

## RESEARCH ON PROCESS OF CUTTING SUPERFICIAL ROOTS IN TREES

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**Abstract.** The subject of this work resides in the current challenges in the field of fruit growing, stipulated in a series of documents developed at the European level, on the one hand, and the existing situation at world level, on the other hand, according to which the fruit growing field is continuously developing in accordance with the market requirements, the development trends and the level of endowment with technical means of the addressed sector. Another aspect is the need, for the distribution chain of fruit to the consumer, for the quantities delivered to be constant, a situation that is satisfied by the level of annual fruit production. For this, a series of maintenance works must be applied to fruit crops, in accordance with the latest technologies adopted by the world's major fruit producers. Recent research in fruit growing has demonstrated that the sectioning of a part of the root system of the trees, correlated with the cuts made in the crown, is beneficial, it contributes to keeping the small size of the trees and to maintaining the growth of the roots within the limit of the nutrition space of each tree. The application of cutting the roots to trees is one of the works that leads to the achievement of an optimal management of the annual fruit production, the mechanical removal of the roots being necessary when the yield of the fruit plantations is reduced. The paper presents a brief presentation of the current state regarding the provision of technical means for cutting at the root level, adopted solutions and a presentation of the work process of the existing equipment. It also presents an innovative equipment for cutting tree roots, the adopted technical solutions, the work process and a mathematical calculation to optimize it, results and conclusions.

**Keywords:** fruit plantations, innovative technical equipment, root cuttings.

### Introduction

Fruit growing is an important branch of Romanian agriculture, both in terms of food supply to the population and the area occupied, Fig. 1, and that is why researchers are making efforts to improve its productive performance. The field of fruit growing occupies an important plan in Romania's agricultural development prospects, a large part of the investments in the field being directed towards fruit farms.

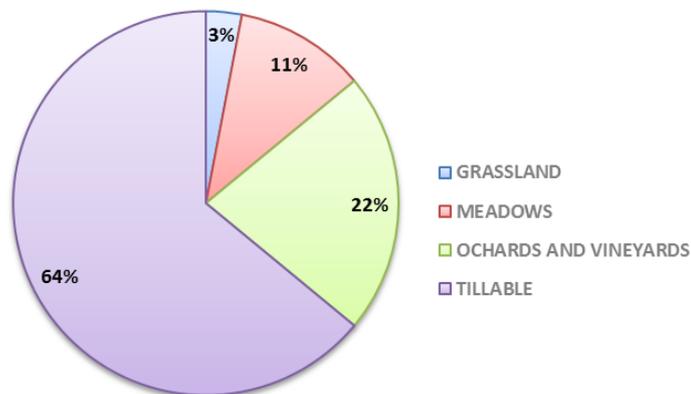


Fig. 1. Agricultural area of Romania, according to the way of use [1]

Romania has a long tradition in the cultivation of fruit trees and is considered among the most important fruit-producing countries in Europe. The total area of fruit plantations in Romania is approximately 237,000 hectares in 2020, and the total fruit production 3.2 million tons. The main fruits grown in Romania are apples, pears, plums, cherries and peaches. Romania pays special attention to the development of fruit growing, especially through the national support program for the fruit and vegetable sector. This program aims to improve the quality and productivity of fruit plantations by providing funds to upgrade the infrastructure and equipment and to promote the development of cultivation technology, [1; 2].

In recent years, fruit growing worldwide has faced a number of new challenges, which can affect both production and fruit quality. Among these challenges are climate changes, with a major impact,

they can lead to an increase in temperatures, sporadic rains or even prolonged droughts, which can affect fruit production and quality. Climate change can also favor the emergence of new pests and diseases.

Globalized trade, can be marked as a new challenge, leads to the rapid spread of diseases and pests throughout the world, which can affect fruit production globally. Currently, there is a significant increase in demand for organic products, including in the field of fruit growing. This can be an opportunity as well as a challenge for producers who can produce and market such products, but it can be difficult for producers who do not have the opportunity to obtain organic fruit certification.

The technological innovations of recent years in the field of horticulture through which new technologies have been developed, such as: soil moisture sensors, drones for monitoring plantations, satellite monitoring technology or even robots for picking fruit. But these innovations may require significant costs to implement and may be difficult to adapt to small farms.

Caring for fruit trees in orchards can be complex and can vary depending on the type of tree, climate and other factors specific to the specific location and crop. A series of steps must be followed and carried out, as follows.

