horticultura brasileira

Research

AGUIAR, BG; GUERRA, JGM; GOULART, JM; ESPINDOLA, JAA; ARAÚJO, ES. Agronomic efficiency of fermented composts formulated with tephrosia phytomass in arugula crop. *Horticultura Brasileira* v.42, 2024, elocation e2624. DOI: http://dx.doi.org/10.1590/s0102-0536-2024-e2624

Agronomic efficiency of fermented composts formulated with tephrosia phytomass in arugula crop

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ABSTRACT

This study aimed to determine the chemical, physical-chemical properties and agronomic efficiency of fermented composts formulated with agro-industrial wastes and tephrosia (*Tephrosia sinapou*) phytomass (TS) in arugula fertilization. The experiment was carried out in two phases, using wheat bran (FT), sugarcane bagasse (BC), TS phytomass and malt bagasse (BM) in the compound formulations. The first stage consisted of evaluating the chemical and physical-chemical properties in a completely randomized experimental design with 9 treatments (60TS+30FT+10BC; 60TS+30BM+10BC; 60TS+20FT+20BC; 60TS+20BM+20BC; 60TS+ 10FT+30BC; 60TS+10BM+30BC; 60TS+40FT; 60TS+40BM; 60TS+40BC) and four replicates. The second stage consisted of evaluating the agronomic efficiency of the formulations 60TS+40FT, 60TS+10FT+30BC, 60TS+40BM, 60TS+10BM+30BC and 60TS+40BC in arugula crop and a control treatment (without fertilizer). The fermented composts showed suitable chemical and physical-chemical properties for being used as fertilizers. Tephrosia phytomass has the potential for producing fermented composts, whose combination with 40% FT or BM, respectively, provided increases in N, P, K, Ca and Mg uptake, and in arugula productivity of 129,14% and 127.32% higher than the control (without any organic fertilizer)

Palavras-chave: *Tephrosia sinapou*, *Eruca sativa*, bokashi, resíduos agrícolas.

RESUMO

Eficiência agronômica de compostos fermentados formulados com a fitomassa da fabácea tefrósia no cultivo de rúcula

Objetivou-se determinar as características químicas, físico-químicas e a eficiência agronômica de compostos fermentados formulados com resíduos agroindustriais e fitomassa de tefrósia (*Tephrosia sinapou*) (TS) na fertilização da rúcula. O trabalho experimental foi conduzido em duas etapas, utilizando-se o farelo de trigo (FT), o bagaço de cana-de-açúcar (BC), a fitomassa de TS e o bagaço de malte (BM) nas formulações dos compostos. A primeira etapa consistiu da avaliação das características químicas e físico-químicas, cujo delineamento experimental foi inteiramente casualizado com 9 formulações (60TS+30FT+10BC; 60TS+30BM+10BC; 60TS+20FT+20BC; 60TS+20BM+20BC; 60TS+10FT+30BC; 60TS+10BM+30BC; 60TS+40FT; 60TS+40BM; 60TS+40BC) e quatro repetições. A segunda etapa constou da avaliação da eficiência agronômica das formulações 60TS+40FT, 60TS+10FT+30BC, 60TS+40BM, 60TS+10BM+30BC e 60TS+40BC no cultivo de rúcula, acrescido de um tratamento controle (sem adubação). Constatou-se que os compostos fermentados apresentam características químicas e físico-químicas que permitem a utilização como fertilizantes. A fitomassa de tefrósia tem potencial para a produção de compostos fermentados, cuja combinação com 40% de FT ou de BM, respectivamente, proporcionou aumentos nas quantidades acumuladas de N, P, K, Ca e Mg, e produtividades de rúcula na ordem de 129,14% e 127,32% superior ao tratamento controle, sem adubação orgânica.

Keywords: *Tephrosia sinapou*, *Eruca sativa*, bokashi, agricultural waste.

Received on September, 19, 2023; accepted on December 5, 2023

Organic agriculture has intensively grown in the last years worldwide. In Brazil, 1.5 million hectares are certified or transition areas, corresponding to 1.96% of global area (Willer *et al*., 2023). In spite of the situation above, this segment still needs to overcome some difficulties to enable the expansion of cultivated areas. One of the main obstacles to the expansion of organic agriculture is related to plant nutrition, as synthetic fertilizers are not permitted.

Taking this into consideration, mineral nutrient sources, which are often used by farmers for growing vegetables, are manures that provide a significant supply of organic matter and great amounts of macronutrients (Rós *et al*., 2014). Although manure is considered a good source of fertilizer, they may be little available in certain regions, also prior composting is required in order to be used in organic agriculture (Brasil, 2021). Moreover, considering the circular economy concepts (Oliveira *et al*., 2019), manure can be also used for fertilizing pasture or grain crop production.

