









Influence of Fertilization Regimes on Productivity and Agro-Economic Indicators of Technical Grape Varieties (*Vitis vinifera* L.) in Karabakh

M. Huseynov^{1*}, E. Musayeva²,
A. Huseynova², G. Ibayeva²,
A. Adilov², V. Salimov²

¹Azerbaijan State University of Economics (UNEC), Baku, Azerbaijan

²Scientific Research Institute of Viticulture and Winemaking, Absheron, Azerbaijan.
movlud.huseynov@unec.edu.az

Abstract. Macro fertilizers play a fundamental role in grape production and are essential for key physiological processes such as photosynthesis, protein synthesis, and nucleic acid formation. However, conventional fertilization practices are often inefficient, environmentally unsafe, and result in low grape productivity, leading to economic losses and environmental risks. This study aimed to investigate the effects of different combinations and dosages of nutrients on agrobiological and quality indicators of technical grape varieties cultivated in the village of Tugh (Karabakh). Field experiments were conducted on local soils using the local grape variety Khindogny and the introduced varieties Cabernet Sauvignon and Pinot noir. The results demonstrated that optimized fertilization regimes significantly improved productivity and quality indicators, highlighting their importance for sustainable viticulture development in the region.

Keywords: fertilization, grape varieties, productivity, quality, nutrition.

1 Introduction

Fertilizers are widely used to meet the growing demand for food production and to maintain or improve soil fertility (Haynes et al., 1998). However, excessive use of chemical fertilizers in agriculture can lead to soil degradation, groundwater contamination, and a reduction in biological diversity. In this context, environmentally friendly agricultural practices, including balanced and rational fertilization, are increasingly recommended to reduce environmental damage and ensure the long-term sustainability of agricultural systems (Sabir et al., 2020).

An effective and balanced soil fertilization programme contributes to improving the physical, chemical, and biological properties of the soil while simultaneously replenishing the nutrients removed by grape plants during the growing season (Winkler et al., 1974; Kasap, 2012). Agricultural crops annually absorb significant amounts of macro and microelements from the soil, which can substantially reduce soil fertility. Therefore, the application of fertilizers should be adjusted according to crop requirements to maintain productivity. Long-term studies have shown that the application of 170–180 kg of

nitrogen, 170–180 kg of phosphorus, and 60–90 kg of potassium per hectare, calculated based on the active substance, can increase vineyard yields by up to 40% (Krasilnikov et al., 2015).

The incorporation of nitrogen fertilizers into deeper soil layers can improve soil structure and enhance microbiological activity. Nevertheless, prolonged and excessive fertilization may alter the composition and functionality of soil microbial communities, potentially leading to adverse environmental effects (Dai et al., 2018). Consequently, further research is required to better understand the influence of fertilizers on soil structure and microbiological processes (Ma et al., 2021).

When determining fertilizer application rates, it is essential to consider soil type and nutrient availability. For ordinary black and brown soils with very low nutrient content, recommended fertilizer rates per hectare are N120, P180, and K240. For soils with low nutrient content, the rates should be N100, P150, and K180, while soils with medium nutrient content require N80, P120, and K120. For soils with high nutrient content, lower rates of N60, P90, and K90 are considered sufficient (Kandelaki and Kenchiashvili, 2011).

To maintain long-term soil fertility, fertilizers must be applied in a balanced manner, with application rates carefully calculated according to plant requirements (Gaiotti et al., 2014). Optimizing nitrogen use efficiency not only increases crop yields but also reduces negative environmental impacts (Midolo et al., 2018; Chen et al., 2020). This approach is particularly important for ensuring agricultural sustainability and economic efficiency (Jat et al., 2012; Zhang et al., 2023).

Soil fertilization is a key agrotechnical practice in viticulture, and its rational application plays a crucial role in achieving stable and high-quality grape yields. Both excessive and insufficient fertilizer doses can negatively affect plant growth and development. Therefore, accurate assessment of nutrient levels in soil and plants is essential to determine optimal fertilizer rates. Proper fertilization ensures balanced plant development while contributing to environmental protection.

