POTENTIAL OF PYROLYGENOUS EXTRACT FROM GRAPE WASTE FOR SOYBEAN GROWTH PROMOTION

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ABSTRACT

As the global population rises, so does the demand for food, leading to increased agro-industrial waste generation. Improper management of these wastes can harm the environment and human health. However, agro-industrial waste holds potential for valorization, promoting a circular economy and sustainable environmental management. Pyrolysis is a promising technology for waste valorization, producing biochar, pyroligneous extract, and gases. Pyroligneous extract, obtained from the condensable gases during pyrolysis, is rich in carbon and valuable chemical groups. Its composition varies based on the raw material and pyrolysis conditions, allowing for tailored applications. Beyond its common use in energy production, pyroligneous extract shows potential in agriculture for pest control, herbicides, fertilizers, soil conditioners, and plant growth promoters. This study aimed to evaluate pyroligneous extract from grape waste for soybean growth promotion. Results indicated that all tested dosages significantly increased root and aerial growth of soybean compared to the control. The biostimulant effects of pyroligneous extract are likely due to its carbon, nutrient content, phytohormones, and phenolic compounds, among others. This study highlights pyrolysis as a sustainable solution for managing agro-industrial waste and promoting plant growth, aligning with several UN Sustainable Development Goals.

Keywords: Pyrolysis. Bio-inputs. Plant growth promoter. Waste valorization. Circular economy.

1 INTRODUCTION

As the world population increases, the demand for food grows exponentially, leading to a significant rise in the generation of agro-industrial waste. Improper management of these wastes can negatively impact the environment and human health. On ther other hand, agro-industrial waste has great potential for valorization, promoting a circular economy and more sustainable environmental management. A promising technology for the valorization of these residues is pyrolysis, which allows for the production of products with various properties and applications, such as biochar, pyroligneous extract, and gases[1-4]. In recent years, pyroligneous extract has attracted the interest of researchers from various fields, including food, medicine, energy, and agronomy[1-3,5-7].

Pyroligneous extract is a liquid obtained from the condensable gases generated during the thermal degradation of waste in the pyrolysis process. This extract is rich in carbon and has a significant concentration of different chemical groups with high added value, which can be obtained through fractionation of the liquid[2,8]. The composition and yield of pyroligneous extract vary according to the type and composition of the raw material, as well as the conditions of the pyrolysis process. This allows for the modulation of compositions based on the desired application[5,7,9]. Despite its common use in energy production, pyroligneous extract shows promising potential for agricultural applications, including pest and disease control, herbicides, fertilizers, soil conditioners, and plant growth promoters[4,6,7,9,10]. In this context, the aim of this work was to evaluate the capacity of pyroligneous extract from grape waste to promote soybean growth.

2 MATERIAL & METHODS

The pyroligneous extract was obtained from the pyrolysis of wastes from grape processing. This pyrolyzed biomass includes the bagasse, stems and seeds of fresh grapes obtained from the fruit pressing process at a winery in Serra Gaúcha region. Pyrolysis was performed in a pilot-scale reactor with a capacity of 10 L of biomass/batch. For this study, 5 kg of grape processing wastes were introduced into the pyrolysis reactor, which can operate at temperatures of up to 850 °C. As the temperature increases, gases are released, and the liquid pyrolysis extract is obtained through the condensation of these gases.

The liquid extract from the pyrolysis of grape wastes was evaluated for its effects on the initial vegetative growth of plants. For this purpose, the test methodology was carried out in pots with the soybean crop. Five soybean seeds were planted in pots containing 300 g of soil. Then, the pots were taken to an incubation chamber and maintained at a controlled temperature of 20 ºC±2 ºC and a photoperiod with artificial light of 12h/12h (light/dark). Moisture was controlled as needed through manual watering. The tests were carried out according to a completely randomized design experiment, with 4 treatments and five replications each. The pyrolysis extract was applied directly to the soil at the initial time, in different dosages diluted in water, as follows: T0: control (without application of the aqueous pyrolysis fraction, just water); T2: 2 mL/L; T5: 5 mL/L; T10: 10 mL/L.

