

The influence of different fertilizer schemes on 'Haschberg' European elderberry growth and fruit production

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ABSTRACT

Due to their nutritional and therapeutic properties of the fruits, elderberry orchards started to gain more and more ground in Romania as well. Therefore, the purpose of this research was to improve soil quality and yield production in an elderberry orchard from Carastelec by applying both organic and mineral fertilizers. For this purpose, five fertilization schemes (FS) were set up with different ratios of cattle manure, mineral fertilizers and soil amendments. The field experiment was carried out in a randomised block design with three replicates. The best plant and yield performance among the four fertilizer schemes were recorded in FS₄ when mineral fertilizers - NPK - 16:16:16 (0,8 kg/tree) + NH₄NO₃ (0,8 kg/tree) + CaCO₃ (5 kg/tree) were applied providing a yield of 204,89±1,87 kg/row equal to 4.09±0.13 kg fruit/tree and 106.93±2.57cm average annual shoot length. Double-dose organic fertilization (50 kg cow manure/tree) increased the yield by 23,8% as compared to control and shoot length by 15,28%, while lower doses of mineral fertilizers and without soil amendments improved yield performance by 38,08% and growth by 11,85%. Therefore, the findings of this study reveal that large amounts of nitrogen are necessary to be applied in combination with soil amendments in order to improve soil quality and increase elderberry yield and growth performance up to 61%.

Keywords: *Sambucus nigra*, preluvisol, cattle manure, fertilization, mineral, yield, shoot length

INTRODUCTION

Sambucus nigra L. also known as European elderberry, European black elderberry, European elder, black elderberry, elderberry, black elder, or elder belongs to Adoxaceae/Caprifoliaceae family which tolerates poor or disturbed soil conditions known as eutrophic soils. European elderberry, predominantly grows on moist woodlands on nutrient-rich, deep, moist, humus-rich clay or loam soils the companion of *Urtica dioica* or

Aegopodium podagraria indicating soils rich in bases and nutrients especially nitrates (Atkinson and Atkinson, 2002). Prefers sunny sites to partial shade, it is frost tolerant and grows well in urban sites exhibiting a slight intolerance of permanent exposure to acid smoke and gases. Very resistant to salt-laden air and winds and withstands drought (Atkinson and Atkinson, 2002; Rolbiecki *et al.*, 2018). Due to birds' activity, elderberry seeds are rapidly spread colonizing forest edges, road sides or rails and fence lines (Finn *et al.*, 2008; Dulf *et al.*, 2013). *Sambucus nigra* L. is a deciduous shrub that grows up to 3-7 m in height and 3 to 5 m in a spread. Annual growth is 60-80 cm in height and 45-60 cm spread forming a short-stemmed tree with a round, domed crown and arching branches. Young shoots are thick, with white porous pith while the old bark is grey, deeply furrowed and corky. Leaves are imparipennate, up to 30 cm long, dull dark green coloured which have a pungent specific smell when crushed. The flowers are creamy white arranged in wide panicles which start to bloom in June. The berries are small (3-8 mm in diameter) shiny dark blue or black, juicy drupes which occur in clusters and are ripe in late summer, from August until September (Ferreira *et al.*, 2020). Elderberries present an increasing commercial value due to their nutritional and therapeutical properties frequently used as dietary supplements or as natural food colorants as an alternative to synthetic dyes or in the prevention or treatment of diseases. *Sambucus* has been known for centuries and different plant parts have been used in folk medicine to treat various diseases. Nowadays, elderberry is known specifically for its high content of bioactive compounds and diverse health functions that exhibits including antioxidant, anti-inflammatory, anticancer, anti-viral, anti-influenza, antimicrobial, antidiabetic, cardiovascular protective, and neuroprotective activities (Liu *et al.*, 2022; Ağalar, 2018). Several cultivars of *Sambucus nigra* L. are known including Cae Rhos Lligwy, Donau, Franzi, Godshill, Haidegg 13, Haidegg 17, Haschberg, Korsor, Sambu, Samdal, Samidan, Samnor, Sampo, Samyl, Urban Lace, Viridis etc. but also local cultivars such as Ina, Nora and Bradet. However, among the vcultivars known *Sambucus nigra* L. Haschberg is the most common European elderberry cultivar used for commercial orchards across Europe, especially in Germany and Austria (Szalóki-Dorkó *et al.*, 2014; Veberic *et al.*, 2009). Its popularity was gained by the promising antiviral and immunomodulatory effects of the abundant clusters of large, juicy, tasty, dark blue, blackish coloured berries that bear in September (Schön *et al.*, 2021; Torabian *et al.*, 2019). Its attractive foliage that comes in various colours (from light or dark green, or golden-yellow or a beautiful deep, dark red to purple-black and slightly glossy) makes this species highly appreciated as ornamental shrub as well. However, European elderberry has been known and harvested for long from the wild and not cultivated on a large scale, little is known about its yielding performance and growth in commercial orchards. Currently, in Romania there are only a few elderberry orchards summarizing approx. 12 ha situated in different parts of the country including Dambovita, Mures and Salaj Counties. Therefore, the main aim of this study was to determine the influence of organic and mineral fertilizers applied in different doses on yield performance and plant growth in *Sambucus nigra* L. 'Haschberg' to share useful information for potential farmers and stimulate future research in this topic.