- *Watering*, ensuring that fruit trees are given enough water to grow and produce fruit. In general, fruit trees need a deep watering once a week during the growing and fruiting season.
- *Administration of fertilizers*, fruit trees need nutrients to grow and produce fruit. During the growing season, organic or mineral fertilizers are applied to improve growth and fruit production.
- *Pruning and shaping*, fruit trees need to be pruned regularly to maintain shape and improve fruit production. Pruning can be done to remove diseased or dead branches and to improve aeration of fruit trees, Fig. 2.
- *Pest and disease control*, fruit trees can be affected by a variety of pests and diseases such as: aphids, beetles, worms and rot. It is generally easier to prevent these problems by maintaining a healthy environment for fruit trees. If a problem occurs, the use of chemical or organic treatments to eliminate pests or diseases is necessary.
- *Harvesting and storage*, when the fruit is ready to be harvested, it must be harvested at the right time to get the best taste and quality. It is also important to store them properly to keep them fresh for as long as possible.

## Materials and methods

The technologies used in the maintenance of fruit trees can help improve production quantitatively and qualitatively, to reduce diseases and pests and to save time and resources, these can vary depending on the cultivated varieties, the nature of the production (classic system, ecological, for fresh consumption or for industrialization), the technical endowment of the farm and the financial condition of the farmer.

Here are some of the most used technologies.

- ***Irrigation systems*** – a well-designed and installed irrigation system can help deliver water in precise amounts to the roots of fruit trees, thereby reducing water loss through evaporation and runoff and conserving water resources. There are various irrigation systems, such as drippers, sprinklers or microjets.
- ***Fertilization systems*** – fertilization systems can help provide essential nutrients to the soil in which fruit trees grow. These can be in the form of chemical or organic fertilizers and can be applied through irrigation systems, by spraying or by burying directly in the soil.
- ***Soil monitoring systems*** – these systems allow monitoring of soil conditions such as pH, moisture levels or the amount of available nutrients. This information can help adjust the amount and type of fertilization as well as the amount of water used.
- ***Pruning and harvesting systems*** – there are a variety of tools used to prune and harvest fruit from fruit trees, such as pruning shears, chainsaws or harvesters. They can save time and be more efficient than manual pruning or manual harvesting.
- ***Pest and disease protection systems*** – these systems include the use of pesticides, fungicides or other substances to control pests and diseases that affect fruit trees. There are also pest and disease monitoring systems that allow early detection and prevention of their spread.

- **Weather protection systems** – these include the use of covering systems to protect fruit trees from wind, hail or other extreme weather conditions.
- **Plant monitoring systems** – these systems use sensors to monitor the health of fruit trees, including leaves and fruit. This information can help in early detection of health problems and intervention accordingly.

The main subject of the paper being the process of cutting the superficial roots of fruit trees, we will continue to focus on its development.

**The process of cutting the superficial roots of trees is also called root aeration.** This technique involves removing some of the tree's superficial roots in order to encourage the development of deeper, stronger roots.

Normally, the shallow roots of a tree grow towards the surface and spread over a wide area in search of water and nutrients. These roots can become a problem in areas with compacted or mounded soil, where they inhibit the growth of other plants or gardens. These roots can also become vulnerable to drought or frost because they are on the surface and exposed to extreme temperatures, [3].

By cutting the shallow roots, some of these roots are removed, which reduces the need for water and nutrients and encourages the growth of deeper roots. These deeper roots can absorb water and nutrients better, which helps the tree grow in general and increase production.

Pruning of aerial roots is usually done during the dormant period of trees, i.e. in the autumn or spring, before the start of active growth. It is important to do this carefully and avoid cutting too many roots so as not to affect the health of the tree too much.

Part of the maintenance technology, as well as part of the pruning system in fruit growing, is the cutting of superficial roots, being a fruit plant maintenance technique that is used to improve root development and promote healthier and more vigorous tree growth, [4]. There are two main systems of cutting superficial roots, depending on the technology used, like the following.

1. **Cutting roots with mechanical tools**, this is a technique used especially for young trees or for periodic cuttings of superficial roots. Special tools such as harrows or knives are used to cut the roots to a certain depth so as not to affect the main roots of the tree. This technique can be performed manually or with the help of mechanized equipment.
2. **Water pressure root cutting**, a technique that uses a water pressure pump to cut superficial roots by hydraulic force. In this case, water is injected under pressure into the soil near the roots, so as to cut the superficial roots and promote the development of deeper and stronger roots. This technique can be used on trees of different ages, but is more common on young trees or new plantings.