Producing organic compounds using agro-industrial and agricultural wastes can be a good alternative to replace manure (Oliveira *et al*., 2014). In this sense, the fermented compost (Bokashi) stands out as it allows a mix of different sources of wastes (Siqueira & Siqueira, 2013), providing expressive quantities of nutrients (Souza Júnior *et al*., 2023). In addition, microorganisms are inoculated during the compost preparation in order to improve plant growth after fertilization.

Farmers can grow fabaceous species, which are rich in nitrogen, and use the phytomass in fermented compost formulations (Souza Júnior *et al*., 2023). One recommended species to be used is tephrosia. This plant produces high quantities of phytomass, adapted in tropical environments and is also pruning tolerant. Another positive aspect is that it can be grown intercropped with crops of economic interest, maximizing the use of the area (Goulart *et al*., 2021).

Given the above, the authors concluded that the use of wastes which are locally available may contribute to produce agronomic efficient compounds in arugula crop (*Eruca sativa*), which represents one of the most cultivated vegetables by family farmers, and which is also widely accepted by the consumers. Thus, this study aimed to determine the chemical, physico-chemical properties as well as the agronomic efficiency of fermented compounds, formulated with agro-industrial wastes and tephrosia phytomass in arugula fertilization.

MATERIAL AND METHODS

The experiment was carried out in two stages, from November to December, 2021, in the municipality of Seropédica, Metropolitan Region of Rio de Janeiro (22°45’25”S, 43°40’26”W, 33 m altitude). The wastes used for the compost formulations were wheat bran (FT), malt bagasse (BM), sugarcane bagasse (BC) and tephrosia phytomass (TS).

FT was obtained at Central de Abastecimento, in the State of Rio de Janeiro, (Ceasa-RJ). BM was collected at Grupo Petrópolis brewery, located in the municicpality of Teresópolis-RJ. BC was obtained in the local market in the municipality of Seropédica. The waste was air-dried naturally and, then, crushed in a TMC-4 crushing machine, sieved using a 2 mm mesh sieve. For TS shoot phytomass, the authors used just the leaflets and tender branches of plants from a production bank, near the experimental area. This material was air-dried and crushed, in the same machine mentioned earlier.

Subsamples of the raw material were dried in an oven at 65ºC, with forced air circulations for 72 h. Afterwards, the material was crushed in a Willey mill and the nutrient contents were determined (Table 1), evaluated according to Nogueira & Souza (2005) methodology.

Table 1. Contents of N, P, K, Ca, Mg, C/N ratio and moisture of the raw material used in formulations of fermented composts. Seropédica, Fazendinha Agroecológica km 47, 2022.

Raw material	Nutrient contents					C/N	Moisture (%)
	N	P	K	Ca	Mg		
	(g/kg)						
Wheat bran	23.47	7.93	9.87	0.93	2.37	17.94	12.0
Tephrosia bran	26.68	2.24	12.31	8.22	2.25	16.15	10.0
Malt bagasse	39.11	4.70	0.57	1.26	1.51	11.41	70.0
Sugarcane bagasse	4.98	0.48	4.14	0.76	0.65	88.65	9.0

The first stage consisted of evaluating chemical and physical-chemical properties of the compounds. The authors used a completely randomized design with 9 compost formulations (60TS+30FT+10BC; 60TS+30BM+10BC; 60TS+20FT+20BC; 60TS+20BM+20BC; 60TS+10FT+30BC; 60TS+10BM+30BC; 60TS+40FT; 60TS+40BM; 60TS+40BC), considering the percentage of dry matter and four replicates.

Wastes were mixed and inoculated with a solution containing microbial inocula collected under the litter of a secondary forest close to the experimental area. To collect the microorganisms, we used bamboo troughs cut horizontally and filled with rice cooked in water. Then, the troughs were protected with shading screen to prevent mammals and small arthropods from accessing rice. The troughs were installed under the litter and kept for seven days.

After this period, 50-g sample of microorganism-colonized rice was taken to be used in the experiment. The sample was packaged in a plastic bottle with 50 g brown sugar and 400 mL water, to activate (multiplication of microorganisms), for seven days. Afterwards, the activated solution was dilluted in water (1% v/v), according to Vieira Filho *et al*. (2023).

In order to prepare the composts, the dilluted solution was slowly added to the mixes until obtaining a stable clod without crumbling or liquid runoff. After this period, the jars were opened, and the 100 g-samples were taken for determining moisturizing content and N, P, K Ca and Mg contents. Furthermore, pH and electrical conductivity were also determined using 1:5 (v/v) ratio, respectively, compost samples and distilled water (Oliveira, 2011).

