	4067
	Error	55691	-	-	-		
	L	260018*	2814 + 2.03 x	ns	0.25		
2014	Q	657463*	2652 + 13.20 x - 0.09 x²	*	0.88	73	3136
	Error	21164	-	-	-		
			Corn/oat (*A. sativa*) system				
	L	2431152*	2281 + 6.21 x	*	0.55		
2013	Q	1950169*	2002 + 25.44 x - 0.15 x²	*	0.99	85	3080
	Error	34732	-	-	-		
	L	10162933*	1746 + 12.70 x	*	0.72		
2014	Q	3576696*	1369 + 38.74 x - 0.21 x²	*	0.98	92	3156
	Error	15006	-	-	-		

SV,source of variation; MS,means square; GY,grain yield; P(b_i) parameter what measures the significance of inclination; R^2,coefficient of determination; N_{MTE}= nitrogen fertilizer dose by the maximum technical efficiency; GY_{MTE},grain yield estimated by N_{MTE} (kg ha^{-1}); L,equation linear; Q,equation quadratic; *,Significant at 5% error probability by *F* or *t* test; ns,not significant.

for grain yield. In soybean/oat (*Avena sativa*) system, in 2013 (Table 1), the maximum technical efficiency of nitrogen fertilizer was obtained with 68 kg N ha^{-1}, in expectation of superior grain yield (4067 Kg ha^{-1}). In 2014, although the maximum technical efficiency is similar to that of 2013 with 73 kg N ha^{-1}, the maximum grain yield was around 3 t ha^{-1} (Table 1), indicating strong reduction of grain yield between the years of cultivation.

For the corn/oat (*A. sativa*) system (Table 1), regardless of the cropping year, the need for greater amount of nitrogen fertilizer was confirmed, mainly because it is a succession system in which the N-residual is less available. This way, the technical maximum efficiency in 2013 was obtained with 85 kg ha^{-1} in an expectancy of grain yield of around 3 t ha^{-1}. It is noteworthy that the grain yield in 2014 (3156 Kg ha^{-1}) is similar to that of 2013 (3080 Kg ha^{-1}), in this system; however, with greater need for nitrogen fertilizer use in 2014. The results obtained confirm the change of nitrogen fertilizer use efficiency for grain yield of oat (*A. sativa*) by the cropping year. It interacts directly with the succession system.

The changes in nitrogen fertilizer use efficiency in the cropping year are best justified by the analysis of Figure 2, which shows the information of rainfall and air temperature during the growing season. In the cropping year 2013, there was greater rainfall. This led to fertilization with N-fertilizer, resulting in more favorable soil moisture. Furthermore, throughout the cultivation cycle after fertilization, the volume and distribution of rainfall were also appropriate, favoring the development of the grain yield.

In Figure 2, the maximum temperatures observed at the beginning of the oat (*Avena sativa*) development (read time) proved superior in 2014; the condition stimulates faster elongation and reduces the incentive to produce new tillers, component directly related to the productivity of biomass and grain. From the fertilization, the variations in temperature did not show strong alteration to the point of harming the culture of oat (*A. sativa*). Therefore, the grain yield results (Table 1) together with weather conditions in the crop cycle (Figure 2) allow one to classify 2013 as a favorable year and 2014 as an unfavorable year in the cultivation of oat (*A. sativa*).

Nitrogen fertilizer is a nutrient that is more absorbed and exported by grasses, and has great effect on crop yields (Prando et al., 2013). The optimal dose of nitrogen fertilizer is dependent on the plant species, type soil, preceding crop, meteorological conditions and quality of fertilizer (Fontoura and Bayer, 2009; Prando et al., 2013; Silva et al., 2015). The conditions of cultivation mostly contribute to the variation of the grain yield (Storck et al., 2014). Mantai et al. (2015) observed that the influence of favorable or unfavorable year of cultivation generates instability in the grain yield of oat (*A. sativa*). Research conducted by Benin et al. (2012) observed higher response of the grain yield of wheat to nitrogen fertilizer when the rains were not limited. However, excessive rains in the grain filling stage may contribute to plant lodging, leading to losses in the productivity and quality of grains (Prando et al., 2013). The type of cultural residue determines the mineralization or immobilization of N-residual by modifying the dose adjustment and ideal season of N-fertilizer in the expression of grain yield components (Silva et al., 2015). Silva et al. (2012) have