Both superficial root cutting techniques analyzed have advantages and disadvantages and must be used according to the specific needs of the plants and the particularities of the soil and climate in the area. Pruning superficial roots can be useful to improve root development and promote healthier and more vigorous tree growth but must be done carefully so as not to damage the plants' main roots.

Often the cutting of the superficial roots is carried out at the same time as the crown maintenance cuts, a scheme in this sense being presented in Fig. 2.

Even if such root cutting is not done every year, it is still quite expensive with high energy costs. In order to exclude excessive expenses of fuels and lubricants, it is necessary that the application of agricultural machines equipped with special knives takes place only in the process of the first cutting of the roots, namely in the 2nd or 3rd year after tree planting.

Root pruning or shallow root pruning involves removing some of the tree's superficial roots, which can help stimulate the growth of deeper, stronger roots. However, the process of root pruning can be quite complex, and requires careful consideration of a number of factors, including the species of the tree, the size and location of the root system, and the timing of pruning.

In this paper, we will review the research on the process of cutting superficial roots in trees. One of the primary factors to consider when pruning tree roots is the species of trees. Different trees have different root systems, and some may be more sensitive to root pruning than others. Another factor to consider is the size and location of the root system.

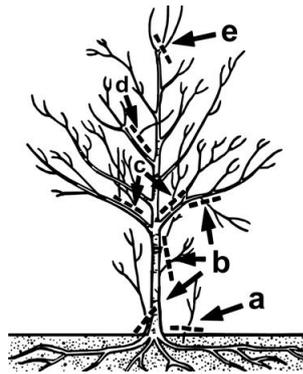


Fig. 2. **Removal of branches that grow inward or threaten to rub against nearby branches, [4]:**

- a – remove suckers originating from below-ground roots; b – low-growing branches; c – upright growing shoots; d – branches that grow inward or rub other branches;
- e – branches that compete with the central leader for dominance

In general, it is recommended that no more than 20-30% of the total root system be pruned at one time, in order to avoid excessive stress on the tree. In addition, it is important to avoid cutting roots that are located close to the trunk, as this can cause significant damage to the tree's stability and health. In general, it is recommended that root pruning be done during the tree's dormant season, in order to minimize stress on the tree. It is also important to avoid root pruning during periods of drought, as the tree may be more vulnerable to water stress.

Research has shown that root pruning can have a number of positive effects on tree health and growth. By removing shallow, weak roots, root pruning can help stimulate the growth of deeper, more robust roots, which can improve the tree's ability to absorb water and nutrients. In addition, root pruning can help reduce the risk of soil compaction.

However, root pruning can also have negative effects on tree health if not done properly. Excessive pruning can lead to root loss, which can cause stress and increase the risk of disease or pest infestation. In addition, improper pruning techniques can cause damage to the tree's root collar or bark, which can also compromise its health.

Studies have shown that restricting the extent and volume of roots by pruning with a utility knife can reduce canopy volume and vigor of fruit trees by nearly 30%. Studies on apples and cherries in Hungary and apples in Ohio demonstrated that flowering is the optimal time for root pruning, and both studies also indicated that the fruit size was reduced by 20...25%.

Other studies show that in the field of soil maintenance in fruit growing, for the purpose of targeted formation of root systems in fruit trees, in the process of scientific research, fruit growers resort to systematic root cutting. In such cases, agricultural machines of the Vibrolaz-80E type or machines equipped with a single working organ, knife, are used.

Some researchers suggest that sectioning off part of a tree's root system can be beneficial under certain conditions, for example, one study found that partial cutting of shallow roots in fruiting shrubs led to a greater increase in the yield, particularly in peaches.

In addition, another research has shown that cutting the side of the root system of peaches can improve the growth and development of branches and leaves. However, it is important to keep in mind that root cutting can also have negative effects on trees. Cutting too many roots or cutting off major roots can weaken the tree and reduce its ability to absorb nutrients and water. Root pruning can also increase the risk of pest and disease infestation.

### ***The technological process of root cutting***

Root cutting is done in spring or autumn on a specially determined line along the row of trees and at a certain distance from the tree trunk. Cutting is done vertically and at a depth of 60...70 cm, and sometimes at 100 cm. Limiting the radial spread of the roots by cutting is carried out starting 2-3 years after planting, periodically, once every 2 years, or even once every 3-4 years.