In the second stage, the agronomic efficiency of the fermented composts in arugula crop was evaluated. Five composts were selected based on the viability of using BC in formulations in contrast with FT and BM. The experimental design used was randomized blocks, with 4 replicates. The treatments consisted of 60TS+40FT; 60TS+10FT+30BC; 60TS+40BM; 60TS+10BM+30BC; 60FTS+40BC; control (without organic fertilization). New composts were prepared in 4 dm^3-capacity containers using the same phytomasses used in the first stage.

The experiment was carried out from July 8 to August 17, 2022. The soil was classified as Red Yellow Latosol (Santos *et al*., 2018) The chemical properties in 0 to 20 cm layer were: pH = 6.19; Al $^{+++}$= 0.0 cmolc/dm^3; Ca^{++}= 3.12 cmol$_c$/dm^3; Mg^{++}= 0.84 cmolc/dm^3; K$^+$= 120.43 mg/dm^3; available P = 227.53 mg/dm$^{3.}$

The experimental plots consisted of a 1-m^2 area, 1.0 x 1.0 m. The seedbeds were built up with the aid of a seedbed tiller and separated by 0.3 m inter-stripping. After marking all plots, fertilization was carried out using different composts, applying a dose of 150 kg total N/ha (seven days before the crop sowing).

Spacing consisted of 0.20 m between rows and 0.10 m between planting holes in sowing rows, keeping 2 plants in each hole. Thus, five rows were kept per plot, totalizing 100 plants. We used Gigante Folha Larga arugula cultivar, and the plant remained in the field for 40 days. The samples in the 0.36 m^2 useful area were used for evaluations, 36 plants of three central rows. The authors evaluated the following phytotechnical components: plant height, number of emitted leaves, leaf area, productivity, contents and amounts of nutrients accumulated in the shoot phytomass. To estimate productivity and amounts of nutrients accumulated per hectare, the authors disregarded the interspersed streets to the seedbeds (23% of the total area).

The obtained data were submitted to tests of normality and homogeneity of error variances. When the assumptions were met, the obtained data were submitted to the analyses of variance by F test ($p \leq 0.5$), the averages were grouped using the Scott & Knott test (5% probability). The statistical analyses were performed using Sisvar software (Ferreira, 2019).

RESULTS AND DISCUSSION

Studying the results of the variance analyses (Table 2), the authors verified significant effects among treatments for pH, electrical conductivity, moisture and macronutrient contents. The pH value of the fermented plant composts after fermentation process (Table 3), regardless formulation, was acid and within the range considered optimal, from 4 to 5.5, for fermented composts (Pian, 2019; Goulart, 2020).

Table 2. Chemical and physical-chemical properties of the fermented composts and summary of variance analysis for the respective variables. Seropédica, Fazendinha Agroecológica km 47, 2022.

Formulations		pH	electrical conductivity (μs/cm)	Moisture (%)	Nutrient contents of fermented composts				
					N	P	K	Ca	Mg
					(g/kg)				
60TS+40FT		4.70 B	1132.50 A	43.16 C	33.9 C	4.04 A	12.29 B	5.25 B	3.28 A
60TS+30FT+10BC		4.84 A	1103.75 A	43.11 C	33.7 C	3.60 A	12.37 B	5.24 B	3.07 A
60TS+20FT+20BC		4.87 A	932.75 B	50.44 A	33.9 C	3.78 A	15.07 A	6.23 A	3.69 A
60TS+10FT+30BC		4.46 C	740.75 C	47.30 B	32.0 D	2.89 B	14.78 A	6.02 A	3.24 A
60TS+40BM		4.74 B	903.25 B	52.23 A	38.9 A	3.06 B	9.58 C	5.59 B	3.07 A
60TS+30BM+10BC		4.53 C	861.25 B	49.07 B	36.6 B	2.99 B	11.48 B	6.13 A	3.01 A
60TS+20BM+20BC		4.39 C	761.75 C	41.53 C	35.3 B	2.75 B	11.26 B	5.81 B	2.99 A
60TS+10BM+30BC		4.13 D	725.50 C	41.94 C	31.8 D	2.46 C	11.28 B	5.64 B	3.04 A
60TS+40BC		4.38 C	667.50 C	46.67 B	31.5 D	2.30 C	14.50 A	6.55 A	2.97 A
F. variation	**GL**	**Mean square**							
Treatments	8	0.2403*	109487.5*	61.326*	0.183*	1.424*	14.228*	0.790*	0.209^{ns}
Waste	27	0.0088	7063.537	5.163	0.043	0.059	1.297	0.183	0.120
Total	35	-	-	-	-	-	-	-	-
CV (%)		2.07	9.66	4.92	6.36	7.89	9.10	7.34	11.01

Means followed by the same letter do not differ from each other by Scott-Knott test (5% probability). TS= tephrosia bran; FT= wheat bran; BM= malt bagasse; BC= sugarcane bagasse; GL= degrees of freedom. *Significant at 5% probability by F test.

