Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 2, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ECONOMIC ASPECTS OF SUSTAINABLE PRODUCTION OF APPLE ROOTSTOCKS, ACCORDING TO BIOECONOMY'S CIRCULAR USE OF ORGANIC MATTER

Dimo ATANASOV, Galya DOBREVSKA, Manol DALLEV

Agricultural University of Plovdiv, 12 Mendeleev Blvd, Plovdiv, Bulgaria, Emails: d.atanasov@au-plovdiv.bg, g_dobrevska@au-plovdiv.bg, manol_dallev@abv.bg

Corresponding author: d.atanasov@au-plovdiv.bg

Abstract

The quality of rootstocks is very important for the long term production results of apple trees. It depends on many factors, such as good air and water regime of the soil, good supply of nutrients etc. Different methods of enriching the soil are practiced in order to produce high quality planting material. Bearing in mind the concepts of sustainable agriculture and bioeconomy's principles of production, the authors of this paper, also scientists at the Agricultural University – Plovdiv, Bulgaria undertook a 3 year experimental project aiming to discover efficient ways for improving quantity and quality of apple rootstocks per unit area, while using cheap soil additives or even organic wastes in an environmentally friendly manner. To what extent the use of natural humates and pyrolysis residue from biogas production can change soil conditions and improve quality of apple rootstocks; have positive environmental impact; reduce production cost and guarantee higher economic results was the unifying idea of the project. This article's main objective is to evaluate the impact of the use of natural humates and pyrolysis residue on apple rootstock's production efficiency from technical and economic perspectives. Natural humates contain a certain amount of moisture-absorbing crystals and pressed organic substances, the use of which drastically reduces the use of water and fertilizers in the production system. These have positive economic as well as environmental impact. Pyrolysis residues are obtained as a result of using biogenic fuels for heating greenhouses. They are waste, but can be used as a valuable resource for soil improvement.

Key words: *apple rootstocks, natural humates, pyrolysis residue, bioeconomy, economic assessment*

INTRODUCTION

The concepts of both the bioeconomy and the circular economy have been introduced in the European Union in response to concerns about the long-term viability of the prevailing resource-intensive economic model. Although different in origin – the first mostly driven by an innovation agenda and the second by environmental concerns and resource scarcity – both aim to contribute to strategic and operational EU policy objectives, such as those described in the Seventh Environment Action Programme (7th EAP) for living well within the ecological limits of the planet [4].
In circular economy, the value of products and materials is maintained for as long as possible. What has previously been considered waste is now a resource that can be reused and reintroduced to the production cycle. Therefore, waste management of both technical and bio-based waste streams plays a central role in the transition towards circular economy. In bioeconomy, the materials are to a certain extent circular by nature. However, biomaterials may also be used in a rather linear way [9]. Bioeconomy is not necessarily always sustainable.
In fact, [6] have identified bioeconomy as a form of „weak sustainability" due to its technological aspect, where a complete change in our consumption patterns is not regarded as necessary. On the other hand, circular economy is seen as supporting „strong sustainability", based on its aim of closing the material loops [9].
Bioeconomy can be seen as a knowledge-based production and use of natural/biological resources, together with biological processes and laws, that allow providing economy goods and services in an environmentally-friendly way. The European commission states byoeconomy comprises those parts of the economy that use renewable biological resources from land and sea – such as crops,

forest, fish, animals, and micro-organisms – to produce food, materials and energy [10].

According to the European commission, bioeconomy is Europe's response to key environmental challenges the world is facing today. It is meant to reduce the dependence on natural resources, transform manufacturing, promote sustainable production of renewable resources from land, fisheries and aquaculture and their conversion into food, feed, fibre, bio-based products and bio-energy, while growing new jobs and industries.

In recent years, the EU produces about 138 million tons of bio-waste per year, which has high potential added value as a feedstock for other productive processes. Biological resources and ecosystems could be used in a more sustainable, efficient and integrated manner. The principles of bioeconomy could be applied to the primary production sectors, such as agriculture, forestry, fisheries and aquaculture, as well as to industries using or processing biological resources, such as the food, pulp, paper industries and parts of the chemical, biotechnological and energy industries. In brief, bioeconomy can contribute to build a more competitive, innovative and prosperous Europe [3].