The objective of this study was to investigate the effects of different fertilization methods, including root and foliar applications, on the technical grape varieties Khindogny, Cabernet Sauvignon, and Pinot noir cultivated in the village of Tugh, Khojavend district. In addition, soil samples from the experimental site were analysed to evaluate the physico-chemical properties influencing grape production.

2 Materials and Methods

The research was conducted from 2022 to 2025 at the experimental site located in the village of Tugh, Khojavend district, within the Karabakh region. The village of Tugh is situated at the foothills of the Karabakh Mountain Range and is characterised by favourable natural conditions for viticulture. The area is known for its agricultural lands, particularly grape cultivation. According to its geological structure and geographical position, the soils of the study area belong mainly to chestnut and brown mountain forest soil types.

The experimental soils consist of organic and mineral components, gases, liquids, and microorganisms essential for plant growth and development. Fertilizer application trials were carried out on 15-year-old grapevines trained using a multi-arm fan formation system. During the study period, annual precipitation in the experimental area ranged from 680 to 740 mm, with the highest precipitation (740 mm) recorded in 2024.

Precipitation was mainly observed during the months of January, February, March, April, May, June, July, October, and December.

Soil samples were collected from the experimental vineyard at depths of 0–30 cm and 30–60 cm to assess the physico-chemical properties of the soil. The collected samples were analysed using established national and international analytical methods to determine key soil characteristics relevant to grape cultivation.

The study focused on evaluating the effects of different fertilization regimes on technical grape varieties cultivated under local conditions. The local grape variety Khindogny, as well as the introduced varieties Cabernet Sauvignon and Pinot noir, were selected as the plant material for the experiment. Fertilizers were applied using different combinations and dosages, including root and foliar applications, in order to assess their influence on agrobiological parameters and productivity indicators of the grapevines.

3 Results and Discussion

The effects of various fertilization regimes on the technical grape varieties Khindogny, Cabernet Sauvignon, and Pinot noir were evaluated over a four-year period (2022–2025) by analysing changes in agrobiological parameters during different phenological stages.

For the Khindogny variety, the total number of green shoots developing from buds under different pruning load rates was 40 shoots in the control variant, 38 shoots in variant III, and 46 shoots in variants I and IV. The highest values were recorded in variant I (N80P80K80 applied to the roots + 1.5 kg/ha NPK 20:20:20 applied foliarly) and variant IV (N150P150K150 applied to the roots + 3.0 kg/ha NPK 20:20:20 applied foliarly), both reaching 46 shoots.

In the Cabernet Sauvignon variety, the number of green shoots was 40 in the control variant, 38 in variants II and III, and 46 in variant IV. The most pronounced effect was observed in variant IV (N150P150K150 applied to the roots + 3.0 kg/ha NPK 20:20:20 applied foliarly), where the number of shoots reached 46.

For the Pinot noir variety, the total number of green shoots was 36 in the control variant, 38 in variants I and III, and 42 in variant IV. The best result was obtained in variant IV (N150P150K150 applied to the roots + 3.0 kg/ha NPK 20:20:20 applied foliarly), with 42 shoots per bush.

Insufficient availability of macro- and microelements in the soil, which are essential for agricultural crops, limits nutrient uptake by plants and negatively affects their development, yield, and product quality (Ateş and Turan, 2015; Karaman, 2012). In viticulture, both the quantity and quality of the harvest depend on varietal characteristics, rootstock, soil type, nutrient availability, and applied agrotechnical practices, including tillage, fertilization, irrigation, plant protection, and pruning (Viets et al., 1973; Winkler et al., 1974; Kovancı and Atalay, 1977).

Due to varietal characteristics, the studied grape varieties differed in the ratio of fertile to non-fertile shoots. The number of fertile shoots ranged from 22 to 26 in the Khindogny variety, from 22 to 29 in the Cabernet Sauvignon variety, and from 21 to 24 in the Pinot noir variety. For the Khindogny variety, the highest number of fertile shoots was observed in variant I (N80P80K80 applied to the roots + 1.5 kg/ha NPK 20:20:20 applied foliarly), reaching 26 shoots. In the Cabernet Sauvignon variety, the highest value (29 shoots) was recorded in variant II (N100P100K100 applied to the roots + 2.0 kg/ha NPK 20:20:20 applied foliarly), while for the Pinot noir variety, variant III

(N120P120K120 applied to the roots + 2.5 kg/ha NPK 20:20:20 applied foliarly) produced the most favourable result, with 24 shoots.

