

Interactions between the vine water status and differential effects of organic and inorganic nitrogen application on grapevine physiology

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Abstract

In organic vineyards, nitrogen (N) and water deficit frequently occur concomitantly, but their interactions are poorly explored. This work aims to evaluate the effects of organic and inorganic N applications on the physiology of grapevines subjected to progressive water stress. In potted vines, the following treatments were compared: i. no N application (T1); ii. soil application of 3g of N as NH_4NO_3^- (T2); foliar application of 3 g of N through protein hydrolysate (T3); combined soil application of 3g of N as NH_4NO_3^- and 3g of protein hydrolysate (T4). All vines were individually subjected to water deficit from day of year (DOY) 170 to the achievement of a pre-dawn water potential ($\text{pd}\Psi$) of -12 bars, and to a subsequent re-watering.

The primary shoot growth was significantly affected by both organic and inorganic N supplementation, with T1 showing lower shoot lengths than other treatments from DOY 157. At the end of the experiment, T2 and T4 had a significantly higher total vine leaf area than T1 (5531 and 5331 vs 2487 cm^2/vine), with T3 setting at intermediate levels. T1 achieved a $\text{pd}\Psi$ of -12 bars later (DOY192 on average) than the other treatments (DOY186 pooling T2, T3 and T4). Correlations between $\text{pd}\Psi$ and gas exchange parameters show that T2, T3 and T4 maintained higher leaf photosynthetic rates (A_N) at $\text{pd}\Psi < -4$ bars. At varying stomatal conductance (g_s), T2, T3 and T4 maintained a significantly higher leaf A_N than T1, especially for $g_s > 0.15 \text{ mol}/\text{m}^2/\text{s}$. T1 achieved stomatal closure at $\text{pd}\Psi \sim -7$ bars vs ~ -12 bars pooling T2, T3, and T4. At $\text{pd}\Psi > -0.4$ Bars, T2, T3 and T4 exhibited significantly higher leaf proline concentration than T1, but at the peak of stress no differences were found between treatments, while T1 leaves had higher H_2O_2 .

Data demonstrates that N availability significantly interacts with vine water consumption and tolerance to water deficit. Foliar application of the organic N in the form of protein hydrolysates showed positive effects like soil mineral N application, and additive doses had minimal impact. Our study demonstrated that in organic vineyards, N fertilization can be implemented using organic fertilizers with no technical differences compared to mineral fertilization.

Keywords: Biostimulants, organic viticulture, proline, physiology, nutrition

Introduction

Grapevine response to water stress is greatly affected by nitrogen availability. On one hand, nitrogen (N) supplementation results in increased vegetative growth, thereby increasing vine water needs. On the other hand, nitrogen supplementation allows the vine to synthesize and accumulate key metabolites such as proline that help manage the oxidative and salt stresses associated with water scarcity. In organic viticulture, only organic fertilizers and biostimulants are permitted. They present a significantly lower N concentration compared to mineral fertilizers, yet they guarantee null leaching towards water bodies. Our study therefore aims to focus on the interaction of water availability and nitrogen supplementation

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on the grapevine physiology of one year old vines. Our broad goal was to understand whether organic N fertilizers can be considered adequate candidates for the substitution of mineral N fertilizers in viticulture.

Material and Methods

The study was conducted on 36 potted 1 year old grapevines cv. Sangiovese that were divided into 4 treatments. T3 and T4 vines received three applications of a foliar biostimulant containing 7% organic N, for a total of 3 g N/plant. T2, and T4 received three soil fertilizations of ammonium nitrates containing 27% N, for a total of 3 g N/plant. T1 received no N application. The treatments were conducted on DOY 142,150, and 158. The vines were then water stressed to individually reach a predawn leaf water potential $pd\Psi$ of -12 bars. All vines were standardized to maintain 2 primary shoots; the lengths of the two primary shoots for every vine were recorded weekly and presented as the sum of the two shoot lengths. Leaf gas exchange parameters were measured every two days along with leaf water potential. Subsequently, the leaves were sampled and immediately frozen in liquid nitrogen. The leaf proline and hydrogen peroxide concentrations were later assessed by spectrophotometric analysis. At the end of the trial, the vines were extracted from the pots and were divided into root, trunk, cane, and leaves for dry weight measurements.

