Journal of Agricultural Sciences (Belgrade)
Vol. 71, No. 2, 2026
Pages 201-208

https://doi.org/10.2298/JAS2602201O
UDC: 634.54(497.11)"2019"
Original scientific paper

HORIZONTAL AND VERTICAL DISTRIBUTION OF HAZELNUT ROOT SYSTEM

Čedo Đ. Oparnica[1*], Dragan D. Radivojević[1], Magdalena M. Milićević[2] and Nemanja M. Tešić[1]

[1]University of Belgrade, Faculty of Agriculture, Belgrade, Republic of Serbia
[2]Monarh plantaže, Velika Krsna, Mladenovac, Republic of Serbia

Abstract: The application of agrotechnical and pomotechnical measures in modern fruit production depends on a thorough understanding of the morphological characteristics of both the above- and below-ground organs of hazelnut varieties. This study aimed to determine the horizontal and vertical distribution of the root system in five-year-old bushes of the hazelnut varieties Tonda di Giffoni and Tonda Gentile Romana. The research was conducted in a hazelnut orchard in Velika Krsna (Mladenovac, Serbia) in 2019. The results showed significant differences in root length depending on the distance from the trunk and soil depth in both varieties. In Tonda di Giffoni, the greatest root length was recorded at a depth of 10–20 cm, reaching 1,914 cm (41%) at a distance of 200 cm from the trunk, while at 50–100 cm it was 861 cm (45%). Root length decreased with increasing distance and depth, whereas root diameter increased with depth but decreased with distance from the trunk. The total root length in this variety was 4,672 cm. In Tonda Gentile Romana, the total root length was higher, amounting to 7,212 cm. The highest root length was also observed at a depth of 10–20 cm, reaching 3,279 cm (45%), and 1,470 cm (45%) at 50–100 cm from the trunk. Root diameter increased with depth (2.35–18.5 mm), while the number of roots decreased. The results indicate that root system distribution is strongly dependent on variety.

Key words: hazelnut, root system, horizontal and vertical distribution.

Introduction

The European hazelnut (*Corylus avellana* L.) belongs to the birch family, Betulaceae, of the order Fagales. It is a fruit species native to Europe and Asia Minor, and is commonly found growing wild throughout these regions. The natural distribution and genetic diversity of this species indicate its potential for cultivation over a wide range of temperate environments (Mehlenbacher, 1991). Almost all

[*]Corresponding author: email: oparnicacedo@gmail.com

widely used varieties were selected over many centuries from local wild populations of the European hazelnut, *C. avellana* L., in Europe and Turkey (Dale et al., 2012).

Hazelnut has become very popular in the last decade, and a significant number of new plantations have been established in Serbia. The average annual production of in-shell hazelnuts in Serbia for the period from 2016 to 2020 was 5,080 tonnes (FAOSTAT, 2022). Considering that many hazelnut plantations are still young, a significant increase in hazelnut production is expected in the coming years.

The significant nutritional and dietary therapeutic value of hazelnuts has led to a constant increase in demand and consumption by the confectionery industry, which is also the largest consumer. As a result, hazelnuts are becoming an increasingly important agricultural product in international trade.

In most plantations established in Serbia, as well as in other hazelnut-producing countries, hazelnuts are mainly grown on their own roots. In the nurseries, layerage is a very common method of propagation (Solar et al., 1994). Only a small number of plantations have been established with plants grafted onto a *Corylus colurna* rootstock. The Turkish hazelnut (*Corylus colurna* L.) is characterised by vigorous growth and a strong root system, which is important for relatively dry regions (Cerović et al., 2009). The own-rooted hazelnuts exhibit rapid above-ground development with large canopy volume, a high number of sprouts, and earlier yield. The grafted plants show greater below-ground development, with smaller canopy volumes and lower yield. However, later, the higher growth rates of the canopy allow these plants to reach the same size as that of the own-rooted hazelnuts and to enter the fruit production phase (Portarena et al., 2022).