The experiments continued until tillering began (15 days after germination). The parameters were evaluated on 3 plants from each replication (n=15), as two seeds from each pot were thinned after observation of germination, to maintain standardization between treatments. The parameters measured concerning the aerial part of the plants were: seedling height (SH), stem diameter (SD) and dry mass of the aerial part (DMAP). The SH was determined by measuring the stem to the apex of the shoot with a graduated ruler, while the SD was measured with a digital caliper. DMAP was determined by weighing the aerial part kept at 50 ºC in a drying oven until constant weight.

Soybean roots were evaluated morphologically using a root scanner (Epson Expression 10000XL, Seiko Epson Corporation, Nagano, Japan). Using the WinRhizo software (Regent Instruments Inc., Sainte-Foy, QC, Canada), it was possible to determine the total length of the roots (TLR), as well as classify the roots as very thin (VTR: Ø < 0.5 mm), thin roots (TNR: Ø > 0.5 < 2 mm) and thick roots (TKR: Ø > 2 mm). The dry mass of the roots (DMR) was also measured. Finally, the Dickson Quality Index (DQI) (Equation 1) was determined to check the quality of seedlings[11]. The results were analyzed using analysis of variance (ANOVA), and the means were compared using the Tukey test at a 5% significance level.

$$DQI = \frac{(DMAP + DMR)}{(SH/SD) + (DMAP/DMR)} \tag{1}$$

Where: DQI: Dickson Quality Index; DMAP: dry mass of the aerial part (g); DMR: dry mass of the roots (g); SH: seedling height (cm); DC: stem diameter (mm).

3 RESULTS & DISCUSSION

The pyroligneous extract obtained from agro-industrial waste has several applications, including the agricultural, food, pharmaceutical and energy areas. More specifically on plant growth promotion, Ofoe et al.[6] reported that pyroligneous extract can increase the germination of tomato seeds and the growth of seedlings by improving the plants' defensive system in situations of oxidative stress. In this context, the pyrolysis extract from grape processing wastes was evaluated for its performance as a soybean growth promoter. Table 1 presents the results obtained from phytometric measurements of soybean seedlings.

Table 1. Phytometric parameters of soybean seedlings compared to different dosages of pyrolysis extract

Treatment	TLR (cm)	VTR (cm)	TNR (cm)	TKR (cm)	SH (cm)	SD (mm)	DMR (g)	DMAP (g)	DQI
T0	67,73^{a}	43,64^{a}	19,63^{a}	4,46^{a}	8,95^{a}	1,59^{a}	0,106^{a}	0,311^{a}	0,049^{a}
T2	116,42^{b}	63,40^{a}	41,54^{ab}	11,48^{ab}	9,55^{ab}	2,12^{b}	0,210^{b}	0,325^{ab}	0,088^{b}
T5	140,51^{b}	68,21^{a}	56,35^{b}	15,95^{b}	10,19^{ab}	2,01^{b}	0,266^{b}	0,335^{ab}	0,095^{b}
T10	131,24^{b}	63,41^{a}	52,22^{b}	15,61^{b}	10,57^{b}	2,28^{b}	0,236^{b}	0,353^{b}	0,096^{b}

T0: Control; T2: 2 mL/L T5: 5 mL/L; T10: 10 mL/L; TLR: total length of the roots; VTR: very thin roots (cm); TNR: thin roots (cm); TKR: thick roots; SH: seedling height (cm); SD: stem diameter (mm); DMR: dry mass of the roots (g); DMAP: dry mass of the aerial part (g); DQI: Dickson Quality Index; Different letters in the columns indicate significant difference by Tukey's test (p<0.05).

Most of the phytometric parameters presented show that the application of the pyrolysis extract resulted in a significant increase in the root and aerial part development of soybeans ($p<0.05$). All dosages tested resulted in higher TLR, SD, DMR and DQI than the control, while T5 and T10 were better than the control group for the TNR and TKR parameters ($p<0.05$). It is known that the increase in roots and aerial part in the initial phase of plant development tends to result in a higher-quality plant and, consequently, greater productivity. The DQI is a tool commonly used to check the quality of seedlings depending on various phytometric parameters[11]. The higher this coefficient, the better the quality of the seedling. The dry mass of the roots and stem diameter are the parameters with the greatest relationship with the DQI[12]. In the current research, both parameters showed a statistical difference compared to the control for soy, which resulted in a better DQI in all dosages of the pyrolysis extract ($p<0.05$).

