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*Full Length Research Paper*

# Nitrogen fertilization applied through drip fertigation and broadcasted in blueberry crop

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**The aim of this experiment was to evaluate the effects of nitrogen fertilization on the blueberry crop throughout three consecutive years with different rates and ways of fertilizer application. The experiment was carried out in a commercial orchard located at the county of Vacaria-RS, in Southern Brazil utilizing the blueberry cultivar 'Bluecrop'. The treatments consisted of the broadcasted nitrogen rates: 0, 50, 100 and 150 kg.ha$^{-1}$ to verify the crop's responsiveness to nitrogen fertilization. Looking for the best way of evaluating nitrogen deliverance, a second experiment was conducted in which a fixed rate of 150 kg.ha$^{-1}$ of nitrogen was broadcasted and applied through fertigation. The nitrogen sources used in both fertilization systems were a mixture of half urea and half ammonium sulphate. Crop yield, number of fruits per plant and mean fruit weight were evaluated during three consecutive years, along with the levels of nutrients in the soil and leaf tissue after three years of broadcasted fertilization. The broadcasted nitrogen fertilization after three consecutive years reduced the soil pH and enhanced the aluminium saturation, but it increased the nitrogen and sulphur uptake by the leaves and reduced the leaves calcium content. These aspects led to a yield reduction of the blueberry crop. Weather conditions affected the efficiency of the N application method (broadcasted or fertigated).**

**Key words:** Nitrogen fertilization, soil pH, *Vaccinium corymbosum*.

## INTRODUCTION

Berry crops cultivation, which are fruits traditionally cultivated in temperate climate regions such as the EU and United States, is quickly gaining interest in Brazil. The main berries cultivated in Brazil are strawberries, raspberries, blackberries and blueberries (Fachinello et al., 2011), with strawberry most cultivated crop of the group (3500 ha), in Brazil, followed by blackberry (400 ha) and blueberry (200 ha) (Antunes and Hoffmann, 2012).

Blueberry crop is still recent in Brazil, but it has a great potential for expansion. The customers are increasingly demanding fruits with recognized beneficial health

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properties such as antioxidants and blueberry fruits meet this requirement. Another appeal for producers is the possibility to export the fruit during the EU's and USA's off season; these are motivating factors for the expansion of the crop, which has high revenues (Fachinello, 2008). However, more technical expertise on cropping systems and especially the suitability of nutritional aspects of the temperate climate regions of Southern Brazil is needed to facilitate further expansion of the crop in Brazil.

Blueberry crop has a distinct nutritional demand, wherein many cultural practices used in other fruit crops, are not suitable for blueberry production (Freire, 2006). This is related with the origin of blueberry plants, which is referred to low soil pH as well as the majority of the nutrients. Thus, blueberry crop requires low fertility, making its nutritional management quite specific and differentiated (Parra, 2007).

Nitrogen (N) is the most demanded nutrient by plants. On blueberry crop, it is fundamental in the vigour maintenance and it is responsible for the development of flower primordium and sprouting (Alarcon, 2003), but it has to be applied in ideal rates and at the correct moment, for an efficient absorption to avoid losses that may occur in several ways.

According to the Comissão de Química e Fertilidade do Solo RS/SC (2004), urea and ammonium sulphate along with ammonium nitrate are considered the main sources of nitrogen fertilizers. The same commission recommends that nitrogen fertilization for blueberry growth and production should be based on the plant's age; being recommended as reduced levels in the first year (10 g of N per plant); on the fifth year 30 g of N per plant and from the ninth year 60 g of N per plant.

The way blueberry orchards are fertilized varies in function of the amount of technologies available. Besides fertilizer broadcasting, blueberry fertigation is widely used through drip irrigation (Pagot, 2006), which delivers water directly to the root system, providing greater efficiency and easing the deliverance of soluble fertilizers to the system. Besides, fertigation makes easier the splitting of nitrogen levels, making possible nutrient supply accordingly to the crop's growth stage, and still reducing salinity stress (Spectrum Analytic, 2016).

Nitrogen fertilization management used nowadays in the blueberry crop aroused from other blueberry producing countries, with is completely different from edafoclimatic conditions. Thus, the present trial had the objectives of: (1) to evaluate the blueberry crop responsiveness to nitrogen fertilization; (2) to evaluate the best way of delivering the nitrogen fertilizer, if through broadcasting or fertigation.