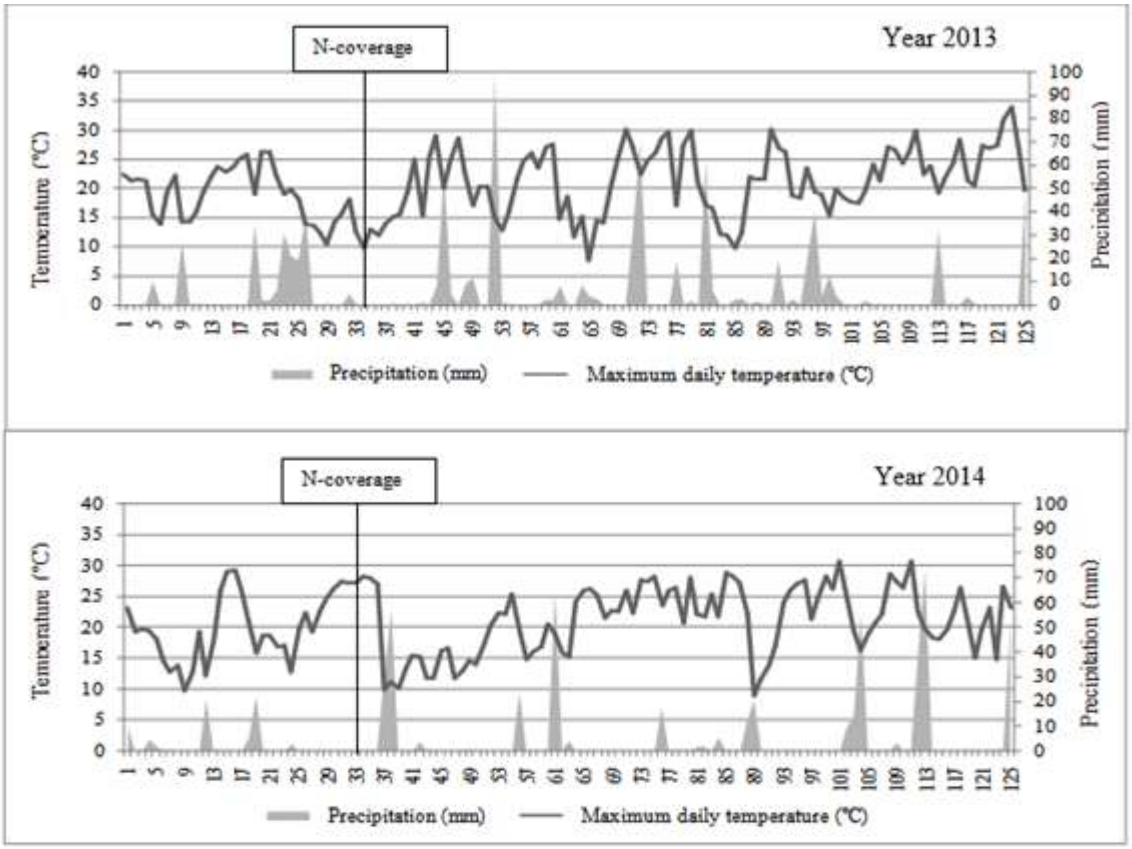

Figure 2. Rainfall and maximum temperature in oat (*A. sativa*) cycle.

shown that biomass yield and grain of oat (*A. sativa*) are favored by the succession system with low C/N ratio, reflecting in economic use of nitrogen fertilizers. Mantai et al. (2015) achieved maximum grain yield of oat (*A. sativa*) by using 70 and 96 kg nitrogen fertilizer ha^{-1} in soybean/oat (*A. sativa*) and corn/oat (*A. sativa*) succession system, respectively; this is similar to the results obtained in this study. Kolchinski and Schuch (2003) also had maximum grain yield of oat (*A. sativa*) in soybean/oat (*A. sativa*) using 70 kg N ha^{-1}.

Simulation of the grain yield per cropping year is not based on efficient models. Strong variation exists in the cultivation year by modifying the capacity of nitrogen fertilizer used for oat (*Avena sativa*). Therefore, the use of multiple linear regressions involving the cumulative effect of the variability between favorable and unfavorable year can ensure the development of coefficients that are more adjusted to the model. Table 2 shows the regression equations that describe the maximum technical efficiency of nitrogen fertilizer, along with the average effects of the components based on the inflorescence of oat (*A. sativa*) and joint analysis of favorable and unfavorable cultivation year.