Table 3. Phytotechnical components of the crop submitted to fertilization with different fermented composts and summary of variance analysis for the respective variables. Seropédica, Fazendinha Agroecológica km 47, 2022.

Formulations		Phytotechnical components of arugula			
		Height (cm)	Nº leaves/plant	AF (cm^2)	Productivity (t/ha)
60TS+40FT		20.46 A	6.73 A	181.78 A	23.90 A
60TS+10FT+30BC		16.16 B	5.33 C	104.24 B	12.78 C
60TS+40BM		19.84 A	6.88 A	187.52 A	25.71 A
60TS+10BM+30BC		18.90 A	6.04 B	148.09 A	16.70 B
60TS+40BC		18.89 A	5.98 B	140.77 A	17.91 B
Control (no fertilization)		15.10 B	5.08 C	88.09 B	10.43 C
F. variation	**GL**	**Mean square**			

Treatment	5	18.003391*	2.070130*	924600.30*	138.788037*
Blocks	3	7.999684*	1.416728*	344277.66	20.537722
Waste	15	2.269338	0.213201	163203.94	13.204119
Total	23	----	----	----	----
CV (%)		8.27	7.69	23.75	20.38

Means followed by the same letter do not differ from each other by Scott-Knott test, at 5% probability. TS= tephrosia bran; FT= wheat bran; BM= malt bagasse; BC= sugarcane bagasse; AF= leaf area; MS= dry matter; MF= fresh matter; GL= degrees of freedom. *Significant at 5% probability by F test.

Acidic pH values, such as the ones observed in ensiled fodder, are related to the conversion of soluble sugars into organic acids, with emphasis on lactic acid, which substantially contributes to reduce pH in fermentation environments (Silva *et al*., 2020). Acidity shall be considered a compost quality indicator, since it allows longer conservation of this organic material. Besides, acidity limits microbial growth, considering that values below 4.5 generally do not allow pathogenic bacteria to grow (Hoffmann, 2001). This makes it safer to handle composts.

For electrical conductivity, formulations with 40 and 30% of FT in the mixes showed the highest values (Table 2). This fact is related mainly to higher K contents found in this natural raw material when compared with BM and BC. We highlight that K in plant phytomass is mostly in ionic form and does not make up any stable organic composts (Ernani *et al*., 2007). This fact shows the influence of this nutrient in electrical conductivity values. We found values ranging from 667.50 to 1132.50 µS/cm; these are considered appropriate values for organic composts (Gao *et al*., 2010).

Moisture contents were different considering formulations, ranging from 41 to 52%, which may be due to intrinsic characteristics of the waste. We highlight that the inoculant solution was added to the mixes until a clod was obtained, after manual compressing (Souza Júnior *et al*., 2023), considering that the quantity of solution required for moisture was different for each formulation. The contents verified are acceptable and ranged from 40 to 55%, which is considered optimal for triggering the fermentation process (Goulart, 2020).

For macronutrient contents present in different fermented plant composts (Table 2), the authors verified that formulation 60TS+40BM showed the highest N content, which is due to higher N contents found in BM and bran of TS phytomass (Table 1). All formulations showed N contents higher than cattle manure (21 g/kg of N), and poultry manure (25.3 g/kg of N) (Freire *et al*., 2013). In relation to P, the formulations 60TS+40FT, 60TS+30FT+10BC, 60TS+20FT+20BC showed the highest contents, showing that even with the partial replacement of FT with BC up to a limit of 20%, the contents of this element do not change. P contents found in these formulations are higher than the ones reported by Freire *et al*. (2013) for cattle manure (1.87 g/kg) and slightly lower for poultry manure (5.63 g/kg).

For K contents, higher contents were verified in the formulations 60TS+20FT+20BC, 60TS+10FT+30BC, 60TS+40BC. The formulation 60TS+40BM showed the lowest content of the nutrient. The reduction of K content in the presence of BM is related to the content of this nutrient in the waste *in natura*. BM showed moisture content of 70% when manipulated in order to produce composts. This is directly related to K contents: as the waste from the brewing industry is deposited in trench silos to drain water, large quantities of this element can be carried away. We highlight that FT *in natura* shows K content corresponding to 1631% higher than the one found in BM.