Results and Discussion

Vine vegetative growth was significantly affected by the treatments. At the end of the trial, the T3 and the T2 vines showed a higher shoot length than T1 (241.5 and 234.8 cm vs 159.6 cm). T3 vines maintained higher primary leaf area compared with T1, T2, and T4. However, T2 and T4 vines showed a higher total leaf area than T3 vines due to higher lateral shoots growth. The increments in vegetative growth in response to protein hydrolysate applications align with the observations reported by (Bavaresco et al., 2020). At the end of the trial, T1 vines showed a lower dry biomass than that of any other treatment in terms of main shoot leaves, main shoot canes, trunk and roots, while no differences were observed between T2, T3, and T4 vines. T2 and T4 vines showed a higher dry biomass of lateral canes than T3 vines (5.76 and 5.16g vs 2.78 g in T3). The enhanced vine biomass accumulation as a response to protein hydrolysates applications is corroborated by Meggio (et al., 2020).

The T2, T3, and T4 vines maintained higher rates of leaf photosynthesis (A_N) than T1 at leaf pre-dawn water potential ($pd\Psi$) < -4 bars. After rewatering, the treated vines maintained an average A_N of $13.71 \mu\text{mol m}^{-2} \text{s}^{-1}$ pooling T2, T3, and T4 compared to $9.84 \mu\text{mol m}^{-2} \text{s}^{-1}$ observed in T1. T1 achieved stomatal closure at an average leaf predawn water potential of -7.9 bars, while in T2, T3, and T4 this occurred at -12.3 bars, pooling the three treatments together (Figure 1).

T2, T3, and T4 vines maintained higher leaf proline concentrations at $pd\Psi > -4$ bar whereas, at the peak of the stress, no differences were observed between treatments whereas, the leaf H_2O_2 concentrations were significantly higher in T1 than T2, T3, and T4.

The average DOY of rewatering was 192 in T1 vines compared to the average rewatering DOY 186 pooling T2, T3, and T4. T1 vines reached the defined -12 bars later than treated vines due to an overall lower leaf area and consequently lower vine evapotranspiration requirements.

In conclusion, foliar applications of protein hydrolysates positively affect vegetative growth, and tolerance to water stress. Furthermore, the biostimulant treated vines showed a improved leaf gas exchange parameters than untreated vines, aligning with minerally fertilized vines. Our data suggests that under the context of organic production, the use of organic N in the form of protein hydrolysates can be a suitable alternative to mineral

fertilization to elicit drought resistance in vines with no negative drawbacks on vegetative growth.

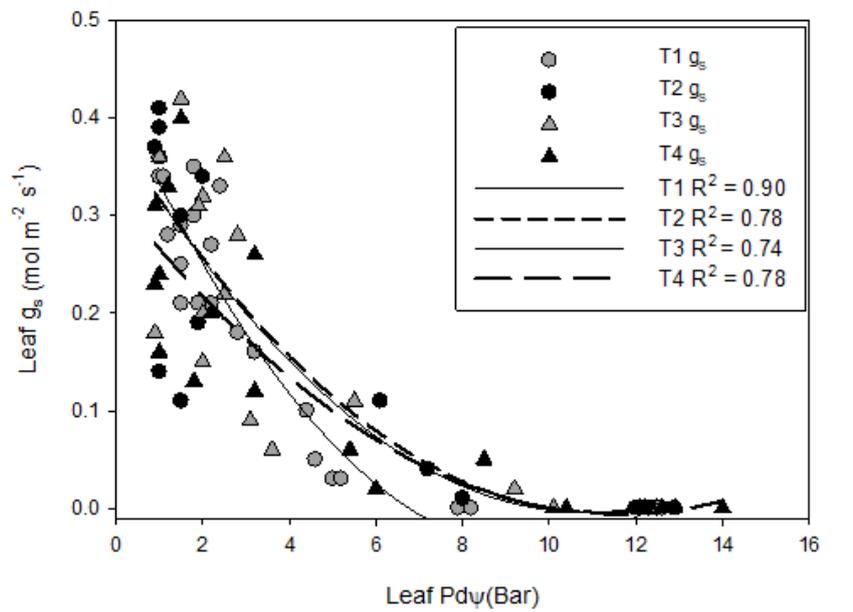


Figure 1: Seasonal evolution of leaf stomatal conductance (Leaf g_s) and leaf pre-dawn water potential ($pd\psi$) in potted grapevines cv. Sangiovese divided into four treatment groups - organic (foliar biostimulants: T3 and T4) and inorganic nitrogen supplementation (T2) and untreated vines (T1) and subjected to a progressive water stress to a predawn leaf water potential of -12 bars. T1: $f=18.47+(-9.16)*x+6.49*x^2$, $p < 0.05$, $R^2 = 0.90$; T2: $f=8.17+(-2.96) *x+1.79*x^2$, $p < 0.05$, $R^2 = 0.78$; T3: $f=6.87+(-2.72) *x+1.72*x^2$, $p < 0.05$, $R^2= 0.74$; T4: $f=9.28+(-3.71) *x+2.32*x^2$, $p<0.05$, $R^2= 0.78$.

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