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ENHANCING SUSTAINABLE TOMATO CROP PRODUCTION IN ECOLOGICAL SYSTEMS THROUGH THE USE OF BIOCHAR AND WOOD VINEGAR

Dan Ioan AVASILOAIEI, Mariana CALARA*, Claudia BĂLĂIȚĂ, Andreea ANTAL-TREMURICI

Vegetable Research and Development Station Bacău, 220 Calea Bârladului Street, Bacău, Romania

KEYWORDS

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ABSTRACT

The escalating demands for sustainable agricultural practices have led to the exploration of eco-friendly approaches to improve crop yield and soil health in ecological systems. This study investigates the synergistic effects of biochar and wood vinegar applications on tomato (*Solanum lycopersicum* L.) growth, yield, and ecological sustainability. A field experiment was conducted over 2023 growing season, during which `Bacuni` tomato variety was subjected to three treatments, including the application of biochar, wood vinegar, and Cropmax. Results indicated that the application of biochar and wood vinegar significantly enhanced tomato plant growth, as evidenced by greater plant height, number of leaves and fruits per plant, and overall biomass production. In addition to improved vegetative growth, tomato fruit production and quality was notably increased in the biochar and wood vinegar-amended plots. The enhanced fruit yield was attributed to the improved availability of essential nutrients, as well as the natural fungicidal properties of wood vinegar that reduced the incidence of soil-borne diseases. These findings highlight the potential use of biochar and wood vinegar as eco-friendly cultivation practices in order to promote ecological sustainability in tomato crop production.

INTRODUCTION

The global demand for tomatoes (*Solanum lycopersicum* L.) continues to rise as these versatile fruits are a staple in countless culinary dishes and contribute essential vitamins and minerals to human diets. As a consequence, tomato production faces the dual challenge of meeting this growing demand while minimizing the environmental impact associated with conventional agricultural practices. In response, ecological systems offer a promising avenue for sustainable tomato cultivation, emphasizing ecological stewardship, reduced chemical inputs, and improved resource efficiency. The challenges for organic tomato growers stemming from the prohibitive costs of inputs encompass a broad spectrum of obstacles, from the financial burden of acquiring organic fertilizers, pesticides, and soil amendments, to the additional expenses associated with organic certification, specialized equipment, and labor-intensive weed and pest management practices, all of which collectively strain the economic viability of organic tomato production.

Organic vegetable growers have a variety of fertilizer options at their disposal to enhance soil fertility, improve plant health, and meet organic certification standards. Each fertilizer type has its advantages and limitations, and their selection should align with the specific needs of the crop, soil conditions, and regional organic regulations. Effective organic vegetable production relies on a holistic approach to soil and crop management, with the careful integration of approved organic fertilizers playing a pivotal role in achieving sustainability and environmental responsibility.

Ecological tomato cultivation prioritizes the principles of environmental sustainability, social responsibility, and economic viability. Within this context, the selection and application of appropriate fertilizers are pivotal in achieving optimal yields while maintaining ecological balance. This paper explores the potential benefits and

* Corresponding author: Calara M.
E-mail address: calaramariana@gmail.com
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challenges associated with the application of biochar, wood vinegar, and CropMax fertilizers in ecological tomato production.

Biochar, a carbon-rich material produced by the pyrolysis of biomass, has gained recognition for its capacity to enhance soil structure (Blanco-Canqui, 2017), water retention (Kassaye et al., 2022), and nutrient availability, which can lead to improved tomato growth and yield. Furthermore, biochar contributes to long-term carbon sequestration in soils, making it an attractive tool for mitigating climate change by promoting carbon neutrality in agriculture (Liu et al., 2014; Brown et al. 2015).

Wood vinegar, a complex mixture of organic compounds produced through the pyrolysis of wood, is also gaining attention for its ability to enhance plant growth, disease resistance, and pest management. Its use in ecological tomato cultivation can reduce the reliance on synthetic chemicals while improving crop health and productivity (Mungkunkamchao et al. 2013, Akhtar et al., 2014)

CropMax, a commercially available organic fertilizer, is formulated with a blend of organic materials, beneficial microorganisms, and essential nutrients. This unique combination offers a comprehensive approach to improving soil fertility and supporting tomato plants throughout their growth cycle.

Tomatoes, due to their sensitivity to environmental conditions and pest pressures, can benefit from the integration of these novel ecological fertilizers into cultivation practices. To date, research exploring the combined application of biochar, wood vinegar, and CropMax in tomato production is limited, and a comprehensive understanding of their individual and interactive effects on tomato crop performance is needed to facilitate informed decision-making for sustainable agriculture.

