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The Effects of Nitrogen Fertilization on Yield and Development in Alphonse Lavallée Grape (*Vitis vinifera* L.) Variety

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Abstract: This study was conducted in the Keçiborlu district of Isparta during the years 2021 and 2022 with the objective of ascertaining the effects of varying nitrogen (N) doses (0, 50, 100, 150, and 200 kg ha^{-1}) on the morphological characteristics and yield of the Alphonse Lavallée grape variety. The study was designed as a randomized block design, with three replications. The following parameters were examined: shoot length, internode length, berry width, berry length, cluster width, cluster length, cluster weight, weight of 100 berries, and yield. The study revealed that N doses had a statistically significant impact on all the characteristics that were examined. The findings of the two-year research study demonstrated that the increase in N doses up to 100 and 150 kg ha^{-1} resulted in an increase in various agronomic characteristics. These include an increase in shoot length, internode length, berry width, berry length, cluster width, cluster length, cluster weight, 100-berry weight, and yield. At higher doses, the measured characteristics either remained constant or decreased. The maximum yield was achieved at a N dose of 100 kg ha^{-1} in both years. The findings of this study suggest that a N dose of 100 kg ha^{-1} is the optimal level, with higher doses showing no additional benefits.

Keywords: Alphonse Lavallée, *Vitis vinifera* L., nitrogen fertilization, grape yield, vegetative growth

1. Introduction

Balanced and considered fertilization practices are crucial for increasing productivity and quality in viticulture. Nitrogen (N) is a macronutrient that directly affects shoot and leaf development, berry formation and yield in grapevines (Delgado et al., 2004; Conradie, 2005; Keller, 2020; Majidi and Doulati Baneh, 2020). As the most essential nutrient for plants, N influences grape and wine yield and quality depending on its concentration in the vine-soil system. Nitrogen deficiency significantly limits vine vigor from bud break to flowering, whereas excess N stimulates vine vigor, resulting in reduced grape yield and quality (Conradie, 2005; Ferrara et al., 2018). Therefore, determining the optimal N dose required by grapevines is critical for sustainable viticulture. Sustainable grapevine cultivation requires careful fertilizer use, particularly of N, to produce high-yielding, high-quality grapes.

In recent years, yield increases resulting from N fertilization have slowed in developed and developing countries (Bohlool et al., 1992), resulting in increased interest in reducing N fertilizer use (Ferrara et al., 2018). Ensuring the efficient use of N in grapevines enhances environmental and economic sustainability in grape production (Zhang et al., 2015).

Numerous studies have investigated the effects of N in viticulture and demonstrated that N applications directly impact vegetative growth and yield (Ollrady et al., 2019; Cocco et al., 2021; Niemiec et al., 2021; Visconti et al., 2023). Sanchez et al. (2003) and Delgado et al. (2004) have stated that N increases photosynthetic capacity, thereby having a positive effect on cluster and berry development. Similarly, Zheng et al. (2017) emphasized that N improves quality parameters such as cluster weight and berry size; however, they also noted that excessive doses could have a negative impact on quality. Furthermore, the quantities of N necessary for the growth of current season shoots and grapevine fruits have been established (Wermelinger and Koblet, 1990; Schreiner, 2016; Ferrara et al., 2018). The wide range of N requirements of vines is determined by many factors, including climate, vine age, training system, variety, rootstock, soil type, and management history (Visconti et al., 2023). However, most of these studies focus on wine grapes (Lorensini et al., 2015; Silva et al., 2016; Cocco et al., 2021; Miliordos et al., 2022; Visconti et al., 2023), and there is limited research and information available on the N concentration or requirements of table grape vines. Given that poor nutrient management reduces grape yield and quality while polluting the environment, further studies are needed with different varieties in different ecological conditions.

This study evaluated the effects of different N doses on the growth and yield characteristics of the Alphonse Lavallee table grape variety through a field experiment conducted under Isparta ecological conditions in 2021 and 2022. This study aimed to determine the most suitable N level for sustainable viticulture by identifying the effects of different N doses on grape yield parameters and vine development, thereby providing recommendations for producers.