Potassium (K⁺) is the most abundant cation in grapevine tissues, grape berries, and processed grape products such as juice and wine. Although the beneficial role of potassium in grapevine development and grape and wine quality is well recognised, additional research is required to fully elucidate the mechanisms underlying its effects (Rogiers, 2017).

The proportion of fertile shoots was determined using mathematical methods. For the Khindogny variety, fertile shoots accounted for 55% in the control variant and ranged from 52.2% to 60.5% in the fertilized variants. In the Cabernet Sauvignon variety, this indicator was 62.5% in the control and varied between 47.8% and 76.3% in the experimental variants. For the Pinot noir variety, the proportion of fertile shoots was 66.7% in the control and ranged from 50.0% to 63.2% under fertilized conditions (Figure 1).

The fertility coefficient of green shoots ranged from 0.54 to 0.80 for the Khindogny variety, from 0.57 to 0.82 for the Cabernet Sauvignon variety, and from 0.74 to 0.85 for the Pinot noir variety. The highest fertility coefficients were recorded in variant I for the Khindogny variety (0.80), in variant II for the Cabernet Sauvignon variety (0.82), and in variant II for the Pinot noir variety (0.85).

The fruitfulness coefficient of fertile shoots, which reflects the average number of bunches per shoot, is a key indicator of yield formation. This coefficient ranged from 1.04 to 1.27 for the Khindogny variety, from 1.04 to 1.18 for the Cabernet Sauvignon variety, and from 1.21 to 1.57 for the Pinot noir variety. The highest values were observed in variant I for the Khindogny variety (1.23), in variant IV for the Cabernet Sauvignon variety (1.18), and in variant IV for the Pinot noir variety (1.57) (Figure 2).

Overall, the results demonstrate that the combined application of root and foliar fertilizers had a significant positive effect on shoot development, fertility, and yield-related agrobiological indicators of the studied grape varieties (Figure 3 and 4).

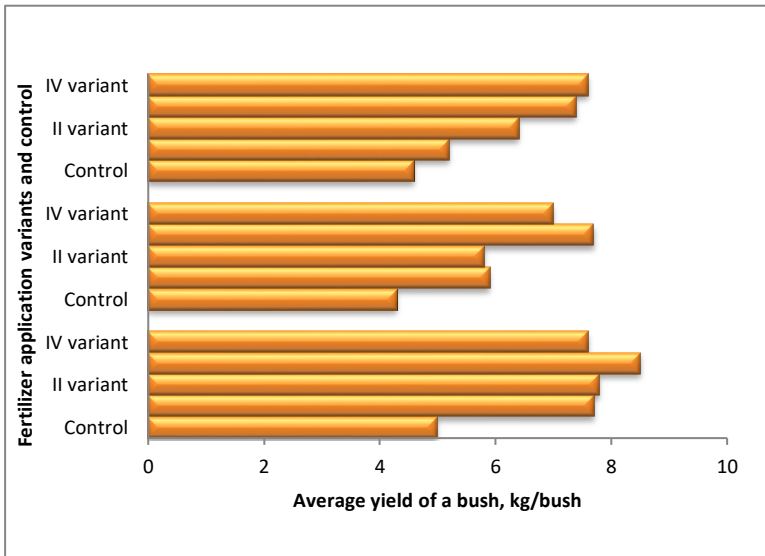


Fig 1. The effect of fertilizers on the bush yield.

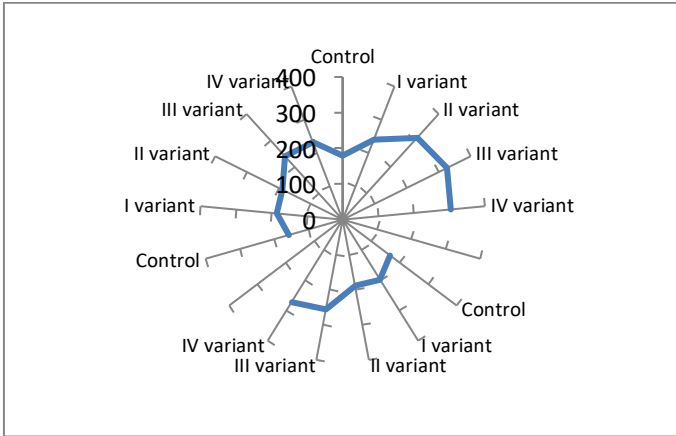


Fig 2. The effect of fertilizers on the average weight of bunches.