## MATERIALS AND METHODS

The experiment was conducted in a commercial orchard belonging to the company Blueberry Mudas e Sementes Ltda, localized in the municipality of Vacaria/RS, with geographical coordinates: latitude S 28°26'30'' longitude W 50°56'35'' altitude of 907 m above sea level. The cultivar chosen for the experiment was 'Bluecrop', which has shown good adaptation to the local weather conditions. The experiment site's soil presented the following chemical characteristics: pH 4.8; SMP index 4.4; organic matter 11.6%; Ca 5.7 $comol_c.dm^{-3}$; Mg 2.0 $comol_c.dm^{-3}$; Al 1.7 $comol_c.dm^{-3}$; H+Al 27.4 $comol_c.dm^{-3}$; Effective Cation Exchange Capacity ($CTC_{effective}$) 10 $comol_c.dm^{-3}$; $CTC_{pH7}$ 35.7 $comol_c.dm^{-3}$; Al saturation 17%; bases saturation 23.1%; P 22.9 $mg.dm^{-3}$; S 28.7 $mg.dm^{-3}$; and K 220 $mg.dm^{-3}$.

It was conducted in two trials at the same site throughout three consecutive years, beginning from 2013 and replicated in 2014 and 2015.

Experiment with rates of N was conducted in a randomized complete block design (RCBD) with four replications. Each plot consisted of three plants, where an untreated control and the N rates of 50, 100 and 150 $kg.ha^{-1}$ were applied. For evaluating the effects of nitrogen (N) rates, the fertilizer was delivered through broadcasting, at the rates: 0, 50, 100 and 150 $kg.ha^{-1}$. The choice of the nitrogen rates was based on the maximum and minimum thresholds found in the literature, according to the plant's age (five years since the planting day).

The experiment compares the ways of delivering N fertilization; the experiment was conducted as RCBD with four replications of three plants per plot. It was used as a fixed rate of 150 $kg.ha^{-1}$ delivered though broadcasting and fertigation.

In both ways of fertilizer deliverance, the sources of nitrogen were urea and ammonium sulphate in equal proportions.

The momentum in which the fertilizers were applied was followed in two steps, with half of the levels in each moment. The first application was done at the floral gems opening and the second 30 days later (CQFS – RS/SC, 2004).

The variables evaluated in both experiments were: number of fruits per plant, yield per hectare ($kg/ha^{-1}$), and mean fruit weight (g). In the third year of experiment, soil and leaf samples for the experiment with N rates were collected.

Leaf samples were obtained by collecting 20 mature and fully expanded (including petiole) leaves localized in the fifth and sixth stem nodes, counting from the extremity of young fruitful branches of the three plants in each plot, in the month of January. For soil sampling, samples were collected in a depth of 0 to 20 cm with three sub-samples per replication in the same date of the leaf sampling. Both chemical analysis was executed by the Laboratório de Química e Fertilidade de Solos at the University of Caxias do Sul.

Looking for the attendance of the ANOVA assumptions, the test of normality of the data was performed using Shapiro-Wilk test. In the first experiment, the results were subjected to analysis of variance ($p \leq 0.05$) through a mixed model to test the interaction of years and rates of nitrogen, and in case of significance the effects of rates were compared using regression analysis ($p \leq 0.05$), and the effects of years through Tukey test ($p \leq 0.05$).

In the second experiment, the data were subjected to analysis of variance ($p \leq 0.05$) through a mixed model to test the interaction of years and treatments for the variables yield, fruit number per plant and mean fruit weight, and in case of significance the effects of the ways of fertilizer deliverance were compared through the t test ($p \leq 0.05$). In all the cases, software Sisvar v.5.6 was used for the statistical analysis.