2. Materials and Methods

This study was conducted in Aydoğmuş Village, Keçiborlu District, Isparta Province/Türkiye, in 2021 and 2022. The vineyards in which the experiment was conducted were established with a row spacing of 3 meters and a between-rows spacing of 2 meters. The vines of the Alphonse Lavallée grape variety were 12 years old and had been grafted onto 41B rootstock. The double-arm Guyot training system was implemented in the vineyards.

The climate data for the experimental area are presented in Table 1. As demonstrated by the available climate data, the mean temperature in 2021 was 12.4 °C, thus indicating that it was at the long-term average (12.3 °C). In 2022, the mean temperature was recorded at 11.4 °C, indicating a slight decrease compared to 2021. The average relative humidity was 60.5% in 2021, which is below the long-term average of 61.5%, and 63.1% in 2022, which is slightly above the aforementioned average. Total precipitation was 459.6 mm in 2021 and 465.4 mm in 2022, both of which were below the long-term average of 567.5 mm (Table 1).

The soil analysis results of the trial area indicate that the soil has a clayey texture and a slightly alkaline (7.92). The electrical conductivity value (0.33 dS m^{-1}) does not pose a problem in terms of salinity. The lime content (15.9%) is high, while the organic matter (2.0%) and total N (0.1%) contents are low. It is evident that essential macro nutrients, such as phosphorus (25 ppm) and potassium (300 ppm), are present in sufficient quantities. The microelement composition of the soil in the test area under investigation was found to be high in calcium and zinc, but low in manganese.

The trial was conducted in a randomized block design, with three replicates, each consisting of ten vines. The study utilized a total of five distinct N doses, namely 0, 50, 100, 150, and 200 kg ha^{-1}. Ammonium nitrate (33%) was utilized as the N fertilizer. Fertilizer applications were made during the pre-flowering period on 25 April 2021 in the first year and 28 April 2022 in the second year. The application of the fertilizer was conducted by means of the insertion of the fertilizers into the holes that had been dug around the root zone of the vines. Following the application, irrigation was conducted utilizing the drip irrigation technique. In order to provide a more effective demonstration of the impact of N fertilization, one row was deliberately

Table 1. Climate data for the trial area

Climate data	Months												Total/ Mean
	1	2	3	4	5	6	7	8	9	10	11	12	
	Long years (1929-2020)												
T (ºC)	1.8	2.9	6.0	10.7	15.4	19.9	23.4	23.3	18.9	13.4	7.8	3.6	12.3
RH (%)	75.3	71.7	65.9	61.3	59.2	52.7	45.6	46.3	52.2	62.3	69.9	76.0	61.5
P (mm)	81.0	67.6	58.8	52.1	57.0	34.3	15.9	14.3	18.5	38.4	44.8	86.7	567.5
	2021												
T (ºC)	4.9	3.8	4.3	10.6	17.1	18.0	23.9	24.0	17.8	11.8	9.1	3.8	12.4
RH (%)	82.5	69.1	68.1	59.5	47.3	61.9	40.1	36.2	52.6	59.4	66.7	82.7	60.5
P (mm)	114.8	64.2	58.2	7.4	19.6	69.6	0.0	0.0	17.6	7.0	19.6	81.6	459.6
	2022												
T (ºC)	-0.8	1.3	1.1	12.1	15.0	19.2	22.8	23.0	18.6	12.9	7.5	4.6	11.4
RH (%)	78.3	80.3	65.1	51.2	57.6	64.6	41.1	54.9	49.3	60.3	69.7	85.4	63.1
P (mm)	50.2	150.8	59.6	24.6	21.2	62.0	1.8	13.6	23.4	10.2	24.0	24.0	465.4

T: Temperature, RH: Relative humidity, P: Precipitation left empty between the rows, and three vine applications were made on the right and left sides of each row.