At the base of this procedure are scientific studies, which state that if the radial spread of a part of horizontal roots is limited, then the tree is forced to force the development and expansive spread of the

other part of horizontal roots. Thus, the direction of the spreading of the roots in certain directions, soil layers and land strips are obtained where the cutting action is expected to be concentrated as agrotechnical measures of soil care (maintenance) in fruit plantations.

#### **Determination of the cutting roots resistance**

The work process performed by the cutting knife involves cutting the soil vertically at a set depth, deforming and moving the cut soil horizontally to a volume equal to the difference between the volume of the knife and the deformed soil and cutting the roots.

Tensile strength when cutting roots,  $R_t$  is determined with relation (1):

$$R_t = R_{td} + R_f + R_{tr}, \quad (1)$$

where  $R_{td}$  – resistance to cutting and soil deformation, daN;  
 $R_f$  – friction resistance of the coulter with the soil, daN;  
 $R_{tr}$  – resistance to root cutting, daN;

Explaining the terms in relation (1) with their expressions, results (2):

$$R_{td} = k_0 \cdot a_c \cdot b_c, \quad (2)$$

$$k_0 = k_t + k_c, \quad (3)$$

$$R_f = \mu_f \cdot G_c, \quad (4)$$

$$R_{tr} = k_{tr} \cdot S_r, \quad (5)$$

where  $k_0$  – soil resistance to cutting and soil deformation, daN·cm<sup>-2</sup>;  
 $k_t$  – specific resistance to soil cutting, daN·cm<sup>-2</sup>;  
 $k_c$  – volume coefficient of compaction;  
 $a_c$  – working depth of the cutting knife, cm;  
 $b_c$  – width of the cutting knife, cm;  
 $\mu_f$  – coefficient of friction between the blade and the ground;  
 $G_c$  – weight taken by the knife from the weight of the equipment, daN;  
 $k_{tr}$  – root cutting resistance, daN·cm<sup>-2</sup>;  
 $S_r$  – sum of the sections of roots cut simultaneously, cm<sup>2</sup>.

Substituting (2) into (1), the relation (6) results:

$$R_t = k_0 \cdot a_c \cdot b_c + \mu_f \cdot G_c + k_{tr} \cdot S_r, \quad (6)$$

The forces acting on the knife during work are shown schematically in Fig. 3.

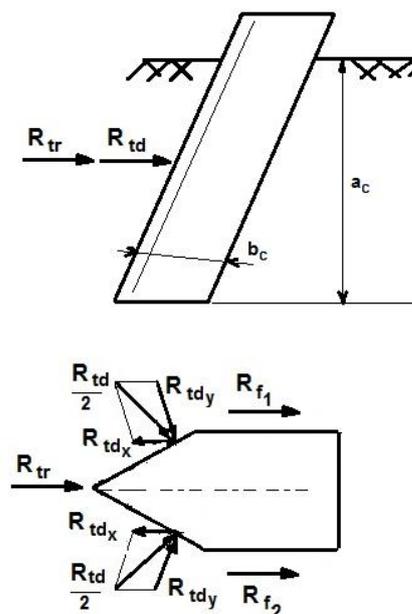


Fig. 3. Forces acting on the cutting knife

When designing a technical equipment to cut the roots of trees, it is necessary to take into account the resistance encountered by the main cutting organ, presented in relations (1 and 3) on the one hand, and the type, nature, condition and characteristics of the soil and the variety of trees, identified by certain physical-chemical properties, on the other hand.

Internationally, there are a number of manufacturers of equipment for the maintenance of fruit plantations, this fact fitting into the very high degree of development, in general, of the sector worldwide. Below are presented some achievements of some specialized manufacturers of such equipment for cutting roots:

The AGROFER company from Italy has made an equipment for shaping the roots, Fig. 4, which has a lamellar knife with hydraulic regulation of the working depth, without pendular movement. In this construction, the equipment works properly on light terrains and without stony inclusions, [5; 6].



Fig. 4. Equipment for shaping tree roots, AGROFER [5]



Fig. 5. Scarifier GZ/P with tree root cutter [6]

The equipment has the following features: Hardox 500 knife 1 m long, hydraulic knife adjustment, horizontal telescopic extension, 500 mm; oblique inclination of the knife, for adjusting the working angle by extension 500 mm and hydraulic extension of the knife for adjusting the working depth to 400 mm.