MATERIALS AND METHODS

The study was conducted in the ecological agriculture plot within Vegetable Research and Development Station Bacău research domain, on a developed medium alluvial soil with a loam-sandy composition, a *p*H level of 6.2-6.8 and an organic matter content within the range of 2-2.6%. Cultivation practices followed the guidelines of organic farming, as per the current regulations (EU Regulation 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products). The tomato seedlings were cultivated within a controlled greenhouse environment, utilizing nutrient cubes and alveolar trays, being sown on March 14th and subsequently planted in the field on May 17th. Disease and pest control exclusively relied on approved copper-based products (2 treatments with Boille Bordellaise - 0,5% were performed during the vegetation season). The irrigation was carried out using sprinklers from May through the first ten days of September. The weather conditions of 2023 vegetation season are presented in Table 1.

Table 1. 2023 weather conditions of vegetation season

Month (Average)	Air temperature (°C)	Solar radiation (W/m^2)	Air Relative Humidity (%)	Wind Speed (m/s)	Soil temperature (°C)	Daily evapotranspiration (ET0) (mm)
September	18.86	172.77	71.33	0.8	18.62	2.62
August	23.03	222.23	66.38	0.65	22.06	3.77
July	22.58	233.81	70.93	0.84	23.02	4.15
June	20.06	223.07	63.37	1.20	21.26	4.03
May	15.91	221.06	57.85	1.62	16.05	3.90

During the growing season, two extreme meteorological events occurred in July, with a one-week interval between them, characterized by heavy rain, whirlwind and large hailstorms causing significant damage to the estimated crop production. Consequently, the fruits that showed signs of damage were removed from the crop to prevent the onset of cryptogamic diseases.

Biological material

`Bacuni` is a mid-early variety of tomato, developed at VRDS Bacău, characterized by determined growth and a height ranging from 65 to 80 cm. The fruits are round shapede, displaying a consistent red hue upon reaching physiological maturity, typically weighting between 90-110 grams each, with four to five seed lodges and a noteworthy degree of firmness. More than 75% of the total yield is classified as Ist Grade and Extra Quality categories. It is cultivated for both fresh consumption and canning, featuring a potential yield of 100-110 t/hectare.

Inputs utilized for the assessment of outcomes

The biochar used in the experiment is commercially known as Bio-GEKKA S, and it is produced by the company Expoclom GK SRL through the pyrolysis carbonization of biomass. It possesses the following

characteristics: bulk density < 3mm - 276 kg/m^3, specific surface area (BET) - 557.76 m^2/g, ash content (550 degrees) - 4.1% (w/w); organic carbon (C) - 91.3% (w/w); total nitrogen (N) - 0.66% (w/w); potassium (K) - 0.25% (w/w); sodium (Na) - 0.02% (w/w); calcium (Ca) - 1.1% (w/w); iron (Fe) - 0.09% (w/w); magnesium (Mg) - 0.05% (w/w); manganese (Mn) - 0.04% (w/w); sulfur (S) - 0.03% (w/w); water retention capacity - 162.5%; moisture - 6%; pH value - 8.76 $CaCl_2$, EPA-PAH (without LOQ) - 6 mg/kg.
The wood vinegar used in the experiment is commercially known as Bio-GEKKA L and is produced by the same company as the biochar (Expoclom GK SRL). It is a byproduct of biomass carbonization through pyrolysis, containing acetic acid and pyroligneous acid. It exhibits the following characteristics: organic carbon (C) - 14 g/l; Kjeldahl nitrogen - 3.37 mg/dm^3; potassium (K) - <20 mg/dm^3; boron (B) - <2 mg/dm^3; copper (Cu) - <0.4 mg/dm^3; iron (Fe) - 533 mg/dm^3; phosphorus (P) - <0.4 mg/dm^3; magnesium (Mg) - 0.809 mg/dm^3; manganese (Mn) - 3.42 mg/dm^3; *p*H value - 4.24; nitrites (NO_{2-}) <5 mg/dm^3; nitrates (NO_{3-}) <5 mg/dm^3.
Cropmax is a concentrated foliar fertilizer featuring the following attributes: *p*H level of 7, nitrogen (N_2) content at 0.2%, phosphorus pentoxide (P_2O_5) at 0.4%, potassium oxide (K_2O) at 0.02%, iron (Fe) concentration of 220 mg/L, magnesium (Mg) content of 550 mg/L, and calcium (Ca) at 10 mg/L.

Experimental display

The randomized experimental field consisted in four variants and three replicates (seven plants/replicate), displayed in one row, as presented in Table 2.

Table 2. Experimental display

Variant	Experimental variants	Interpretation
V1	1 Biochar application * 2 Cropmax treatments	Biochar - uniform application at the soil level, followed by Skin-deep incorporation. Cropmax treatment - a dosage of 10 ml per 10 liters of water per 100 square meters
V2	2 Wood vinegar * 2 Cropmax treatments	Wood vinegar treatment - a dosage of 20 ml per 10 liters of water per 100 square meters Cropmax treatment - a dosage of 10 ml per 10 liters of water per 100 square meters
V3	2 Cropmax treatments	Cropmax treatment - a dosage of 10 ml per 10 liters of water per 100 square meters
V4	Control (untreated)	

Figure 1 shows the placement of the tomato crop and the application of biochar following the establishment of the experiment, with superficial incorporation at the soil level.

