Scientia Horticulturae 207 (2016) 1–6

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Contribution of nitrogen from urea applied at different rates and times on grapevine nutrition

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ARTICLE INFO

Article history:
Received 14 August 2015
Received in revised form 23 March 2016
Accepted 8 May 2016

Keywords:
^{15}N uptake
N derived from fertilizer
Plant N distribution
Residual soil N
Vitis vinifera

ABSTRACT

In Brazilian vineyards planted in sandy soils, nitrogen (N) should be applied at optimal rates and timing that correspond to greatest demand, thus minimizing N losses. The aim of this study was to evaluate the grapevine N distribution and recovery of urea-^{15}N applied at budding and bloom. In 2009, in a vineyard (*Vitis vinifera* cv. Cabernet Sauvignon) planted in Santana do Livramento, south Brazil, grapevines were treated with 10 kg N ha^{-1} at budding +10 kg N ha^{-1} at full bloom (10B + 10F); 20 kg N ha^{-1} at budding +20 kg N ha^{-1} at full bloom (20B + 20F); 20 kg N ha^{-1} at budding (20B); and 40 kg N ha^{-1} at full bloom (40F). Budding of grapevines in 2009 and 2010 was at the end of August and full bloom in November. In February 2010 and 2011, grapevine organs (leaves, berries, stem and roots) were collected, and in February 2011 soil samples were also collected in the profile. The wine-producing grapevines grown in the sandy soil took up more N derived from 20B treatment, compared with other N treatments, especially in the first crop season. The N derived from fertilizer applied at different rates and time was preferentially distributed in annual plant organs, but most N contained in the plant organs was derived from other sources than the fertilizer N. In the following season, ^{15}N applied in the previous year was recovered preferentially in leaves and fruits, again in low amounts. Nitrogen derived from fertilizer applied at different rates and time in a sandy soil apparently contributes little to grapevine nutrition.

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1. Introduction

Sandy soils planted with vineyards normally have low to medium organic matter content which gives them a low capacity for supplying grapevines with mineral nitrogen (N) (Brunetto et al., 2007). Therefore, some wine producers maintain legumes in the inter-row spacing to promote the sumbiotic fixation of atmospheric N_2. During decomposition of shoots of cover crops in the soil surface and roots below the surface, N contained in the plant tissue is released within the root zone of grapevines and is taken up in small amounts by these crops (Brunetto et al., 2011, 2014). However, usually grapevines show low levels of N in the leaves (<16 g N kg^{-1}) (CQFS-RS/SC, 2004). This may cause a decline in crop yield and negatively affect the composition of grape. Thus, the addition of a mineral N source such as urea has been recommended.

Application of urea on the soil surface, it is rapidly hydrolyzed by urease extracellular enzymes produced by microorganisms such as bacteria, actinobacteria and soil fungi and produces ammonium carbonate $(NH_4^+)_2CO_3$ which is not stable in the soil. In the presence of water it decomposes into HCO_3^-, OH^- and ammonium (NH_4^+). The HCO_3^- may then decompose into CO_2 and OH^-. If the NH_4^+ reacts with OH^-, a loss of NH_3 can occur to the atmosphere. However, part of NH_4^+ is transformed through biological oxidation into nitrite (NO_2^-) followed by nitrate (NO_3^-) which may be taken up

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http://dx.doi.org/10.1016/j.scienta.2016.05.002
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by plant roots or lost by leaching, especially in soils with a sandy texture (Barlow et al., 2009; Lorensini et al., 2012). However, the amount of N leached is especially dependent on the amount of N in the soil and the volume of rainfall (Nielsen et al., 1982; Hajrasuliha et al., 1998). A strategy for minimizing the NO_3^- leaching losses in the soil profile is to apply the fertilizer N at phenological stages with greater crop N demand (Conradie, 1990, 1991).

Literature shows contradicting results as to the most appropriate time for N application for grapevines production (Spayd et al., 1991). Some studies report that grapevines recover a satisfactory amount of N from fertilizer applied at the beginning of budding—this was shown by Conradie (1991) in South Africa, Löhnertz (1991) in Germany, Glad et al. (1994) in France, Araujo et al. (1995) in California, the United States and Brunetto et al. (2006b) in the south of Brazil. Most of these authors attribute this fact to mild temperatures and proper soil moisture at the end of winter which increases the activity of the microbial population in the soil and consequently the availability of mineral N in the soil. Also the emergence of active roots is greater at this time Brunetto et al. (2006b, 2014). However, Vos et al. (2004) in the United States and Schreiner and Scagel (2006) observed that grapevines recovered more N when fertilizer was applied from blooming to six weeks after blooming, in comparison with the application at the beginning of budding with a crop recovery of N greater than 20%.