Modern hazelnut orchards require the application of adequate agrotechnical and pomotechnical measures, which is conditioned by knowledge of the morphological characteristics of the above-ground and underground organs of cultivated varieties.

The term "root system architecture" refers to the spatial arrangement of the root system in the environment in which it grows (Koevoets et al., 2016). Hazelnut trees are shallow rooted. Feeder roots are concentrated in the surface layer of the soil, extending outwards from the trunk to beyond the spread of the limbs. Below this level, the number of feeder roots decreases rapidly. Hazelnut trees have very few anchoring roots. Almost all European hazelnut varieties form suckers, but the amount depends on the variety (Dale et al., 2012; Miljković, 2018).

The study of the root system is highly complex and demanding, as excavating it from the soil substrate is a difficult and delicate operation that requires preserving as much of the root mass as possible.

To intensify the production of this increasingly important fruit species, it is essential to understand the structure of the root system. This knowledge enables the most correct soil preparation for the establishment of plantations, ongoing soil maintenance, incorporation of fertilisers at the appropriate depth, as well as the application of other necessary agrotechnical practices.

The aim of this research was to determine the horizontal and vertical distribution of the root system in five-year-old bushes of the most important hazelnut varieties in the agro-ecological conditions of Serbia.

Material and Methods

Research was carried out in the hazelnut orchard in Velika Krsna (Mladenovac) during 2019. The subject of the investigation was the horizontal and vertical arrangement of the root system of hazelnut varieties. The experiment included two hazelnut varieties: Tonda di Giffoni (TDG) and Tonda Gentile Romana (TGR), grown as bushes with 3 to 5 scaffold branches, at a planting distance of 4.5 x 3.5 m. The orchard was established in autumn of 2014 with one-year-old plants on their own roots (saplings), covering an area of 15 ha. The soil was maintained by regular mechanical tillage, without an irrigation system, and standard pest management was applied.

To make the research as realistic and precise as possible, the soil was carefully removed from the root system expansion zone on three bushes per tested variety, after which the root system was washed with water. The root system was measured manually using a measuring tape, where the main roots (>1 mm) were included, however, small roots (absorptive) were not included in the measurements. The diameter of the root system was measured using a calliper. These measurements were carried out in the laboratory of the Faculty of Agriculture in Belgrade. The horizontal arrangement of the roots was determined in four circular rings located at 0–50 cm, 50–100 cm, 100–150 cm and 150–200 cm from the trunk of the bush. The vertical spread of the root system was determined in the same circular rings at depths of 0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm from the soil surface.

Results and Discussion

Based on the obtained results, noticeable differences can be observed in the length of roots at different distances from the trunk of the bush, as well as in the depth of root penetration in both tested varieties. In the examined conditions, in the TDG variety, the greatest root system was found at a depth of 10–20 cm, measuring 1,914 cm (41%) at a total distance of 200 cm from the trunk of the bush. At the same depth, but at 50–100 cm from the trunk, the root length was 861 cm (45%). As the distance from the trunk and the depth increased, the root length decreased.

The diameter of the roots increased with depth, and decreased with the distance from the trunk, with the smallest diameter (1.3 mm) observed at a depth of

0–10 cm and 50–100 cm from the trunk. The total root system length was 4,672 cm. The hazelnut root system mainly extends in the surface soil layer, with the largest root mass found at a depth of up to 40 cm (Manušev, 1988; Miljković, 2018; Korać et al., 2020). The results are shown in Table 1.

Table 1. Horizontal and vertical distribution of the root system of the hazelnut variety Tonda di Giffoni.