Figure 1. Experimental setup and biochar application on the tomato crop (original photo)

Quantitative evaluations

Some biometrical characteristics, such as the plant height, number of leaves/plant, stem diameter, number of flowers/plant, number of inflorescences/plant and number of fruits/plant were determined in two succesive months (June and July), the results being expressed in dynamics. Both the chlorophyll pigments and anthocyanin content were measured using two similar devices, CCM 200 plus and ACM 200 plus, manufactured by Optisciences. The results obtained were expressed using indices that accurately represent the total concentration of chlorophyll pigments and anthocyanins, namely the Chlorophyll Concentration Index and the Anthocyanin Content Index.
The yields obtained for the four variants were expressed per plant as differences between the variants, considering that extreme weather events significantly influenced the quantity of the harvest.

Qulitative evaluations

The assessment of the quality of organically grown tomato under the influence of the three treatments performed was determined by evaluating various factors like total soluble solids (TSS), titratable acidity (TA) measured in malic acid, dry matter content (DM), water content (W), carotene content and lycopene levels.
Total soluble solids (TSS) - using a precision portable refractometer; results are expressed in ◦Brix, according to 932:12 methods (AOAC, 2005).

Dry matter content (DM) - fresh, homogenized samples were subjected to a forced air drying oven (Biobase) at a temperature range of 103 ± 2°C for a period of 24 hours until a consistent weight was achieved, as outlined in AOAC (2000) guidelines (see Figure 2); results are expressed in %.
Water content (W) - It was determined using the formula: W% = 100% - DM%.

β-carotene and lycopene content - were extracted using petroleum ether and the quantitative analysis was conducted spectrophotometrically at distinct wavelengths: 452 nm for β-carotene and 472 nm for lycopene; to determine the total β-carotene and lycopene fractions, the absorbance values were multiplied by a factor of 19.96 and 14.495, respectively (see Figure 3). The results were then reported as milligrams per 100 grams of fresh weight (mg·100 g^{-1} F.W.).

Figure 2. Determination of total dry matter content (original photo)

Figure 3. Determination of β-carotene and lycopene content (original photo)

Titratable acidity (TA) - was calculated using the following equation: % malic acid= mL NaOH x F x 25 x 2 x 0.0067 (see Figure 4).

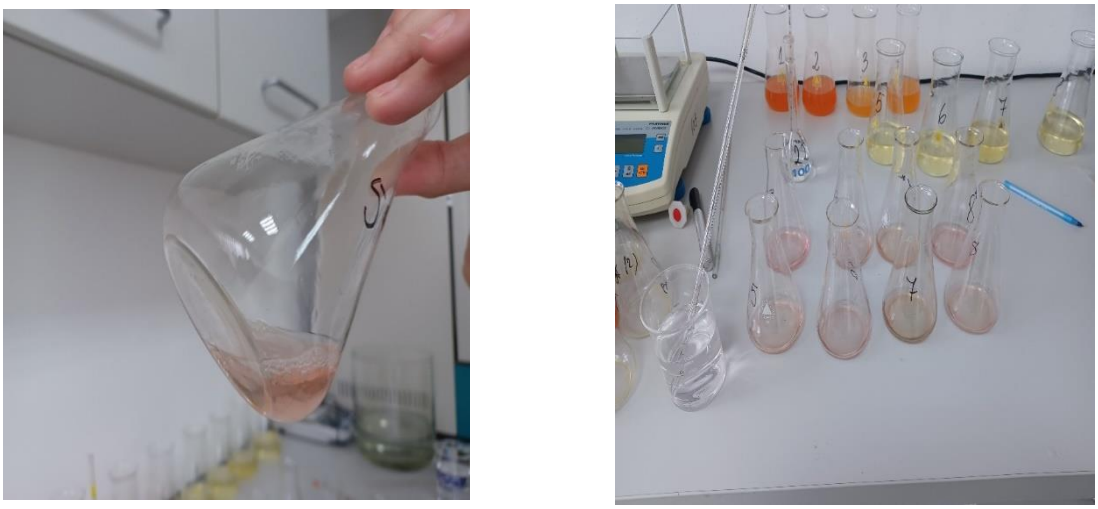


Figure 4. Titratable acidity (TA) determination in tomato fruits (original photo)

The results were presented as averages with accompanying standard errors. The statistical significance among the four variants regarding the total yield obtained per plant was analyzed using the ANOVA test.

RESULTS AND DISCUSSION

To assess the impact of the three treatment recipes applied in the organic tomato cultivation, we conducted a series of quantitative measurements as well as evaluations related to the production quality. Furthermore, the quantitative aspects were further divided into indicators for vegetative growth and indicators for generative growth.