MATERIALS AND METHODS

Site Location and Experimental Design

In order to determine the impact of different fertilization schemes on fruit production and plant growth in elderberry, a field experiment has been carried out in a 6-years-old elderberry plantation situated in Carastelec, Salaj County in the North-Western part of Romania (N 47°16'60", E 22°41'11"). The elderberry orchard is established on a slope of 2%, at the altitude of 220 m with sod culture practice and mono-stem elderberries to improve soil quality and soil stabilization (Figure 1). The soil type identified in the orchard is preluvisol with a clayish

or dusty-clayish texture in horizon A ocric (Ao) and loamy in horizon Bt (intermediate layer) with texture differentiation index of 1,3-1,5 (Țarau *et al.*, 2012; Florea and Munteanu, 2012). Coarse sand content is relatively low, of 0.4-2.8%, which reflects medium-fine texture for the parent material. Fine sand content is 23-34%, with insignificant differentiations between horizons. The lower horizons have a higher content of dust, of 22-39% (Figure 1). Preluvisols have moderate acid soil reaction, its pH being 5.45 but only in the upper horizons (Ao) and slightly alkali reaction, pH of 7.05 in the lower layer (Bt).

The degree of base saturation of preluvisols is 53% (Deleanu *et al.*, 2019; IUSS Working Group WRB, 2015; Mihuş *et al.*, 2013). Regarding the physical and chemical properties of this soil type, preluvisols are considered favorable for almost any crops due to its high humus content in the A layer (7.3%) and high total cationic exchange capacity, nitrogen supply (Dincă and Bratu, 2020).

However, in order to improve soil quality, it is recommended to apply balanced complementary fertilization consisting of organic manure and fertilizers. Organic manures help to improve soil tilth, aeration, water holding capacity and microbial activities.

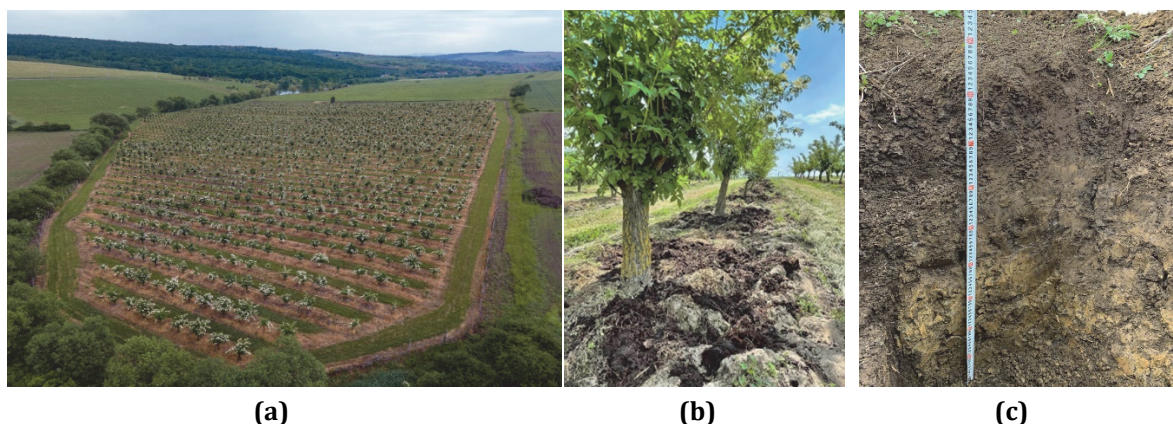


Fig 1. Top view of the Elderberry plantation situated in Carastelec, Salaj County in the North-Western part of Romania (N 47°16'60", E 22°41'11") **(a)**; Close up of the mono-stem trained elderberry plants **(b)**; Sampled soil profile of Haplic Luvisol from the elderberry plantation **(c)**.