In recent years, the bioeconomy has also become a key focus of political and technological interest both nationally and internationally [2].

The concept of bioeconomy has gained wide popularity. The topic became part of various reports and strategies in a number of countries. Bioeconomy definitions and perspectives shift from factor substitution to biotechnology innovation perspective and nowadays the concept is much more complex and environmentally oriented than before [1].

In this context, the purpose of the paper is is to evaluate the impact of the use of natural humates and pyrolysis residue on apple rootstock’s production efficiency from technical and economic perspectives.

MATERIALS AND METHODS

This article and the research project completed by the authors, lay on the understanding that more sustainable and efficient production systems should abandon technologies based on fossil carbon and transform to technologies using renewable carbon raw materials. Any possibilities for development of a circular bioeconomy in which basic carbon, water and nutrient resources are recovered and reused should be sought. Efficient use of raw materials, including residues where possible and new technologies for recycling and reuse of carbon-based materials can contribute to the sustainable transformation of economy on micro- and macro- level.

The experiment on which this article was built on was conducted in the study field of the Department of Fruit Growing at the Agraricultural University – Plovdiv, located on the territory of Brestnik village, Plovdiv region, South-Central Bulgaria. According to [8], the annual precipitation in the region is below the national average. Rain is very unevenly distributed, both by seasons and by months. Summer is very dry and hot. The high average daily temperatures further increase the effect of the drought during summer time [8].

The study was carried out, based on the block method of Fisher (four replicates with ten plants for each combination). In the soil were introduced two different amounts of natural humate tablets and two different amounts of pyrolysis residue. The following options of the experiment have been observed and analyzed:

•*Natural humate tablets*:
Option I – with 0 kg/da;
Option II – with 25 kg/da;
Option III – with 50 kg/da;

•*Pyrolysis residue*:
Option I – with 0 kg/da;
Option II – with 250 kg/da;
Option III – with 500 kg/da;

The natural humates and respectively the pyrolysis residue were imported at the beginning of vegetation, at the base of the root shoots in the covering soil layer. This application is enough for about four years. A total of three soil coverings were carried out during the vegetation.

Agricultural systems have to be technically and economically viable in order to guarantee their long-term sustainability. Technical efficiency is a function of production technology and represents the way in which incoming resources are transformed into a useful result. Economic efficiency on the other hand compares income from production volumes and the cost of utilised factors of production. The greater the difference between the two, the greater the economic efficiency of production.

The current study analysed the technical and economic efficiency of the apple rootstock production process by taking into consideration the final quantitative and qualitative values and by accounting for the influence of the added natural humates and pyrolysis residue on economic performance of the system.

The main goal of the production unit (farm), based on the principles of sustainability and circular bioeconomy is to achieve the highest possible return on resources, to maximize its profits, to create the greatest benefit for society and to minimize its harmful impact on the environment. The organization, management and control of the production process must focus on the use of such a combination of resources as to enable all these objectives to be achieved simultaneously.

For the purposes of this analysis, a simple methodology for optimization of relationships between the production factors and the obtained technical and economic results was used. The Production Function in short-term (Type A production function) makes it possible to optimize the level of input resources in connection to desired level of output.

Y = f (x1).(x2, x3,… xn)............................(1)

where:
x1 is the variable factor,
x2, x3,… xn are fixed resources within the production cycle.

Thus, one can evaluate and analyze how the change in x1 affects the final result Y (yield) of production.

Depending on their dynamics in the production process, production factors are divided into constant ones and variable ones. The constant factors don’t change within one production cycle (sown area, crop variety, machines, buildings, etc.). The variable factors may change within the production cycle (rate of fertilization, rate of irrigation, chemical spraying, etc.). In the short term, the area of the land, the variety of cultivated crops cannot be changed, but the norms of fertilization, chemical spraying or irrigation may vary.

Based on the methodology, used for the purposes of this study, we assume that there is only one variable factor, the influence of which was measured on the final results. In the last three years, two experiments have been performed with two different soil additives for the studied parameter, excluding the influence of other factors during sowing (Table 1).