## RESULTS AND DISCUSSION

### Effect of broadcasted nitrogen rates on the production parameters

Broadcasted nitrogen fertilization presented significant effect to the variables yield and fruit quality beginning at

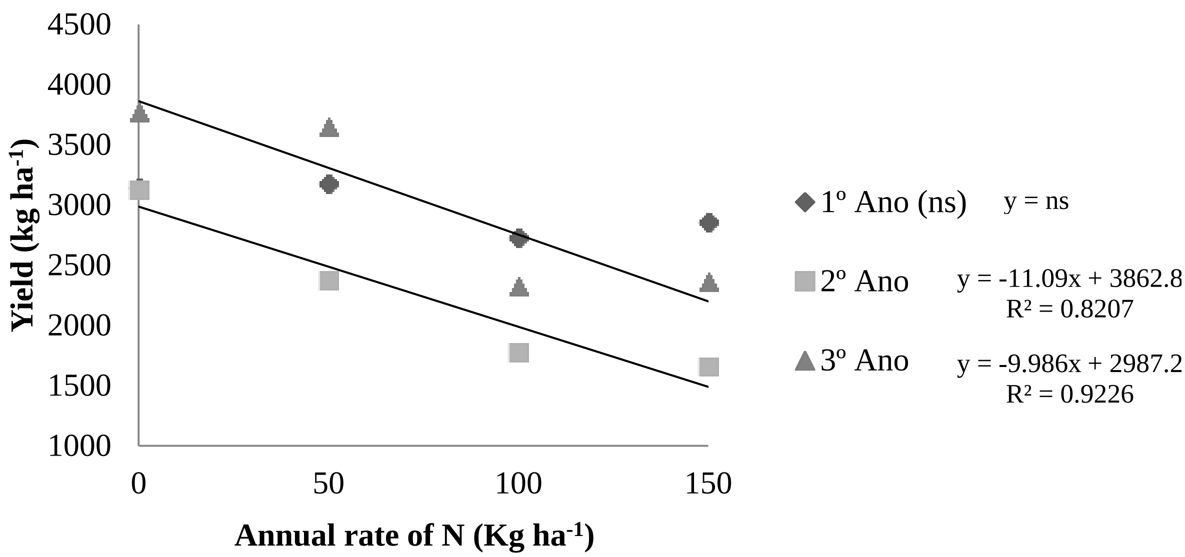


**Figure 1.** Blueberry fruit yield in function of broadcasted nitrogen rates over three consecutive years. Vacaria – RS, 2016. ns: Non significant by the F test ($p \leq 0.05$).

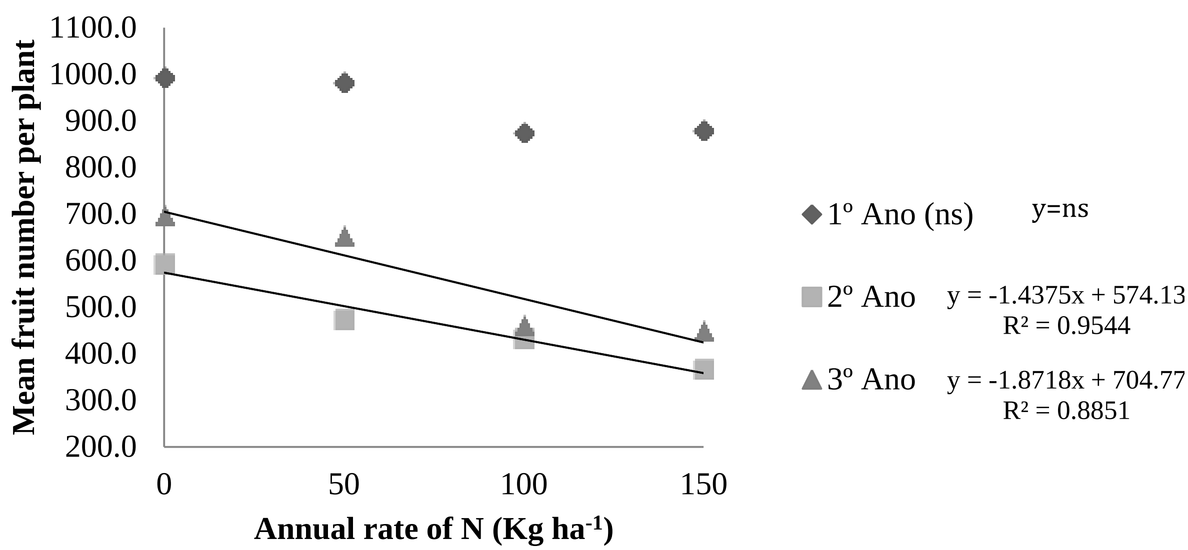


**Figure 2.** Mean blueberry fruit number per plant in function of broadcasted nitrogen rates applied over three consecutive years. Vacaria – RS, 2016. ns: Non significant by the F test ($p \leq 0.05$).