The study encompassed a comprehensive examination of various parameters, including shoot length, node interval, berry width, berry length, cluster width, cluster length, cluster weight, 100-berry weight, and vine yield. For each application, the width and length of 20 berries per cluster were measured using a caliper and recorded in millimeters (Anonymous, 2009). The width and length of five clusters from each vine were measured using a caliper, and the mean was calculated (Anonymous, 2009). The measurements pertaining to the clusters were conducted on 10 clusters that were randomly selected from each plot. The weights of 100 berries obtained by sampling from each repetition were measured using a precision balance, and the average weight of 100 berries was determined in grams according to the applications (Bahar et al., 2011). The grapes obtained from the clusters each repetition were weighed and divided by the number of vine find the average grape yield per cluster kilograms per vine (kg vine^{-1}) (Akın, 2011).

The two-year data obtained from the research were subjected to the Levene homogeneity test; combined variance analyses were performed on the data determined to be homogeneous. The data obtained in the study were then subjected to variance analysis in accordance with the random block experimental design. The LSD (Least Significant Difference) test was utilized to ascertain the disparities between the means (Turan, 1995).

3. Results

All characteristics examined in the study were found to be statistically significantly affected at the 1% level by N doses, according to two-year averages. The interaction between year X N dose was found to be significant at the 1% level only in terms of internode length. Differences between years were found to be significant at the 1% level in shoot length and internode length, and at the 5% level in berry width and cluster weight (Table 2 and 3).

Increases in N doses caused an increase in shoot length. According to two-year averages, the highest shoot length was determined at 200.0 cm with a N dose of 150 kg ha^{-1}, while the lowest value was found in the control application at 134.7 cm. Differences between years in shoot length were also significant, with the average shoot length being higher in 2021 (181.0 cm) (Table 2).

The year x N interaction was found to be significant in terms of internode length, with the highest values occurring in 2021 at 150 and 200 kg ha^{-1} N doses, at 7.03 and 7.08 cm, respectively. The lowest value (4.78 cm) was obtained in the control plot in 2022. Based on two-year average values, N doses of 150 and 200 kg ha^{-1} yielded the highest

Table 2. Shoot length, internode lengths, berry width and berry length obtained at different N doses[1]

N doses (kg ha^{-1})	Shoot length (cm)			Internode length (cm)		
	2021	2022	Two-year average	2021	2022	Two-year average
0	140.1	129.3	134.7 D	5.21 e	4.78 f	5.00 D
50	167.3	155.6	161.5 C	6.24 d	5.12 e	5.68 C
100	196.1	192.3	194.2 B	6.89 b	6.45 c	6.67 B
150	202.9	197.1	200.0 A	7.03 ab	6.48 c	6.76 A
200	198.7	182.9	190.8 B	7.08 a	6.36 cd	6.72 AB
Average	181.0 A	171.4 B		6.49 A	5.84 B	
LSD (Y)		5.94**			1.85**	
LSD (N)		4.64**			0.14**	
LSD (YxN)		ns			0.20**	
N doses (kg ha^{-1})	**Berry width (mm)**			**Berry length (mm)**		
	2021	2022	Two-year average	2021	2022	Two-year average
0	18.11	17.66	17.89 D	19.22	18.81	19.02 D
50	18.86	18.43	18.65 C	19.93	19.51	19.72 C
100	19.45	18.95	19.20 B	20.35	19.95	20.15 BC
150	20.23	19.67	19.95 A	21.21	20.69	20.95 A
200	19.31	18.59	18.95 BC	20.42	20.03	20.23 B
Average	19.19 A	18.66 B		20.23	19.80	
LSD (Y)		0.39*			ns	
LSD (N)		0.52**			0.51**	
LSD (YxN)		ns			ns	

Y: Year, [1]: Means followed by the same letter were not significantly different at 0.05 level, *: F-test significant at p<0.05, **: F-test significant at p<0.01, ns: Not significant values, while the shortest internode length was observed in the control treatment. When comparing years, it was determined that the shoot length in the first year of the experiment (6.49 cm) was greater than in the second year (Table 2).