Table 1. Quantities of natural humate tablets and pyrolysis residues used

Experiment 1		**Experiment 2**	
Option	Natural humates	Option	Pyrolysis residues
	kg/da		kg/da
1	0	1	0
2	25	2	250
3	50	3	500

Source: Own experiments 2019-2021.

The amount of the variable factor x1 (natural humate tablets or pyrolysis residue) is optimized in order to maximize the economic effect. The economic added value of the used soil improvers was calculated as a difference between additional revenue from the extra rootstocks sold on the market and the additional costs paid for the delivery of the natural humate tablets or pyrolysis residue as variable production factors, using the formula:

TFI = TFR – TFC ....(2)

where:
TFI (total factor income) – income received from the use of the input factor;
TFR (total factor revenue) – revenue from the extra rootstocks sold on the market;
TFC (total factor cost) – the cost, payed for delivery of the input factors;
From the producer’s point of view, TFI should be maximized. TFI will keep rising

until each additional unit of input, invested in the production system contributes to higher revenue than the price, payed for it. The economic result will improve as long as the marginal income from the factor assumes positive values:

MI = MR – MC > 0...................................(3)

where:
MI (marginal income)
MR (marginal revenue) – the revenue from the last unit of input used in the system;
MC (marginal cost) – the cost, spent for the last unit of input used in the system;

MR = MPP. Py ....(4)

where:
MPP – marginal physical product;
Py – market price of the final product;

MPP = ΔTPP/Δx ....(5)

where:
ΔTPP – the change of total physical product (yield);
Δx – the change of quantity of input resource [7].

RESULTS AND DISCUSSIONS

Regarding the content of organic matter in the soil for both options with lower and higher amount of natural humate tablets, an increase in its values was observed, which improves the growing conditions and the better yields were expected. In the two options with lower and higher amounts of pyrolysis residue, a positive change in the content of organic matter was also reported. In this experiment, the organic carbon present in the pyrolysis residue, acts as water absorbent and doesn't allow indiscriminate movement of nutrients, but retains them in the area of the root system. The lowest level of organic matter was observed in the option without natural humate tablets or pyrolysis residue.

Table 2. Technical efficiency of natural humate tablets in apple rootstock production

Option	Natural humates tablets	Number of shoots/plants	Number of plants per da	Rootstocks	Change
	kg/da			units/da	%
1	0	16.32	1,666	27,189.12	0,00
2	25	17	1,666	28,322	+ 4.17
3	50	17.33	1,666	28,871.78	+ 6.19

Source: Own experiments 2019-2021.

The technical efficiency, measured in this case as the number of rooted apple rootstocks per unit of area, was improved when natural humate tablets were used. The yield of quality rooted apple rootstocks increased by 4.17% in the variant with 25 kg/da humate tablets and by 6.19% in the variant with 50 kg/da. In the first case it is an increase of 1132 pieces, and in the second case, the increase is by 1682 pieces, compared to the option 1 (without soil improvers) (Table 2).

Economic efficiency of apple rootstock production was also positively affected by the addition of natural humate tablets in the soil.

As it can be seen above, the yield y (TPP) grows with the increase of natural humate tablets per unit area (Fig. 1). According to the methodology, the variable input resource must follow increasing trend as long as the revenue generated from the sale of last unit of additional product is greater than the cost of the last unit of input that caused this increase. In other words, if the marginal revenue is greater than the marginal cost (the price of one unit of input resources), MR > MC (Px1), the option is cost effective and creates added value per unit of production. In both cases of adding natural humate tablets, this is met and it can be seen from the values of marginal income (MI), which is positive (Table 3).

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 2, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

Table 3. Economic results

Option	x1	y (TPP)	APP	MPP	Py	Px1 (MC)	MR	MI
1	0	27,189.12	0.00	0.00	0.30	0.00	0.00	0.00
2	25	28,322.00	1,132.88	45.32	0.30	2.50	13.59	11.09 > 0
3	50	28,871.78	577.44	21.99	0.30	2.50	6.60	4.10 > 0

Source: Own experiments 2019-2021.