For Ca content (Table 2), the authors noticed that the formulations 60TS+20FT+20BC, 60TS+10FT+30BC and 60TS+30BM+10BC, 60TS+40BM showed the highest contents, being similar to the ones found in poultry manure by Freire *et al*. (2013). For Mg content, the authors noticed no differences among treatments. We verified that fermented composts showed favorable characteristics to be used as organic fertilizers, considering chemical and physicochemical properties.

For phytotechnical components of arugula crop (Table 3), the authors noticed significant effects for height, number of leaves, leaf area and productivity. For height and leaf are (Table 3), formulation 60TS+10FT+30BC showed the lowest performances, not differing from the control. In relation to number of leaves and productivities, formulations 60TS+40FT and 60TS+40BM provided the best results. The highest productivity verified with these formulations are associated with the highest nutrient release rate in a quite short period of time, mainly in relation to N (Oliveira *et al*., 2014; Goulart, 2020).

The formulations which provided the best crop yields, lead to an increase in productivity 131.73% and 127.30% higher than the control without fertilization. The obtained results are superior to the ones found by Ferreira *et al*. (2017), using 20 t/ha of organic compost and Cunha *et al*. (2013) obtaining productivities ranging from 8.9 to 16 t/ha, both experiments using cultivar Gigante Folha Larga.

The results found in this study, using fermented plant compost, highlight the importance of reusing agroindustrial wastes for fertilizing vegetables. Moreover, the use of tephrosia phytomass in agricultural systems contributes to reduce the use of nitrogen fertilizers, valorizing biogeochemical cycles such as biological nitrogen fixation.

In relation to nutrient contents in arugula phytomass, no significant differences were observed among treatments. We highlight that the soil of the experimental area, as mentioned in the results of chemical analysis, presented high nutrient contents. This fact may have contributed to level the nutrient concentration in arugula phytomass at the end of the cycle. We point out that macronutrient levels were found (in g/kg): 20.05 N; 4.64 P; 32.57 K; 19.97Ca and 4.94 Mg.

For accumulated amounts of N, P, K, Ca and Mg, variance analysis showed significant differences among the treatments (Table 4). The fermented composts formulated with 60TS+40FT and 60TS+40BM provided higher accumulated amounts of macronutrients (Table 4). This fact is related to higher amounts of phytomass in arugula crop provided by these treatments. We point out that the formulations provided average exportations of 79.28; 19.83; 141.93; 79.63 and 19.63 kg/ha, respectively, N, P, K, Ca and Mg.

Table 4. Accumulated amounts of N, P, K, Ca and Mg in the arugula phytomass submitted to fertilization using different fermented composts and summary of variance analysis for the respective variables. Seropédica, Fazendinha Agroecológica km 47, 2022.

Formulations		**Accumulated amounts of nutrients in arugula phytomass**				
		N	**P**	**K**	**Ca**	**Mg**
				(kg/ha)		
60TS+40FT		80.59 A	18.59 A	138.46 A	69.43 A	19.06 A
60TS+10FT+30BC		46.58 B	11.25 B	73.04 B	46.79 B	12.43 B
60TS+40BM		77.97 A	21.08 A	145.40 A	89.84 A	20.21 A
60TS+10BM+30BC		56.53 B	13.21 B	87.69 B	54.26 B	14.51 B
60TS+40BC		63.82 A	13.00 B	100.82 B	55.44 B	13.12 B
Control (no fertilization)		38.40 B	8.70 B	57.90 B	45.09 B	10.38 B
F. variation	**GL**			**Mean Square**		
Treatment	5	1132.906624*	86.393354*	4951.75193*	1144.055697*	60.329387*
Blocks	3	344.636160	0.525982	1246.54694	194.823782	11.890028
Waste	15	223.413793	11.56942	779.867208	181.605509	12.993918
Total	23	-	-	-	-	-
CV (%)		24.65	23.77	27.77	22.41	24.10

Means followed by the same letter do not differ from each other by Scott-Knott test, at 5% probability. TS= tephrosia bran; FT= wheat bran; BM= malt bagasse; BC= sugarcane bagasse; GL= degrees of freedom. *Significant at 5% probability by F test.

We concluded that the fermented composts showed chemical and physical chemical properties, making them suitable to be used as fertilizers. Tephrosia phytomass has potential to produce fermented composts, whose combination with 40% FT or BM, respectively, provided increases in accumulated amounts of N, P, K, Ca and Mg, and productivities of arugula, 129.14% and 127.32% superior than the control, without organic fertilization.

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