the second year of the experiment. Fruit yield decreased inversely proportional to the increment in nitrogen rate, as shown in Figure 1. The yield reduction was explained by the reduction in the number of fruits per plant (Figure 2), as well as the mean fruit weight (Figure 3). It is noteworthy that even with the mean fruit weight reduction, the results obtained in all the treatments for the second and third year are considered satisfactory for commercial standards, considering that the mean weight of an individual blueberry is 1.5 g (Carreira, 2012).

Previous studies with the cultivar 'Bluecrop', 'Mercik' and 'Smolark' (1995) recorded that nitrogen rates above 150 kg/ha$^{-1}$ reduced the yield, which confirms our results. In the present experiment, however, the yield reduction started from the lowest nitrogen rate tested, demonstrating a higher sensitivity of the crop to the environmental conditions. Hanson and Hancock (1996) stated that the nitrogen level itself does not interact with blueberry yield. However, many factors interact with nitrogen availability required by the plants such as soil type, plant age, genotype, weather, etc. According to Bañados (2006), recommendations of rates and timing of

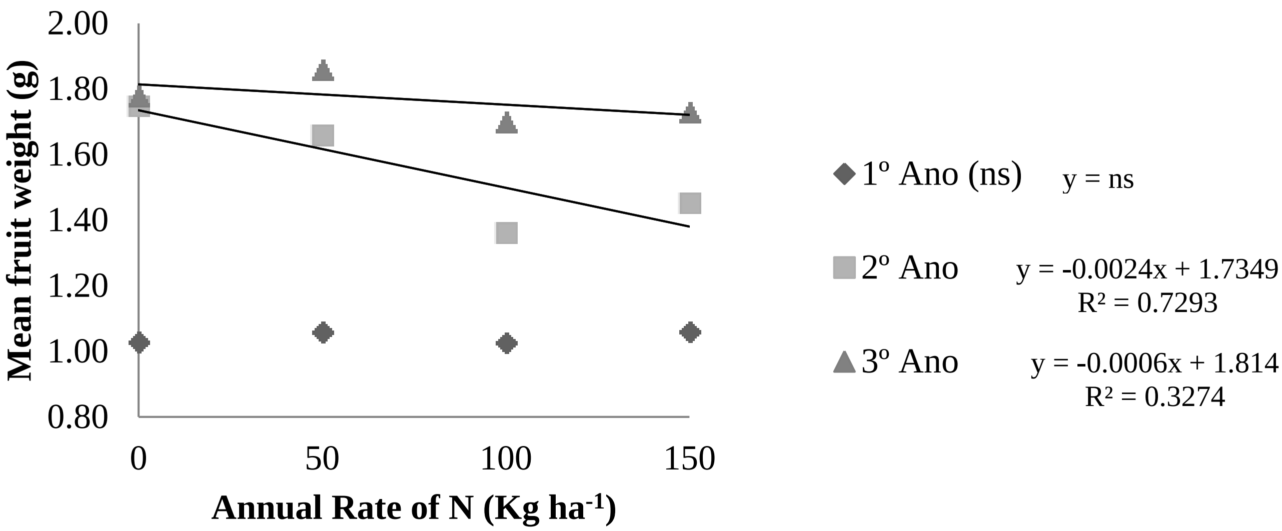


**Figure 3.** Mean blueberry fruit weight (g) in function of broadcasted nitrogen rates applied over three consecutive years. Vacaria – RS, 2016. ns: Non significant by the F test ($p \leq 0.05$).