Increases in N doses had a positive effect on berry width and length values. According to two-year averages, the highest berry width (19.95 mm) and longest berry length (20.95 mm) were determined in the 150 kg ha^{-1} N application, while the lowest values (17.89 mm and 19.02 mm) were determined in the control plot. The berry width value in the first year of the study (19.19 mm) was found to be higher than in the second year (Table 2).

The cluster width and length values also increased with increasing N doses, with the highest values determined at 100 and 150 kg ha^{-1} N doses and the lowest values in the control plot according to the two-year averages (Table 3).

Cluster weights also increased with N doses, with the highest two-year average cluster weights of 385 and 380 g obtained at 100 and 150 kg ha^{-1} N doses. When comparing years, the average cluster weight for 2021 (334 g) was higher. Similar to cluster weight, the highest values for 100-berry weights were obtained at 100 and 150 kg ha^{-1} N doses, with 579 and 576 g, respectively. The lowest cluster weight and 100-berry weight were observed in the control treatment (Table 3).

Increasing N doses up to 100 kg ha^{-1} resulted in significant increases in yield, but higher doses showed a decreasing trend. According to two-year averages, the lowest grape yield was 5.59 kg in the control treatment, while the highest yield was 8.53 kg in the 100 kg ha^{-1} N application (Table 3).

Table 3. Cluster width, cluster length, cluster weight, 100 berry weight and yield obtained at different N doses

N doses (kg ha^{-1})	Cluster width (cm)			Cluster length (cm)		
	2021	2022	Two-year average	2021	2022	Two-year average
0	10.52	10.32	10.42 C	18.11	17.71	17.91 C
50	12.25	12.13	12.19 B	19.65	19.19	19.42 B
100	12.96	12.71	12.84 A	20.23	19.82	20.03 A
150	13.06	12.59	12.83 A	20.21	19.69	19.95 A
200	12.11	11.68	11.90 B	19.63	19.02	19.33 B
Average	12.18	11.89		19.57	19.09	
LSD (Y)		ns			ns	
LSD (N)		0.33**			0.49**	
LSD (YxN)		ns			ns	
N doses (kg ha^{-1})	Cluster weight (g)			100 Berry weight (g)		
	2021	2022	Two-year average	2021	2022	Two-year average
0	219	209	214 D	496	481	489 D
50	321	307	314 C	526	503	515 C
100	395	375	385 A	581	576	579 A
150	390	369	380 A	580	572	576 A
200	346	342	344 B	550	543	547 B
Average	334 A	320 B		547	535	
LSD (Y)		8.25*			ns	
LSD (N)		8.75**			14.68**	
LSD (YxN)		ns			ns	
N doses (kg ha^{-1})	Yield (kg $vine^{-1}$)					
	2021	2022	Two-year average			
0	5.61	5.56	5.59 E			
50	7.56	7.43	7.50 D			
100	8.59	8.47	8.53 A			
150	8.43	8.09	8.16 B			
200	7.87	7.66	7.77 C			
Average	7.57	7.44				
LSD (Y)		ns				
LSD (N)		0.20**				
LSD (YxN)		ns				

Y: Year, [/]: Means followed by the same letter were not significantly different at 0.05 level, *: F-test significant at p<0.05, **: F-test significant at p<0.01, ns: Not significant