Depth (cm)		Distance from the trunk (cm)				Sum
		0–50	50–100	100–150	150–200	
0–10	TRL	379.2	41.8			421
	ARD	3.68	1.3			
	NR	23	8			31
10–20	TRL	668	861	342	43	1914
	ARD	7.68	7.14	3.51	1.4	
	NR	25	30	20	7	82
20–30	TRL	336	815	420	53	1624
	ARD	9.2	6.95	3.91	1.5	
	NR	14	28	21	7	70
30–40	TRL	74.8	290	292	54.2	711
	ARD	23.86	14.1	7.2	1.6	
	NR	2	11	15	9	37
Sum	TRL	1458	2007.8	1056	150.2	4672
	NR	64	77	56	23	220

TRL – Total root length (cm); ARD – Average root diameter (mm); NR – Number of roots.
Source: Authors' own research.

The study of horizontal root distribution revealed pronounced differences between the examined hazelnut cultivars. In the TGR cultivar, most of the total root length (TRL) was found in the 0–100 cm zone from the trunk, accounting for about 87%. This indicates a relatively compact root system. In contrast, the TDG cultivar had a more expansive root structure, with a larger proportion of roots extending beyond 100 cm, approximately 26%. A similar trend was observed in the number of roots (NR), with TDG having more roots in the outer zones (100–200 cm), suggesting a greater ability to explore the soil horizontally.

These results align with previous studies showing that root system structure is largely dependent on genotype and plays a critical role in the absorption of water and nutrients. For example, Lynch (1995) has pointed out that plants with broader root systems are better suited to varied soil environments, especially when water is limited. Additionally, Gregory (2006) has found that horizontal root growth significantly aids resource gathering for perennial crops. The greater presence of roots in outer zones for TDG may indicate a stronger ability to use soil resources, particularly in dry conditions.

Furthermore, the distribution pattern matches the findings of Fitter (1987) who has observed that species and cultivars with wider root systems often show increased resilience to environmental stress. They are better at reaching water and nutrients from larger areas of soil. In this regard, the more localised root system of the first cultivar might suggest a stronger reliance on resources near the trunk, while TDG showed qualities associated with better adaptability. These differences are important for improving irrigation methods and orchard management, as highlighted in earlier research on woody perennial crops. In terms of vertical distribution, both cultivars clearly showed a layered root system. Most roots were found in the topsoil layers (0–30 cm), which is typical for hazelnuts and other woody species. However, there were noticeable differences between the two cultivars.

Table 2. Horizontal and vertical distribution of the root system of the hazelnut variety Tonda Gentile Romana.

Depth (cm)		Distance from the trunk (cm)				Sum
		0–50	50–100	100–150	150–200	
0–10	TRL	1013				1013
	ARD	2.35				
	NR	53				53
10–20	TRL	1358	1470	451		3279
	ARD	4.82	4.63	2.23		
	NR	62	65	35		162
20–30	TRL	707	1103	254		2064
	ARD	9.56	8.76	3.1		
	NR	26	37	16		79
30–40	TRL	259	406	137	50	852
	ARD	18.5	7.61	3.1	1.7	
	NR	10	15	9	7	41
Sum	TRL	3337	2979	842	50	7212
	NR	151	117	60	7	335

TRL – Total root length (cm); ARD – Average root diameter (mm); NR – Number of roots.
Source: Authors' own research.

Experience with *Corylus colurna* L. used as a rootstock in the USA has shown that varieties of this species are more resistant to drought and frost than *Corylus avellana L.* They have a strong root system and can reach depths of 3 to 4 m (Rovira, 2021).

The TGR cultivar had a higher concentration of both TRL and NR in the shallowest layer (0–20 cm), indicating a mostly shallow root system. In contrast, TDG showed a steadier decrease in root presence as soil depth increased, with a relatively higher proportion of roots found deeper (20–40 cm). This suggests a more balanced vertical distribution, allowing better access to water stored in deeper soil layers. This pattern supports the findings of Gregory, P. J. (2006) that deeper root growth enhances plant resilience during droughts, as well as the conclusion of Lynch (1995) that genotypes with better vertical root spread are more efficient at capturing resources from below the surface. Thus, TDG appears to have a functional advantage in variable water conditions, as it can access both surface and deeper layers more effectively.