Significant biostimulant effects observed in several phytometric parameters of soybean seedlings may be related to the levels of carbon, nutrients and other elements important for plant growth present in the product, which may have favored the development of soybean. Although water is its main component, pyroligneous extracts contain more than 200 organic compounds resulting from the thermal degradation of biomass, which can act as plant growth stimulants or phytopathogens[5,8,10,13,14]. Furthermore, pyroligneous extracts are reported to have phenolic compounds in their composition[1]. It is recognized that phenolic compounds contribute to antioxidant activity[15], which is an important parameter for initial plant development[6]. As a result, it was verified that the pyrolysis extract resulted in higher-quality soybean seedlings.

4 CONCLUSION

In the present study, it was possible to test the pyroligneous extract obtained from pyrolysis on a pilot scale (5 kg) of grape processing wastes for its ability to stimulate plant growth. The pyrolysis extract has shown promise for use as a soybean growth promoter, as it has increased several phytometric parameters of the vegetative development of this crop. This potential highlights the contribution that pyrolysis has to different areas of knowledge, as it is a solution for the management of agro-industrial waste, valuing waste generated during grape processing while developing products of agricultural and environmental interest. Therefore, the circular economy and other aspects of sustainability are promoted through this technology, contributing to the achievement of several Sustainable Development Goals (SDGs) of the United Nations (UN).

REFERENCES

[1] FERRARI, V., NAZARI, M. T., DA SILVA, N. F., CRESTANI, L., RAYMUNDO, L. M., DOTTO, G. L., PICCIN, J. S., OLIVEIRA, L. F. S., BERNARDES, A. M. 2024. Environ. Dev. Sustain. 1-35.
[2] HU, J., CHEN, L., CHEN, P., GU, S., ZHOU, Y., ZHANG, J., ZHAO, W., TAO, H., ZHOU, N., MI, B., WU, F. 2023. Fuel Process. Technol. 25. 107912.
[3] QAMAR, O. A., JAMIL, F., HUSSAIN, M., AL-MUHTASEB, A. H., INAYAT, A., WARIS, A., AKHTER, P., PARK, Y. K. 2023. Chem. Eng. J. 454(2). 140240.
[4] XUE, R., CUI, E. L., HU, G. Q., ZHU, M. Q. 2022. Ind. Crops and Prod. 178. 114586.
[5] GOLLAKOTA, A. R., SHU, C. M., SARANGI, P. K., SHADANGI, K. P., RAKSHIT, S., KENNEDY, J. F., GUPTA, V. K., SHARMA, M. 2023. Renew. Sust. Energ. Rev. 187. 113700.
[6] OFOE, R., GUNUPURU, L. R., WANG-PRUSKI, G., FOFANA, B., THOMAS, R. H., ABBEY, L. 2022. Plant Stress. 4. 100083.
[7] SINGH, S., PANT, K. K., KRISHANIA, M. 2023. J. Anal. Appl. Pyrolysis. 175. 106160.
[8] WU, Q., ZHANG, S., HOU, B., ZHENG, H., DENG, W., LIU, D., TANG, W. 2015. Bioresour. Technol., 179, 98-103.
[9] ALHAZMI, H., LOY, A. C. L. 2021. Bioresour. Technol. Reports. 14. 100682.
[10] LOO, A. Y., JAIN, K., DARAH, I. 2008. Food Chem. 107(3). 1151-1160.
[11] DICKSON, A., LEAF, A. L., HOSNER, J. F. 1960. For. Chron. 36 (1). 10-13.
[12] BINOTTO, A. F., LÚCIO, A. D. C., LOPES, S. J. 2010. Cerne. 16. 457-464.
[13] MUNGKUNKAMCHAO, T., KESMALA, T., PIMRATCH, S., TOOMSAN, B., JOTHITYANGKOON, D. 2013. Sci. Hortic. 154. 66-72.
[14] YIN, X., WEI, L., PAN, X., LIU, C., JIANG, J., WANG, K. 2021. Front. Plant Sci. 12. 670061.
[15] LIU, Q., YAO, H. 2007. Food Chem. 102(3). 732-737.

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