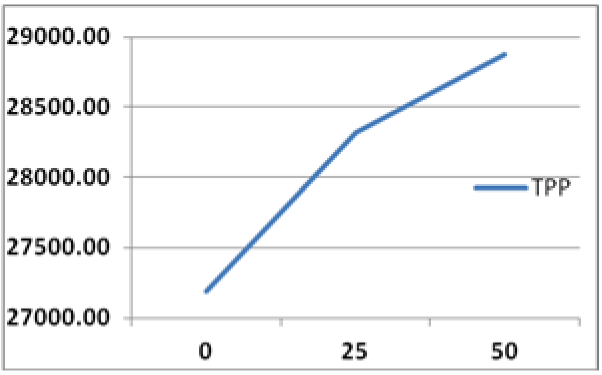

Fig. 1. Number of rooted apple rootstocks (pc/da) under the 3 technologies
Source: Own experiments 2019-2021.

In order to isolate the net economic benefit from the two technological options, the methodology for calculation of the factor income was used.

TFI = TFR – TFC.....................................(6)

Calculations on economic efficiency, shown in the following table are made on the bases of market price of humate tablets of BGN 10/kg and market prices of the finished apple rootstocks of BGN 0.30/pc (Table 4). As pointed out in the methodology part, natural humate tablets are introduced into the soil once every four years, enough for maintaining the necessary soil composition to provide optimal conditions for the development of apple rootstocks.

Table 4. Revenue, cost and income of natural humate tablets (BGN/da)

Option	TFC	TFR	TFI
1	0	0	0
2	62.50	339.86	277.36
3	125.00	504.80	379.80

Source: Own experiments 2019-2021

Graphically, the utility of natural humate tablets, added as soil improvers in the apple rootstock cultivation is presented in Fig. 2. It is obvious that under option 2, spending the cost of BGN 62.5/da for humate tablets per year provides BGN 339.86/da more revenue, which guarantees a net added value of BGN 277.36/da. In option 3, the extra revenue is BGN 504.80/da and the added value is BGN 379.80/da (Table 4).

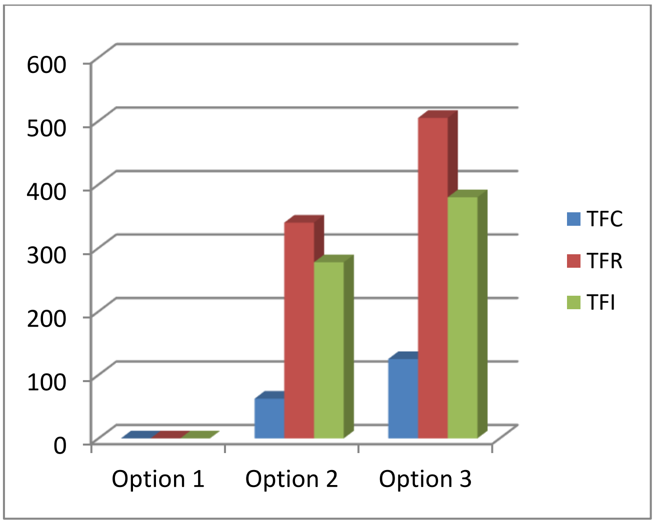

Fig. 2. Factor revenue, factor cost and factor income (BGN/da)
Source: Own experiments 2019-2021.

It can be concluded that using natural humate tablets for improving the soil composition when producing apple rootstocks is technically and economically efficient.

From the conducted experiments it is obvious that Option 3, with 50 kg/da humate tablets is more efficient, providing 6.19% more rootstocks and almost BGN 380/da added value.

The technical efficiency, measured as the number of rooted apple rootstocks per unit area, increased by the use of pyrolysis residue. The yield of quality rooted rootstocks went up by 5.5% in the case with 250 kg/da and by 11.75% in the case with 500 kg/da. Under option 2, this was an increase of 1,466 pieces over option 1. Under option 3, the increase was even higher (+3,132 pieces), over the base option (Table 5).

Table 5. Technical efficiency of pyrolysis residue used in apple rootstock production

Option	Pyrolysis residue	Number of shoots/plant	Number of plants per da	Rootstocks	Change
	kg/da			units/da	%
1	0	16	1,666	26,656	0.00
2	250	16.88	1,666	28,122.08	+5.50
3	500	17.88	1,666	29.788.08	+11.75

Source: Own experiments 2019-2021.

The economic efficiency of the production of apple rootstocks was also positively affected by the use of pyrolysis residue.