**Table 1.** Interaction of treatment (nitrogen rates) in function of the years according to the F test.

| Treatment | Yield (kg ha$^{-1}$) | Mean fruit number | Mean fruit weight (g) |
|---|---|---|---|
| Nitrogen rates | ns | ** | ns |
| Years | *** | *** | *** |
| N. rates×Years | * | ** | ns |
| CV N. rates (%) | 22.19 | 8.10 | 25.10 |
| CV Years (%) | 6.31 | 7.49 | 17.61 |
| CV N. rates×Years (%) | 6.96 | 6.04 | 13.91 |

ns: Non significant; *Significant at ($p \leq 0.05$); **Significant at ($p \leq 0.01$); ***Significant at ($p \leq 0.001$). CV: Coefficient of variation.

application of nitrogen varies with location, that is, there is influence of edafoclimatic factors and so studies have to investigate the best fertilization method for each producing region.

On the interaction of years and the treatments, significant differences were observed for the cropping yield throughout the years (Table 1). There was fruit yield variation along the years, as the fruit bearing in the first and third years were similar and lower fruit bearing in the second year (Figure 1).

The plant fruit number was greater in the first year even though no significant difference among N rates were found, and on the following two years there was a sharp reduction on the number of fruits per plant (Figure 2). In this case, there was significant difference when the interaction of N rates was analysed as shown in Table 1.

The mean fruit weight had significant variation among the three years, and there was an increase for this variable from the first to the third year. According to Rufato (2015), some temperate climate fruit crops may produce smaller fruits in years with elevated fruit bearing, being recommended as the fruit thinning in extreme cases, aiming to balance yield and quality. It was observed in this experiment at the year with greater fruit number (first year) that the fruits had reduced mean weight.

The variation on the variables tested in this experiment, observed along the years, stands out the influence of the weather on the crop's response to N fertilization. According to Cantarella (2007), the N cycle in the soil-plant system is quite complex, and it is controlled by physical, chemical and biological factors, greatly controlled by the weather conditions.

### Effect of broadcasted nitrogen rates on the soil chemical parameters

In analysing the soil chemical condition, a reduction was observed on the pH levels with the rise of nitrogen rates, as shown in Figure 4A. In regards to the Al level, there was an enhancement in the soil levels, as shown in Figure 4B.

The reduction of the soil pH and the increment of the aluminium (Al) availability were reflected on the enhancement of the potential acidity (Figure 4G) and aluminium saturation (Figure 4H). According to Malavolta (2006), when the percentage of aluminium saturation surpasses 20%, it can be harmful for the crop and values above 45% are highly toxic for plants. The results obtained in this experiment demonstrated that only at the untreated control the Al saturation remained below 20%, while it reached 40% at the highest N rate tested (150 kg $ha^{-1}$). The increase in Al concentrations may account for the yield reduction noted at higher N rates.

Silveira et al. (2016) stated that in Southern Brazil a part of the blueberry orchards are presenting reduced growth rates or even plant death due to low soil pH and elevated levels of toxic Al, manganese (Mn) and iron (Fe), associated with poor or nonexistent mycorrhization for complexation of these metals, suggesting that a pH increase to 5.5 could soften these negative effects.

The levels of basic cations in the soil like calcium (Ca), magnesium (Mg) and potassium (K) presented effect in its concentrations being more elevated inversely proportional to the rates of N applied, as shown in Figure 4C, D, and E. The reduction in the levels of these nutrients resulted in a decrease of the soil bases saturation (Figure 4F).

This effect occurred through the reduction of the pH levels and elevation of the Al levels accordingly with the increment of the nitrogen rates negatively affecting the availability of other nutrients as explained by Malavolta and Cantarella (2007), where a usual nutrient interaction occurs with N and K as the uptake of one nutrient leading to the increment for the demand of the other nutrient, and the stimulus promoted to the plant by the supplementation of N may lead to the deficiency of K.

For the soil micronutrients, only boron (B) and Mn presented significant difference, with increasing levels as nitrogen rates were elevated. It is unlikely that B availability was affected by the treatments, as the majority of the available micronutrient is brought through the decomposition of the organic matter and conditions that favour its decomposition (Abreu et al., 2007). But the increment in the Mn levels is strictly related to the decrease of soil pH, observed on the treatments with elevated N rates. According to Lindsay (1972), the activity and consequently the availability of Mn in the soil solution enhances approximately 100 times per unit of pH decreased.

The levels of organic matter (OM), phosphorus (P), as well as the micronutrients zinc (Zn), cooper (Cu) and sodium (Na) did not show significant effect in function of the N rates tested.