Scarifier GZ/P with a root cutter is used to decompact and loosen the soil in order to improve its physical and biological properties, Fig. 5.

The working elements are as follows: anchors (900 mm), interchangeable decompaction knives (100 mm) and the root cutting knife. It can be used only as a scarifier or combined (scarifier + tree and vine root cutting). The technical characteristics of the range of scarifiers are presented in Table 1.

Table 1

Scarifying technical features

Model	GZ/P	GZ-2/P	GZ-3/P
Number of anchors	1	2	3
Working depth, cm	70		
Distance between anchors, cm	-	100	70
Weight, kg	180	275	370
Power required, HP	61	88	122

The Dutch company BORECO made a device for shaping tree roots, similar to the one produced by AGROFER, but it has a stability system consisting of a train of wheels that is used in work and transport, Fig. 6 [7].

The company RAMONT STAR SRL sells a device for cutting the roots of trees and vines PKH, Fig.7, model: PKH with hydraulic adjustment of depth (max. 60 cm) and working width, which works in aggregate with 65 tractors CP, [8]. The construction of this device is similar to that of the Italian

company, without a stability system and without the lamellar knife actuation during work. The technical characteristics are the working depth 0.65 m, weight 320 kg and the required power 62 HP.



Fig. 6. Device for shaping tree roots, BORECO [7]



Fig. 7. Tree and vine root cutter PKH, [8]

In 2014, the Northwest Michigan Horticulture Research Centre created, for research purposes, a tree root cutter, with a lamellar knife-type working organ, according to Fig. 8.



Fig. 8. Root cutter – Northwest Michigan [9]

### Results and discussion

In accordance with the considerations presented, INMA Bucharest realized the project for a technical equipment for cutting tree roots, according to Fig. 9.

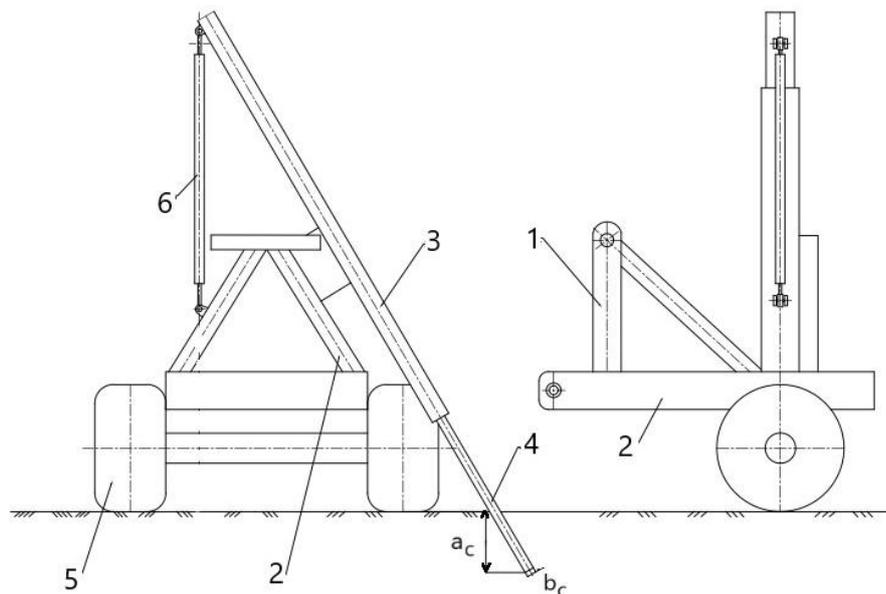


Fig. 9. Scheme of the equipment for cutting tree roots: 1 – clamping triangle; 2 – frame; 3 – knife holder; 4 – cutting knife; 5 – support wheels; 6 – hydraulic installation

The equipment consists of a welded, robust structure, composed of the attachment triangle (pos. 1) on the three-point suspension device of the aggregate tractor and the frame (pos. 2), on which a knife

holder (pos. 3), cutting knife (pos. 4), two support and running wheels during work item 5 and a hydraulic installation item 6, consisting of a cylinder and connecting elements are installed. The equipment is also equipped with a knife overload protection system.

For operation, position the equipment with the knife at a set distance from the row of trees, depending on the age and size of the tree. The hydraulic system is actuated and the knife is inserted to the predetermined depth according to the cutting technology adopted by the user. Start the tractor from the aggregate and carry out the operation of cutting the roots.