As it can be seen above, the yield y (TPP) grows when the quantity of pyrolysis residue added to the soil is going higher.

Table 6. Economic results

Option	x1	y (TPP)	APP	MPP	Py	Px1 (MC)	MR	MI
1	0	26,656	0	0	0.3	0	0	0
2	250	28,122.08	112.49	5.86	0.3	0.25	1.76	1.51
3	500	29,788.08	59.58	6.66	0.3	0.25	2.00	1.75

Source: Own experiments 2019-2021.

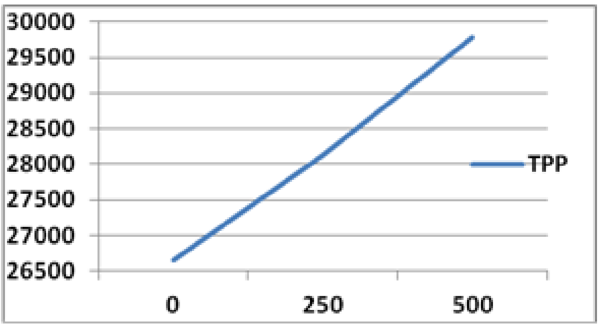

Fig. 3. Number of rooted apple rootstocks (pc/da) under the 3 technologies
Source: Own experiments 2019-2021.

Again, according to the methodology, the variable input resource must follow increasing trend as long as the revenue generated from the sale of last unit of additional product is greater than the cost of the last unit of input that caused this increase.
In other words, if the marginal revenue is greater than the marginal cost (the price of one unit of input resources), MR > MC (Px1), the option is cost effective and creates added value per unit of production. In both cases of adding pyrolysis residue, this is met and it can be seen from the values of marginal income (MI), which is positive (Table 6).
In order to isolate the net economic benefit from the two technological options, the methodology for calculation of the factor income was used.

TFI = TFR – TFC ....(7)

Calculations on economic efficiency, shown in the following table are made on the bases of market price of pyrolysis residue of BGN 1/kg and market prices of the finished apple rootstocks of BGN 0.30/pc.
Pyrolysis residue too is introduced into the soil once every four years.
This is enough to maintain the necessary soil composition to provide optimal conditions for the development of apple rootstocks.

Table 7. Revenue, cost and income of pyrolysis residue (BGN/da)

Option	**TFC**	**TFR**	**TFI**
1	0	0	0
2	62,5	439.82	377.32
3	125	939.62	814.62

Source: Own experiments 2019-2021.

Graphically, the utility of pyrolysis residue, added as soil improver in the apple rootstock cultivation is presented in Fig. 4. It is obvious that under option 2, spending the cost of BGN 62.5/dka for pyrolysis residue per year provides BGN 439.82/dka more revenue, which guarantees a net added value of BGN 377.32/dka. In option 3, the extra revenue is BGN 939.62/dka and the added value is BGN 814.624/dka (Table 7).

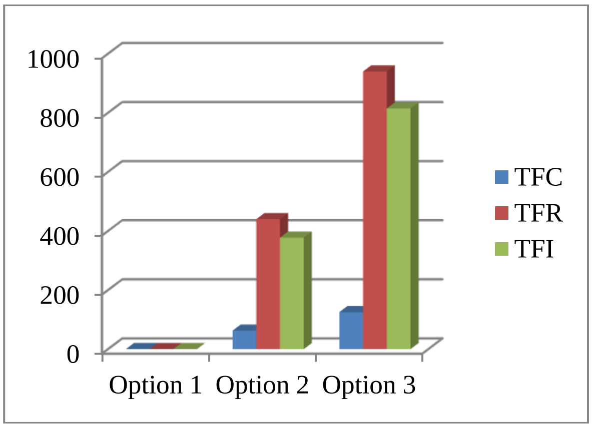

Fig. 4. Factor revenue, factor cost and factor income (BGN/da)
Source: Own experiments 2019-2021.

It can be concluded that using pyrolysis residue for improving the soil composition when producing apple rootstocks is technically and economically efficient. From the conducted experiments it is obvious that Option 3, with 500 kg/da pyrolysis residue is more efficient, providing 12% more rootstocks and more than BGN 800/da added value.