## Effect of broadcasted nitrogen rates on the plant nutrient uptake and leaf tissue contents

The application of different rates of nitrogen significantly influenced the absorption of macro- and micronutrients, as evidenced by the leaf tissue analysis. There was an increment on the levels of nitrogen and sulfur that was attributed to the fertilization with ammonium sulfate, which contains sulfur (S) in its composition, and a reduction in the levels of Ca and the micronutrients B, Zn and Cu with the application of growing rates of nitrogen, as shown in Figure 5.

These calcium level responses in the leaf tissue may be accredited to the preeminent concentration of the other ions (Malavolta, 2006). The author states that high concentration of $NH^{4+}$ decrease the amount of uptaken calcium which might have occurred as a matter of the nitrogen rates elevation.

According to CQFS-RS/SC (2004), the concentration of N in the leaf tissue that are considered as normal for the blueberry crop are between the threshold of 18.0 to 21.0 mg/kg with the exception of the untreated control, which was below normal.

The macronutrients P, K and Mg did not present significant effect of leaf tissue levels when subjected to different rates of nitrogen ($p<0.05$).

## Effect of the ways of delivering nitrogen on the production parameters

In regards to the ways of delivering nitrogen (broadcasted or through fertigation), using the rate of 150 $kg.ha^{-1}$, no significant differences were found between the two ways, for the production variables: cropping yield, mean fruit number per plant and mean fruit weight in all years, as shown in Table 2.

In an experiment testing rates of nitrogen of 0, 50, 100, and 150 kg $ha^{-1}$, using urea through fertigation and broadcasted ammonium sulfate, Bryla and Machado (2011) found that the fertigation method is more effective than broadcasted application only for the more elevated rates of nitrogen, differently from this trial where no effect of N fertigation was found for the tested rate.

Differences were observed along the years for the same application method, which stands out the importance of weather conditions on the N fertilization. It is known that the dynamics of nutrients in the soil of crops grown in the field is dependant of the season's rainfall regime.

According to Yamada and Abdalla (2000), the nitrogen is a quite dynamic element in the soil and is susceptible to great losses, especially in the gas form, which may reach up 40% when applied without incorporation and associated to low rainfall.

Throughout the three years of the experiment, the rainfall regime that came about at the N fertilization application (September) until the end of the yield evaluations (December) yearly were elevated. The rainfall recorded in this period was 795, 718, and 999 mm, in 2013, 2014, and 2015, respectively (INMET,

**Table 2.** Blueberry production data as a function of the application of 150 Kg $ha^{-1}$ of N in broadcasting and fertigation. Vacaria – RS, 2016.

| Year | Yield/ha (kg)[1] | | No. of fruits/plant | | Mean fruit weight (g)[1] | |
|---|---|---|---|---|---|---|
| | Broadcasting | Fertigation | Broadcasting | Fertigation | Broadcasting | Fertigation |
| 1º | $2860^{ans}$ | $2746^{a}$ | $882^{ans}$ | $735^{a}$ | $1.06^{bns}$ | $1.22^{b}$ |
| 2º | $1663^{bns}$ | $1856^{a}$ | $368^{bns}$ | $428^{b}$ | $1.44^{ans}$ | $1.42^{ab}$ |
| 3º | $2141^{abns}$ | $2251^{a}$ | $428^{bns}$ | $455^{b}$ | $1.64^{ans}$ | $1.62^{a}$ |
| CV (%) | 3.10 | | 18.0 | | 22.05 | |

[1]Means submitted to logarithmic transformation (log (x)). Different lower case letters in the same column indicates the means are statistically different according to the Tukey test (p≤0.05). [ns]Means in the same line did not differ according to the F test (p≤0.05).