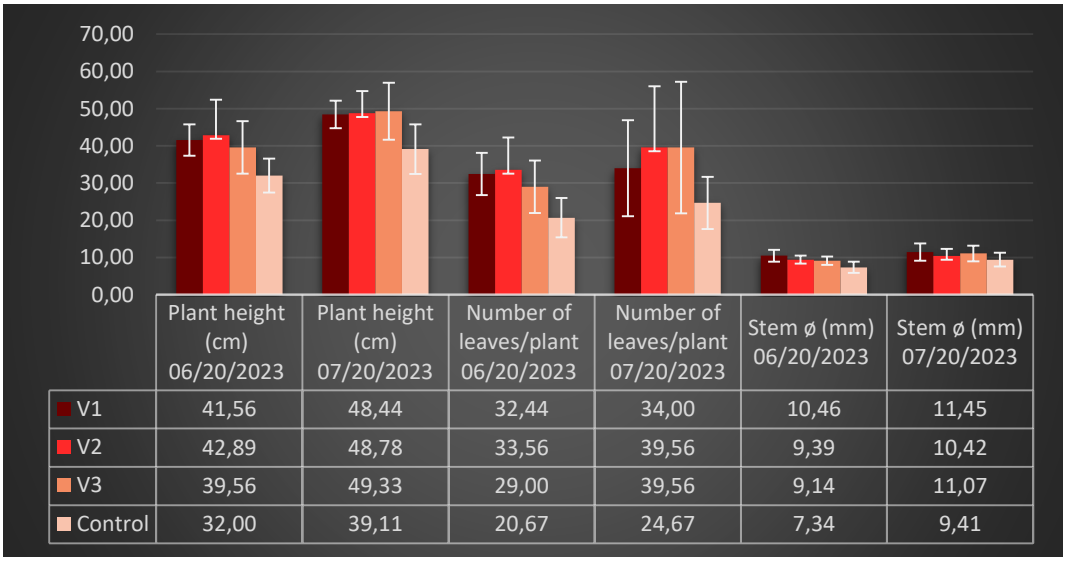
Quantitative evaluations

Vegetative growth indicators

Plant Height (cm)
In June, V2 variant had the highest plant height at 42.89 cm, followed closely by V1 at 41.56 cm. V3 had slightly shorter plants, with a recorded value of 39.56 cm, while the Control (V4) recorded the lowest value of 32.00 cm. In July, the plant heights increased for allvariants, with V3 having the highest height at 49.33 cm, followed by V2 at 48.78 cm and V1 at 48.44 cm. The Control (V4) also showed an increase to 39.11 cm. As such, the dynamics of plant height show a consistent increase from June to July for all treatments, with V3 having the highest plant height in July, indicating its potential for promoting tomato plants growth.

Number of Leaves per Plant
In June, V2 variant had the highest number of leaves per plant at 33.56, followed by V1 at 32.44. V3 had fewer leaves at 29.00, while the Control (V4) had the fewest at 20.67. In July, V2 maintained the highest number of leaves at 39.56, indicating a significant increase. V3 also had 39.56 leaves per plant, while V1 had 34.00 leaves. The control (V4) increased to 24.67 leaves. Thus, the number of leaves per plant increased for all treatments in July, with V2 variant recording the highest level, suggesting its positive impact on leaf development.

Stem Diameter (mm):
In June, the V1 variant had the highest stem diameter at 10.46 mm, followed by V2 at 9.39 mm. V3 had a slightly smaller stem at 9.14 mm, while the Control (V4) had the smallest diameter at 7.34 mm. In July some exchanges occured, with V3 variant having the highest stem diameter at 11.07 mm, followed by V1 at 11.45 mm. V2 had a slightly thinner diameter at 10.42 mm, while the Control (V4) recorded the lowest value of 9.41 mm. So, stem diameter exhibited growth over time for all variants, with the V3 hone aving the highest stem diameter in July (Figure 5).



	Plant height (cm) 06/20/2023	Plant height (cm) 07/20/2023	Number of leaves/plant 06/20/2023	Number of leaves/plant 07/20/2023	Stem ø (mm) 06/20/2023	Stem ø (mm) 07/20/2023
V1	41,56	48,44	32,44	34,00	10,46	11,45
V2	42,89	48,78	33,56	39,56	9,39	10,42
V3	39,56	49,33	29,00	39,56	9,14	11,07
Control	32,00	39,11	20,67	24,67	7,34	9,41