Part of N taken up by the crop is incorporated into the carbonate structures, such as allantoin (4N:4C), arginine (4N:4C), and citrulline (3N:3C), or, moreover, in mineral forms, such as NH_4^+ and NO_3^- transported through the stem and branches older than one year to the vegetative organs with active cell division and consequently with a higher dry matter increase, such as leaves, shoots, and bunches (berries + rachis) (Glad et al., 1994). Part of accumulated N in the annual organs throughout the period of leaf senescence may be redistributed to the perennial organs, especially to roots and stem/trunk (Bates et al., 2002; Zapata et al., 2004; Brunetto et al., 2005, 2006a, 2014). For studies on N recovery and accumulation in organs of fruit-bearing plants like grapevines, ^{15}N isotope has been used as a tracer since it allows a precise monitoring of fertilizer N taken up by the crop and its distribution in the plant (Brunetto et al., 2006a,b; Menino et al., 2007; Neto et al., 2008).

The aim of this study was to evaluate the grapevine N distribution and recovery of urea-^{15}N applied at budding and bloom. We hypothesized that fertilizer N applied at blooming in the previous year is remobilized for vegetative and flowering organs in the following season, whereas N applied at budding is especially used in the current season.

2. Materials and methods

2.1. Description of the experiment

The experiment was conducted from September 2009 to February 2012 in a vineyard at Santana do Livramento, Rio Grande do Sul—Brazil (longitude 655321.09 m E; latitude 6593897.74 m S). The vineyard (*Vitis vinifera*) was the Cabernet Sauvigon cultivar grafted on SO4 (*Vitis berlandieri* × *Vitis riparia*) rootstock. Plant density per hectare was 3703 (1.0 m × 2.7 m) on a spur pruned cordon system. Climate in the region is subtropical humid, Cfa2 type, according to the Köppen classification and is characterized by mild temperature and rainfall with little variation throughout the year. Mean annual rainfall for a long period is 1600 mm; the mean temperature of the hottest month (January) is 23.8 °C and the mean temperature of the coldest month (July) is 12.4 °C. Data on mean monthly temperature and accumulated rainfall throughout the experimental period are shown in Table 1. The soil is a Typic Hapludalf and the chemical properties in the 0–0.20 m layer are shown in Table 2. Plants in the inter-rows spacing were desiccated with non-residual herbicide. In this inter-rows, a mixture of plants was cultivated, especially the *Paspalum notatum*, *Trifolium repens* and *Lolium perenne*.

Table 1
Mean monthly values of rainfall (mm), air temperature (°C), and air relative humidity (%RH) during the experimental period.

Year/Month	Phenological Stage	Rainfall (mm)	Air temperature (°C)	Air RH (%)
2009				
August	Begin of budbreak	45.3	14.2	77.9
September	Budbreak	269.4	13.3	86.6
October	End of budbreak	135.9	16.9	77.8
November	Begin of bloom	540.8	20.8	86.7
December	End of bloom	219.0	21.7	79.2
2010				
January	Veraison	204.1	23.4	77.3
February	Veraison	240.7	23.1	82.8
March	Harvest	58.9	21.8	79.9
April	Start falling leaves	132.0	17.1	78.8
May	falling leaves	133.4	14.3	86.7
June	falling leaves	33.7	12.1	84.0
July	End of falling leaves	295.3	10.9	80.9
August	Budbreak	53.3	11.6	78.5
September	Budbreak	182.6	14.4	81.2
October	End of budbreak	19.4	16.2	68.1
November	Begin of bloom	29.0	19.7	59.8
December	End of bloom	56.0	23.7	57.3
2011				
January	Veraison	61.6	25.0	70.3

Table 2
Main physical and chemical characteristics of the soil in the experimental site at 0 – 0.20 m soil layer.

Soil characteristics	Unit	0–0.20 m
Clay	g kg^{-1}	63
Silt	g kg^{-1}	115
Sand	g kg^{-1}	822
Organic matter	g kg^{-1}	15.0
Total N	mg kg^{-1}	2.300
$pH_{(H_2O)}$	–	6.00
Exchangeable aluminum		0.00
Exchangeable magnesium	$cmol_c$ kg^{-1}	0.80
Exchangeable calcium	$cmol_c$ kg^{-1}	1.75
Exchangeable potassium	mg kg^{-1}	50.0
Available phosphorus	mg kg^{-1}	40.0

In 2009, grapevines received the following four treatments: 10 kg N ha^{-1} at budding +10 kg N ha^{-1} at full bloom (10B + 10F); 20 kg N ha^{-1} at budding +20 kg N ha^{-1} at full bloom (20B + 20F); 20 kg N ha^{-1} at budding (20B); and 40 kg N ha^{-1} at full bloom (40F). Budding of grapevines in 2009 and 2010 was at the end of August, and full bloom in November. The N source was urea enriched with 3% ^{15}N atom excess. The urea was incorporated into the soil surface in the row, below the of grapevine canopy. In addition, five plants without ^{15}N application were used as control plants. The experimental design was under randomized blocks with five replications, with three central plants in each plot being used for measurements. The leaves of grapevines collected in the veraison contained (%): 0.90 N, 0.2 P, 2.0 K, Ca 1.5 and 0.4 Mg.

In February 2010 and 2011, eight bunches of grapes were collected randomly from each grapevine. Then, berries from the upper, middle and lower part of each bunch were separated and frozen in liquid N, dried in a freeze-dryer until constant weight, and reserved for testing. The eight rachis of bunches were also reserved for analysis. Afterwards, mature leaves were collected from the middle third of three shoots chosen at random in each plant. Leaves and rachis

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