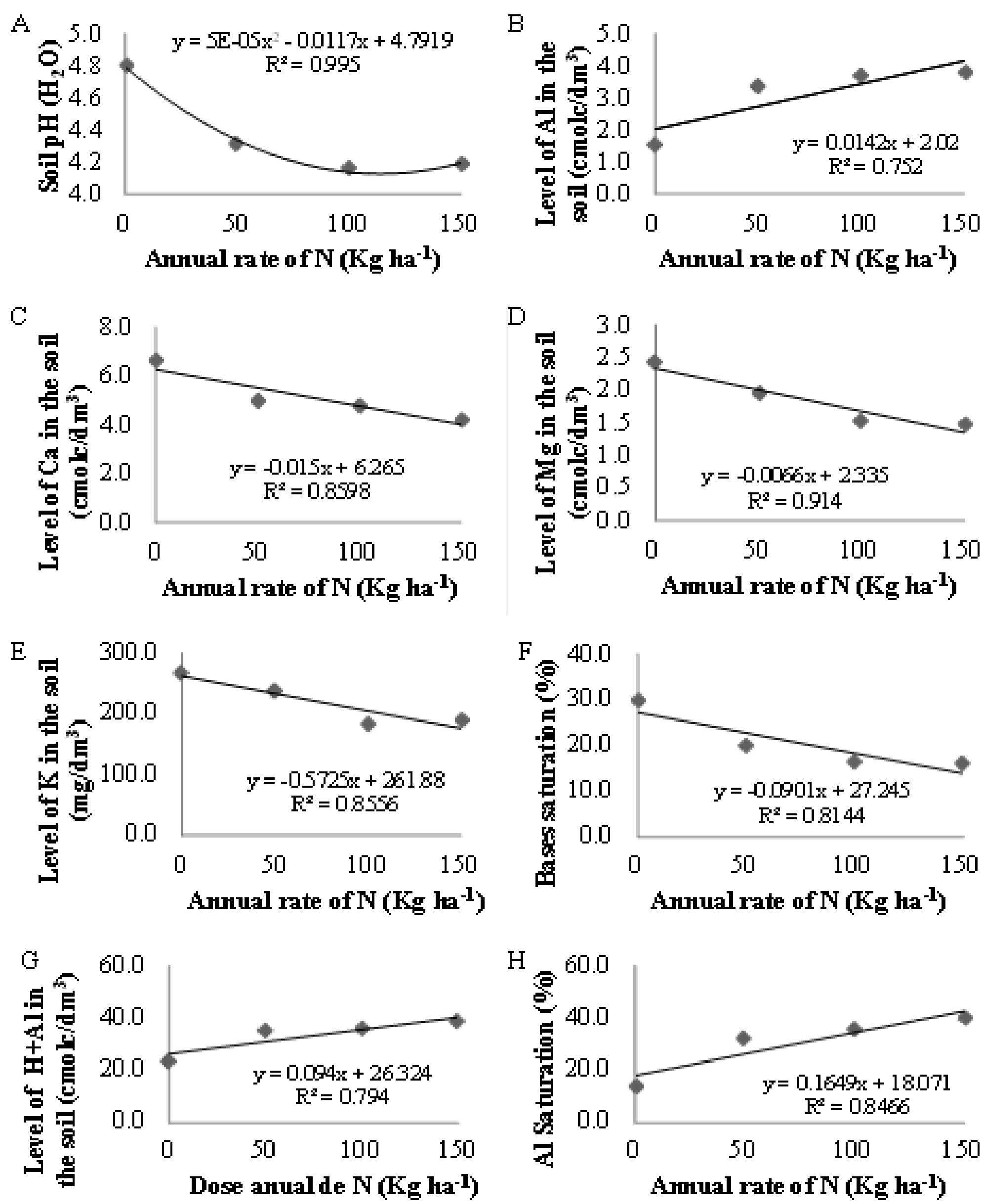


**Figure 4**. pH (A), level of Al (B), level of Ca (C), level of Mg (D), level of K (E), bases saturation (F), level of H+Al (G) and Al saturation (H) in the soil in function of broadcasted nitrogen rates applied on the blueberry crop. Vacaria – RS, 2016.