4. Discussion and Conclusion

The findings indicated that the application of N levels had a substantial impact on both the growth of the plants and the yield of grapes. The impact of N on plant growth is a subject that has been extensively explored in the extant literature. In this study, it was demonstrated that vegetative parameters, including shoot length and internode length, exhibited statistically significant increases in response to varying N doses. In particular, the application of 150 kg ha^{-1} N resulted in the greatest increase in shoot length and internode length according to two-year averages. In consideration of the pivotal function of N in protein synthesis and cell division, this outcome is anticipated (Majidi and Doulati Baneh, 2020). However, at a dose of 200 kg ha^{-1}, the increase curve became horizontal or even decreased in some characteristics. This suggests that the use of N in excess of that required by the plant may impede vegetative growth and potentially induce metabolic stress. On the other hand Deldago et al. (2004), excess N also causes more vegetative growth, which competes with sugar translocation and pigment accumulation in the grape. Bell and Robson (1999) studied the effects of N application on growth, canopy density, and yield. They found that the highest shoot length was observed with 100 g of N among different N doses (0, 50, 100, 200, and 400 g $vine^{-1}$), while shoots were shorter in vines receiving 400 g of N. Furthermore, the efficacy of N applications in affecting growth parameters, including berry size, cluster size, and weight, has been demonstrated. The highest values for berry width and length were determined at a dose of 150 kg ha^{-1} N. This finding is consistent with the findings of Kassem and Marzouk (2002). In addition, the observed rise in both cluster size and weight is consistent with the findings of Thomidis et al. (2016). The extant literature suggests that N promotes cell expansion, thereby increasing fruit size, particularly during the process from flowering to fruit set. Cocco et al. (2021) reported that N doses of 240 and 480 kg ha^{-1} of ammonium nitrate applied to Carignano wine grapes did not significantly affect berry weight. However, there was a tendency for higher berry weight in vines receiving N fertilization. However, cluster weight was higher with the 240 kg ha^{-1} application of ammonium nitrate in the first year of the experiment and with both N doses in the second year, compared to control vines. Another study investigating the effect of different N fertilization rates on Savvatiano grape berry and must composition reported that N fertilization significantly increased berry and seed weight, thereby increasing cluster weight (Miliordos et al., 2022). However, the combined application of different doses of N and potassium (K) (0, 50, and 200 g N $vine^{-1}$ and 0, 60, and 120 g K_2O $vine^{-1}$) to 'Tempranillo' grapevines had no effect on vine vigor productivity, or berry size (Reynolds et al., 2005). These differing results are thought to stem from developmental differences between wine grapes and table grapes despite them being the same species. Zheng et al. (2017) observed that excessive N application may suppress vegetative growth, thereby inhibiting generative development, suggesting that high doses do not contribute to yield increases. As demonstrated by Sanchez et al. (2003) and Delgado et al. (2004), the utilization efficiency of nutrients is diminished when the application exceeds the optimal dose.

The highest yield values were obtained at a N dose of 100 kg ha^{-1}. The application of this dose resulted in an increase of approximately 50% in both years, as compared to the control plots. This clearly demonstrates the positive effect of N on yield. However, no significant increase in yield was observed at doses of 150 and 200 kg ha^{-1}. This finding indicates that beyond the optimal N dose, there may be a limit to or even a decline in yield increases. This observation was corroborated by a study conducted by Cocco et al. (2021), who reported higher yields per vine in those subjected to N fertilization. The highest yields were obtained from vines treated with 240 or 480 kg ha^{-1} ammonium nitrate. However, Abd El-Razek et al. (2011) found that applying N at rates of 24, 36, and 48 kg ha^{-1} reduced the number of clusters and negatively impacted the yield per vine of Crimson Seedless grapes. While there are inconsistencies between studies, it is believed that the effect of N application on grape composition largely depends on the form of N used, the timing of application, and the variety. It is known that excessive N can be more harmful than beneficial, and that the form and timing of N application are at least as important as the dose.

In this study, the highest yield was obtained with a N dose of 100 kg ha^{-1} applied every two years to the Alphonse Lavallée grape variety, when N doses of 0, 50, 100, 150 and 200 kg ha^{-1} were compared. These results suggest that 100 kg ha^{-1} is the optimal N dose, as higher doses offer no additional benefits. From a sustainable viticulture perspective, it is important to reduce chemical inputs and manage fertilizer use. However, N requirements can vary depending on the grape variety, soil type and fertilizer management history. Further research is needed to determine the minimum N thresholds that guarantee high-quality table grape production.

Ethical Statement

The author declares that ethical approval is not required for this research.

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Declaration of Conflicts of Interest

No conflict of interest has been declared by the author.

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