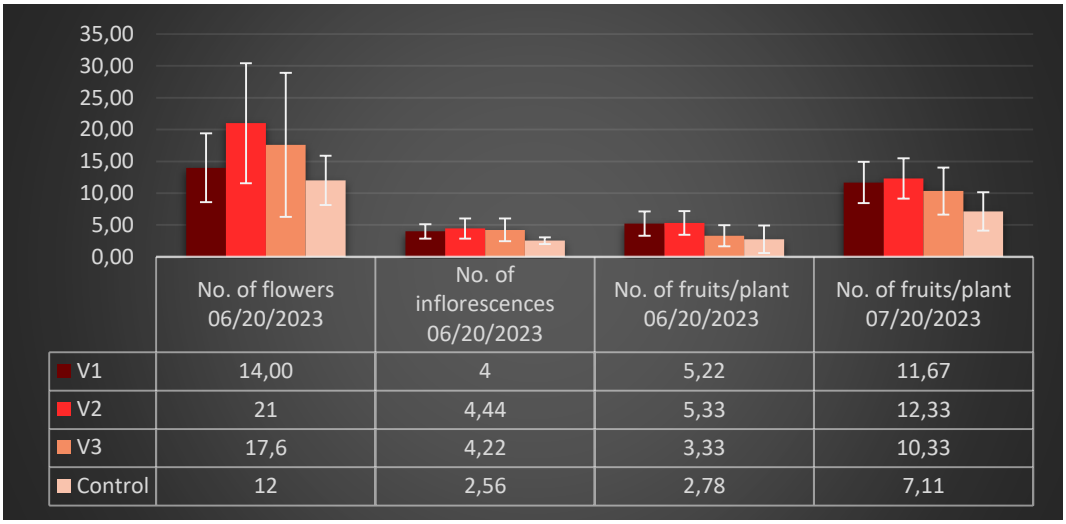
Figure 5. The influence of the three studied products on some plants growth metrics

Generative growth indicators

Number of flowers per plant
In June, the V2 variant (wood vinegar) recorded the highest number of flowers per plant (21 flowers), indicating a notable increase in flowering. The V3 variant (Cropmax) also had a relatively high number of flowers at 17.6. Furthermore, the V1 variant (Biochar) had 14 flowers per plant, while the Control variant (V4) had the fewest at 12.

Number of inflorescences per plant
Similar to the number of flowers per plant, regarding the number of inflorescences/plant, the V2 stands out with the highest number of 4.44 inflorescences, indicating a robust development of flowering clusters. Quite similar, the V3 variant had 4.22 inflorescences per plant, while the V1 variant recorded 4 inflorescences per plant, as opposed to the Control variant (V4) with the fewest inflorescences - 2.56.

Number of Fruits per Plant
In June, the number of fruits per plant was the highest for V2 variant at 33.56, followed by V1 at 32.44. The V3 variant had 29 fruits, and the Control (V4) had 20.67. In July, the number of fruits per plant increased for all variants. V2 had the highest at 12.33, followed by V1 at 11.67. The V3 variant had 10.33, while the Control one (V4) had only 7.11 fruits/plant (Figure 6).



	No. of flowers 06/20/2023	No. of inflorescences 06/20/2023	No. of fruits/plant 06/20/2023	No. of fruits/plant 07/20/2023
V1	14,00	4	5,22	11,67
V2	21	4,44	5,33	12,33
V3	17,6	4,22	3,33	10,33
Control	12	2,56	2,78	7,11

Figure 6. The influence of the three studied products on some reproductive development metrics

In conclusion, it seems that wood vinegar stands out as the input that had the most significant impact on the number of flowers, inflorescences, and fruits. It exhibited the highest number of flowers and inflorescences in June and had the highest number of fruits in both June and July. Cropmax also showed positive effects on flower production and fruit yield, although not as pronounced aswood vinegar. Biochar variant had slightly fewer flowers and inflorescences than wood vinegar and Cropmax ones in June, but it still contributed to a healthy fruit yield in both June and July months.

Chlorophyll and anthocyanin content

Chlorophyll Content
In June, the V1 variant recorded the highest chlorophyll content index at 58.02, indicating that Biochar contributed to a higher level of chlorophyll in tomato plants grown in organic system. The Control variant had the second-highest index at 45.14, followed by V3 at 43.17 and V2 at 48.34. In the next month, chlorophyll content decreased for all variants, with V1 still having the highest index at 44.69. The V3 variant had the second-highest index at 41.13, followed by V2 at 33.67 and V4 at 24.23.

Anthocyanin Content
In June, the V1 variant had the highest anthocyanin content index at 16.59, indicating a high level of anthocyanin in tomato plants treated with Biochar. It follows, in descending order, the V4 variant which had the second-highest index at 13.12, followed by V3 at 11.8 and V2 at 11.83. In July, anthocyanin content decreased for all variants. V1 still had the highest index at 11.61, followed by V4 at 11.26, V3 at 9.76, and V2 at 9.84 (Figure 7).
Thus, In June, the Biochar variant displayed the highest levels of both chlorophyll and anthocyanin content. This suggests that the wood charcoal had a positive effect on the photosynthetic pigments (chlorophyll) and secondary metabolites (anthocyanin) in tomato plants. The control variant also had relatively high values in June, indicating that natural growth conditions contributed to chlorophyll and anthocyanin levels. The wood vinegar treatment had the second-highest chlorophyll content in June but had lower anthocyanin levels compared to the other treatments. Regarding the Cropmax treatment, it had intermediate values for both chlorophyll and anthocyanin content in June.
In order to enhance both photosynthetic activity and the production of secondary metabolites like anthocyanin, Biochar (V1) stands out as the promising option.