Elderberry, similarly to other fruit trees, uptakes large amount of nutrients from the soil during the fruiting period. The manure requirements of an orchard is strongly influenced by various factors such as age of the tree, type of the soil, climatic conditions and cultural practices that are going to be followed.

In this regard, to carry out this experiment four fertilizations schemes were set up and applied during a two-year (2020-2021) in the elderberry orchard as presented in Table 1 and Table 2.

Table 1 Description of the fertilization schemes applied in the elderberry orchard

Treatments	Description and application doses of fertilizers
Control	No organic or mineral fertilizers were applied
FS_1	25 kg of cattle manure/tree
FS_2	50 kg of cattle manure/tree
FS_3	NPK - 16:16:16 (0,8 kg/tree) + NH_4NO_3 (0,8 kg/tree)
FS_4	NPK - 16:16:16 (0,8 kg/tree) + NH_4NO_3 (0,8 kg/tree) + CaCO_3 (5 kg/tree)

Table 2 Characteristics of mineral fertilizers and amendments used in the elderberry orchard

Name of fertilizer	Characteristics	Technical requirements
NPK 16:16:16	Aspect	Coloured granules
	Total N	16%
	Nitrate-N	7,2%
	Ammoniacal N	8,8%
	Total P ₂ O ₅	16%
	Soluble P ₂ O ₅ in water	63%
	Soluble P ₂ O ₅ in citric acid 2%	98%
	K ₂ O soluble in water from potassium chloride	16%
	pH	Min. 4,5%
	Water content	Max. 0,5%
	Granularity	1-4 mm min. 95% < 1 mm max. 5%
NH₄NO₃	Aspect	White granule, slightly coloured
	Total N	33,5%
	Nitrate-N	16,75%
	Ammoniacal N	16,75%
	pH	Min. 0,45%
	Granularity	2-5 mm min. 90% < 1 mm max 5% < 0,5 mm max 3%
CaCO₃ - amendment	Type	Dust
	Application	Roots
	pH	7,5
	Solubility in soil	Fast-release
	Water content	Max. 20%
	Macronutrients	N, Ca

FS_1 and FS_2 and CaCO₃ were applied in autumn prior to the growing period. NPK fertilizers were applied in spring at bud break, late March – early April, in single dose, while NH₄NO₃ was applied twice in equal doses, first in February and then in May. The experiment was carried out in a randomized block design in three replicates. Every treatment was applied to a number of 50 trees. To monitor the impact of fertilizers on plant growth, shoot length was measured during the active growing period at three-time intervals. Yield performance was determined based on the fruit quantity harvested following every treatment. At the end of the season randomly chosen fruit clusters (50 clusters/treatment) from every treatment were collected and weighed to confirm the efficiency of the treatment.

Statistical analyses

All the data recorded was averaged and presented as means, (±) standard error. In order to check the existence of any statistically significant difference between the means, ANOVA test was carried to analyse the means. When the null hypothesis was rejected, Tukey's multiple range test was further performed to identify significant differences between the means at p=0.05 using the IBM SPSS Statistics 20 Software.

RESULTS AND DISCUSSIONS

The difference regarding the effect of different fertilization schemes applied in the elderberry orchard on growth and yield performance was evidenced by annual shoot growth and yield quantity being considered the two most relevant indicators for plant productivity. The results show that both organic and mineral fertilizers had beneficial effects on the vegetative and reproductive parameters measured (Table 3). Regarding plant growth, it has been observed, that the most intensive growth period in elderberry is from March to May, when shoots reach 80% of their annual growth, followed by flowering and fruit set, which slow down vegetative growth. Among the four fertilization schemes applied, FS_4 stimulated the most shoot growth exceeding 1 m in length (106.93 ± 2.5) which was 23% higher as compared to control. This significant growth might be explained by the high amount of N and soil amendments that has been applied during this treatment. FS_2 had very similar effects, stimulating shoot growth by 13% more as compared to control. The double dose of cattle manure increased N uptake and implicitly growth but also yield. Similar results have been reported by Milošević and Milošević (2018) in red, black and white currants and also by Lund *et al.* (1980) and Suntoro *et al.* (2018) in various agricultural crops such as maize, pearl millet and rye. Lower doses of cattle manure stimulated plant growth more than NPK + NH_4NO_3 in lack of the application of soil amendments.