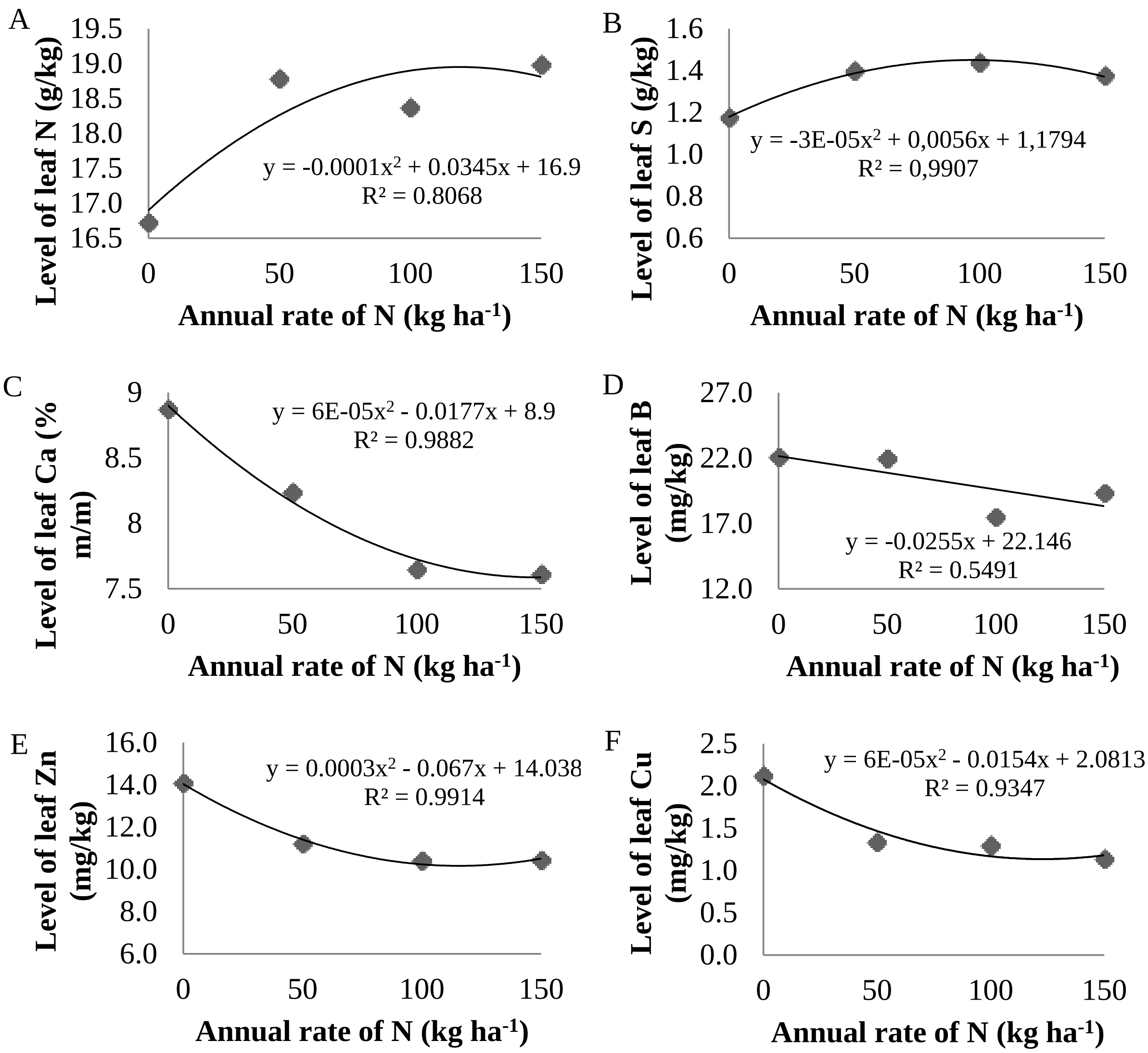


**Figure 5.** Level of leaf N (A), level of leaf S (B), level of leaf Ca (C), level of leaf B (D), level of leaf Zn (E) and level of leaf Cu (F), in function of broadcasted nitrogen rates in the blueberry crop. Vacaria – RS, 2016.

2017); moreover, the N applications took place in rainy days, and so it might have dwindled nitrogen losses and minimized possible effects of N fertigation.

## Conclusions

(1) Broadcasted nitrogen fertilization decreases blueberry cropping yield. The optimal fertilization, in broadcasting, for Southern Brazil would be between 0 and 50 kg N $ha^{-1}$.
(2) The application of broadcasted nitrogen in increasing rates over three consecutive years reduced soil pH and increased Al saturation in the soil.
(3) Nitrogen fertilization increased the blueberry plant absorption of nitrogen and sulphur and drastically reduced the absorption of calcium.
(4) Weather conditions affected the efficiency of the N application method (broadcasted or fertigated).

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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