In Table 2, in the joint analysis (2013 + 2014) of the soybean/oat (*A. sativa*) system, the optimal dose of nitrogen fertilizer (70 kg ha^{-1}) was obtained, with an estimate grain yield of 3.6 t ha^{-1}. For the corn/oat (*A. sativa*) system, the maximum efficiency (90 kg N ha^{-1}) was obtained with an expectation of 3.1 t of grain yield. The soybean/oat (*Avena sativa*) system afforded an increase grain yield higher than 500 kg ha^{-1} and with reduction of 20 kg ha^{-1} N-fertilizer. These results strengthen the benefits of soybean/oat (*A. sativa*) succession system by using N-residual. Another positive fact is the greater stability provided by soybean/oat (*A. sativa*) system on the panicle components, indicating that increase in N-fertilizer doses does not alter panicle length, grain mass of panicle, panicle mass and number of grain per panicle. The differences in this system were obtained only in the number of spikelets per panicle and the harvest index of panicle. In the corn/oat (*Avena sativa*) system (Table 2), the mean of panicle components showed no change when subjected to N-fertilizer, both at reduced or elevated dose of the nutrient; though the absence of the nutrient significantly reduces the expression of these variables. Overall, in the joint analysis of N-fertilizer doses (0 to 120), there was higher contribution of the averages of panicle components of oat (*Avena sativa*) in soybean/oat (*A. sativa*) and corn/oat (*A. sativa*) system (Table 2).

Silva et al. (2012) observed that the type of vegetable residue interferes in the elaboration of the components

Table 2. Summary of variance analysis the regression equation and its parameters with estimation optimal dose of nitrogen fertilizer and grain yield and average values of the panicle components by N-fertilizer doses in cropping systems.

Year	SV	MS (GY)	Equation $GY=b_0 \pm b_1 x \pm b_2 x^2$	P (b_i)	R^2	N_{MTE} ($kg\ ha^{-1}$)	GY_{MTE} ($kg\ ha^{-1}$)
Soybean/oat (*A.sativa*) system							
	L	747566*	3143 + 2.43 x	ns	0.17	-	-
(2013+2014)	Q	3575514*	$2876 + 20.84x - 0.15x^2$	*	0.99	70	3600
	Error	52985	-	-	-	-	-
Corn/oat (*A. sativa*) system							
	L	1126772*	2013 + 9.45 x	*	0.67	-	-
(2013+2014)	Q	5404487*	$1685 + 32.02x - 0.18x^2$	*	0.99	90	3110
	Error	61043	-	-	-	-	-

Variables panicle	Nitrogen fertilizer doses (2013+2014) 0	30	60	120	(0-120)
soybean/oat (*A. sativa*) system					
GMP (g)	2.06^A	2.04^A	2.15^A	2.05^A	2.07
PL (cm)	19.19^A	19.46^A	20.17^A	19.77^A	19.65
PM (g)	2.78^A	2.69^A	2.83^A	2.70^A	2.75
NSP (n)	41^B	40^B	45^A	45^A	43
NGP (n)	80^A	74^A	82^A	80^A	79
HIP ($g\ g^{-1}$)	0.74^B	0.76^A	0.76^A	0.76^A	0.76
Corn/oat (*A. sativa*) system					
GMP (g)	1.40^B	1.91^A	2.14^A	2.06^A	1.88
PL (cm)	17.54^B	19.10^A	19.02^A	19.68^A	18.83
PM (g)	1.99^B	2.61^A	2.79^A	2.72^A	2.53
NSP (n)	33^B	41^A	46^A	46^A	41
NGP (n)	59^B	75^A	84^A	83^A	75
HIP ($g\ g^{-1}$)	0.70^B	0.73^A	0.77^A	0.76^A	0.74