In order to be able to make an assessment of the energy efficiency of the tractor aggregate + equipment for cutting the roots, the tensile strength during the operation of cutting the roots is determined using relation 3. For the coefficients and parameters involved in relation 6, the following values were adopted, [10]:

- specific resistance to soil cutting:  $k_t = 5...10 \text{ daN}\cdot\text{cm}^{-1}$ ;
- volumetric compaction coefficient:  $k_c = 1...2 \text{ daN}\cdot\text{cm}^{-2}$ ;
- soil-knife friction coefficient:  $G_c = 100 \text{ daN}$ ;
- working depth of the knife:  $a_c = 50 \text{ cm}$ ;
- root cutting resistance (determined experimentally)  $k_{tr} = 60...75 \text{ daN}\cdot\text{cm}^{-2}$ , we adopt the average of  $67.5 \text{ daN}\cdot\text{cm}^{-2}$ .

Substituting the known values in relation 6 results in  $R_t$ , the tensile strength for different categories of soil according to Table 2, calculated for the working depth of the knife of 50 cm.

Table 2

Root cutting resistance,  $a_c = 50 \text{ cm}$ , for the roots  $S = 1\text{cm}^2$ 

Soil category	$R_{td}$ , daN	$R_f$ , daN	$R_{tr}$ , daN	$R_t$ , daN
Light soil	300	40	67.5	407.5
Middle soil	450	50	67.5	567.5
Heavy soil	600	60	67.5	727.5

For variable working depths of the knife, the variation of the resistance to cutting the roots is according to the graph in Fig. 10.

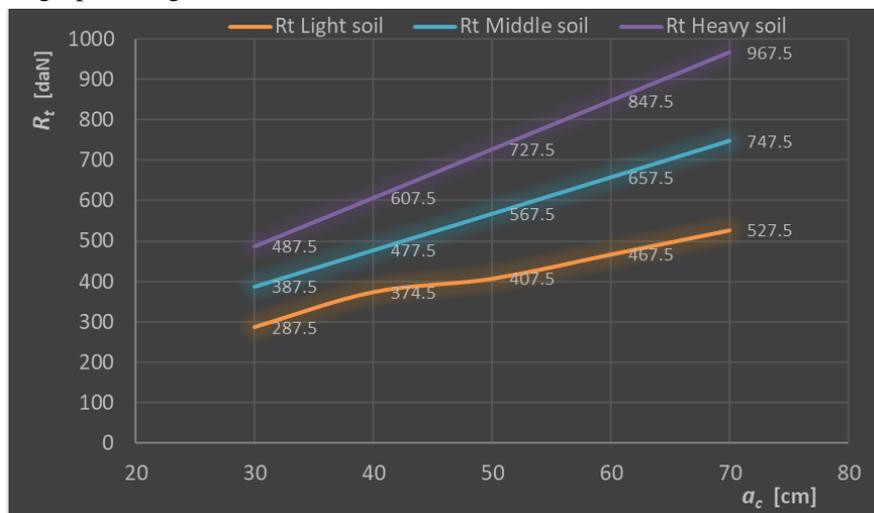


Fig. 10. Variation of resistance to root cutting depending on the working depth

The working speed in certain working conditions is limited by the power of the tractor in the aggregate.

The power consumption  $P$  used only to operate the equipment is given by relation 7.

$$P = R_t \cdot v_e \quad (7)$$

where  $R_t$  – shear strength,  $\text{daN}\cdot\text{cm}^{-1}$ ;  
 $v_e$  – working speed of the equipment,  $\text{m}\cdot\text{s}^{-1}$ .