Research by Miljković (1976) has confirmed that the largest root diameter occurs at a depth of 20–30 cm and 50–100 cm from the bush trunk. It found that there were twice as many roots near the trunk as at 100 cm away, and three times as many as at 150 cm from the trunk. Since hazelnuts typically have relatively shallow root systems, a lack of rainfall or growing them without irrigation negatively affects their growth, yield, and fruit quality.

It is crucial to balance vegetative and generative activities. Achieving this balance requires proper pruning and agricultural practices, such as irrigation, fertilisation, and soil management, tailored to the needs of each variety.

Conclusion

This study highlighted clear genotypic differences in both horizontal and vertical root distribution among the hazelnut cultivars reviewed. TDG displayed a more extensive and spatially distributed root architecture, with more roots extending beyond the trunk area and a balanced vertical distribution throughout the soil layers. In contrast, the first cultivar exhibited a more compact and shallow root system, concentrating most of its root length in the upper layers and near the trunk. These differences represent distinct strategies for acquiring soil resources. Functionally, TDG's larger root system suggests a better ability to take up water and nutrients, especially under uneven water supply. Its capacity to explore deeper and wider soil zones may give it an adaptive advantage during drought conditions, while the first cultivar's more localised root distribution implies a higher dependence on easily accessible resources in the topsoil. These findings agree with previous studies emphasising the role of root system structure in determining a plant's adaptability and efficient resource use in woody perennial species.

Overall, the results stress that root system structure is a key characteristic that impacts the ecological performance and irrigation needs of hazelnut cultivars. The differences between genotypes provide useful insights for improving orchard management methods, particularly regarding irrigation scheduling and soil water management. Selecting cultivars with better root distribution patterns, such as TDG, may enhance resilience and promote more efficient use of soil water resources in changing environmental conditions.

Acknowledgements

This paper is the result of research conducted under the contract for the implementation and financing of scientific research work in 2023, between the Ministry of Science, Technological Development and Innovation of the Republic of Serbia and the Faculty of Agriculture, University of Belgrade, contract number 451-03-34/2026-03/200116.

References

Cerović, S., Ninić-Todorović, J., Gološin, B., Ognjanov, V., & Bijelić, S. (2009). Grafting methods in nursery production of hazelnut grafted on *Corylus colurna* L. *Acta Horticulturae*, *845*, 279-282.

Dale, A., Galic, D., Leuty, T., Filotas, M., & Currie, E. (2012). Hazelnuts in Ontario - Biology and Potential Varieties. *Ministry of Agriculture, Food and Rural Affairs*, *12*, 1-8.

FAOSTAT (2022). Crops. Retrieved December 10, 2022, from http://www.fao.org/faostat/en/#data/QC

Fitter, A. H. (1987). An architectural approach to the comparative ecology of plant root systems. *New Phytologist, 106*(Suppl.), 61–77. https://doi.org/10.1111/j.1469-8137.1987.tb04683.x

Gregory, P. J. (2006). Roots, rhizosphere and soil: The route to a better understanding of soil science? *European Journal of Soil Science*, *57*(1), 2–12. https://doi.org/10.1111/j.1365-2389.2005.00778.x

Koevoets, I. T., Venema, J. H., Elzenga, J. T. M., & Testerink, C. (2016). Roots withstanding their environment: exploiting root system architecture responses to abiotic stress to improve crop tolerance. *Frontiers in Plant Science*, *7,* 1335, 1–19. https://doi.org/10.3389/fpls.2016.01335

Korać, M., Cerović, S., Ninić-Todorović, J., Gološin, B., Sekulić, R., Vajgand, D., Roversi, A., & Bijelić, S. (2020). *Leska*. Univerzitet u Novom Sadu, Poljoprivredni fakultet, Novi Sad.

Lynch, J. P. (1995). Root architecture and plant productivity. *Plant Physiology, 109*(1), 7–13. https://doi.org/10.1104/pp.109.1.7

Manušev, B. (1988). *Uzgoj leske*. Zadrugar, Sarajevo.