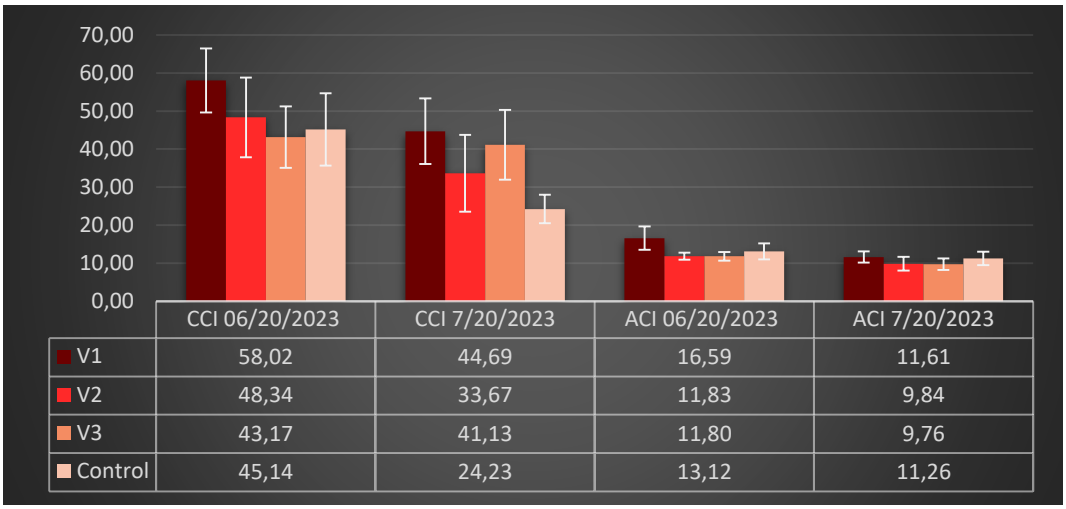


Figure 7. The influence of the three studied products on chlorophyll and anthocyanin levels

Yield per plant (g)

The Biochar variant (V1) recorded a yield percentage per plant of 127.04% compared to the Control variant (V4), indicating a 27.04% increase in yield. In the same way, the wood vinegar variant (V2) had a yield percentage of 117.11%, signifying an increase in yield by 17.11% compared to the Control.
Finally, the Cropmax treatment enhanced yield with a percentage of 17.07% compared to Control variant, generating a total yield percentage of 117.07%.
In terms of yield differences per plant, the V1 variant had a difference in yield of +99.67 g/plant compared to the Control, a very significant positive increase in the amount of harvested tomatoes per plant. The V2 variant generated a difference in yield of +26.33 g/plant compared to the control. This represents a distinct significant increase in the amount of harvested tomatoes per plant. The same conclusion can de drown in case of the V3 variant, where the difference in yield of +26 g/plant compared to the control also indicates a distinct significant positive increase in tomato yield (Table 3).

Table 3. The influence of the three studied products on tomatoes yield per plant

Variant	Absolute yield (g/plant)	Relative yield (%)	Absolute difference (g/plant)	Relative difference (%)	Significance
V1	938.00	127.04	199.67	27.04	***
V2	864.67	117.11	126.33	17.11	**
V3	864.33	117.07	126.00	17.07	**
V4 (Control)	738.33	100.00	0.00	0.00	

Ld 5% = 62.74 g Ld 1%= 95.01g Ld 0.1%= 152.64 g

Generally, all three treatments (V1, V2, and V3) exhibited significant increases in yield percentage compared to the control, with V1 having the highest increase at 27.04%. The differences in yield (measured in grams per plant) for all three treatments were notably positive, with V1 having the highest increase at +99.67 g/plant. These differences are categorized as "very significant" (V1) or "distinctly significant" (V2 and V3), and underscores the effectiveness of these treatments in boosting tomato yield. This finding are similar to those emphasized by other authors (Jeong et al., 2015; Pan et al. 2017; Simma et al., 2017; Lei et al. 2018).

Qulitative evaluations

Lycopene content
Regarding the lycopene content of tomato fruits, V2 variant had the highest lycopene content at 4.75 mg · $100g^{-1}$, indicating that wood vinegar contributed to a slightly higher lycopene level in tomatoes compared to the other treatments. V1 variant, where Biochar was used to augment the overall characteristics of tomato fruits, had a lycopene content of 4.32 mg · $100g^{-1}$, which was slightly lower than V2 but still higher than V3 and V4. At V3 variant, the lycopene content was of 4.12 mg · $100g^{-1}$, indicating a lower level compared to V2 and V1. In the same way, the Control variant had a lycopene content at 4.11 mg · $100g^{-1}$, which was very similar to V3.