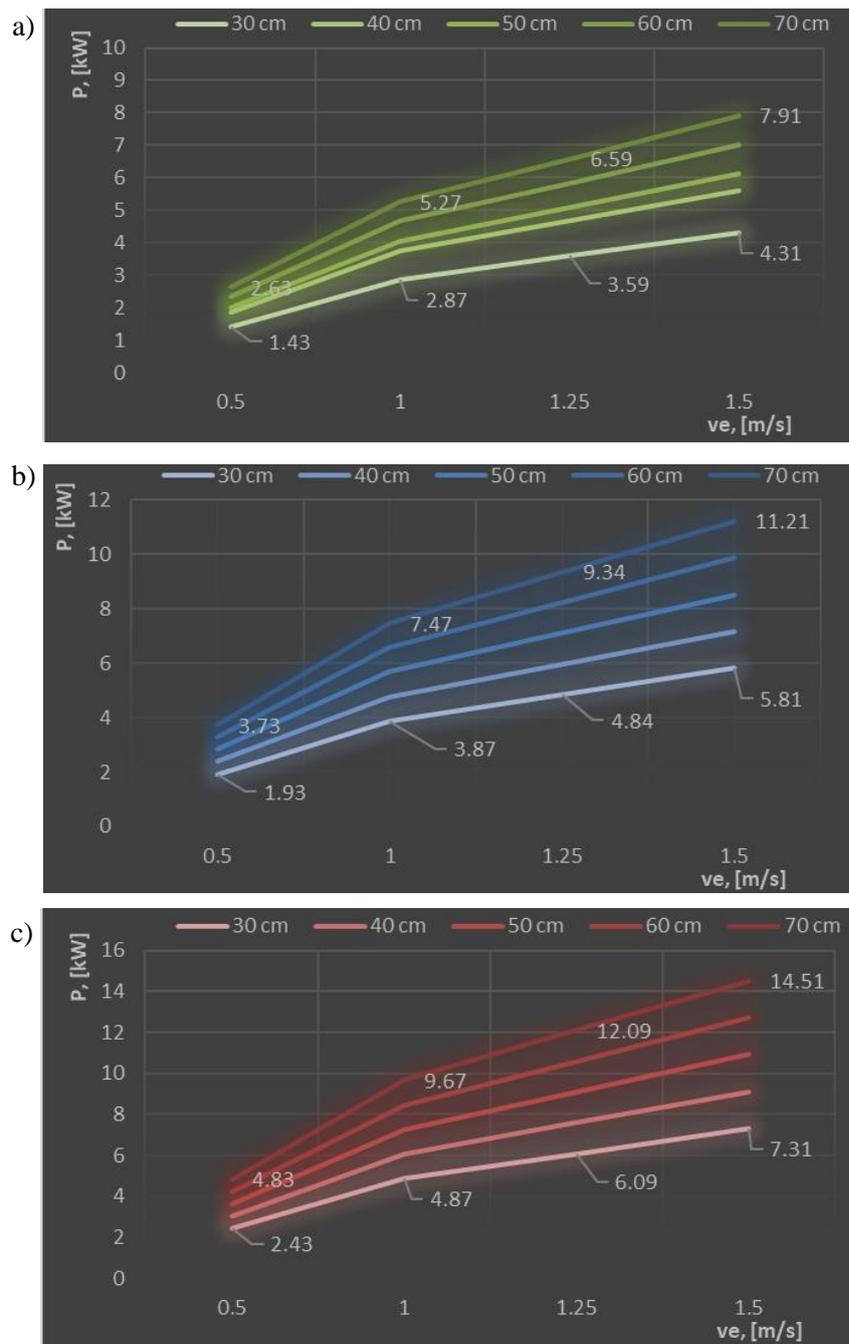


Fig. 11. Variation of power consumption depending on the working speed:  
a – light soil; b – middle soil; c – heavy soil

## Conclusions

1. Root pruning is an important technique in pomiculture that can help improve the health and growth of trees. However, it is important to carefully consider the species of trees, the size and location of the root system, and the timing of pruning in order to minimize stress and avoid damage. Following best practices and investing time to properly plan and execute root pruning can help ensure tree health.
2. It is important to consider the benefits and risks of cutting roots and make informed and well-founded decisions about cutting them. It is usually recommended that root cutting be avoided unless absolutely necessary for the health and safety of nearby trees or structures. It is also important to carry out the pruning properly with the help of an arborist or tree care specialist to minimize the stress on the trees and to ensure as fast and complete recovery as possible.

3. In recent years, in Romania, several new technologies have been developed in the maintenance of fruit plantations, which have improved efficiency and productivity, namely:
- the use of drones for monitoring fruit trees;
  - the use of blockchain technology for tracking agricultural products, including fruit;
  - the use of sensors to monitor soil and climate conditions;
  - the use of geographic information systems (GIS);
  - the use of robots for harvesting.

These are just a few examples of the new technologies used in the maintenance of fruit plantations in Romania. It is important to note that the adoption of these technologies depends on the financial resources of the agricultural landowners and the availability and accessibility of these technologies in different areas of the country.

#### Author contributions

All the authors have contributed equally to creation of this article.

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