SV, source of variation; MS, mean squared; GY, grain yield; P (b_i), parameter what measures the significance of inclination; R^2, coefficient of determination; N_{MTE}, nitrogen fertilizer dose the maximum technical efficiency; GY_{MTE}, grain yield estimated by N_{MTE} ($kg\ ha^{-1}$); L, equation linear; Q, equation quadratic; GMP, grain mass of panicle; PL, panicle length; PM, panicle mass ; NSP, number of spikelets per panicle; NGP, number of grain per panicle; HIP= harvest index panicle (MGP/MP); *, Significant at 5% error probability by *F* or *t* test; ^{ns}, not significant. Means followed by same letter horizontally do not differ statistically each other at the level of 5% probability of error by Scott & Knott model.

linked to the panicle of oat (*A. sativa*) changing the grain yield. Freitas et al. (2012) state that the use of legumes for straw production is a favorable management; it increases the content and availability of nitrogen fertilizer in the soil for culture succession. Silva et al. (2014) found that the panicle mass of Sudan grass is the component that expresses highest variability in the panicle characters. In oat (*A. sativa*), Hartwig et al. (2006) concluded that the panicle mass increment is based on the increased number of grain per panicle, with little effect of the grain mass of panicle. Silva et al. (2015) observed that the mass of spike and number of grains per spike of wheat are the components that showed the greatest change on the inflorescence.

In the indication of potentials variables for inclusion in the multiple model, Table 3 presents the significance of means square of the variables by *stepwise* technique, in individual condition per dose of N-fertilizer and joint analysis in the cropping systems. In the soybean/oat (*Avena sativa*) system, the harvest index of the panicle was qualified to compose the multiple linear regression equation in all doses of N-fertilizer tested. using the highest dose (120 kg N ha^{-1}), the inclusion of the number of grains per panicle was also appropriate. In the corn/oat (*A. sativa*) system, the harvest index of panicle proved to be adjusted for simulation by multiple regression in the absence of N-fertilizer use. On the other hand, 60 kg N ha^{-1} dose was used to identify the panicle mass and number of spikelets per panicle as the most adjusted.

The possible combination of the panicle components of oat (*A. sativa*) with N-fertilizer (Table 3) for the simulation of grain yield using multiple linear regression, and joint analysis (0-120) of the soybean/oat (*A. sativa*) system confirmed the harvest index of panicle with the N-fertilizer for multiple model composition. In corn/oat (*A. sativa*) system, the use of harvest index of panicle with the N-fertilizer has also been made viable; however, with the need to include the number of spikelets per panicle and

Table 3. Means square values in identifying of potentials variables by *stepwise* technique for use in the multiple regression model.

Source of variation	Means square/*stepwise* (2013+2014)				
	0	30	60	120	(0-120)
Soybean/oat (*A. sativa*) system					
Regression	557125*	759972*	2352557*	588907*	2630021*
GMP (g)	ns	ns	ns	ns	ns
PL (cm)	ns	ns	ns	ns	ns
PM (g)	ns	ns	ns	ns	ns
NSP (n)	ns	ns	ns	ns	ns
NGP (n)	ns	ns	ns	509250*	ns
HIP (g g^{-1})	298524*	1487783*	3694273*	491476*	3568478*
N (kg ha^{-1})	-	-	-	-	887438*
Error	29662	42351	97355	49113	138872
Corn/oat (*A. sativa*) system					
Regression	995688*	ns	119449*	ns	3179631*
GMP (g)	ns	-	ns	-	ns
PL (cm)	ns	-	ns	-	ns
PM (g)	ns	-	116673*	-	ns
NSP (n)	ns	-	245820*	-	395156*
NGP (n)	ns	-	ns	-	1353118*
HIP (g g^{-1})	1145125*	-	ns	-	2029257*
N (kg ha^{-1})	-	-	-	-	3303315*
Error	28064	-	10070	-	97524

GMP, grain mass of panicle; PL,panicle length; PM, panicle mass; NSP, number of spikelets per panicle; NGP, number of grain per panicle; HIP, harvest index of panicle (MGP/PM); N, dose of nitrogen fertilizer; *,Significant at 5% error probability by *F* test; ^{ns,}not significant.

number of grain per panicle (Table 3).

The verification of components is essential; it estimates significantly the grain yield of crop by management techniques (Leal et al., 2015). Balbinot et al. (2005) comment that the use of *stepwise* technique allows the selection of potential components for simulation using multiple linear regression. In studying corn, these authors defined the spike mass components, number of grains per row, number of row per spike and number of spikes and plant per area as the most appropriate in the simulation of grain yield. For rice, Dalchiavon et al. (2012) used this technique by selecting the number of panicles, panicle mass, number of spikelets per panicle and thousand grain mass using the multiple model composition for simulation of grain yield.