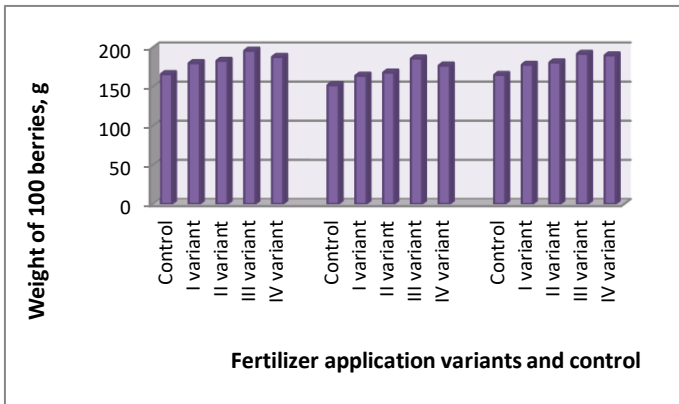


Fig 3. The effect of fertilizers on the weight of 100 berries.

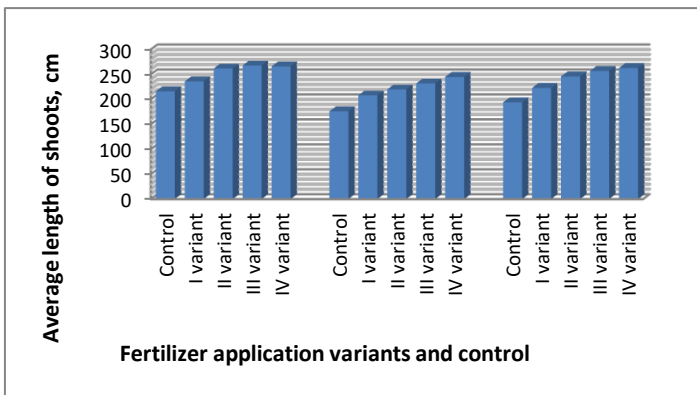


Fig 4. The effect of fertilizers on the growth and average length of shoots.

4 Conclusion

As a result of the implementation of the effective fertilization methods developed in this study, grape yield per bush reached 5.0–8.5 kg for the Khindogny variety, 4.3–7.7 kg for the Cabernet Sauvignon variety, and 4.6–7.6 kg for the Pinot noir variety.

During the research period, the most optimal fertilizer combinations and application rates were identified, which had a significant influence on both yield quantity and grape quality. The most effective fertilization regimes were determined as follows: for the Khindogny variety, N120P120K120 applied to the roots combined with 2.5 kg/ha NPK 20:20:20 applied foliarly (variant III), resulting in a yield of 8.5 kg per bush; for the Cabernet Sauvignon variety, N120P120K120 applied to the roots combined with 2.5 kg/ha NPK 20:20:20 applied foliarly (variant III), with a yield of 7.7 kg per bush; and for the Pinot noir variety, N150P150K150 applied to the roots combined with 3.0 kg/ha NPK 20:20:20 applied foliarly (variant IV), resulting in a yield of 7.6 kg per bush.

The applied fertilization regimes positively affected not only grape yield but also the growth and agrobiological characteristics of the grapevines. Improved formation and development of inflorescences under fertilized conditions contributed to an increased number of fertile shoots and the formation of larger grape clusters.

Berry number and berry weight played a decisive role in determining the average cluster weight and directly influenced overall yield formation. Compared with the control variants, fertilized treatments showed an increase in both the average number of berries per cluster and the average cluster weight, leading to a significant increase in grape productivity. The most pronounced effects were observed in variants III and IV.

No adverse effects of the applied fertilizers on vegetative organs or the overall development of grapevines were observed during the study period. Based on the obtained results, the combined fertilization programmes involving both root and foliar applications, developed in this study, are recommended for practical implementation. These programmes take into account the physico-chemical properties of the soil as well as the nutritional requirements of grape plants and can contribute to improving productivity and sustainability in viticulture.