Carotene content
On the carotene conten, V2 variant highlighted the highest carotene content at 5.11 mg · $100g^{-1}$, showing wood vinegar preeminence regarding antioxidant activities in tomato fruits. V3 variant had a carotene content of

4.55 mg · 100 g^{-1}, which was slightly lower than V2 but higher than V1 and V4. Moreover, V1 variant had carotene content of 4.27 mg · 100g^{-1}, indicating that Biochar had a slightly lower impact on carotene levels compared to V2 and V3. The Control variant (V4) had carotene content at 4.62 mg · 100g^{-1}, which was similar to V1 and V3.

Titrable Acidity

V2 variant exhibited the highest titrable acidity at 0.38%, indicating increased acidity levels when wood vinegar was used in organic tomato crops compared to the other treatments. The V4 variant (Control) had the second-highest titrable acidity at 0.3%. The V1 and V3 variants recorded titrable acidity values of 0.24% and 0.28%, respectively.

In order to summarize, the variant where wood vinegar was used had the highest levels of both lycopene and carotene, suggesting that wood vinegar was the most effective treatment in enhancing the content of these antioxidants in tomatoes. The utilization of Cropmax recorded moderate results, with carotene content slightly higher than the lycopene one. While not as effective as V2, it still had a positive impact on the nutritional content of tomatoes. Similarlly, when Biochar was used, slightly lower lycopene and carotene content compared to V2 and V3 were registered, but one can conclude that it still performed better than the Control variant (V4).

The control group (V4) had the lowest lycopene and carotene content, highlighting the potential benefits of the treatments used for enhancing the antioxidant content of tomatoes (see Figure 8).

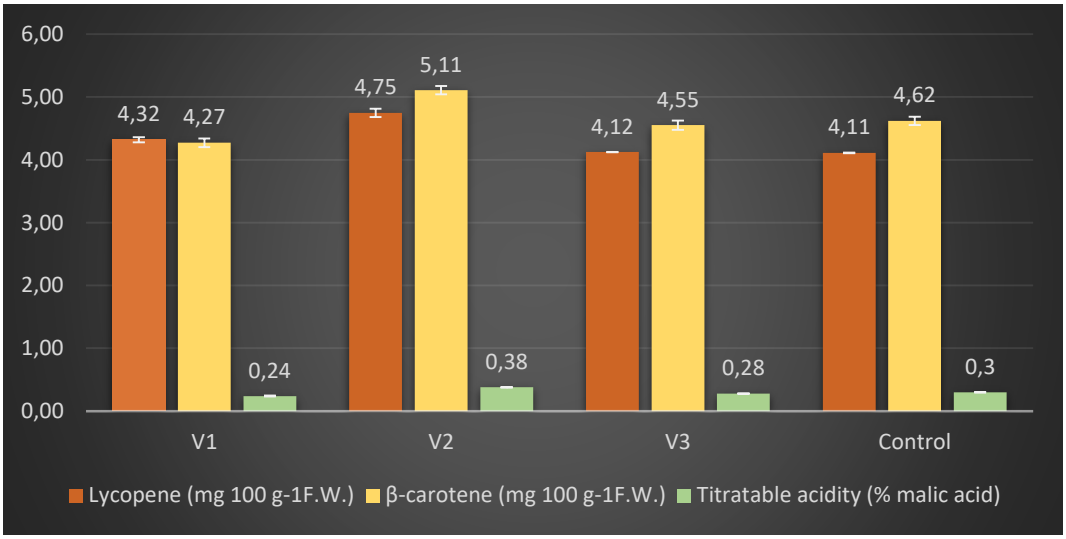


Figure 8. The influence of the three studied products on titrable acidity, lycopene and β-carotene content

Water Content (100%)

The control variant (V4) exhibited the highest water content at 96.4%, indicating that it had the highest level among all the treatments. This can be seen as a potential drawback since higher water content can affect the texture and taste of tomatoes. On the contrary, the V2 variant displayed the lowest water content at 94.8%, suggesting that wood vinegar had a dehydrating effect on the tomatoes. This could lead to a more concentrated flavor and better storage quality. The V3 variant fell in between V1 and V2 variants regarding water content. Despite not having the same dehydrating effect as V2, Cropmax fertilizer still showed a reduction in water content compared to the Control (V4).

Dry Matter content (%)

The V2 variant exhibited the highest dry matter content at 5.2%. This indicates that wood vinegar played a significant role in reducing the water content and increasing the solid, dry matter portion of the tomatoes. Higher dry matter often corresponds to a more concentrated flavor and better suitability for processing into products like tomato paste or sauce.