Table 4 presented the linear multiple regression equations used for simulation of grain yield per nitrogen fertilizer and the combination of the fertilizer. Potential variables of panicle were used; they were selected by the *stepwise* technique (Table 3). The nitrogen fertilizer dose obtained by the technical maximum efficiency was considered and the average values of the panicle components were determined by joint analysis (2013 + 2014) (Table 2).

In both succession systems of soybean/oat (*A. sativa*) and corn/oat (*A. sativa*)), the grain yield estimated was near the grain yield observed, including within the confidence interval set for reliability of the equation (Table 4). In the system with low C/N ratio (soybean/oat (*A. sativa*), the model proposed denoted by $GY = -1075 + 2719.7\,HIP + 2.7\,N$ proved efficient in the estimation of grain yield. It presented a small grain yield difference of 34 kg ha^{-1} between the actual value and that predicted. In the succession system with high C/N ratio (corn/oat (*A. sativa*), the model $GY = -181 + 1859.7\,HIP + 27.2\,NGP - 33.7\,NSP + 6.8\,N$ was also effective, with differences between the value estimated. Grain yield of 45 kg ha^{-1} (Table 4) was obtained. The use of multiple linear equation allows one to compose in the model the panicle components and the management conditions of N-fertilizer, decisive factors for simulation of the main variable. This gives credibility to the simulation of grain yield of oat (*A. sativa*) with practicality and efficiency.

The utilization of multiple linear regression has been widely used in various vegetal species; it provides important information for culture, mainly grain yield allied with the most influential traits for species; examples are oat (*A. sativa*) (Chai et al., 2012), wheat (Leilah and Al-Khateeb, 2005), rice (Dalchiavon et al., 2012; Godoy et al., 2015), corn (Balbinot et al., 2005), soybean (Merchant et al., 2010), beans (Bonfim-Silva et al., 2014),

Table 4. Multiple linear regression to estimative grain yield per panicle components and nitrogen fertilizer doses in cropping systems.

Variable GY/ N	Equation	GY_E	GY_O	CI_{LL}	CI_{UL}
	soybean/oat (*A. sativa*) system				
GY/0	GY = 1320 + 2031.8 HIP	2864	2873	2691	3032
GY/30	GY = 1525 + 2454.3 HIP	3366	3377	3163	3564
GY/60	GY = 298 + 4370.2 HIP	3576	3587	3224	3906
GY/120	GY = 3245 + 1429.9 HIP – 13.4 NGP	3242	3245	3018	3446
GY/(0-120)	GY = 1075 + 2719.7HIP + 2.7N	3304	3270	3135	3397
	Corn/oat (*A. sativa*) system				
GY/0	GY = 149 + 2117.3 HIP	1673	1665	1437	1865
GY/30	-	-	-	-	-
GY/60	GY = 3774 + 451.4 PM - 45.7 NSP	2917	2915	2812	3005
GY/120	-	-	-	-	-
GY/(0-120)	GY = - 181 + 1859.7 HIP + 27.2 NGP -3 3.7 NSP + 6.8 N	2465	2510	2353	2656

GY, grain yield (g); HIP, harvest index of panicle (g g^{-1}); NGP, number of grains per panicle (n); PM, panicle mass (g); NSP, number of spikelets per panicle (n); N, dose of nitrogen fertilizer (kg ha^{-1}); GY_E, estimated grain yield; GY_O, grain yield observed; CI_{LL}, lower limit of the confidence interval; CI_{UL}, upper limit of the confidence interval.

among others.

Conclusion

In soybean/oat (*Avena sativa*) system, the harvest index of panicle is efficient to compose the multiple regression linear model, regardless of the amount of nitrogen; but in high doses, the number of grain per panicle is included. In the corn/oat (*Avena sativa*) system, the panicle harvest index, the number of grains and spikelets panicle are adjusted to compose the multiple linear model. The use of multiple linear regression is efficient in the simulation of oat (*Avena sativa*) grain yield with the use of N-fertilizer and panicle components selected by stepwise technique.

Conflict of Interests

The authors have not declared any conflict of interests.

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