Table 3. The influence of fertilization schemes on annual shoot growth in European elderberry

Treatment Time	20/03/21- 29/05/21	30/05/21- 15/06/21	16/06/21- 05/07/21	Total length
Control	70.40 $\pm$ 0.72 a	6.10 $\pm$ 0.11 a	5.30 $\pm$ 0.10 a	81.8 $\pm$ 2.91 a
FS_1 (25 kg com manure/tree)	78.17 $\pm$ 1.65 c	7.77 $\pm$ 0.11 b	5.70 $\pm$ 0.26 b	91.5 $\pm$ 0.80 b
FS_2 (50 kg cow manure/tree)	78.57 $\pm$ 0.71 c	7.59 $\pm$ 0.09 b	8.31 $\pm$ 0.16 d	94.32 $\pm$ 2.12 c
FS_3 -NPK - 16:16:16 (0,8 kg/tree) + NH_4NO_3 (0,8 kg/tree)	74.30 $\pm$ 1.01 b	8.60 $\pm$ 0.26 c	7.30 $\pm$ 0.10 c	90.2 $\pm$ 1.04 b
FS_4 - NPK - 16:16:16 (0,8 kg/tree) + NH_4NO_3 (0,8 kg/tree) + CaCO_3 (5 kg/tree)	85.60 $\pm$ 1.90 d	9.81 $\pm$ 0.17 d	11.53 $\pm$ 0.24 e	106.93$\pm$2.57 d

Not only plant growth, but yield performance of the elderberry plants under study was significantly influenced by the fertilization treatments applied. Fruit bearing followed a very similar decreasing pattern of fruit bearing as shoot growth, the highest elderberry production being registered at the beginning of the harvest season (16/08/2021). The highest yield resulting from the first harvest time was 98.60 ± 1.35 recorded in FS_4, followed by the yield of 82.33 ± 1.11 recorded in FS_3 (Figure 2). Contrary to shoot length, the results show that the application of cattle manure had a positive influence on yield, but FS_4 consisting of NPK - 16:16:16 (0,8 kg/tree) + NH_4NO_3 (0,8 kg/tree) + CaCO_3 (5 kg/tree) proved to be more effective in terms of fruiting capacity of elderberries. With the occasion of the first fruit harvest, more than 50% of the yield was picked up from the trees. During the second and third harvest the yield decreased depending on the fertilizers applied. Hence, it was observed that high content of N, and especially ammonium nitrate applications almost doubled the yield (increased by 56.11%) as compared to control. The findings of this research show that the higher content and more accessible forms of N significantly increased fruit production in elderberry. Therefore, the highest yield was recorded in FS_4,

204.90±1.57, followed by FS_3 (174.00±1.75) and FS_2 155.92±0.22 (Figure 2).

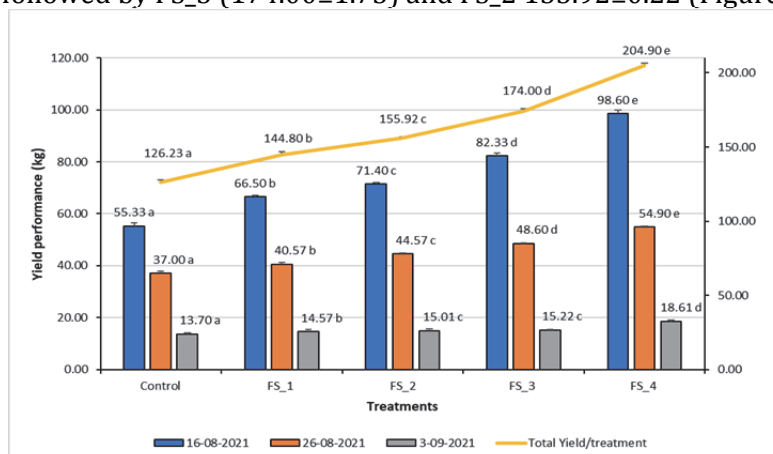


Figure 2. Yield performance in elderberry obtained by the application of four different fertilization schemes; Control – no organic or mineral fertilizers were applied; FS_1 – 25 kg of cattle manure/tree; FS_2 – 50 kg of cattle manure/tree; FS_3 – NPK - 16:16:16 (0,8 kg/tree) + NH_4NO_3 (0,8 kg/tree); FS_4 – NPK - 16:16:16 (0,8 kg/tree) + NH_4NO_3 (0,8 kg/tree) + CaCO_3 (5 kg/tree)