References

1. Ateş, K., Turan, V.: Some properties and productivity levels of agricultural soils in the central district of Bingöl province. *TUTAD* 2, 108–113 (2015)
2. Chen, Y., Fan, P., Mo, Z., Kong, L., Tian, H., Duan, M., Li, L., Wu, L., Wang, Z., Tang, X., Pan, S.: Deep placement of nitrogen fertilizer affects grain yield, nitrogen recovery efficiency, and root characteristics in direct-seeded rice in South China. *Journal of Plant Growth Regulation* (2020). <https://doi.org/10.1007/s00344-020-10107-2>
3. Gaiotti, F., Marcuzzo, P., Battista, F., Belfiore, N., Petoumenou, D., Tomasi, D.: Compost amendment effects on grapevine root density and distribution. In: *1st International Symposium on Grapevine Roots*, pp. 1136 (2014)
4. Jat, R., Wani, S., Sahrawat, K., Singh, P., Dhaka, S., Dhaka, B.: Recent approaches in nitrogen management for sustainable agricultural production and eco-safety. *Archives of Agronomy and Soil Science* 58, 1033–1060 (2012). <https://doi.org/10.1080/03650340.2011.557368>
5. Kandelaki, N.D., Kenchiashvili, N.R.: The influence of mineral fertilizers on grape yield and wine quality. *Winemaking and Viticulture*, No. 6, 33 (2011)

6. Karaman, M.R.: Plant Nutrition. 2nd edn. GÜBRETAS Guide Books Series, Turkey (2012)
7. Kasap, Y.: Viticulture and Fertilization. Ravza Publications, Istanbul (2012)
8. Kovanci, I., Atalay, I.Z.: Macronutrient elements and soil–plant relations in vineyards. *Plant* 4(2), 192–212 (1977)
9. Krasilnikov, A.A., Russo, D.E., Prakh, A.V.: The influence of microelements on the growth and development of shoots, leaf area, and productivity of grapes. *Winemaking and Viticulture*, No. 2, 40–44 (2015)
10. Ma, Q., Sun, L., Tian, H., Rengel, Z., Shen, J.: Deep banding of phosphorus and nitrogen enhances *Rosa multiflora* growth and nutrient accumulation by improving root spatial distribution. *Scientia Horticulturae* (2021). <https://doi.org/10.1016/j.scienta.2020.109800>
11. Midolo, G., Alkemade, R., Schipper, A., Benítez-López, A., Perring, M., de Vries, W.: Impacts of nitrogen addition on plant species richness and abundance: A global meta-analysis. *Global Ecology and Biogeography* (2018). <https://doi.org/10.1111/geb.12856>
12. Rogiers, S.Y., Coetzee, Z.A., Walker, R.R., Deloire, A., Tyerman, S.D.: Potassium in the grape (*Vitis vinifera* L.) berry: Transport and function. *Frontiers in Plant Science* 8, 1629 (2017)
13. Sabir, A., Gayretli, Y., Abdulhadi, A.S.: Physiological and vegetative development responses of grapevine rootstock saplings to grape pomace, spent mushroom compost, and farmyard manure applications. In: 4th International Eurasian Agriculture and Natural Sciences Congress, pp. 86–92 (2020)
14. Viets, F.W., Grady, J.D., Lindsay, W.A.: Testing soils for zinc, copper, manganese, and iron. In: Walsh, L.M., Beaton, J.O. (eds.) *Soil Testing and Plant Analysis*, pp. 153–172. Soil Science Society of America, Madison, WI (1973)
15. Winkler, A.J., Cook, J.A., Kliwer, W.M., Lider, L.A.: *General Viticulture*. University of California Press, Berkeley (1974)
16. Zhang, L., Zhang, W., Meng, Q., Hu, Y., Schmidhalter, U., Zhong, C., Zou, G., Chen, X.: Optimizing agronomic, environmental, health, and economic performances in summer maize production through fertilizer nitrogen management strategies. *Plants* 12 (2023). <https://doi.org/10.3390/plants12071490>

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