Mehlenbacher, S. A. (1991). Hazelnuts (Corylus). *Genetic Resources of Temperate Fruit and Nut Crops 290*, 791–838. https://doi.org/10.17660/ActaHortic.1991.290.18

Miljković, I. (1976). Korijenova mreža lijeske u crvenici na zapadnoj obali Istre. *Agronomski glasnik: Glasilo Hrvatskog agronomskog društva, 38*(7-9), 285–294.

Miljković, I. (2018). *Lijeska*. Hrvatska voćarska zajednica, Zagreb.

Portarena, S., Gavrichkova, O., Brugnoli, E., Battistelli, A., Proietti, S., Moscatello, S., Famiani, F., Tombesi, S., Zadra, C., & Farinelli, D. (2022). Carbon allocation strategies and water uptake in young grafted and own-rooted hazelnut (*Corylus avellana* L.) cultivars. *Tree Physiology*, *42*(5), 939–957. https://doi.org/10.1093/treephys/tpab164

Rovira, M. (2021). Advances in hazelnut (*Corylus avellana* L.) rootstocks worldwide. *Horticulturae*, *7*, 267.https://doi.org/10.3390/horticulturae7090267

Solar, A., Smole, J., & Štampar, F. (1994). Investigations of different methods of propagation of hazelnut (*Corylus avellana* L.). *Acta horticulturae*, *351,* 381–386. https://doi.org/10.17660/ActaHortic.1994.351.42

Received: 24 November 2025
Accepted: 06 March 2026

HORIZONTALNA I VERTIKALNA DISTRIBUCIJA KORENOVOG SISTEMA LESKE

Čedo Đ. Oparnica[1*], Dragan D. Radivojević[1], Magdalena M. Milićević[2] i Nemanja M. Tešić[1]

[1]Univerzitet u Beogradu, Poljoprivredni fakultet, Beograd, Srbija
[2]Monarh plantaže, Velika Krsna, Mladenovac, Srbija

R e z i m e

Primena agrotehničkih i pomotehničkih mera u savremenoj voćarskoj proizvodnji zavisi od detaljnog poznavanja morfoloških karakteristika nadzemnih i podzemnih organa sorti leske. Cilj ovog istraživanja bio je utvrđivanje horizontalne i vertikalne distribucije korenovog sistema kod petogodišnjih žbunova sorti leske Tonda di Giffoni i Tonda Gentile Romana. Istraživanje je sprovedeno u zasadu leske u Velikoj Krsni (Mladenovac, Srbija) tokom 2019. godine. Rezultati su pokazali značajne razlike u dužini korena u zavisnosti od udaljenosti od stabla i dubine zemljišta kod obe sorte. Kod sorte Tonda di Giffoni, najveća dužina korena utvrđena je na dubini 10–20 cm i iznosila je 1.914 cm (41%) na udaljenosti od 200 cm od stabla, dok je na 50–100 cm iznosila 861 cm (45%). Dužina korena se smanjivala sa povećanjem udaljenosti i dubine, dok se prečnik korena povećavao sa dubinom, a smanjivao sa udaljenošću od stabla. Ukupna dužina korenovog sistema kod ove sorte iznosila je 4.672 cm. Kod sorte Tonda Gentile Romana, ukupna dužina korenovog sistema bila je veća i iznosila je 7.212 cm. Najveća dužina korena takođe je utvrđena na dubini 10–20 cm, gde je iznosila 3.279 cm (45%), dok je na 50–100 cm iznosila 1.470 cm (45%). Prečnik korena se povećavao sa dubinom (2,35–18,5 mm), dok se broj korenova smanjivao. Rezultati ukazuju na to da je raspored korenovog sistema u velikoj meri zavisan od sorte.

Ključne reči: leska, korenov sistem, horizontalna i vertikalna distribucija.

Primljeno: 24. novembra 2025.
Odobreno: 06. marta 2026.

*Autor za kontakt: e-mail: oparnicacedo@gmail.com