The lowest, but statistically significant difference was registered in FS_1, when only a single dose of cattle manure was applied all through the growing season of the plants. Similar results have been reported in other fruit species as well, such as strawberry, when the yield increased by 38% and 84% in 'Camarosa' and 'Selva' cultivars, when the plants were grown in the 25 NH_4 :75 NO_3 solution. The increased yield at the 25 NH_4 :75 NO_3 ratio was the result of the increase in fruit size, length and fresh weight of fruits (Tabatabaei *et al.*, 2006). After harvest, beside the total fruit production/treatment, the fruit production/tree was also determined. As presented before, depending on the complexity of the fertilization scheme applied, the yield increased as the N application was increased. In this context, the results clearly show that FS_4 was the most efficient treatment applied to increase the yield performance of elderberry (Figure 2 and Figure 3).

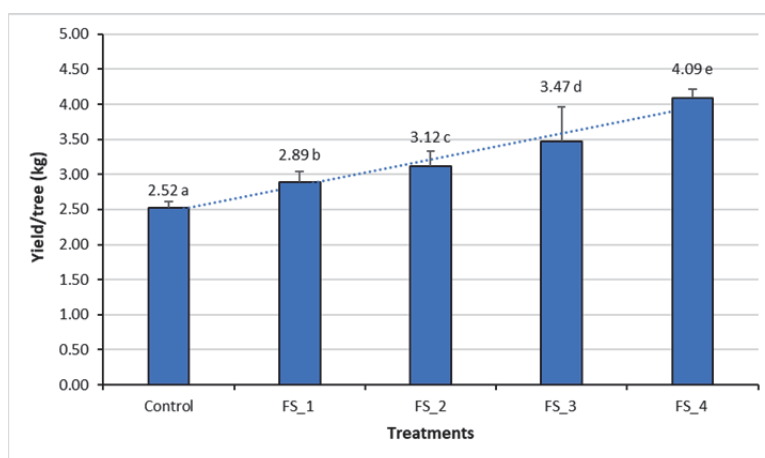


Figure 3. Yield per tree in European elderberry obtained due the application of four different fertilization schemes; Control – no organic or mineral fertilizers were applied; FS_1 – 25 kg of cattle manure/tree; FS_2 – 50 kg of cattle manure/tree; FS_3 – NPK - 16:16:16 (0,8 kg/tree) + NH_4NO_3 (0,8 kg/tree); FS_4 – NPK - 16:16:16 (0,8 kg/tree) + NH_4NO_3 (0,8 kg/tree) + CaCO_3 (5 kg/tree)

The highest quantity of fruits recorded/tree in this treatment was 4.09 ± 0.13 , followed by FS_3 (3.47 ± 0.49), FS_2 (3.12 ± 0.22), FS_1 (2.89 ± 0.15). The lowest fruit quantity was registered in control (2.52 ± 0.10).

In order to confirm the efficiency of FS_4, fruit clusters have been randomly harvested and weighed to prove the ultimate success of this fertilization scheme upon yield. According to the data recorded, the biggest and heaviest fruit clusters were obtained in FS_4 as presented in Figure 4. One fruit cluster weighed 152 ± 0.12 g while 50 berries weighed 50 ± 0.12 g, representing an increase of 38.4% against control.



Figure 4. Fruit clusters obtained from FS_4 - NPK - 16:16:16 (0.8 kg/tree) + NH_4NO_3 (0.8 kg/tree) + CaCO_3 (5 kg/tree)

CONCLUSIONS

European elderberry (*Sambucus nigra*) is grown as a commercial fruit crop across Europe and not only. Based on market size and the increasing demand against this berry fruit, there are several opportunities to improve both the production and processing of elderberry through the value chain. Currently, the use of fruits or flowers as a natural dye for the food industry is on the rise, making elderberry a potential candidate for this purpose. However, it is important to mention that elderberry is listed as an underdeveloped commercial crop, because very little is known about its cultivation, orchard management, production, pest and disease control, yield and economical potential or soil requirements and productive longevity. The findings of this study, however, provide useful information regarding the fertilization success of elderberry and its yield and growth performance, serving also as pioneer research which could provoke more farmers and scientists to invest in this valuable species.

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