While V1 variant had a slightly lower dry matter content compared to V2, it still contained more solid content than V3 and the Control (V4). This also suggests that Biochar contributed to a reduced water content and increased dry matter compared to the untreated variant.

Total Soluble Solids

The total soluble solids content varied but was generally higher in V1, V2, and V3 variants compared to the control (V4). These higher soluble solids are indicative of elevated sugar content, which can contribute to a sweeter and more flavorful tomato product.

Overall, V2 variant stands out as the most effective treatment for reducing water content, increasing dry matter, and elevating total soluble solids. This combination suggests that wood vinegar has a positive impact on tomato quality, making it potentially suitable for processing purposes. In the same way, the V1 variant also displayed a reduction in water content and an increase in dry matter and total soluble solids, indicating its potential to enhance the quality of tomatoes, especially in terms of flavor and suitability for processing. The V3 variant showed moderate results but was less effective in terms of reducing water content compared to V2. However, it still had a positive effect on the overall composition of the tomatoes (see Figure 9). The Control variant (V4) had the highest water content and the lowest dry matter and soluble solids, suggesting that all the products used for organic tomatoes were effective in altering these parameters and potentially improving the tomatoes' quality.

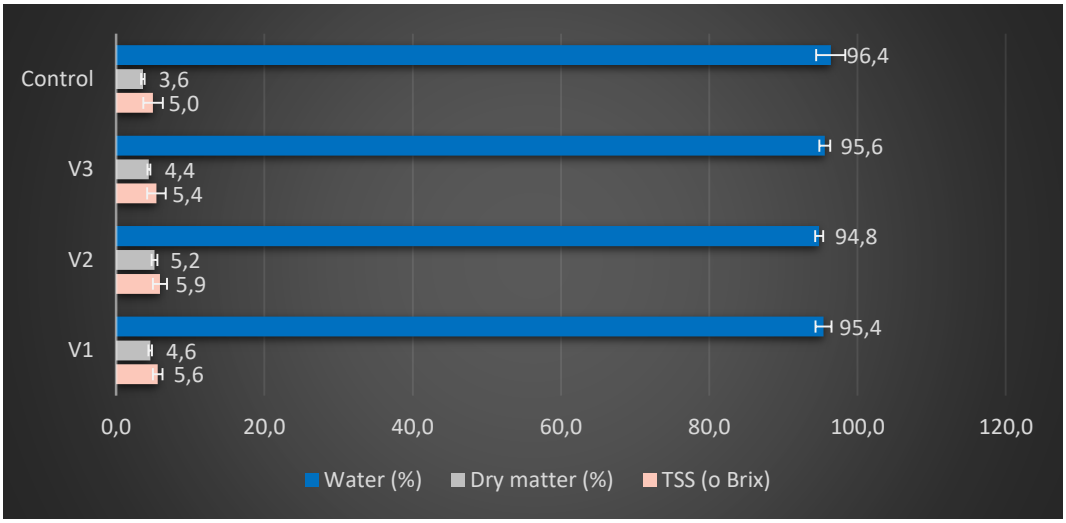


Figure 9. The influence of the three studied products on total soluble solids, water and dry matter content

CONCLUSION

Wood vinegar stands out as the most effective treatment for reducing water content, increasing dry matter, and elevating total soluble solids. This combination suggests that wood vinegar has a positive impact on tomato quality, making it potentially suitable for processing purposes. In the same way, Biochar also displayed a reduction in water content and an increase in dry matter and total soluble solids, indicating its potential to enhance the quality of tomatoes, especially in terms of flavor and suitability for processing.

Cropmax showed moderate results but was less effective in terms of reducing water content compared towood vinegar. However, it still had a positive effect on the overall composition of the tomatoes. The Control variant (V4) had the highest water content and the lowest dry matter and soluble solids, suggesting that all the inputs used for organic tomatoes were effective in altering these parameters and potentially improving the tomatoes' quality.

Wood vinegar appears to be the most effective treatment for promoting flower development, inflorescences, and fruit production. It resulted in the highest number of fruits in both June and July, suggesting its potential for improving tomato yield. Cropmax also showed positive effects on flower and fruit production, making it a promising treatment for enhancing tomato yield.

Biochar had a positive impact on fruit production and, to a slightly lesser extent, on flower development and inflorescences.

Biochar appears to be the most effective in significantly increasing tomato yield, with both a high percentage increase and a substantial difference in yield per plant. This suggests that it might have a strong positive impact on tomato production.

Wood vinegar also showed a significant increase in yield, though not as pronounced as Biochar. Nevertheless, it represents a valuable option for enhancing tomato harvest. Cropmax also displayed similar effects to wood vinegar in terms of increasing yield, demonstrating its potential for improving tomato production.

Due to the extreme weather events that occurred during the course of the experiment, it becomes imperative to repeat these experiments in the following years for the results to gain greater significance.

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