CONCLUSIONS

Reducing the environmental pressure along the products life cycle, increasing efficiency in the consumption of resources and use of renewable raw materials, and shifting the economic system toward a circular and a climate-neutral model represent the heart of the current macro-trends of the European Union (EU) policy agendas. The circular economy and bioeconomy concepts introduced in the EU's Circular Economy Action Plan and the Bioeconomy Strategy support innovation in rethinking economic systems focusing on market uptaking of greener solutions based on lessintensive resource consumption (Gatto, F.; Re, I. 2021).
The impact of two soil additives (natural humates and pyrolysis residue) in two different quantities each on the technical and economic efficiency of appale rootstock production was evaluated and assessed. The results shown in the analyses were obtained during a three year experiment at the Agricultural University – Plovdiv. This eloquently showed that the innovative technology, consisting of some simple, easy and cheap steps and practices, turned out to be efficient and at the same time sustainable. The economic and environmental benefits, obtained by the use of natural humates and pyrolysis residues should be further popularized. They improve the soil organic conditions, which impact on the quantity and quality of the production of apple rootstocks. The technology could be used in other agricultural production sectors with the same or even better success. In the era of technological, scientific and educational innovations, such possibilities should be employed in order to achieve society's higher demand for food and fiber, with less natural resources and ever challenging social, economic and environmental conditions and policies.

REFERENCES

[1]Beluhova-Uzunova, R., M. Shishkova, B. Ivanova 2019. Concepts and Key sectors of the Bioeconomy, Trakia Journal of Sciences, Vol. 17, Suppl. 1, pp 227-233, 2019.
[2]BW.de, Bioekonomie, https://www.biooekonomie-bw.de/en/bw/definition, Accessed on June 11, 2021.
[3]European Commission, Horizon 2020, Details on EU funding Programme which ended in 2020 and links to further information, https://ec.europa.eu/programmes/horizon2020/en/h2020-section/bioeconomy, Accessed on June 07, 2021.
[4]European Environment Agency, 2018 The circular economy and the bioeconomy – Partners in sustainability, doi: 10.2800/02937, Accessed on June 11, 2021.
[5]Gatto, F., Re, I., 2021, Circular Bioeconomy Business Models to Overcome the Valley of Death. A Systematic Statistical Analysis of Studies and Projects in Emerging Bio-Based Technologies and Trends Linked to the SME Instrument Support. Sustainability 2021, 13, 1899, https://doi.org/10.3390/su13041899, Accessed on June 10, 2021.
[6]Loiseau, E., Saikku, L., Antikainen, R., Droste, N., Hansjurgens, B., Pitkanen, K., Leskinen, P., Kuikman, P., Thomsen, M., 2016. Green Economy and related concepts: An overview. Journal of Cleaner Production, pp. 361–271, 2016. https://doi.org/10.1016/j.jclepro.2016.08.024, Accessed on June 08, 2021.
[7]Mihaylov, M., Krinkov, H., Todorova, S., Aleksiev, A., Zapryanov, A., Penov, I., 2002, Agricultural Economics, Academ¬ic Publishing House of the Agricultural University of Plovdiv, 70-73 (Bg).
[8]Popova R., Dobrevska, G., Dzhugalov, H., Kaymakanov, P., Paralinov, H., 2015, Soil

characteristics of the Training and Experimental Field of the Department of Fruit Growing - AU - Plovdiv in the area of the village of Brestnik. Jubilee Scientific Conference with International Participation "70 Years of Agricultural University", Round Table "Soil Health - Mission of the Future", Scientific Papers of AU, Volume 59, Vol. 5, Academic Publishing House of the University of Plovdiv.

[9]Vanhamaki, S., Medkova, K., Malamakis, A., Kontogianni, S., Marisova, E., Dellago, D.H., Moussiopoulos, N., 2019, Bio-based Circular Economy in European National and Regional Strategies, 2019 WIT Press, http://www.witpress.com/journals DOI: 10.2495/SDP-V14-N1-31-43, Accessed on June 11, 2021.

[10]Youmatter.world, 2020, Bioeconomy definition: Benefits, Economic growth and Sustainability, https://youmatter.world/en/definition/bioeconomy-definition, Accessed on June 11, 2021.